Clear Lake Source Water Assessment and Watershed Sanitary Survey

August 2023

LAKE COUNTY

NRCS

California Rural Water Association

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SECTION 1- INTRODUCTION

1.1- PURPOSE OF REPORT

This report has been prepared to address the need for both a Source Water Assessment and a Sanitary Survey for Clear Lake and for the 17 water purveyors that rely on Clear Lake as a source for drinking water supply.

The California State Water Resources Control Board (SWRCB) has defined both a Source Water Assessment and a Watershed Sanitary Survey. A Watershed Sanitary Survey (WSS) includes a more detailed evaluation than a Source Water Assessment (SWA). According to the SWRCB website, "A complete, comprehensive WSS should contain most of the information necessary for a minimum SWA. The purpose of a WSS is to identify what treatment facilities are needed to properly treat the source water. The purpose of a SWA is to determine the types of Possible Contaminating Activities (PCAs) in the watershed and identify those that are most significant." This document is intended to both identify PCAs and review potable water treatment processes.

The first Clear Lake Watershed Sanitary Survey was completed in 1996. The California Surface Water Treatment Rule requires the survey to be updated every five years. The last report was completed in 2012 by Forsgren and Associates. This 2023 report provides an update to the 2012 Sanitary Survey and was funded in part through a grant from the National Resource Conservation Service (NRCS) under the United States Department of Agriculture (USDA).

Figure 1.1.1- Clear Lake and Mount Konocti

1.2- THE NATIONAL WATER QUALITY INITIATIVE

The National Water Quality Initiative (NWQI) is a multi-year funding program offered through the United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS). Developed in 2011, it is intended to address impaired waterbodies and provide targeted funding for technical assistance and implementation of voluntary conservation practices. NRCS partners with state water quality agencies and the United States Environmental Protection Agency (USEPA) to identify impaired waterbodies throughout the nation that would greatly benefit from targeted conservation practices on private land. Please refer to Attachment H for an assessment of NRCS' ability to help partners reach the source water protection goals and objectives.

There are two phases to the NWQI; the planning phase and the implementation phase. During the planning phase, a Watershed Assessment Plan (WAP) is completed to characterize the watershed and impaired drinking water source(s), provide recommendations for conservation practices, outline an outreach plan, and develop metrics for monitoring the effectiveness of BMPs and other related projects. Upon NRCS approval of the WAP, the projects will advance to the implementation phase where targeted funding becomes available to implement the WAP objectives.

1.3- WATERSHED SUMMARY

The NWQI project study area is in the County of Lake, California (Figure 1.3.1) and consists of sixteen Hydraulic Unit Code (HUC)-12 watersheds. A HUC-12 watershed is a local sub-watershed designated by the United States Geological Service (USGS). It covers 271,360 acres of land, excluding lake area.. There are approximately 79,000 acres of combined forest, crop land, and grazing lands that contribute to drainage into Clear Lake (County of Lake, 2022). Over 85% of natural wetland has been lost in the region. The loss of wetlands significantly diminishes the natural filtration capacity and contributes to eutrophication in the lake. Wetlands only account for 1.4% of the watershed area (DePalma-Dow, McCullough & Brentrup, 2022).

The main tributary that feeds Clear Lake is the Rodman Slough, a wetland that marks the convergence of Scott's Creek and Middle Creek located between North Lakeport and Nice. The land surrounding Rodman Slough was converted from natural wetland to agricultural land between 1918 and 1933. Since 1978 efforts have been made to convert the agricultural land back to wetland to mitigate sedimentation (Middle Creek Restoration Coalition, 2022). The County of Lake has since purchased several parcels from willing sellers located within the Middle Creek Project Area with the intention of restoring this area back to native wetland habitat (County of Lake, 2022). Other significant tributaries include Adobe Creek, Manning Creek, Kelsey Creek, Cole Creek, and Schindler Creek. Cache Creek flows through the Cache Creek Dam and is the only outflow from Clear Lake. Dam outflows are regulated by Yolo County Flood Control and Water Conservation District (Yolo County Flood Control & Water Conservation District, 2022) however, the lake flow is limited by the Grigsby Riffle, located at the confluence of Cache Creek and Siegler Canyon Creek in Lower Lake, CA.

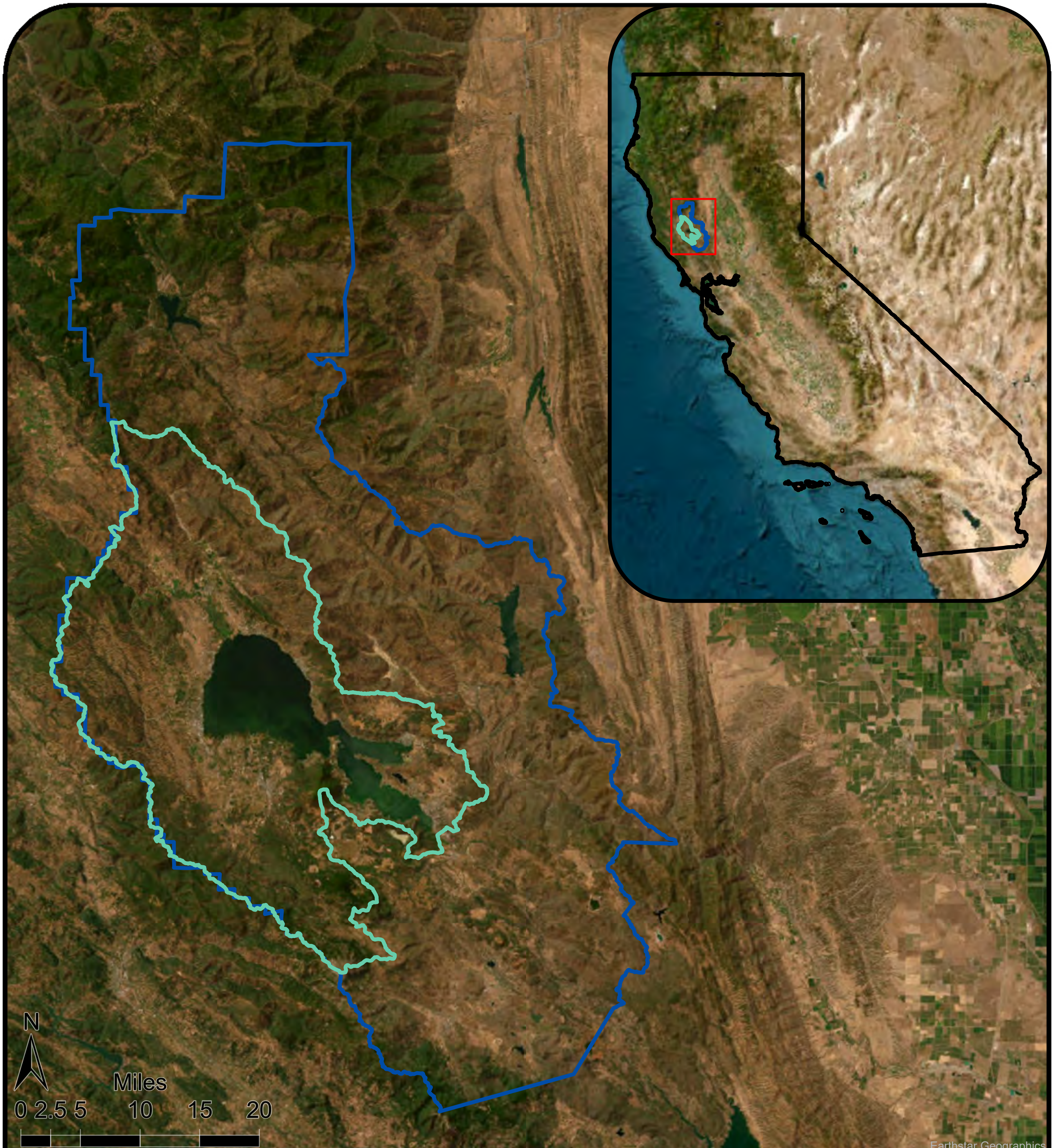

Figure 1.3.1: NWQI Project Area

Lake County Source Water Assessment

California State Boundary
Clear Lake Watershed and NWQI Project Area
Lake County Boundary

California Rural Water Association

Water Quality Impairments

Clear Lake is listed on the 303(d) list of impaired waterbodies in California and is subject to a total maximum daily load (TMDL) for nutrients, specifically sediment-associated phosphorus (California State Water Resources Control Board, 2007). The beneficial uses impaired by nutrient input include municipal and domestic water supply, tribal cultural and subsistence, freshwater habitat, contact and non-contact water recreation, spawning, reproduction, and early fish development. Most of these impairments are indirect consequences of nutrient loading in combination with shoreline wetland removal (see table 2). External phosphorus and nitrogen inputs contribute to the development of seasonal freshwater harmful algal blooms (FHABs or HABs) in Clear Lake. HABs impair municipal and domestic water supplies and contact water recreation. HAB decomposition increases pH and decreases dissolved oxygen, which impairs contact and non-contact recreation, freshwater habitat, fish spawning, reproduction, and early development.

While this report is focused on water quality impairments related to nutrients, other impairments such as mercury, boron, and pesticide runoff are also discussed at a high level.

Table 1.3.1: Beneficial Use Impairments and Probable Causes in Clear Lake

<table>
<tr><th>Impaired Beneficial Use</th><th>Probable Cause(s) of Impairment</th><th>TMDL Issued?</th><th>Relation to Nutrients</th></tr>
<tr><td rowspan="2">Municipal and Domestic Water Supply</td><td>Nutrients</td><td>Yes</td><td>Direct impairment</td></tr>
<tr><td>HABs</td><td rowspan="8">No</td><td rowspan="2">Nutrients fuel development of CHM containing HABs</td></tr>
<tr><td rowspan="2">Contact Water Recreation</td><td>HABs</td></tr>
<tr><td>pH</td><td rowspan="3">Nutrients fuel HAB development, which increases pH</td></tr>
<tr><td>Non-Contact Water Recreation</td><td>pH</td></tr>
<tr><td rowspan="2">Freshwater Habitat</td><td>pH</td></tr>
<tr><td>Dissolved Oxygen (DO)</td><td>Nutrients fuel HAB development, which decreases DO</td></tr>
<tr><td>Spawning, Reproduction, and/or Early Development</td><td>Dissolved Oxygen (DO)</td><td>Nutrients fuel HAB development, which decreases DO</td></tr>
<tr><td>Agricultural Supply</td><td>Boron</td><td>No known relation</td></tr>
<tr><td>Commercial and Sport Fishing</td><td>Mercury</td><td>Yes[1]</td><td>No known relation</td></tr>
</table>

HABs hamper Lake County's recreational and sport fishing economy, present health risks for humans and animals, disrupt the local ecosystem, and create significant drinking water treatment challenges. The blooms cover vast areas of the lake. They vary in color from cyan to white, and can reseemble spilled paint or thick foam (Figure 1.3.2). They often emit a smell like untreated sewage, which causes concern among local residents and respiratory issues for the health compromised (McCosker, 2020; Breedlove, 2022). The look and smell of the lake during peak recreational months (i.e. June-

[1] *The TMDL for mercury is limited to tailings from the Sulfur Bank Mercury Mine, a USEPA Superfund Site.*

September) deters visitors and limits the areas that are suitable for swimming. When blooms decay, they release neurotoxins and hepatotoxins that pose human health concerns and may be deadly to domestic animals and livestock (Cheung et. al., 2013). Increasing temperatures from climate change in both the surface and bottom waters create a favorable environment for the development of toxin producing HABs over their non-toxin producing counterparts. This can result in more frequent blooms with higher toxin concentrations in the future (Cheung et. al., 2013; DePalma-Dow, McCullough, & Brentrup).

Decay of the HABs and algae can also create hypoxic or anoxic conditions that disrupt the ecosystem. Depleted oxygen levels limit fish habitat and may result in large-scale fish kills (Figure 1.3.3 and 1.3.4). This condition may also kill plant life and halt the development of fish eggs which significantly alters food web dynamics in the ecosystem (Michele, J., & Michele, V., 2002).

Figure 1.3.2: FHAB surrounding drinking water intake (Photo by Donny Breedlove)

Figure 1.3.3: Fish Kill in Clear Lake, 2017 (Source: KTVU)

Figure 1.3.4: Fish Kill in Clear Lake, 2012 (Source: County of Lake Department of Water Resources)

The treatment of HABs in conventional drinking water systems is complex and highly variable depending on initial water quality parameters, which can change rapidly in Clear Lake. Clear Lake water systems are faced with many species of algae, cyanobacteria, and classes of toxins, all of which behave differently during conventional treatment. As a result, Clear Lake's water treatment facilities are among the most complex in the State of California. In addition, there are many self-supplied water systems that include private intakes. Private intakes may draw water directly from the lake to a residential dwelling for consumptive use. Many of these intakes are not equipped with the technology needed to effectively remove cyanobacterial cells and associated toxins. This poses serious health concerns for the residents of homes that are not connected to a public water system.

Phosphorus and nitrogen are the main nutrient sources that cyanobacterial cells use to fuel their metabolic processes; therefore, decreasing nutrient transport into Clear Lake may decrease the severity and duration of future blooms. Internal nutrient loading also contributes to HAB development; however, this phenomenon is biological in nature and cannot be mitigated with voluntary land-based conservation practices.

The remediation of internal loading and implementation of in-lake technologies is beyond the scope of the WAP and NWQI land-based mitigation focus. In-lake remedies could be pursued to maximize the effectiveness of land and watershed-based sediment and nutrient management measures.

Clear Lake is traditionally and naturally eutrophic, so complete eradication of HABs is unrealistic and unlikely. However, the conservation practices outlined in this WAP can help to decrease external nutrient loading and thereby decrease the severity and frequency of HABs in the local ecosystem, lake-side communities, and related potable water treatment plants. Implementation of conservation practices will support and complement any concurrent in-lake management efforts.

Voluntary conservation practices will benefit the communities surrounding Clear Lake because of improved lake aesthetics and by providing additional recreation opportunities. Strategically placed and designed conservation practices will also benefit the surface water purveyors because it can reduce the burden on treatment plants and operations personnel. Improvements in source water quality will benefit the rate payers associated with surface water treatment systems because they can reduce the need for additional rate increases needed to comply with water quality regulations. The voluntary conservation practices will also benefit the households that have private intakes on the lake.

1.4- DRINKING WATER SYSTEMS

Seventeen drinking water purveyors draw water from Clear Lake (see Figure 1.3.5) (SDWIS, 2020). Although the toxins produced by HABs (also known as cyanotoxins) are not regulated by the USEPA, the affected purveyors take proactive measures to protect the health and safety of their communities. Treating HABs may require retrofitting existing infrastructure, adding new infrastructure, and obtaining higher treatment certifications, all of which result in increased operation and maintenance costs. Robust processes such as on-site ozone generation, advanced oxidation via ultraviolet light, granulated (and powdered) activated carbon, pH adjustment, microfiltration, and dissolved air flotation are used to supplement conventional water treatment processes in Clear Lake (Little, 2019). Appendix A outlines the treatment mechanisms currently employed at Clear Lake's surface water treatment facilities.

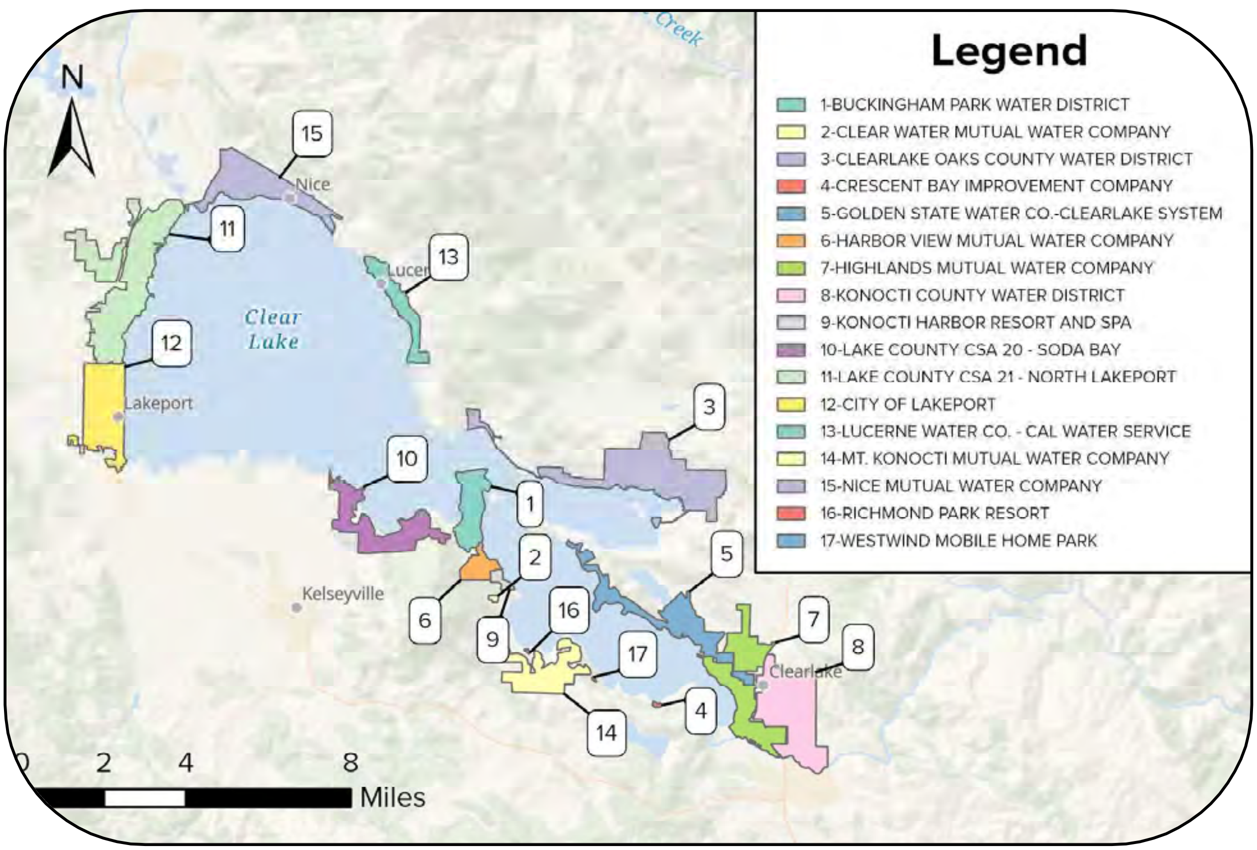

Figure 1.3.5: Surface Water Purveyors that Draw from Clear Lake

The supplemental water treatment processes come at an increased cost not only for discrete capital improvements but also for ongoing costs that include highly qualified water treatment operators and increased operation and maintenance costs. These costs are distributed amongst a relatively small rate base resulting in high water rates for the local communities. The County of Lake has one of the lowest median household incomes in California with most communities classified as economically distressed, disadvantaged, or severely disadvantaged (Figure 1.3.6). Affordable water thresholds indicate that the cost of drinking water should consume no more than 1.5% of gross monthly income whereas the average contribution of gross monthly income among Clear Lake surface water purveyors is 3.0% (Kennard, 2021). Therefore, the cost of treated surface water from Clear Lake imposes a disproportionate financial burden on rate payers.

Although water purveyors on Clear Lake share the same water source, the water quality at each intake varies widely, resulting in different treatment requirements. In general, the Lower and Oaks Arm are deeper, but due to the common wind patterns and lake currents, they undergo more severe HABs than the Upper Arm (Horne, 1975; Kennedy, 2020). However, there are areas of the Upper Arm that undergo intense eutrophication as well as quiescent coves in the Lower Arm that rarely experience eutrophication.

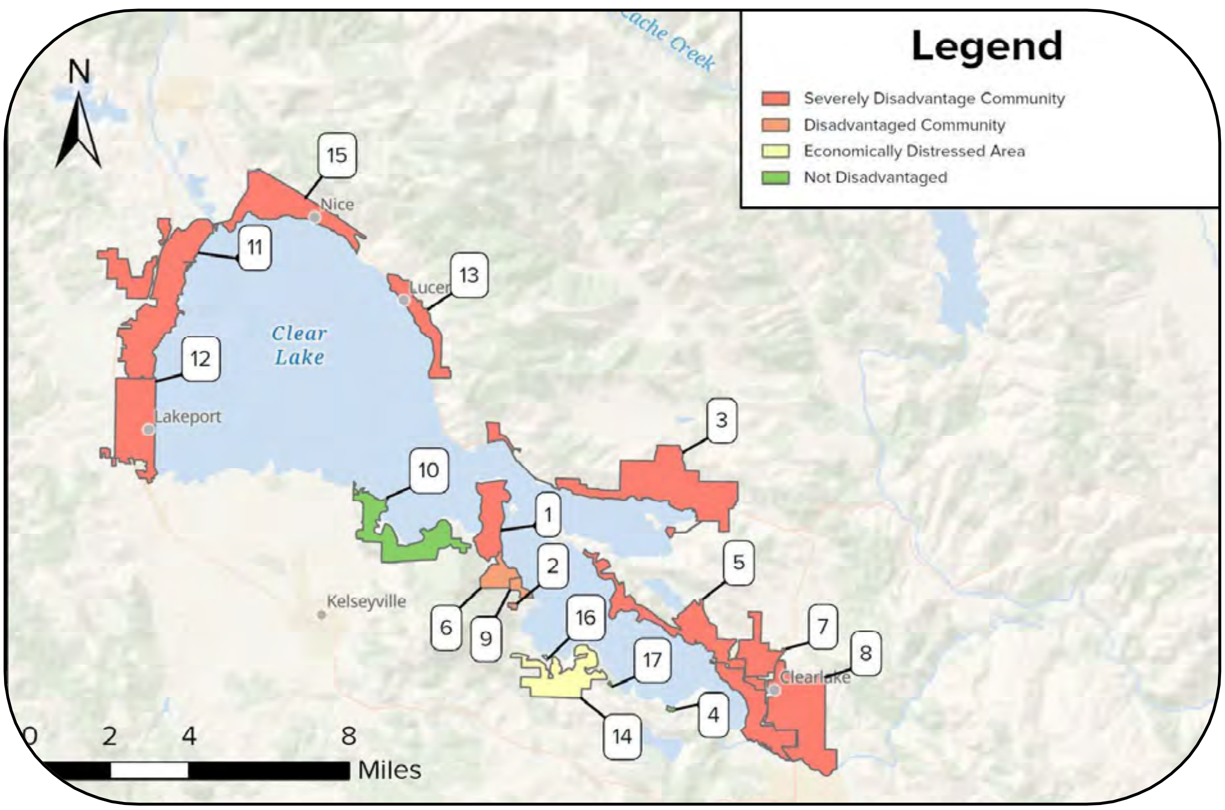

Figure 1.3.6: Socioeconomic Classifications in the Communities Surrounding Clear Lake

(Verified by the California Department of Financial Assistance in 2022)

Sixteen of the seventeen purveyors continually meet state and federal standards for drinking water (Kennard, 2021; Schott, 2022). The Crescent Bay Improvement Company has been on a boil water order since 1997 because the filtration system is not an approved design and, as a result, disinfection byproducts are an ongoing issue (Forsgren Associates, Inc., 2012). All other historical violations among the seventeen purveyors were discrete events related to disinfection byproducts and not HAB or lake-derived contaminants (Schott, 2022). Most systems have since upgraded their treatment processes to reduce the formation of disinfection byproducts by replacing the pre-oxidation chemical from sodium hypochlorite to potassium permanganate.

The purveyors success in removing microcystins and continually meeting state and federal drinking water standards is due in large part to the dedication and adaptability of operational staff and managers, state and federal funding support for infrastructure improvements, the support provided by local tribes and regulatory agencies, and the well-established communication network between purveyors on the lake. HABs are not a new occurrence in Clear Lake. The treatment and management of HABs is ever-evolving as new information becomes available. Provided that HABs continue to worsen across the nation due to climate change, there is increasing concern about the cost of water treatment, the struggle to retain qualified operators, and the treatment challenges associated with source water affected by HABs (Cheung et al., 2013). The degree to which purveyors are faced with water treatment challenges vary, but there is a consensus that conditions in Clear Lake are worsening, which increases the strain on treatment facilities.

In addition to the seventeen surface water purveyors, there are roughly 500 individual self-supply intakes that draw water directly from the lake for consumptive use at one or several households. These private self-supply intakes are not classified as public or commercial water systems and are not required to conduct monitoring under state or federal programs. As a part of the California Water Assessment of Toxins for Community Health (Cal-WATCH) study, voluntary monitoring was conducted at several private self-supplied intakes (Cal-WATCH, 2022). Results showed that, despite point of entry treatment units, many intakes tested positive for total coliform, E. coli, nitrates, cyanotoxins, and cyanobacteria (County of Lake, 2021). These results suggest that households with private self-supply intakes that are not required to monitor treatment effectiveness are at an increased risk of consuming water with known contaminants.

Water Treatment Challenges

The water quality parameters that contribute to treatment challenges in Clear Lake include silting, organic loading (high concentrations of natural organic matter at the headworks), pH swings, limited oxygen availability, and cyanotoxins. As a result, purveyors are often faced with high settled water turbidity (high turbidity after sedimentation), clogged filters, increased energy use and chemical demand, increased sludge volume, and high disinfectant byproducts. Purveyors on Clear Lake also face problems associated with taste, odor, color, iron, manganese, and ammonia. The complexity of drinking water treatment in Clear Lake, coupled with worsening conditions in the lake, consistently tests the limits of existing infrastructure and staff expertise. Operational staff must adapt to rapidly changing lake conditions and respond to unforeseen problems during treatment.

Silting

Following storm events, heavy silting may increase raw turbidity at surface water intakes to over 200 Nephelometric Turbidity Units (NTU) (Highlands Mutual Water Company, 2016), resulting in high settled turbidity and decreased filter run times (Ahart, 2021). Turbidity in the range of 1000-4000 NTU has been witnessed by Lake County Staff in tributaries after fires and storm events. Because Clear Lake is polymictic, turnover (i.e. when bottom waters, including sediments mix with surface waters due to wind or temperatures changes) happens on a daily, sometimes hourly basis, which causes periods of heavy silting and increased iron and manganese concentrations at the intake (Breedlove, 2022).

Organic Loading

Algal cells contribute to organic loading in the spring, summer, and early fall. Increased organic loading results in high settled turbidity similar to the effect of silting, however, organic matter clogs filters more quickly than colloidal silt. During a FHAB event, filters may require backwashing every couple of hours as a result of increased solids loading (Breedlove, 2022). Frequent backwashing induced by organic loading increases energy demand and the volume of sludge that must be disposed. Additionally, some treatment plants require personnel to be onsite around the clock during HAB events to manage backwash schedules and chemical dosages. This increases the overall cost of water treatment (Jensen, 2022). Algal cells clog intake screens and contribute to taste, odor, and disinfectant byproduct concerns. In most cases, taste and odor are treated with granulated activated carbon vessels. Most purveyors faced with high disinfectant byproduct formation reduce this potential via pre-oxidation with potassium permanganate.

pH

HABs can increase the pH of raw water to above 10 in Clear Lake, which significantly decreases the effectiveness of coagulation and disinfection processes. Many purveyors increase their coagulant dose from 10-20 mg/L in the winter to 60-120 mg/L when HABs are present (Ahart, 2021; McCocker, 2022). Coagulant is the most significant chemical cost during HAB events (Kennard, 2021). Disinfectant demand can go from 3-4 mg/L in the winter to over 20 mg/L in the summer months (McCosker, 2022). Fluctuations in coagulant and disinfectant demand make it difficult to maintain effective coagulation and a steady disinfectant residual as required by the Surface Water Treatment Rule (USEPA, 2022). In addition, the process is exacerbated by pH swings. Overnight, when the algae are not photosynthesizing, the pH can be neutral but during the daylight hours the pH increases drastically, which can upset the treatment process (Cheung et. al., 2013). Some purveyors have installed acid feed systems to manually reduce the pH of the raw water to decrease coagulant and disinfectant demand.

Oxygen availability

HABs deplete the available oxygen in the water which may result in hypoxia or anoxia in the lake, which can release iron, manganese, and ammonia from the sediment floor. Increased levels of iron and manganese can result in color, taste, and odor problems in finished water. Ammonia impedes the disinfection process via the creation of chloramines, which increases disinfectant demand (Kerri, 2008). Ammonia is present in the lake throughout the year, however, the presence of HABs increases the concentration of ammonia.

Cyanotoxins

Cyanotoxins increase disinfectant demand and complicate water treatment processes. If toxin-producing species of cyanobacteria are present, cellular decomposition and cell lysis release toxins. Cellular decomposition is a natural process whereas cell lysis can be induced by the treatment process. Therefore, special care is taken to avoid cell lysis during conventional treatment. A treatment process is optimized when it removes intact algal cells without inducing cell lysis (Westrick, 2010; Cheung et al., 2013; Schmidt et al., 2002). Shearing of flocculant, or the use of an aggressive pre-oxidant, can lyse the cells and release toxins. The disinfection process inactivates the remaining toxins and high toxin levels in source water may significantly increase disinfectant demand. Furthermore, effective treatment methods for one species of cyanobacteria may not be effective for another; therefore, a detailed understanding of limnology is required to optimize a surface water treatment plant that treats FHABs.

1.5- PRIOR AND ONGOING WORK BY OTHER ORGANIZATIONS

Various State, Tribal, and Local Government agencies and the University of California, Davis have recently made significant contributions related to monitoring, analyzing, and improving water quality within Clear Lake. The intent of the "Source Water Assessment" is to summarize, highlight, and build upon those contributions by others while identifying additional follow up activities and projects. A high-level summary of each primary agency's involvement and relevant publications follows.

State Water Resources Control Board (SWRCB)

The SWRCB has issued a Total Maximum Daily Load (TMDL) limit for mercury and nutrient loadings for the Clear Lake water body. The Central Valley Water Board developed a "Basin Plan" for the Clear Lake Nutrient Control Program in 2006. This program set specific load limits for point source nutrient discharges in the Clear Lake watershed. The total allocated p hosphorus loading for the basin was set at 87,100 kg/year. The basin plan included an original compliance date of June 2017 to meet allocation requirements. Caltrans, the County of Lake, the City of Clearlake, and the City of Lakeport were named as point source dischargers and assigned maximum nutrient load allocations, of 2,000 kg/year, in the 2006 Basin Plan.

In addition to "point source dischargers" several "nonpoint sources" have been monitored and regulated under the Clear Lake Nutrient Control Program. According to the Clear Lake Nutrient TMDL TM issued in 2021, "The allocation for nonpoint sources includes a combined allocation of 85,000 kg/year of phosphorus for the US Bureau of Land Management, the US Forest Service, Lake County, and Irrigated Agriculture combined. This equates to a 40% load reduction goal for each responsible party."

The SWRCB has also funded research related to Clear Lake water quality. In 2021, the SWRCB contracted with the University of Southern California (USC) and the Southern California Coastal Water Research Project (SCWWRP) to prepare a study titled "Drivers of Cyanobacteria Blooms in a Polymictic Lake". This is a study of internal and external nutrient loading and the effects on Clear Lake algae blooms.

County of Lake Water Resources Department

The County of Lake Water Resource Department is the local agency responsible for the protection of Clear Lake's entire watershed basin. The Lake County Watershed Protection District is a separate district, housed within the same physical space as the Lake County Water Resources Department. A memo titled "WHAT IS the Lake County Watershed Protection District" issued by Lake County states that the Watershed Protection District is separate from the Lake County Department of Public Works, Water Resources/Lakebed Management Division.

The Watershed Protection District has published the following information:

- Clear Lake Integrated Watershed Management Plan (2010)
- Kelsey Creek, Middle Creek, and Scotts Creek Watershed Assessments (2010)

The Lake County Watershed Protection District has also contributed to the 2019 Integrated Regional Water Management Plan spanning Yolo, Lake, Solano, and Napa Counties.

The County of Lake Water Resource Department maintains Aquatic Plant Management, Clean Water Program (Storm Water Management), Flood Management, Groundwater Management, Invasive Mussel Prevention, and Lakebed Management Programs for Clear Lake. Several of the County of Lake Water Resource Department programs are managed by the Lake County Watershed Protection District. A description of select programs follows.

Aquatic Plant Management

The Aquatic Plant Management Program is responsible for managing the application of aquatic plant herbicide and manual treatments in Clear Lake, as permitted by the California Department of Pesticide Regulation, County Department of Agriculture, and the California Department of Food and Agriculture. Aquatic Plant Management activities conform to the Clear Lake Integrated Aquatic Plant Management Plan as published in 2004, and the Monitoring and Reporting Plan as updated in 2013.

Lake County Clean Water Program

The Lake County Clean Water Program is a consortium of agencies in Lake County that discharge stormwater from municipal separate storm sewer systems (i.e. MS4) into Clear Lake. The County of Lake, City of Lakeport, and the City of Clearlake have joined together as co-permittees under the SWRCB NPDES requirements. This program was initiated in 2004, is still active today, and is led by the Lake County Clean Water Program Management Council. Various documents published by the Lake County Clean Water Program may be found at the Clean Water Program Website. Notable recent Lake County Clean Water Program (Program) reports are listed below:

- Storm Water Management Plan (2003-2008)
- Program Annual Fiscal Year Reports
- Program Effectiveness Assessment and Improvement Plan (2021)
- Trash Truck Implementation Plan (2019)

Lake County Groundwater Management Program

The Lake County Groundwater Management Program is responsible for managing groundwater resources within Lake County, and conducting groundwater monitoring for the California Statewide Groundwater Elevation Monitoring Program (CASGEM). Further information can be found on the Groundwater Management Program Website, in the 2006 Lake County Watershed Protection District Groundwater Management Plan, and in the 2006 Lake County Water Demand Forecast.

Lake County Invasive Mussel Prevention

The Lake County Invasive Mussel Prevention Program is focused on the prevention of quagga and zebra mussel infestation in Clear Lake. The program includes screening of water vessels and employs other related regulations. Funding has been provided, in part, by the California State Parks Division of Boating and Waterways and the US Fish and Wildlife Service. The Mussel Prevention Program has published the following plans and reports:

- Lake County Quagga and Zebra Mussel Prevention Plan (2019)
- 2018-2022 Annual Program Reports

Other Lake County Departments

Agricultural activities within Lake County are managed by other Lake County Departments. The Lake County Farm Burau Education Corporation has published the following relevant reports:

- Lake County Crop Reports (2005-2021)
- Lake County Clear Lake Nutrient TMDL Agricultural Report (2019)

Clear Lake Blue Ribbon Committee for the Rehabilitation of Clear Lake

In 2017, Assembly Bill No. 707 Chapter 842 added Division 14.5 Section 22085 to the California Public Resources Code, relating to Clear Lake. This bill established the "Blue Ribbon Committee for the Rehabilitation of Clear Lake" within the California Natural Resources Agency. This bill also required the committee to meet quarterly for the purposes of discussion, reviewing research, planning, and providing oversight regarding the health of Clear Lake, and provide an annual report to the Governor and the Legislature. The committee was also authorized to receive funds from public and private sources to conduct research on Clear Lake water quality.

Since the acceptance of Assembly Bill No. 707, the Clear Lake Blue Ribbon Committee (BRC) has led extensive research efforts focused on Clear Lake Water Quality and related Socioeconomic impacts. Annual reports have been produced for calendar years 2019 through 2022. The annual reports and quarterly meeting minutes are available on the California Natural Resources Agency Blue BRC website.

A significant amount of UC Davis research has been financed with BRC funds. According to the BRC 2020 Report to the Governor and California State Legislature, the following efforts run parallel to, but are technically separate from, the BRC's efforts.

- Joint UC Davis Tahoe Environmental Research Center (TERC)/ US Geological Survey (USGS) Watershed and Lake Remediation Research that includes:
    - Ongoing water quality and watershed monitoring efforts made available through a public data repository
    - Evaluation of re-oxygenating the bottom of Clear Lake near the Oaks Arm (construction funding to be requested in the 2023/24 budget)
    - Summary report on metals and metalloids in Clear Lake based on historical data
    - Remote sensing of cyanobacteria blooms
    - Three-Dimensional Modeling of nutrient cycles and dissolved oxygen levels within Clear Lake (mercury model to be incorporated in 2023) USGS will be developing a similar but independent model of Clear Lake
    - Ongoing 10-cm bathymetrical survey of Clear Lake

    - Research on the impacts of wildfire smoke on Clear Lake
- Tribal Environmental Research and Restoration Programs including:
    - Big Valley Band of Pomo Indians ongoing cyanotoxin monitoring for Clear Lake
    - US EPA mercury monitoring and remediation from the Sulphur Bank mercury mine (legacy project)
- UC Davis Center for Regional Change and Center for Community and Citizen Science
    - Clear Lake Socioeconomic Development Research and Economic Development Strategy

Please refer to the 2022 Blue Ribbon Committee Report to the Governor of California for remediation projects that have been funded, approved, or recommended for funding by the Clear Lake BRC. Additional information is available in the 2023 BRC proposal package.

UC Davis completed the following additional reports related to Clear Lake water quality, independent of the BRC.

- "The Causes and Control of Algal Blooms in Clear Lake" – UC Davis 1994
- "Human Influences to Clear Lake"- UC Davis 2009

USGS

USGS has been monitoring a handful of streams around Clear Lake for over 50 years, and they have established several additional stream monitoring gauges in the past few years to further collect information in a partnership with UC Davis. Newer stream gauges and monitoring locations have been established to provide monitoring data for streamflow and water quality during water years 2022-2024 by collecting sufficient data so that daily loads of key constituents can be computed at various gaging stations. The USGS efforts include targeting 12 samples per year at most sampling locations. The work will include sediment fingerprinting and hydrological runoff modeling to identify the spatial variations in water quality and related external loading.

The USGS has also published the following related reports and studies:

- Scotts Creek Nutrient Erosion Study (2021)
- Mercury in Fishes from Clear Lake 2019 and 2020 csv file
- The Geochemistry of Mercury and Other Constituents in Redox Manipulated Sediment Cores from Clear Lake (September 2021)
- Surface Water Geochemistry of Mercury, Methylmercury, Nutrients, and Other Constituents in Clear Lake

Many of these reports can be found online at [usgs.gov.](usgs.gov)

SECTION 2– AREA OF INFLUENCE CHARATERIZATION

2.1- CLEAR LAKE VICINITY OVERVIEW

Clear Lake is a naturally eutrophic multi-purpose recreational lake that also serves as a drinking water source for roughly 44,000 people who live along its shore, or 68% of the County of Lake's population (Safe Drinking Water Information System SDWIS, 2022). It is a large, shallow, warm polymictic[1] lake with a mediterranean climate consisting of three interconnected but fundamentally distinct basins: the Upper Arm, the Lower Arm, and the Oaks Arm. The basins are connected by a mile long strait called the Narrows (Horne, 1975) (Figure 2.1.1). The lake is 18 miles long, covers 43,790 acres, has roughly 100 miles of shoreline, and has an average depth of 26 feet (Highlands Mutual Water Company, 2016). It is the largest natural lake wholly contained in California and one of the oldest lakes in North America with estimates of its age dating back to 2.5 million years. The lake was formed by volcanic activity from the neighboring (now dormant) volcano, Mount Konocti. The lake's current shape is due to Mount Konocti's most recent eruption that took place nearly half a million years ago ("History of Clear Lake", 2022).

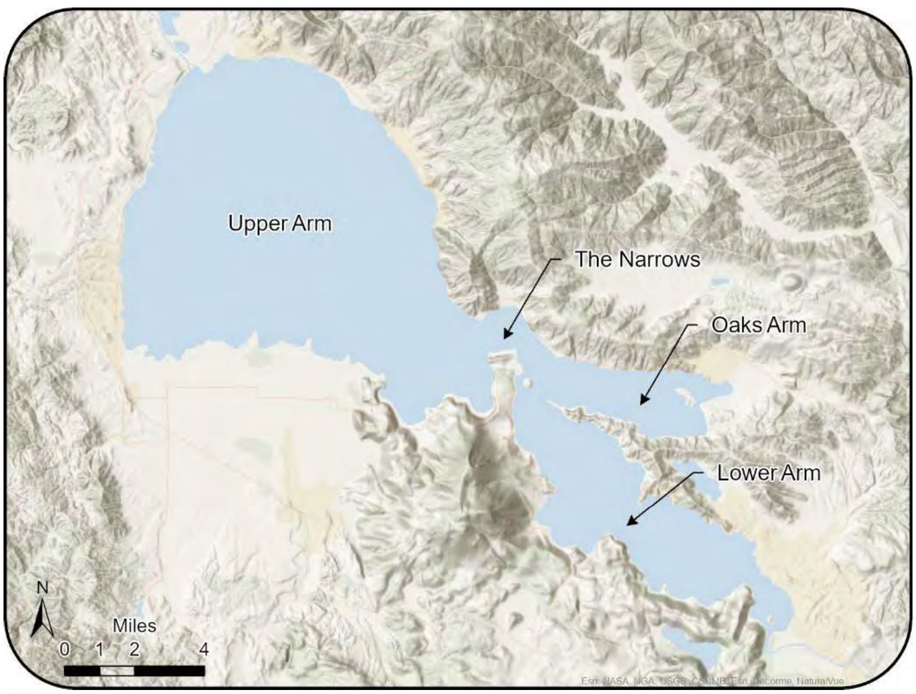

Figure 2.1.1: Clear Lake Basins

2.2- LAKE COUNTY LAND USE

The Lake County General Plan includes 14 residential, commercial, industrial, and other land use designations that define the types of land uses that are designated throughout the County. A copy of the Lake County General Plan land use diagram is presented in Figure 2.2.1.

[1] *A lake that is too shallow to maintain regular thermal stratification. Clear Lake undergoes periods of intermittent thermal stratification but is relatively well mixed throughout the year.*

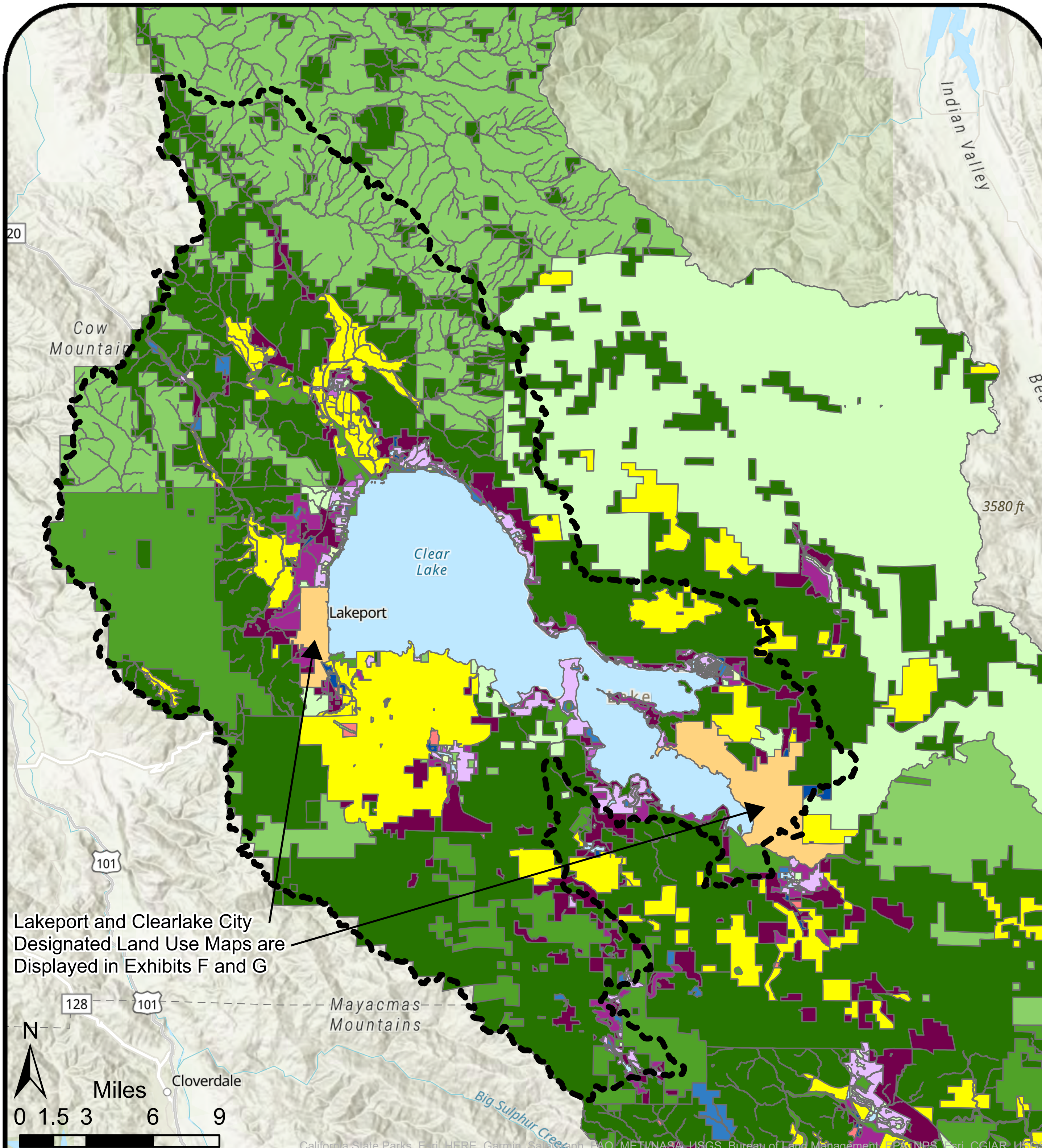

Figure 2.2.1 Clear Lake General Plan Land Use

Clear Lake Source Water Assessment

- Clear Lake Watershed
- City
- A - Agriculture
- Cc - Community Commercial
- Cl - Local Commercial
- Cr - Resort Commercial
- Cs - Service Commercial
- I - Industrial
- HDR - High Density Residential
- LDR - Low Density Residential
- MDR - Medium Density Residential
- SRe - Suburban Residential Reserve
- RR - Rural Residential
- PF - Public Facilities
- PL - Public Lands
- RC - Resource Conservation
- RL - Rural Lands

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General Land Ownership and Use

Much of the watershed consists of undeveloped lands that are

utilized to some extent for low-intensity recreation. The federal government is the largest landowner with the U.S. Bureau of Land Management (BLM) Cow Mountain Recreation Area and the U.S. Forest Service (USFS) Mendocino National Forest responsible for overseeing and administering much of the public land. Irrigated and non-irrigated agriculture account for the largest use of developed lands. Prime agricultural lands are used for orchards and vineyards. Several ore deposits were historically mined for mercury, sulfur, and borax. Active mining today consists largely of sand and gravel operations. Historic development of the watershed led to erosion problems from disturbance of riparian corridors such as gravel mining in creek beds, clean cultivation of walnut orchards on steep slopes, and road cuts. Wetlands reclamation eliminated much of the lake's natural filtration system for removing eroded sediments flowing from the upper watershed.

Residential

Low-density rural dwellings and ranches are located throughout much of the watershed but most development is concentrated around Clear Lake itself. The urban environment constitutes less than two percent of land in the watershed. The City of Clearlake on the Lower Arm is a center of commerce with a population of 16,690 (2020 US Census). The City of Lakeport on the Upper Arm is the county seat with a population of about 5,030 (2020 US Census). The total population in Lake County was estimated to be 68,158 as of the 2020 Census.

Numerous other small towns and communities exist around the lake. Most of the population around the lake is served by wastewater collection systems and treatment plants. However, communities such as Soda Bay, Kelseyville Riviera, Finley, South Lakeport, and others are served by high-density septic systems.

Table 2.2.1- Land Use Categories and Areas

Land Use Category	Total Area (Acres)	Percent of Total
Bare Rock/Sand/Clay	966	0.34
Deciduous Forest	110,029	39.00
Deciduous Shrub Land	48,390	17.15
Emergent Herbaceous Wetlands	90	0.03
Grassland/ Herbaceous	65,824	23.33
High Intensity Commercial/ Industrial/ Transportation	646	0.23
High Intensity Residential	2	<0.01
Low Intensity Residential	4,794	1.70
Mixed Forest	23,053	8.17
Open Water (not including Clear Lake)	1,491	0.53
Other Grasses (Urban/ Recreational, e.g. Parks)	141	0.05
Pasture/ Hay	9,683	3.43
Planted/ Cultivated (Orchards/ Vineyards, Groves)	16,538	5.86
Quarries/ Strip Mines/ Gravel Pits	58	0.02
Row Crops	6	<0.01
Small Grains	1	<0.01
Transitional	429	0.15
Woody Wetlands	1	<0.01
Total	282,138	100.00

Source: Total Maximum Daily Load (TMDL) for Nutrients in Clear Lake, Tetra Tech, 2004

2.3- CLEAR LAKE WATERSHED DELINEATIONS

The Clear Lake watershed includes a total of 16 separate sub-sheds, each with a unique Hydrologic Unit Code. A Hydrologic Unit Code (HUC) is a unique code, consisting of two to eight digits, used to identify watersheds based on the United States Geological Survey's four-level classification system. These sub-sheds are presented below in Figure 2.3.1.

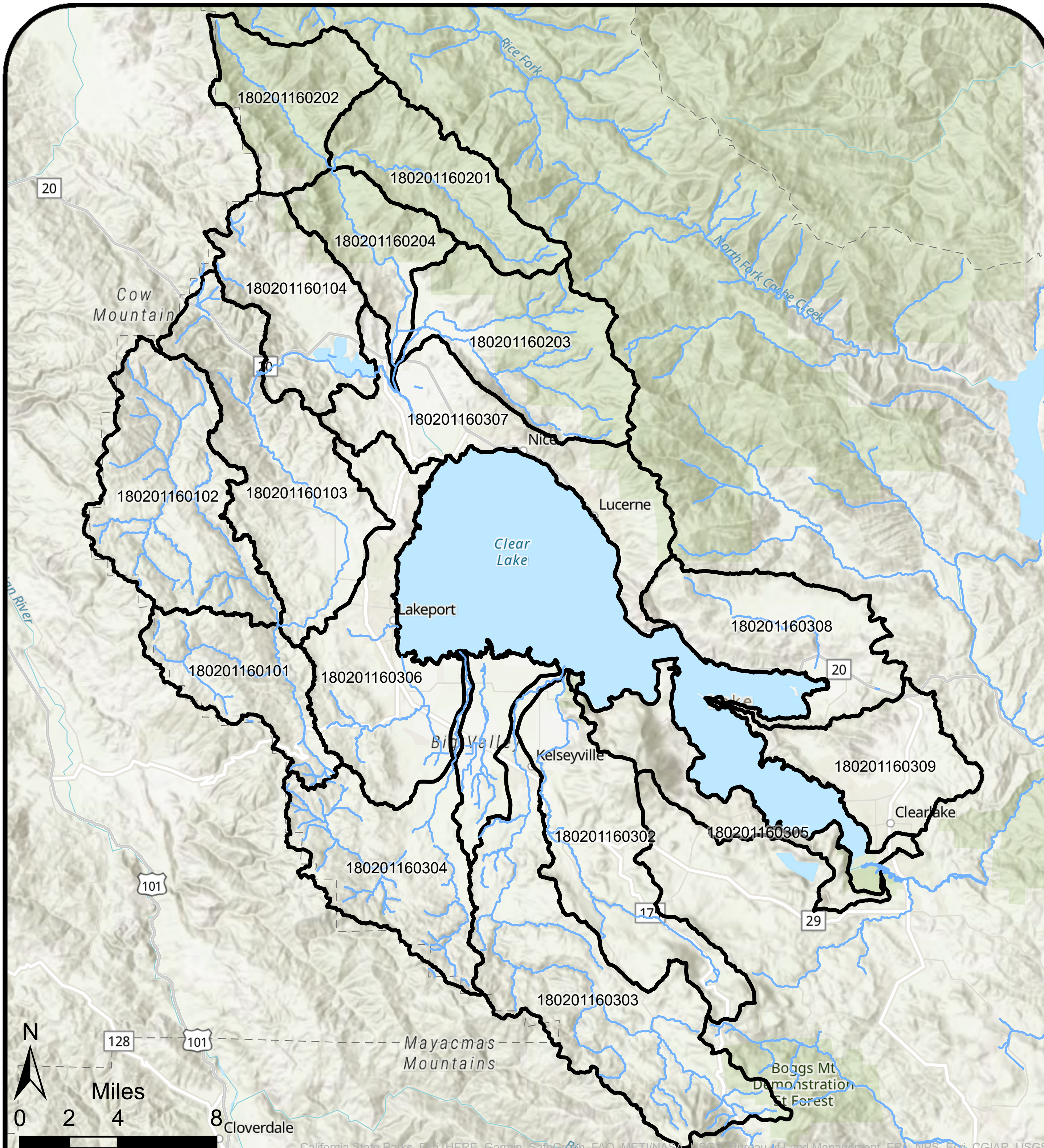

Figure 2.3.1: Clear Lake HUC 12 Watersheds

Lake County Source Water Assessment

Creeks & Streams — HUC 12 Watersheds

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Table 2.3.1- HUC 12 Project Area List

No.	HUC Code	Name
1	180201160309	Burns Valley-Frontal Clear Lake
2	180201160202	West Fork Middle Creek
3	180201160104	Lower Scotts Creek
4	180201160102	Upper Scotts Creek
5	180201160307	Rodman Slough-Frontal Clear Lake
6	180201160304	Adobe Creek
7	180201160308	Schindler Creek-Frontal Clear Lake
8	180201160203	Clover Creek
9	180201160305	McGaugh Slough-Frontal Clear Lake
10	180201160103	Middle Scotts Creek
11	180201160302	Cole Creek
12	180201160303	Kelsey Creek
13	180201160201	East Fork Middle Creek
14	180201160101	South Fork Scotts Creek
15	180201160204	Salt Flat Creek-Middle Creek
16	180201160306	Manning Creek-Frontal Clear Lake

2.4- AQUIFER DESCRIPTIONS

Clear Lake is surrounded by a patchwork of groundwater basins interspersed with non-basin terrain as shown on the following map. The California Department of Water Resources (DWR) Sustainable Groundwater Management Act (SGMA) Dashboard (https://gis.water.ca.gov/app/bp-dashboard/final/) maps include seven DWR defined groundwater basins in the study area. Both the major and minor aquifers feeding domestic wells and the one public water system (City of Lakeport) still using wells draw water from these basins. DWR descriptions of each basin, as listed below, along with more detail regarding the characteristics of the individual basins, can be found in Attachment B. Figure 2.4.1 displays the locations of groundwater basins in the watershed.

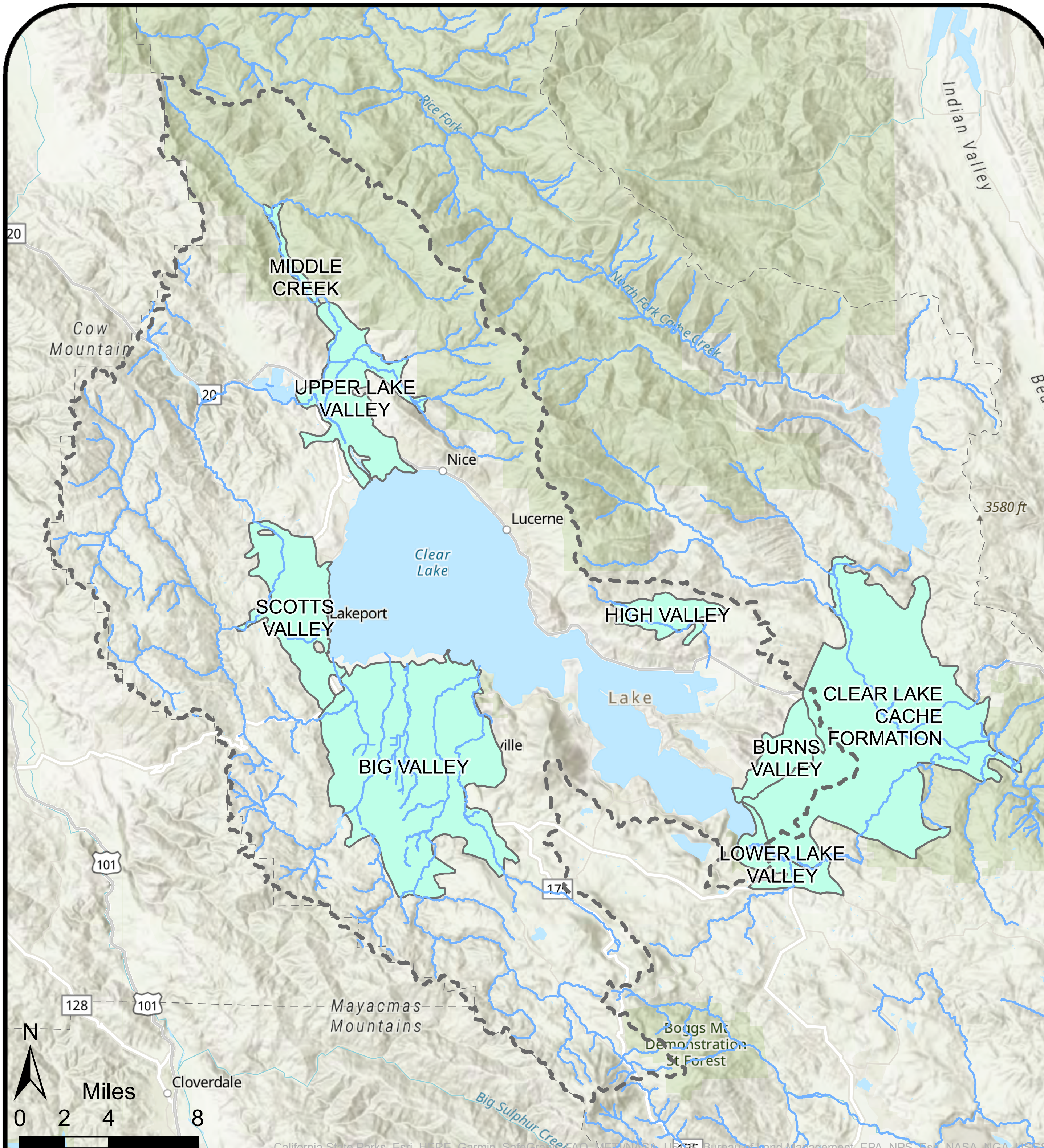

Figure 2.4.1 Clear Lake Groundwater Basins

Clear Lake Source Water Assessment

Creeks and Streams | Groundwater Basins | Clear Lake Watershed

California
Rural Water Association

2.5- HISTORY OF WATER QUALITY ISSUES IN CLEAR LAKE

According to mud core samples conducted at Clear Lake, FHABs started to increase during the 1920s and 30s coinciding with heavy land disturbance and development around the lake. After 1927, the flow of sediment into the lake drastically increased due to the usage of heavy machinery to create areas for farming and roads, paving the way for large amounts of future agriculture and road building. Over the next few decades, much of the wetlands to the northwest of the lake were destroyed and in the process the Rodman Slough was created. The slough became a narrow-confined waterway that allowed water to freely flow into the lake from the watershed above. Removal of the wetlands eliminated a natural filtering system, and allowed sediment suspended in the water to flow into the lake. With these filtration systems removed, nutrient loading from sediment in the runoff has increased along with associated algal blooms.

According to the Lake County Water Resources Department website, 85% of existing wetlands around the lake have been removed for development, as well as much of the lakeside vegetation. The amount of lakeside vegetation that remains is primarily tules, a large species of sedge that grows in shallow water. These tules also reduce lakeside erosion and provide habitats for many bird, fish, and mammal species. The County of Lake's Water Resources Department is developing a "Shoreline Stewardship Program" for Clear Lake shoreline property owners based off the data gathered from a "Score-the-Shore" survey that was conducted from 2020-2022.

SECTION 3- HYDROLOGY AND WATER QUALITY CHARACTERIZATION

3.1- HYDROLOGY

The limits and tributary sheds of the of the overall Clear Lake watershed were introduced in the previous section. The related groundwater basins and streams are described in this section, including a description of the surface water related inflows and related contaminant transport mechanisms. Limited discussions are included on the contribution of groundwater contaminants due to the sparse amount of water quality data available. An emphasis is placed in subsequent sections on the surface water tributaries that contribute to the external loading of various contaminants in the lake. Watersheds introduced in Section 2 are described in more detail to identify their relative contribution to the overall mass loading of the most problematic contaminants, including phosphorus and other nutrients that tend to promote FHAB growth.

Surface Water Hydrology

The area of the entire Clear Lake basin is not precisely defined and varies in size depending on the source consulted. The Middle Creek Watershed Assessment (2010) places the basin at 475 square miles whereas the California Nevada River Forecast Center (2022) uses a value of 319 square miles. Please refer to Section 2 of this report for a watershed delineation map.

The California River Forecast Center reports that over the past 30 years the average annual precipitation in the basin was 34.5 inches. The resulting inflow ranges from 590,000 to 870,000-acre feet depending on the size of the watershed. Most of the precipitation ultimately enters Clear Lake either through direct runoff or via groundwater flows from the surrounding groundwater basins. Precipitation is seasonal with the majority of rainfall occurring

during the winter and early spring months as depicted in Figure 3.1.1.

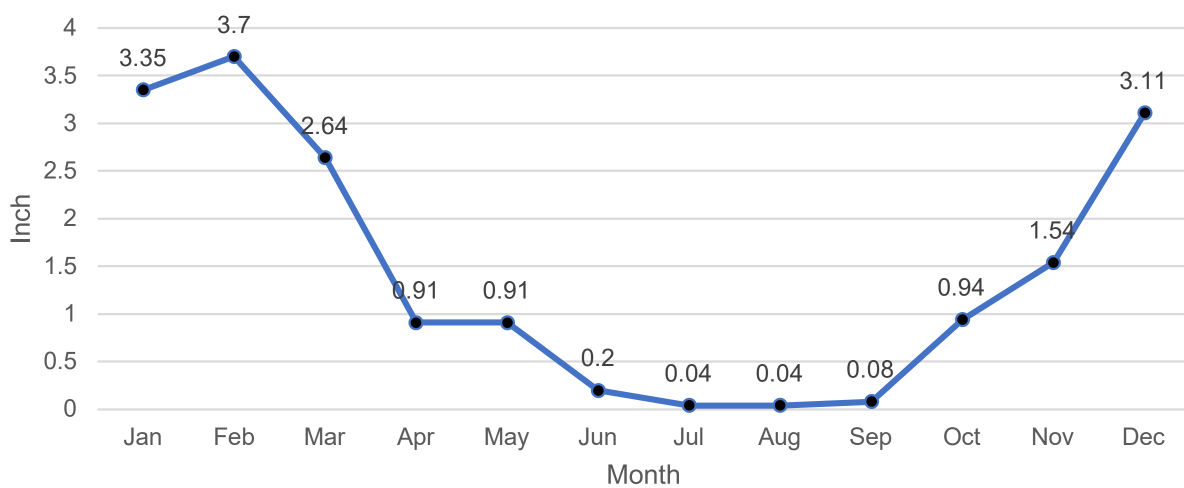

Figure 3.1.1: Average Yearly Rainfall in Clearlake, CA

Note : Historic rainfall data has been obtained from weather-us.com.

The interplay of numerous factors distribute rainfall between surface runoff and percolation. A partial listing of factors influencing the percentage of a given rainfall event ending up as surface flow includes permeability of the local land surface, precipitation rates, elevated groundwater tables without available storage space or conversely depressed groundwater levels, vegetation and anthropogenic groundcover, local topography, soil types, and other variables.

The Clear Lake Basin receives less than one inch of snow per year with that amount increasing as elevation rises around the perimeter of the watershed. Snow produces subdued surface flow as the melting process is slow in comparison to rainfall events, thereby allowing a high percentage of the snow melt to percolate into the groundwater table.

The network of streams within the Clear Lake watershed are depicted in Figure 2.3.1 and only the larger streams have gauging stations. Stream flows in the study area are monitored by both the USGS and DWR. Gauging stations are described in more detail in the Water Quality portion of this report. Stream flow is highly seasonal.

Groundwater Basins and Groundwater Hydrogeology

The County of Lake Department of Water Resources and the Lake County Watershed Protection District monitor groundwater throughout Lake County. Groundwater in the basins contain localized high iron, manganese, calcium, sodium, sulfate, and total dissolved solids (TDS). High boron concentrations may be an issue for irrigation in some basins. Impairments to water quality in the High Valley basin include locally high ammonia, phosphorus, chloride, iron, and manganese. Groundwater quality data for each major basin, as available from DWR monitoring, is summarized in Attachment B. A summary of groundwater use for each basin, including the number of public wells and irrigated acres is provided below in Table 3.1.1

Table 3.1.1- Groundwater Use by Basin

Basin	Number of Public Wells	Total Wells	Irrigated Acres	Total Acre/Ft Year
Upper Lake	6	282	2,070	2,828
Scotts Valley	8	522	1,208	3,114
Big Valley	8	872	7,906	19,107
Lower Lake	6	57	117	219
Clear Lake Cache	3	134	158/	317
Burns Valley	0	115	378	854
High Valley	3	26	153	136

Note: This data has been obtained from the Sustainable Groundwater Management Act (SGMA) database.

Watersheds

Creeks connected to Clear Lake, such as Middle Creek and Scott's Creek, convey flows from watersheds that drain into Clear Lake. Middle Creek and Scotts Creek watersheds encompass approximately one half of the Clear Lake watersheds alone. These watersheds carry phosphorous-bound sediments into Clear Lake via erosion and allow for phosphorous to be released into the lake. Middle Creek and Scotts Creek alone contribute 51% of Clear Lake water inflow and are responsible for 71% of phosphorous loading. Please refer to Exhibit A for a map of the Scotts Creek watershed.

Wetlands inhibit sediment deposition in Clear Lake, as the plants in the wetland environment slow water down, allowing for sediments to be trapped so nutrients can be absorbed by the plants. Over the years, wetlands have been reclaimed for agricultural and residential use. Levees have been constructed along riverbanks which channelize stream flow and result in greater nutrient loading in the lake. The US Fish and Wildlife Service maintains a national wetlands inventory online map which includes wetlands in Lake County. This map link is included in the references list at the end of this report.

Culverts

A significant percentage of overland flow that enters Clear Lake will at some point concentrate and pass through a manmade culvert. These locations are considered critical points with respect to a variety of forms of related runoff, including agricultural and non-point sources within each sub-watershed. Culverts provide a strategic location to mitigate nutrient loading in Clear Lake. These points can be ideal for implementing potential BMP's to reduce current and future nutrient loading. Figure 3.1.2 shows culverts managed by Caltrans, and Figure 3.1.3 shows culverts managed by Lake County or the City of Clearlake.

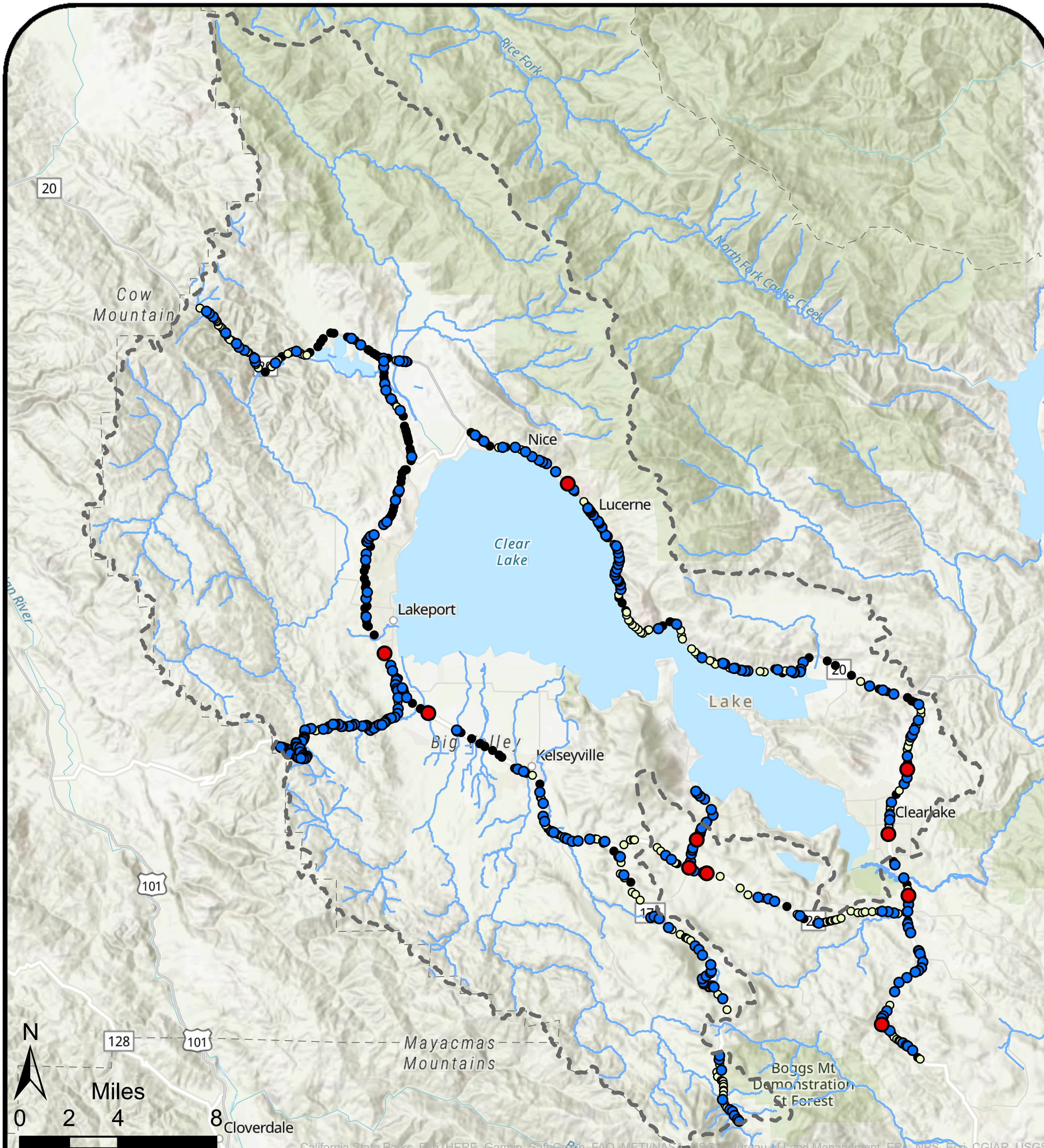

Figure 3.1.2: Caltrans Culverts

Lake County Source Water Assessment

Culverts > 0"
Culverts > 20"
Culverts > 80"
Culvert Size NA
Creeks & Streams
Clear Lake Watershed

California
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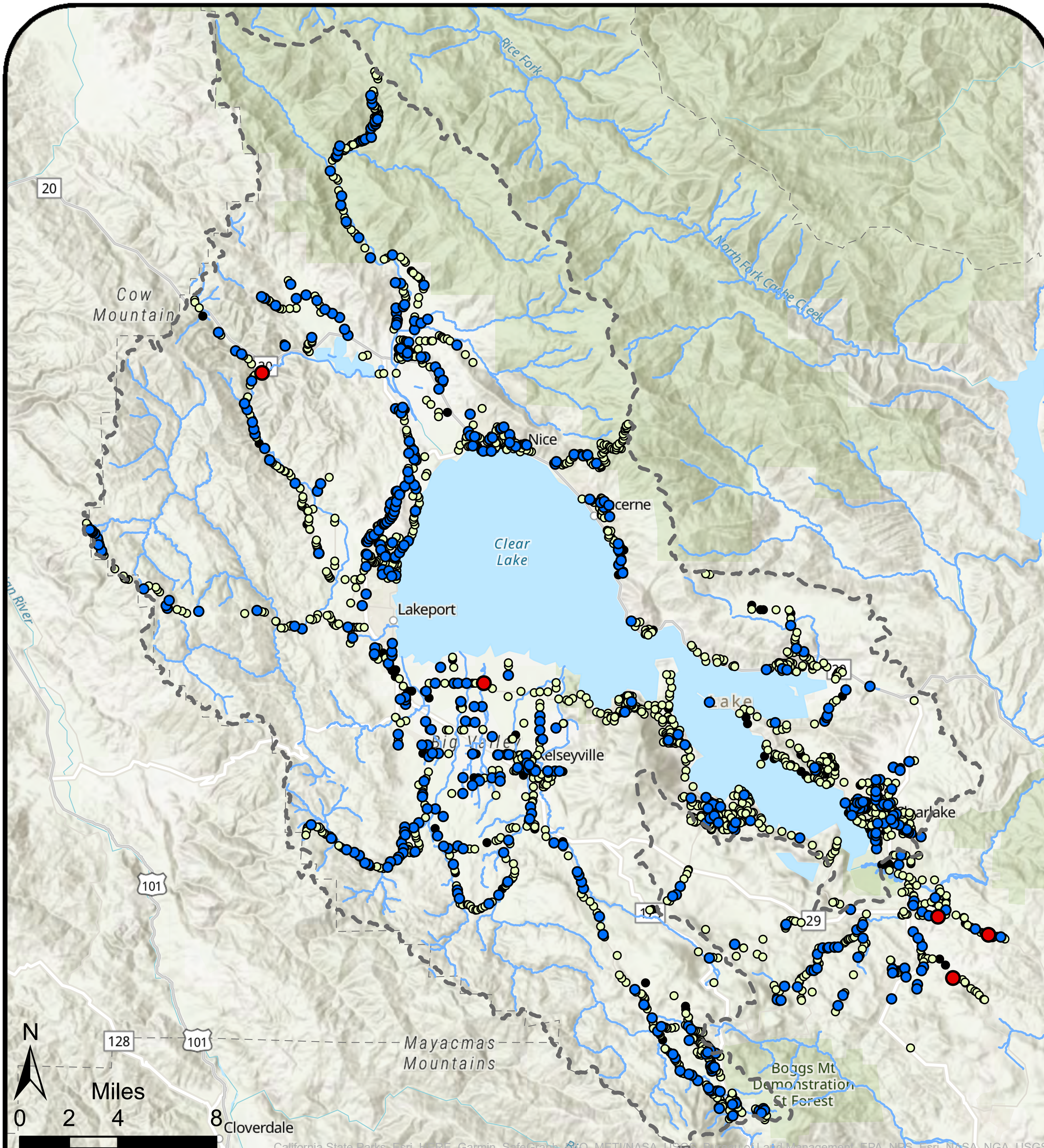

Figure 3.1.3: Lake County Culverts

Lake County Source Water Assessment

Culverts > 0"
Culverts > 20"
Culverts > 80"
Culvert Size NA
Creeks & Streams
Clear Lake Watershed

California Rural Water Association

3.2- WATER QUALITY MONITORING

Water quality monitoring in Clear Lake and at lake inlets such as streams and culverts, is conducted regularly by multiple agencies. The following agencies publish Clear Lake water quality data for review by the public:

- Local Water Purveyors that maintain a Surface Water Intake
- Lake County
- California DWR (Lake County has replaced DWR Monitoring)
- United States Geological Survey (USGS) / UCD TERC (as part of the Clear Lake Blue Ribbon committee)

A map of recently published water quality sampling sites is presented in Figure 3.2.1. Each sampling site is described in further detail in the following pages.

Clear Lake Influent Water Quality Monitoring

The Lake County Watershed Protection District collects nutrient-related water quality information at select culverts on the north side of the lake as part of the Lake County Clean Water Program (NPDES co-permittee consortium). The California DWR and the USGS maintain gauges at select streams that flow into Clear Lake. The stream gauges monitor stream flowrate. Some USGS stream gauges are near a nutrient monitoring sampling site. Please refer to Table 3.2.1 for an overview of constituents tested and the sampling frequency of each agency.

Table 3.2.1: Clear Lake Influent Water Quality Monitoring

Agency	Sample Location Type	Constituents Tested	Sampling Frequency	Notes	Raw Testing Data Public URL
Lake County Watershed Protection District	Urban Culvert Sampling Site	Metals CAM 17 Nitrogen Suite Total Phosphorous Total Suspended Solids	During storm events >1” per 24 hour period	-	Click to View
California DWR	Stream Gage	Turbidity	Real-Time	Real-Time Stream Flow is Available	Click to View
USGS	Stream Gage	Turbidity pH Nitrogen, Phosphate (various forms)	≈ Bi-Monthly Nutrients are not Tested at all Sites	Real-Time Stream Flow is Available	Click to View
	Stream Nutrients Sample Site	Nutrients	-	-	NA

Note: Sampling locations are illustrated in Figure 3.2.1.

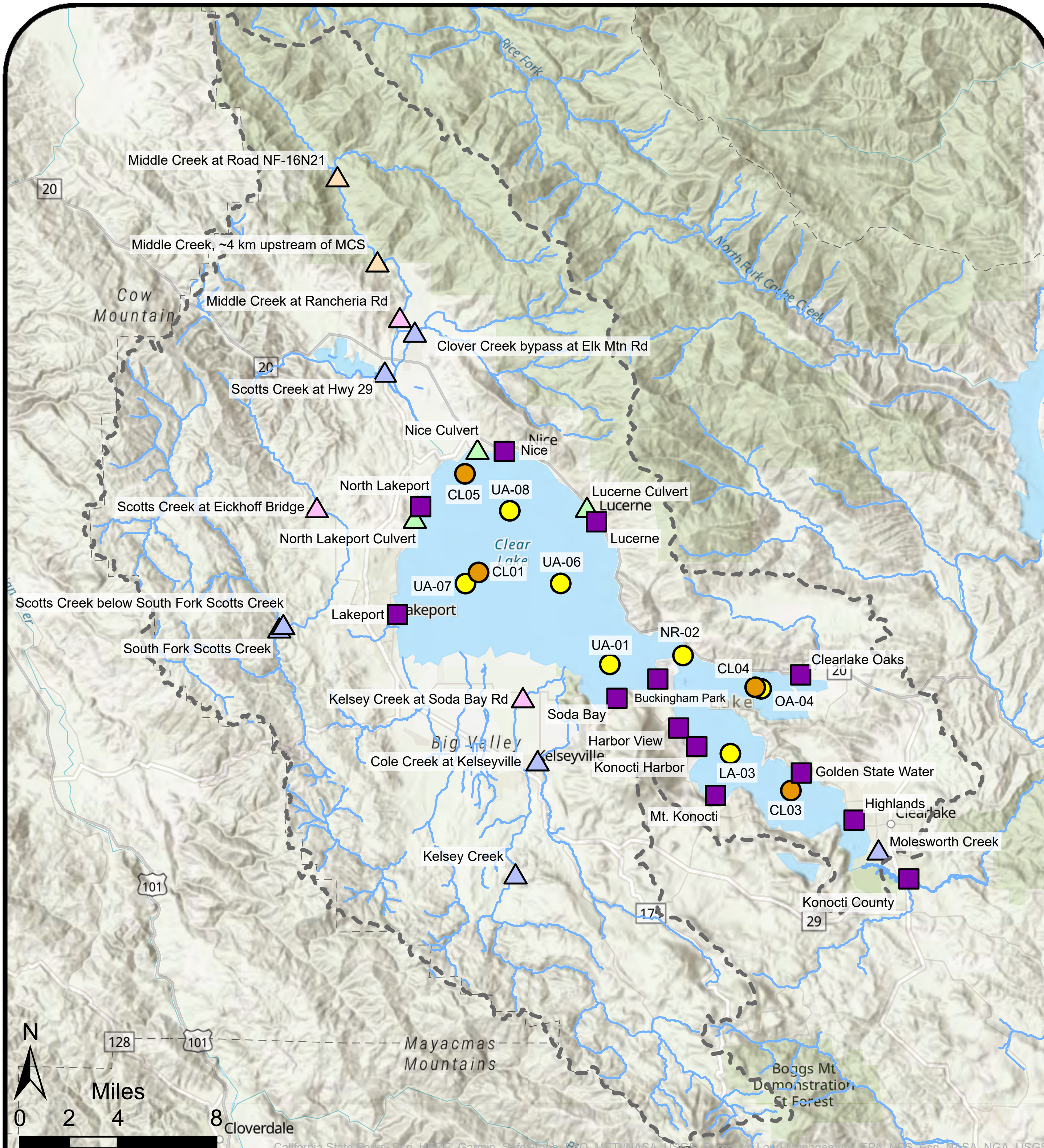

Figure 3.2.1: Water Quality Monitoring Sites

Clear Lake Source Water Assessment

Lake Water Quality Monitoring

- Various Surface Water Purveyors
- CA DWR Mid-Lake Water Quality Sample Site (Historical Data Only, DWR Monitoring Ceased in 2020)
- Lake County Mid-Lake Water Quality Sample Site

Stream Water Quality Monitoring

- USGS Stream Gage
- USGS Stream Nutrients Sampling Site
- CA DWR Stream Gage
- Lake County Urban Culvert Sampling Site

- Clear Lake Watershed
- Creeks and Streams

California Rural Water Association

Clear Lake Ambient Water Quality Monitoring

An extensive amount of ongoing raw water quality data has been recorded by 16 Clear Lake surface water purveyors and made available to the public through the Safe Drinking Water Information System (SDWIS) data repository. Each surface water purveyor is assigned a raw water monitoring schedule by the California DDW. A typical raw water monitoring schedule is presented in Attachment D of this report.

The California DWR has conducted regular water quality testing at three locations within Clear Lake. The DWR testing sites are known as the "Upper Arm", the "Oaks Arm", and the "Lower Arm". The Lake County Watershed Protection District monitoring efforts replaced previous water quality monitoring by the DWR in July 2020. Some gaps and inconsistencies in data collection occurred during this transition near the start of the COVID-19 pandemic.

Please refer to Table 3.2.2 for an overview of constituents tested and the sampling frequency of each agency. Please refer to Figure 3.2.1 for a map of water quality sampling locations.

Table 3.2.2: Clear Lake Ambient Water Quality Monitoring

Agency	Sample Location Type	Constituents Tested	Sampling Frequency	Notes	Raw Testing Data Public URL
Various Surface Water Purveyors	Raw Water Intake Water Quality Reporting	TSS, pH, Nitrogen, Phosphorus, Mercury See Attachment D for Detailed List	See Attachment D	-	Click to View
Lake County	Mid-Lake Water Quality Sample Site	Turbidity	Daily Logs from 2019 to 2021	Data is Presented as a Function of Depth	Click to View
California DWR	Mid-Lake Water Quality Sample Site	Turbidity, pH, Nitrogen, Phosphorus, Mercury, Boron	Monthly	Lake County Assumed DWR Sampling in 2020	Click to View

Note: Sampling locations are illustrated in Figure 3.2.1.

Water Quality Monitoring Findings

A summary of water quality data for seven primary constituents monitored at Clear Lake follows. Please refer to Attachment C for a more detailed summary of recent water quality data published by Lake County.

Turbidity

Turbidity tends to have two main sources, rainfall, and algal growth. During seasons with significant algae present turbidity will spike. Turbidity also can spike during seasons with heavy rainfall. Recent turbidity measurements published by Lake County have ranged from 0.88 NTU to 49.8 NTU.

Dissolved Oxygen

Dissolved oxygen tends to drop in the summer months during the time when algal blooms are most prevalent. This is caused by the algae decomposing. Dissolved oxygen values published by Lake County can range from 0.1 mg/L to 16.32 mg/L.

Ammonia

Ammonia spikes are most common during the summer months when large amounts of algae are decomposing. Water quality data published by Lake County has indicated that ammonia can jump as high as 3.09 mg/L versus 0.01 mg/L during the winter months.

pH

The pH levels in Clear Lake rise during the summer months when algae is photosynthesizing during the daytime and consuming carbon dioxide in the water. Water quality data published by Lake County has indicated that summertime pH levels commonly rise into the 9.0-9.5 range with some spikes into the 10s, while in the winter pH levels are around 7.5.

Boron

The California DDW established a “notification level” for Boron in finished drinking water as 1 mg/L. Water quality monitoring data published by Lake County and the California DWR indicates that Boron concentration at Lower Arm, Oaks Arm, and Upper Arm sampling sites typically ranges between 0.8 and 2 mg/L.

Mercury

All recent water quality data for 16 surface water purveyors on Clear Lake indicate “0” ug/L total Mercury content. Other government agencies and research groups have indicated positive test results for free mercury in the lake water, however most findings have been within DDW drinking water standards. Fish caught in Clear Lake often contain elevated levels of methylmercury, which is a different form of mercury than free mercury in the lake water.

Arsenic

The California maximum contaminant level (MCL) for Arsenic in finished drinking water is 10 micrograms per liter. Select samples obtained by the California DWR at the “Upper Arm” sampling site in 2015 and 2016 are above this MCL. Other recent data published by the California DWR and Lake County between 2015 and 2021 at the Lower Arm, Oaks Arm, and Upper Arm is at or below the finished water MCL.

3.3- BLUE GREEN ALGAE (FHABS)

The excessive and persistent presence of blue-green algae blooms (FHABs) is a significant water quality issue at Clear Lake. Every year, the algae blooms peak in late summer. There are multiple different strains of algae, and each year different strains become the prevalent type in the lake. There are many different variables including temperature, phosphorus, nitrogen, iron, dissolved oxygen, and pH levels that factor into determining which strain of algae is the most prevalent. Richerson, 1994, stated that the most common strains of cyanobacteria are Microcystis and Anabaena in the late summer to early fall, and Aphanizomenon in the lake spring and early summer. Other common algae along with other organisms in the food tree are listed in Attachment F. Non-nitrogen fixing cyanobacteria tend to be more prevalent earlier in the summer cycle as nitrogen levels are higher and they can out compete the nitrogen fixing cyanobacteria, as the nitrogen fixers need to spend a significant amount of energy fixing nitrogen from the atmosphere. The nitrogen fixing bacteria will then flourish when the nitrogen to phosphorus ration drops down to lower levels later in the summer.

The FHAB blooms are a visible component of a complex water quality cycle that recurs every year. A simplification of this complex cycle follows.

In the winter and early spring, seasonal rainfall brings nutrients (phosphorus and nitrogen) into Clear Lake through both streams and culverts. The seasonal rainfall temporarily increases the opacity of lake water as soil and other fine particles become suspended. Several Clear Lake monitoring stations report a related spike in turbidity during this season. As the water temperature increases throughout the summer and day length increases, the blue-green algae has a greater potential for photosynthesis and begin to rapidly multiply. Nitrogen, phosphorus, and other nutrients are processed by the growing algae population. The algae increase the pH of the lake water as carbon dioxide is extracted. By late summer, select limiting nutrients have been exhausted, and the blue-green algae begins to die. The large mass of dead algae is consumed by other forms of aerobic bacteria. The aerobic bacteria population multiplies as the algae matter continues to decay and soon the dissolved oxygen (DO) concentration in the lake begins to decrease. Low DO has previously resulted in fish kills as illustrated in Section 1 of this report.

The algae cycle is largely driven by nutrient loading and warm weather. Nutrients enter Clear Lake through a variety of sources. As outdoor water temperature is beyond practical human control, potential projects intended to manage FHABs at Clear Lake should be primarily focused on capturing nutrients that are entering the lake. A description of potential nutrient loading sources and conveyance routes are described later in this report section.

Figure 3.3.1: Algae Growth Imagery from ESA Satellite Sentinel 2

3.4- GEOGRAPHICAL INFLUENCE ON WATER QUALITY

There are several geographical factors that influence Clear Lake water quality. The lake sits in the Clear Lake Volcanic Field at around 1,300 ft elevation. The highest volcanic mountain peaks in the vicinity are closer to 4,700 ft. The geography in this area has been heavily influenced by volcanic activity. Because of the volcanic influence, the soil in the watershed is heavy in phosphorus. Phosphorus in the soil is good for agriculture, however the soil is also a large natural driver for FHABs in Clear Lake.

Although the surface of Clear Lake is around 1,300 ft in elevation, it shares the same Köppen Climate Classification (Csa) as most of the Central Valley in California. This classification is a temperate climate with a hot summer drought. During the summer, the Clear Lake area regularly reaches 90ºF -100ºF and beyond. Clear Lake itself is very shallow, as noted in the Integrated Watershed Plan, Clear Lake has an average depth of approximately 27 feet and a maximum depth of around 55 ft below the high-water line. According to the Lake County Department of Water Resources website, the lake surface fluctuates about 5.6 feet on average each year. Simplified bathymetric contours are illustrated in Figure 3.4.2.

The high seasonal temperatures and shallowness of the lake results in a warmer minimum lake temperature during the summer months. Lake County water data monitoring shows lake water itself during the summer average temperature of above 70ºF, with a July and August average of 77ºF. Peak water temperatures during this time can easily reach into the low 80s. This warmer minimum temperature leads to ideal temperature growth ranges for cyanobacteria. The Southern California Coastal Water Research Project found that cyanobacteria require temperatures above 68°F for growth rates to be competitive with eukaryotic phytoplankton taxa, and above 77°F for growth rates to be competitive with diatoms.

The physical layout of the lake also contributes to water quality problems. The lake is divided into three arms. Water flow between each arm is restricted by peninsulas giving only around a roughly 2000-foot gap. Recent modeling has demonstrated that water entering the lake can recirculate indefinitely in one of the three lake arms. The UC Davis Tahoe Environmental Research Center developed a hydrodynamic computer model that can simulate particle travel in Clear Lake. Exhibit E (located at the end of this report) shows three possible paths using this model. Furthermore, water flowing out of the lake is limited by the Redbank Gorge, a roughly 6.5-mile, 100-ft wide channel that water needs to flow down before making it to the Cache Creek Dam. These bottlenecks hamper the ability for nutrients to flow about and leave the lake, and make it difficult to prevent future internal loading of nutrients.

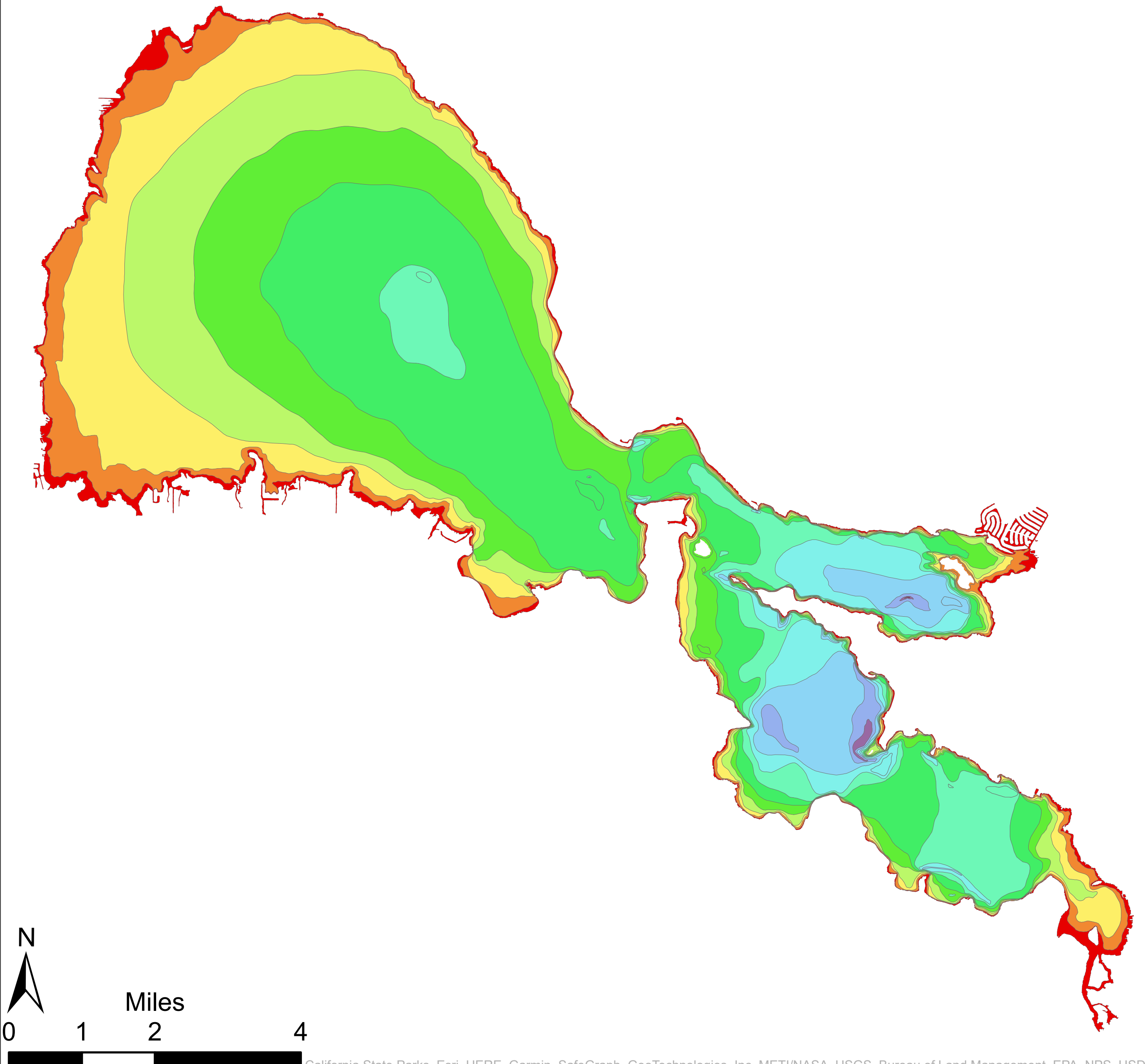

Figure 3.4.2 Clear Lake Bathymetric Contours

Clear Lake Source Water Assessment

Depth (Feet)

0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55

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3.5- POTENTIAL SOURCES OF EXTERNAL LOADING

Nutrient loading can be either internal or external. External loading refers to any nutrient loading that occurs outside of Clear Lake, while internal loading happens when nutrients are recycled inside the lake. There are multiple sources of potential external nutrient loading and toxic constituent contamination within the Clear Lake watershed. Urban, agricultural, roadway, and forest areas surround the perimeter of the lake. For context, please refer to Figure 3.5.1 for a general overview map of land use within the vicinity of the lake.

The California Central Valley Regional Water Quality Control Board (RWQCB) adopted total maximum daily loads for various external nutrients from point and non-point sources in 2008. The Central Valley staff concluded that:

"Most sources of phosphorus to Clear Lake are sediment driven and include erosion from agricultural and urban areas, instream channel erosion, timber harvesting, runoff from roads, construction, gravel mining, wildfires, control burns, off highway vehicle (OHV) use, and dredging and filling. Fertilizer use (both urban and rural) and sewer and septic overflows may also contribute phosphorus to the Lake.

The following potential sources of lake water contamination are presented in this report section:

- Erosion of Natural Soils
- Agriculture (Crops and Livestock)
- Timber and Forestry
- Septic Systems
- Urban Runoff
- Urban Wastewater
- Landfills
- Mining

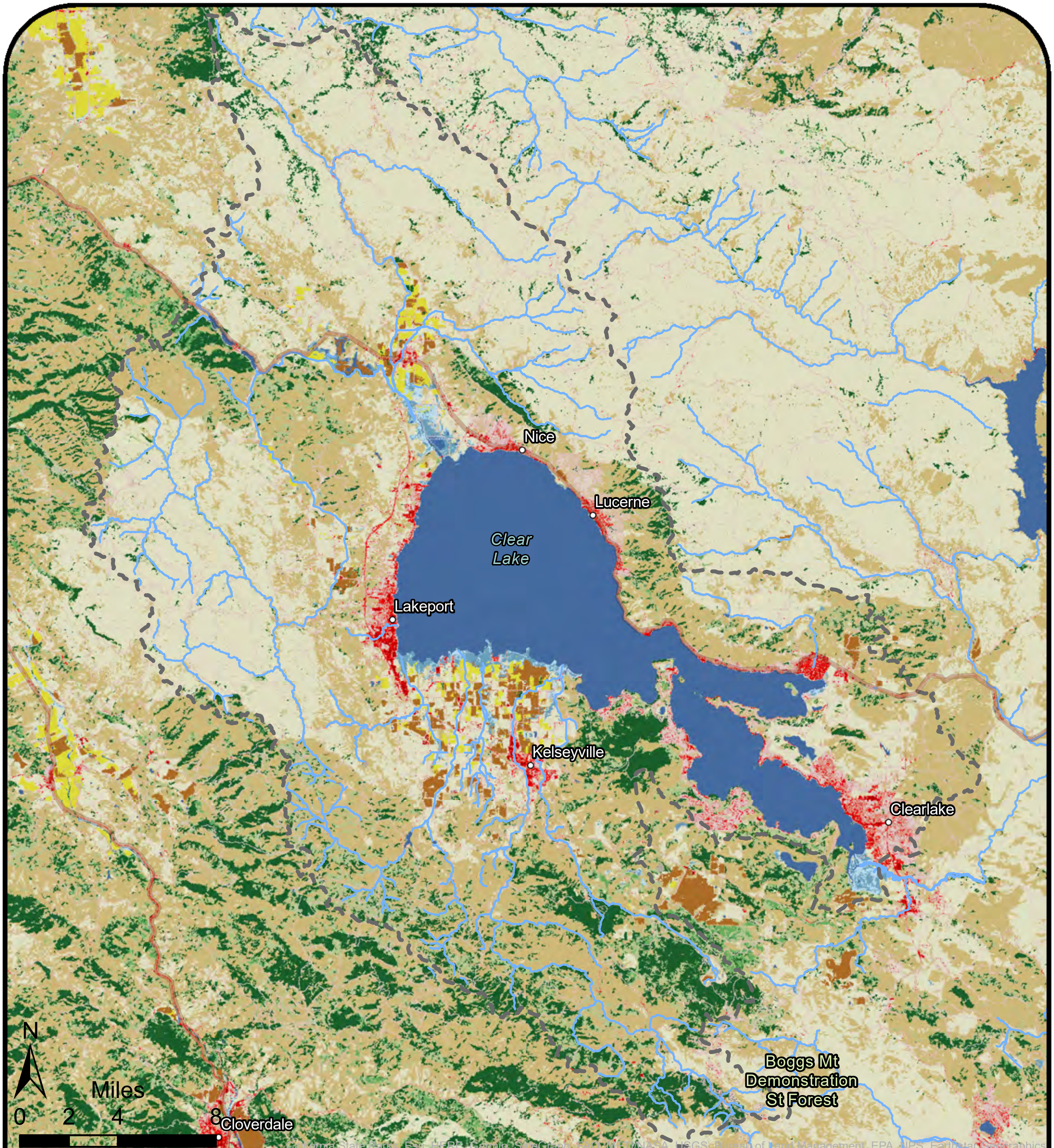

Figure 3.5.1: Clear Lake Vicinity Landcover

Clear Lake Source Water Assessment

- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Herbaceous
- Hay/Pasture
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands
- Creeks and Streams
- Clear Lake Watershed

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Erosion

The sources of erosion in the Clear Lake watershed are numerous and recent studies continue to confirm the role that erosion and the transport of fine sediments into the lake play, particularly with respect to the potential to increase the nutrient loading and resulting FHAB blooms. Based on findings by Richardson, (1994), it has been established that the soil around Clear Lake is rich in phosphorus, one of the key drivers of algal growth. Flowing water can pick up soil particles and carry them into channels that flow into the lake where it then settles and dissolves.

General categories contributing to erosion are described below:

- *Paved and unpaved roads:* Roadways tend to alter the natural overland flow of runoff and concentrate flows into roadside ditches and culverts, thus increasing the velocity and related scour potential. Culverts can concentrate flows to areas where sheet flow was previously. As flows are concentrated, velocities and scour potential increases substantially.
- *Agriculture:* As natural vegetation is displaced by crops and open fields, the soil can become more vulnerable to erosion, particularly when considering related drainages and concentrations of flow into un-lined channels.
- *In-stream channel erosion:* Whenever flows are channelized the resulting soils become more susceptible to erosion. This is particularly the case when natural vegetation is removed and flows increase due to increases in runoff associated with increased runoff from impermeable surfaces and a reduction in permeable soils in urban areas.
- *Construction:* Soil disturbances during construction often result in a loss of ground cover and channelization of flows, thus increasing erosion and scour potential.
- *Gravel mining:* In stream gravel mining has been reduced significantly and by 1990 only one operation in Scotts Creek remained in service.
- *Wildfires and control burns:* Recent years have seen a dramatic increase in wildfires in Lake County. Efforts are on-going to analyze the impacts and increased erosion potential associated with recent burns and loss of forest in and near the watershed. Ash from fires can also contribute to Lake water quality degradation.
- *Timber harvesting:* There is limited timber harvesting in the Clear Lake watershed. When present, the resulting runoff can be concentrated by fire roads and exacerbated by the loss in tree and ground cover.
- *Livestock grazing*: Livestock trample riparian areas making them more susceptible to erosion. Livestock feces are a source of nutrients.
- *Off highway vehicles:* Roads associated with OHV use can contribute to erosion. Current studies are on-going to investigate the impact of the Cow Mountain OHV area.
- *Dredge and fill operations:* Fill operations expose raw sediments to the lake. Most dredging has been prohibited, however, but some does occur to maintain access and clearance in select locations.

The excerpt below was obtained from the EPA's National Water Quality Initiative Management Measures documentation (Water Quality and Forestry Activities Section 3):

"Erosion from roads can be disproportionately high because roads lack vegetative cover, are exposed to direct rainfall, have a tendency to channel water on their surfaces, and are disturbed repeatedly when used. Erosion from roads can be exacerbated by instability on cut-and-fill slopes, water flow over the road surface or through a roadside ditch, flow from surrounding areas becoming concentrated and channeled by a road surface, and lack of a protective surfacing. Much of the sediment load to streams that is associated with roads can be attributed to older roads, which may have been constructed with steep gradients and deep cut-and-fill sections and which may have poorly maintained drainage structures."

Erosion in the Clear Lake watershed is highly visible along roadways where significant cuts have been made. An example of erosion along Highway 20 is presented in Figure 3.5.2A.

Figure 3.5.2A- Typical Erosion at the Cut of a Slope along Highway 20

Figure 3.5.2B provides an example of how the channelization of flows into isolated culverts can accelerate erosion. This is an extreme case that was reportedly partly due to a failed spillway. It was exacerbated by the concentration of flows into a single culvert that drains to Thurston Lake. Roadways, related drainages, and associated runoff is considered a viable first phase target for implementing various BMPs to address non-point loadings.

Figure 3.5.2B- Example of Severe Erosion on Nearby Highway 29 South Of Clear Lake

Note: This culvert is not part of the Clear Lake lakeshed. This image is included for illustration only.

Agriculture

Agriculture has been identified as a significant non-point pollution source associated with the nutrient loading in the Clear Lake watershed. Grading, drainage improvements, access roads, and farming practices can increase the potential for erosion from both natural runoff as well as on-going irrigation practices. Some watering practices such as overwatering associated with flood irrigation, or heavy rainfall related runoff, can pick up loose soil and transport fine sediments through the watershed and into the lake. Additionally, farmers use fertilizers and pesticides to improve yield as well as repel pests. Therefore, it is important that best practices for the relatively significant agricultural land areas in the basin are maintained to reduce the nutrient loading potential in Clear Lake.

There are three main areas that contain most of the agriculture around the Clear Lake watershed. The Big Valley area south of Lakeport is the largest and extends up to the edge of the lake. The area along Middle Creek around Upper Lake contains agricultural areas close to the water that extends up the valley. Another main area is in the Scotts Creek Valley just over the hills west of Lakeport. Other smaller areas include the Red Hills south of Mt Konocti, and High Valley which is in an upper watershed north of Clearlake Oaks.

Background

In the late 90s, many dry-farmed walnut orchards were converted into vineyards. During this period soil erosion increased due to the development of the vineyards, and because this conversion qualified as agricultural grading, they were exempt from permitting requirements under previous grading ordinances. In response to this, the Erosion Prevention and Education Committee (EPEC) was formed and tasked with recommending erosion mitigation procedures for vineyard developments. Extensive agricultural BMPs have since been implemented, which has resulted in an estimated 77% reduction in erosion as described in the Clear Lake Agriculture Nutrient TMDL report. Various standard agricultural BMPs that are commonly implemented in Lake County are described in Section 4 of this report.

The Irrigated Lands Regulatory Program (ILRP), founded in 2003, establishes discharge (real or potential) requirements for irrigated agricultural lands to prevent surface water impairments. Due to the permit and monitoring expense for individual permits, almost all irrigated agricultural landowners in Lake County have joined the Sacramento Valley Water Quality Coalition (SVWQC) to comply with the conditional waiver requirements. Figure 3.5.3 shows which parcels contain irrigated lands participating in this program. As part of the SVWQC water quality monitoring plan, monitoring is carried out in Lake County six times a year. These monitoring events sample representative surface water sites during a range of hydrologic conditions, including first storm flush, winter and spring flows, and the dry season. Representative monitoring sites are chosen based on proximity to concentrated agriculture and lack of influence from urban sources.

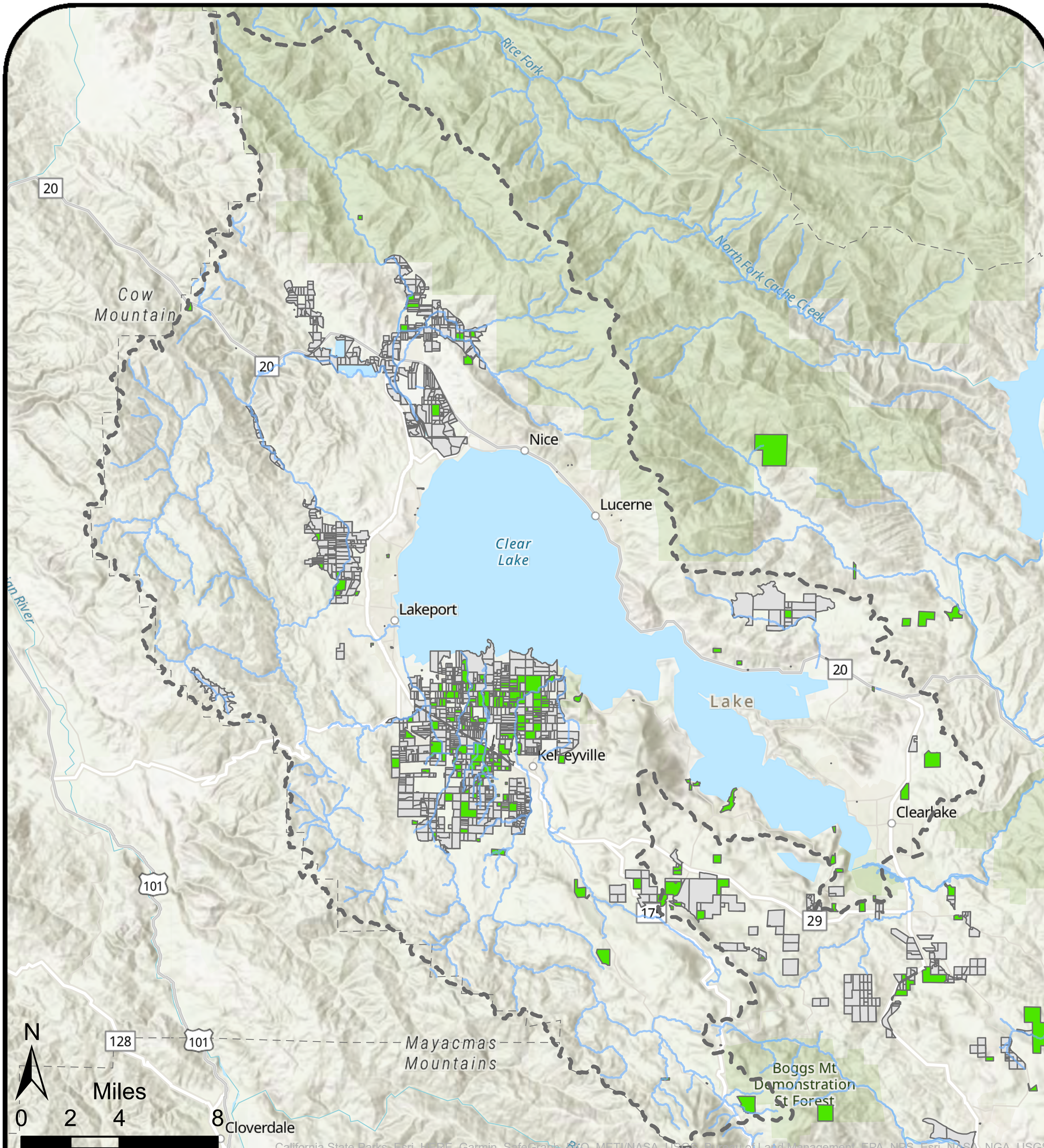


Figure 3.5.3: Clear Lake SVWQC Participation

Lake County Source Water Assessment

Creeks and Streams
Genral Plan Ag Parcels
Participating Parcels
Clear Lake Watershed

California
Rural Water Association

Agriculture Grown

There are three main crops grown around Clear Lake, wine grapes, pears, and walnuts. Table 3.5.1 shows acreage and gross values for agricultural products in Lake County from 2021.

Table 3.5.1: 2021 Lake County Crop Acreage

Category	Crop	Acres	% of Acres	Gross Value $	% Value
Fruit/Nuts	Wine Grapes	10,361	58.7	59,393,072	72.0
	Pears	1,478	8.4	17,718,903	21.5
	Walnuts	3,500	19.8	684,560	0.8
	Misc. Fruits/nuts	106	0.6	244,500	0.3
Nursery	Misc.	22	0.1	1,135,927	1.4
Vegetables	Beans, Cabbage, Carrots, Corn, Cucumbers, etc.	7.52	0.0	240,045	0.3
Field and seed	Irrigated Pasture	300	1.7	30,000	0.0
	Alfalfa, Oat Hay, Grass Hay, Wild Rice, Grains	1,870	10.6	868,522	1.1
Industrial Hemp		8	0.0		
Livestock	Cattle			1,229,600	1.5
	Misc.			816,012	1.0
Livestock/Poultry Products	Misc.			161,555	0.2
Total		17,652		82,522,696	

Fertilizer Usage

The main ingredients in standard fertilizers are nitrogen, phosphorus, and potassium. The California Department of Food and Agriculture (DFA) has published fertilization guides on a variety of crops grown commonly in California. For wine grapes, the DFA recommended applying phosphorus and potassium fertilizers during crop dormancy during winter and early spring, nitrogen and potassium fertilizers during full bloom phase, and continued nitrogen fertilization through to harvest. Mature pear trees typically only require an even nutrient fertilizer once a year. According to the 2010 Clear Lake Integrated Watershed Management Plan, the primary component in fertilizers in Lake County is Nitrate. The Executive Summary of this plan states that “Phosphorus fertilizer is utilized in agriculture; however, it is applied at such low rates that it is unlikely to be a significant phosphorus source for Clear Lake”.

Pesticide Usage

The California Department of Pesticide Regulations’ Surface Water Protection Program monitors agricultural and non-agricultural sources of pesticide residues in surface water. The program includes both a preventative and a response component aimed at reducing the presence of pesticides in surface water. The preventative component includes local outreach to promote management practices that reduce pesticide runoff, while the response component includes mitigation options to meet water quality goals and identify self-regulating efforts to reduce pesticide exposure.

Pesticide usage varies in quantity from crop to crop. Table 3.5.2 shows how much pesticide was used in total in 2018 in pounds of active ingredient applied for each type of the main three crops grown in Lake County. This data includes the entirety of Lake County, not just around Clear Lake, however it is a good overall representation of usage patterns. Pesticide data was taken from California's Department of Pesticide Regulation, and crop acreage was reproduced from Lake County's 2018 Crop Report.

Table 3.5.2: Pesticide Usage in Lake County 2018

Crop	lbs. of Pesticides	Acres of Crop	lbs. of Pesticide/Acre
Wine Grapes	473,607	9,254	51.2
Pears	1,070,393	2,011	532.3
Walnuts	16,512	3,350	4.9

1. *Pesticide amounts from CA DPR 2018 Lake County Pesticide Report*
2. *Crop Acreage from Lake County 2018 Crop Report*

Pesticides are used at a much higher rate for pears than the more popular wine grapes. This is likely because pear trees are much larger than grapevines. Pear orchards also apply pesticides quite frequently after the flowers bloom to keep pests from ruining the growth of the crop. This leads to more pesticide usage per acre over other crops.

Livestock

As presented in Table 3.5.1, livestock and their products make up an estimated 2% of the gross farm related production values in all of Lake County. Most of the acreage associated with pastures are not immediately next to the lake as is the case for cultivated crops. Instead, they are located either far upstream or not in the watershed at all. The 2022 Clear Lake annual Blue Ribbon Report contained a map depicting grazing cattle density which is included in Exhibit D. This map further illustrates that very few cattle are raised in Lake County, thus posing a relatively minor impact.

Agriculture Conclusion

The current nutrient mass loading rate into Clear Lake from agricultural activity has not been numerically quantified. Nutrient loading from agriculture has reduced following recent regulations, however it remains unclear exactly how much it has been reduced. The Blue Ribbon Committee and UC Davis Tahoe Research Center are currently working on a project in the Clear Lake basin related to nutrient loading from agricultural sources intended to quantify these impacts.

Forestland

Mixed forest land and shrubs cover most of the dry land within Lake County. Several sources of nutrient loading and contamination can be found in these forested areas. A brief list of non-point sources are presented below:

- Steep slopes, dirt roads, and off-highway-vehicle (OHV) trails can be a source of sediment contribution from erosion. Cow Mountain OHV trails are illustrated in Figure 3.5.4.
- Timber harvesting requires the use of heavy equipment that can promote erosion or push sediments into streams
- If used, forest management chemicals can pollute watersheds

Please refer to the EPA National Management Measures to Control Nonpoint Source Pollution from Forestry Exhibit 3E page 3 for a table of standard values for soil disturbance percentage by timber harvesting equipment.

Figure 3.5.4- Cow Mountain OHV Trails

Forest Fires

The frequency and intensity of forest fires in the western US continues to rise. Forest fires have both direct and indirect impacts on nutrient loading. Wildfires can remove vegetative soil cover and cause chemical changes in the soil. The chemical changes create an increased resistance to water infiltration in the upper soil layer and can increase surface runoff and sheet erosion.

Direct impacts include destruction of natural landcover. This leads to plant material being carried down the watershed into the lake and the terrain to be less erosion resistant meaning more phosphorus loading from soils. Additionally, fire-retardant chemicals are used to combat forest fires which could also have an impact on water quality. Indirect impacts are caused by fires not in the watershed causing ash to be pumped into the atmosphere where it eventually is carried by the wind and deposited into the watershed or directly into the lake. Research is ongoing with the UC Davis Tahoe Environmental Research Center into how wildfires impact the Clear Lake watershed.

Figure 3.5.5 shows a satellite image from NASA on August 7, 2018, showing the multiple wildfires in California and the geographical extent of ash.

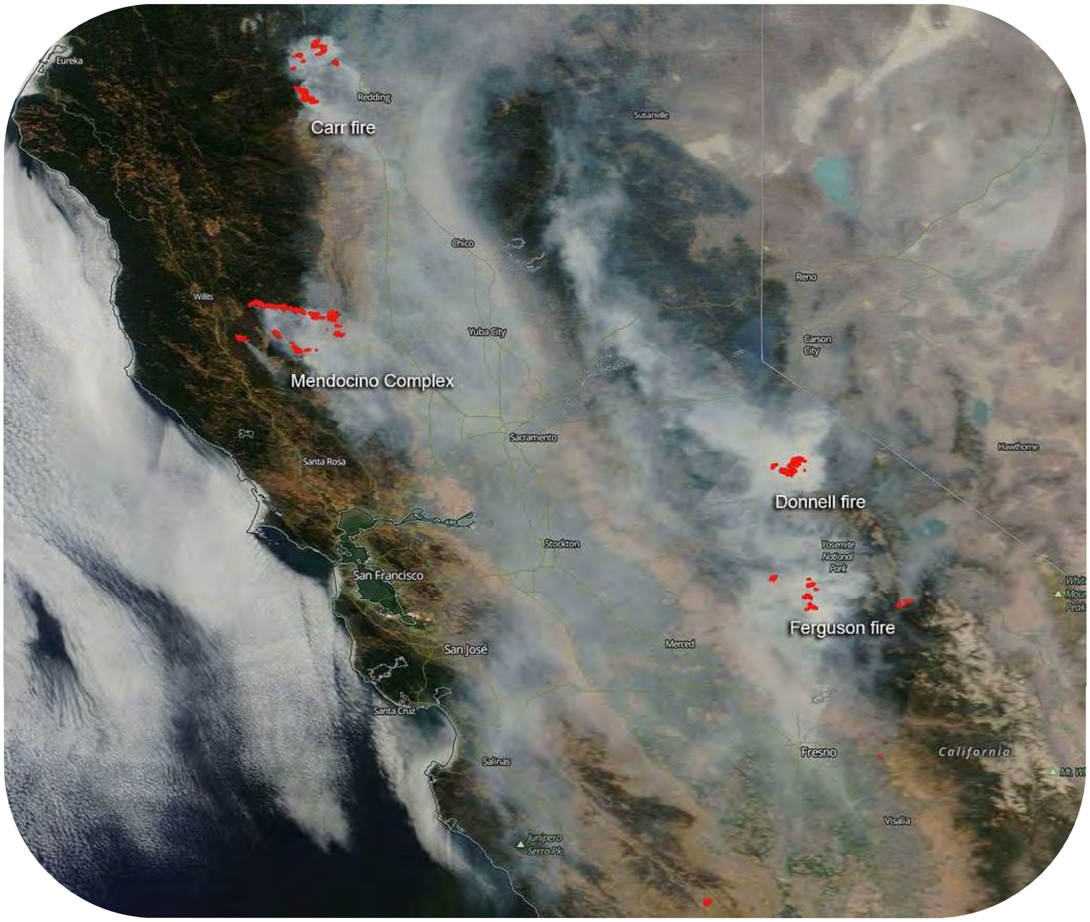


Figure 3.5.5 NASA Satellite Imagery of Fires in California Aug 7, 2018

Septic Systems

With the exception of the sewered areas served by a publicly owned treatment works (POTW), a relatively high number of lakeside properties are served by on site wastewater treatment systems (OWTS). The main areas served by POTWs are the more densely developed areas including the City of Lakeport, Clearlake Oaks, and the City of Clearlake. Septic systems are most concentrated along the shores of the Lower Arm, but also exist in the Upper and Oaks Arms. The 2012 Clear Lake Watershed Sanitary Survey prepared by Forsgren provided a thorough overview of the issues related to OWTS and their potential impact to nearby water utilities with lake intakes. Please refer to this 2012 report for a map of communities with a dense concentration of septic systems.

This report also included the following recommendations:

- Upgrades to substandard septic systems
- Routine maintenance and inspection programs for septic systems
- Continue formal monitoring for coliform bacteria, including location, time of day, and month sampling (e.g., regular monthly monitoring coupled with sampling done during especially wet and dry weather)
- Increased public education of septic system construction, operation, and maintenance by the County through the use of mailings and "advertising"
- A County initiative to offer incentives to landowners for upgrading substandard septic systems to meet basic construction, operation, and maintenance requirements.
- A letter to the County proposing the preceding initiatives.

Some of the observations and recommendations by Forsgren identified that Lake County has no formal OWTS maintenance or inspection program. Reviews are generally associated with new construction or when repairs are made to existing systems. Monitoring the impacts of OWTS is reportedly focused on testing for E. coli presence in select areas with numerous OWTS' during the summer months. The Forsgren update acknowledges that the summer dry season is not typically the time when failing leach fields would present the biggest problems. These systems become limited during periods of heavy rainfall and runoff since much of the failures are associated with root intrusion and limited percolation capacity in the disposal area.

It should be noted that while the Forsgren report focused on impacts to nearby lake intakes, this report is concerned with the overall aquatic environment and nutrient loading from external sources for the lake. Residential septage contains nitrates and phosphates (contained in detergents) that add nutrient loading while the E. coli serves as an indicator organism for fecal contamination.

A recent study by MC Engineering, Inc. for the Gualala County Sanitation District (GCSD) in nearby Mendocino County suggested that approximately 80% of the existing on-site systems are experiencing some type of failure that could be contributing to discharging essentially raw leachate, particularly during periods of high rainfall. Gualala is an area with higher annual precipitation and more dense trees and forest, therefore Mendocino County requires that all existing septic systems be inspected and, if necessary, repaired prior to the sale of a home. The related inspection records, in addition to those maintained by the County of Mendocino, provided a firm basis for a septic to sewer conversion program in and around the town of Gualala, Ca.

A similar inquiry was made with Lake County and it was determined that no such enforcement policy currently exists although failing systems could be identified through on-going home inspections at the time of sale and when problems are identified by the homeowner that warrant repairs and related permits. Septic system effluent entering the lake can be problematic especially through porous lava regions around the south shore of the lake.

The University of Florida has published a variety of studies on the fate of nutrients in septic tank leachate. Florida is a state that has a high propensity of OWTS for residences, many of which are adjacent to water bodies.

The excerpt below was found to be a good reference for the expected concentrations of phosphorus:

"Approximately 20%–30% removal of P in the septic tank is expected as solids settle at the bottom. As a result, septic tank effluent almost always contains total P concentrations at 80%–100% of that found in the raw wastewater (Lowe et al. 2007, 2009; McCray et al. 2005; Crites and Tchobanoglous 1998). Otherwise, there are no appreciable means of P removal from septic tanks."

The USEPA has published an online document titled "Septic Systems and Surface Water" that contains an overview of the issues associated with septic systems and their potential impact to nearby surface waters. Please refer to this document for a diagram of septic leachate entering a surface water body. The EPA publication emphasizes the vulnerability associated with placing a leach field too close to a nearby surface water body and that the further away a leach field is from both surface and groundwaters the more effective the treatment capabilities in the native soils.

Urban Runoff

Urban runoff is stormwater runoff that flows over man-made surfaces like paved streets, parking lots, buildings as it is not able to soak into the ground. This runoff can then pick up a variety of pollutants and carry them to Clear Lake.

Roadways

Roads build up lots of pollutants over time from various sources. Rubber from car tires, car exhaust residue, oil from cars, spills along the roadway, and trash and debris all are among items that can be swept away into drainage systems that run into Clear Lake.

Lawn Fertilizers

Like agriculture, lawn fertilizers commonly contain the big three nutrients: nitrogen, phosphorus, and potassium. Unlike agriculture, the average lawn is much smaller than the typical agricultural field, but lawns are not subject to stricter ordinances, legislation, and BMPs the same way agriculture is.

NPDES Permitting Considerations

The Central Valley Water Board adopted Order Number 2013-0001-DWQ on February 5, 2013 (subsequently amended) which established discharge requirements for small municipal storm sewer systems. The County of Lake, City of Clearlake, and City of Lakeport collectively are the Permittees that discharge into Clear Lake and regulated under this permit. The permit requires compliance with certain TMDLs and implementation of various best management practices (BMPs). The final deadline to meet TMDL requirements is September 30, 2024. Prior to that time, the permittees are required to prepare a BMP Effectiveness Report and a Sediment/Phosphorus Reduction Plan. The MS4 boundaries for each regulated area are presented in Exhibit B.

On 25 October 2022, The County of Lake Water Resources Department (Lake County) submitted the Task 4 Work Plan to comply with the requirements established by the Clear Lake Nutrient Total Maximum Daily Load (Clear Lake Nutrient TMDL) and the 10 October 2019 Order pursuant to California Water Code Section 13267 (Order) issued to Lake County. The Work Plan was required under compliance task 4 of the order and it was accepted by the Central Valley RWQCB on December 16, 2022.

Caltrans can be considered another permittee subject to urban/roadway related runoff BMPS and monitoring. Caltrans is currently regulated by Order No. 2012-0011. Caltrans is subject to the MS4 requirements since storm water permits are required for discharges from a municipal separate storm sewer system (MS4) serving a population of 100,000 or more. The USEPA defined MS4 to include road systems owned by states which are in an area with a population greater than 100,000.

Municipal Wastewater

There are seven municipal wastewater treatment plants around the Lake. In the 1990s a regional pipeline was constructed to collect treated effluent from select wastewater treatment plants around the lake and pump it to a County facility north of Clearlake and to the Geysers for injection and geothermal power generation. A more detailed discussion on the municipal plants and a map of the regional pipeline can be found in the 2012 report by Forsgren.

Raw sewage from sanitary sewer overflows (SSOs) pose a threat to water quality due to both pathogens and nutrients that can enter the lake and potentially jeopardize drinking water supplies and add to the overall nutrient loading and FHAB problem. During extreme flooding, such as the events that occurred in 2017 and again in 2019, the sewer systems become surcharged and are vulnerable to exfiltration. Figure 3.5.6 shows the effects of high water in the keys during the 2017 floods when water levels rose into the streets and manholes were under water. Similar events were experienced during the floods of 1986 and 1998.

During the two recent events, the Clearlake Oaks system was inundated such that in 2017 lift stations failed and diluted wastewater had to be trucked from the Keys to the CLOCWD treatment plant. Shortly thereafter, in 2019, the flood waters required additional emergency actions including efforts to seal manholes, provide auxiliary pumping, and utilize upgrades to the peak wet weather flow related facilities and detention ponds completed in 2018.

Other municipalities around the lake reportedly experienced similar challenges during the recent flood events. The relatively high number of pipe defects in the collection system, including cracks, offset joints, leaking manholes, etc. add to the likelihood of exfiltration, particular during these extreme events. On-going collection system I/I related improvements are needed to maintain the integrity of the gravity systems around the lake and minimize the likelihood of exfiltration and SSOs in the future.

The treated wastewater effluent forcemain on the north side of the lake could provide an opportunity to convey flows from failing septic systems by implementing STEP (septic tank effluent pumping) or additional gravity sewers near existing collection systems. The conditions associated with the flood events pose relatively high threats for SSOs now and into the future and the related water quality implications should be considered in future investigations and mitigation related projects. Existing septic systems and leach fields are also more vulnerable and much less effective in retaining domestic leachate during periods of high rainfall and high groundwater.

Figure 3.5.6

Flooding of Streets and Underwater Manholes (Keys Blvd Feb. 2017)

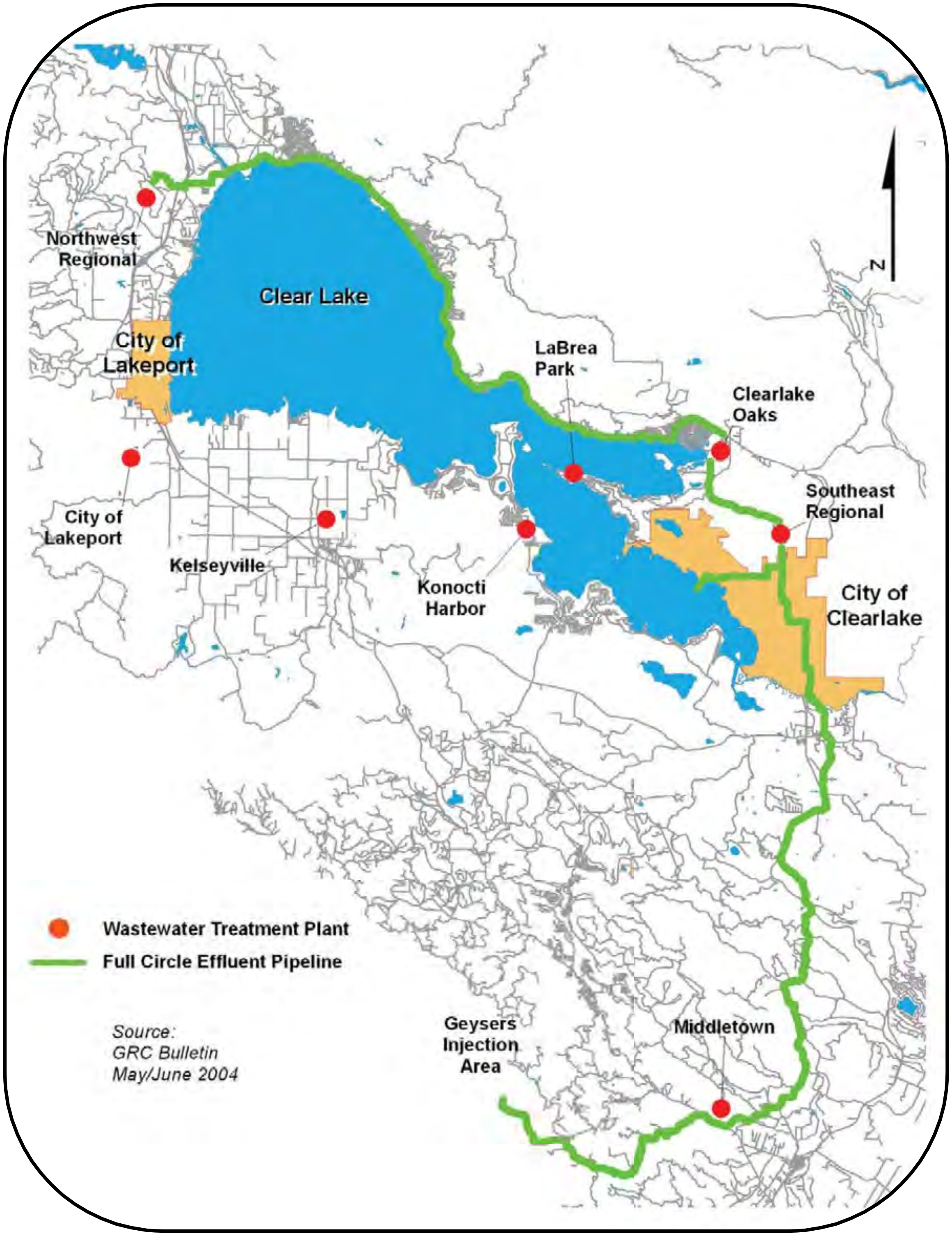


Figure 3.5.7: Wastewater treatment plant locations around Clear Lake.

This figure has been reproduced from the 2012 Clear Lake Watershed Sanitary Survey

Mining

Directly adjacent to the south-eastern end of Clear Lake between the communities of Clearlake Oaks and the City of Clearlake is an abandoned mercury mine known as the Sulphur Bank Mine. This abandoned mine boarders Elem Indian Colony tribal land. According to the USGS, the Sulphur Bank property encompasses 200-acres and it includes approximately three million cubic yards of contaminated mine waste. This site is extremely rich in rare minerals due to its proximity to prior volcanic activity and currently active geothermal hot springs. The site was originally mined for Sulphur and Borax after opening in the mid-1850's. Beginning in the early 1870's, the site was then mined for mercury (cinnabar) until 1957 when the mine was permanently closed (cite-The Herman Pit).

Figure 3.5.8- Sulphur Bank Mercury Mine

This image has been reproduced from Google Earth

Historic mining at this site from the 1850's to early 1900's was primarily conducted in deep vertical shafts with connecting horizontal shafts. The surface was later excavated over a large area, which became known as the Herman pit. Waste materials from the pit were deposited along the shore of Clear Lake to create an earthen dam. Some references indicate that this waste material is contaminated with excessive amounts of mercury and other toxic materials.

The Herman pit is currently flooded with groundwater. According to various sources, the pH of this water is between 2.9 and 3.5 (cite-tracers). The water is acidic due to an abundance of naturally occurring sulfur, which forms sulfuric acid. According to the USGS, "Mine drainage forms from a chemical reaction between water and rocks containing sulfur-bearing minerals. The resulting waters become rich in sulfuric acid and dissolved iron. As the iron settles out of the water, it can form red, orange, or yellow sediments. Iron and other minerals that have precipitated out of the acidic water have caused the water to appear bright blue and it has formed a layer of orange-tinted precipitate on the bottom of the pit, as shown in Figure 3.5.9.

This site has been selected by the EPA as a superfund site, and long-term plans are being developed to contain waste, fill the Herman pit, and cover it with vegetation. Further information about EPA clean-up activities can be found at the EPA superfund website and in a recently published EPA handout (Attachment E).

Figure 3.5.9- Acidic Water in the Flooded Herman Pit, Sulphur Bank

Image source: [Sulphur Bank Mercury Mine Superfund Site, Clear Lake, CA | Flickr]

Potential Mercury Contamination in Clear Lake from the Sulphur Bank Mine

The USEPA has set the current standard for mercury in drinking water at 2 ppb (0.002 mg/L). An article published in the Ecological Society of America, Journal Volume 18 Issue 8 states that, "Clear Lake is one of the most mercury contaminated lakes worldwide". The article provides testing data from the late 1990's which indicated that total particulate mercury in Clear Lake surface water was in the range of 10 mg/L near the abandoned mine. The researchers provided a graph of mercury concentration as a function of distance from the Sulphur Bank Mine (Exhibit C). This graph indicates that total particulate mercury is higher in Lake Water near the mine. According to the study, Acid Mine Drainage (AMD) can enter Clear Lake through advective subsurface flow and by diffusion at greater distances.

In at least one instance, in the late 1990's, a substantial subsurface flow from the flooded pit entered Clear Lake. Subsurface flow occurs because the hydraulic head in the pit is often several feet higher than the surface of Clear Lake. Abandoned mine shafts or unidentified conduits may be a preferred pathway into the lake. Figure 3.5.10 presents a simplified diagram illustrating the flow of Herman Pit water into Clear Lake. The UC researchers explain that the transport path from the Herman Pit to Clear Lake is challenging to estimate. "It cannot be estimated. . . how much <fluid> is going into the lake or the precise path the flow is taking. . . [O]f the approximate 630 L/s flowing into and out of the Herman Pit, fluid may leave the pit and flow directly into the lake through the waste rock piles, through the native sediment that underlies the waste rock piles, or simply flow elsewhere." (Schladow, 2008)

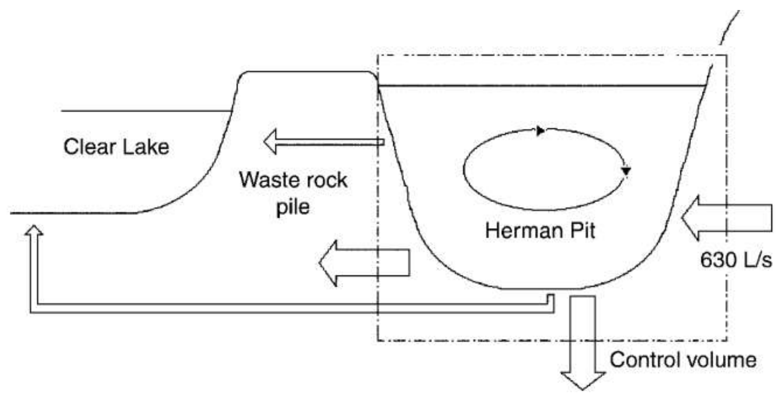


Figure 3.5.10- Herman Pit Potential Flow Path into Clear Lake

This image has been reproduced from "Use of Tracers to Quantify Subsurface Flow Through a Mining Pit" as published by UC Davis in 2008

Interestingly, the acidic water in the Herman Pit does not show elevated levels of mercury. According to the USEPA, "While the concentration of Hg in the Herman Pit water is substantial (300 ng/L or 0.3 ppb), it does not exceed the USEPA drinking water standards (2 ppb). Once the pit and meteoric waters pass through mine wastes, however, their quality is further degraded. . . (17 ppb)" This EPA publication suggests that mercury in Clear Lake could originate from the Sulphur Bank Mine Waste Rock Dam. Other researchers have hypothesized that geothermal springs venting directly into Clear Lake can deposit mercury into the Lake.

Mercury and FHAB Relationship

Mercury methylation is the process of forming methylmercury (MeHg) from mercury (Hg) through a biotic or abiotic process. Methylmercury is a form of mercury that is toxic to humans. According to the research paper "Pathways of Acid Mine Drainage to Clear Lake: Implications for Mercury Cycling", moderate sulfate levels generally enhance the methylation of mercury. "High sulfate content in the AMD has the potential to promote the activity of sulfate-reducing bacteria in the organic-rich lake sediments, which leads to methylation of Hg^{+2}, making it both more toxic and bioavailable." AMD from the Sulphur Bank mine may contribute sulfate to Clear Lake which can promote sulfate-reducing bacteria. According to the Science Direct research paper "Cyanobacteria as Regulators of Methylmercury Production in Periphyton" there is a positive correlation between the presence of cyanobacteria and biotic mercury methylation. This research indicates that mercury methylation by cyanobacteria is a significant source of the methylmercury toxin.

"Levels of mercury in the lake water consistently meet state and federal standards. However, there are occasional and naturally occurring algal and cyanobacteria blooms that occur in Clear Lake that can make the water unsafe to swim in. . ." -EPA Sulphur Bank Superfund Site Cleanup Update 2022

According to the EPA, nearly all methylmercury exposures in the United States occur through eating fish and shellfish. (US EPA) This is because mercury is a pollutant that will "bioaccumulate" and concentrate as it moves up the aquatic food chain. The California Office of Environmental Health

Hazard Assessment (OEHHA) released an advisory in 2005[1] which recommends mercury-intake based consumption limits for various fish species from Clear Lake.

Landfills

Eastlake Landfill, seen in Figure 3.5.11, is the only landfill in the Clear Lake watershed. It has been in service since 1972 and is owned and operated by Lake County. The landfill is currently being expanded to manage a rising demand over the last decade. The landfill is located east of Clearlake in the foothills on its own isolated hill. The landfill is used as a buffer for the waste treatment facility. There is currently no indication that contaminated groundwater has entered Clear Lake from this landfill. More research can be done to investigate any impacts this landfill may have on the nutrient loading in Clear Lake.

Figure 3.5.11: Eastlake Landfill Area Imagery from Google Earth

POTENTIAL FOR INTERNAL LOADING

Internal loading of is the recycling of nutrients internally to the lake on a seasonal cycle. Clear Lake absorbs a significant amount of the external loading it receives into the soil at the bottom of the lake during the winter and spring rainy season and releases it in the spring and summer. Richardson, 1994 says that feedback loops form when scum forming blue-green algae are not eaten by zooplankton after they finish their lifecycle. This causes the algae to decay over time at the bottom of the lake. The decomposition lowers dissolved oxygen levels which in turn releases phosphorus and iron into the water from the soil at the bottom of the lake further fueling algae growth. During periods of high dissolved oxygen levels, phosphorus, and iron form an insoluble ferric phosphate. When dissolved oxygen drops the ferric phosphate dissolves into the water further increasing phosphorus levels in the lake.

[1] Advisory 05-01 has been updated since the initial release.

SECTION 4– CONTAMINANT SOURCE ASSESSMENT AND MITIGATION

This section includes an overview of primary contaminant sources of concern, recent efforts that are underway to analyze the impacts of various contaminant sources, and potential strategies to manage and reduce the contaminant loading contributed by each source.

4.1- PRIMARY CONTAMINANT SOURCES OF CONCERN

As discussed in previous sections, the primary water quality issue in Clear Lake is the impact of FHABS and associated toxins that occur mostly during the summer and early fall. Recent academic papers and Blue Ribbon Committee related findings emphasize that phosphorus loading from a variety of sources (most notably soil erosion) is the primary contributor to the growth of FHABs. Nitrogen may play a role as a co-limiting nutrient since the system is overloaded with phosphorus. Analysis and solutions related to the management of mercury and pesticide loadings are not discussed in this section.

Although various other constituents can be problematic (i.e. mercury, iron, boron, etc.), the emphasis must be placed on controlling external nutrient loading. Due to the size of Clear Lake and sedimentation rate, open-water dredging and removal of bottom sediments for internal mitigation is not considered practical. Given the documented phenomenon of internal loading, it is not certain how long it will take to influence the impact of external nutrient loads associated with erosion and sediment transport from streams, culverts, and irrigated lands along with other impacts that can include urban runoff and sewage from ineffective or failing OWTS (septic systems and related leach field discharges into the groundwater near the lake).

The following potential sources of nutrient loading into Clear Lake were discussed at a high-level in Section 3 of this report:

- Erosion of Natural Soils
- Agriculture
- Timber and Forestry
- Septic Systems
- Urban Runoff
- Urban Wastewater

4.2- CONTAMINANT ANALYSIS

The potential phosphorus loading contribution from each type of source should be quantified and tied to specific watersheds and streams throughout the Clear Lake basin. It will be necessary to determine which surface water sources may transport the most nutrients into Clear Lake. Surface water sources that contribute a high amount of nutrient loading should be prioritized for implementation of nutrient transport mitigation measures. Septic system effluent may enter Clear Lake through groundwater and is subject to alternative mitigation measures. The establishment of actionable and targeted mitigation and best management projects throughout the watershed is subject to additional analysis and review of the effectiveness of various BMPs.

Given the extremely large area and number of water sources, multiple efforts are underway to prioritize future mitigation measures by identifying the most problematic sources through analysis and modeling. Notable recent efforts include the Blue-Ribbon Committee USGS/UCD/BLM Modeling and the Lake County Clean Water Program TMDL BMP Effectiveness Calculator. A more detailed discussion of these leading efforts follows:

Blue-Ribbon Committee USGS/UCD/BLM Modeling

A collaborative project is currently underway between USGS, UC Davis and the Bureau of Land Management (BLM) to pinpoint and address nutrient related issues. This recent project was described in the Blue-Ribbon Committee 2022 report. A summary follows:

Flow Monitoring and Water Quality Sampling

As described in Section 3 of this report, four new stream gages were recently installed and activated in September of 2022 in an effort to quantify tributary flows and loadings from Scotts Creek at Hwy 29, Clover Creek Bypass, Cole Creek, and Molesworth Creek. When combined with all existing stream flows and subsequent sediment fingerprinting, these new gauges will be used in conjunction with the runoff modeling to develop the resulting mass balance model for each major watershed and various sub-sheds. USGS maintains three other stream gauges including one at Kelsey Creek near Kelseyville, one on the south fork of Scotts Creek near Lakeport, and a third on Scotts Creek (also near Lakeport). Two of the gauges on Scotts Creek, which are funded by the BLM, have an ISCO autosampler that monitor temperature and turbidity to calculated daily sediment loads. A total of 58 water quality samples were recorded for 9 different locations in 2022 with 37 analyzed for filtered and unfiltered nutrients at the UCD TERC lab and 24 at the USGS lab.

Sediment Fingerprinting

The USGS collected streambed, streamside, soil, roadside ditch, and integrator samples in order to identify the “fingerprint” sources of the various sediments collected as part of the water quality sampling in order to pinpoint the sources throughout the Clear Lake tributary watersheds. This project would identify the land use types and sub-watersheds that re contributing most to the sediment bank. The overall sediment fingerprinting study calls for 750 samples with 75 taken from each of the 10 major watersheds under the analysis. As of December 2022, a total of 386 samples were collected.

Rainfall-Runoff Modeling (HSPF)

The rainfall model is intended to provide the lake inflows that, when combined with concentrations, can be used to determine the spatial distribution and quantities of external nutrient loads. A total of 33 rain gauges and 24 air temperature sensors are installed in and surrounding the Clear Lake study area. The stations are used to produce hourly climate grids that drive the HSPF and spatially referenced regression on watershed attributes (SPARROW) models.

Mass-Balance Modeling (SPARROW)

This model is being developed to represent the sources, fate, and transport of nutrients and suspended sediment in streams in the watershed for the 2022-2024 time period. The recent status report included the following description: “These databases include agricultural practices (fertilizer and manure application), atmospheric deposition, geology, soils, and land-use data, and other datasets that affect the fate and transport of nutrients and suspended sediment in the watershed.” The results of this model will help to identify the nutrient loading based on sub-watershed scales.

Web Portal Access

USGS Water Quality Studies and information can be found at usgs.gov.

Lake County Clean Water Program TMDL BMP Effectiveness Calculator

In response to the recent order (Water Quality Order 2013-0001-DWQ) as amended, The County of Lake, City of Clearlake, and City of Lakeport have submitted various documents intended to meet permit requirements, quantify total maximum daily loads (TMDLs) of phosphorus, comply with assigned waste load allocations (WLAs), and implement a variety of best management practices (BMPs). A workplan was developed to reduce the phosphorus loads and comply with the designated load allocation for each entity.

Compliance with the TMDL issued by the Central Valley Regional Water Quality Control Board (CVRWQCB Resolution No. 2006-0060) necessitated the development of an accounting tool that could be used to calculate the phosphorus load reduction for a variety of stormwater BMPS implemented in the Clear Lake watershed. The following metrics were used in developing the TMDL and related limits:

- Total baseline load of phosphorus: 150,000 kg/yr (based on Tetra Tech studies from 1992 to 2000)
- Total allocated loading of phosphorus: 87,100 kg/yr (representing a required 40% reduction on average from the model's baseline prediction)
    - Point source limits: 2,000 kg/yr (NPDES co-permitees combined contribution)
    - Caltrans NPDES limits: 100 kg/yr
- Non-point source limits: 85,000 kg/yr: The entities responsible for controlling the non-point sources include the County of Lake, the US Bureau of Land Management (BLM), the US Forest Service (USFS), and irrigated agriculture within the basin.

The accounting tool is an Excel-based spreadsheet that calculates the loads reduced for a variety of stormwater BMPS in order to assess progress in the 2,000 kg/yr limit. The tool can reportedly be used to assess progress related to other non-point sources in the watershed. The tool assigns a removal efficiency to each BMP and it is based on the assumption that sediment removal efficiency is an appropriate surrogate for phosphorus removal. Reductions are based on the following formula:

$$\text{Annual Load of Phosphorus Reduced} = \boldsymbol{A_i \cdot P_\gamma \cdot EE_f}$$

Where:

A_i =Area addressed or treated by BMP_i (acres)

P_γ = Baseline phosphorus yield (kg/acre-year) for the location of BMP_i

EE_f = Pollutant removal efficiency factor (% removed) for BMP_i

More recent estimates projected the total load of phosphorus flowing into the watershed to be 90,000 kg/yr to 125,000 kg/yr, representing baseline estimates that are 17% to 40% lower than the 1990's baseline load of 150,000 kg/year. In explaining the refined baseline estimate of 125,000 kg/yr the March 5, 2021 report assumes that recent stormwater policies were responsible for the lower estimates in 2007/2008. Table 4.2.1 provides that most recent updates to the anticipated reductions required.

Table 4.2.1- Lake County Phosphorus TMDL Accounting Tool Overview

Source Category	Responsible Party (RP)/ Other	Weighting Factor[1]	Area (Acres)	Distribution of WLA or LA[2] (kg/year)	Percent of the TMDL	Phosphorus Baseline Load Estimates (kg/year)		Required Load Reduction (kg/year)
						1999	2007	
Point Sources	Lake County MS4	56%	8,766	1,117	-	1,923	1,603	486
	Clearlake MS4	31%	3,454	624	-	1,075	896	272
	Lakeport MS4	13%	1,990	259	-	446	372	113
	Co-Permittees Subtotal		14,210	2,000	2.3%	3,444	2,870	870
	Caltrans		260	100	10.0%	172	144	44
Nonpoint Sources	Lake County Non-MS4		166,752	57,948	66.5%	99,796	83,163	25,215
	All Other Nonpoint Sources		77,845	27,052	31.1%	46,588	38,823	11,771
	All Nonpoint Sources-Subtotal		244,597	85,000	97.6%	146,383	121,986	36,986
Other- Not Identified in the TMDL	Tribal Areas/ Rancheria Properties		971		-	-	-	-
Total Clear Lake Watershed			260,038	87,100	100.0%	150,000	125,000	37,900
1- A weighting factor was calculated based on a combined metric of population and area for the 3 co-permittee MS4 areas. This factor was used to allocate both the baseline load and the WLA across the 3 MS4 areas.								
2- WLA = Waste Load Allocation, LA= Load Allocation								

Septic System Phosphorus Loading Analysis

At the time of this report, a formal analysis of potential phosphorus loading into Clear Lake from failing septic systems has not been initiated. It is anticipated that failing septic systems may contribute significant nutrients to Clear Lake. A high-level review of potential nutrient loading from septic systems follows. This calculation should ultimately be refined in tandem with a survey of septic system failure rate as described later in this Section.

The role that on-site septic systems play in adding nutrients to the lake was introduced in Section 3. Those systems in close proximity to the lake (i.e. within 1,500 LF) are of particular concern. Of the 12,000 or so on-site systems, it is unknown how many are immediately adjacent to the lake, in areas with porous volcanic soil types, or in areas with high water tables. It is also unknown if nutrients enter the lake through surface water, through small tributaries, or through transmission by shallow groundwater movement. These potential nutrient loadings, from either failing leach fields or directly form inefficient and deteriorated septic tanks, should be quantified further by first identifying the remaining number of septic systems located in close proximity to the Lake or nearby tributaries.

Experience has shown that a majority of the nutrient loadings from failing septic systems occur in the late winter and spring and in some cases can continue all the way through the summer months. The impacts of the existing and potential failing septic systems can be greatly influenced by the amount of winter and spring precipitation, runoff, and high groundwater. Assuming that a fair percentage of these systems are failing it is possible to quantify the potential nutrient loading. For those septic systems within 500 feet of the lake it would be safe to assume that the discharge is essentially directly to the Lake. Increasing the prevalence of centralized treatment by constructing sewers in un-sewered areas may be a potential mitigation. The feasibility of septic to sewer programs should be evaluated on a case-by-case basis. The use of Septic Tank Effluent Pumping (STEP) systems could be used to reduce the cost by collecting liquid streams via small forcemains in lieu of deeper more costly gravity sewers in select areas.

For illustration purposes, if 15% of the 12,000 on-site systems are discharging directly to the lake, and the phosphorus concentration is at 10 mg/L as previously noted, the estimated loading could be determined based on a hypothetical occupancy rate of 50% and a flow rate of 100 gpd/du as follows:

0.15 x (12,000) x 0.50x100/1,000,000 MGD x 8.34 x 10 mg/L x 365 = 2,250 lb/year (1,020 kg/yr)

The baseline estimate for phosphorus associated with Lake County is 1,603 kg/year. The hypothetical calculation above illustrates the importance of further investigations into the role of failing septic on nutrient loading since 1,020 kg/yr is 2.1 times the annual reduction goal of 486 kg/year for the TMDL in Lake County for phosphorus.

4.3- TREATMENT AND MITIGATION OPPORUNITIES

A variety of established BMPs can be leveraged to manage external nutrient loading from various sources. As previously described, the findings of the ongoing Blue Ribbon Committee Clear Lake watershed modeling can help to prioritize BMP locations based on anticipated reduction potential. The following agencies have established standard BMPs that may be implemented at select locations within the Clear Lake watershed:

1. California Stormwater Quality Association (CASQA) Standard BMPs (Implemented by Lake County)
2. Caltrans
3. United States Department of Agriculture (USDA) National Resource Conservation District (NRCS) BMPs
4. United States Environmental Protection Agency (EPA)

These BMPs are based on either (1) controlling erosion, (2) removing sediments, or (3) treating runoff. A description of these typical BMPs and other potential mitigation projects follows.

CASQA Standard BMPs

A summary of the BMPs listed in the Lake County BMP effectiveness calculator is presented in Table 4.3.1. These BMP practices have been obtained from the California Stormwater Quality Association (CASQA).

Table 4.3.1 Summary of Lake County BMP Effectiveness Calculator

BMP Category	BMP Type	Sediment Removal (%)	Confidence Rating
Erosion/ Sediment Controls	Construction Controls	70%	Low
	Grading Controls	70%	Low
	General Erosion Controls	65%	Moderate
	Good Housekeeping (e.g. NPDES permit compliance)	70%	Low
	Slope and Shoreline Stabilization Techniques	72%	Moderate
	Streambank Restoration	80%	Moderate
Removes Sediment (S)	Channel Dredging	5%	Low
	General Sediment Removal	34%	Low
	Hydrodynamic Separation Devices	39%	High
	Inlet-Based Fill Trash Capture Devices	29%	Moderate
	Storm Drain Inlet Cleaning- Annual	11%	Moderate
	Storm Drain Inlet Cleaning- Twice Annually	16%	Moderate
	Street Sweeping- Monthly w/Mechanical Broom Sweeper	7%	Moderate
	Street Sweeping- Monthly w/ Regenerative Broom Sweeper	16%	Moderate
	Street Sweeping- Weekly w/Mechanical Broom Sweeper	14%	Moderate
	Street Sweeping- Weekly w/Regenerative Broom Sweeper	41%	Moderate
Reduces or Treats Runoff	Bioretention	77%	High
	Detention Basin	66%	High
	General Runoff Reduction/Treatment	66%	Moderate
	Media Filter	84%	High
	Low Impact Development (LID)	82%	Moderate
	Oil/Grit Separators and Baffle Boxes	57%	High
	Porous Pavement PP	71%	High
	Retention Pond	76%	High
	Vegetated Swale/Grass Swale	47%	High
	Vegetation Buffer/Grass Strip	52%	High
	Wetland Basin	61%	High
Other (O)	Public Education and Outreach	4%	Low

Caltrans Urban Runoff BMPs

The California Department of Transportation (Caltrans) identified a related list of BMPs in their January 2004 final report "BMP Retrofit Pilot Program". The Caltrans study, and related report, was prepared in response to lawsuits filed by the Natural Resource Defense Council, the Santa Monica Bay Keeper, the San Diego Bay Keeper, and the USEPA. The litigation resulted in a requirement that Caltrans develop a Best Management Practice (BMP) Retrofit Pilot Program in Caltrans Districts 7 (Los Angeles) and 11 (San Diego). Several structural BMPs were evaluated for treating stormwater from Caltrans facilities, including review of costs, performance, and maintenance for these facilities.

The Caltrans study consists of 316 pages along with relatively detailed costs and performance data related to each BMP. A salient finding in the Caltrans study is summarized below:

"*Extended detention basins have an especially extensive history of implementation in many areas and are recognized as one of the most flexible structural controls. The pollutant removal observed in the extended detention basins was similar to that reported in previous studies (Young, 1996) and appeared to be independent of length/width ratio, which is a commonly used design parameter. Resuspension of previously accumulated material was more of an issue in the concrete-lined basin, which exhibited less constituent concentration reduction than in-situ, earthen designs. Based on these findings, unlined extended basins are preferred except where potential groundwater contamination is an over-riding concern.*"

The study results related to removal efficiencies of the various BMPs are summarized in Table 4.3.2. It was observed that unlined extended detention basins provided 39% removal of total phosphorus (TP), out-performing most of the other, more elaborate and expensive BMPs, including lined detention basins and storm filter systems.

Table 4.3.2- Summary of Caltrans Pollutant Removal Efficiency for Pilot Study

BMP Category	BMP Type	TSS	TN	TP
Media Filters	Austin Sand Filter	90	32	39
	Delaware Sand Filter	81	9	44
	Multi-Chambered Treatment Train	75	0	18
	Storm-Filter	40	13	17
Extended Detention Basin	Extended Detention Basin	72	14	39
Drain Inlet Inserts	FossilFilter™	NA	NA	NA
	StreamGuard™	NA	NA	NA
Biofiltration	Swale	49	30	NA
	Strip	69	10	NA
Infiltration Devices	Basin	NA	NA	NA
	Trench	NA	NA	NA
Wet Basin	Wet Basin	94	51	5
Oil-Water Separator	Oil-Water Separator	NA	NA	NA
Continuous Deflective Separation	Continuous Deflective Separation	NA	NA	NA

Caltrans is identified as one of the dischargers responsible for reducing non-point sources in the Clear Lake. Although their contribution was estimated at 0.1% of the nutrient loading associated with the TMDL, they do offer a variety of applicable solutions described in detail in their 2005 report along with accompanying removal efficiencies, construction costs, and operating costs. The list of Caltrans BMPs presented in Table 4.3.2 are of greater interest when considering the cumulative impact of other non-improved roads and County roads with drainage-related contributions to the overall sediment and nutrient loading. The measures identified by Caltrans that have been deemed effective at controlling nutrients (phosphorus) and sediment loadings, that could be applied at various locations throughout the watershed and are applicable to both urban and public lands, include:

- Extended Detention Basins (unlined)
- Austin Sand Filters
- Delaware Sand Filters
- Storm Filters

NRCS Conservation Practice Standards

The cultivated lands within the basin account for roughly 10% of the area in the watershed. The USDA national water quality initiative is intended to fund voluntary investments for these properties that are focused on improving water quality. The surface water sources of Clear Lake have been identified by the NWQI as a high priority area. The National Resource Conservation Service (NRCS) provides a field handbook and list of acceptable ACTs (Avoid, Control, Trap) aimed at either avoiding, controlling, or trapping sediments that contribute to water quality degradation. The applicable ACTs are summarized in Table 4.3.3

Table 4.3.3- NRCS Field Handbook of Acceptable ACTs Overview

Core Practices	Code	Avoiding	Controlling	Trapping
Waste Storage Facility	313	X	X	
Animal Mortality Facility	316		X	
Composting Facility	317	X	X	
Conservation Cover	327	X		X
Conservation Crop Rotation	328	X		
Residue and Tillage Management, No Till/Strip Till/Direct Seed	329		X	X
Contour Farming	330		X	X
Contour Orchard and Other Perennial Crops	331		X	X
Contour Buffer Strips	332			X
Cover Crop	340	X		X
Critical Area Planting	342		X	X
Residue and Tillage Management, Reduced Till	345		X	X

Table 4.3.3 Continued

Well Water Testing	355	X		
Waste Treatment Lagoon	359		X	
Waste Facility Closure	360	X		
Anaerobic Digester	366		X	
Field Border	386		X	X
Riparian Herbaceous Cover	390			X
Riparian Forest Buffer	391			X
Filter Strip	393		X	X
Stream Habitat Improvement and Management	395	X		
Grade Stabilization Structure	410		X	X
Grassed Waterway	412		X	
Irrigation Reservoir	436		X	
Irrigation Water Management	449		X	
Access Control	472	X		
Prescribed Grazing	528	X		
Drainage Water Management	554		X	
Heavy Use Area Protection	561	X		
Trails and Walkways	575		X	
Streambank and Shoreline Protection	580	X		
Nutrient Management	590	X		
Terrace	600		X	
Vegetative Barrier	601			X
Saturated Buffer	604			X
Denitrifying Bioreactor	605			X
Tree/Shrub Establishment	612	X		X
Waste Treatment	629		X	
Waste Recycling	633		X	
Waste Transfer	634	X		
Vegetated Treatment Area	635			X
Water and Sediment Control Basin	638		X	X
Constructed Wetland	656			X

These BMPs could be applied for many of the non-point pollutant sources in the watershed. Applicable measures for the Clear Lake watershed are those that can be used to mitigate the most concerning regional issues and relevant water quality impairments, most notably external nutrient loading associated with erosion, fine sediment transport, and resulting FHAB blooms. Those measures deemed most appropriate for controlling erosion and nutrient loading, and the corresponding Conservation Practice Standard (CPS) code, include:

- Field Borders (386)
- Stream Habitat Improvement and Management (395)
- Irrigation Reservoirs and Ponds (436 and 378)
- Drainage Water Management (554)
- Streambank and Shoreline Protection (580)
- Nutrient Management (590)
- Vegetated Barriers and Treatment Areas (601 and 635)
- Water and Sediment Control Basins (638)
- Constructed/Restored Wetlands (656)
- Wetland Enhancement (659)
- Irrigation Ditch Lining (428)
- Irrigation Pipeline (430)
- Lined Waterway or Outlet (468)
- Surface Drain or Field Ditches (607 and 608)
- Access Road and Related Drainage Improvements (560)

Other Mandatory Agricultural BMPs in Lake County

Agricultural producers in Lake County are required to maintain BMPs on their property. Chapter 30 of the Lake County Code includes a Grading Ordinance (Ord. No 2830, § 1, 7-17-2007). This ordinance requires BMPs for agricultural grading or clearing of non-current agricultural land for ponds/reservoirs over one acre foot in capacity. Implementation of these BMP's are also required for any new agricultural properties that convert from native vegetation and on properties that convert from deep rooted crops on soils that have a moderate or greater hazard rating. This ordinance goes into detail on restrictions on soil types, distance to water sources, distances to riparian habitats, and more.

The Lake County Winegrape Commission (LCWC) has been providing education to winegrape growers since 1991, and in 2005 the LCWC started to introduce winegrape sustainability programs to encourage further environmental sustainability. The California Sustainable Winegrowing Alliance (CSWA) is the most prominent program and focuses on erosion control, water use and ecosystem management.

As described in Section 3, after the pear industry declined heavily in 2001, orchards began to be replaced by winegrape vineyards. Since the turn of the century, there have been multiple programs, regulations and ordinances promoting BMPs, most of which focus on soil erosion control in Lake County. These actions help identify best farm practices like the growing of cover crops to reduce soil erosion, nutrient budgeting to avoid leaching into groundwater, monitoring, and preventing discharges.

The Clear Lake Agriculture Nutrient TMDL report for 2019 indicated that the BMPs that were recently introduced prevented a combined weighted 77% average reduction in erosion.

- Changing crop types from walnut orchards to winegrape vineyards and implementing best management practices including cover crops and drip irrigation which reportedly produced a 99.46% reduction in sediment loading with an assumed 15% average slope.
- An experiment covering 2,387 acres converting from high-till, no cover crop walnut orchards to no-till vineyards with cover crop which reportedly resulted in a 99.73% reduction in sediment loading.
- In other areas, 333 acers had year-round cover crops while tilling the middle rows reportedly produced a 29.2% reduction.
- 142 acres involving a conversion to vineyards with cover crop, wherein the soil was tilled in the spring reportedly resulted in a 28.5% reduction in sediment loading.
- An estimated 15% reduction in loading was found from swapping from flood irrigation to sprinkler or drip irrigation in pear orchards covering 600 acres.
- 700 acres reportedly realized a 94% reduction in sediment loading from adding sediment catchment basins.

These efforts combined were estimated to result in an estimated 30% phosphorus loading reduction across the entire watershed. The report also noted that the reductions do not consider the reduction in loadings from the Lake County Grading Ordinance and the Winegrape Sustainability Programs. Please refer to Attachment H for a description of the current level of treatment in the Source Water Protection Area, and an assessment of how treatment is balanced with producer participation.

EPA National Management Measures

The Environmental Protection Agency (EPA) has developed an extensive library of National Management Measures to reduce sediments and other constituents from non-point sources. Chapters 3E, 3G, and 3I of the document, "National Management Measures to Control Nonpoint Source Pollution from Forestry" contain detailed descriptions of potential management measures. A summary of the key practices identified in this document follows:

National Management Measures for Timber Harvesting (Chapter 3E)

- Install landing drainage structures to avoid sedimentation to the extent practicable. Disperse landing drainage over side slopes.
- Construct landings away from steep slopes and reduce the likelihood of fill slope failures. Protect landing surfaces used during wet periods. Locate landings outside streamside management areas.
- Protect stream channels and significant ephemeral drainages from logging debris and slash material.

National Management Measures for Prescribed Fires (Chapter 3G)

- Plan burning to consider weather, time of year, and fuel conditions. Evaluate ground conditions to control the pattern and timing of the burn.
- Execute the prescribed burn with an agency-qualified crew and burn boss.
- Avoid burning on steep slopes in high-erosion-hazard areas or areas that have highly erodible soils.

National Management Measures for Forestry Chemicals (Chapter 3I)

- Locate mixing and loading areas and clean all mixing and loading equipment thoroughly after each use, where pesticide residues will not enter streams or other water bodies.
- Dispose of pesticide waste and containers according to state and federal laws.
- Take precautions to prevent leaks and spills.
- Develop a spill contingency plan that provides for immediate spill containment and cleanup, and notification of proper authorities.

Forestland and Other Open Space

Key forest management practices as established by the EPA have been previously outlined in this report Section.

The US Forest Service (USFS) and the US Bureau of Land Management have been required by the SWRCB TMDL to reduce phosphorus loadings by 40%. The United States Forest Services have implemented various best management practices (BMPs) to work towards this goal. Recent BMPs as outlined in an official letter dated March 10th, 2020 from the USFS to the SWRCB are as follows:

- Enforcement of management practices for areas causing steep erosion.
  - Installing drain drips to prevent tread soil loss.
  - Redepositing soil into steep trail sections with deep ruts when drain drip failure occurs.
- Implementing management practices for project activities related to range, timber, and roads and recreation.
- Surveying at least 50% of OHV trails on a rotating basis during every grant application cycle.
  - Constructed a native vegetation sediment basin neighboring the OHV practice area in the Middle Creek Campground.
  - Closed all OHV trails contributing to erosion in the watershed.
  - Added rock to channel crossings to harden the crossing and preclude erosion.
- Implemented storm proofing methods to decrease sediments in the stream system.
- Implemented the Bartlett Hazard Tree Abatement and Deer Valley Tree Abatement Program to decide if significant existing or potential problems (SEPES) were indicated.

Failing Septic System Mitigation

A preliminary analysis of the potential impacts of failing septic systems was previously described. The related follow-up associated with verifying and reducing the impact of septic systems include:

- Conduct a survey to verify the number of homes and estimated occupancy in close proximity to the lake and/or related tributaries
- Verify through additional research and sampling, the estimated concentration of phosphorus and other nutrients in the septic tank and leach field discharges
- Institute a septic tank and leachfield inspection program in an effort to quantify the number of failing systems
- Identify those systems that are near enough to an existing POTW such that a septic tank effluent pump (STEP) system or gravity sewer may be feasible
- Quantify the impacts accordingly and identify related funding sources for mitigating problematic systems in an effort to minimize impacts to dis-advantaged communities around the lake

Wetland and Riparian Watershed Improvements

As discussed in Section 3 of this report, wetlands serve as a natural filtration for streamflow into Clear Lake. The total area of wetlands adjacent to Clear Lake has decreased significantly over time. Potential wetland remediation solutions are listed below:

- Existing wetlands held by private landowners could be purchased
- Select agricultural parcels can be purchased and restored as wetlands
- Native vegetation can be incorporated into existing streams
- Select streams can be diverted into an existing wetland
- Select levees that serve to channelize flow entering the lake can be removed

Please refer to Attachment A for a table of recent related creek and wetland remediation projects that are planned, in progress, or have been implemented by Lake County.

LAKE TAHOE COMPARISON

There are several parallels between nutrient assessment and mitigation strategies that are ongoing within the Lake Tahoe and Clear Lake watershed basins. Please refer to Attachment G for an overview of contamination studies and results related to Lake Tahoe.

SECTION 5 – SUMMARY AND RECOMMENDATIONS

This report section includes the following information:

1. A summary of the primary Clear Lake water quality impairments
2. An overview of the general location of potential contamination sources
3. Potential treatment methods for various nonpoint sources, and metrics to monitor the effectiveness of treatment.
4. A list of initial water quality related projects, and related environmental clearances that may be required

The initial projects, collaborative work, and due diligence efforts discussed below have been identified as effective first steps towards implementing practical BMPs on a watershed-wide basis. The initial projects can be used to evaluate the feasibility of proposed solutions that can be expanded upon in the future as additional data is gathered.

5.1 WATER QUALITY IMPAIRMENTS AND CONTAMINATION SOURCES

Water Quality Impairments

As previously described, the primary water quality impairment in Clear Lake is recurring FHAB blooms. The blooms and other invasive aquatic weed growth are a result of excessive nutrients in the lake. Nutrients enter Clear Lake water through both internal and external loading.

External Nutrient Loading Sources (Critical Source Areas)

The focus of this report is reducing external loading. Previous studies prepared by UC Davis have indicated that external nutrient loading in Clear Lake can be largely attributed to phosphorus loading from soil erosion. Phosphorus-rich soil can erode forestland, agricultural properties, urban areas, and other lands. Nitrogen loading from fertilizer application can also occur. Phosphorus, Nitrogen, and other nutrients can also enter the lake through failing septic and sewer infrastructure. Figure 5.1.1 illustrates the generalized locations of potential external nutrient loading sources within the Clear Lake Basin.

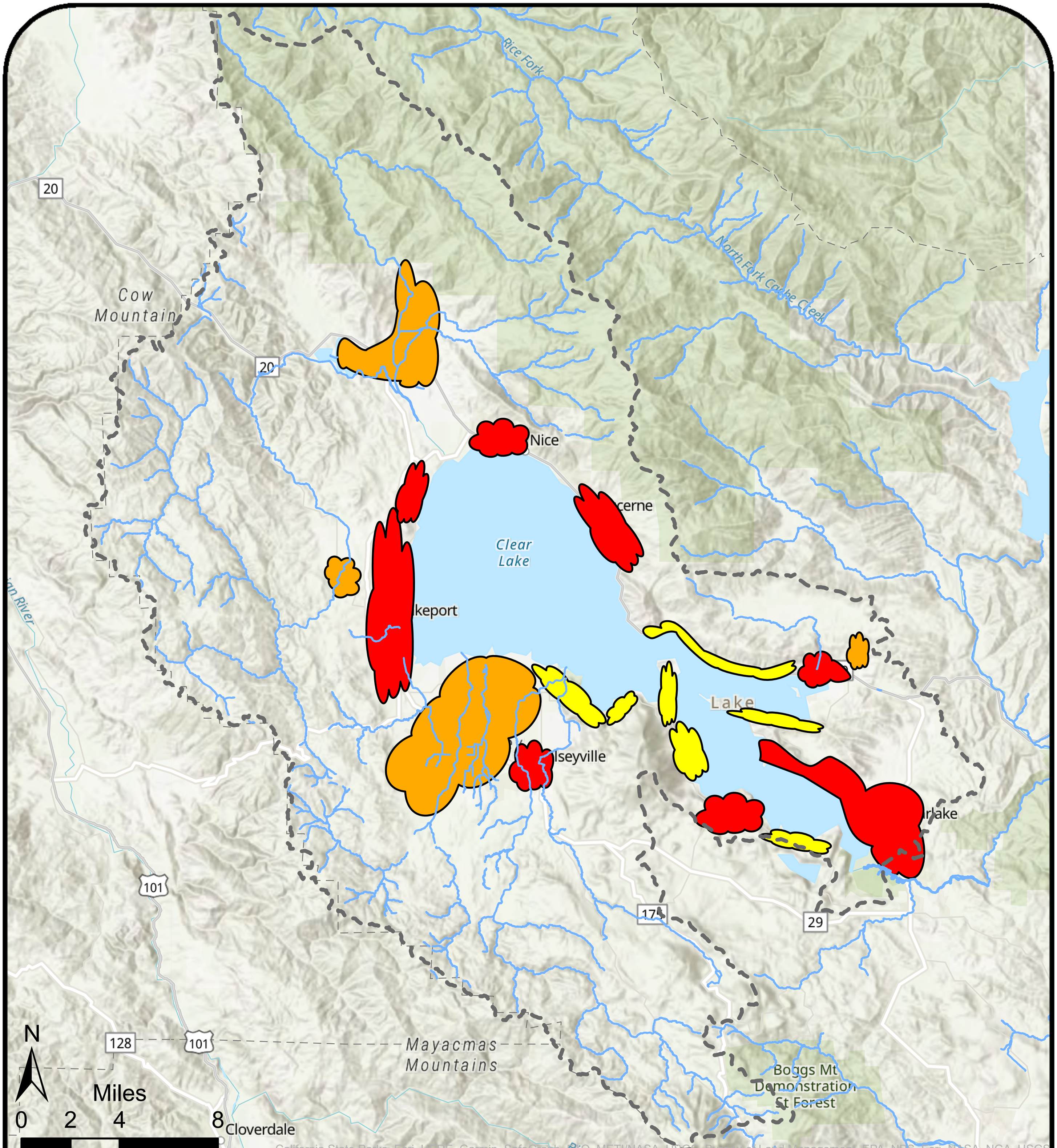


Figure 5.1.1: Potential Clear Lake Nutrient Loading Sources

Lake County Source Water Assessment

Urban · Septic · Agriculture

Clear Lake Watershed · Creeks and Streams

California
Rural Water Association

Work is on-going to further delineate the distribution in loadings throughout the Clear Lake watershed. This work consists of the various monitoring programs described in previous sections including, perhaps most importantly, the extensive data collection and modeling efforts currently underway by UC Davis, USGS, and County of Lake, which is funded by the Clear Lake Blue Ribbon Committee. The work by the Blue Ribbon Committee and others is very focused on quantifying and pinpointing various sources throughout the watershed.

Wetlands have historically served as a natural buffer and have limited the flow of nutrients into Clear Lake. In the last 100 years, a significant amount of wetland acreage has been developed. The reduction of wetlands results in the channelization of runoff and stream flow entering the lake. The effect of channelization of flows is a major concern as it relates to the loss of wetlands for many of the major drainages around the lake. The corresponding NWQI National Management Measure documentation describes the issue of channelization resulting from the loss of wetlands as follows:

"Wetlands and riparian areas play a significant role in protecting water quality and reducing adverse water quality impacts associated with NPS (nonpoint source) pollution, and they help decrease the need for costly stormwater and flood protection facilities. Thus, wetlands and riparian areas are an important component of a combination of management practices that can be used to reduce NPS pollution."

Wetlands can reduce the flow of both naturally occurring and human introduced nutrients into Clear Lake. The restoration of natural wetlands should be considered as part of a nonpoint source nutrient loading treatment and mitigation plan.

Potential Treatment Methods

Potential treatment methods for reducing nutrient loading to Clear Lake were introduced in Section 4. The standard BMP technologies designated by Caltrans, the NRCS, and CASQA may be applicable for reducing erosion and nutrient loading throughout the lakeshed.

The effectiveness of all proposed BMPs will be largely dependent upon the degree and success of on-going maintenance activities. On-going maintenance will require additional costs beyond that of the initial capital project. The County's existing BMP calculator along with the 2005 Caltrans BMP Retrofit Pilot Program report, and EPA estimates can be updated and used as initial references for anticipated County-wide programs and maintenance activities that must be considered in the long-range funding for proposed mitigation efforts.

5.2 INITIAL RECCOMENDED PROJECTS (AREAS NEEDING TREATMENT)

While preparing this study, several initial projects were identified that should be the focus of subsequent phases. Priorities will likely vary based on available funding and the need for additional engineering and CEQA for some projects. Initial projects should ultimately be coordinated with the priorities established from the on-going work by the Blue-Ribbon Committee and resulting SPARROW modeling efforts. A map of initial areas that are requiring treatment is presented on the next page. This map is followed by a description of each proposed project.

Proposed Project 1- Failing Septic System Mitigation:

Failing on-site septic systems can play a significant role in the Clear Lake nutrient loading. More investigations and follow-up analysis are needed to quantify the related impacts, including the effect of high groundwater and proximity to the lakeshore for nearby systems (i.e. within 1,500 feet of the shoreline) on small lots. Priority septic systems may include those along the south shore of the Upper Arm within the Big Valley basin.

Related mitigation programs should include the following:

- Upgrades to substandard septic systems
- Routine maintenance and inspection programs for septic systems
- Continue formal monitoring for coliform bacteria, including location, time of day, and month sampling (e.g., regular monthly monitoring coupled with sampling done during especially wet and dry weather)
- Increased public education of septic system construction, operation, and maintenance by the Lake County Department of Environmental Health through the use of mailings and "advertising"
- A County initiative to landowners for upgrading substandard septic systems to meet basic construction, operation, and maintenance requirements
- A letter to the County proposing the preceding initiatives
- Septic to sewer projects to eliminate on-site systems in select locations

The County of Lake Special Districts department has proposed converting from septic to sewer as part of a project that includes Big Valley, Finley, Soda Bay, State Park and Clearlake Riviera. This project will include the development of a new regional "Full Circle" tertiary treated wastewater conveyance pipeline and will complement the existing wastewater pipeline that serves the North side of Clear Lake. The anticipated scope of the upcoming planning and design phase of this project includes an evaluation of existing wastewater facilities in the area which may provide tertiary treated wastewater, and a description of the features and requirements of the proposed effluent pipeline.

Proposed Project 2- Public Sewer System Rehabilitation:

As discussed in previous sections, leaking public sewers and sanitary sewer overflows can contribute to the nutrient loading in the lake. The three largest public sewer systems (Lakeport, Clearlake, and Clearlake Oaks) should be targeted for on-going investments in collection system repair programs. Proposed mitigations include:

- CCTV programs to identify sources of exfiltration and excessive I/I
- Cured-in-Place Pipe (CIPP) lining to minimize exfiltration and I/I related overflows
- Manhole pressure grouting and lining projects
- Service lateral replacements and repairs, including options for the use of top hats and T-liners for laterals from points of connection to sewer mains
- On-going smoke testing and related repairs

Grant funding should be pursued for low-income sewered communities around the Lake for collection system condition assessment and construction of related mitigation projects.

Proposed Project 3- Cole Creek Flooding Mitigation:

Representatives from the Lake County Farm Bureau have expressed an interest in reducing erosion and flooding at Cole Creek. The creek reportedly overflows during peak storm events and creates localized erosion and flooding south of the highway. This flooding is occurring on private irrigated lands.

The Cole Creek flooding could potentially be mitigated by implementing one or more BMPs. Applicable BMP options that are eligible for NRCS grant funding are listed below:

- Field Borders (386)
- Stream Habitat Improvement and Management (395)
- Drainage Water Management (554)
- Streambank and Shoreline Protection (580)
- Vegetated Barriers and Treatment Areas (601 and 635)
- Water and Sediment Control Basins (638)
- Irrigation Ditch Lining (428)
- Irrigation Pipeline (430)
- Lined Waterway or Outlet (468)
- Surface Drain or Field Ditches (607 and 608)
- Access Road and Related Drainage Improvements (560)

Details and specifications for the above BMPS can be found in the NRCS Field Office Technical Guide associated with each potential solution.

Proposed Project 4- Clearlake Keys Agricultural Runoff Mitigation

The Clearlake Oaks Keys are a subdivision of single-family homes located on the North Shore of Clear Lake along Highway 20. These homes have been constructed with over 6.5 miles of waterfront channels. The channels have poor circulation and exhibit some of the most extreme algae and aquatic weed blooms on the lake. The keys can contribute to poor water quality in Clear Lake by spreading algae and weeds to other areas of the lake, and by "banking" nutrients in the channels. Nutrients can enter the keys channels through agricultural runoff, urban runoff, or other non-point erosion runoff. The primary inlets into the keys are Shindler Creek, the Highway 20 stormwater channel, and other stormwater inlets on the west side of the keys. Please refer to the aerial view in Figure 5.2.1 for an illustration of portions of the Clearlake Keys stormwater system.

Figure 5.2.1: Storm Drain Network in the Clearlake Oaks Area

Note: Culverts are illustrated in red.

The Clearlake Keys Property Owners Association (POA) has proposed installing BMPs to reduce nutrient loading in the keys from agricultural runoff. BMP projects have been proposed at the Schindler Creek and the Highway 20 Drainage Channel. The Schindler Creek Drainage Basin project would include sediment basins and/or riparian buffers. The project would mitigate agricultural and vineyard runoff from High Valley. The Highway 20 drainage channel project is described in more detail as part of the "Wetland Restoration Projects" section.

It is anticipated that the projects will leverage USDA National Water Quality Initiative Agriculture Storm Water Implementation Funds and will be managed by the Lake Conty Watershed Protection District. More detailed engineering review, right-of-way research, and preliminary designs are needed prior to finalizing the most viable solutions for controlling sediment and nutrient loadings at these locations. The POA has also partnered with the Pinecrest Environmental Company and the Robinson Rancheria to acquire California Department of Fish and Wildlife (CDFW) restoration funds for related efforts.

Several additional projects have been proposed that are intended to manage aquatic weed growth in the keys and remove nutrients from the channels. For more information about these internal loading and weed management projects, please refer to the January 25th, 2023, Blue Ribbon Committee Meeting update video posted by the Clearlake Keys POA YouTube channel.

Figure 5.2.2 Concrete Drainage Channel in Clearlake Oaks (along north side of Hwy 20)

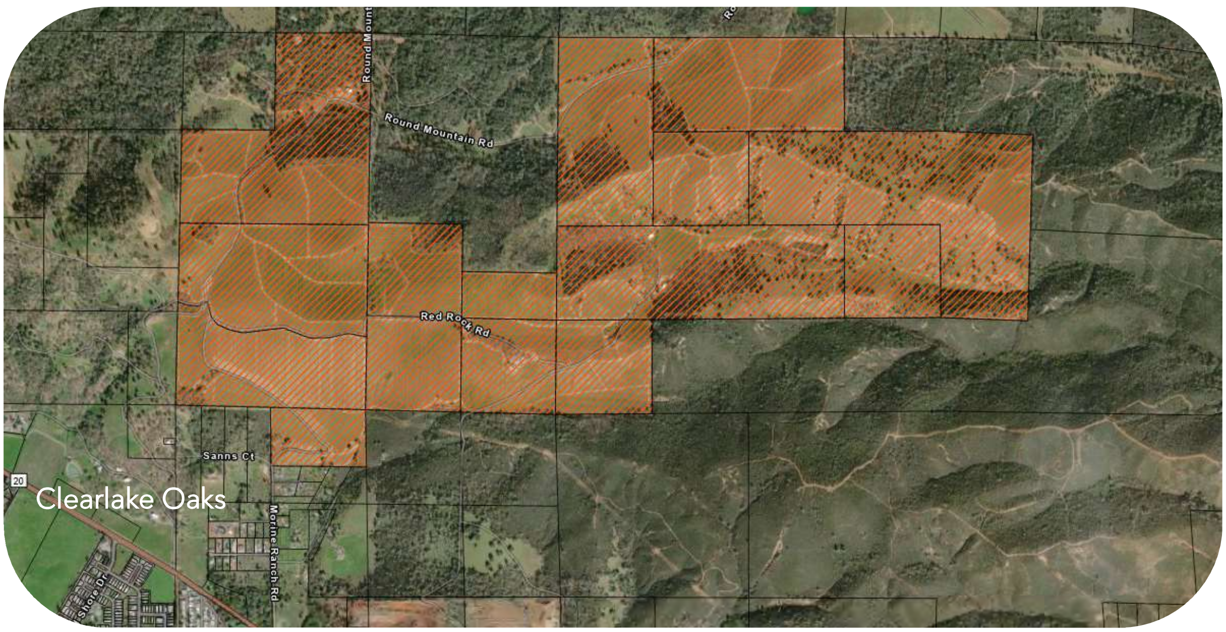
Proposed Project 5- Additional Agricultural Runoff Mitigation:

Irrigated lands are considered a high priority for future projects. As previously discussed, the USDA NRCS NWQI Implementation Program has grant funding available for the construction of agricultural BMPs on private property. Agricultural landowners and other Clear Lake stakeholders are encouraged to submit requests for grant funding to the NRCS.

During the course of this study, the team contacted representatives from Shannon Ranches, one of Lake County's largest vintners. Since grapes are the most predominant crop, BMPs applicable to Shannon Ranches could be applied to other vintners in the watershed.

The initial list of applicable measures related to water quality impacts, as provided by Shannon Ranches, include:

- Cover Crops (NRCS handbook #332)
- Waste Treatment Lagoons (359)
- Stream Habitat Improvement/Management (395)
- Irrigation Reservoir (436)
- Access Road and Related Drainage Improvements (560)
- Streambank and Erosion Protection (580)
- Shrub Establishment (612)
- Waste Recycling (633)
- Wetland Wildlife Habitat Management (644)
- Wetland Enhancement (659)



Shannon Ranches Vineyards (Northeast of Clearlake Oaks)

The Lake County Watershed Protection District is seeking to identify additional agricultural runoff mitigation related projects that may qualify for NRCS grant funding. The District is planning to distribute digital and hard copy versions of a questionnaire aimed at gaging interest in participation in the NWQI Implementation Program, and to collect general locations and estimated measures. After initial solicitation of interested landowners, site reviews would follow that would result in preliminary projects of the type previously listed under the NRCS grant fundable measures.

It should be noted that the NRCS, while providing funding for construction of a variety of projects, does not fund related outreach, engineering, or CEQA coverage. As such, Lake County, or another organization, would need to acquire related funding and resources needed to refine and vet these projects prior to preparing plans and environmental documents for related BMPs. Once implemented, showcase projects and follow-up metrics can be developed to expand upon these programs throughout the watershed and agricultural community.

Proposed Project 6- Open Space and Forest Runoff Mitigation:

Public lands and open space make up much of the watershed and are reportedly responsible for the majority of the non-point source loading of contaminants and nutrients. The related open space areas included miles of unimproved and semi-improved roads, trails, drainages, and un-vegetated erosion sources.

Potential water quality improvement projects associated with forest land and other open spaces were presented in Section 4 of this report and the list of the types of projects is extensive and not re-iterated here. More detailed surveys and analysis are recommended to document and prioritize future projects and provide on-going maintenance of existing BMPs while continuing to pursue the types of projects presented previously in Section 4.

Proposed Project 7- Urban Runoff Mitigation:

It is understood that urban areas generally discharge directly into storm drains that make their way to Clear Lake through a series of culverts and outfalls. Maps of county and Caltrans culverts were presented in Section 4 that can be targeted for installation of various BMPs including detention basins, storm filters, and related upstream improvements on irrigated lands and open spaces. Roadway oils, spills, and lawn fertilizers are examples of typical tributary sources in populated areas and Lake County has an on-going outreach effort to curb related issues.

The most important urban storm drains to target should be identified based on a review of existing infrastructure as well as consideration of tributary flows and loadings. The County is embarking on a watershed-focused stormwater management plan that will include additional information from which priority projects can be selected for installation of BMPs in the future.

Section 4 provided a list of BMPs and associated performance metrics for controlling various forms of urban runoff. It is important to note that most all measures require a degree of on-going operations and maintenance along with related funding needs. The County as well as the Cities of Lakeport and Clearlake, will need to verify that adequate staffing and budget is available to support these activities. The proposed County Stormwater Management Plan is one mechanism that can be used to identify the on-going O&M needs, in addition to forming a foundation for related capital improvements and related grant funding.

The EPA has extensive resources available related to stormwater maintenance. A list of reference topics made available on the EPA website follows:

- Identification of the parties responsible for maintenance
- Maintenance schedules
- Inspection requirements
- Frequency of inspections
- Easements or covenants for maintenance
- Identification of a funding source
- Description of basic maintenance activities like weeding, mulching, trimming of shrubs and trees, replanting, sediment and debris removal, and inlet/outlet cleaning

Funding sources will likely need to include appropriate county-wide assessments that can be levied through initiatives, Mello Roos districts (the act of selling bonds to finance a project), or other legislative programs and policies.

Proposed Project 8- Wetland Restoration:

Due to the critical role that wetlands play for removing contaminants, and that the fact that approximately 80% of the wetlands around the lake have been reclaimed and developed over, a continued effort to restore these critical lands should be maintained. Future projects, funded by NRCS, USACE, SWRCB, and others as appropriate, should be identified in coordination with active acquisitions currently taking place and for those planned in the future based on continued collaboration with groups that include the Lake County Land Trust, and others. After acquiring land and/or easements, restoring wetlands can be an extensive process that includes breaching levees, channel removal and restoration and other enhancements that will require detailed surveying, engineering, hydraulics, and habitat evaluation. Near-term related work is anticipated for the Middle Creek and Wright Wetlands.

In addition, the Lake County Watershed Protection District has begun initial discussions related to wetland acquisition and easement management for the wetland area that is located to the East of the Clearlake Keys. The Lake County Land Trust is committing to pursue a wetland purchase to obtain an easement to mitigate runoff from a concrete channel along Highway 20 that discharges into the Keys. The Highway 20 Drainage Channel runs parallel to Highway 20 and flows directly into the keys and adjacent wetland. A "Clearlake Oaks Keys Inflow Video" with drone footage of the proposed project site has been posted to the Clearlake Keys POA YouTube Channel.

This project may entail construction of an unlined detention basin and/or related improvements that would allow for settlement and/or filtration using a vegetative filter/buffer to remove sediments and nutrients prior to discharge between the Caltrans culvert and the Keys.

More details regarding specific project needs should be identified in subsequent phases based on prioritization according to estimated impacts, potential contaminant load reductions, and available funding sources.

5.3 METRICS REQUIRED TO REFINE LOCATIONS AND TRACK PROGRESS

A variety of metrics for calculating load reductions were introduced in Section 4 of this report with an emphasis on sediment removal that could be correlated with reductions in nutrient loading. The applicable methodology will vary based on the type of BMP and targeted source.

Based on examples from other lakes eutrophic-state reversal, the ultimate result of improved water quality, will likely take decades to fully materialize. The effect of climate, including rainfall and impacts from increased water temperatures, combined with legacy nutrient banks, will tend to complicate the ability to directly correlate activities with immediate results.

Several methods have been developed, as explained in detail in Section 4, to estimate BMP performance and removal efficiencies including:

- Lake County BMP Effectiveness Calculator
- Caltrans 2005 Pilot Program estimated removal efficiencies for specific contaminants and various BMPs
- Related TERC models developed for Lake Tahoe that consider the role of fine sediments and available nutrients (i.e. phosphorus) that contribute to FHAB growth and bloom events

As existing BMPs are monitored and new ones continue to implemented, efforts to further refine and quantify benefits should consider each of the above approaches in order to help prioritize projects based on anticipated results.

By working in partnership with the Blue Ribbon Committee, the on-going implementation of BMPs and results can be used to further target the best projects and determine long-term effects and impacts to water quality.

5.4 PERMITTING AND ENVIRONMENTAL (CEQA/NEPA) CONSIDERATIONS

It is recognized that implementing projects in California, particularly those that impact wetlands, can present challenges related to permitting and environmental clearances. Both CEQA and NEPA documents will need to be prepared for projects that include federal funding. It is anticipated that all projects ultimately have a net positive impact on the environment, however, issues that include those associated with the endangered species act (ESA), and other biological, cultural, air quality, or archeological impacts could require related mitigations that could complicate the implementation process. It is recommended that a dedicated team of environmental consultants be identified that can serve as a resource to the watershed-wide coalition discussed earlier in this section. Appropriate environmental processes could include any of the following:

- Categorical exemption (Cat X) for those projects with minimal or no negative environmental impact
- Negative Declaration
- Full EIR
- Related NEPA documents for those projects involving federal funding
- Where applicable, projects should be included under the "Cutting the Green Tape" Initiative, which fast-tracks CEQA processes for implementation projects that have a net environmental benefit such as pollution-prevention, reduction, or habitat creation.

Funding for the required environmental document(s) will need to be identified for each project. In addition to environmental documents, anticipated permits could include:

- USFWS Streambed Alteration Agreements
- CDFW Streambed Alteration Agreement (LSAS, RSAs)
- USACE 404 Permits
- Caltrans Encroachment Permits (if impacting a State Highway)
- Lake County Permits such as Public Works Encroachment permits if project impacts a county-maintained roadway or point of access
- SWRCB NPDES permit revisions
- Other Clear Lake area specific permits

5.5 WATERSHED COALTION NEEDS

A wide variety of potential contaminant sources are located around the lake, and many types of nutrient loading mitigation projects could be implemented. Given the diverse nature of potential projects, the need to prioritize the most effective solutions, and the need to incorporate the concerns of multiple stakeholders, it is imperative that a Clear Lake watershed coalition is established. The primary focus of this coalition would be to develop actionable nutrient loading mitigation projects that are related to the Blue Ribbon Committee findings. This work would include identifying and securing project funding.

As previously discussed, the Blue-Ribbon Committee is responsible for making recommendations for rehabilitating Clear Lake. UCD TERC and USGS have partnered to develop a nutrient loading model to quantify the nutrient loading contributions from various sources around Clear Lake.

The leading organizations, and stakeholders working to restore water quality in the lake have been discussed in previous sections and they include:

- Clear Lake Blue Ribbon Committee *(Agencies involved in this Committee are listed on the Blue Ribbon Committee Website)*
- Lake County Departments, Agencies, and Committees
    - County of Lake Department of Water Resources
    - Lake County Watershed Protection District
    - Middle Creek Restoration Project Committee
    - Lake County Farm Bureau
- Cities of Lakeport, and Clearlake
- United States Army Corps of Engineers
- Environmental Protection Agency (EPA)
- Lake County Land Trust
- Lake County Resource Conservation District

In the early 2000's a similar organization called the "Clear Lake Advisory Subcommittee" was established. After a decade of involvement, this organization disbanded. According to Lake County staff, acquiring funding for projects was an ongoing challenge. The proposed watershed coalition should build upon the findings of the advisory subcommittee and investigate all available funding sources.

Watershed Coalition Funding Considerations

Grant and low-interest loan funding can be pursued for implementation of select projects. Possible sources of funding could include:

- USDA and the National Resource Conservation Service (NRCS)
- State Department of Water Resources (DWR)
- US Army Corps of Engineers (USACE)
- Local Organizations, Businesses, and Committees (local watershed planning groups)
- State Water Resources Control Board (SWRCB) (Post-Fire Monitoring Funding)
- United States Bureau of Reclamation (USBR)
- United States Forest Service (USFS)
- United States Bureau of Land Management (BLM)
- Other Special Interest Groups

It is suggested that a strategic funding initiative be implemented that includes a grant research team and grant writers that can follow through with project specific grants applicable to each of the above potential funding sources in the future. The Lake County Watershed Protection District has historically served a lead role in acquiring grant funding for Clear Lake water quality remediation projects, and it is assumed that the County would continue to be involved in this process. This funding acquisition effort will require an on-going investment in resources and considerable time and commitment on the part of all stakeholders.

Clear Lake Integrated Watershed Management Plan

Key Blue Ribbon Committee findings and a more detailed roadmap for ongoing prioritization, implementation, and funding acquisition for select projects could be potentially outlined in more detail in an updated Clear Lake Integrated Watershed Management Plan. The most recent Clear Lake Integrated Watershed Management Plan was produced by Lake County in 2010 with Cal Fed and Prop 50 grant funds. Since this date, the Blue Ribbon Committee has been established and Lake County has implemented select mitigation projects throughout the watershed. The 2010 Lake County Integrated Watershed Management Plan should be updated to include recent findings and include a chapter specific to in-lake management to accompany external loading management projects.

A comprehensive Watershed Management Plan is a document intended to provide an analytic framework for managing efforts to both restore water quality and to protect overall watershed health. The EPA has listed nine minimum elements to be included in watershed management plans for threatened or impaired waters:

1. Identify causes and sources of pollution
2. Estimate pollutant loading into the watershed and the expected load reductions
3. Describe management measures that will achieve load reductions and targeted critical areas
4. Estimate amounts of technical and financial assistance and the relevant authorities needed to implement the plan
5. Develop an information/education component
6. Develop a project schedule
7. Describe the interim, measurable milestones
8. Identify indicators to measure progress
9. Develop a monitoring component

The excerpt below is a statement found in the EPA's National Water Quality Initiative (NWQI) material that is worth noting:

"Watershed plans lay out the route for water quality improvements. These plans address the sources of the problem and identify critical areas where focused work will make the most impact on water quality. A watershed can contain dozens or hundreds of NPS pollution sources and these can fluctuate over time. Finding solutions is not a simple task! Watershed plans help local groups take a holistic approach to restoring water quality. This approach requires four key things: people, money, work and time. If one of those four is missing, success is simply out of reach."

The previous statement summarizes the need to incorporate the efforts of multiple Clear Lake water quality stakeholder organizations and individuals to develop an updated Clear Lake Integrated

Watershed Management Plan. There is potential to involve the proposed Clear Lake Watershed Water Quality Mitigation Project Implementation Coalition in this effort.

A Clear Lake Watershed Management Plan development project was proposed and approved by the Blue Ribbon Committee in Spring 2023, but funding allocation is still being determined while the State of California is in a budget deficit. This plan was proposed to follow the Lake Management guidelines as described by the North American Lake Management Society and once completed, will be a valuable chapter within an updated Clear Lake Integrated Watershed Management Plan.

6- CLEAR LAKE SURFACE WATER PURVEYOR INDIVIDUAL ASSESSMENTS

This section includes individual assessments for each of the seventeen surface water systems that draw raw water from Clear Lake. Each assessment describes the water system's ability to meet the requirements of the California Code of Regulations (CCR) Title 22 Chapters 15, 15.5, 17, and 17.5. Each system's assessment includes a description of the treatment process, summary of water quality data, and a compliance evaluation. The data captured in this section spans from 2017-2021 and came from the following sources:

- The Safe Drinking Water Information System (SDWIS) website, which contains primary and secondary water quality results and general information about the water system.
- Individual utilities provided consumer confidence reports (CCRs), sampling results, regulatory worksheets, and treatment plant data.
- The California State Water Resources Control Board Division of Drinking Water provided microcystin monitoring results from Order No. 02_03_21M_001.
- Observations during site visits.
- Personal communications with utility operators during site visits and/or through telephone and email.

6.1- GENERAL

Clear Lake is generally regarded as a challenging drinking water source requiring grade 3 or 4 treatment plants in most locations around the lake. Seasonal harmful algal blooms release cyanotoxins, increase organic loading, cause pH swings, decrease oxygen availability, increase the concentration of ammonia, and may precipitate iron and manganese. The resulting water treatment challenges include decreased filter run times from clogged filters, high settled water turbidity, increased sludge production, more frequent backwash cycles, increased coagulant and disinfectant demand, increased energy demand, the formation of chloramines and disinfection byproducts, and taste, color, and odor concerns. Years with high heat and low precipitation exacerbate these conditions, often testing the limits of existing infrastructure. Additionally, Clear Lake is polymictic, which can increase turbidity on daily or hourly timescales. Stormwater runoff contributes to heavy silting during the winter months and introduces excess phosphorus into the lake, providing additional nutrients for the development of harmful algal blooms.

Despite significant water quality challenges, nearly all surface water purveyors that draw raw water from Clear Lake meet the requirements set forth by the CCR Title 22 Chapters 15, 15.5, 17, and 17.5. The CCR Title 22 chapter 15 contains articles that outline monitoring programs such as the Groundwater Rule and the California Revised Total Coliform Rule. This chapter also regulates chemical contaminants such as volatile organic compounds (VOCs), synthetic organic compounds (SOCs), inorganic compounds (IOCs), radiological contaminants, and constituents with secondary maximum contaminant levels (MCLs). Chapter 15.5 contains articles that outline the Disinfection Byproducts Rule and Chapter 17.5 contains articles that outline the Lead and Copper Rule.

In addition to the requirements set forth in Chapters 15, 15.5, and 17.5, surface water purveyors must also comply with Chapter 17, the Surface Water Treatment Rule. Because surface water is especially susceptible to bacteriological contamination, special care must be taken to ensure that treated surface water is free of pathogens and disease-causing bacteria. All surface water treatment plants must at a minimum achieve the following:

- A total of 99.9 percent (3 log) reduction of *Giardia lamblia* cysts through filtration and disinfection
- A total of 99.99 percent (4 log) reduction of viruses through filtration and disinfection
- A total of 99 percent (2 log) removal of *Cryptosporidium* through filtration

Compliance with the abovementioned treatment requirements is demonstrated through the use of the best available technologies, raw and effluent turbidity monitoring, and disinfection contact time. Water leaving the treatment plant must have a minimum disinfectant residual of 0.2mg/L to ensure no contamination is present in the finished water supply.

Surface water purveyors must also conduct monthly bacteriological monitoring at the intake using a quantitative method. Total coliform and *E. coli* are indicators of bacteriological water quality. The presence of total coliform does not necessarily indicate the presence of harmful bacteria, but it triggers the need for additional treatment to minimize the risk of contamination. The presence of *E. coli* indicates recent fecal contamination. The presence of total coliform or *E. coli* at the intake is not surprising because the water has not undergone treatment, however, the presence of total coliform or *E. coli* in the distribution system triggers the need for investigation and immediate action. Treated bacteriological monitoring is regulated by the California Revised Total Coliform Rule and requires samples to be collected throughout the distribution system to further ensure that the distribution system is free of bacteriological contamination.

The individual utility assessments are organized as follows:

1) <u>Water System Summary</u> – general information about the water system including treatment and distribution classification, treatment plant capacity, number of pressure zones and storage tanks, connection count, and population.

2) <u>Treatment, Operations, and Infrastructure Upgrades</u> – Summary of the treatment process, recent and planned projects.

3) <u>Water Quality and Compliance with Regulations</u> – Summary of water quality and compliance with the following regulatory programs and water quality initiatives between 2017-2021. Violations of regulatory programs include a recommendation section.

    a) *Surface Water Treatment Rule* – violations of the surface water treatment rule are outlined in this section.

    b) *Raw Turbidity* – included to assess treatment challenges and seasonal lake dynamics. Raw turbidity peaks can help determine the type of turbidity faced by the water system. Peaks during the winter are mostly associated with storm events while peaks during the late summer and early fall are mostly associated with harmful algal blooms. Peaks from storm events are composed of mostly colloidal silt whereas the peaks associated with harmful algal blooms are composed largely of organic material, which clog filters more quickly and require more frequent backwashing than colloidal silt.

c) *Bacteriological Water Quality & The Total Coliform Rule* – summary of raw bacteriological results and compliance with the Total Coliform Rule. Raw bacteriological results are reported in the most probable number per 100 milliliters (MPN/100mL). This unit is commonly used for quantitative bacteriological analyses in drinking water and requires a 15-tube dilution factor. Distribution system bacteriological monitoring is reported using a qualitative presence/absence method.

The California State Water Resources Control Board Division of Drinking Water revised the Total Coliform Rule in July 2021. It is now referred to as the California Revised Total Coliform Rule (CArTCR), however, since this compliance summary covers the years of 2017-2021, we based compliance on the original Total Coliform Rule. The subsequent sanitary survey should include the requirements of the CArTCR.

d) *Primary and Secondary Standards* – summary of water quality data for analytes with primary or secondary maximum contaminant levels that were detected between 2017-2021. If a regulated contaminant is not listed, it was not detected during the study period. Compliance with primary and secondary standards is based on the water quality delivered to customers. While utilities are required to monitor raw water (before treatment), they have the option to monitor finished water (after treatment) at the entry point to the distribution system or the treatment effluent location to determine compliance with MCLs and SMCLs. When systems conduct quarterly monitoring, compliance is based on the running annual average (RAA). The RAA is the average of the current and previous three quarters of water quality results.

e) *Disinfection Byproducts Precursors* - Compliance with disinfection byproducts precursors is required for all community and nontransient community water systems utilizing conventional surface water filtration processes. Compliance is achieved through effective total organic carbon (TOC) removal. Compliance is based on the running annual average (RAA) of monthly TOC removal percentage calculations. Monthly alkalinity and total organic carbon results from the intake determine the percentage of TOC required (15% - 50%).

f) *Disinfectants and Disinfection Byproducts Rule (DBPR)* – Compliance with the DBPR is required for community and nontransient noncommunity water systems using a disinfectant. Total trihalomethanes and total haloacetic acids samples are taken either annually or quarterly from pre-selected locations throughout the distribution system. If the system samples quarterly, compliance is based on the locational running annual average (LRAA), which is the average of the current and previous three quarters of monitoring results for each location. If the system samples annually, compliance is based on annual results. If the LRAA or annual results exceed the MCL, then the water system is in violation of the DBPR.

g) *Lead and Copper Rule (LCR)* - Compliance with the LCR is based on the 90th percentile of sample results, which is calculated differently depending on the number of samples that are required. First draw samples are taken from pre-selected customer homes that meet certain tiering criteria. If the 90th percentile exceeds the action level, the system must conduct further investigation and monitoring to determine if corrosion control treatment is required.

h) *Microcystins Monitoring* – Microcystins are a class of unregulated cyanotoxins. The short-term effects of microcystin exposure can include heavy breathing, vomiting, weakness, diarrhea, gastrointestinal liver inflammation, hemorrhage pneumonia, and dermatitis. The long-term health effects from microcystin exposure include tumor formation and liver failure leading to death. Rulemaking for microcystins and other classes of cyanotoxins are likely to be adopted in the future. The harmful algal blooms in Clear Lake contain algal species capable of releasing four classes of cyanotoxins: microcystins, cylindrospermopsin, anatoxins, and saxitoxins.

The United States Environmental Protection agency issued 10-day health advisories for microcystins and cylindrospermopsin. The health advisories for children under the age of six years are 0.3μg/L and 0.7μg/L respectively whereas the health advisories for people older than six years are 1.6μg/L and 3.0μg/L, respectively. The World Health Organization issued a guideline of 1.0μg/L for microcystins in drinking water. As of November 2022, the State Water Resources Control Board requested assistance from the Office of Environmental Health and Hazard Assessment to develop notification levels for microcystins, cylindrospermopsin, anatoxins, and saxitoxins.

In 2021, the State Water Resources Control Board Division of Drinking Water issued a microcystins monitoring order to the seventeen surface water purveyors that draw from Clear Lake. Raw and treated water was sampled for microcystins regularly between May and October 2021. Results of that monitoring order are summarized in this section. Results show treatment effectiveness for microcystins inactivation. No intake or treated water data is currently available for cylindrospermopsin, anatoxins, and saxitoxins.

i) *pH, Disinfection, and Coagulation* – This section is included for the systems that provided daily pH, disinfection dosage, and coagulation dosage data. There are many biological and chemical processes that occur during harmful algal blooms; the ability to choose a single parameter as a proxy for harmful algal blooms is constrained by the available data. The best parameters are cyanotoxin concentrations, however, Lake County's toxin data is sparse and thus cannot be used to measure harmful algal blooms. Daily data is needed to determine the relationship between harmful algal blooms, coagulation, and disinfection. The most frequent cyanotoxin monitoring is taken bi-weekly, which doesn't account for daily treatment changes. In the absence of toxin data, chlorophyll-a measurements can be used as an indicator for algal biomass. However, due to inconsistent funding for sample analysis, the California Department of Water Resources has limited chlorophyll-a data in Clear Lake. The relatively large data gaps may not account for significant changes in chlorophyll-a concentrations and therefore cannot be reliably used as a proxy for harmful algal blooms. Turbidity did not prove to be a reliable indicator because winter inflows result in turbidity peaks but are not associated with bloom events. pH, which is indicative of the water chemistry changes that accompany harmful algal blooms, proved to be the most reliable proxy for harmful algal blooms.

During a bloom event, pH increases during the daylight hours and decreases at night. These fluctuations are driven by the rapid uptake of carbon dioxide in the water column during the day when photosynthesis peaks and the subsequent decrease in carbon dioxide uptake during the night. As carbon dioxide is added to water, which happens overnight, water dissociates into bicarbonate and hydrogen atoms which causes the pH to decrease. As carbon dioxide is removed from water, as in the case during algal photosynthesis, the reaction does not dissociate into bicarbonate and hydrogen ions but rather stays as carbonic acid, causing the pH to increase.

Both primary coagulant and polishing disinfectant doses increase significantly during harmful algal blooms, which significantly increases the cost of water treatment. Disinfectant demand increases during harmful algal blooms because high settled turbidity resulting from organic loading requires higher disinfection doses to inactivate pathogens and cyanotoxins. Additionally, increased ammonia levels during harmful algal blooms require higher disinfection doses to overcome chloramine formation to reach breakpoint chlorination.

The coagulation process is pH dependent; most coagulants react optimally between a pH of 6-7.5. Harmful algal blooms increase pH, which decreases the effectiveness of coagulation. In response, water treatment operators increase coagulant doses to force the coagulation reaction to happen. Coagulant doses average roughly 20-30mg/L during the winter months but can increase to 120mg/L during the summer months when harmful algal blooms are present. The cost of primary coagulant is the most significant chemical cost for water purveyors treating harmful algal blooms. Except for a select few systems largely shielded by pH swings and harmful algal blooms, we recommend an acid feed system at the intake to lower the raw pH before it undergoes coagulation. We also recommend the use of a charge analyzer or streaming current monitor to optimize coagulant dosages.

j) *Ammonia* – A graph of ammonia concentrations is provided for those systems that provided ammonia data. Increased ammonia in the lake is an indication of algal decay. When blooms decay as they do during the mid-to-late summer, cyanobacterial cells release ammonia into the lake. Increased ammonia concentrations in the lake create challenges for drinking water disinfection. When chlorine is introduced to water containing ammonia, chloramines are developed. While many systems purposely use chloramines as a disinfectant, chloramines do not inactivate cyanotoxins and therefore are not used in Clear Lake. As a result, chlorine dosages must be increased significantly to reach breakpoint chlorination.

6.2- BUCKINGHAM PARK WATER DISTRICT

6.2.1- Water System Summary

The Buckingham Park Water District (BPWD) is located on the Buckingham Peninsula between the Upper Arm and the Lower Arm. The intake is in a quiescent cove on the eastern side of the peninsula (Figure 6.2.1). The BPWD is a severely disadvantaged community (SDAC). It has a total of 457 connections (450 residential and 7 commercial) and serves a population of 1,501. The system has three pressure zones due to the varied topography of the area. It has one surface water treatment plant, two storage tanks, one pressure tank, and three booster pump stations. Additional system information is outlined in Table 6.2.1.

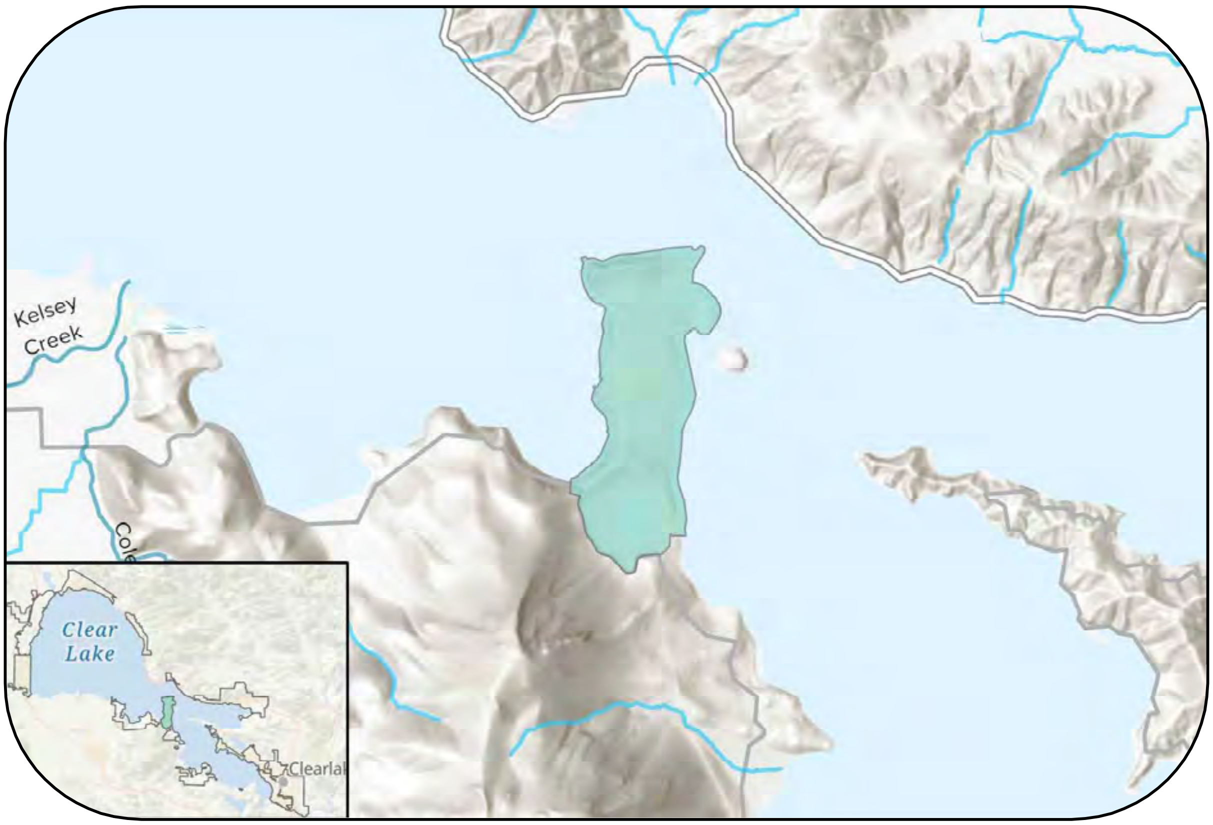


Figure 6.2.1 BPWD System Boundary Map

Table 6.2.1: BPWD System Attributes

System Name	**Address**	
Buckingham Park Water District	2880 Eastlake Drive, Kelseyville CA 95451	
Public Water System No.	**Connection Count**	**Population**
CA1710011	457	1,501
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community Water System	Intake/Active	300/0.432
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
5 (primary), 10 (secondary)	D2	T3

6.2.2- Treatment, Operations, and Infrastructure Upgrades

The BPWD treatment plant is a conventional water treatment plant consisting of two raw water pumps, an up-flow clarifier, two multimedia pressure filters, and two granulated activated carbon filters. Raw water is pumped through one of two variable frequency drive intake pumps and dosed with sodium hypochlorite as it enters into a static mixer. Water is then dosed with Propac 9800 before it enters a second static mixer. After flash mix, water enters into a 44,000 gallon up-flow clarifier. Flocculation occurs in the mixing cone and sedimentation causes floc to sink and settled water to flow upwards towards the weirs. Water entering the weirs is seasonally dosed with Propac 9890, a coagulant aid, to assist when settled turbidity is high from organic loading from harmful algal blooms.

Water then enters one of two mixed media filters that run in parallel. Flow is then combined and enters two granulated activated carbon units that run in series. Finally, water is dosed with sodium hypochlorite for disinfection and effluent water enters into a 200,000-gallon clearwell. The clearwell is equipped with an aeration system and a baffle wall. The aeration system helps to reduce disinfection byproducts and other volatile organic compounds. The baffle wall helps to prevent short circuiting in the tank and facilitates contact time compliance. Finished water is then pumped to the two storage tanks and a pressure tank to gravity feed the system. Figure 6.2.2 shows a process diagram of the BPWD's treatment process.

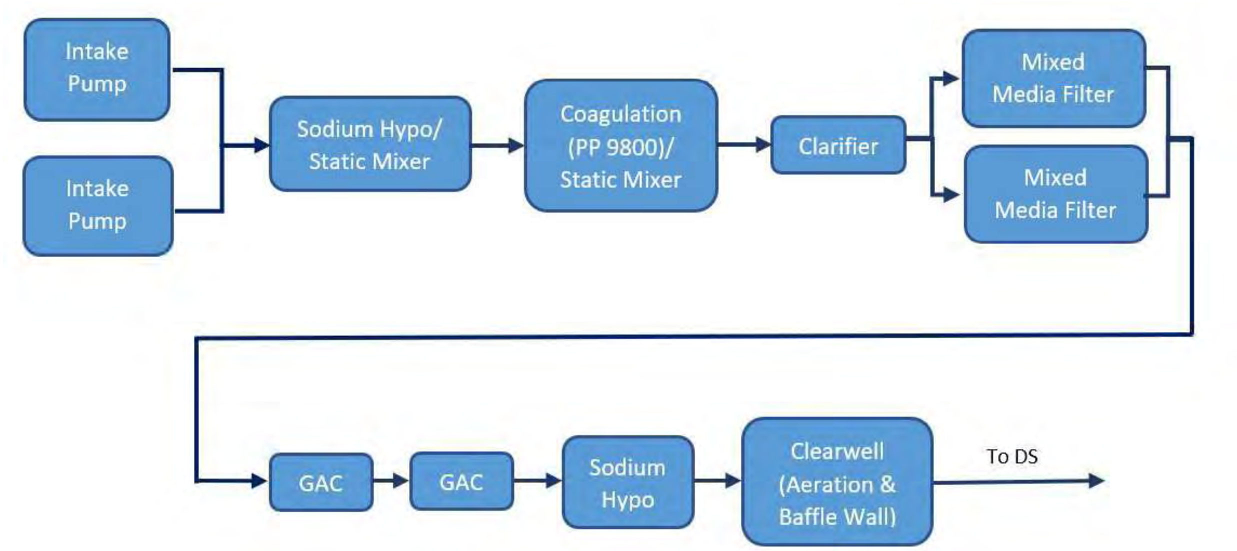


Figure 6.2.2: BPWD Water Treatment Plant Process Diagram

6.2.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The BPWD maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.2.3 shows the BPWD's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms, but the highest peaks align with the months when harmful algal blooms are present. The BPWD's intake is located in a quiescent cove that is largely shielded from sedimentation associated with storm events. Turbidity from storm events averages around 10 NTU whereas other purveyors with intakes that are more exposed to sedimentation have regular spikes up to 200 NTU. Relative to other utilities in this study, the BPWD has low to moderate raw turbidity levels. The highest peaks took place between July and early November, which are the months when harmful algal blooms are most severe in Clear Lake. The highest result was 34.1 NTU in July 2018. Although the intake is in the Lower Arm, which is known to undergo severe blooms, the cove has relatively mild water quality. This phenomenon is partially due to the wind shadow provided by Mt. Konocti and the lack of sediment flow into the area.

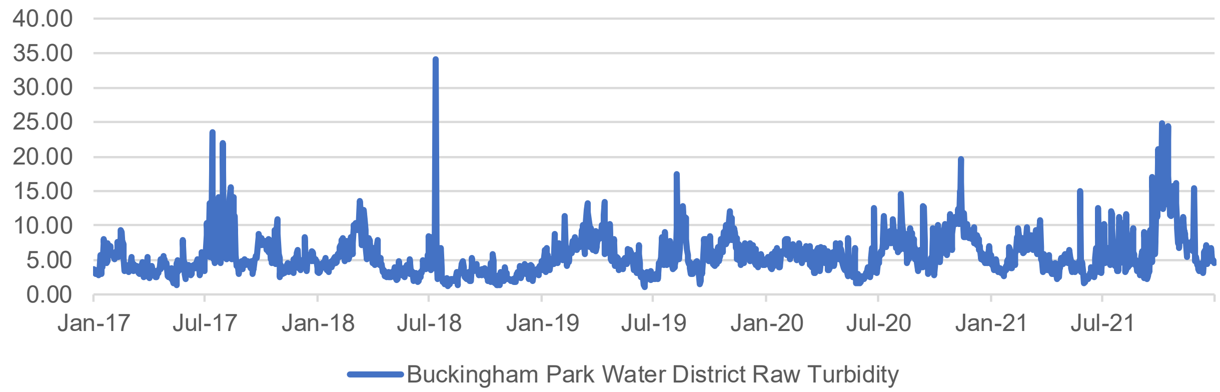


Figure 6.2.3: BPWD Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The BPWD sampled at least monthly at the intake for total coliform and *E. coli*. 2018 was sampled bi-weekly. Table 6.2.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 46% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.2.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the BPWD provides adequate treatment and disinfection for bacteriological quality.

Table 6.2.2: BPWD Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	77	>2,419.6	8.6	1,986.3
Escherichia coli (*E. coli*)	MPN/100mL	77	54.6	ND	1

ND: Not Detected

Table 6.2.3: BPWD Distribution System Bacteriological Monitoring (2017-2021)

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.2.4 and 6.2.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.2.4 and 6.2.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The BPWD had no primary drinking water standard violations between 2017-2021. However, the finished water RAA regularly exceeded the SMCL for odor throughout the study period. We recommend that the BPWD continue to monitor their finished water for odor and investigate the possibility of replacing the granulated activated carbon media.

Arsenic rose steadily throughout the study period. Arsenic levels in Clear Lake are known to be naturally occurring from volcanic soils. The BPWD's proximity to Mount Konocti may influence the concentration of arsenic. Low water levels and the impact of wildfires may further concentrate arsenic in the lake. Raw results rose from 2.3µg/L in 2017 to 6.4 µg/L in 2021. Finished water results were significantly lower, however, finished results also increased. We recommended that the BPWD continue to monitor finished water to determine compliance with the arsenic MCL.

Table 6.2.4: BPWD Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 99	ND	None
Arsenic	µg/L	10/--	2.3 – 7.4	ND – 3.2	None
Barium	µg/L	1,000/--	ND – 110	ND	None
Fluoride	mg/L	2/--	0.11 – 0.16	0.1 – 0.14	None

ND: Not Detected

Table 6.2.5: BPWD Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	7.1 – 9.6	16 – 23	None
Color	Color Units	15	11 – 90	ND – 13	None
Conductivity	umho/cm	1,600	270 – 400	310 – 440	None
Sulfate	mg/L	500	2.8 – 3.9	2.7 – 3.8	None
Total Dissolved Solids	mg/L	1,000	170 – 270	180 – 270	None
Iron	µg/L	300	ND – 270	ND	None
Odor	TON	3	14 – 32	ND - 120	The finished water RAA regularly exceeded the SMCL during the study period
Manganese	µg/L	50	47 – 180	ND – 36	None

ND: Not Detected

Disinfection Byproducts Precursors

Table 6.2.6 summarizes the BPWD's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.2.6: BPWD Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	120 – 180	3.93 – 5.74	25% - 35%	62%	None
2018	140 – 170	4.5 – 5.68	25%	57%	None
2019	120 – 160	3.7 – 4.91	25% - 35%	45%	None
2020	140 – 180	3.75 – 4.96	25%	47%	None
2021	170 – 200	2.43 – 6.72	25% - 35%	40%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.2.7 summarizes the BPWD's compliance with the disinfection byproducts rule (DBPR). No violations were observed.

Table 6.2.7: BPWD Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	19.4 – 66.5	47.5	None
Total Haloacetic Acids	µg/L	60	9.9 – 53.8	41.9	None

Lead and Copper Rule (LCR)

Table 6.2.8 summarizes compliance with the Lead and Copper Rule (LCR). The BPWD is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2019. There were no action level exceedances.

Table 6.2.8: BPWD Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	90th Percentile	Violation Description
Lead	μg/L	15	ND	None
Copper	mg/L	1.3	0.25	None

ND: Not Detected

Microcystins Monitoring

Table 6.2.9 and figure 6.2.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710011. The BPWD's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a detection limit of 0.15μg/L. Hence, all finished water results were below 0.15μg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3μg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 18μg/L, but this result was much higher than all other raw water results. The second highest result was 8μg/L. Relative to other utilities in this study, the BPWD has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the BPWD continue to monitor raw and treated water for microcystins in future years.

Table 6.2.9: BPWD Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	μg/L	23	0.3	18	< 0.15

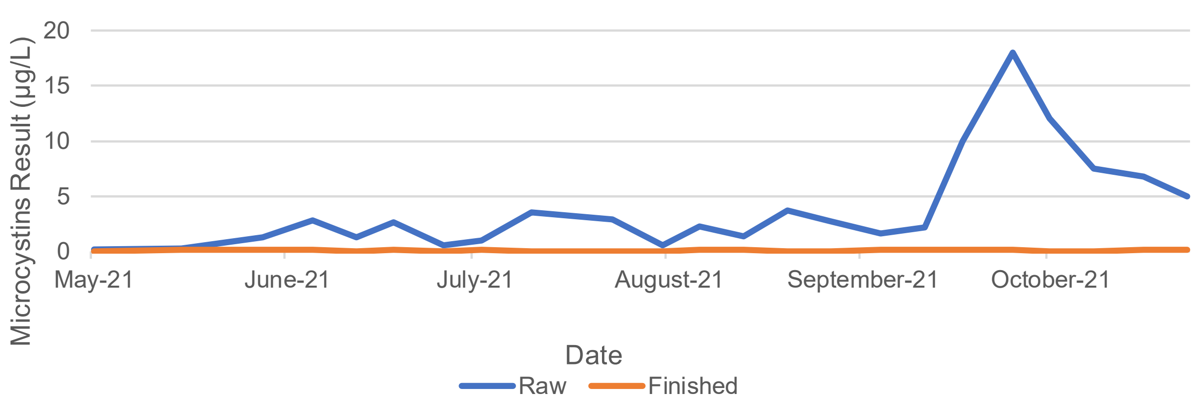


Figure 6.2.4: BPWD Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.2.5 – 6.2.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH, coagulant doses, and disinfection doses from 2017-2021 show that rising pH during Quarter 3 and Quarter 4 are accompanied by higher disinfection doses, though there is no such relationship with coagulant doses. The BPWD is largely shielded from pH swings, which allows them to run a relatively constant coagulant dose throughout the year. The BPWD does not own a charge analyzer, but they periodically check their coagulant dosages with charge analyzers belonging to neighboring water systems. If pH swings reach levels above 9, the BPWD may consider purchasing a charge analyzer and install an acid feed system to mitigate coagulant dosages.

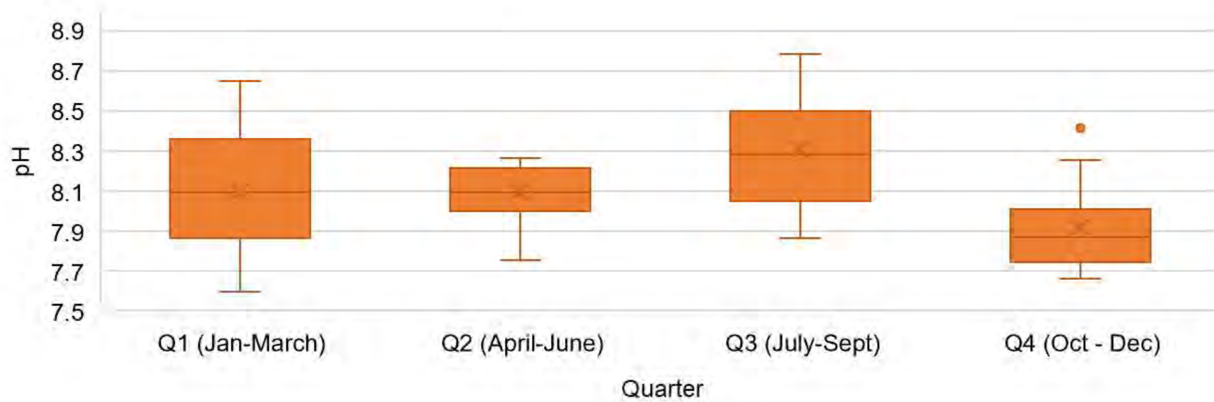


Figure 6.2.5: BPWD Quarterly Aggregate pH (2017-2021)

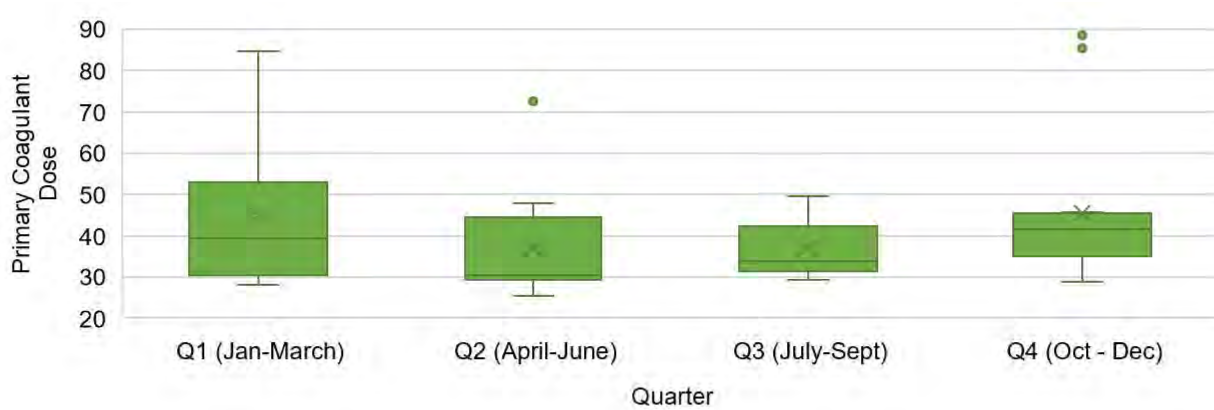


Figure 6.2.6: BPWD Quarterly Aggregate Coagulant Dose (2017-2021)

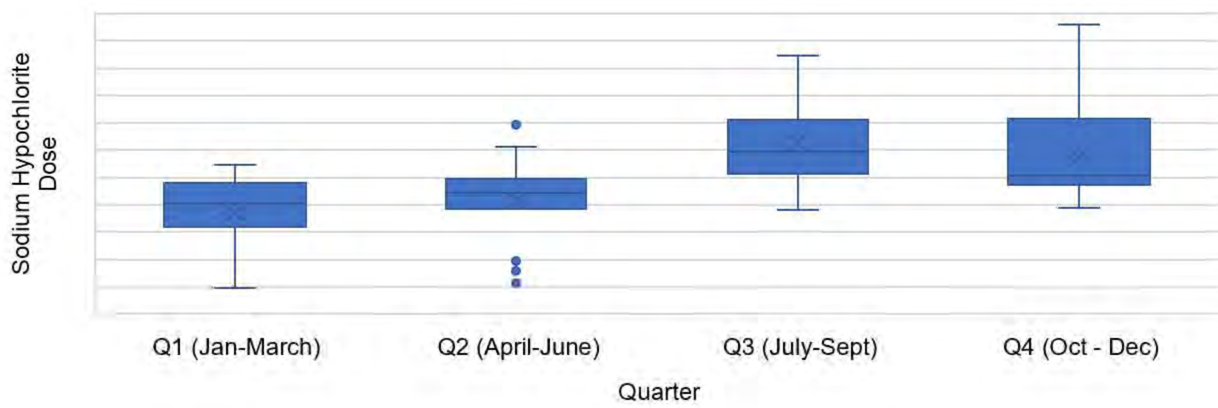


Figure 6.2.7: BPWD Quarterly Aggregate Sodium Hypochlorite Dose (2017-2021)

Ammonia

Figure 6.2.8 shows the available ammonia data provided by the BPWD. Concentrations are cyclical with the highest concentrations in the late fall and winter. Peaks in ammonia are associated with higher chlorine demand.

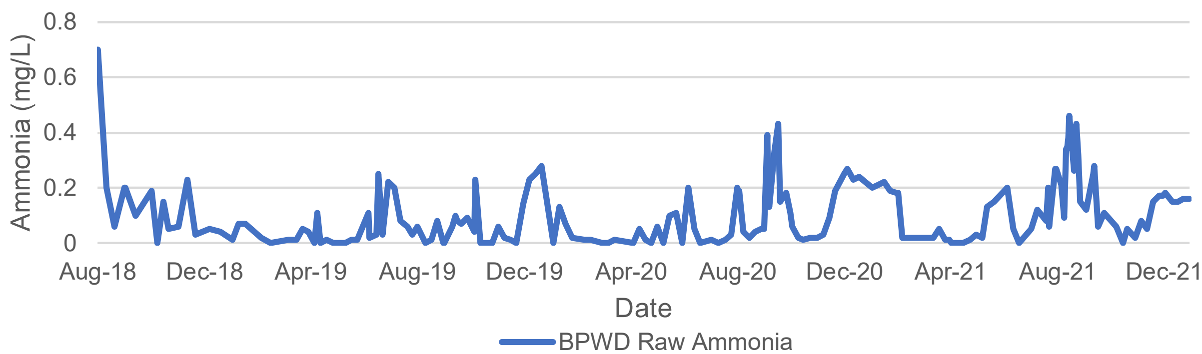


Figure 6.2.8: BPWD Raw Ammonia Concentrations (2018-2021)

6.3- CALIFORNIA WATER SERVICE COMPANY – LUCERNE

6.3.1- Water System Summary

The California Water Service Company – Lucerne System (Cal Water Lucerne) is located on the southeastern side of the Upper Arm (Figure 6.3.1). The intake is located approximately 340 feet offshore and rests approximately twelve feet below the lake surface. No intake extension projects have been necessary as of November 2022. Cal Water Lucerne purchased an emergency-use motorized floating intake that can be used if the intake is at risk of being exposed or if water quality at the intake location is severely degraded. Cal Water Lucerne is a severely disadvantaged community (SDAC). It has a total of 1,245 connections (1,197 residential and 48 commercial) and serves a population of 2,174. The system has two pressure zones, one surface water treatment plant, six storage tanks totaling 820,000 gallons, some of which are equipped with aeration systems for disinfection byproducts reduction, and four booster pump stations. Additional system information is outlined in Table 6.3.1.

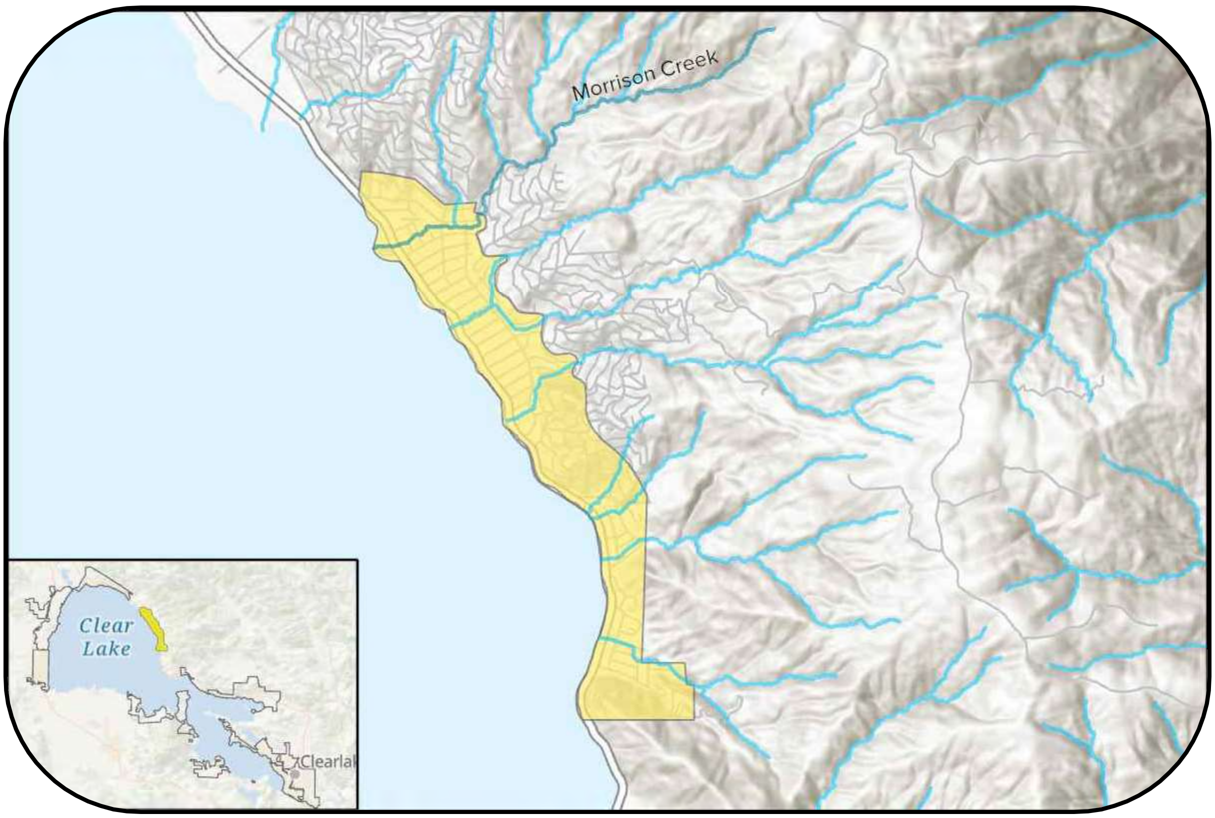


Figure 6.3.1: Cal Water Lucerne System Boundary Map

Table 6.3.1: Cal Water Lucerne System Attributes

System Name	Address	
California Water Service Company – Lucerne System	6125 East Highway 20, Lucerne, CA 95458	
Public Water System No.	**Connection Count**	**Population**
CA1710005	1,245	2,174
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community Water System	Intake/Active	694/1.0
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
10	D2	T4

6.3.2- Treatment, Operations, and Infrastructure Upgrades

Cal Water Lucerne's treatment plant is a conventional water treatment plant consisting of two raw water pumps, one reclaimed backwash pump that can account for up to 10% of the total flow, an up-flow clarifier, two 75-micron Amiad pre-filter master/slave units, two 200-micron Amiad pre-filter master/slave units, two Pall-Aria microfiltration membrane skids each containing twenty-two 0.1-micron membranes, two ultraviolet light reactors, and six granulated activated carbon units. Raw water is pumped to the treatment plant where it is dosed with potassium permanganate for pre-oxidation. A sulfuric acid feed system was added to the intake in 2022. Reclaimed water can be added after pre-oxidation and pH adjustment where the combined flow is dosed with Propac 9800 (primary coagulant) before it enters the flash mixer and up-flow clarifier. After sedimentation, water flows through one of two Amiad pre-filter options that each have a master/slave set up. Operational staff can choose the 75-micron Amiad filters (usually used during winter) or the 200-micron Amiad filters (usually used during summer). The flow then enters one of two Pall-Aria microfiltration membrane skids. Water first passes through the strainers on the skid before it enters the feed tank for the nominal 0.1-micron membranes. Each Pall-Aria membrane skid has a capacity of 350gpm.

After filtration, operational staff can choose one of two ultraviolet light treatment options. The first option is to send the full flow through a twelve-inch pipe containing four 2,100-watt ultraviolet lamps. This option is utilized during the winter when they are not faced with severe taste and odor concerns. The second option, which is considered to be an advanced oxidation process, is usually utilized during the summer months when taste and odor concerns increase. Water is dosed with 25% hydrogen peroxide before water enters into a twenty-four-inch pipe equipped with eight 9,100-watt ultraviolet lamps. After advanced oxidation, water enters into a series of six granulated activated carbon units. The six units run in series with a shared influent and effluent manifold. Water enters the units through the top of the vessels and exits through the bottom. Water is then dosed with zinc orthophosphate (corrosion control) and sodium hypochlorite (polishing disinfectant) before it enters the clearwell to meet contact time requirements. Some distribution storage tanks are equipped with aeration devices to reduce the formation of disinfection byproducts. Figure 6.3.2 shows a process diagram of Cal Water Lucerne's treatment process.

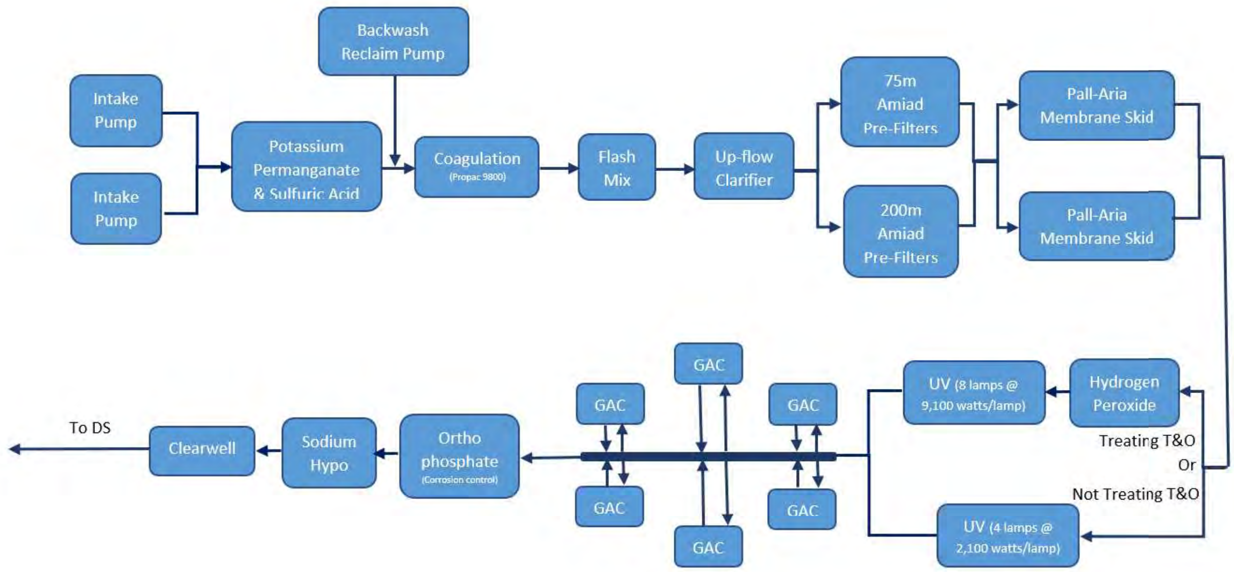


Figure 6.3.2: Cal Water Lucerne Water Treatment Plant Process Diagram

6.3.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

Cal Water Lucerne maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.3.3 shows Cal Water Lucerne's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms, but the highest peaks align with the months when winter storms are prevalent. Cal Water Lucerne's intake is located in the Upper Arm, which receives stormwater runoff via Clear Lake's largest tributary, the Rodman Slough, and via drainage channels that come from the Mendocino National Forest. Turbidity from storm events average around 70 NTU whereas other purveyors with intakes exposed to stormwater sedimentation have spikes up to 200 NTU. Relative to other utilities in this study, Cal Water Lucerne has moderate raw turbidity levels. The highest result was 135 NTU in January 2017.

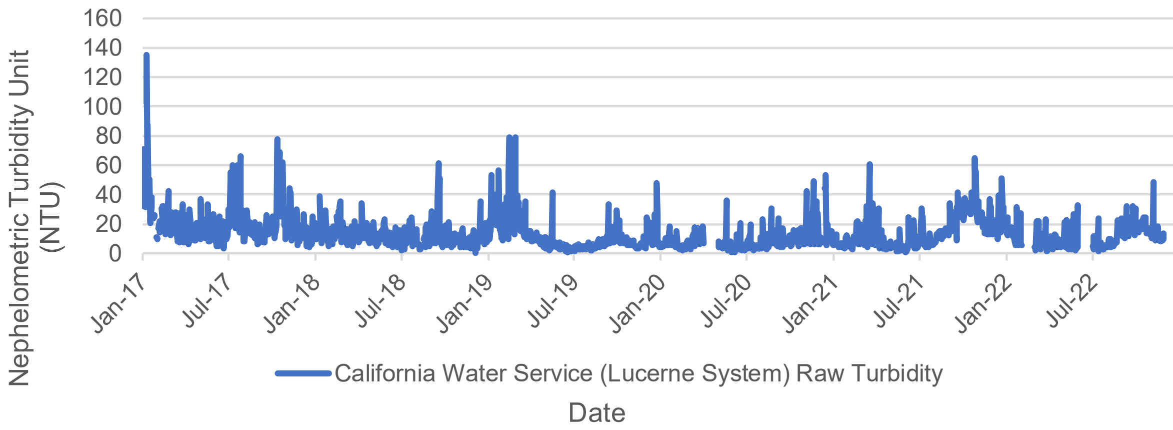


Figure 6.3.3: Cal Water Lucerne Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

Cal Water Lucerne sampled weekly at the intake for total coliform and *E. coli* between 2017-2021. Table 6.3.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 57% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.3.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. Cal Water Lucerne had one positive detection for total coliform in 2019 and another positive detection in 2021. All follow-up sample results were absent. This does not constitute a violation of the California Revised Total Coliform Rule.

Table 6.3.2: Cal Water Lucerne Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	304	2419.6	ND	2419.6
Escherichia coli (*E. coli*)	MPN/100mL	304	686.7	ND	2

ND: Not Detected

Table 6.3.3: Cal Water Lucerne Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	1	0	0
2020	0	0	0
2021	1	0	0

Primary and Secondary Standards

Tables 6.3.4 and 6.3.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.3.4 and 6.3.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). Cal Water Lucerne had no primary or secondary drinking water standard violations between 2017-2021. A finished color sample collected on May 29th, 2020, had a result equal to the SMCL. However, the RAA was below the SMCL in 2020.

Table 6.3.4: Cal Water Lucerne Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 250	ND	None
Fluoride	mg/L	2/--	ND – 0.14	ND – 0.12	None

ND: Not Detected

Table 6.3.5: Cal Water Lucerne Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	200	ND – 250	ND	None
Chloride	mg/L	500	5.1 – 8.3	13 – 16	None
Color	Color Units	15	ND – 100	ND – 15	None
Conductivity	umho/cm	1,600	240 – 350	260 – 370	None
Sulfate	mg/L	500	3.9 – 5.9	3.7 – 6.6	None
Total Dissolved Solids	mg/L	1,000	140 – 200	140 – 200	None
Iron	µg/L	300	ND – 2,600	ND	None
Odor	TON	3	ND – 10	ND – 2.5	None
Manganese	µg/L	50	ND – 1,200	ND – 16	None

ND: Not Detected

Disinfection Byproducts Precursors

Table 6.3.6 summarizes Cal Water Lucerne's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.3.6: Cal Water Lucerne Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	116 – 150	3.4 – 6.2	15% - 25%	48%	None
2018	130 – 170	4.1 – 6.2	25%	44%	None
2019	100 – 160	3.1 – 4.7	15% - 25%	47%	None
2020	130 – 150	3.1 – 4.7	15% - 25%	34%	None
2021	150 – 220	4.0 – 7.0	25%	35%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.3.7 summarizes compliance with the disinfection byproducts rule (DBPR) between 2017-2021. No violations were observed.

Table 6.3.7: Cal Water Lucerne Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	13.3 – 106.1	64.2	None
Total Haloacetic Acids	µg/L	60	6.8 - 72	36.7	None

Lead and Copper Rule (LCR)

Table 6.3.8 summarizes compliance with the Lead and Copper Rule (LCR). Cal Water Lucerne is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2017 and 2020. There were no action level exceedances.

Table 6.3.8: Cal Water Lucerne Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	µg/L	15	2017	ND	None
			2020	ND	None
Copper	mg/L	1.3	2017	ND	None
			2020	0.04	None

ND: Not Detected

Microcystins Monitoring

Table 6.3.9 and figure 6.3.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710005. Cal Water Lucerne's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as non-detect with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 0.79μg/L. Relative to other utilities in this study, Cal Water Lucerne has low microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that Cal Water Lucerne continues to monitor raw and treated water for microcystins in future years.

Table 6.3.9: Cal Water Lucerne Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	μg/L	14	0.3	0.79	ND

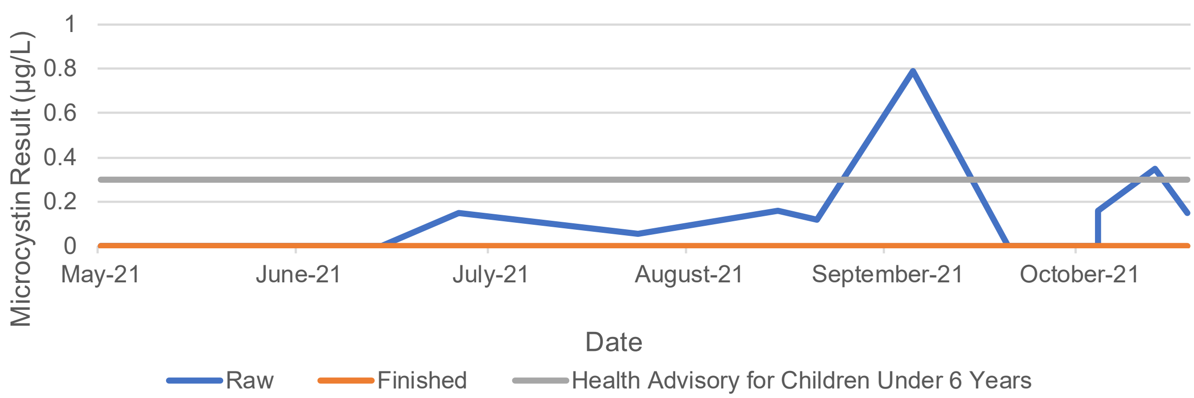


Figure 6.3.4: Cal Water Lucerne Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.3.5 – 6.3.7 show the relationship between pH, coagulation, and disinfection. Most water treatment plants on Clear Lake have a direct relationship between pH, coagulation, and disinfection. As pH rises during quarter 3 and 4, which corresponds to the months when harmful algal blooms are present, coagulation and disinfection dosage demands also increase. In Cal Water Lucerne's case, the raw water pH is almost always higher than the effective range for most primary coagulants, which results in a less clear relationship between pH and primary coagulant. Many of the systems on Clear Lake have neutral raw water pH during the winter and spring and higher pH levels during the summer and fall. However, since Cal Water Lucerne's raw water pH is almost always above 8, the demand for coagulant is nearly constant throughout the year. Quarterly aggregate disinfection dosages show a clearer relationship between pH and disinfection. As pH increases during quarter 3 and 4, disinfection doses also increase. This is primarily due to increased organic loading on the treatment plant, cyanotoxin inactivation, and inorganic materials such as iron and manganese.

Cal Water Lucerne installed a sulfuric acid feed system at the intake in 2022. It is anticipated that the feed system will decrease demand for primary coagulant and disinfectant during bloom events. We recommend that this analysis be updated with new data during the 2026 sanitary survey to compare average chemical demand before and after the installation of the acid feed system. A corresponding chemical cost analysis can also shed light on the long-term savings produced by the acid feed system.

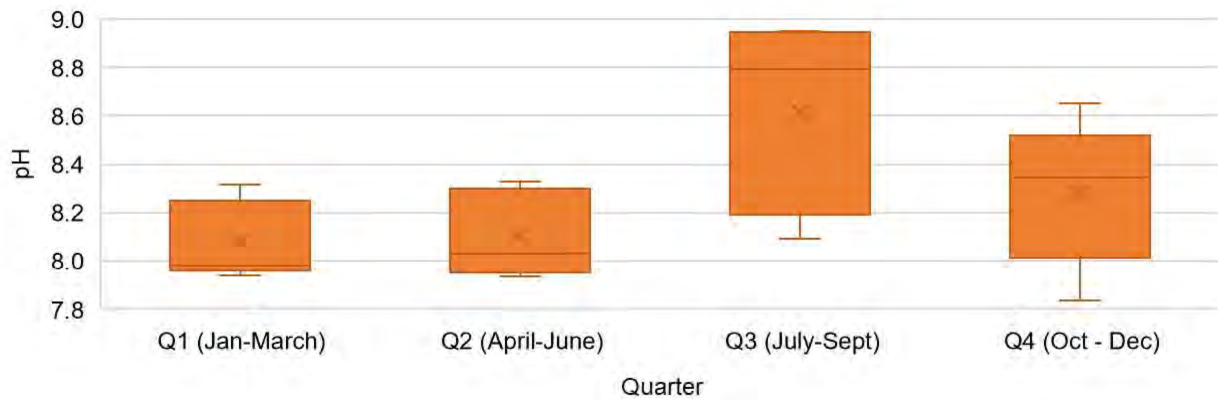


Figure 6.3.5: Cal Water Lucerne Quarterly Aggregate pH (2017-2021)

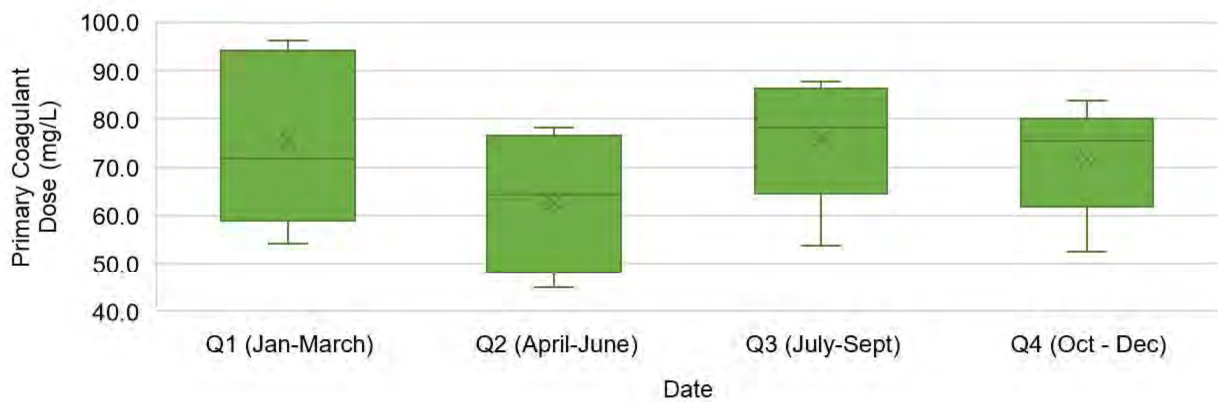


Figure 6.3.6: Cal Water Lucerne Quarterly Aggregate Primary Coagulant (2017-2021)

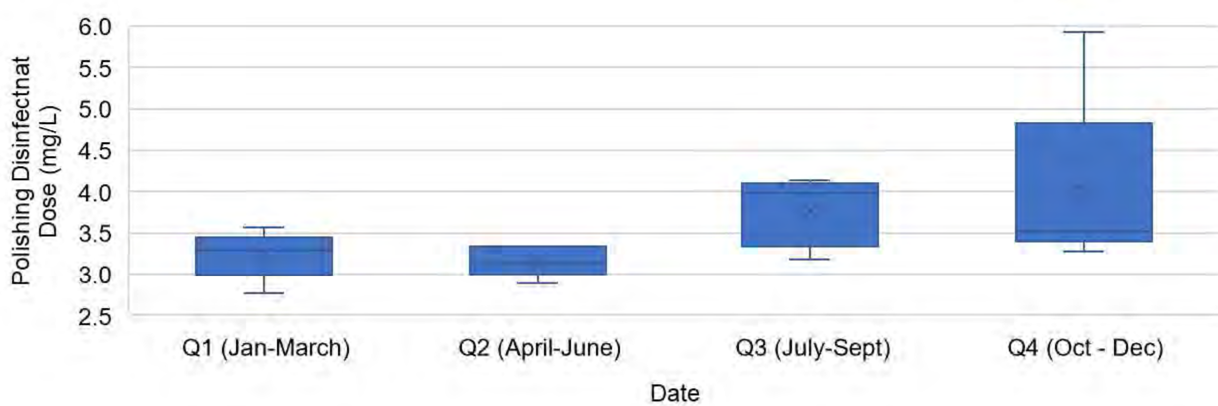


Figure 6.3.7: Cal Water Lucerne Quarterly Aggregate Polishing Disinfectant (2017-2021)

Ammonia

Figure 6.3.8 shows the available ammonia data provided by Cal Water Lucerne. Concentrations were not detected from 2018-2020 but increased slightly in 2021. This is not likely due to changes in water chemistry but rather due to the times and dates of sample events. Samples were collected between May and October during 2018-2020, but monitoring extended into December during 2021. Higher detections are associated with the winter months (November and December). A more comprehensive ammonia monitoring program was initiated in 2022.

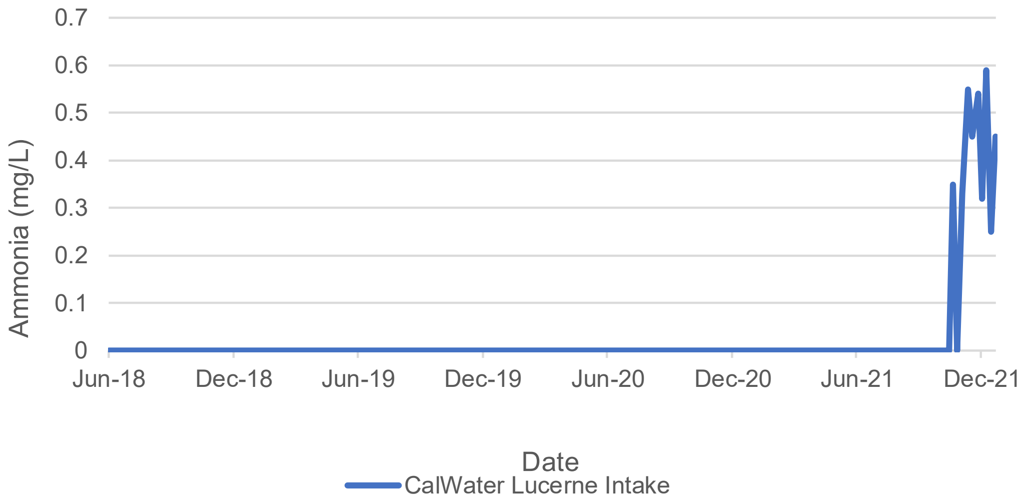


Figure 6.3.8: Cal Water Lucerne Raw Ammonia Concentrations (2018-2021)

6.4- CITY OF LAKEPORT

6.4.1- Water System Summary

The City of Lakeport is the furthest northwestern purveyor located on the Upper Arm of Clear Lake (Figure 6.4.1). The intake is located approximately 2,200 feet offshore. No intake extension projects have been necessary as of November 2022. The surface water treatment plant accounts for less than 20% of the overall supply. Groundwater wells supply most of the water for the City of Lakeport. The City of Lakeport is a severely disadvantaged community (SDAC). It has a total of 2,314 connections (1,818 residential and 496 commercial) and serves a population of 4,762. The system has one pressure zone, one surface water treatment plant, four groundwater wells, and two storage tanks totaling 2.5 million gallons of storage (one million gallon tank and one 1.5 million gallon tank). Additional system information is outlined in Table 6.4.1.

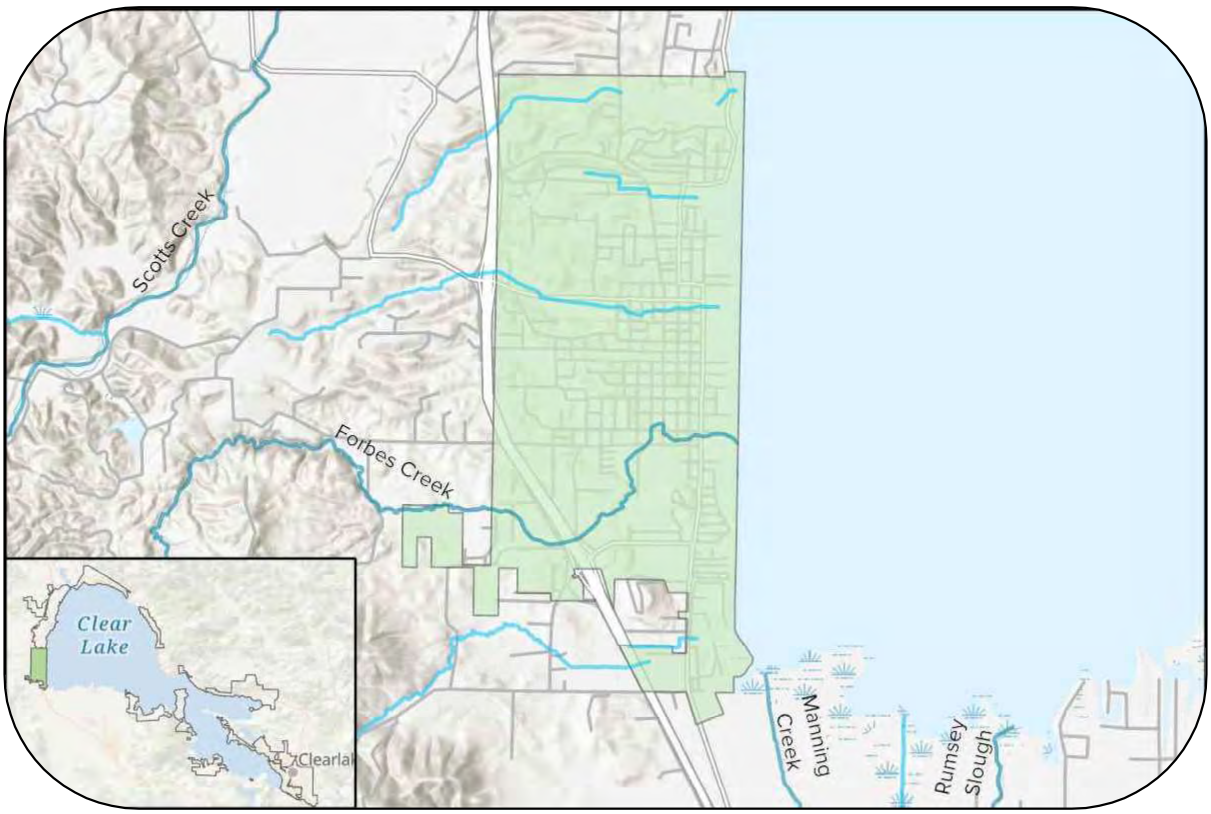


Figure 6.4.1: City of Lakeport System Boundary Map

Table 6.4.1: City of Lakeport System Attributes

System Name	Address	
City of Lakeport	590 Konocti Avenue, Lakeport, CA 95453	
Public Water System No.	**Connection Count**	**Population**
CA1710004	2,314	4,762
System Classification	**Source Type/Status**	**Treatment Plant Capacity, (GPM/MGPD)**
Community Water System	1 Intake/Active, 4 Wells/Active	1500/2.16
Combined Well Capacity, (GPM/MGPD)	**Distribution Classification**	**Treatment Classification**
1,675/2.4	D2	T3

6.4.2- Treatment, Operations, and Infrastructure Upgrades

Unlike all other surface water purveyors that draw from Clear Lake, the City of Lakeport is the only purveyor that has groundwater supplies. The city uses groundwater for most of the year. The decision to use the surface water treatment plant is based on lake conditions. Operational staff are able to avoid harmful algal blooms and the storm season.

The surface water treatment plant is classified as an alternative technology treatment plant. The City of Lakeport's treatment plant does not have the typical conventional sequence of coagulation, flocculation, sedimentation, and filtration. Rather, it utilizes two ozone chambers that replace flocculation and sedimentation. Two intake pumps that each have a capacity of 900 gpm (but have a maximum combined capacity of 1,400gpm), pump raw water into a wet well. From there it enters a pre-ozone contact chamber where it is dosed with ozone gas. Coagulation and filter aid chemicals are then added (Propac 9890 and Clarifloc C-309-P, respectively) and is flash mixed via a static mixer. The flow is then split into two parallel trains with adsorption clarifiers and mixed media filters that contain anthracite coal, sand, garnet sand, and silica gravel. After filtration, the flow is combined, and water enters the post-ozone chamber where it is dosed with ozone gas again. After the final ozonation step, the flow is split and fed through two parallel trains, each consisting of two granulated activated carbon units. Flow is combined and dosed with gas chlorine before it enters the clearwell to meet contact time requirements. Figure 6.4.2 shows a process diagram of the City of Lakeport's treatment process. The schematic does not include backwash and backwash recycling lines. The ozonation process precipitates metals that must be filtered out of solution. Each ozone chamber is followed by filtration, which optimizes the system for suspended solids.

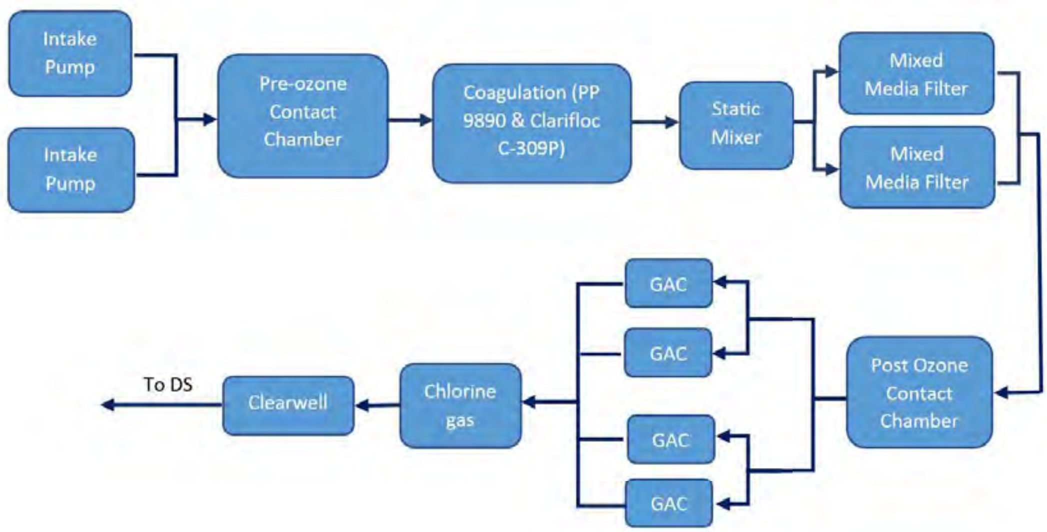


Figure 6.4.2: City of Lakeport Water Treatment Plant Process Diagram (backwash lines excluded)

6.4.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The City of Lakeport maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.4.3 shows the City of Lakeport's raw daily turbidity data from 2017-2021. Since turbidity readings are only taken when the surface water plant is running, limited data is available. There are no discernable trends in the data. The surface water treatment plant is turned on when lake conditions are good (i.e when turbidity is low) and is turned off when there are peaks in turbidity. The highest turbidity result is 30.1 NTU, which is low relative to other purveyors in the Upper Arm. This is likely because operational staff can turn off the treatment plant when turbidity rises.

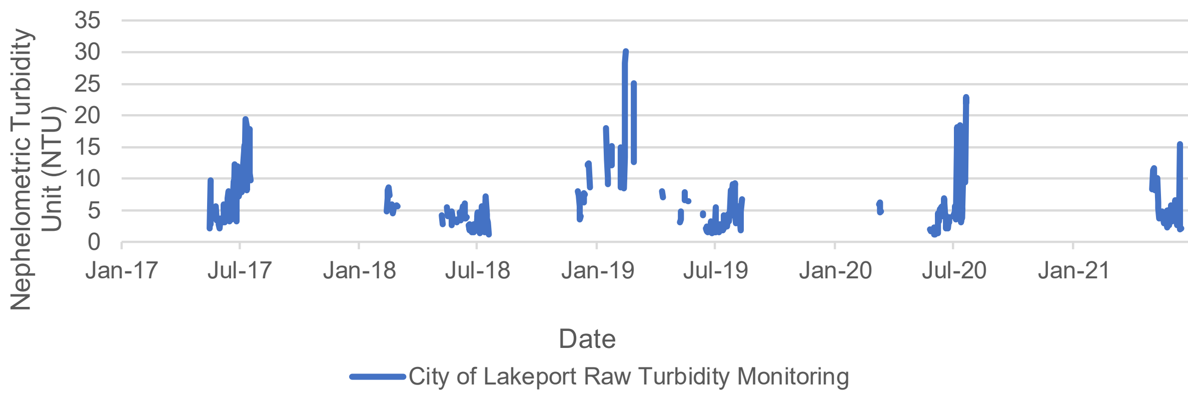


Figure 6.4.3: City of Lakeport Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The City of Lakeport sampled monthly at the intake for total coliform and *E. coli* when the treatment plant was online. Table 6.4.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 52% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.4.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. Total coliform or *E. coli* was not detected in the distribution system between 2017-2021, which indicates that the City of Lakeport provides adequate treatment and disinfection for bacteriological quality.

Table 6.4.2: City of Lakeport Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	23	2,419.6	34.8	2,419.6
Escherichia coli (*E. coli*)	MPN/100mL	23	29.5	ND	ND

ND: Not Detected

Table 6.4.3: City of Lakeport Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.4.4 - 6.4.7 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. Tables 6.4.4 and 6.4.5 show the surface water results while tables 6.4.6 and 6.4.7 shows groundwater results. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The City of Lakeport's groundwater wells undergo disinfection but no other treatment mechanism, therefore, compliance for the groundwater wells is based on raw water results. Surface water results may have raw water detections above the MCL/SMCL, however, compliance is based on results taken from finished water, if available.

The City of Lakeport's groundwater wells had no primary or secondary drinking water standard violations between 2017-2021. The City of Lakeport's surface water supplies had no primary drinking water standard violations between 2017-2021. However, the SMCL for aluminum was exceeded during quarter 2 2019, and the SMCL for iron was exceeded during quarter 2 2019 and quarter 2 2021. Additionally, the SMCL for manganese was regularly exceeded throughout the monitoring period. We recommend that the City of Lakeport collect aluminum, iron, and manganese samples at the treatment plant effluent to determine if levels are reduced during treatment. If raw results continue to exceed the SMCL, the City of Lakeport must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

The treatment plant effluent regularly exceeded the SMCL for odor. We recommend that the City of Lakeport monitor quarterly for odor at the intake and treatment plant effluent per 22 CCR § 64449 (c). We also recommend that the City of Lakeport determine if the granulated activated carbon units require a media change-out.

Table 6.4.4: City of Lakeport Primary Standards Monitoring at the Wells (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Violation Description
Fluoride	mg/L	2/--	0.1 – 0.12	None
Nitrite	mg/L	10/--	ND – 0.26	None
Gross Alpha Particle Activity	pCi/L	15/--	0.83	None

ND: Not Detected

Table 6.4.5: City of Lakeport Secondary Standards Monitoring at the Wells (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Violation Description
Chloride	mg/L	500	3.1 – 4.2	None
Conductivity	umho/cm	1,600	210 – 230	None
Sulfate	mg/L	500	6.9 – 9.8	None
Total Dissolved Solids	mg/L	1,000	120 – 160	None

Table 6.4.6: City of Lakeport Primary Standards Monitoring at the Intake (2017-2021)

Analyte	Units	MCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 430	NA	None
Arsenic	µg/L	10/--	ND – 5.6	NA	None
Fluoride	mg/L	2/--	ND – 0.14	NA	None
Gross Alpha Particle Activity	pCi/L	15/--	0.827	0.737	None

ND: Not Detected NA: Not Available

Table 6.4.7: City of Lakeport Secondary Standards Monitoring at the Intake (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	200	ND – 430	NA	The SMCL was exceeded during Q2 2019
Chloride	mg/L	500	5.5 – 8.8	NA	None
Conductivity	umho/cm	1,600	260 - 360	NA	None
Sulfate	mg/L	500	3.8 – 6.9	NA	None
Total Dissolved Solids	mg/L	1,000	150 - 260	NA	None
Copper	µg/L	1,000	ND – 51	NA	None
Iron	µg/L	300	ND - 750	NA	The SMCL was exceeded during Q2 2019 & Q2 2021
Odor	TON	3	7.4 – 28	ND – 63	The SMCL was regularly exceeded during the study period
Manganese	µg/L	50	55 – 410	NA	The SMCL was regularly exceeded during the study period

ND: Not Detected NA: Not Available

Disinfection Byproducts Precursors

Total organic carbon (TOC) removal requirements do not apply to City of Lakeport because the water treatment plant utilizes an alternative treatment process.

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.4.8 summarizes compliance with the disinfection byproducts rule (DBPR). No violations were observed.

Table 6.4.8: City of Lakeport Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	ND – 51.6	26.6	None
Total Haloacetic Acids	µg/L	60	ND – 21.3	8.7	None

Lead and Copper Rule (LCR)

Table 6.4.9 summarizes compliance with the Lead and Copper Rule (LCR). The City of Lakeport is required to monitor for lead and copper every three years. Monitoring during 2017-2021 took place in 2018 and 2021. There were no action level exceedances.

Table 6.4.9: City of Lakeport Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	μg/L	15	2018	ND	None
			2021	ND	None
Copper	mg/L	1.3	2018	0.13	None
			2021	0.21	None

ND: Not Detected

Microcystins Monitoring

Microcystins monitoring was required under Order No. 02_03_21M_001_ CA1710004, however, the City of Lakeport did not utilize their treatment plant for most of the monitoring period outlined in the order. The City of Lakeport collected raw and treated microcystin samples twice throughout the required monitoring frequency. All results were less than 0.15μg/L.

pH, Disinfection & Coagulation

Because the City of Lakeport does not continuously use the water treatment plant throughout the year, dosage trends with harmful algal blooms cannot be determined.

Ammonia

The City of Lakeport does not currently monitor for ammonia. Monitoring for ammonia in the future may help the City of Lakeport better manage chlorine dosages and chloramine formation at the surface water treatment plant.

6.5- CLEARLAKE OAKS COUNTY WATER DISTRICT

6.5.1- Water System Summary

The Clearlake Oaks County Water District (CLOCWD) is located on the Oaks Arm of Clear Lake (Figure 6.5.1). The CLOCWD is a severely disadvantaged community (SDAC). It has a total of 2,212 connections, many of which are vacant lots, and serves a population of 2,359. The system has five pressure zones due to the varied topography of the area. It has one surface water treatment plant, six storage tanks, and four booster pump stations. Additional system information is outlined in Table 6.5.1.

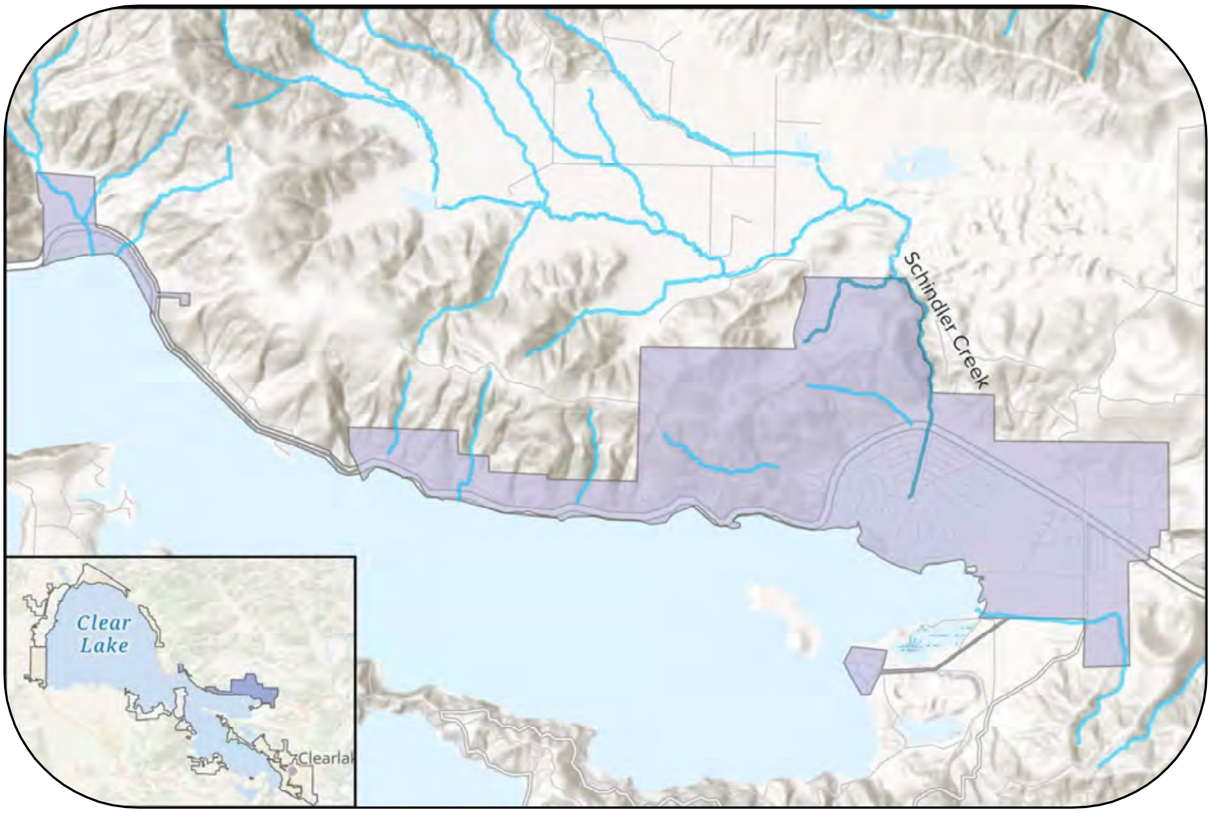


Figure 6.5.1: CLOCWD System Boundary Map

Table 6.5.1: CLOCWD System Attributes

System Name	Address	
Clearlake Oaks County Water District	12952 E. Highway 20, Clearlake Oaks, CA 95423	
Public Water System No.	**Connection Count**	**Population**
CA1710001	2,212	2,359
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community	Intake/Active	850/1.22
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
25/50	D3	T3

6.5.2- Treatment, Operations, and Infrastructure Upgrades

The CLOCWD treatment plant is a conventional water treatment plant consisting of three raw water pumps (two 25hp pumps and one 50 hp emergency pump), two ozone towers, two up-flow clarifiers, three multimedia pressure filters, two granulated activated carbon filters, and a clearwell. Raw water is pumped through one of three intake pumps into an ozone chamber for pre-oxidation if needed. Although the CLOCWD has two ozone towers, their air compressor is not large enough to run both chambers, so they operate using one chamber. After ozonation, water is dosed with Propac 9800 for coagulation. Propac9890 (filter aid) and sodium hypochlorite (pre-oxidant) are used seasonally during the summer and late fall. Water then enters into one of two up-flow clarifiers rated at 425gpm each. Flocculation occurs in the mixing cone and sedimentation causes floc to sink and settled water to flow upwards towards the weirs. Water then enters one of three mixed media filters that contain gravel, sand and anthracite coal. Either one large filter (1,100 gpm) can run independently or else two smaller filters (540gpm) run in parallel. Water then enters two granulated activated carbon units that run in parallel. Finally, water is dosed with sodium hypochlorite for disinfection and effluent water enters into a clearwell. The plant has the ability to dose zinc orthophosphate for corrosion control, but it is not currently in use due to high effluent pH. Figure 6.5.2 shows a process diagram of the CLOCWD's treatment process.

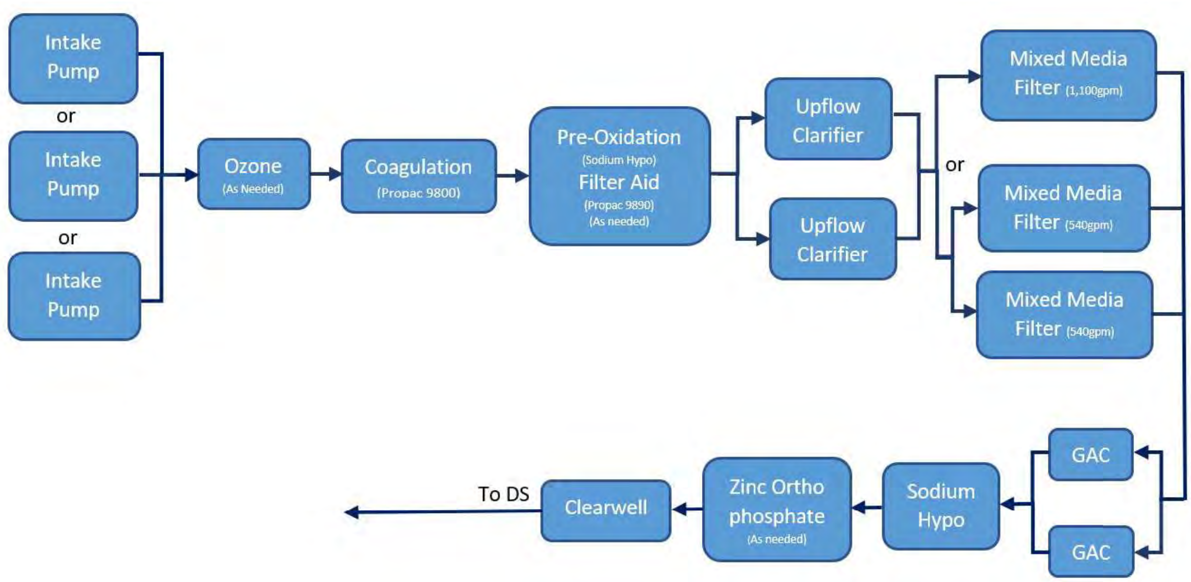


Figure 6.5.2: CLOCWD Water Treatment Plant Process Diagram

6.5.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The CLOCWD maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.5.3 shows the CLOCWD's raw daily turbidity data from 2018-2021. Data from 2017 was not submitted for review. Seasonal peaks correspond to both storm events and harmful algal blooms, but the highest peaks align with the months when harmful algal blooms are present. Relative to other utilities in this study, the CLOCWD has moderate raw turbidity levels. The highest peaks took place between June and October, which are the months when harmful algal blooms are most severe in Clear Lake. The highest result was 85.9 NTU in June 2020.

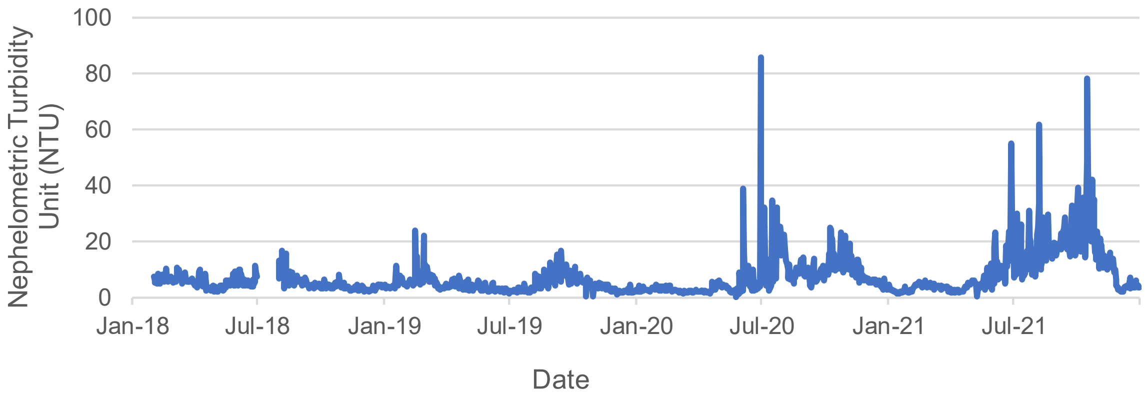


Figure 6.5.3: CLOCWD Raw Daily Turbidity (2018-2021)

Bacteriological Water Quality & The Total Coliform Rule

The CLOCWD sampled at least monthly at the intake for total coliform and *E. coli*, but water quality data could not be obtained from the system. Table 6.5.2 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2018-2021, which indicates that the CLOCWD provides adequate treatment and disinfection for bacteriological quality. Data from 2017 was unable to be recovered.

Table 6.5.2: CLOCWD Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.5.3 and 6.5.4 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.5.3 and 6.5.4 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The CLOCWD had no primary drinking water standard violations between 2017-2021. However, the finished water RAA regularly exceeded the SMCL for odor throughout the study period. We recommend that the CLOCWD continue to monitor their finished water for odor and investigate the possibility of replacing the granulated activated carbon media.

Table 6.5.3: CLOCWD Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	50 – 110	ND – 99	None
Arsenic	µg/L	10/--	ND – 5.8	ND – 2.6	None
Fluoride	mg/L	2/--	ND – 0.15	ND – 0.1	None

ND: Not Detected

Table 6.5.4: CLOCWD Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	6	14 – 21	None
Color	Color Units	15	10 – 18	ND – 7	None
Conductivity	umho/cm	1,600	260 – 310	300 – 400	None
Sulfate	mg/L	500	6.1	3.1 – 5.7	None
Total Dissolved Solids	mg/L	1,000	150	170 – 260	None
Iron	µg/L	300	130 – 150	ND	None
Odor	TON	3	ND – 3.4	ND – 34	The finished water LRAA regularly exceeded the SMCL throughout the study period
Manganese	µg/L	50	ND – 25	ND	None

ND: Not Detected

Disinfection Byproducts Precursors

Table 6.5.5 summarizes the CLOCWD's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.5.5: CLOCWD Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	120 – 160	4.3 – 9.9	25% - 35%	51%	None
2018	140 – 170	4.2 – 6.2	25%	55%	None
2019	110 – 160	2.5 – 5.0	15% - 35%	30%	None
2020	140 – 180	3.6 – 6.5	15% - 25%	49%	None
2021	170 – 200	3.0 – 7.4	15% - 25%	44%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.5.6 summarizes compliance with the disinfection byproducts rule (DBPR). Under the direction of the Division of Drinking Water, the CLOCWD changed the location of a Stage 2 disinfection byproducts sampling site in 2019. The sample collected at the new location in 2019 had a total trihalomethane result of 153.8μg/L, resulting in an LRAA exceedance of the total trihalomethanes MCL in 2019. In 2020, the CLOCWD collected two disinfection byproducts samples at this location which resulted in a LRAA of 107.3μg/L, which again exceeded the MCL for total trihalomethanes. Operational staff determined the cause of high total trihalomethane concentrations to be from a broken aerator in a nearby tank. The aerator was fixed in 2020 and subsequent monitoring shows results that are below the MCL for total trihalomethanes.

Table 6.5.6: CLOCWD Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	μg/L	80	23 – 153.8	153.8	The LRAA was exceeded during 2019 and 2020.
Total Haloacetic Acids	μg/L	60	9.3 – 53.6	27.6	None

Lead and Copper Rule (LCR)

Table 6.5.7 summarizes compliance with the Lead and Copper Rule (LCR). The CLOCWD was switched from triennial monitoring to annual monitoring in 2017. It is unclear why the CLOCWD's sampling frequency was initially changed because results did not show an action level exceedance and the required number of samples were collected at the required frequency in 2017. The CLOCWD collected annual LCR samples in 2018 but failed to collect annual LCR samples in 2019. For this reason, the CLOCWD was switched to a biannual monitoring frequency. Monitoring during 2017-2021 took place in 2017, 2018, and 2020. There were no action level exceedances.

Table 6.5.7: CLOCWD Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	µg/L	15	2017	ND	None
			2018	ND	None
			2019	--	Annual monitoring not conducted in 2019
			2020	ND	None
			2020	ND	None
Copper	mg/L	1.3	2017	0.29	None
			2018	0.36	None
			2019	--	Annual monitoring not conducted in 2019
			2020	0.79	None
			2020	0.40	None

ND: Not Detected

Microcystins Monitoring

Table 6.5.8 and figure 6.5.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710001. The CLOCWD's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 560µg/L. This result is substantially higher than other results seen during the monitoring period and aligns with the severe lake conditions that were experienced during 2021. Relative to other utilities in this study, the CLOCWD has high microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the CLOCWD continues to monitor raw and treated water for microcystins in future years.

Table 6.5.8: CLOCWD Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	24	0.3	560	< 0.15

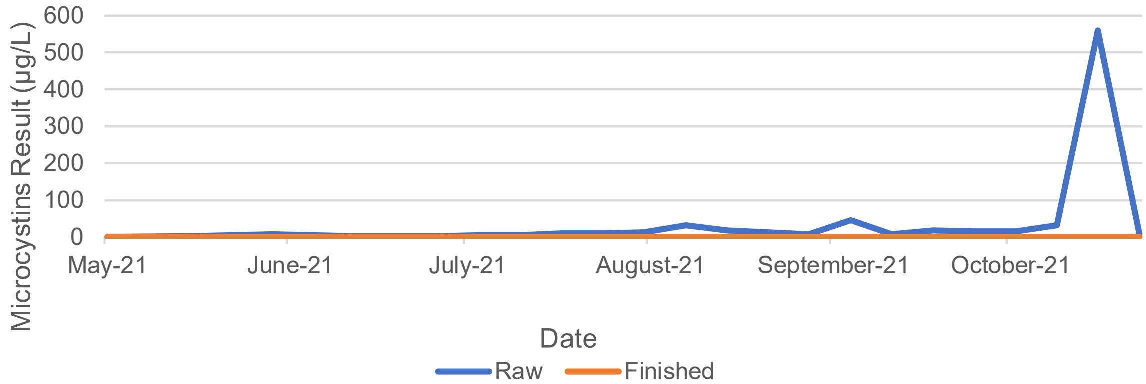


Figure 6.5.4: CLOCWD Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

The CLOCWD does not regularly track coagulant and disinfection dosages, therefore, a relationship between harmful algal blooms and chemical additives cannot be determined.

Ammonia

The CLOCWD does not regularly monitor for ammonia. When chlorine residuals drop at the treatment plant effluent, they take ammonia samples to determine if the decrease is from increased ammonia levels. This data is collected infrequently and used primarily for troubleshooting. Monitoring regularly for ammonia in the future may help the CLOCWD better manage chlorine dosages and chloramine formation.

6.6- CLEARWATER MUTUAL WATER COMPANY

6.6.1- Water System Summary

The Clear Water Mutual Water Company (CWMWC) is located on the southwestern side of Clear Lake's Lower Arm (Figure 6.6.1). The CWMWC is a disadvantaged community (DAC) with 89 connections (88 residential and 1 commercial) and a population of 252. The system has one pressure zone, one surface water treatment plant, two storage tanks (an additional storage tank is under construction as of January 2023), and one booster pump station. Additional system information is outlined in Table 6.6.1.

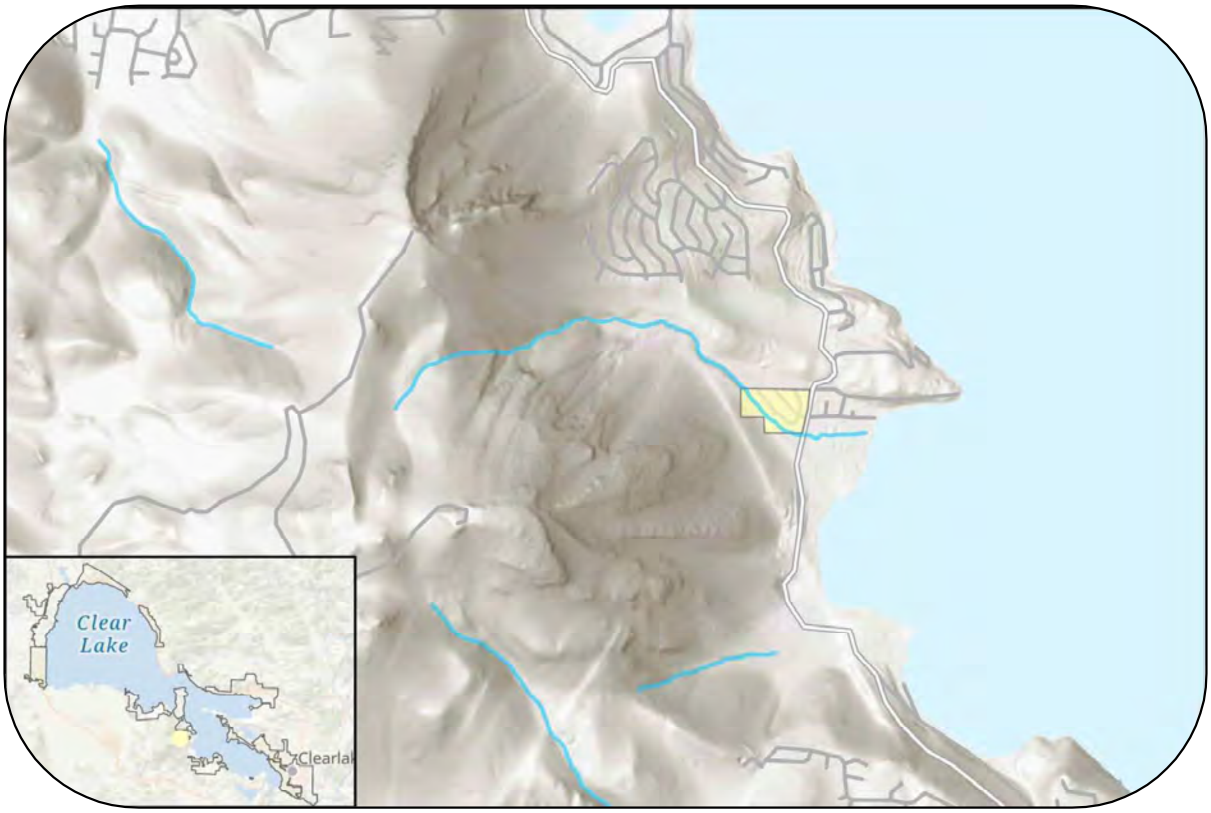


Figure 6.6.1: CWMWC System Boundary Map

Table 6.6.1: CWMWC System Attributes

System Name	Address	
Clear Water Mutual Water Company	4151 Osceola Avenue, Kelseyville, CA 95451	
Public Water System No.	**Connection Count**	**Population**
CA1700546	89	252
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community Water System	Intake/Active	50/0.072
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
5/7.5	D1	T3

6.6.2- Treatment, Operations, and Infrastructure Upgrades

The CWMWC treatment plant is a conventional water treatment plant consisting of two raw water pumps, an up-flow clarifier, a surge tank, two tri-media filters, and a granulated activated carbon (GAC) filter. Raw water is pumped through one of two raw water pumps located approximately 240 feet offshore. Raw water is dosed with sodium hypochlorite as a pre-oxidant and Propac 9800 as primary coagulant before it enters into the flash mixer. Water then enters into the up-flow clarifier where flocculation and sedimentation occur. The settled water enters into the surge tank before it enters into one of two tri-media filters that run in parallel. The tri-media filters are composed of garnet, sand, and anthracite. After filtration, flow is combined and enters into a GAC filter to mitigate taste, color, and odor in finished water. Effluent water is then dosed with sodium hypochlorite and pumped to the clearwell where adequate contact time is achieved. Figure 6.6.2 shows a process diagram of the CWMWC's treatment process.

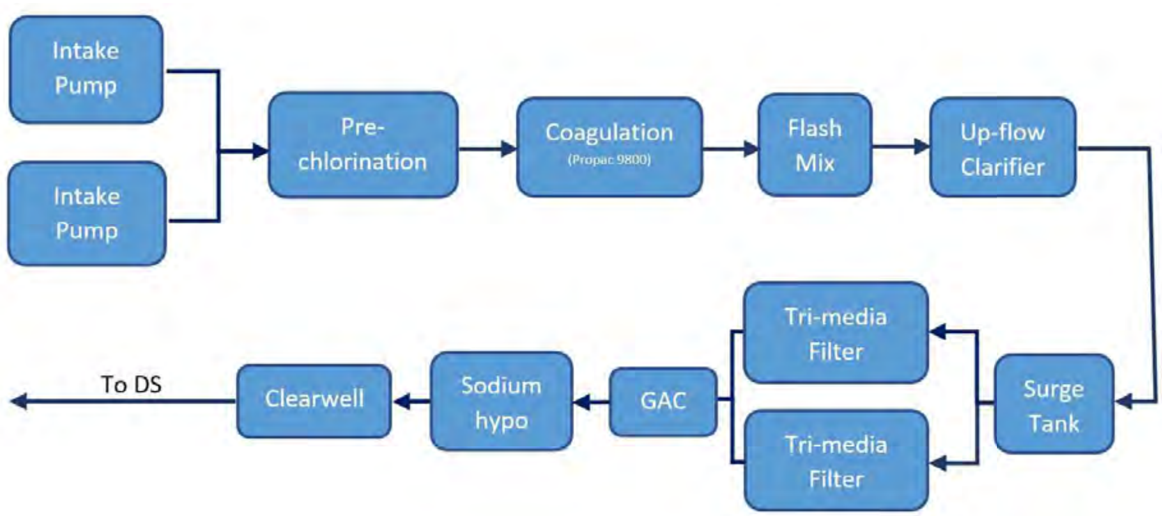


Figure 6.6.2: CWMWC Water Treatment Plant Process Diagram

6.6.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The CWMWC maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.6.3 shows the CWMWC's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms. The CWMWC's intake is located in a cove that is largely shielded from sedimentation associated with storm events. Turbidity from storm events averages around 8 NTU whereas other purveyors with intakes that are more exposed to sedimentation have regular spikes up to 200 NTU. Relative to other utilities in this study, the CWMWC has low raw turbidity levels. The highest result was 16.2 NTU in November 2021. Although the intake is in the Lower Arm, which is known to undergo severe blooms, the cove has relatively mild water quality. This phenomenon is partially due to the wind shadow provided by Mt. Konocti and the lack of sediment flow into the area.

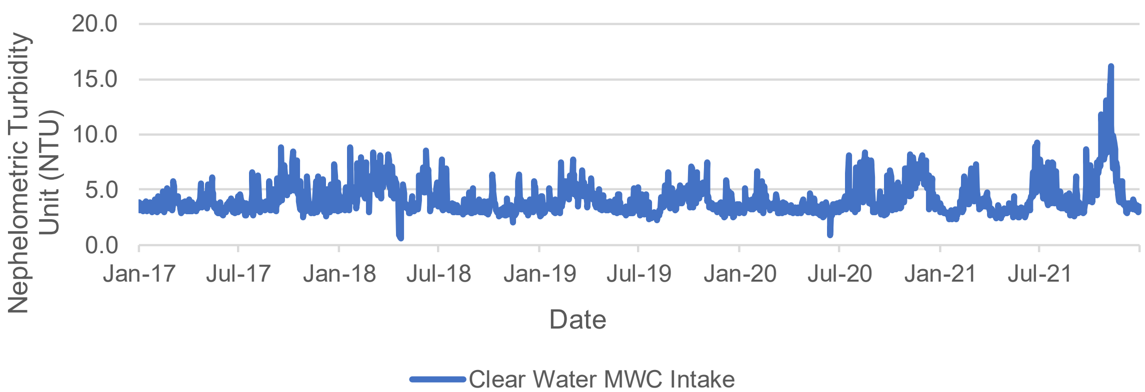


Figure 6.6.3: CWMWC Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The CWMWC sampled at least monthly at the intake for total coliform and *E. coli*. 2018 was sampled bi-weekly. Table 6.6.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 24% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.6.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the CWMWC provides adequate treatment and disinfection for bacteriological quality.

Table 6.6.2: CWMWC Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	71	2419.6	ND	547.5
Escherichia coli (*E. coli*)	MPN/100mL	71	37.3	ND	ND

ND: Not Detected

Table 6.6.3: CWMWC Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.6.4 and 6.6.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.6.4 and 6.6.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA).

The CWMWC had no primary drinking water standard violations between 2017-2021. However, the finished water RAA regularly exceeded the SMCL for odor throughout the study period. Since the last GAC media changeout took place roughly seven years ago and because odor continues to be a concern in finished water, we recommend that the CWMWC replace the GAC media. We also recommend that the CWMWC determine the feasibility of adding another GAC unit for redundancy, ease of maintenance, and added protection against odor and color concerns.

The Drinking Water Branch database indicates that two samples (color and odor) were taken from finished water on September 19th, 2017, both with identical abnormally high results (50 TON and 50units, respectively). The chief operator confirmed that finished water monitoring for secondary parameters did not commence until 2018. Therefore, the two erroneous results were omitted from this analysis.

Table 6.6.4: CWMWC Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 72	ND	None
Arsenic	µg/L	10/--	2.1 – 4.1	NA	None
Barium	µg/L	1,000/--	ND – 160	NA	None
Fluoride	mg/L	2/--	ND – 0.34	NA	None

ND: Not Detected NA: Not Available

Table 6.6.5: CWMWC Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	6.1	13 – 19	None
Color	Color Units	15	10 – 25	ND – 5	None
Conductivity	umho/cm	1,600	290	310 – 390	None
Sulfate	mg/L	500	3.9	4.1 – 5.6	None
Total Dissolved Solids	mg/L	1,000	180	180 – 220	None
Foaming Agents (MBAS)	mg/L	0.5	0.07	ND	None
Iron	µg/L	300	ND	ND – 110	None
Odor	TON	3	1.4 – 70	1 – 24	RAA for finished water regularly exceeded the SMCL throughout the study period
Manganese	µg/L	50	27	ND	None

ND: Not Detected

Disinfection Byproducts Precursors

Total organic carbon (TOC) removal requirements do not currently apply to the CWMWC due to a waiver from the California Department of Public Health.

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.6.6 summarizes compliance with the disinfection byproducts rule (DBPR). The CWMWC is required to monitor disinfection byproducts (DBPs) annually at one location. No violations were observed. The CWMWC met but did not exceed the MCL for total trihalomethanes in 2021. If the MCL for total trihalomethanes or total haloacetic acids is exceeded in subsequent years, the CWMWC must monitor quarterly and base compliance on the locational running annual average (LRAA) per 22 CCR § 64534.2.

Table 6.6.6: CWMWC Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest Result	Violation Description
Total Trihalomethanes	µg/L	80	41 – 80	80	None
Total Haloacetic Acids	µg/L	60	10 – 25	25	None

Lead and Copper Rule (LCR)

Table 6.6.7 summarizes compliance with the Lead and Copper Rule (LCR). The CWMWC is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2019. There were no action level exceedances.

Table 6.6.7: CWMWC Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	90th Percentile	Violation Description
Lead	µg/L	15	ND	None
Copper	mg/L	1.3	0.242	None

ND: Not Detected

Microcystins Monitoring

Table 6.6.8 and figure 6.6.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1700546. The CWMWC's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was 0.16µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion. The highest concentration of microcystins was 21µg/L. Relative to other utilities in this study, the CWMWC has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the CWMWC continue to monitor raw and treated water for microcystins in future years.

Table 6.6.8: CWMWC Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	25	0.3	21	0.16

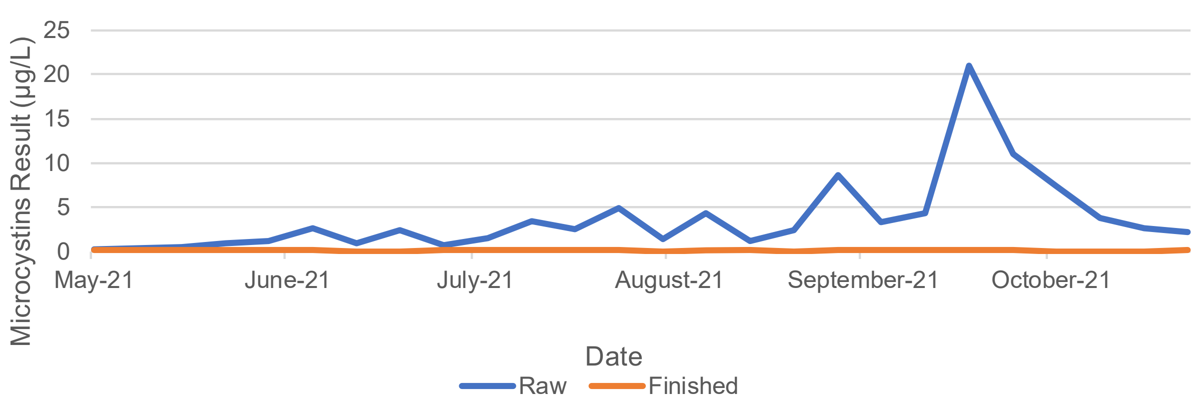


Figure 6.6.4: CWMWC Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

The CWMWC does not regularly track raw water pH, therefore, a relationship between harmful algal blooms and chemical additives cannot be determined.

Ammonia

The CWMWC does not regularly monitor for ammonia. Monitoring for ammonia in the future may help the CWMWC better manage chlorine dosages and chloramine formation.

6.7- CRESCENT BAY IMPROVEMENT COMPANY

6.7.1- Water System Summary

The Crescent Bay Improvement Company (CBIC) is located on the southeastern side of Clear Lake's Lower Arm (Figure 6.7.1). As of 2022, the CBIC is not classified as a disadvantaged community (DAC). It has a total of 24 connections (24 residential and 0 commercial) and serves a year-round population of 18, which can swell to 72 during peak summer and weekends. The system has one pressure zone, one surface water treatment plant, three clearwells totaling 20,000 gallons and 10,000 gallons of additional storage. Additional system information is outlined in Table 6.7.1.

Figure 6.7.1: CBIC System Boundary Map

Table 6.7.1: CBIC System Attributes

System Name	Address	
Crescent Bay Improvement Company	12890 Anderson Road, Lower Lake, CA 95457	
Public Water System No.	**Connection Count**	**Population**
CA1700519	24	30
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community Water System	Intake/Active	20/0.028
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
3	D1	T2

6.7.2- Treatment, Operations, and Infrastructure Upgrades

The CBIC treatment plant consists of two raw water pumps, two Yardney sand filters that run in series, one sand and gravel media filter, and two diatomaceous earth (DE) filters that run in parallel. Raw water is pumped through a 3-horsepower intake pump to the series of two Yardney sand filters. Water may be dosed with low doses of coagulant prior to the filters, but coagulant is not used consistently. Water then enters into the media filter before it enters the DE filters, receiving coagulant on its way to the DE filters. Effluent water is then dosed with sodium hypochlorite before it is pumped to the clearwell where adequate contact time is achieved. Figure 6.7.2 shows a process diagram of the CBIC's treatment process.

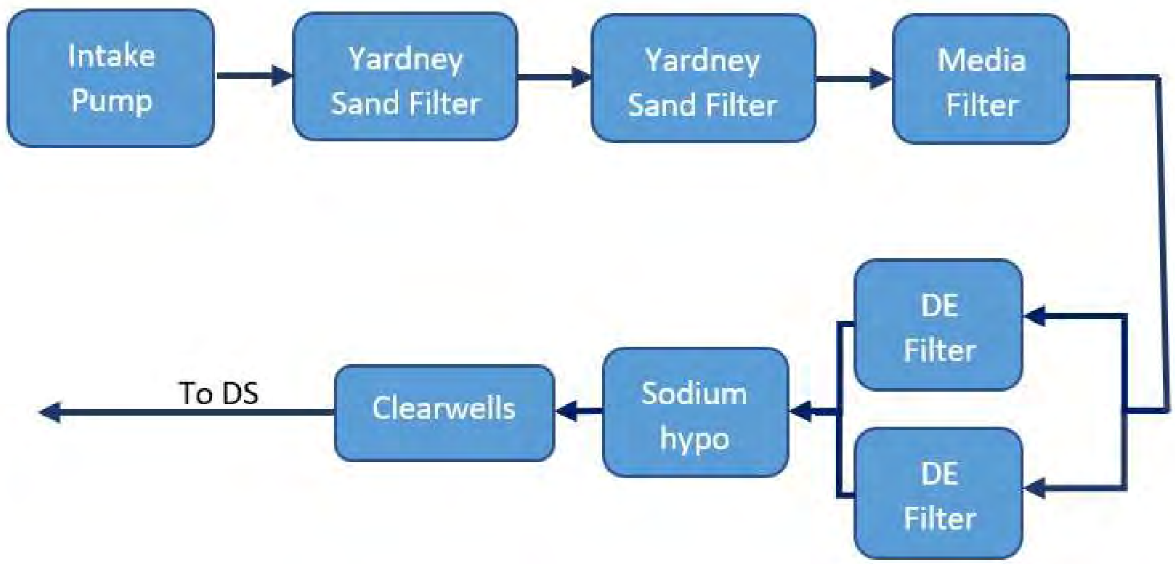


Figure 6.7.2: CBIC Water Treatment Plant Process Diagram

6.7.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

CBIC customers were under a boil water notice from 1997 until 2016 because surface water treatment requirements have not been met. The California Department of Public Health issued a citation in September of 1998. The CBIC issued a boil water notice in 2021 because the diatomaceous earth system does not regularly meet the effluent turbidity limitation of 0.5NTU. The CBIC is in the process of consolidating with a larger water system that will address the ongoing surface water treatment rule violation and boil water notice.

Turbidity

Figure 6.7.3 shows the CBIC's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms, but the highest peaks align with the months when harmful algal blooms are present. The CBIC's intake is located in a cove that is largely shielded from sedimentation associated with storm events. Turbidity from storm events averages around 15 NTU whereas other purveyors with intakes that are more exposed to sedimentation have regular spikes up to 200 NTU. Relative to other utilities in this study, the CBIC has low to moderate raw turbidity levels. The highest peaks took place between June to mid-October, which are the months when harmful algal blooms are most severe in Clear Lake. The highest result was 30.7 NTU in September 2019. Although the intake is in the Lower Arm, which is known to undergo severe blooms, the cove has relatively mild water quality. This phenomenon is partially due to the wind shadow provided by Mt. Konocti and the lack of sediment flow into the area.

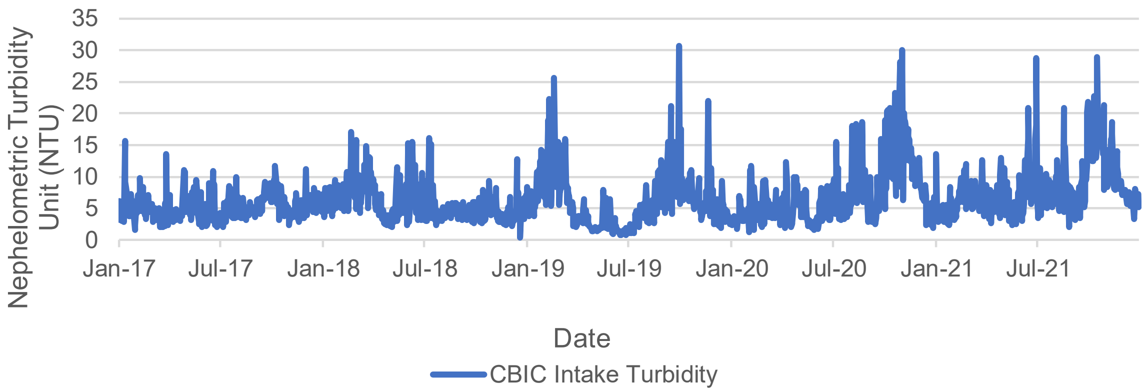


Figure 6.7.3: CBIC Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The CBIC sampled at least monthly at the intake for total coliform and *E. coli*. 2018 was sampled bi-weekly. Table 6.7.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 47% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.7.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the CBIC provides adequate treatment and disinfection for bacteriological quality.

Table 6.7.2: CBIC Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	77	2419.6	ND	1553.2
Escherichia coli (*E. coli*)	MPN/100mL	77	1732.9	ND	1.0

ND: Not Detected

Table 6.7.3: CBIC Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.7.4 and 6.7.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.7.4 and 6.7.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The CBIC had no primary drinking water standard violations between 2017-2021. However, raw water results exceeded the SMCL for aluminum in 2020. There were no finished water results for aluminum during the study period. Additionally, finished water results exceeded the SMCL for odor in 2018 and 2021. Finally, the SMCL for manganese was exceeded in raw water during 2020. The SMCL for color was met but not exceeded in 2020.

It is recommended that the CBIC monitor after treatment for contaminants that exceed the MCL/SMCL at the intake. Monitoring can be on an as-needed basis when MCLs/SMCLs are exceeded, or a part of the regular monitoring schedule. If the SMCL for aluminum, odor, or manganese is exceeded again, the CBIC must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

Table 6.7.4: CBIC Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 370	NA	None
Arsenic	µg/L	10/--	ND – 2.6	NA	None
Barium	µg/L	1,000/--	ND – 160	NA	None
Chromium	µg/L	50/--	ND – 1.6	NA	None
Fluoride	mg/L	2/--	0.17 – 0.26	NA	None
Nitrate	mg/L	10/--	ND – 0.69	NA	None
Gross Alpha Particle Activity	pCi/L	15/--	1.05	NA	None

ND: Not Detected   NA: Not Available

Table 6.7.5: CBIC Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	200	ND – 370	NA	SMCL exceeded in 2020
Chloride	mg/L	500	5.7 – 8.8	NA	None
Color	Color Units	15	10 – 25	5 – 15	None
Conductivity	umho/cm	1,600	240 – 340	NA	None
Sulfate	mg/L	500	5.1 – 7.3	NA	None
Total Dissolved Solids	mg/L	1,000	160 – 220	NA	None
Iron	µg/L	300	110 – 180	NA	None
Odor	TON	3	4 – 35	ND – 17	SMCL exceeded during 2018 & 2021
Zinc	mg/L	5	ND – 0.27	NA	None
Manganese	µg/L	50	ND – 69	NA	SMCL exceeded during 2020

ND: Not Detected   NA: Not Available

Disinfection Byproducts Precursors

Total organic carbon (TOC) removal requirements do not apply to the CBIC because the water treatment plant utilizes an alternative treatment process.

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.7.6 summarizes compliance with the disinfection byproducts rule (DBPR). The CBIC's locational running annual average (LRAA) at CA1700519_DST_004 exceeded the MCL for total trihalomethanes during quarter 3 and 4 of 2019. Results for subsequent quarters decreased significantly because the CBIC changed out the aeration pump that feeds the distribution system tanks and moved aeration from the clearwells to one of the distribution system tanks. Results for total trihalomethanes have not exceeded the MCL since 2019.

The LRAA at CA1700519_DST_004 exceeded the MCL for total haloacetic acids throughout the study period. The CBIC issues Tier 2 Public Notifications on a quarterly basis per 22 CCR § 64463.4. High total haloacetic acid results are linked to high effluent turbidity. While total trihalomethanes are inherently volatile and come out of solution with aeration, total haloacetic acids tend to stay in solution. High turbidity levels (>0.3NTU) at the treatment plant effluent increase the formation potential for disinfection byproducts. To decrease the levels of total haloacetic acids, we recommend reconfiguring the treatment process to achieve lower effluent turbidity levels. This can be achieved in several different ways, but due to the small geographic footprint of the treatment plant, the difficulty of transporting materials down the ravine, and limited financial resources, the CBIC has not been able to significantly reconfigure the treatment system. The consolidation project will address the ongoing DBPR violation.

Table 6.7.6: CBIC Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	ND – 150	80.2	LRAA exceeded the MCL during Q3 & Q4 2019
Total Haloacetic Acids	µg/L	60	24.2 – 220	154	LRAA exceeded the MCL throughout the monitoring period

Lead and Copper Rule (LCR)

Table 6.7.7 summarizes compliance with the Lead and Copper Rule (LCR). The CBIC is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2017 and 2021. There were no action level exceedances.

Table 6.7.7: CBIC Lead and Copper Monitoring (2017 & 2021)

Analyte	Units	Action Level	Year Sampled	90^{th} Percentile	Violation Description
Lead	µg/L	15	2017	ND	None
			2021	5.2	None
Copper	mg/L	1.3	2017	0.22	None
			2021	0.47	None

Microcystins Monitoring

Table 6.7.8 and figure 6.7.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1700519. The CBIC's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was 0.23µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion. The highest concentration of microcystins was 7.9µg/L. Relative to other utilities in this study, the CBIC has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the CBIC continue to monitor raw and treated water for microcystins in future years. However, the CBIC does not have plans to continue monitoring microcystins.

Table 6.7.8: CBIC Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	17 raw; 18 finished	0.3	7.9	0.23

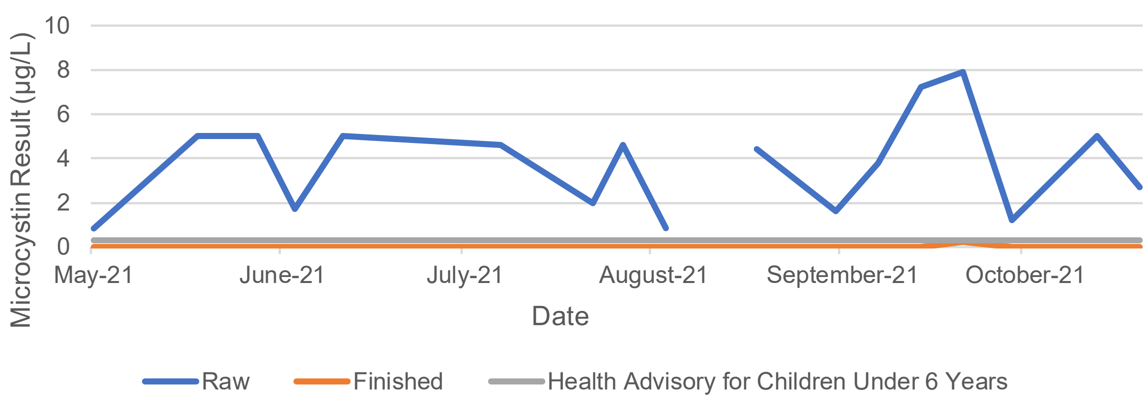


Figure 6.7.4: CBIC Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

The CBIC does not regularly track coagulant and disinfection dosages, therefore, a relationship between harmful algal blooms and chemical additives cannot be determined.

Ammonia

The CBIC does not currently monitor for ammonia. Monitoring for ammonia in the future may help the CBIC better manage chlorine dosages and chloramine formation.

6.8- GOLDEN STATE WATER COMPANY - CLEARLAKE

6.8.1- Water System Summary

The Golden State Water Company – Clear Lake System (GSWC Clearlake) is located on the northern side of the Lower Arm (Figure 6.8.1). Purveyors with intakes in the Lower and Oaks Arm of Clear Lake treat the most severe harmful algal blooms, and as a result, have high operational expenses. GSWC Clearlake is classified as a severely disadvantaged community (SDAC). It has a total of 2,163 connections (2,115 residential and 48 commercial) and serves a population of 4,713. The system has three pressure zones due to the varied topography of the area. Additional system information is outlined in Table 6.8.1.

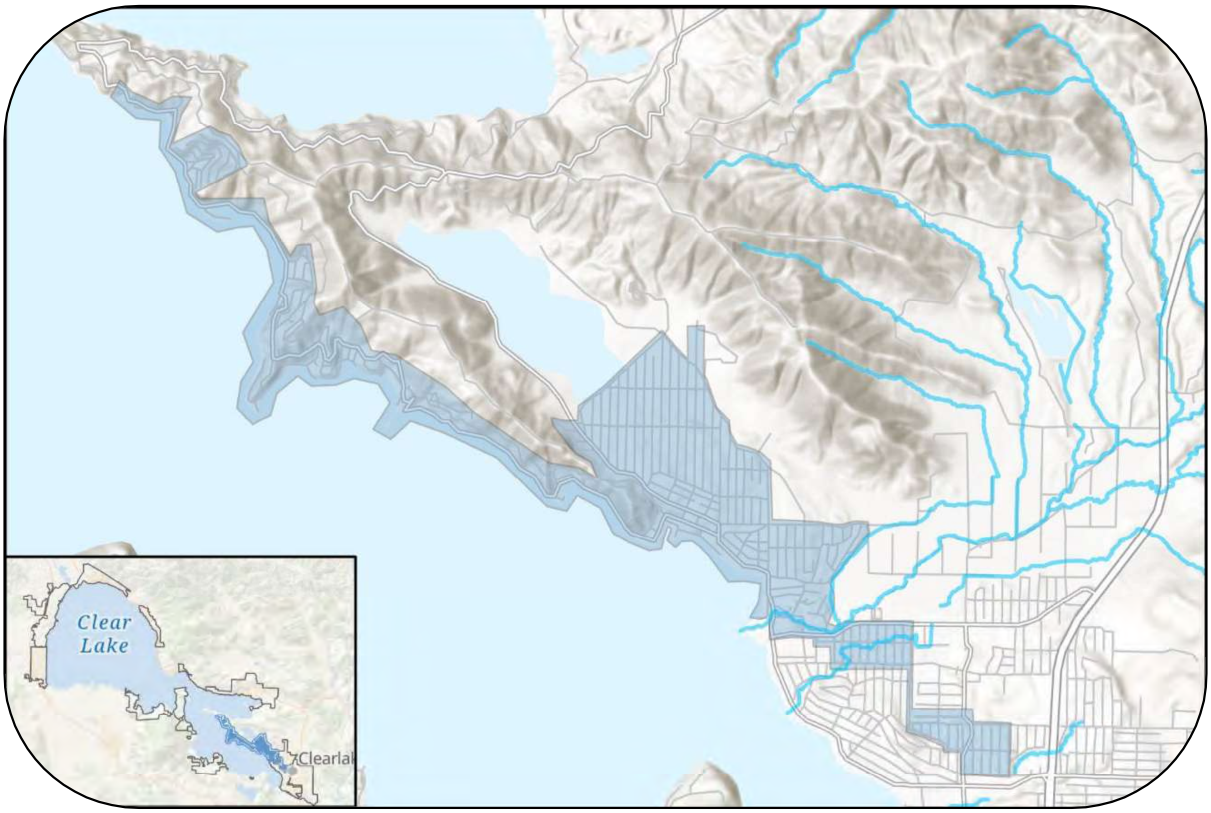


Figure 6.8.1: GSWC Clearlake System Boundary Map

Table 6.8.1: GSWC Clearlake System Attributes

System Name	Address	
Golden State Water Company – Clear Lake System	13455 Sonoma Ave, Clear Lake, CA 95424	
Public Water System No.	**Connection Count**	**Population**
CA1710002	2,163	4,713
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community	Intake/Active	720/1.03
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
30	D2	T3

6.8.2- Treatment, Operations, and Infrastructure Upgrades

The GSWC Clearlake treatment plant is a conventional water treatment plant consisting of three raw water pumps, a static mixer, a conventional flocculation/sedimentation basin, two dual-media filters, two granulated activated carbon units, and a 192,000 baffled clearwell. Raw water is pumped through one of three 30 horsepower submersible pumps where it is dosed with potassium permanganate then pumped through a 3,300-foot transmission line to the headworks. Upon arrival at the treatment plant, water is dosed with primary coagulant (SWT 2000) and coagulant aid (SWT 9309A). Powdered activated carbon is added as needed to mitigate taste and odor concerns associated with harmful algal blooms and other natural organic matter compounds.

Immediately downstream of chemical injection points is a static mixer that ensures adequate mixing before water enters into one of two conventional flocculation/sedimentation basin trains each consisting of two chambers. After flocculation and sedimentation, water is dosed with a filter aid (SWT 9309A) and pumped into one or both of two horizontal dual-media pressure filters that operate in parallel. Each filter contains anthracite and garnet sand. The combined filter effluent flow is combined and split again as it enters into one of two vertical granulated activated carbon units that operate in parallel. Water is then dosed with zinc orthophosphate for corrosion control and sodium hypochlorite as a polishing disinfectant. Finished water then enters into a 192,000 baffled clearwell where adequate contact time is achieved. Figure 6.8.2 shows a process diagram of the GSWC Clearlake's treatment process.

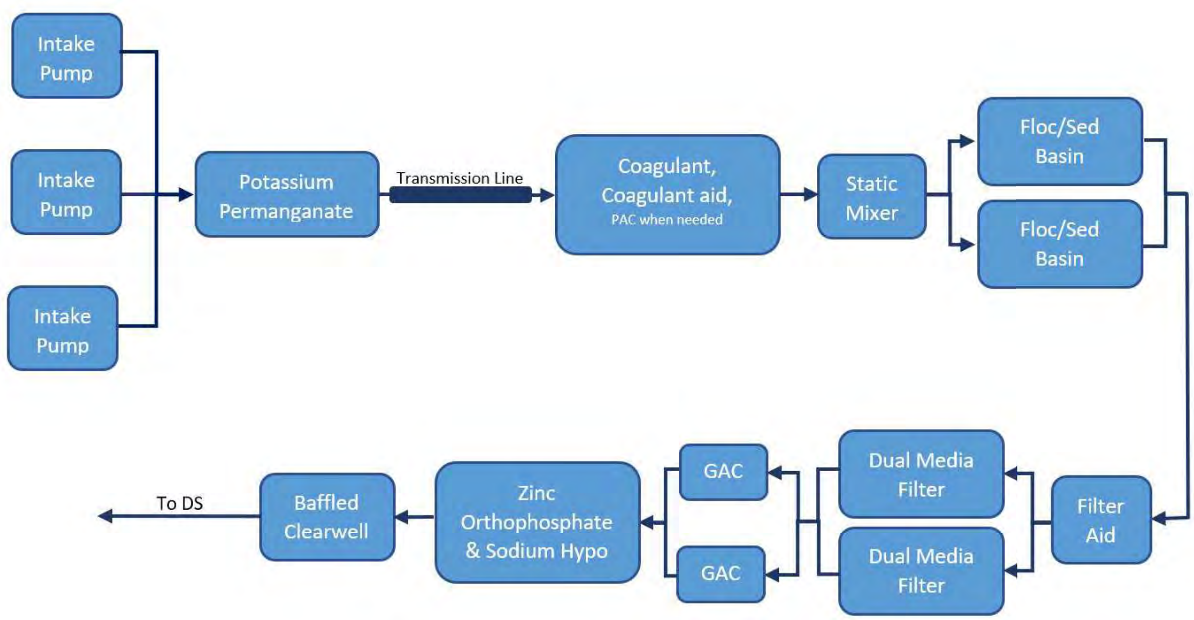


Figure 6.8.2: GSWC Clearlake Water Treatment Plant Process Diagram

6.8.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

GSWC Clearlake maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.8.3 shows GSWC Clearlake's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms. Turbidity from storm events average around 20 NTU whereas other purveyors with intakes exposed to stormwater sedimentation have spikes up to 200 NTU. Relative to other utilities in this study, GSWC Clearlake has low raw turbidity levels. The highest result was 33.2 NTU in January 2017.

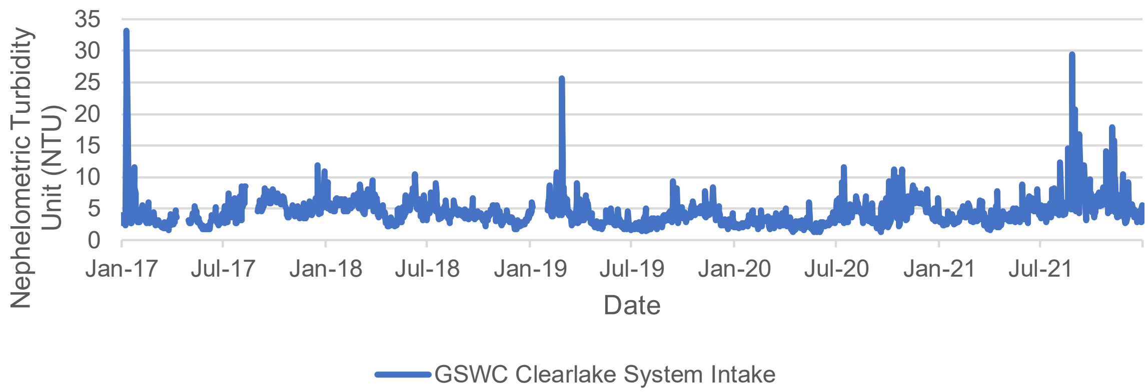


Figure 6.8.3: GSWC Clearlake Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

GSWC Clearlake sampled weekly at the intake for total coliform and *E. coli*. Table 6.8.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 36% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.8.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that GSWC Clearlake provides adequate treatment and disinfection for bacteriological quality.

Table 6.8.2: GSWC Clearlake Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	264	2419.6	ND	1986.3
Escherichia coli (*E. coli*)	MPN/100mL	264	75.9	ND	1

ND: Not Detected

Table 6.8.3: GSWC Clearlake Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.8.4 and 6.8.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.8.4 and 6.8.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). GSWC Clearlake did not have primary or secondary drinking water standard violations between 2017-2021.

Table 6.8.4: GSWC Clearlake Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 180	ND	None
Arsenic	µg/L	10/--	ND – 3.8	ND	None
Fluoride	mg/L	2/ --	0.12 – 0.14	NA	None

ND: Not Detected NA: Not Available

Table 6.8.5: GSWC Clearlake Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	6.9 – 8.4	12 – 16	None
Color	Color Units	15	15 – 40	ND	None
Conductivity	umho/cm	1,600	310 – 530	350 – 380	None
Sulfate	mg/L	500	3.8 – 7.0	4.1 – 5.8	None
Total Dissolved Solids	mg/L	1,000	170 – 300	200 – 220	None
Foaming Agents (MBAS)	mg/L	0.5	ND – 0.11	NA	None
Iron	µg/L	300	ND – 440	ND	None
Odor	TON	3	2 – 200	ND – 2	None
Manganese	µg/L	50	ND – 52	ND	None

ND: Not Detected NA: Not Available

Disinfection Byproducts Precursors

Table 6.8.6 summarizes GSWC Clearlake's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.8.6: GSWC Clearlake Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	130 – 170	4.3 – 15	25% – 30%	59%	None
2018	150 – 170	5.7 – 12	25% – 30%	59%	None
2019	130 – 160	3.8 – 6.2	15% – 25%	51%	None
2020	140 – 170	3.8 – 5.4	15% – 25%	48%	None
2021	180 – 210	4.4 – 8.0	25%	46%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.8.7 summarizes compliance with the disinfection byproducts rule (DBPR) between 2017-2021. No violations were observed.

Table 6.8.7: GSWC Clearlake Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	4.2 – 65	34.5	None
Total Haloacetic Acids	µg/L	60	13 – 44	42.8	None

Lead and Copper Rule (LCR)

Table 6.8.8 summarizes compliance with the Lead and Copper Rule (LCR). GSWC Clearlake is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2017 and 2020. There were no action level exceedances.

Table 6.8.8: GSWC Clearlake Lead and Copper Monitoring (2017-2021)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	µg/L	15	2017	ND	None
			2020	ND	None
Copper	mg/L	1.3	2017	0.18	None
			2020	0.31	None

ND: Not Detected

Microcystins Monitoring

Table 6.8.9 and figure 6.8.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_008_ 1710002. GSWC Clearlake water treatment plant effectively inactivated microcystins during the monitoring period. There were no detections in the finished water supply. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest raw water detections of microcystins are denoted as >5µg/L, which is the upper detection limit used at Eurofins Eaton Analytical. Most utilities subject to the abovementioned microcystin monitoring order used Kennedy Environmental, which has a higher upper detection limit for EPA method 546. Therefore, the raw water concentrations at GSWC Clearlake cannot be compared against other utilities around the lake. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that GSWC Clearlake continue to monitor raw and treated water for microcystins in future years.

Table 6.8.9: GSWC Clearlake Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	24	0.3	>5.0	ND

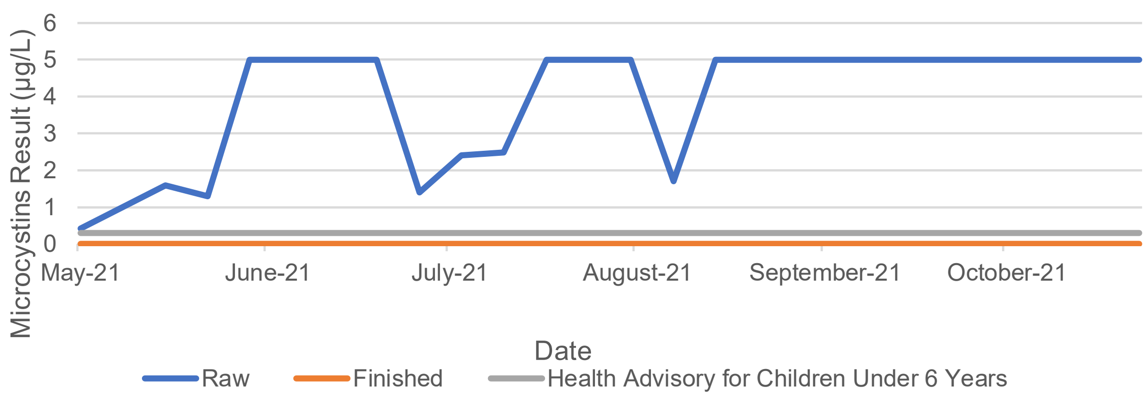


Figure 6.8.4: GSWC Clearlake Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.8.5 – 6.8.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH, coagulant doses, and disinfection doses from 2017-2021 show that rising pH during Quarter 3 are accompanied by higher coagulation and disinfection doses. The pH data aligns with both microcystins data and visual observation which show Quarter 3 to undergo the most severe harmful algal blooms.

Kennard and Sandoval-Solis (2021) conducted a chemical cost analysis for three Clear Lake water treatment plants and found the main chemical cost driver to be primary coagulant. All other chemicals, including sodium hypochlorite, are insignificant when comparing actual chemical costs. They found that the chemical cost per thousand gallons of water produced during Quarter 3 and Quarter 4 increased by up to four times the chemical cost required during Quarter 1 and 2. To decrease water treatment costs, it is recommended that GSWC Clearlake implement an acid feed station at the intake to decrease raw water pH before the primary coagulant is added.

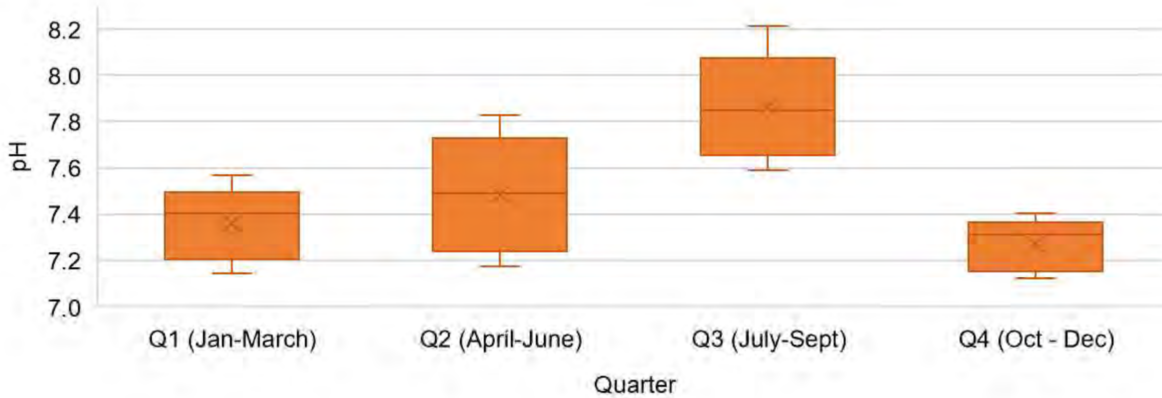


Figure 6.8.5: GSWC Clearlake Quarterly Aggregate pH (2017-2021)

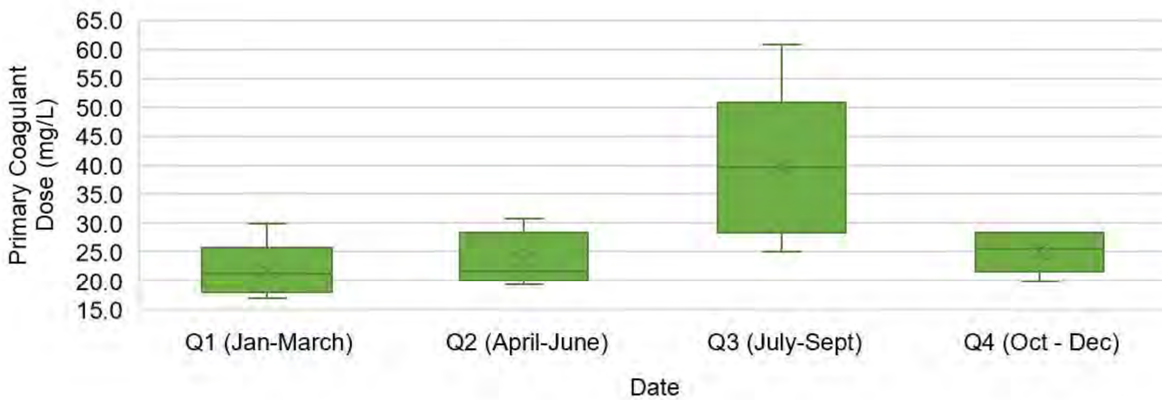


Figure 6.8.6: GSWC Clearlake Quarterly Aggregate Primary Coagulant (2017-2021)

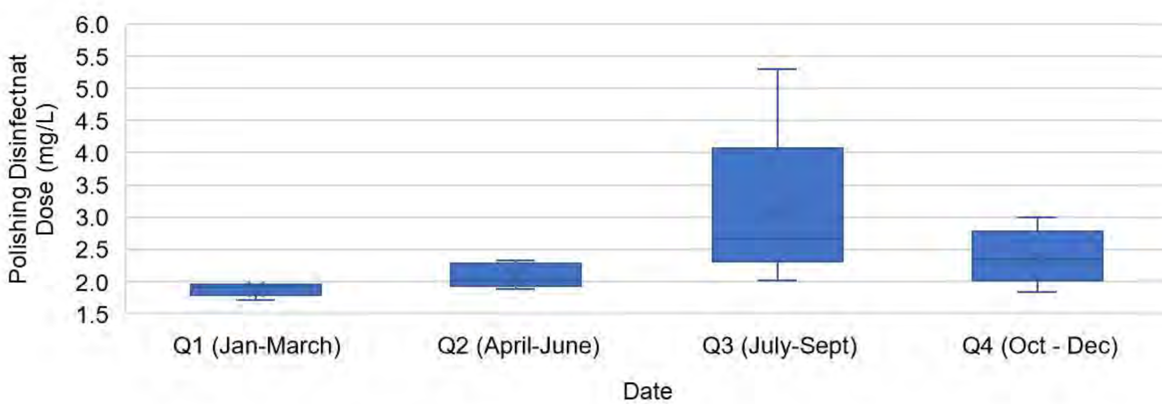


Figure 6.8.7: GSWC Clearlake Quarterly Aggregate Polishing Disinfectant (2017-2021)

Ammonia

Figure 6.8.8 shows the available ammonia data provided by GSWC Clearlake. Concentrations are cyclical with the highest concentrations in the summer and fall. Peaks in ammonia are associated with higher chlorine demand.

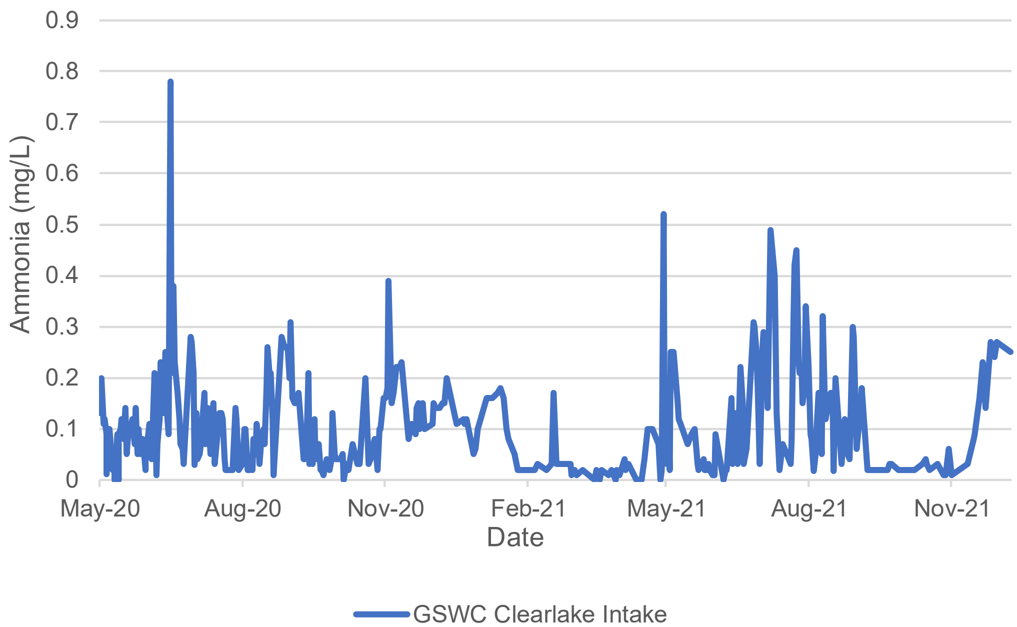


Figure 6.8.8: GSWC Clearlake Intake Ammonia Concentrations (2020-2021)

6.9- HARBOR VIEW MUTUAL WATER COMPANY

6.9.1- Water System Summary

The Harbor View Mutual Water Company (HVMWC) is located immediately southeast of Buckingham Peninsula on the Lower Arm of Clear Lake. The intake is in a quiescent cove on the eastern side of the peninsula (Figure 6.9.1). The HVMWC is a disadvantaged community (DAC). It has a total of 250 connections (250 residential and 0 commercial) and serves a population of 550. The system has three pressure zones, one surface water treatment plant, three storage tanks, and four booster pump stations. Additional system information is outlined in Table 6.9.1.

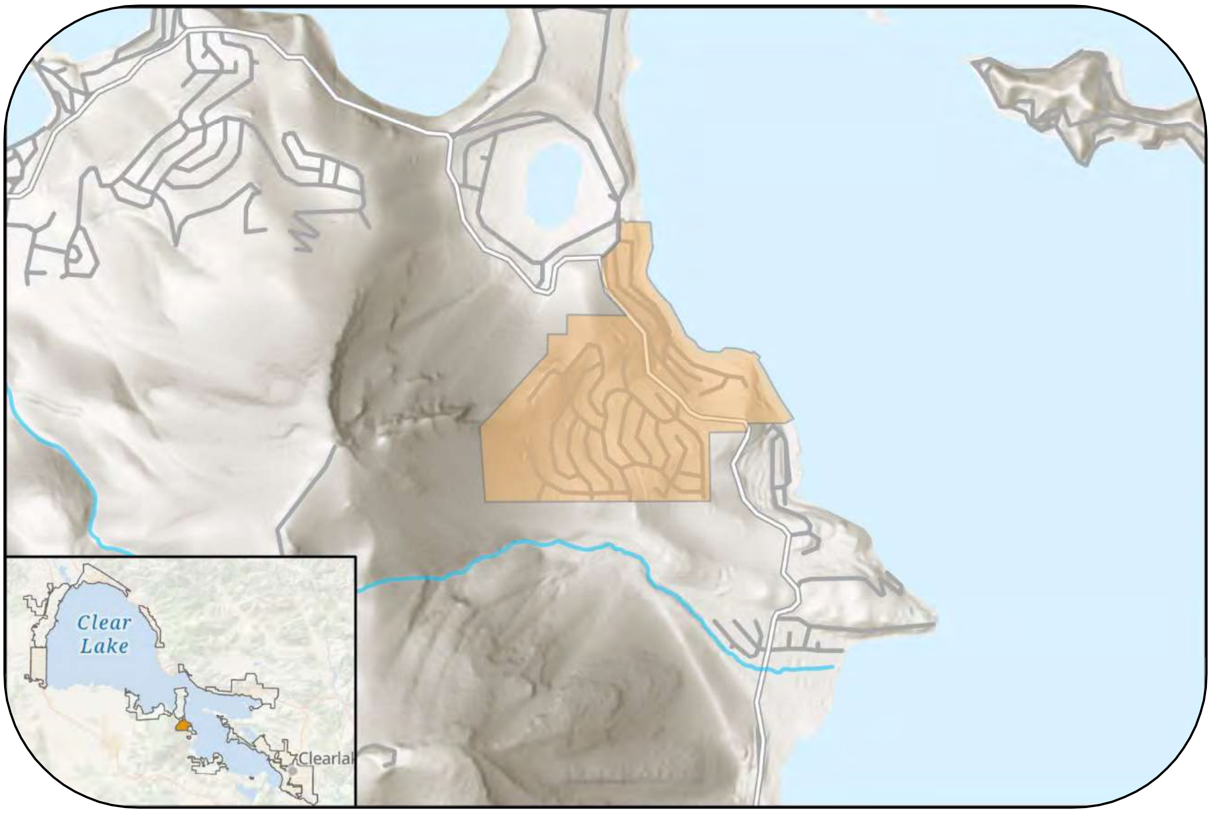


Figure 6.9.1: HVMWC System Boundary Map

Table 6.9.1: HVMWC System Attributes

System Name	**Address**	
Harbor View Mutual Water Company	8475 Harbor View Drive, Kelseyville CA 95451	
Public Water System No.	**Connection Count**	**Population**
CA1700568	250	550
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community	Intake/Active	170/0.244
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
15	D1	T3

6.9.2- Treatment, Operations, and Infrastructure Upgrades

The HVMWC treatment plant consists of two raw water pumps, an automatic screen filter, a dissolved air floatation (DAF) system, three dual-media pressure filters, and two granulated activated carbon (GAC) filters. Raw water is pumped through one of two constant speed intake pumps and dosed with potassium permanganate before it passes through the automatic screen filter to remove large debris. Water is then dosed with Propac 9810 for coagulation and muriatic acid (as needed for pH adjustment) before it enters into the DAF system. Within the DAF system, saturated air is injected at the bottom of the unit, causing the floc to float to the top of the unit where it can be sloughed off. Settled water then enters into an equalization tank where it is dosed with Propac 9890 (as needed for filter aid) and pumped into three dual media (anthracite and sand) pressure filters that run in parallel. Water then flows through two GAC units that can either run in series or in parallel. Effluent water is then dosed with sodium hypochlorite and enters a contact pipe where adequate contact time is achieved. Figure 6.9.2 shows a process diagram of the HVMWC's treatment process.

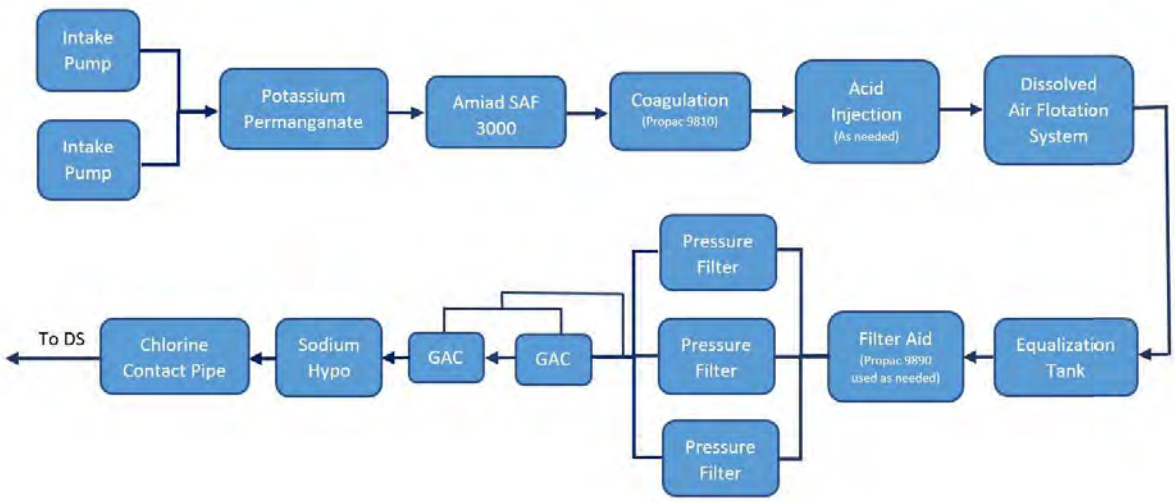


Figure 6.9.2: HVMWC Water Treatment Plant Process Diagram

6.9.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The HVMWC maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.9.3 shows the HVMWC's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms. Turbidity from storm events averages around 5 NTU whereas other purveyors that are more exposed to sedimentation have regular spikes up to 200 NTU. Relative to other utilities in this study, the HVMWC has low raw turbidity levels. The highest peaks took place between June and July, which are typically months when harmful algal blooms are severe in Clear Lake. The highest result was 50 NTU in July 2021.

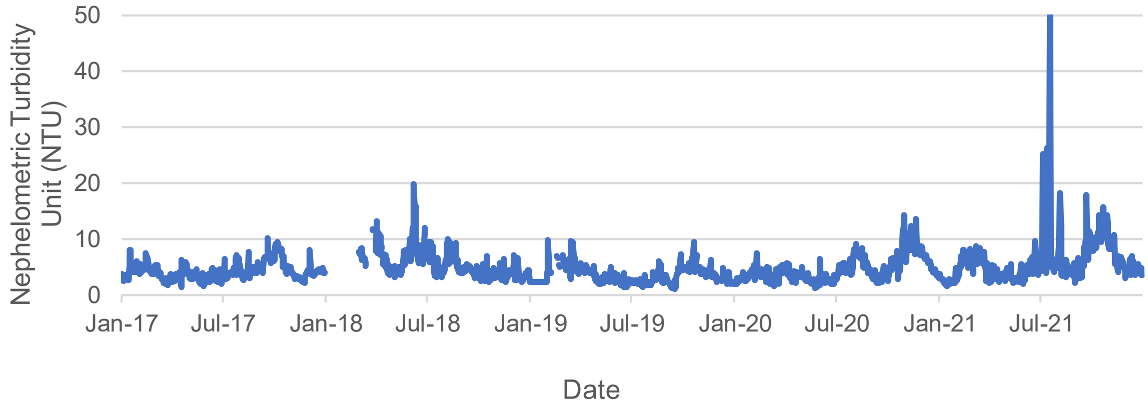


Figure 6.9.3: HVMWC Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The HVMWC sampled at least monthly at the intake for total coliform and *E. coli*. 2018 was sampled bimonthly. Table 6.9.2 summarizes raw total coliform and *E. coli* data from 2018 - 2021. Data from 2017 could not be obtained for this study. There is no discernible seasonal trend in raw bacteriological results. 46% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.9.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the HVMWC provides adequate treatment and disinfection for bacteriological quality.

Table 6.9.2: HVMWC Raw Bacteriological Monitoring (2018-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	56	2419.6	1.0	1389.6
Escherichia coli (*E. coli*)	MPN/100mL	56	125.9	ND	1.0

ND: Not Detected

Table 6.9.3: HVMWC Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.9.4 and 6.9.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.9.4 and 6.9.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The HVMWC had no primary drinking water standard violations between 2017-2021. However, the finished water RAA regularly exceeded the SMCL for odor throughout the study period. We recommend that the HVMWC continue to monitor their finished water for odor and investigate the possibility of replacing the granulated activated carbon media.

Additionally, the 2019 result for manganese met but did not exceed the SMCL. If manganese is detected in raw water at levels near the SMCL in the future, we recommend that the HVMWC collect manganese samples from the finished water tap to determine if manganese is removed during the treatment process. If the SMCL for manganese is exceeded in the future, the HVMWC must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

Table 6.9.4: HVMWC Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 150	ND	None
Arsenic	µg/L	10/--	ND – 2.9	NA	None
Fluoride	mg/L	2/--	0.11 – 0.17	NA	None

ND: Not Detected NA: Not Available

Table 6.9.5: HVMWC Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	7.5 – 9.9	NA	None
Color	Color Units	15	18 – 35	ND	None
Conductivity	umho/cm	1,600	300 – 360	NA	None
Sulfate	mg/L	500	4.3 – 7.6	NA	None
Total Dissolved Solids	mg/L	1,000	180 – 250	160 – 260	None
Iron	µg/L	300	ND – 250	ND	None
Odor	TON	3	3.2 – 140	ND – 45	The finished water LRAA regularly exceeded the SMCL throughout the study period
Zinc	mg/L	500	ND – 61	NA	None
Manganese	µg/L	50	ND – 50	NA	None

ND: Not Detected NA: Not Available

Disinfection Byproducts Precursors

Table 6.9.6 summarizes the HVMWC's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.9.6: HVMWC Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	120 – 150	4.08 – 5.68	25%	68%	None
2018	140 – 170	4.5 – 5.76	15% - 25%	56%	None
2019	110 – 160	1.76 – 5.29	25% - 35%	36%	None
2020	140 – 180	3.76 – 5.96	25%	46%	None
2021	170 – 210	4.05 – 7.08	25% - 35%	44%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.9.7 summarizes compliance with the disinfection byproducts rule (DBPR). The HVMWC monitored annually for disinfection byproducts between 2017 and 2020. During that time, compliance was based on annual samples. In 2018, the HVMWC's annual total trihalomethane result was 108.02µg/L, which exceeded the MCL of 80µg/L. The HVMWC did not switch to quarterly monitoring at this time. In 2020, the HVMWC's annual total trihalomethane and total haloacetic acid results were 85.5µg/L and 64.2µg/L, respectively, which exceed their relative MCLs. The exceedance was due to a spray pump failure in the tank. Once the spray pump was fixed and proper aeration was reestablished, the concentration of disinfection byproducts decreased to pre-pump failure levels. Since the HVMWC had an MCL exceedance for total trihalomethanes and total haloacetic acids in 2020, they switched to quarterly monitoring and base compliance on the locational running annual average. There were no violations in 2021.

Table 6.9.7: HVMWC Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	27.8 – 108.0	108.0	The LRAA was exceeded in 2018 and 2020
Total Haloacetic Acids	µg/L	60	14.5 – 64.2	64.2	The LRAA was exceeded in 2020

Lead and Copper Rule (LCR)

Table 6.9.8 summarizes compliance with the Lead and Copper Rule (LCR). The HVMWC failed to collect triennial samples in 2018. As a result, they were ordered to conduct LCR monitoring every six months. After two rounds of biannual LCR monitoring cycles, their monitoring frequency was changed back to triennial. There were no action level exceedances throughout the monitoring period.

Table 6.9.8: HVMWC Lead and Copper Monitoring (2019-2020)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	µg/L	15	2019	ND	None
			2020	ND	None
Copper	mg/L	1.3	2019	0.30	None
			2020	0.38	None

ND: Not Detected

Microcystins Monitoring

Table 6.9.9 and figure 6.9.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710568. The HVMWC's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 30µg/L. Relative to other utilities in this study, the HVMWC has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the HVMWC continues to monitor raw and treated water for microcystins in future years.

Table 6.9.9: HVMWC Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	26	0.3	30	< 0.15

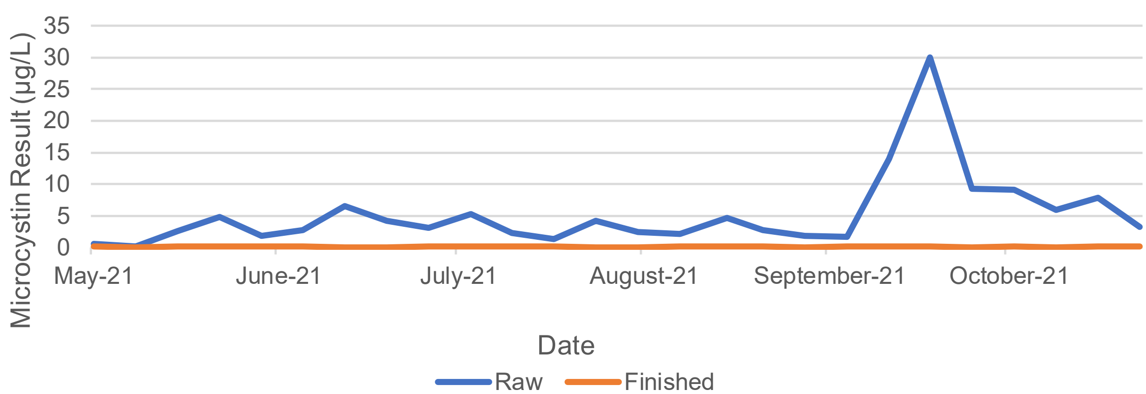


Figure 6.9.4: HVMWC Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.9.5 – 6.9.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH from 2017-2021 does not show a trend in rising pH during Quarter 3 and Quarter 4.

Rather, pH has a large range throughout each quarter. Additionally, both coagulant and disinfection doses have a large range throughout each quarter, which makes determining a relationship based on quarterly aggregates difficult. The HVMWC utilizes an acid feed system as needed to decrease the pH of water entering the treatment plant, but use of the system is infrequent.

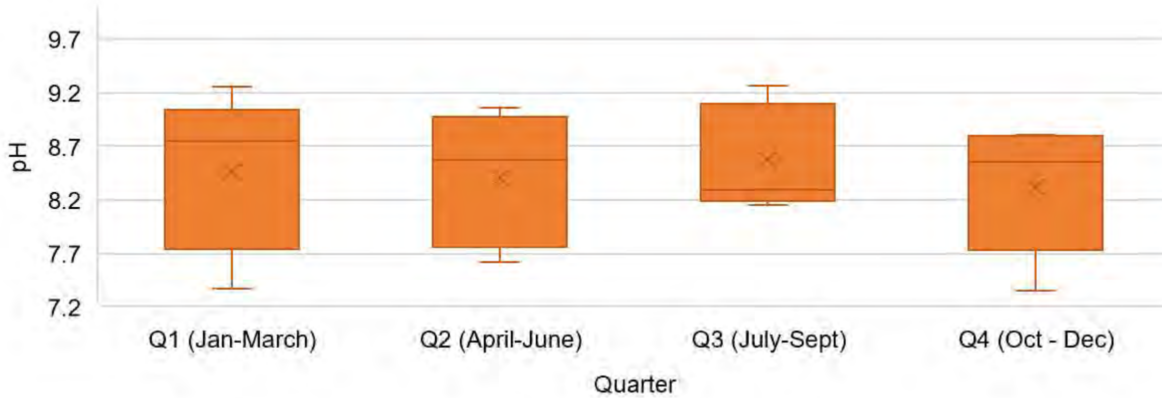


Figure 6.9.5: HVMWC Quarterly Aggregate pH (2017-2021)

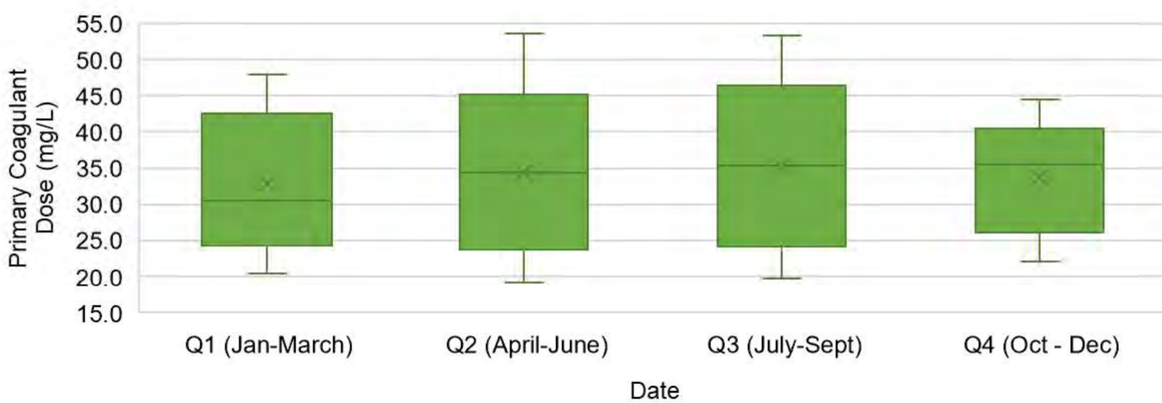


Figure 6.9.6: HVMWC Quarterly Aggregate Coagulant Dose (2017-2021)

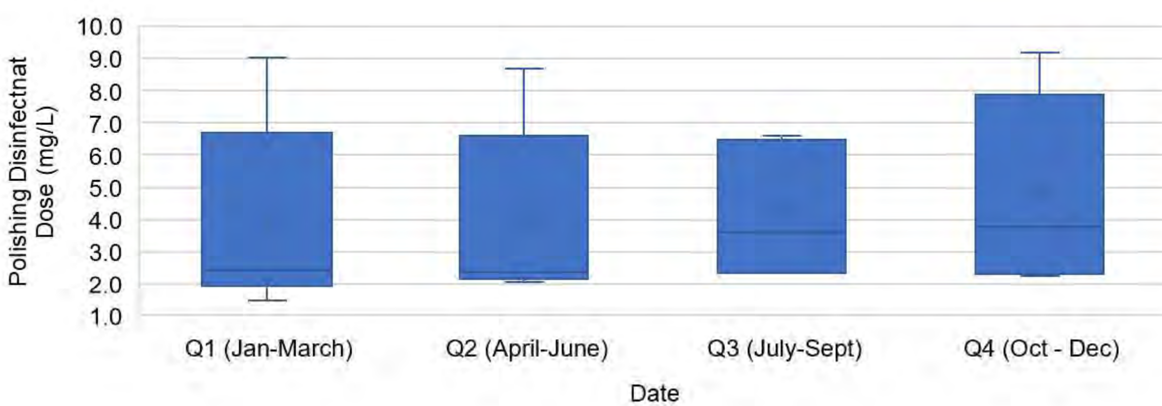


Figure 6.9.7: HVMWC Quarterly Aggregate Sodium Hypochlorite Dose (2017-2021)

Ammonia

The HVMWC does not regularly monitor for ammonia. Monitoring regularly for ammonia in the future may help the HVMWC better manage chlorine dosages and chloramine formation.

6.10- HIGHLANDS MUTUAL WATER COMPANY

6.10.1- Water System Summary

The Highlands Mutual Water Company (HMWC) is located on the Lower Arm of Clear Lake (Figure 6.10.1). Purveyors with intakes in the Lower and Oaks Arm of Clear Lake treat the most severe harmful algal blooms, and as a result, have high operational expenses. The HMWC is a severely disadvantaged community (SDAC). It has a total of 2,879 connections (2,616 residential and 263 commercial) and serves a population of 9,494. The system has four pressure zones due to the varied topography of the area. It has one surface water treatment plant, six storage tanks totaling 4.88 million gallons, and three booster pump stations. Additional system information is outlined in Table 6.10.1.

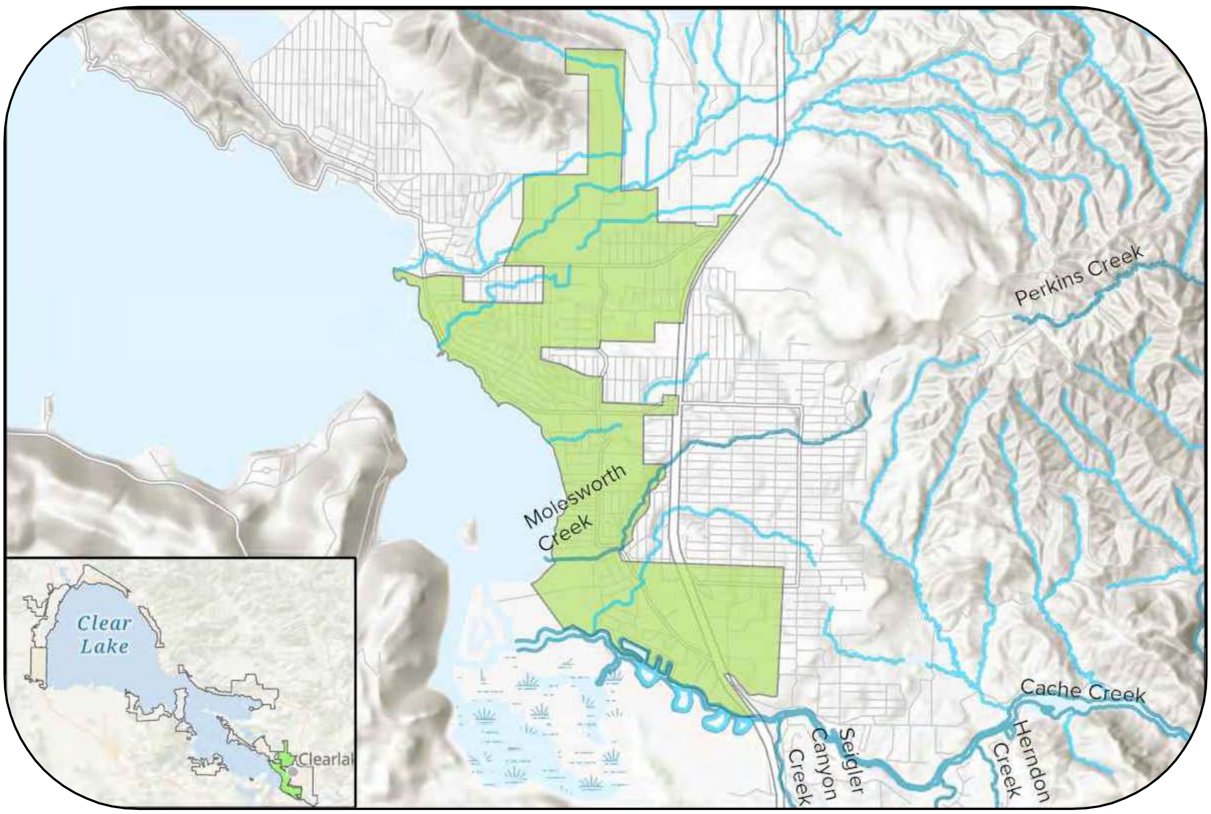


Figure 6.10.1: HMWC System Boundary Map

Table 6.10.1: HWMC System Attributes

System Name	Address	
Highlands Mutual Water Company	14774 Hillcrest Avenue, Clearlake, CA 95422	
Public Water System No.	**Connection Count**	**Population**
CA1710003	2,879	9,494
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community Water System	Intake/Active	2,500/3.6
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
150 x2	D2	T4

6.10.2- Treatment, Operations, and Infrastructure Upgrades

The HMWC treatment plant is a conventional water treatment plant consisting of two raw water intake pumps, two ozone towers, two clarifiers, four dual media pressure filters, two vertical granulated activated carbon (GAC) units consisting of bituminous coal, two horizontal coconut carbon GAC units, and two clear wells. Water enters the treatment plant through one of two 150 horsepower intake pumps at 2,500 gallons per minute. The water is dosed with potassium permanganate before it flows through two ozone towers. After ozonation, water can be dosed with sodium hypochlorite (if needed) and is dosed with a coagulant (ACH 9800). In 2022, the HMWC switched from ACH 9800 to ProPac 9890 for coagulation. From there, the flow is split into two trains, one for each clarifier. The clarifiers are configured to run one at a time or in parallel.

After water exits the clarifiers, it is dosed with a filter aid (ACH and Polyamene) and sodium hypochlorite (if needed) before it enters two parallel dual media pressure filters. After filtration, filter effluent flow is combined and enters into two parallel vertical GAC units followed by two parallel horizontal GAC units. Finally, effluent water is dosed with sodium hypochlorite and sent to two clearwells that run in series to meet contact time requirements. Two of the storage tanks are equipped with spray aeration to reduce total trihalomethanes. Figure 6.10.2 shows a process diagram of the HMWC's treatment process.

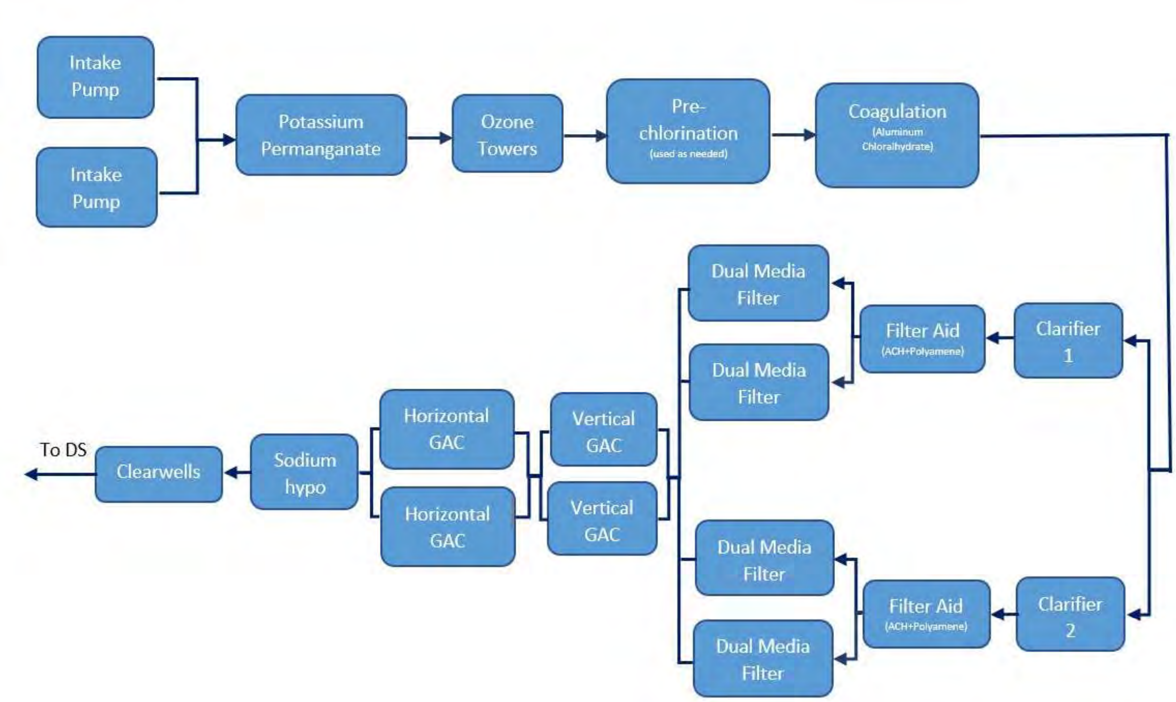


Figure 6.10.2: HMWC Water Treatment Plant Process Diagram

6.10.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The HMWC maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.10.3 shows the HMWC's raw daily turbidity data from 2017-2021. Results show a cyclical pattern of higher results during the late summer and winter. Seasonal peaks correspond to both storm events and harmful algal blooms, but the highest peaks align with storm events. The highest peak was in January 2017 with a result of 177 NTU. The second highest peak was in January 2019 with a result of 54.4 NTU. All other results range from 0.3 – 30.3 NTU. Harmful algal blooms are known to increase turbidity, but the peaks that occur during storm events overshadow the turbidity increases from harmful algal blooms.

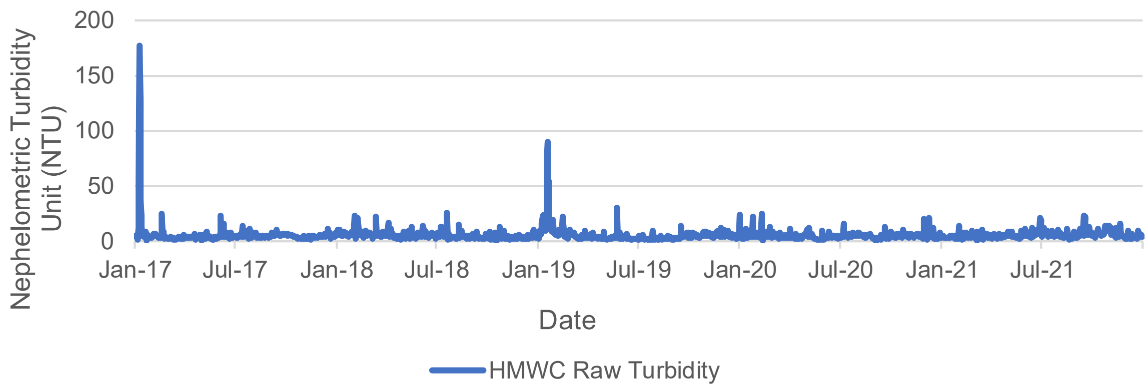


Figure 6.10.3: HMWC Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The HMWC sampled weekly at the intake for total coliform and *E. coli*. Table 6.10.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 39% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.10.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. The HMWC had one total coliform positive result in 2021, but all follow-up sample results were absent. This does not constitute a violation of the California Revised Total Coliform Rule.

Table 6.10.2: HMWC Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	260	>2,419.6	ND	1,119.9
Escherichia coli (*E. coli*)	MPN/100mL	259	648.8	ND	1

ND: Not Detected

Table 6.10.3: HMWC Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	1	0	0

Primary and Secondary Standards

Tables 6.10.4 and 6.10.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.10.4 and 6.10.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The HMWC had no primary drinking water standard violations between 2017-2021. However, they exceeded the SMCL for odor in 2018. This was a discrete event and did not reoccur during the study period. If the SMCL for odor is exceeded again, the HMWC must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

Table 6.10.4: HMWC Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	61 – 110	ND – 150	None
Arsenic	µg/L	10/--	ND – 3.6	ND	None
Fluoride	mg/L	2	ND – 0.14	ND – 0.12	None

ND: Not Detected

Table 6.10.5: HMWC Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	6.2 – 9.3	17 – 26	None
Color	Color Units	15	ND – 150	ND – 7	None
Conductivity	umho/cm	1,600	270 – 360	290 – 400	None
Sulfate	mg/L	500	3.8 – 6.7	3.9 – 6.8	None
Total Dissolved Solids	mg/L	1,000	150 – 220	150 – 220	None
Iron	µg/L	300	ND – 220	ND	None
Odor	TON	3	ND – 1,000	ND – 14	The SMCL was exceeded in 2018
Manganese	µg/L	50	ND – 28	ND	None

ND: Not Detected

Disinfection Byproducts Precursors

Table 6.10.6 summarizes HMWC's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.10.6: HMWC Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	120 – 170	2.6 – 10	15% - 30%	54%	None
2018	140 – 170	2.2 – 6.6	15% - 25%	43%	None
2019	120 – 140	4.7 – 6.5	25%	55%	None
2020	140 – 180	4.1 – 6.3	25%	54%	None
2021	170 – 220	4.6 – 8.6	25% - 30%	63%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.10.7 summarizes compliance with the disinfection byproducts rule (DBPR). The HMWC exceeded the locational running annual average (LRAA) for total haloacetic acids in quarters 1 and 2 of 2019 and quarters 1 and 2 of 2021. The LRAA at the end of the study period (quarter 4 of 2021) was 46.3µg/L, which is below the MCL of 60 µg/L. The HMWC has taken proactive measures to reduce the formation of disinfection byproducts. Switching to potassium permanganate helps reduce both total haloacetic acids and total trihalomethanes. The aeration sprayers at two of the six storage tanks help to reduce total trihalomethanes but does not reduce total haloacetic acids.

There are three places at the treatment plant where sodium hypochlorite may be added as pre-treatment (before clarifiers, after clarifiers, and after dual media filters). When pH is high, pre-chlorine dosages are increased to better facilitate coagulation, and potassium permanganate is turned off. We recommend that the HMWC implement an acid feed station at the intake to decrease pH to better facilitate coagulation without the need for pre-chlorination. Potassium permanganate can still be used as a pre-oxidant because it forms less disinfection byproducts than sodium hypochlorite. Trace amounts of chlorine can be used to mitigate algal growth in the clarifiers if the addition does not result in a disinfection byproduct exceedance.

Table 6.10.7: HMWC Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	ND – 61.34	36.4	None
Total Haloacetic Acids	µg/L	60	3.5 – 73.3	63.6	LRAA exceeded MCL during Q1 and Q2 2019 and Q1 and Q2 2021

Lead and Copper Rule (LCR)

Table 6.10.8 summarizes compliance with the Lead and Copper Rule (LCR). The HMWC is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2020. There were no action level exceedances.

Table 6.10.8: HMWC Lead and Copper Monitoring (2020)

Analyte	Units	Action Level	90th Percentile	Violation Description
Lead	µg/L	15	ND	None
Copper	mg/L	1.3	0.93	None

ND: Not Detected

Microcystins Monitoring

Table 6.10.9 and figure 6.10.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710003. The HMWC's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during the monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 170µg/L. Relative to other utilities in this study, the HMWC has high microcystin levels. These results are consistent with the current understanding that the Lower and Oaks Arms undergo more severe harmful algal blooms than the Upper Arm. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the HMWC continues to monitor raw and treated water for microcystins in future years.

Table 6.10.9: HMWC Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	26	0.3	170	< 0.15

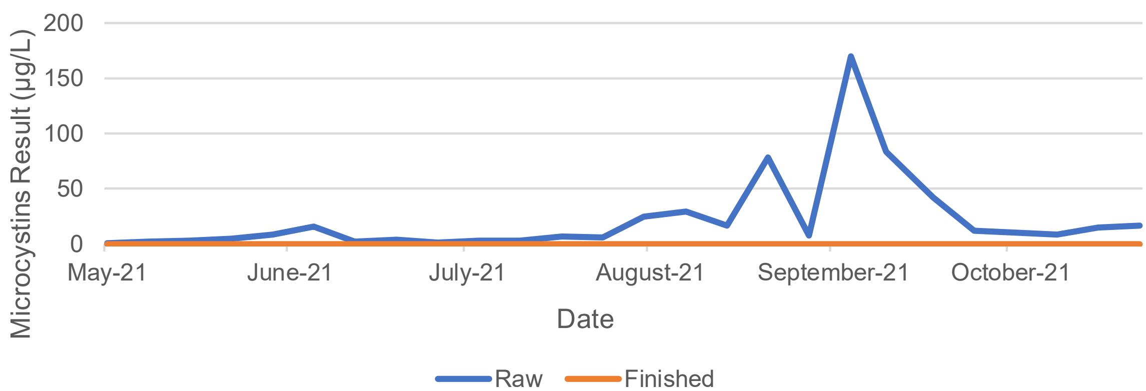


Figure 6.10.4: HMWC Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.10.5 – 6.10.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH and disinfection doses from 2017-2021 and coagulant doses from 2020-2021 show that rising pH during Quarter 3 and Quarter 4 are accompanied by higher coagulation and disinfection doses. The pH data aligns with both microcystins data and visual observation which show Quarter 3 and Quarter 4 to undergo the most severe harmful algal blooms.

The HMWC purchased a charge analyzer in 2020 to better inform their decisions regarding coagulant doses. Before 2020, the HMWC lacked the tools necessary to determine effective coagulant dosages, resulting in a relatively steady coagulant dose throughout the year. To show a representative relationship between pH and coagulant doses, we chose to only include coagulant doses from 2020-2021, which are the years when the charge analyzer was utilized.

Kennard and Sandoval-Solis (2021) conducted a chemical cost analysis for three Clear Lake water treatment plants and found the main chemical cost driver to be primary coagulant. All other chemicals, including sodium hypochlorite, are insignificant when comparing actual chemical costs. They found that the chemical cost per thousand gallons of water produced during Quarter 3 and Quarter 4 increased by up to four times the chemical cost required during Quarter 1 and 2. To decrease water treatment costs, it is recommended that the HMWC implement an acid feed station at the intake to decrease raw water pH before the primary coagulant is added.

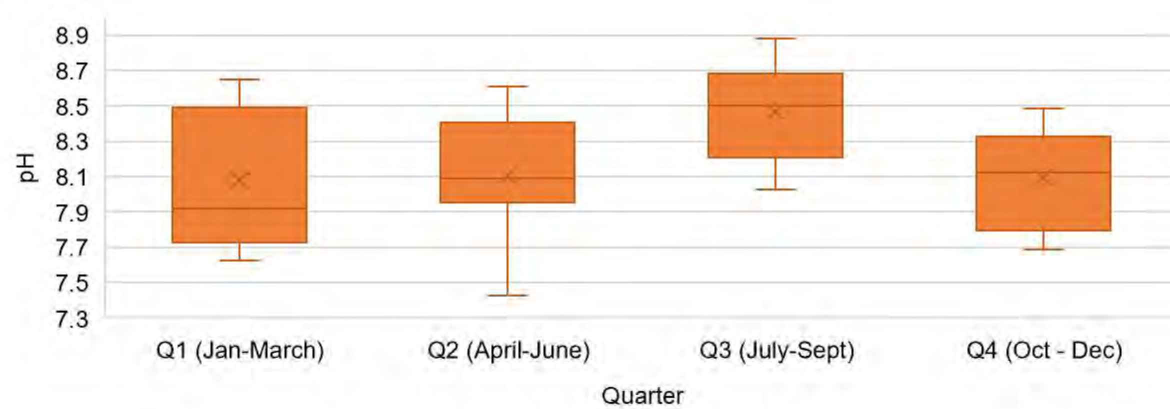


Figure 6.10.5: HMWC Quarterly Aggregate pH (2017-2021)

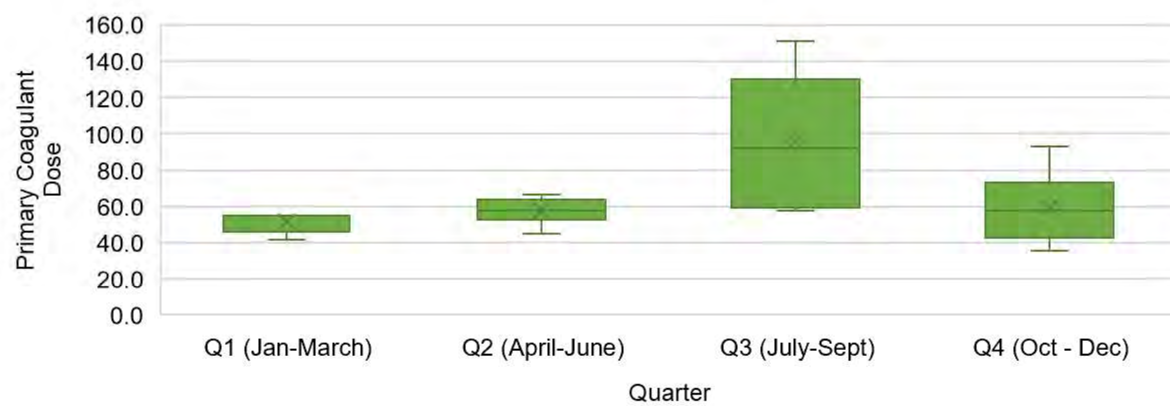


Figure 6.10.6: HMWC Quarterly Aggregate Primary Coagulant Dose (2020-2021)

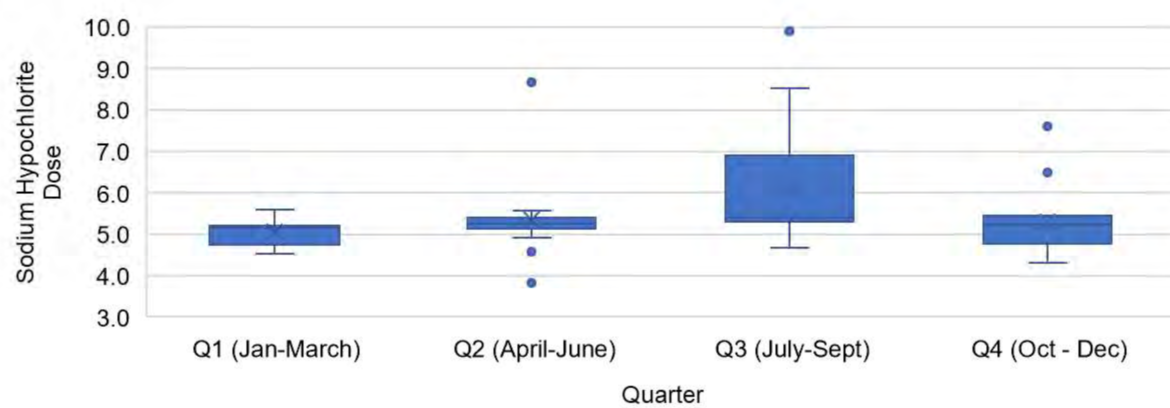


Figure 6.10.7: HMWC Quarterly Aggregate Sodium Hypochlorite Dose (2017-2021)

Ammonia

The HMWC does not currently monitor for ammonia. Monitoring for ammonia in the future may help the HMWC better manage chlorine dosages and chloramine formation.

6.11- KONOCTI COUNTY WATER DISTRICT

6.11.1- Water System Summary

The Konocti County Water District (KCWD) is located on the Lower Arm of Clear Lake (Figure 6.11.1). Purveyors with intakes in the Lower and Oaks Arm of Clear Lake treat the most severe harmful algal blooms, and as a result, have high operational expenses. The KCWC is a severely disadvantaged community (SDAC). It has a total of 2,100 connections, of which 1,821 are active, and serves a population of 5,928. The system has two pressure zones, one surface water treatment plant, five storage tanks totaling 1.85 million gallons, and one booster pump station. The system has two intakes, one low flow (40bhp) six-inch intake located 580 feet offshore and one high flow (60bhp) eight-inch intake located 500 feet offshore. Additional system information is outlined in Table 6.11.1.

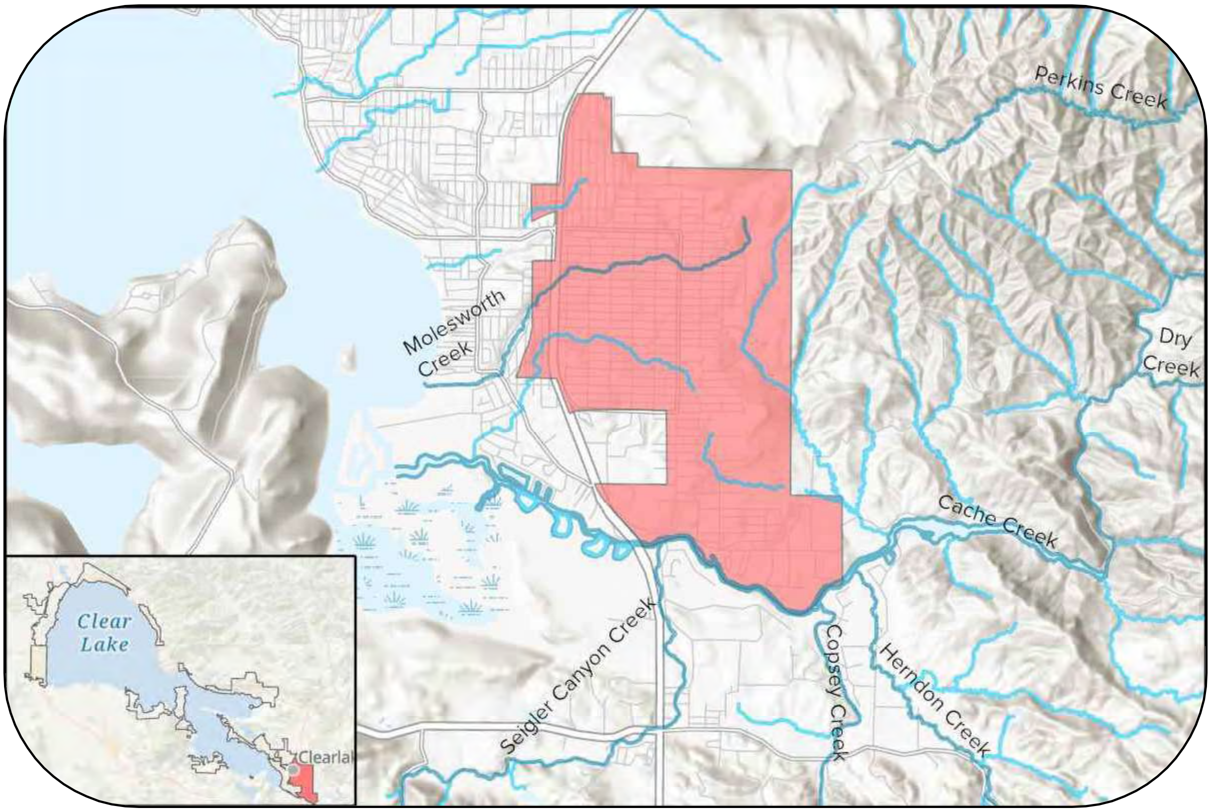


Figure 6.11.1: KCWD System Boundary Map

Table 6.11.1: KCWD System Attributes

System Name	Address	
Konocti County Water District	15449 Stanyon Avenue, Clearlake CA 95422	
Public Water System No.	**Connection Count**	**Population**
CA1710006	2,100 (1,821 active)	5,928
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community Water System	Intake/Active	692/0.996
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
40/60	D2	T4

6.11.2- Treatment, Operations, and Infrastructure Upgrades

The KCWD treatment plant is a conventional water treatment plant consisting of two raw water pumps, an onsite ozone generator, two up-flow clarifiers, one surge tank, three dual media filters, and two granulated activated carbon filters. Raw water is pumped through one of two intake pumps and dosed with potassium permanganate before it is pumped up to the treatment plant where it is injected with ozone. From there, hydrochloric acid is added for pH adjustment followed by the addition of sodium hypochlorite, primary coagulant (Propac 9800), and coagulant aid (Propac 9890) if needed. Water then enters the flash mixer before it enters one of two upflow clarifiers that run in parallel.

After sedimentation is complete, the flow is combined via a surge tank and dosed with filter aid (Propac 9890) if needed. Water then flows through one of three dual media filters that run in parallel. After filtration, water runs through two granulated activated carbon units that can be run in series or in parallel. Finally, effluent water is dosed with ortho phosphate for corrosion control and sodium hypochlorite. Finished water enters a clearwell where contact time is achieved. Figure 6.11.2 shows a process diagram of the KCWD's treatment process.

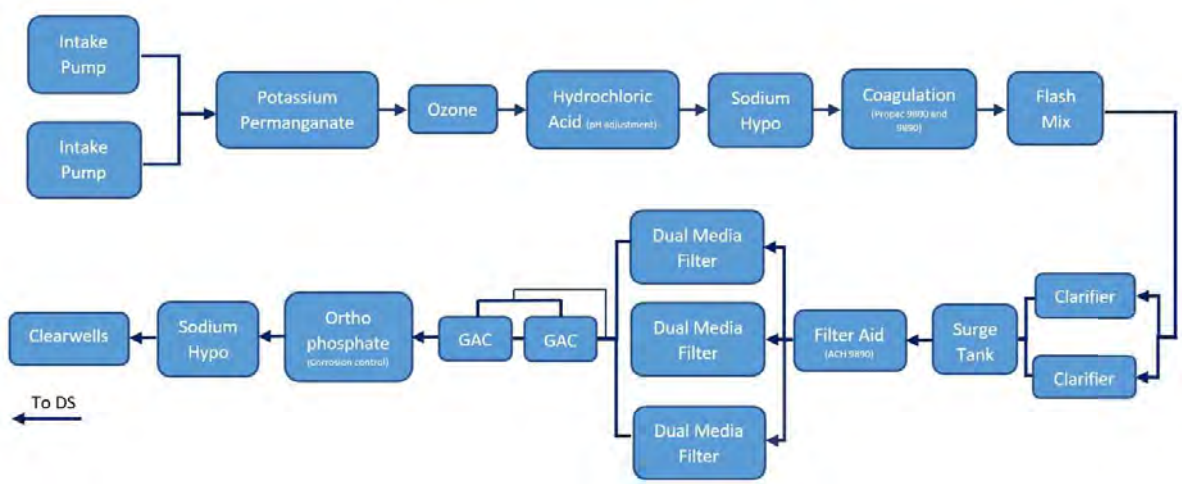


Figure 6.11.2: KCWD Water Treatment Plant Process Diagram

6.11.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The KCWD maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.11.3 shows the KCWD's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to storm events. The Cache Creek dam is located in the Lower Arm and is the only outlet for Clear Lake. Water from storm events flows toward the Lower Arm, resulting in high turbidity. Relative to other utilities in this study, the KCWD has high raw turbidity levels, which is primality due to the Lower Arm's limnology. The highest result was 281 NTU and was recorded on January 8, 2017, and October 11, 2017.

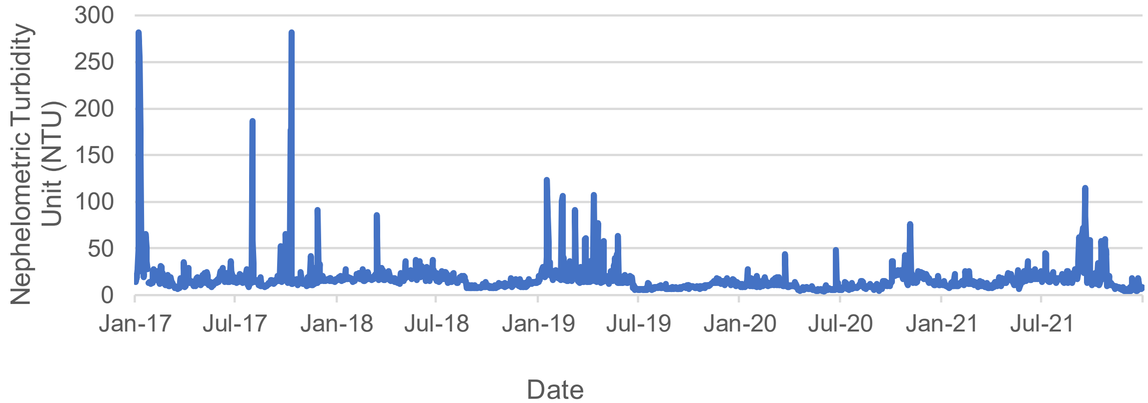


Figure 6.11.3: KCWD Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The KCWD sampled at least monthly at the intake for total coliform and *E. coli*. 2018 was sampled bi-weekly. Table 6.11.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 60% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.11.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the KCWD provides adequate treatment and disinfection for bacteriological quality.

Table 6.11.2: KCWD Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	83	2419.6	20.3	2419.6
Escherichia coli (*E. coli*)	MPN/100mL	83	344.8	ND	3.10

ND: Not Detected

Table 6.11.3: KCWD Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.11.4 and 6.11.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.11.4 and 6.11.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The KCWD had no primary drinking water standard violations between 2017-2021. However, they exceeded the SMCL for aluminum in 2018. This was a discrete event that did not recur during the study period. If the SMCL for aluminum is exceeded again, the KCWD must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

Additionally, the finished water RAA regularly exceeded the SMCL for odor throughout the study period, and exceeded the SMCL for manganese throughout 2021. The finished water RAA for color met but did not exceed the SMCL during Q4 2021. We recommend that the KCWD continue to monitor their finished water quarterly for color, odor and manganese and investigate the possibility of replacing the granulated activated carbon media. Although the SMCL for iron was not exceeded during the study period, finished water results seem to be trending upward. This may reinforce the need to replace the granulated activated carbon media.

Table 6.11.4: KCWD Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 140	ND – 630	None
Arsenic	µg/L	10/--	ND – 4.9	ND – 3	None
Barium	µg/L	1,000/--	ND – 100	ND	None
Fluoride	mg/L	2/--	0.1 – 0.15	ND – 0.11	None
Gross Alpha Particle Activity	pCi/L	15/--	0.81	NA	None

ND: Not Detected NA: Not Available

Table 6.11.5: KCWD Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	200	ND – 140	ND – 630	SMCL exceeded during 2018
Chloride	mg/L	500	7	20 – 50	None
Color	Color Units	15	17	ND – 36	None. RAA met but did not exceed the SMCL during Q4 2021
Conductivity	umho/cm	1,600	250 – 340	290 – 460	None
Sulfate	mg/L	500	3.2	290 – 5.4	None
Total Dissolved Solids	mg/L	1,000	180	180 – 290	None
Iron	µg/L	300	ND – 620	ND – 220	None
Odor	TON	3	17	ND – 63	RAA regularly exceeded the SMCL during the study period.
Manganese	µg/L	50	25 – 77	ND – 230	RAA exceeded the SMCL during 2021

ND: Not Detected

Disinfection Byproducts Precursors

Table 6.11.6 summarizes the KCWD's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.11.6: KCWD Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	120 – 170	4.05 – 8.1	25% - 30%	48%	None
2018	140 – 170	4.8 – 6.8	25%	71%	None
2019	120 – 150	4.58 – 6.45	25%	66%	None
2020	140 – 180	3.95 – 6.29	25%	57%	None
2021	170 – 200	4.23 – 8.39	25% - 30%	54%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.11.7 summarizes compliance with the disinfection byproducts rule (DBPR). No violations were observed.

Table 6.11.7: KCWD Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	12.6 – 79	52	None
Total Haloacetic Acids	µg/L	60	3.6 – 48.7	32.5	None

Lead and Copper Rule (LCR)

Table 6.11.8 summarizes compliance with the Lead and Copper Rule (LCR). The KCWD is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2019. There were no action level exceedances.

Table 6.11.8: KCWD Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	90th Percentile	Violation Description
Lead	µg/L	15	ND	None
Copper	mg/L	1.3	0.33	None

ND: Not Detected

Microcystins Monitoring

Table 6.11.9 and figure 6.11.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710006. The KCWD's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 110µg/L. Relative to other utilities in this study, the KCWD has high microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the KCWD continues to monitor raw and treated water for microcystins in future years.

Table 6.11.9: KCWD Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	26	0.3	110	< 0.15

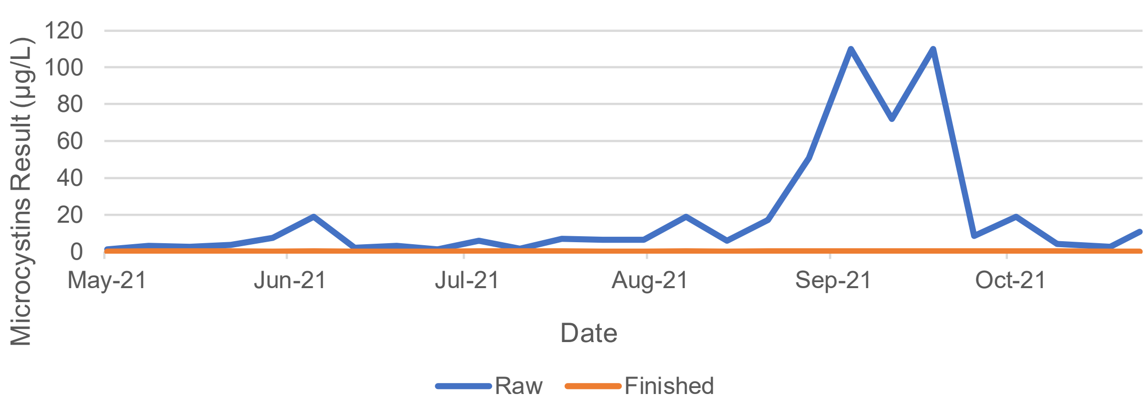


Figure 6.11.4: KCWD Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.11.5 – 6.11.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH, disinfection, and coagulant doses from 2017-2021 show that rising pH during Quarter 3 and Quarter 4 are accompanied by higher coagulation and disinfection doses. The pH data aligns with both microcystins data and visual observation which show Quarter 3 and Quarter 4 to undergo the most severe harmful algal blooms.

Kennard and Sandoval-Solis (2021) conducted a chemical cost analysis for three Clear Lake water treatment plants and found the main chemical cost driver to be primary coagulant. All other chemicals, including sodium hypochlorite, are insignificant when comparing actual chemical costs. They found that the chemical cost per thousand gallons of water produced during Quarter 3 and Quarter 4 increased by up to four times the chemical cost required during Quarter 1 and 2.

The KCWD installed a hydrochloric acid feed system in 2019, which is anticipated to decrease demand for primary coagulant and disinfectant during bloom events. However, coagulant dosages were not changed in response to optimal pH levels until 2021. We recommend that this analysis be updated with new data during the 2026 sanitary survey to compare average chemical demand before and after coagulant dosages were adjusted in response to optimal pH levels. A corresponding chemical cost analysis can also shed light on the long-term savings produced by the acid feed system.

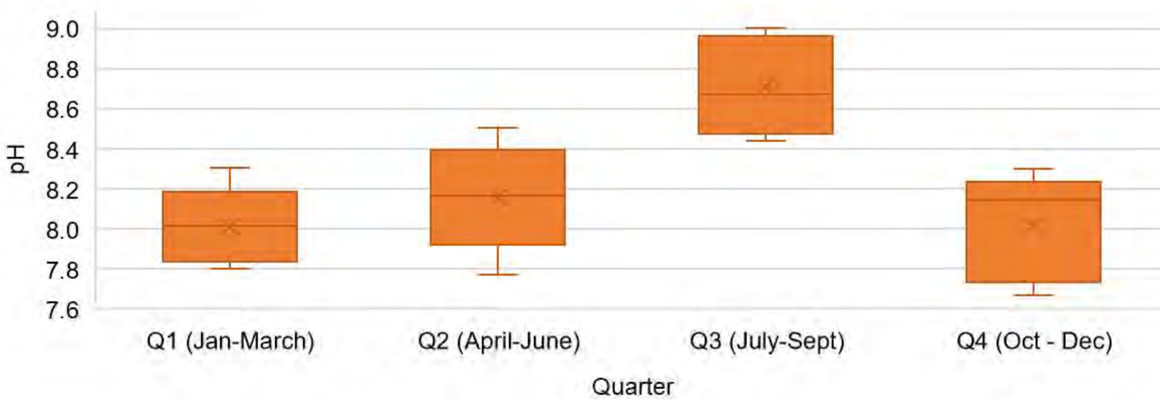


Figure 6.11.5: KCWD Quarterly Aggregate pH (2017-2021)

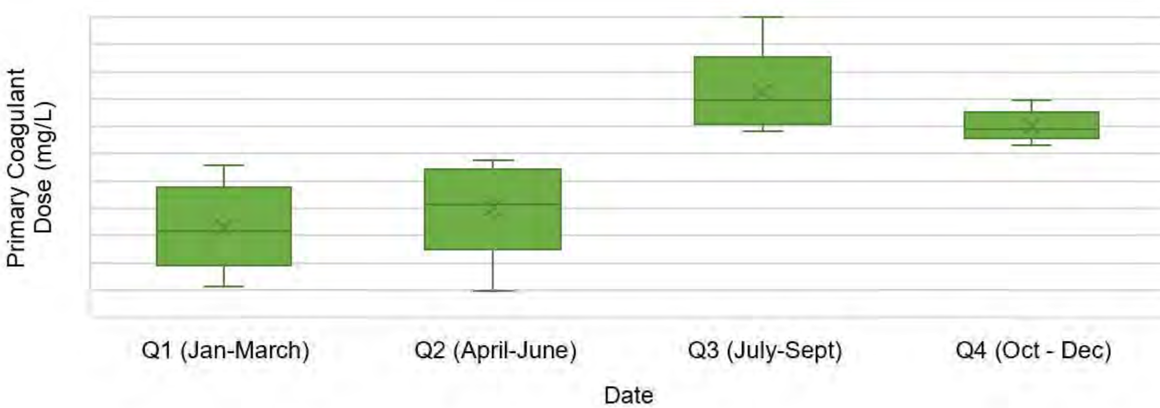


Figure 6.11.6: KCWD Quarterly Aggregate Primary Coagulant Dose (2020-2021)

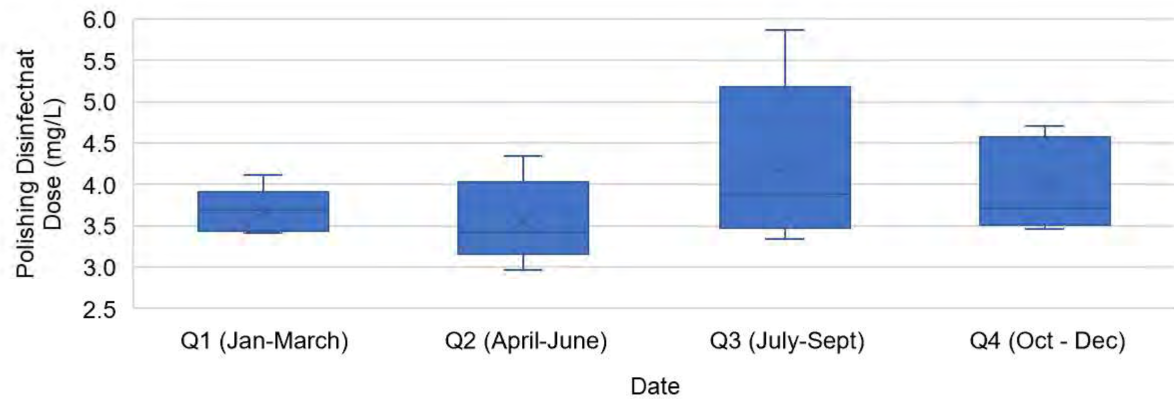


Figure 6.11.7: KCWD Quarterly Aggregate Sodium Hypochlorite Dose (2017-2021)

Ammonia

Ammonia monitoring is taken in accordance with the KCWD Disinfection Plan and Ammonia and Free Chlorine Monitoring Plan. Monitoring data between 2017-2021 was sparse and do not show data trends. The KCWD Disinfection Plan and Ammonia and Free Chlorine Monitoring Plan helps the KCWD better manage chlorine dosages and chloramine formation.

6.12- KONOCTI HARBOR RESORT

6.12.1- Water System Summary

The Konocti Harbor Resort (KHR) is located immediately southeast of Buckingham Peninsula on the Lower Arm (Figure 6.12.1). The KHR is a disadvantaged community (DAC). It has a total of 33 connections (2 residential and 31 commercial) and serves a population of 75. Additional system information is outlined in Table 6.12.1

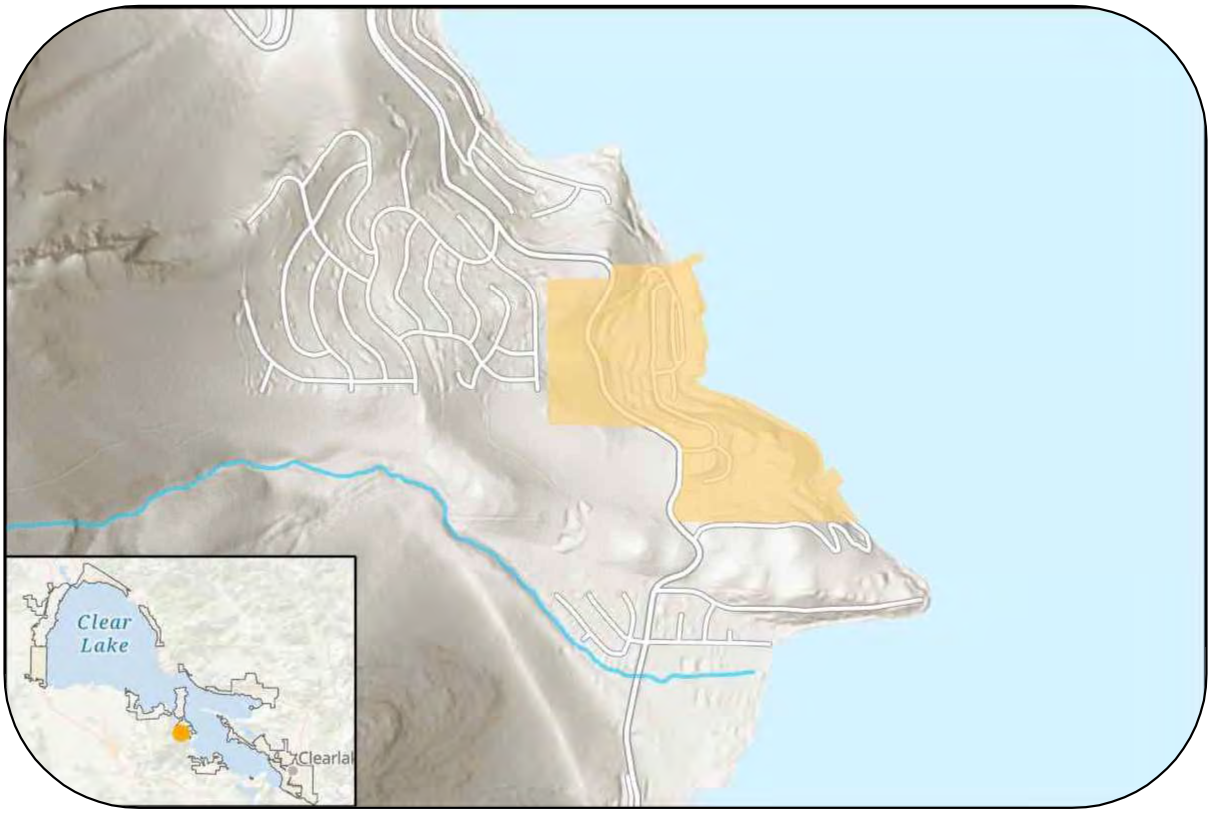


Figure 6.12.1: KHR System Boundary Map

Table 6.12.1: KHR System Attributes

System Name	**Address**	
Konocti Harbor Resort	8727 Soda Bay Road, Kelseyville, CA 95451	
Public Water System No.	**Connection Count**	**Population**
CA1710016	33	75
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Non-transient Non-community Water System	Intake/Active	150/0.22
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
Data not provided by utility	D1	T3

6.12.2- Treatment, Operations, and Infrastructure Upgrades

Data pertaining to the water treatment system was not provided by the utility. The following information was taken from the 2012 Sanitary Survey. The treatment plant is a conventional treatment plant containing a raw water pump, pre-chlorination with sodium hypochlorite, coagulation with alum, one solid contact clarifier, two pressure filters, granulated activated carbon treatment, disinfection with sodium hypochlorite, and finished water storage.

6.2.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The KHR maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Turbidity data was not provided by the utility.

Bacteriological Water Quality & The Total Coliform Rule

Bacteriological water quality data was not provided by the utility.

Primary and Secondary Standards

Tables 6.12.2 and 6.12.3 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.12.2 and 6.12.3 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The KHR had no primary drinking water standard violations between 2017-2021. However, the finished water RAA regularly exceeded the SMCL for odor throughout the study period. We recommend that the KHR continue to monitor their finished water quarterly for odor and investigate the possibility of replacing the granulated activated carbon media.

Additionally, the SMCL for manganese was exceeded during 2021. It is recommended that the KHR monitor quarterly for manganese at the intake and after treatment to see if manganese is removed by the treatment process. Because the SMCL for manganese was exceeded during 2021, the KHR must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

Table 6.12.2: KHR Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 90	NA	None
Arsenic	µg/L	10/--	ND – 6.8	NA	None
Barium	µg/L	1,000/--	ND – 110	NA	None
Chromium, total	µg/L	50/--	ND – 1.2	NA	None
Fluoride	mg/L	2/--	0.13 – 0.26	NA	None

ND: Not Detected

Table 6.12.3: KHR Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	7.5 – 11	NA	None
Color	Color Units	15	ND – 25	ND – 5	None
Conductivity	umho/cm	1,600	280 – 400	NA	None
Sulfate	mg/L	500	3.5 – 6.9	NA	None
Total Dissolved Solids	mg/L	1,000	160 – 310	NA	None
Iron	µg/L	300	110 – 270	NA	None
Odor	TON	3	ND - 100	ND – 40	The finished water RAA exceeded the SMCL for odor throughout the study period.
Manganese	µg/L	50	ND – 89	NA	The SMCL for manganese was exceeded during 2021.

ND: Not Detected NA: Not Available

Disinfection Byproducts Precursors

The KHR is not required to calculate TOC removal because of their status as a non-transient non-community water system.

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.12.4 summarizes compliance with the disinfection byproducts rule (DBPR). The KHR regularly exceeded the MCL for total trihalomethanes throughout the study period. Adding aeration mechanisms in water storage tanks as well as replacing pre-chlorination with the addition of potassium permanganate may reduce the levels of total trihalomethanes in finished water.

Table 6.12.4: KHR Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	30.9 – 129.6	106.3	The LRAA exceeded the MCL regularly throughout the study period
Total Haloacetic Acids	µg/L	60	20.5 – 49.2	46.0	None

Lead and Copper Rule (LCR)

Table 6.12.5 summarizes compliance with the Lead and Copper Rule (LCR). The KHR is required to monitor under the LCR every six months. Monitoring during 2017-2021 took place in 2017 and 2021. There were no action level exceedances.

Table 6.12.5: KHR Lead and Copper Monitoring (2017 & 2021)

Analyte	Units	Action Level	Year	90th Percentile	Violation Description
Lead	µg/L	15	2021 (Nov)	ND	None
			2021 (April)	ND	None
			2017 (Aug)	5.8	None
			2017 (Feb)	ND	None
Copper	mg/L	1.3	2021 (Nov)	0.138	None
			2021 (April)	0.685	None
			2017 (Aug)	0.18	None
			2017 (Feb)	0.135	None

ND: Not Detected

Microcystins Monitoring

Table 6.12.6 and figure 6.12.2 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710016. The KHR's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 19µg/L. Relative to other utilities in this study, the KHR has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the KHR continues to monitor raw and treated water for microcystins in future years.

Table 6.12.6: KHR Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	22	0.3	19	<0.15

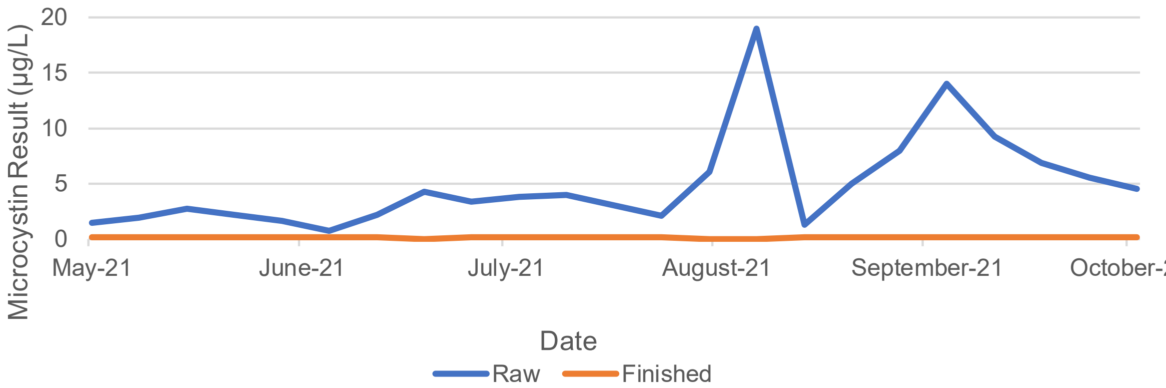


Figure 6.12.2: KHR Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

The KHR does not regularly track coagulant and disinfection dosages, therefore, a relationship between harmful algal blooms and chemical additives cannot be determined.

Ammonia

The KHR does not regularly monitor for ammonia. Monitoring regularly for ammonia in the future may help the KHR better manage chlorine dosages and chloramine formation.

LAKE COUNTY SPECIAL DISTRICTS - NORTH LAKEPORT

6.13.1- Water System Summary

The Lake County Special Districts Community Service Area (CSA) # 21 – North Lakeport (LCSD-NL) is located immediately south of the Rodman Slough on the Upper Arm of Clear Lake (Figure 6.13.1). The LCSD-NL is a severely disadvantaged community (SDAC). It has a total of 1,291 connections (1,245 residential and 46 commercial) and serves a population of 4,260. The system has three pressure zones due to the varied topography of the area. It has one surface water treatment plant, four storage tanks, and two booster pump stations. Additional system information is outlined in Table 6.13.1.

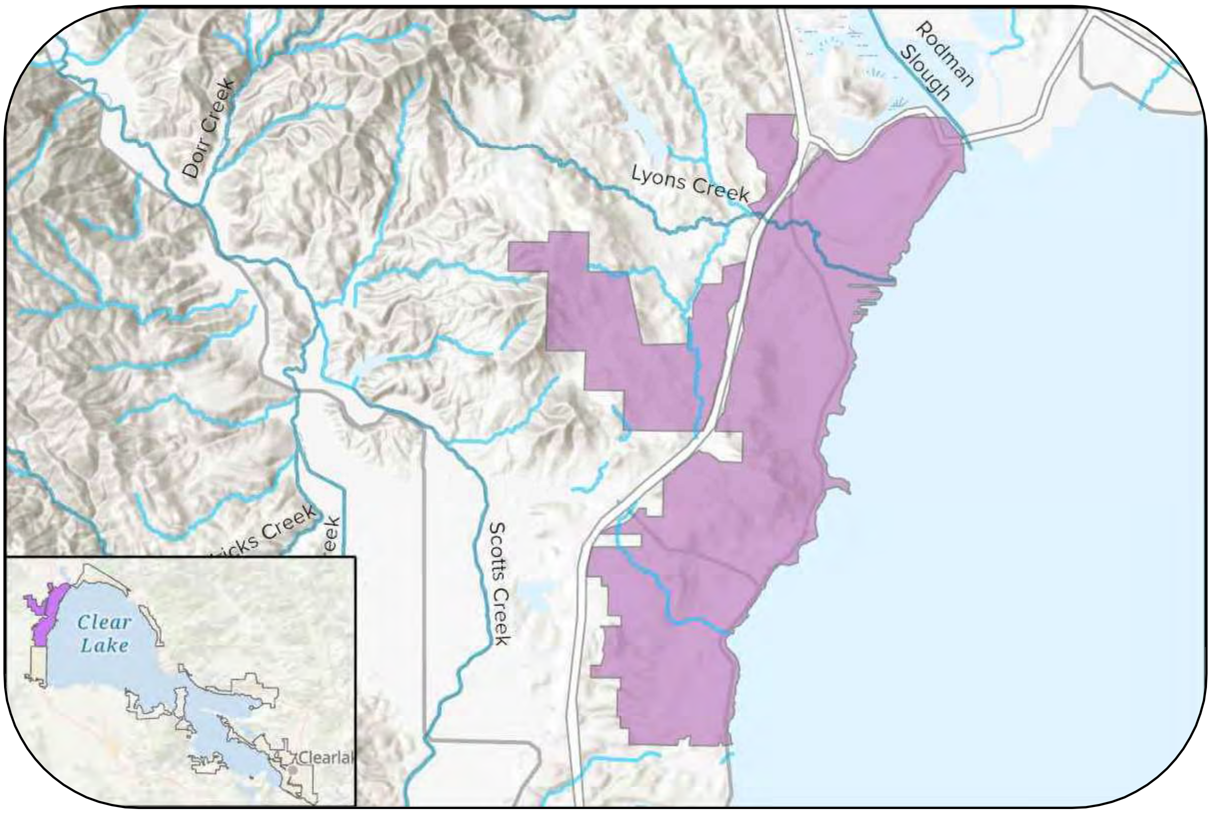


Figure 6.13.1: LCSD-NL System Boundary Map

Table 6.13.1: LCSD-NL System Attributes

System Name	Address	
Lake County CSA 21 – North Lakeport	230 N. Main Street, Lakeport CA 95453	
Public Water System No.	**Connection Count**	**Population**
CA1710021	1,291	4,260
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community	Intake/Active	750/1.08
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
20 x 2	D2	T3

6.13.2- Treatment, Operations, and Infrastructure Upgrades

The LCSD-NL treatment plant consists of two raw water pumps, a strainer, an ozone tower, a static mixer, a flash mixer, three Trident package plants, and three granulated activated carbon (GAC) units. Raw water is pumped through one of two twenty horsepower intake pumps to a strainer where larger materials are removed prior to treatment. Water is then pumped to the top of the ozone vessel where it flows down a cascade of baffles and comes into contact with ozone. After ozonation, Propc 9890 (primary coagulant) and PA50 (floc aide) is injected into a static mixer followed by an Archimedes screw for flash mix. Then the water splits into three Trident treatment trains that run parallel. Three identical trains are operated at 225gpm each with a maximum of 350gpm each. The package plants are both a clarifier and mixed media filter. After filtration, water flows into one of three GAC units that run in parallel, injected with chlorine gas, and sent to the clearwell where adequate contact time is achieved. Figure 6.13.2 shows a process diagram of the LCSD-NL's treatment process.

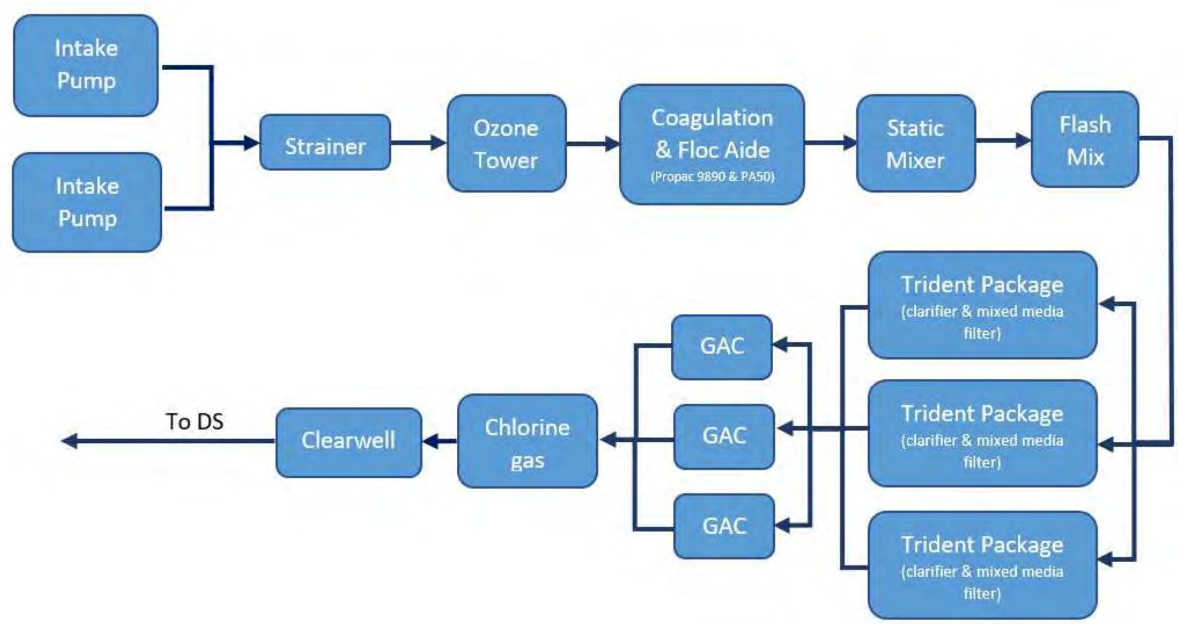


Figure 6.13.2: LCSD-NL Water Treatment Plant Process Diagram

6.13.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The LCSD-NL maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.13.3 shows the LCSD-NL raw daily turbidity data from 2017-2021. Peaks correspond to both harmful algal blooms and storm events. Due to the LCSD-NL's proximity to the Rodman Slough, they are especially susceptible to high turbidity from storm events. Relative to other utilities in this study, the LCSD-NL has high raw turbidity levels. The highest results were 300 NTU, which were recorded throughout the study period.

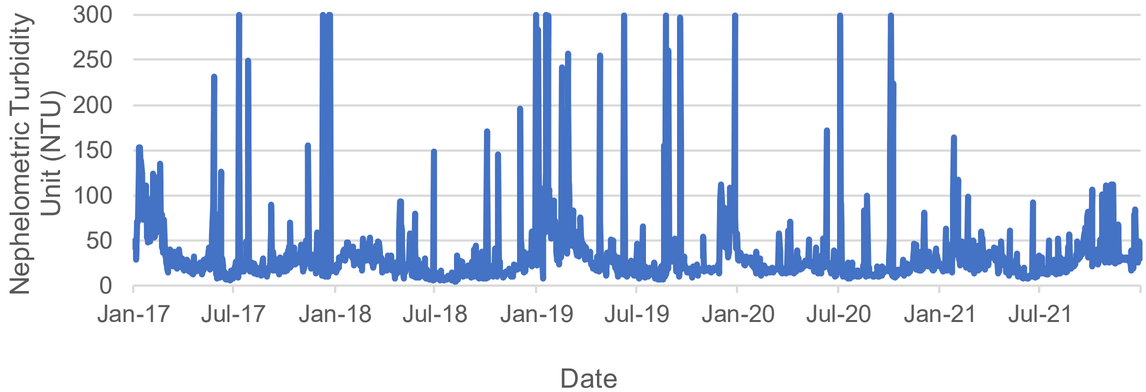


Figure 6.13.3: LCSD-NL Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The LCSD-NL sampled at least monthly at the intake for total coliform and *E. coli*. Table 6.13.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 43% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.13.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the LCSD-NL provides adequate treatment and disinfection for bacteriological quality.

Table 6.13.2: LCSD-NL Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	60	> 2,419.6	32.3	1,483.4
Escherichia coli (*E. coli*)	MPN/100mL	60	51.2	ND	ND

ND: Not Detected

Table 6.13.3: LCSD-NL Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.13.4 and 6.13.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.13.4 and 6.13.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The LCSD-NL had no primary drinking water standard violations between 2017-2021. However, the finished water RAA regularly exceeded the SMCL for odor throughout the study period. We recommend that the LCSD-NL continue to monitor their finished water for odor and investigate the possibility of replacing the granulated activated carbon media.

Table 6.13.4: LCSD-NL Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 120	NA	None
Arsenic	µg/L	10/--	2.1 – 8.9	NA	None
Fluoride	mg/L	2/--	ND – 0.21	NA	None

ND: Not Detected   NA: Not Available

Table 6.13.5: LCSD-NL Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	5.8 – 7.6	11 – 17	None
Color	Color Units	15	ND – 34	10 – 11	None
Conductivity	umho/cm	1,600	240 – 310	300 – 370	None
Sulfate	mg/L	500	3.6 – 5.2	4.0 – 5.9	None
Total Dissolved Solids	mg/L	1,000	160 – 190	190 – 230	None
Foaming Agents (MBAS)	mg/L	0.5	ND – 0.1	ND	None
Iron	µg/L	300	110 – 170	ND	None
Odor	TON	3	ND – 130	2.2 – 100.0	Finished water RAAs regularly exceeded the SMCL throughout the study period.
Manganese	µg/L	50	58 – 380	ND - 31	None

ND: Not Detected

Disinfection Byproducts Precursors

Total organic carbon (TOC) removal requirements do not apply to the LCSD-NL because the water treatment plant utilizes an alternative treatment process.

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.13.6 summarizes compliance with the disinfection byproducts rule (DBPR). No violations were observed.

Table 6.13.6: LCSD-NL Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	23.5 – 98.72	66.6	None
Total Haloacetic Acids	µg/L	60	ND – 81.9	50.2	None

Lead and Copper Rule (LCR)

Table 6.13.7 summarizes compliance with the Lead and Copper Rule (LCR). The LCSD-NL is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2018 and 2021. There were no action level exceedances.

Table 6.13.7: LCSD-SB Lead and Copper Monitoring (2018 & 2021)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	µg/L	15	2018	6.6	None
			2021	5	None
Copper	mg/L	1.3	2018	0.75	None
			2021	0.14	None

ND: Not Detected

Microcystins Monitoring

Table 6.13.8 and figure 6.13.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_017_ CA1710021. The LCSD-NL water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest raw water concentration of microcystins was 1.7µg/L. Relative to other utilities in this study, the LCSD-NL has low microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the LCSD-NL continues to monitor raw and treated water for microcystins in future years.

Table 6.13.8: LCSD-NL Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	21	0.3	1.7	< 0.15

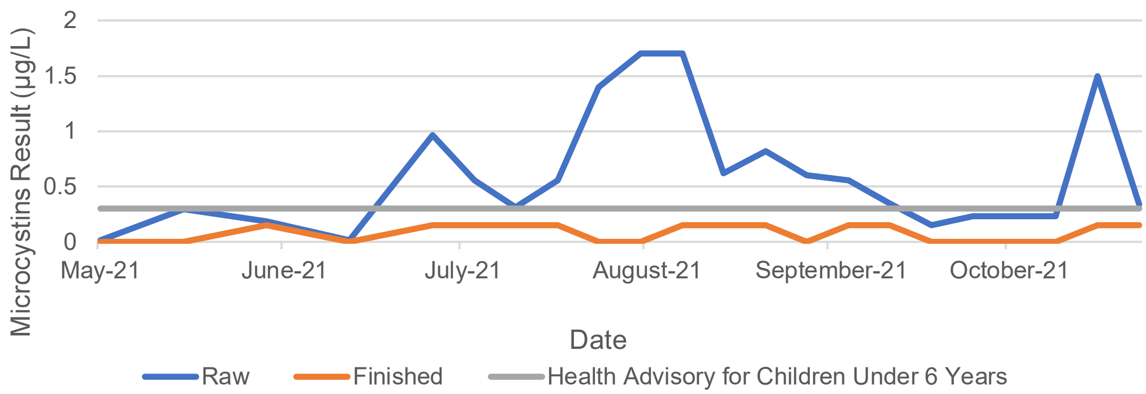


Figure 6.13.4: LCSD-NL Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.13.5 – 6.13.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH, coagulant doses, and disinfection doses from 2017-2020 show that rising pH during Quarter 3 and Quarter 4 are accompanied by higher disinfection doses, though there is no such relationship with coagulant doses. Relative to other purveyors in this study, the relationship between raw pH, coagulant, and disinfectant is less clear for the LCSD-NL. This is most likely due to the relatively mild increases in pH throughout the year, which allows the LCSD-NL to maintain a year-round coagulant dose of roughly 16-20mg/L and a year-round disinfectant dose of roughly 2.0-2.3mg/L. Additionally, the use of ozone at the headworks can also decrease the demand for chemical additives. LCSD-NL utilizes streaming current monitor to optimize coagulant dosages. Therefore, we do not have any recommendations to improve the LCSD-NL treatment plant at this time.

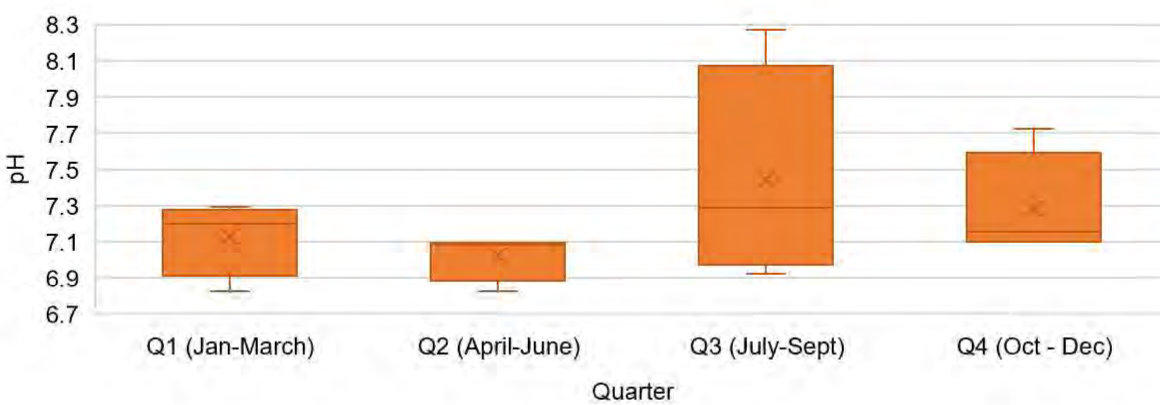


Figure 6.13.5: LCSD-NL Quarterly Aggregate pH (2017-2020)

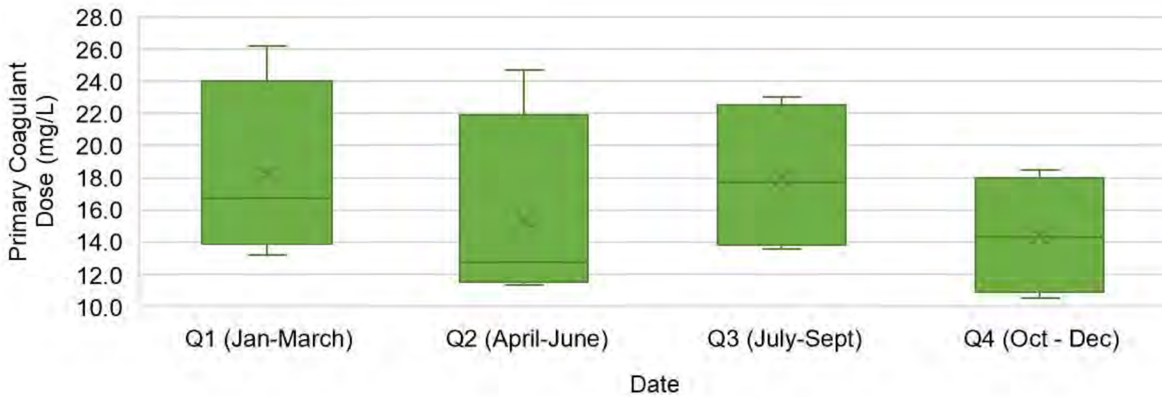


Figure 6.13.6: LCSD-NL Quarterly Aggregate Coagulant Dose (2017-2020)

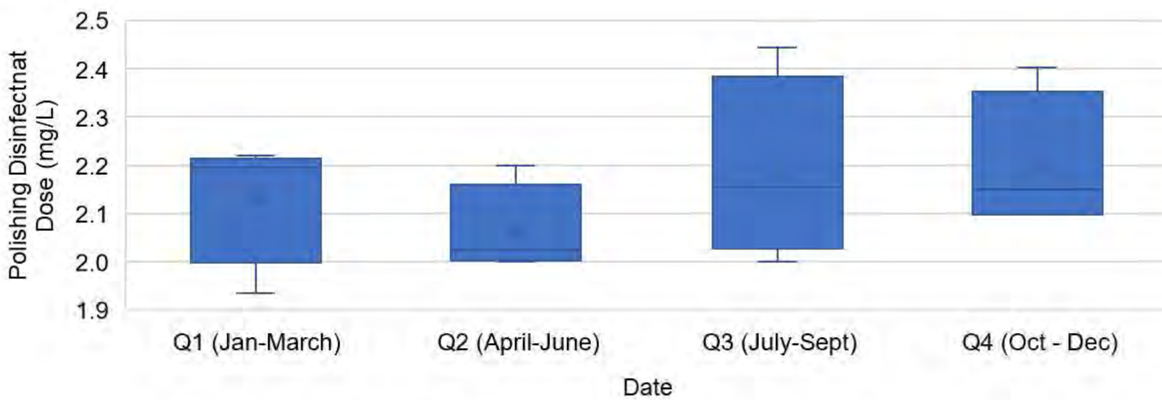


Figure 6.13.7: LCSD-NL Quarterly Aggregate Chlorine Gas Dose (2017-2020)

Ammonia

The LCSD-NL does not regularly monitor for ammonia. Monitoring for ammonia in the future may help the LCSD-NL better manage chlorine dosages and chloramine formation.

6.14- LAKE COUNTY SPECIAL DISTRICTS - SODA BAY

6.14.1- Water System Summary

The Lake County Special Districts Community Service Area (CSA) # 20 – Soda Bay (LCSD-SB) is located immediately west of Buckingham Peninsula on the Upper Arm of Clear Lake (Figure 6.14.1). As of 2022, the LCSD-SB is not classified as a disadvantaged community (DAC). It has a total of 662 connections (655 residential and 7 commercial) and serves a population of 2,185. The system has six pressure zones due to the varied topography of the area. It has one surface water treatment plant, six storage tanks, and three booster pump stations. Additional system information is outlined in Table 6.14.1.

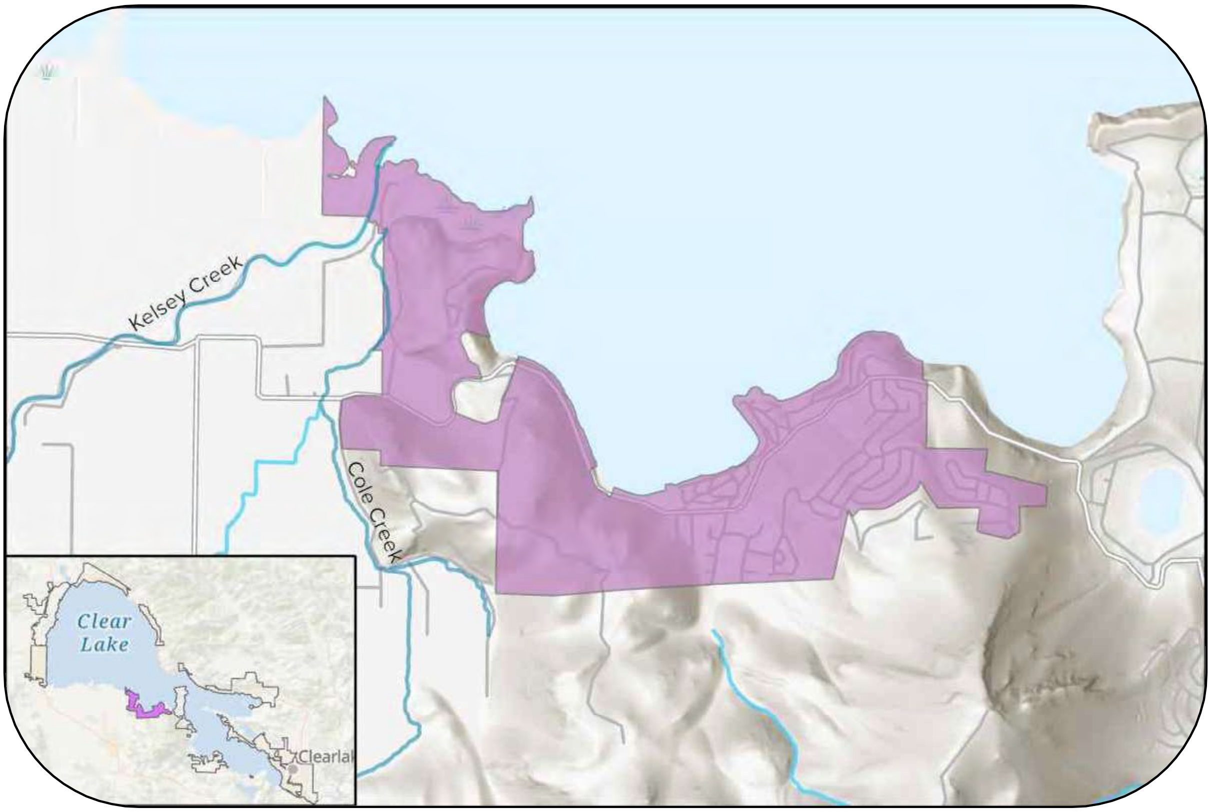


Figure 6.14.1: LCSD-SB System Boundary Map

Table 6.14.1: LCSD-SB System Attributes

System Name	Address	
Lake County CSA 20 – Soda Bay	230 N. Main Street, Lakeport CA 95453	
Public Water System No.	**Connection Count**	**Population**
CA1710022	662	2,185
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community	Intake/Active	400/0.576
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
25 x 2	D3	T3

6.14.2- Treatment, Operations, and Infrastructure Upgrades

The LCSD-SB water treatment plant consists of two raw water pumps, an ozone contact vessel, a static mixer, two trident package plants, and two granulated activated carbon (GAC) filters. Raw water is pumped through one of two twenty-five horsepower intake pumps to the top of the ozone vessel where it flows down a cascade of baffles and comes into contact with ozone. After ozonation, Propac 9890 (primary coagulant) is injected into a static mixer. The flow then splits into two Trident package treatment trains that run parallel and can handle 200gpm each. The package plants are both a clarifier and mixed media filter. After filtration, water flows into a series of two GAC units and injected with sodium hypochlorite. Water then enters the clearwell where adequate contact time is achieved. Figure 6.14.2 shows a process diagram of the LCSD-SB's treatment process.

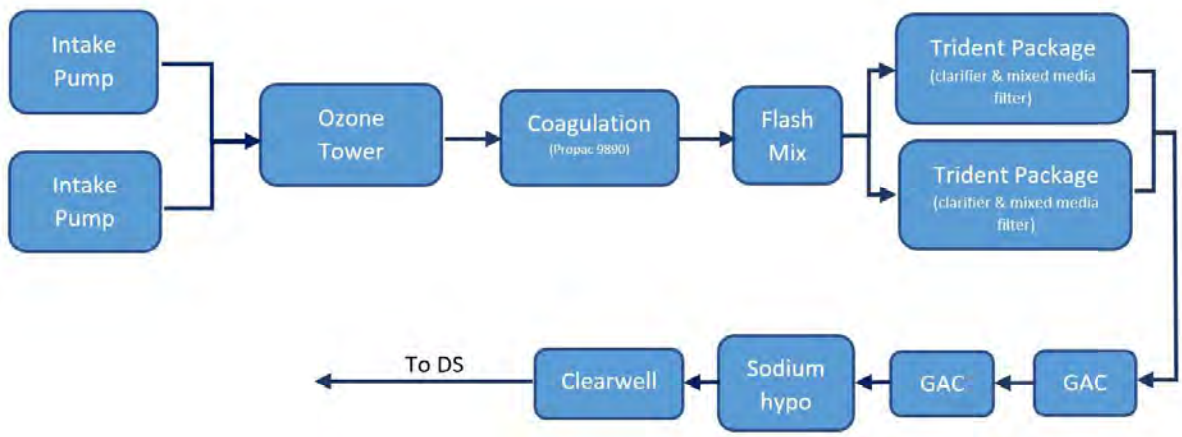


Figure 6.14.2: LCSD-SB Water Treatment Plant Process Diagram

6.14.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The LCSD-SB maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.14.3 shows the LCSD-SB's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms, but most peaks align with storm events. Although the LCSD-SB is located in the Upper Arm, which is known for heavy silting, the intake is located in a quiescent cove that is largely shielded from heavy sedimentation. Turbidity from storm events averages around 10-15 NTU whereas other purveyors with intakes that are more exposed to sedimentation have regular spikes up to 200 NTU. Relative to other utilities in this study, the LCSD-SB has low to moderate raw turbidity levels. The highest result was in March 2019 and July 2021 with a result of 20 NTU.

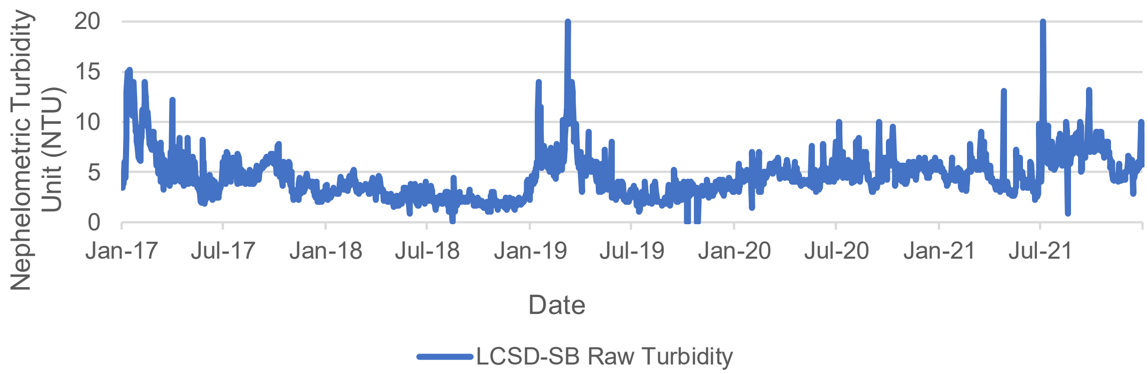


Figure 6.14.3: LCSD-SB Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The LCSD-SB sampled at least monthly at the intake for total coliform and *E. coli*. Table 6.14.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 32% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.14.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the LCSD-SB provides adequate treatment and disinfection for bacteriological quality.

Table 6.14.2: LCSD-SB Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	59	2,419.6	ND	1,101.2
Escherichia coli (*E. coli*)	MPN/100mL	59	238.2	ND	ND

ND: Not Detected

Table 6.14.3: LCSD-SB Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.14.4 and 6.14.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.14.4 and 6.14.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The LCSD-SB exceeded the MCL for aluminum in

2019. This was a discrete event and did not reoccur during the study period. We recommend collecting an aluminum sample at the treatment plant effluent to determine if levels are reduced during treatment. If the treated results exceed the MCL, the LCSD-SB must notify the regulator within 48 hours and commence with quarterly sampling. The LCSD-SB may instead inform the regulator within seven days and collect a confirmation sample within fourteen days per 22 CCR § 64432. The LCSD-SB is still required to collect raw water aluminum samples regardless of whether treated samples are collected.

Likewise, the SMCL for aluminum was exceeded in 2017 and 2019. If the SMCL is exceeded again, the LCSD-SB must monitor quarterly and base compliance on the running annual average per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency. Finally, finished water results regularly exceeded the SMCL for odor throughout the study period. We recommend that the LCSD-SB continue to monitor their finished water for odor and investigate the possibility of replacing the granulated activated carbon media. It may also be beneficial to look into the feasibility of pre-treatment with potassium permanganate to decrease odor in finished water.

Table 6.14.4: LCSD-SB Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 1,700	NA	MCL exceeded in 2019
Arsenic	µg/L	10/--	ND – 4.1	NA	None
Barium	µg/L	1,000/--	ND – 120	NA	None
Fluoride	mg/L	2/--	ND – 0.13	NA	None
Nickel	µg/L	100	ND – 14	NA	None

ND: Not Detected   NA: Not Available

Table 6.14.5: LCSD-SB Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	200	ND – 1,700	NA	SMCL exceeded in 2017 & 2019
Chloride	mg/L	500	5.6 – 7.3	12 – 14	None
Color	Color Units	15	14 – 30	ND	None
Conductivity	umho/cm	1,600	250 – 290	340 – 380	None
Sulfate	mg/L	500	4.2 – 7.0	5.0 – 5.8	None
Total Dissolved Solids	mg/L	1,000	140 – 160	210 – 230	None
Iron	µg/L	300	110 – 3,300	ND	None
Odor	TON	3	ND – 20	ND – 63	SMCL regularly exceeded throughout the study period
Manganese	µg/L	50	40 – 530	ND	None

ND: Not Detected

Disinfection Byproducts Precursors

Total organic carbon (TOC) removal requirements do not apply to the LCSD-SB because the water treatment plant utilizes an alternative treatment process.

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.14.6 summarizes compliance with the disinfection byproducts rule (DBPR). No violations were observed.

Table 6.14.6: LCSD-SB Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	1.18 – 85.62	62.7	None
Total Haloacetic Acids	µg/L	60	8.5 – 70.1	58.0	None

Lead and Copper Rule (LCR)

Table 6.14.7 summarizes compliance with the Lead and Copper Rule (LCR). The LCSD-SB is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2017 and 2020. There were no action level exceedances.

Table 6.14.7: LCSD-SB Lead and Copper Monitoring (2017 & 2020)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	µg/L	15	2017	ND	None
			2020	ND	None
Copper	mg/L	1.3	2017	0.91	None
			2020	0.73	None

ND: Not Detected

Microcystins Monitoring

Table 6.14.8 and figure 6.14.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_018_ CA1710022. The LCSD-SB's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 0.93µg/L. Relative to other utilities in this study, the LCSD-SB has low microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the LCSD-SB continues to monitor raw and treated water for microcystins in future years.

Table 6.14.8: LCSD-SB Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	18	0.3	0.93	< 0.15

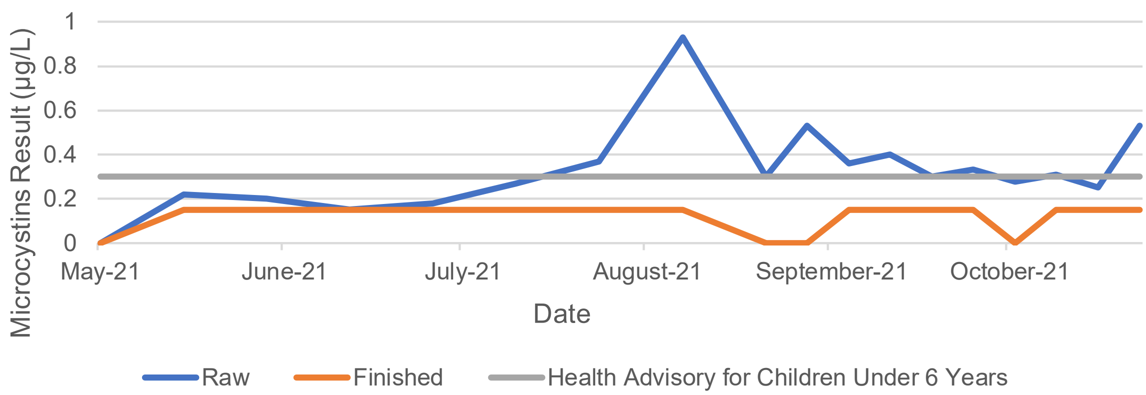


Figure 6.14.4: LCSD-SB Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.14.5 – 6.14.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH, coagulant doses, and disinfection doses from 2017-2021 show that rising pH during Quarter 3 are accompanied by higher coagulation and disinfection doses. The pH data aligns with both microcystins data and visual observation which show Quarter 3 to undergo the most severe harmful algal blooms.

Kennard and Sandoval-Solis (2021) conducted a chemical cost analysis for three Clear Lake water treatment plants and found the main chemical cost driver to be primary coagulant. All other chemicals, including sodium hypochlorite, are insignificant when comparing actual chemical costs. They found that the chemical cost per thousand gallons of water produced during Quarter 3 and Quarter 4 increased by up to four times the chemical cost required during Quarter 1 and 2. To decrease water treatment costs, it is recommended that the LCSD-SB implement an acid feed station at the intake to decrease raw water pH before primary coagulant is added.

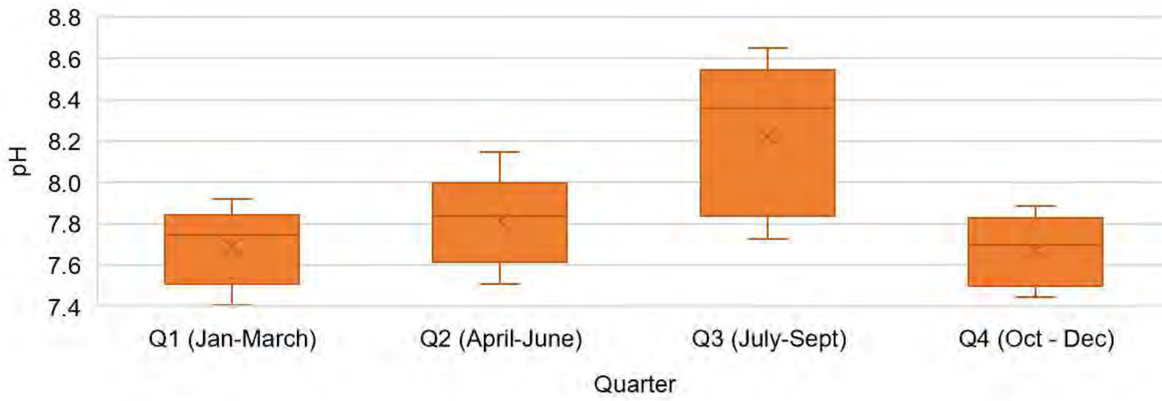


Figure 6.14.5: LCSD-SB Quarterly Aggregate pH (2017-2021)

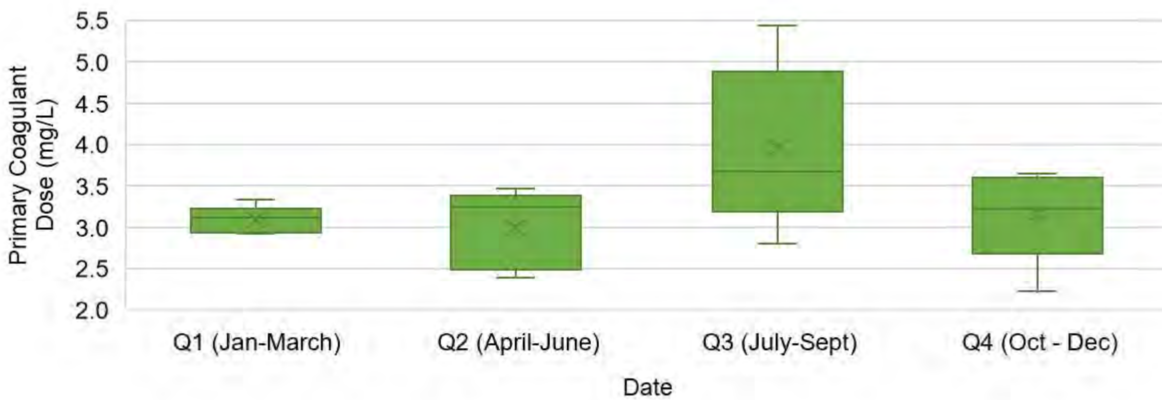


Figure 6.14.6: LCSD-SB Quarterly Aggregate Coagulant Dose (2017-2021)

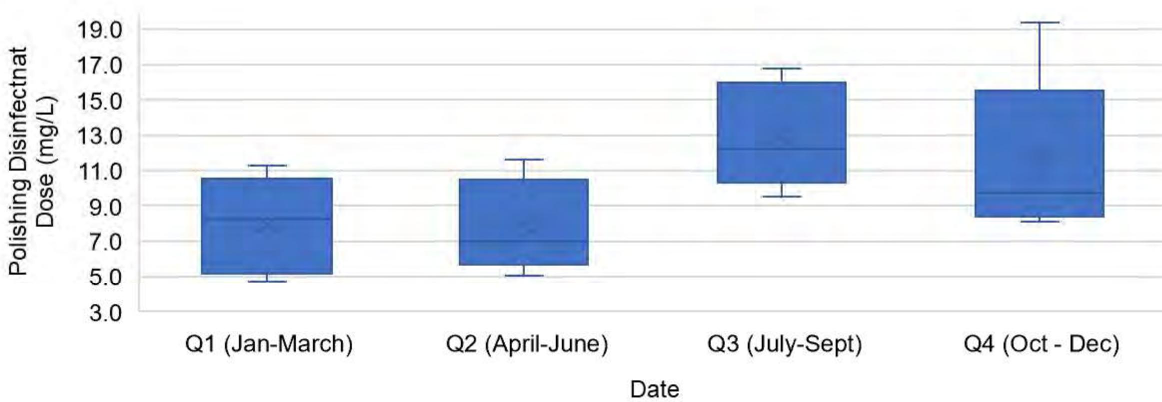


Figure 6.14.7: LCSD-SB Quarterly Aggregate Sodium Hypochlorite Dose (2017-2021)

Ammonia

The LCSD-SB does not regularly monitor for ammonia. Monitoring for ammonia in the future may help the LCSD-SB better manage chlorine dosages and chloramine formation.

6.15- MOUNT KONOCTI MUTUAL WATER COMPANY

6.15.1- Water System Summary

The Mt. Konocti Mutual Water Company (MKMWC) is located on the Lower Arm of Clear Lake (Figure 6.15.1). The MKMWC is classified as an economically distressed area. It has a total of 1,595 connections (1,580 residential, 14 commercial, and 1 agricultural) and serves a population of 4,360. The system has nine pressure zones due to the varied topography of the area. It has one surface water treatment plant, nine storage tanks totaling 1.5 million gallons, and five booster pump stations. Additional system information is outlined in Table 6.15.1.

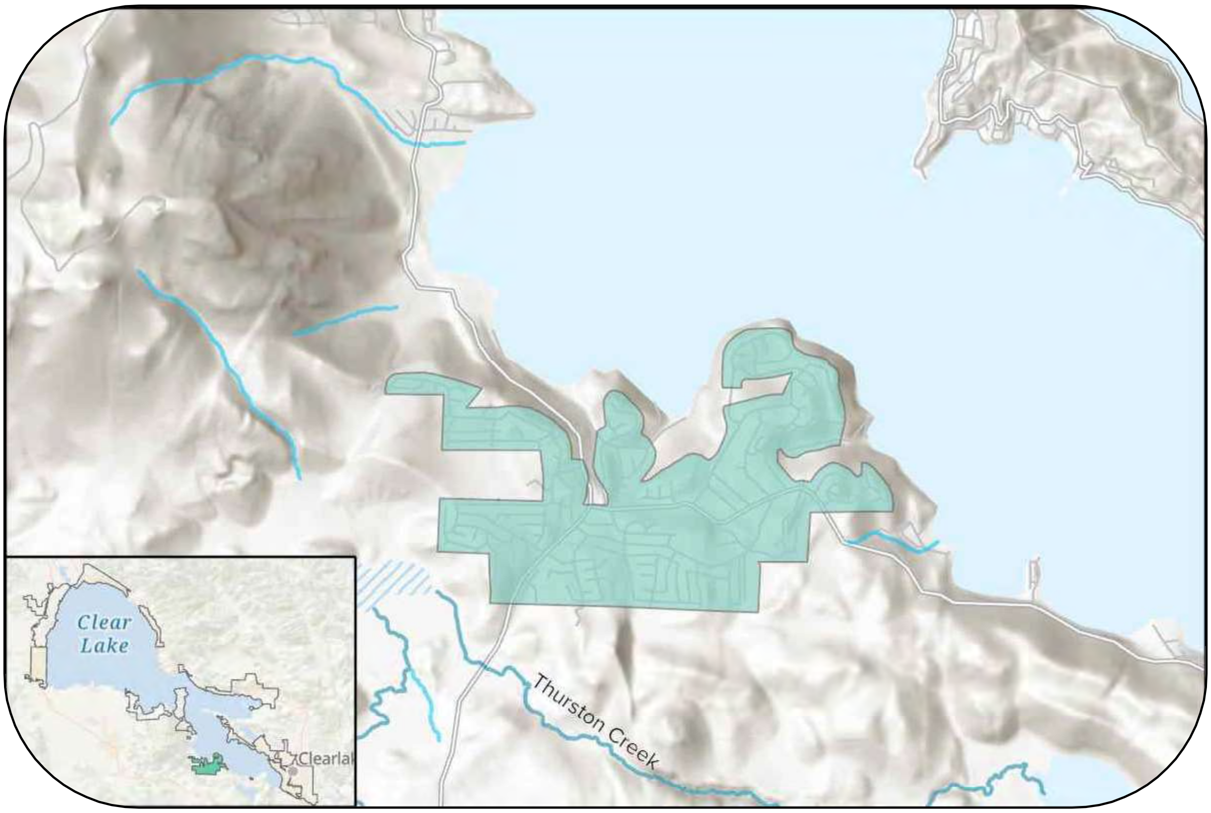


Figure 6.15.1: MKMWC System Boundary Map

Table 6.15.1: MKMWC System Attributes

System Name	Address	
Mt. Konocti Mutual Water Company	4905 Hawaina Way, Kelseyville CA 95451	
Public Water System No.	**Connection Count**	**Population**
CA1710014	1,595	4,360
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community	Intake/Active	700/1.0
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
100 x 1; 125 x 2	D3	T3

6.15.2- Treatment, Operations, and Infrastructure Upgrades

The MKMWC treatment plant is a conventional water treatment plant consisting of three raw water pumps, two up-flow clarifiers, two surge tanks, two dual-media pressure filters, and four granulated activated carbon filters. Raw water is pumped through one of three intake pumps and dosed with sodium hypochlorite or potassium permanganate. Sodium hypochlorite and potassium permanganate are optional chemical additions that are interchanged on a seasonal basis. Sodium hypochlorite is used as needed during the winter and spring while potassium permanganate, which has a lower disinfection byproduct formation potential and does not immediately lyse cyanobacterial cells, is used as needed during the summer and fall as a pre-oxidant.

Water is then dosed with Propac 9800 before it enters into one of two upflow clarifiers that run in parallel. Flocculation occurs in the mixing cone and sedimentation causes floc to sink and settled water to flow upwards towards the weirs. Water entering the weirs empties into a surge tank. Flow from the two surge tanks is combined and water is dosed with sodium hypochlorite and a filter aid (Propac 9890) as needed, to assist when settled turbidity is high from organic loading. Water then enters one of two dual media filters (anthracite and sand) that run in parallel. Flow is combined and enters one of two granulated activated carbon trains each consisting of two units that run in parallel. Finally, water is dosed with sodium hypochlorite for disinfection and zinc orthophosphate for corrosion control. Finished water then enters into a 300,000-gallon redwood clearwell where adequate contact time is achieved. Figure 6.15.2 shows a process diagram of the MKMWC's treatment process.

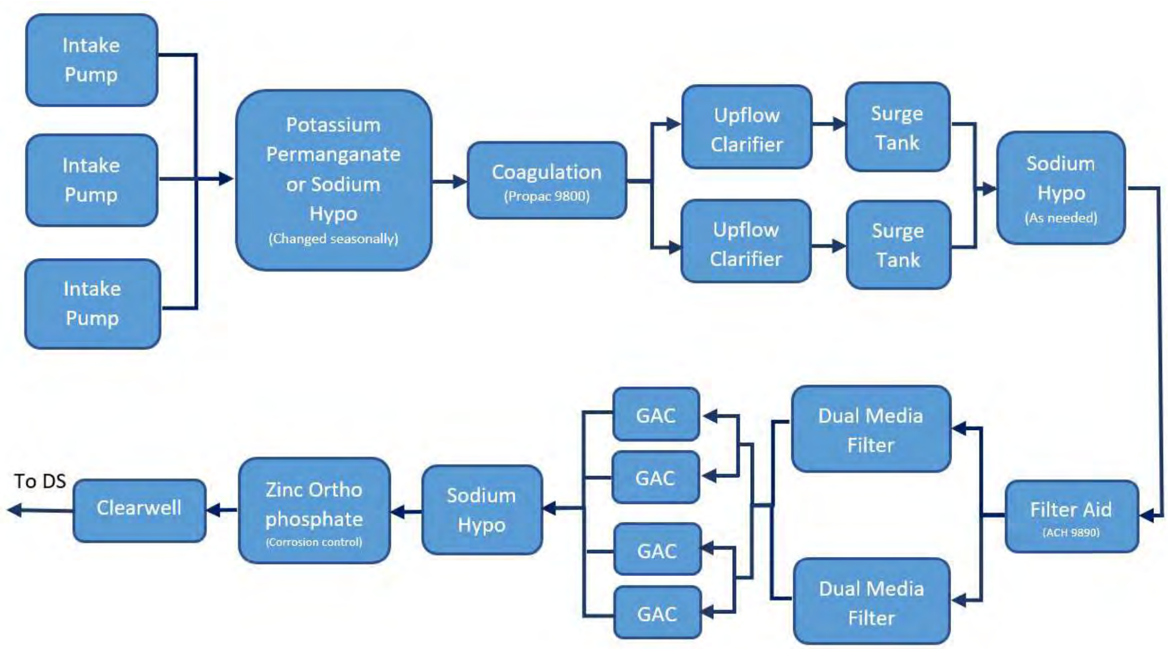


Figure 6.15.2: MKMWC Water Treatment Plant Process Diagram

6.15.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The MKMWC maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.15.3 shows the MKMWC's raw daily turbidity data from 2017-2021. Seasonal peaks correspond to both storm events and harmful algal blooms. The MKMWC's intake is largely shielded from sedimentation associated with storm events. Turbidity from storm events averages around 5 NTU whereas other purveyors with intakes that are more exposed to sedimentation have regular spikes up to 200 NTU. Relative to other utilities in this study, the MKMWC has low raw turbidity levels. The highest peaks took place in August and October. The highest result was 16.1 NTU in August 2021.

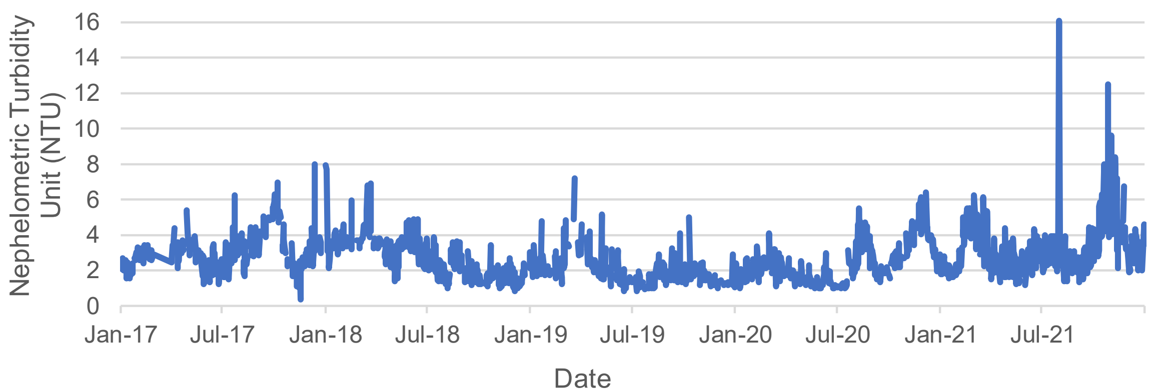


Figure 6.15.3: MKMWC Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The MKMWC sampled monthly at the intake for total coliform and *E. coli*. Table 6.15.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 34% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.15.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the MKMWC provides adequate treatment and disinfection for bacteriological quality.

Table 6.15.2: MKMWC Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	56	2419.6	3.0	517.95
Escherichia coli (*E. coli*)	MPN/100mL	56	19.9	ND	ND

ND: Not Detected

Table 6.15.3: MKMWC Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.15.4 and 6.15.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.15.4 and 6.15.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The MKMWC had no primary drinking water standard violations between 2017-2021. However, the finished water RAA regularly exceeded the SMCL for odor throughout the study period. We recommend that the MKMWC continue to monitor their finished water for odor and investigate the possibility of replacing the granulated activated carbon media.

Table 6.15.4: MKMWC Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	ND – 80	ND	None
Arsenic	µg/L	10/--	2.1 – 5.3	ND – 2.0	None
Fluoride	mg/L	2/--	0.12 – 0.15	ND – 0.14	None
Nitrate	mg/L	10/--	ND – 0.6	ND	None

ND: Not Detected

Table 6.15.5: MKMWC Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	8.0 – 11.0	8.8 – 19	None
Color	Color Units	15	ND – 35	ND – 11	None
Conductivity	umho/cm	1,600	300 – 420	320 – 430	None
Sulfate	mg/L	500	2.8 – 6.2	2.8 – 5.5	None
Total Dissolved Solids	mg/L	1,000	200 – 260	200 – 240	None
Iron	µg/L	300	ND – 200	ND	None
Odor	TON	3	4.1 – 54	ND – 63	The finished water RAA exceeded the SMCL throughout the study period
Manganese	µg/L	50	ND – 37	ND	None

ND: Not Detected

Disinfection Byproducts Precursors

Table 6.15.6 summarizes the MKMWC's compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.15.6: MKMWC Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	130 – 170	3.76 – 5.82	15% - 25%	48%	None
2018	140 – 160	4.2 – 6.04	15% - 25%	41%	None
2019	130 – 160	4.23 – 4.94	25%	47%	None
2020	140 – 180	3.58 – 4.86	25%	43%	None
2021	170 – 440	2.04 – 6.55	15% - 25%	32%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.15.7 summarizes compliance with the disinfection byproducts rule (DBPR). The MKMWC's locational running annual average (LRAA) for one of the DBPR monitoring sites exceeded the MCL for total haloacetic acids between the third quarter of 2018 and the second quarter of 2019. Subsequent monitoring in the third quarter of 2019 brought the LRAA down to below the MCL for total haloacetic acids. No MCL exceedances for disinfection byproducts have occurred since 2019.

Table 6.15.7: MKMWC Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	ND – 59.47	41.1	None
Total Haloacetic Acids	µg/L	60	12.0 – 79.9	66.9	The LRAA exceeded the MCL from Q3 2018 until Q2 2019

Lead and Copper Rule (LCR)

Table 6.15.8 summarizes compliance with the Lead and Copper Rule (LCR). The MKMWC is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2017 and 2021. There were no action level exceedances.

Table 6.15.8: MKMWC Lead and Copper Monitoring (2017 & 2021)

Analyte	Units	Action Level	Year Sampled	90th Percentile	Violation Description
Lead	µg/L	15	2017	ND	None
			2021	ND	None
Copper	mg/L	1.3	2017	0.13	None
			2021	0.13	None

ND: Not Detected

Microcystins Monitoring

Table 6.15.9 and figure 6.15.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710014. The MKMWC's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 30µg/L. Relative to other utilities in this study, the MKMWC has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the MKMWC continues to monitor raw and treated water for microcystins in future years.

Table 6.15.9: MKMWC Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	25	0.3	30	< 0.15

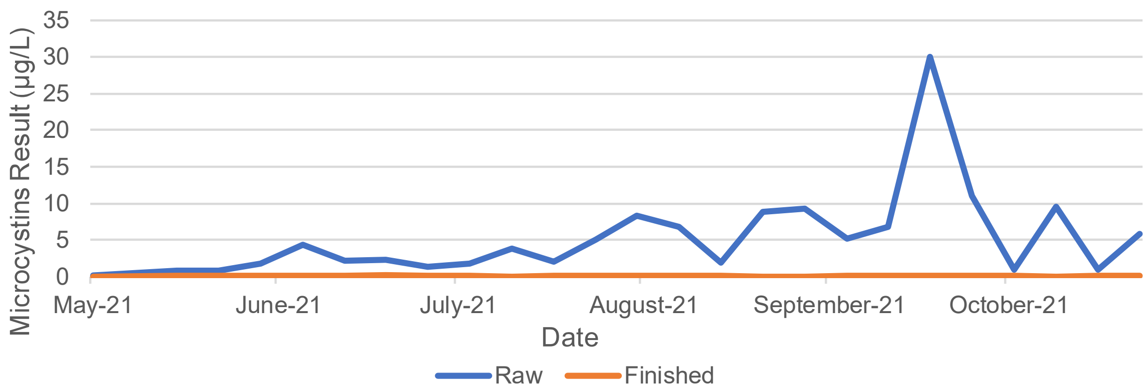


Figure 6.15.4: MKMWC Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

Figures 6.15.5 – 6.15.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH, coagulant doses, and disinfection doses from 2017-2021 show that rising pH during Quarter 3 and Quarter 4 are accompanied by higher disinfection doses, though there is no such relationship with coagulant doses. Additionally, higher pH values during Quarter 1 do not have an associated increase in disinfection or coagulant dose. This may be due to the overall raw water pH range for the MKMWC. The highest raw water pH values at the MKMWC are around 8.1. When pH increases closer to 9, the need for higher dosages increases. At this time, it is unnecessary for the MKMWC to consider the installation of an acid feed station.

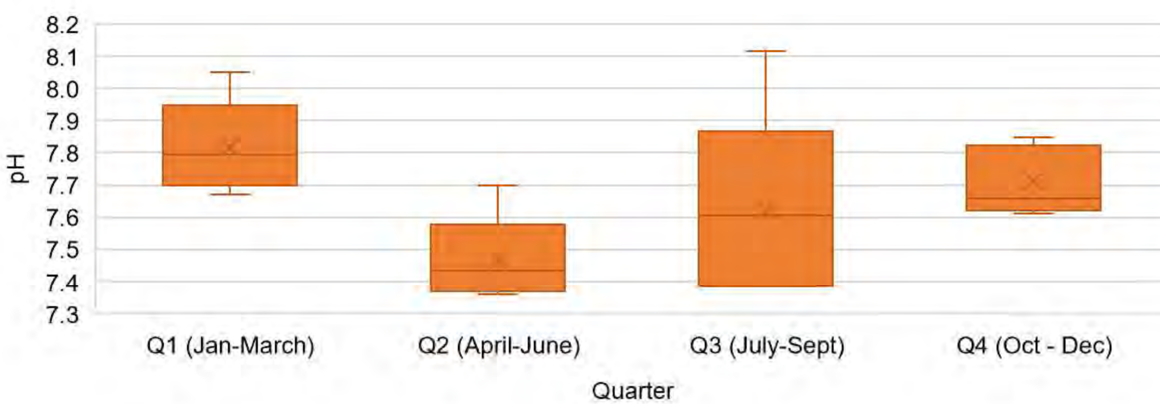


Figure 6.15.5: MKMWC Quarterly Aggregate pH (2017-2021)

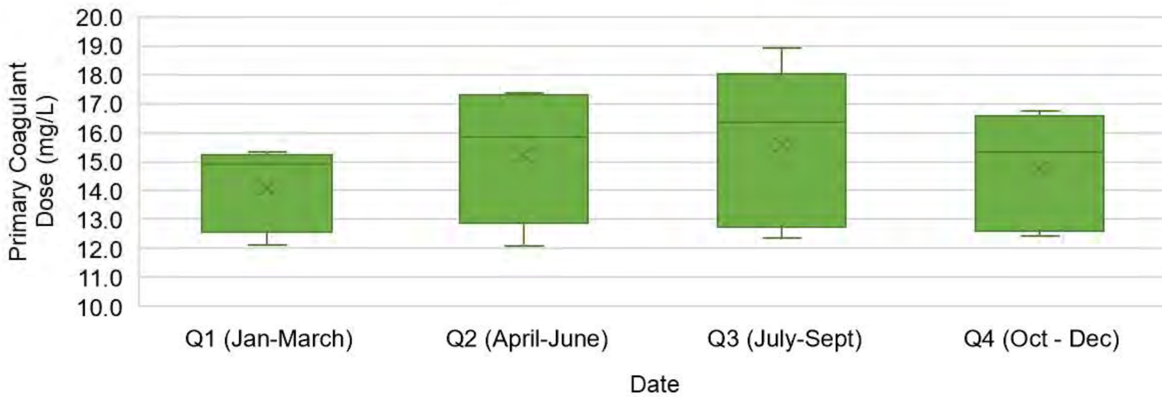


Figure 6.15.6: MKMWC Quarterly Aggregate Coagulant Dose (2017-2021)

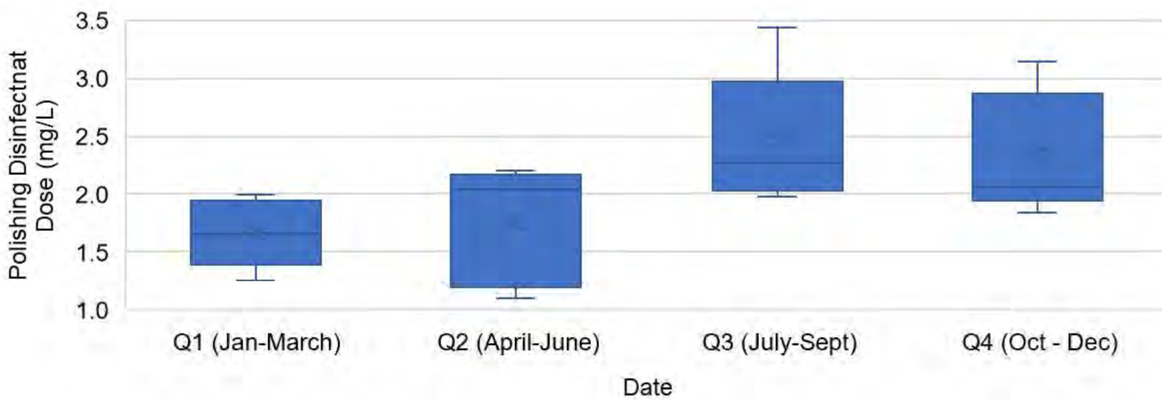


Figure 6.15.7: MKMWC Quarterly Aggregate Sodium Hypochlorite Dose (2017-2021)

Ammonia

The MKMWC does not regularly monitor for ammonia. Monitoring for ammonia in the future may help the MKMWC better manage chlorine dosages and chloramine formation.

6.16- NICE MUTUAL WATER COMPANY

6.16.1- Water System Summary

The Nice Mutual Water Company (NMWC) is located immediately east of the Rodman Slough, one of Clear Lake's main tributaries, on the northeastern side of Clear Lake (Figure 6.16.1). The NMWC is classified as a severely disadvantaged community (SDAC). It has a total of 1,069 connections (980 residential and 89 commercial) and serves a population of 2,731. The system has four pressure zones due to the varied topography of the area. It is equipped with two surface water treatment plants that run in parallel, eight storage tanks and two booster pump stations. Additional system information is outlined in Table 6.16.1.

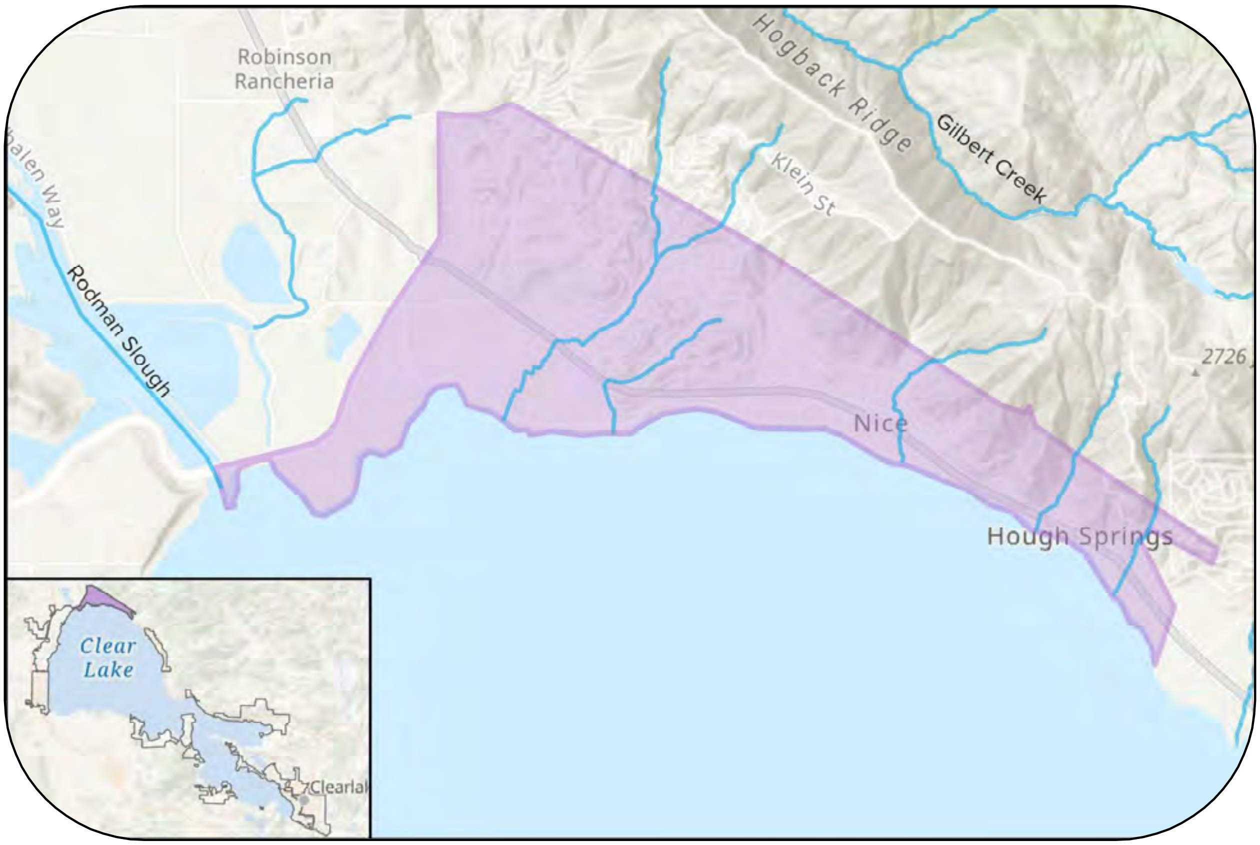


Figure 6.16.1: NMWC System Boundary Map

Table 6.16.1: NMWC System Attributes

System Name	Address	
Nice Mutual Water Company	3246 Lakeshore Blvd P.O Box 578, Nice, CA 95464	
Public Water System No.	**Connection Count**	**Population**
CA1710008	1,069	2,731
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Community Water System	Intake / Active	650 / 0.917
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
10	D2	T4

6.16.2- Treatment, Operations, and Infrastructure Upgrades

In addition to the treatment challenges that result from harmful algal blooms, the system's proximity to Rodman Slough creates turbidity spikes during storm events, which clog filters and requires higher coagulant doses. The Upper Arm is the shallowest arm in Clear Lake, which makes it particularly vulnerable to drought conditions. The low lake levels that result from drought years has triggered several intake extension projects over the years. The NMWC intake is approximately 600 feet from the shoreline and has not been affected by drought conditions.

The NMWC treatment plant consists of two treatment systems that run in parallel. One train is treated via conventional filtration whereas the other is treated via membrane filtration. Raw water is gravity fed into a caisson and is pumped into one of two parallel trains. Water entering the conventional treatment plant is immediately dosed with Propac 9800 for flash mix coagulation. Water is dosed with low levels of sodium hypochlorite immediately before entering the clarifiers to prevent algal growth in the clarifiers. Water then enters one of two clarifiers running in parallel where flocculation occurs in the mixing cone. Sedimentation causes floc to sink and clear water to flow upwards towards the weirs. Settled water is pumped into one of three mixed media filters running in parallel. The primary pump is 10 horsepower whereas the other two are 7.5 horsepower. During normal operations, only the primary pump runs but it is possible to run two pumps simultaneously. The output of each filter is set to 450 GPM to adhere to the limitations of the clarifiers and to meet turbidity requirements. Effluent water combines with effluent water from the membrane treatment plant where it is further treated before distribution.

Raw water entering the Siemens Memcor ultrafiltration membrane plant passes through the ultrafiltration membrane skid at approximately 200 gpm. Plumbing has been set up to add another skid at a later date. The skid consists of two racks of 24 ultrafiltration modules for a total of 48 modules. Water exiting the skid combines with effluent water from the conventional treatment plant.

Effluent water is combined from both plants and filtered through two granulated activated carbon units that run in series. Water is disinfected with ultraviolet (UV) light to meet the required log inactivation of Giardia and Cryptosporidium. Water is then dosed with sodium hypochlorite and enters an underground contact time pipe. Disinfected water enters the 20,000-gallon clearwell until contact time is achieved. Finished water is fed into the distribution system via a pump station. Figure 6.16.2 shows a process diagram of the NWMC's treatment process.

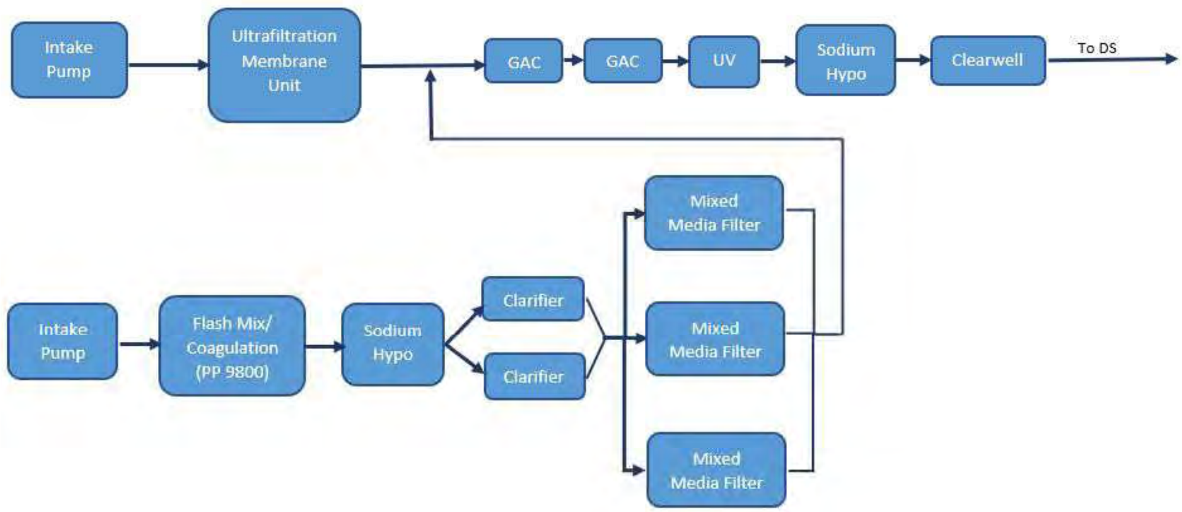


Figure 6.16.2: NMWC Water Treatment Plant Process Diagram

6.16.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The NMWC maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Figure 6.16.3 shows the NMWC's raw daily turbidity data from 2017-2021. Most peaks correspond to storm events. Due to the NMWC's proximity to the Rodman Slough, they are especially susceptible to high turbidity from storm events. Harmful algal blooms are known to increase turbidity, but the peaks that occur during storm events overshadow the turbidity increases from harmful algal blooms.

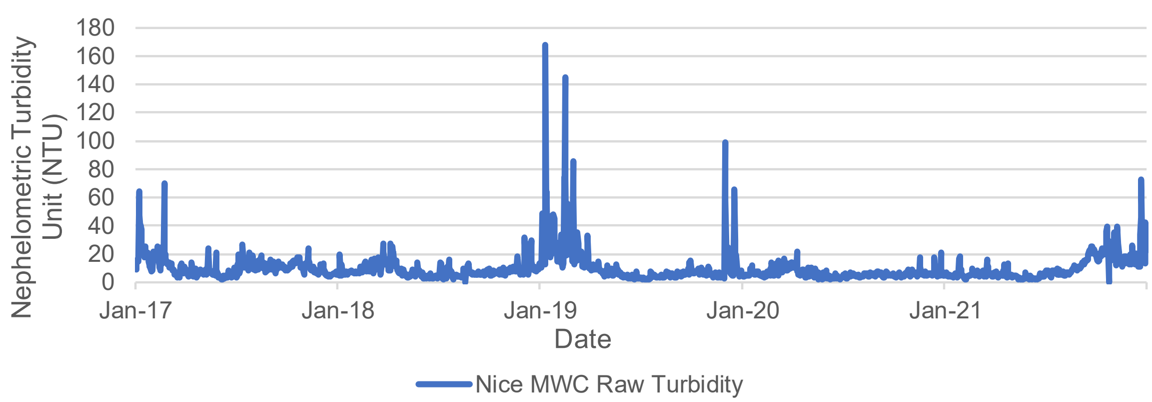


Figure 6.16.3: NMWC Raw Daily Turbidity (2017-2021)

Bacteriological Water Quality & The Total Coliform Rule

The NMWC sampled at least monthly at the intake for total coliform and *E. coli*. 2018 was sampled bi-weekly. Table 6.16.2 summarizes raw total coliform and *E. coli* data from 2017- 2021. There is no discernible seasonal trend in raw bacteriological results. 44% of the raw total coliform samples had a result in excess of the upper detection limit (2,419.6 MPN/100mL). Table 6.16.3 summarizes bacteriological results within the distribution system per the Total Coliform Rule. No detections of total coliform or *E. coli* were found in the distribution system between 2017-2021, which indicates that the NMWC provides adequate treatment and disinfection for bacteriological quality.

Table 6.16.2: NMWC Raw Bacteriological Monitoring (2017-2021)

Constituent	Units	Sample Count	Maximum	Minimum	Median
Total Coliform	MPN/100mL	75	> 2,419.6	ND	1,732.9
Escherichia coli (*E. coli*)	MPN/100mL	75	22.8	ND	1

ND: Not Detected

Table 6.16.3: NMWC Distribution System Bacteriological Monitoring Summary

Year	# Of Total Coliform Detections	# Of *E. coli* Positive Detections	# Of Months in Violation
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

Primary and Secondary Standards

Tables 6.16.4 and 6.16.5 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table 6.16.4 and 6.16.5 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The NMWC had no primary drinking water standard violations between 2017-2021. However, they exceeded the SMCL for odor during Q4 2017. This was a discrete event and did not reoccur during the study period. If the SMCL for odor is exceeded again, the NMWC must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

Table 6.16.4: NMWC Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Aluminum	µg/L	1,000/200	330 – 440	ND	None
Barium	µg/L	1,000/ --	100	NA	None
Fluoride	mg/L	2/ --	ND – 0.11	NA	None

ND: Not Detected NA: Not Available

Table 6.16.5: NMWC Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/l	500	5 – 7.9	NA	None
Color	Color Units	15	17 – 60	ND	None
Conductivity	umho/cm	1,600	240 - 340	NA	None
Sulfate	mg/L	500	4.4 – 7.3	ND	None
Total Dissolved Solids	mg/L	1,000	140 – 190	NA	None
Iron	µg/L	300	410 – 780	ND	None
Odor	TON	3	13 – 16	ND – 28	Finished water exceeded the SMCL during Q4 2017
Manganese	µg/L	50	29 – 120	ND	None

ND: Not Detected   NA: Not Available

Disinfection Byproducts Precursors

Table 6.16.6 summarizes the NWMC compliance with total organic carbon (TOC) removal requirements during the study period. No violations were observed.

Table 6.16.6: NMWC Disinfection Byproducts Precursors Compliance (2017-2021)

Year	Raw Alkalinity Range	Raw TOC Range	Percent Removal Required Range	RAA	Violation Notes
2017	100 – 150	3.43 – 4.96	25%	45%	None
2018	120 – 160	4.06 – 5.34	25%	42%	None
2019	100 – 150	3.56 – 6.16	15% - 30%	37%	None
2020	130 – 170	3.34 – 5.65	15% - 25%	39%	None
2021	160 – 200	3.86 – 8.09	15% - 30%	37%	None

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.6.7 summarizes compliance with the disinfection byproducts rule (DBPR). The NMWC exceeded the MCL for total haloacetic acids during quarter 2 of 2019 and quarter 4 of 2021. Recent data from 2022 show that this violation is ongoing. The NMWC issues Tier 2 Public Notifications on a quarterly basis per 22 CCR § 64463.4. The NMWC is currently working to correct this violation. The cause of this violation is related to the multi-year drought leading to low lake levels and concentrated organics in the lake. Increased rainfall in the region will help to reduce the concentration of total haloacetic acids.

Table 6.16.7: NMWC Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	19.8 – 94.3	62.3	None
Total Haloacetic Acids	µg/L	60	17.5 - 83	61	The LRAA exceeded the MCL during Q2 2019 and Q4 2021. Exceedances Continue into 2022.

As of November 2022, the NMWC is working to reduce the total haloacetic acid LRAA by conducting jar testing to optimize coagulation, investigating the use of potassium permanganate before the clarifiers, reducing disinfection residual, increasing tank turnover, backwashing the granulated activated carbon units more frequently, and decreasing the flow to the ultrafiltration units. They replaced the granulated activated carbon media in May 2022.

Our recommendations are consistent with what the NMWC is working on. First, we recommend that the treatment plant be reconfigured to allow the full flow of raw water to enter the clarifiers before water enters the ultrafiltration units, if possible. This may require adding another clarifier if the full flow needed to meet demand exceeds the capacity of the current clarifiers. This recommendation is dependent on whether the site has enough space for another clarifier or pretreatment mechanism. The NMWC purchased the neighboring lot, which opens the possibility of expanding the current treatment plant footprint. As a temporary alternative, the NMWC can decrease the ratio of water entering the ultrafiltration units. This will require an internal investigation to see how much water can be sent through the ultrafiltration units without exceeding the total haloacetic acids MCL. As of November 2022, the NMWC is conducting this investigation. If results of the investigation show that the flow to conventional treatment plant must be increased significantly, it may require an additional clarifier or pretreatment mechanism.

Ultrafiltration units are an asset in Clear Lake, but water should have relatively low turbidity before it enters the units to extend the lifetime of the filters and to maintain high rates of organics removal. Some form of pretreatment must be in place before water enters the ultrafiltration units. There is room onsite for another ultrafiltration skid. If pretreatment was added, it may be possible to add another skid in the future and take full advantage of the benefits of ultrafiltration.

We also suggest that granulated activated carbon filter media be changed regularly to maintain a high rate of organics removal. The last media changeout was in May 2022. The more organics removed before the disinfection stage, the lower the disinfection byproducts will be. Finally, the NWMC currently doses trace amounts of sodium hypochlorite before water enters the clarifiers to mitigate algal growth in the clarifiers. We recommend that the NWMC switch to potassium permanganate. Potassium permanganate forms less disinfection byproducts than sodium hypochlorite and may lower the overall concentration of total trihalomethanes and total haloacetic acids. The NMWC is investigating the potential of using potassium permanganate in place of sodium hypochlorite at the clarifiers.

Lead and Copper Rule (LCR)

Table 6.16.8 summarizes compliance with the Lead and Copper Rule (LCR). The NMWC is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2019. There were no action level exceedances.

Table 6.16.8: NMWC Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	90th Percentile	Violation Description
Lead	µg/L	15	ND	None
Copper	mg/L	1.3	0.46	None

ND: Not Detected

Microcystins Monitoring

Table 6.16.9 and figure 6.16.4 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1710008. The NMWC's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 0.7µg/L. Relative to other utilities in this study, the NMWC has low microcystin levels. These results confirm our current understanding of lake limnology whereby the Lower and Oaks Arm undergo more severe harmful algal blooms than the Upper Arm. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the NWMC continues to monitor raw and treated water for microcystins in future years.

Table 6.16.9: NMWC Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	20	0.3	0.7	< 0.15

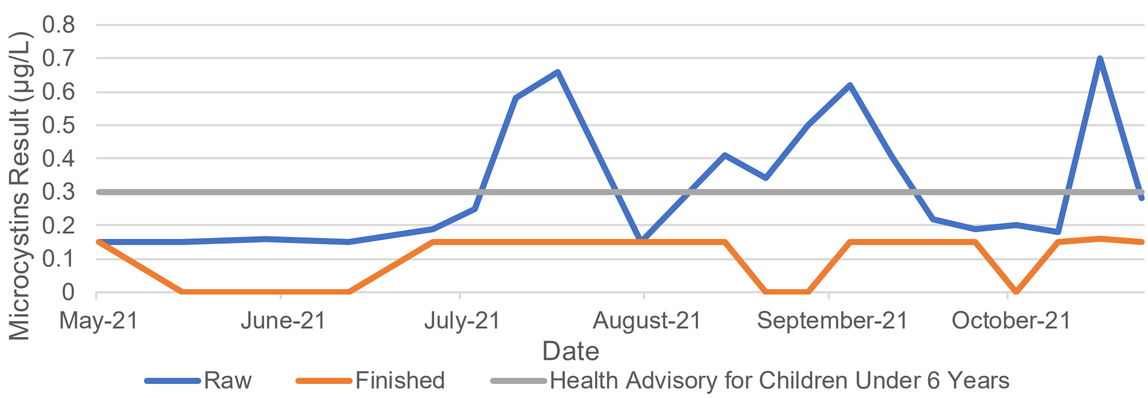


FIGURE 6.16.4: NMWC MICROCYSTINS MONITORING RESULTS (2021)

pH, Disinfection & Coagulation

Figures 6.16.5 – 6.16.7 show the relationship between pH, coagulation, and disinfection. Quarterly aggregate pH, coagulant doses, and disinfection doses from 2017-2021 show that rising pH during Quarter 3 and Quarter 4 are accompanied by higher coagulation and disinfection doses. The pH data aligns with both microcystins data and visual observation which show Quarter 3 and Quarter 4 to undergo the most severe harmful algal blooms.

Kennard and Sandoval-Solis (2021) conducted a chemical cost analysis for three Clear Lake water treatment plants and found the main chemical cost driver to be primary coagulant. All other chemicals, including sodium hypochlorite, are insignificant when comparing actual chemical costs. They found that the chemical cost per thousand gallons of water produced during Quarter 3 and Quarter 4 increased by up to four times the chemical cost required during Quarter 1 and 2. To decrease water treatment costs in the long term, it is recommended that the NMWC implement an acid feed station at the intake to decrease raw water pH before the primary coagulant is added.

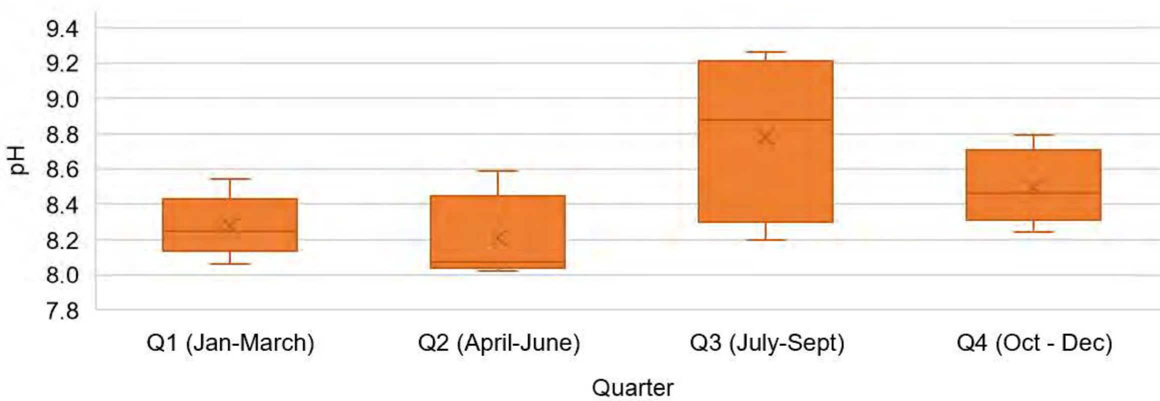


Figure 6.16.5: NMWC Quarterly Aggregate pH (2017-2021)

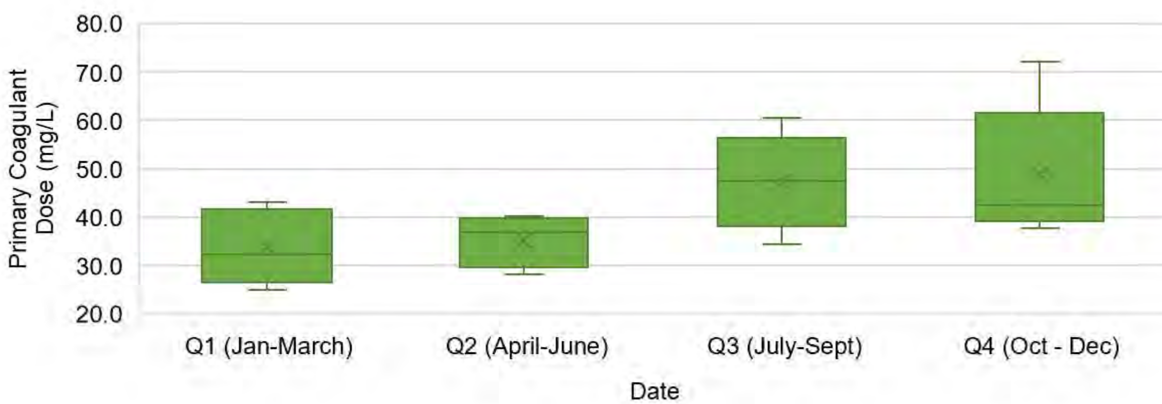


Figure 6.16.6: NMWC Quarterly Aggregate Primary Coagulant (2017-2021)

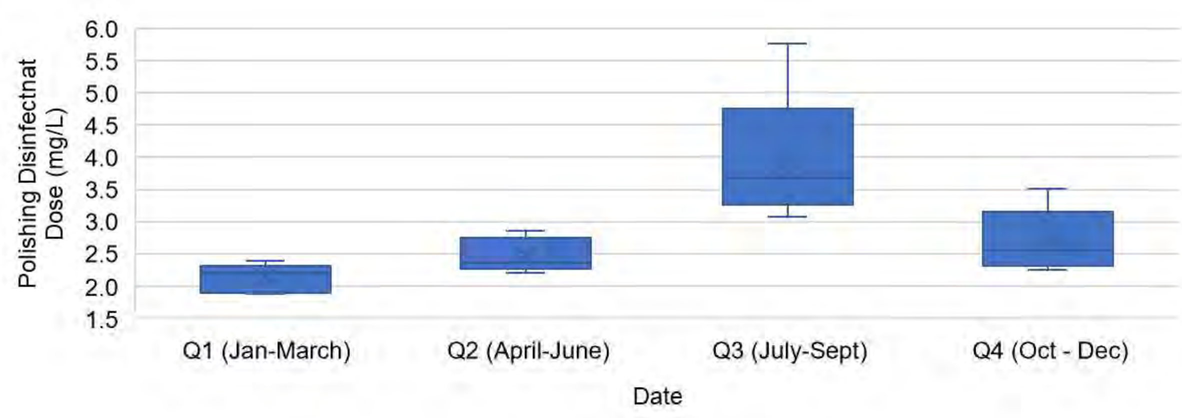


Figure 6.16.7: NMWC Quarterly Aggregate Polishing Disinfectant (2017-2021)

Ammonia

The NWMC does not currently monitor for ammonia. Monitoring for ammonia in the future may help the NMWC better manage chlorine dosages and chloramine formation.

6.17- RICHMOND PARK RESORT

6.17.1- Water System Summary

The Richmond Park Resort (RPR) is located on the Lower Arm of Clear Lake (Figure 6.17.1). The RPR is classified as an economically distressed area. It has a total of 30 connections (29 residential and 1 commercial) and serves a population of 34. The system has one pressure zone, two storage tanks each with a 4,900-gallon capacity, and one booster pump. Additional system information is outlined in Table 6.17.1.

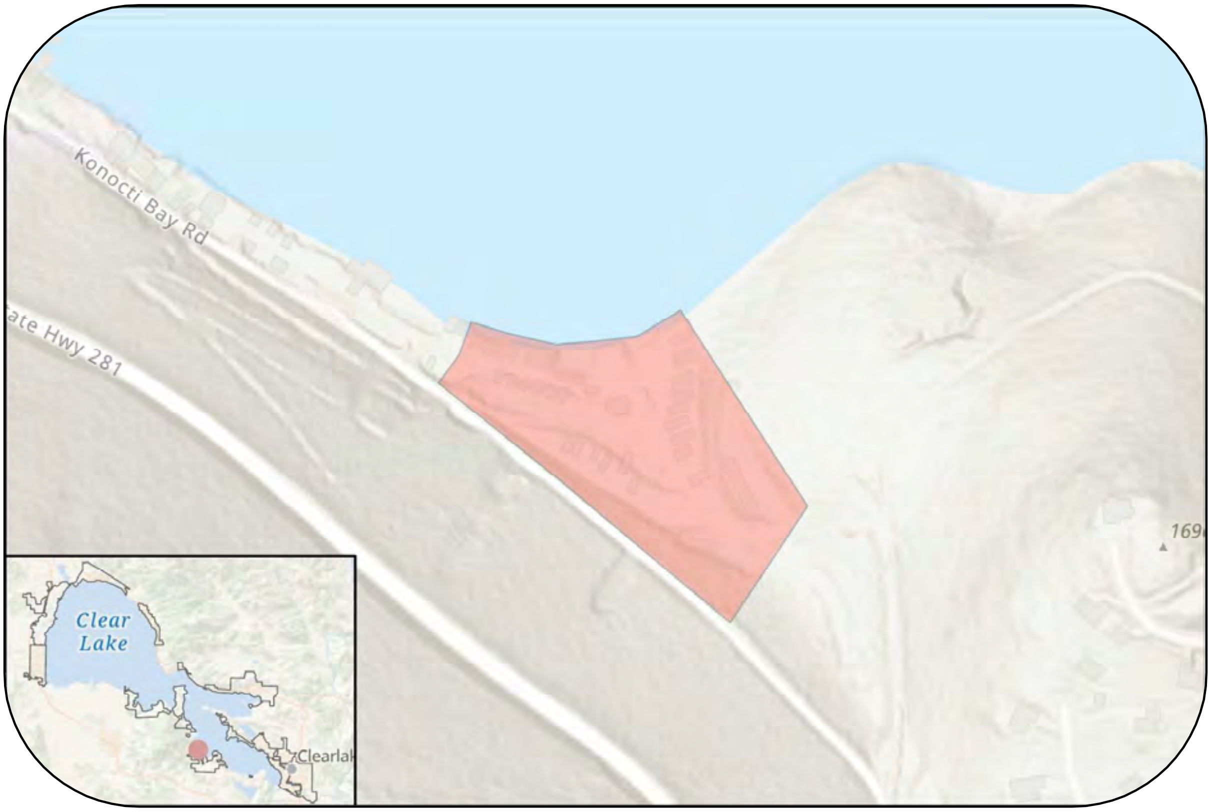


Figure 6.17.1: RPR System Boundary Map

Table 6.17.1: RPR System Attributes

System Name	Address	
Richmond Park Resort	9435 Konocti Bay Road, Kelseyville CA 95451	
Public Water System No.	**Connection Count**	**Population**
CA1700603	30	34
System Classification	**Source Type/Status**	**Capacity, (GPM/MGPD)**
Transient Non-Community Water System	Intake/Active	10/0.01
Motor Horsepower	**Distribution Classification**	**Treatment Classification**
Data not provided by utility	D1	T3

6.17.2- Treatment, Operations, and Infrastructure Upgrades

The RPR water treatment plant is a direct filtration treatment system. It contains a raw water pump station, perchlorination with sodium hypochlorite, coagulation with Propac 9800, one solid contact clarifier, one dual media pressure filter, one granulated activated carbon unit, disinfection with sodium hypochlorite, one clearwell, one finished water hydroneumatic tank, and one backwash storage tank. Figure 6.17.2 shows a process diagram of the RPR's treatment process.

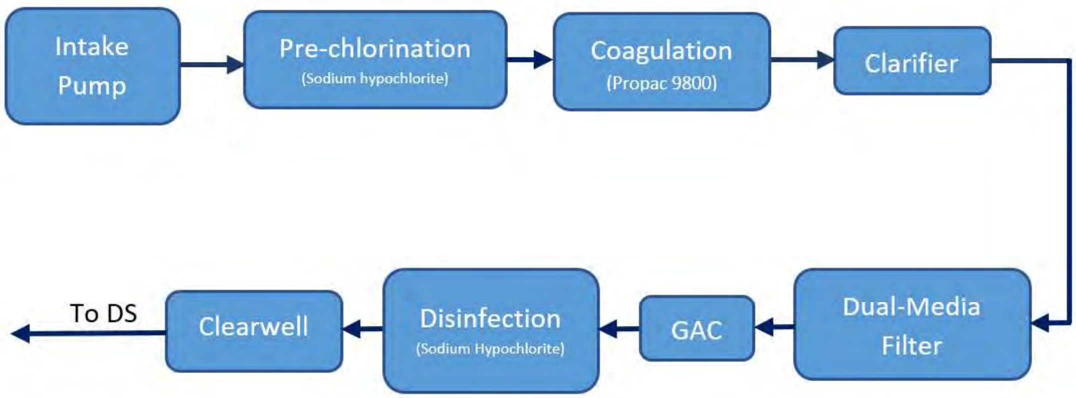


Figure 6.17.2: RPR Treatment Schematic

6.17.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The RPR maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Turbidity data was not provided by the utility.

Bacteriological Water Quality & The Total Coliform Rule

Bacteriological water quality data was not provided by the utility.

Primary and Secondary Standards

The RPR is required to monitor annually for nitrate and triennially for nitrite. No other water quality parameters have required monitoring schedules. There were no detections of nitrate or nitrite throughout the study period.

Disinfection Byproducts Precursors

The RPR is not required to calculate TOC removal because of their status as a transient non-community water system.

Disinfectants and Disinfection Byproducts Rule (DBPR)

The RPR is not required to monitor under the DBPR because of their status as a transient non-community water system.

Lead and Copper Rule (LCR)

The RPR is not required to monitor under the LCR because of their status as a transient non-community water system.

Microcystins Monitoring

Table 6.17.2 and figure 6.17.2 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1700603. The RPR's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 25µg/L. Relative to other utilities in this study, the RPR has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the RPR continues to monitor raw and treated water for microcystins in future years.

Table 6.17.2: RPR Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	24	0.3	25	<0.15

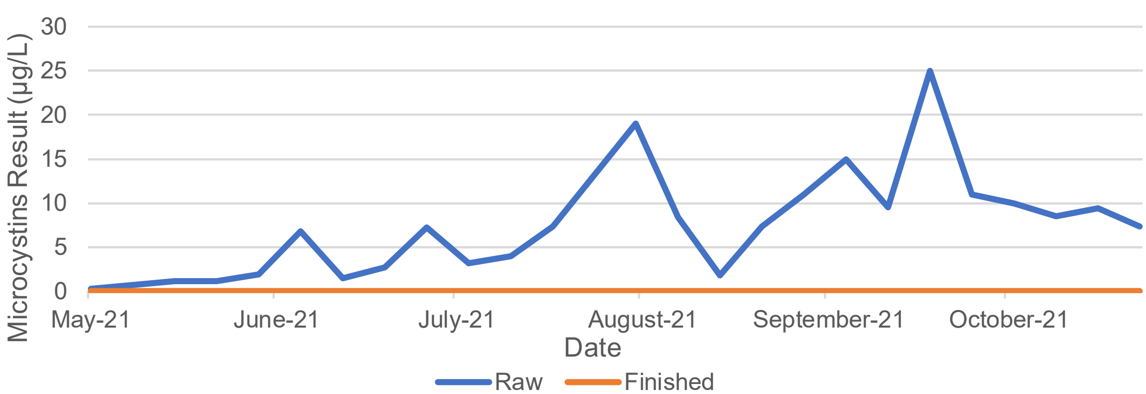


Figure 6.17.2: RPR Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

The RPR does not regularly track coagulant and disinfection dosages, therefore, a relationship between harmful algal blooms and chemical additives cannot be determined.

Ammonia

The RPR does not regularly monitor for ammonia. Monitoring regularly for ammonia in the future may help the RPR better manage chlorine dosages and chloramine formation.

6.18- WESTWIND MOBILE HOME PARK

6.18.1- Water System Summary

The Westwind Mobile Home Park (WMHP) is located on the Lower Arm of Clear Lake (Figure 6.18.1). The WMHP is not currently classified as a disadvantaged community. It has a total of 38 residential connections and serves a population of 104. The system has one pressure zone, one surface water treatment plant, and two storage tanks. Additional system information is outlined in Table 6.18.1.

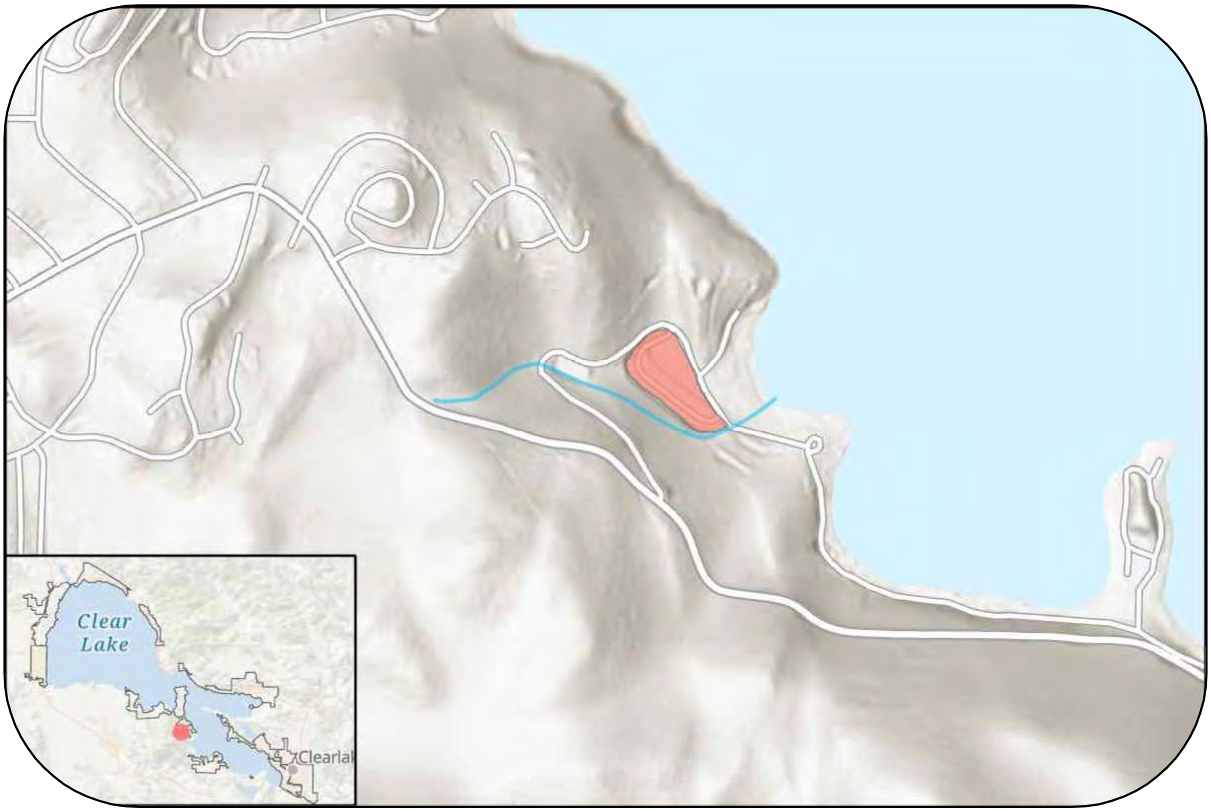


Figure 6.18.1: WMHP System Boundary Map

Table 6.18.1: WMHP System Attributes

System Name	Address	
Westwind Mobile Home Park	11270 Konocti Vista Drive #B, Lower Lake CA 95457	
Public Water System No.	Connection Count	Population
CA1700584	38	104
System Classification	Source Type/Status	Capacity, (GPM/MGPD)
Community Water System	Intake/Active	40/0.057
Motor Horsepower	Distribution Classification	Treatment Classification
10	D1	T2

6.18.2- Treatment, Operations, and Infrastructure Upgrades

Data pertaining to the water treatment system was not provided by the utility. The following information was taken from the 2012 Sanitary Survey. The water treatment plant is a direct filtration treatment system. It contains a raw water pump, a raw water storage tank, an ozone contactor, coagulation with Propac 9890, two dual media pressure filters, one granulated activated carbon unit, disinfection with sodium hypochlorite, a finished water storage tank, and corrosion control treatment with orthophosphate. Backwash water is used for irrigation.

6.18.3- Water Quality and Compliance with Regulations

Surface Water Treatment Rule

The WMHP maintained compliance with the requirements set forth in 22 CCR Chapter 17 during the study period. A minimum of 3 log reduction of Giardia lamblia cysts, 4 log reduction of viruses, and 2 log removal of Cryptosporidium was achieved, and the minimum disinfection residual was maintained at the treatment plant effluent. Proof of compliance is shown through monthly reports submitted to the State Water Resources Control Board Division of Drinking Water.

Turbidity

Turbidity data was not provided by the utility.

Bacteriological Water Quality & The Total Coliform Rule

Bacteriological water quality data was not provided by the utility.

Primary and Secondary Standards

Tables 6.18.2 and 6.18.3 summarize water quality data for detected analytes with primary or secondary maximum contaminant levels between 2017-2021. While some analytes in table6.18.2 and 6.18.3 have raw water detections above the MCL/SMCL, compliance is based on results taken from finished water, if available. If more than one sample is taken during a calendar year, compliance is based on the running annual average (RAA). The WMHP had no primary drinking water standard violations between 2017-2021. However, raw water results exceeded the following SMCLs during the study period: color (2019 & 2020), iron (2019), odor (2017-2021) and manganese (2017 & 2021).

It is recommended that the WMHP monitor after treatment for contaminants that exceed the MCL/SMCL at the intake. Monitoring can be on an as-needed basis when MCLs/SMCLs are exceeded, or a part of the regular monitoring schedule. If the SMCL for color, iron, odor, or manganese is exceeded again, the WMHP must monitor quarterly per 22 CCR § 64449 (c). After one year of quarterly monitoring if all results are below the SMCL, the utility may request a reduction in monitoring frequency.

Table 6.18.2: WMHP Primary Standards Monitoring (2017-2021)

Analyte	Units	MCL/ SMCL	Raw Water Range	Finished Water Range	Violation Description
Arsenic	µg/L	10/--	ND – 3.8	NA	None
Barium	µg/L	1,000/--	ND – 150	NA	None
Fluoride	mg/L	2/--	0.11 – 0.15	NA	None

ND: Not Detected

Table 6.18.3: WMHP Secondary Standards Monitoring (2017-2021)

Analyte	Units	SMCL	Raw Water Range	Finished Water Range	Violation Description
Chloride	mg/L	500	6.9 – 9.3	NA	None
Color	Color Units	15	10 – 17	ND	Raw water results exceeded the SMCL for color during 2019 & 2020. Finished water was not monitored during this time.
Conductivity	umho/cm	1,600	300 – 360	NA	None
Sulfate	mg/L	500	3.2 – 5.9	NA	None
Total Dissolved Solids	mg/L	1,000	170 – 250	NA	None
Iron	µg/L	300	ND – 470	NA	Raw water results exceeded the SMCL for iron during 2019. Finished water was not monitored during this time.
Odor	TON	3	10 – 280	16 - 20	The SMCL for odor was regularly exceeded throughout the study period.
Manganese	µg/L	50	ND – 53	NA	Raw water results the SMCL for manganese was exceeded in 2017 and 2021. Finished water was not monitored during this time.

ND: Not Detected   NA: Not Available

Disinfection Byproducts Precursors

The WMHP is not required to calculate TOC removal because they utilize direct filtration rather than conventional treatment.

Disinfectants and Disinfection Byproducts Rule (DBPR)

Table 6.18.4 summarizes compliance with the disinfection byproducts rule (DBPR). The locational running annual average (LRAA) exceeded the MCL for total haloacetic acids during the third and fourth quarters of 2018. Subsequent monitoring was below the MCL.

Table 6.18.4: WMHP Disinfection Byproducts Monitoring (2017-2021)

Analyte	Units	MCL	Range of Detections	Highest LRAA	Violation Description
Total Trihalomethanes	µg/L	80	1.84 – 93.9	76.42	None
Total Haloacetic Acids	µg/L	60	ND – 92.5	71.7	The LRAA exceeded the MCL during Q3 and Q4 2018

Lead and Copper Rule (LCR)

Table 6.18.5 summarizes compliance with the Lead and Copper Rule (LCR). The WMHP is required to monitor under the LCR every three years. Monitoring during 2017-2021 took place in 2019. There were no action level exceedances.

Table 6.18.5: WMHP Lead and Copper Monitoring (2019)

Analyte	Units	Action Level	90th Percentile	Violation Description
Lead	µg/L	15	7.25	None
Copper	mg/L	1.3	0.085	None

ND: Not Detected

Microcystins Monitoring

Table 6.18.6 and figure 6.18.2 show the microcystins monitoring results that were required under Order No. 02_03_21M_001_ CA1700584. The WMHP's water treatment plant effectively inactivated microcystins during the monitoring period. The highest finished water result was denoted as "detected but not quantified" with a lower detection limit of 0.15µg/L. Hence, all finished water results were below 0.15µg/L. The United States Environmental Protection Agency's health advisory for children under six years is 0.3µg/L, therefore, water delivered to customers during this monitoring period did not pose a health risk from microcystin ingestion.

The highest concentration of microcystins was 13µg/L. Relative to other utilities in this study, the WMHP has moderate microcystin levels. Harmful algal blooms are anticipated to worsen with climate change and drought. It is recommended that the WMHP continues to monitor raw and treated water for microcystins in future years.

Table 6.18.6: WMHP Microcystins Monitoring Summary

Analyte	Units	# Of Paired Samples	Health Advisory for Children Under Six	Highest Raw Water Detection	Highest Finished Water Detection
Microcystins	µg/L	25	0.3	13	<0.15

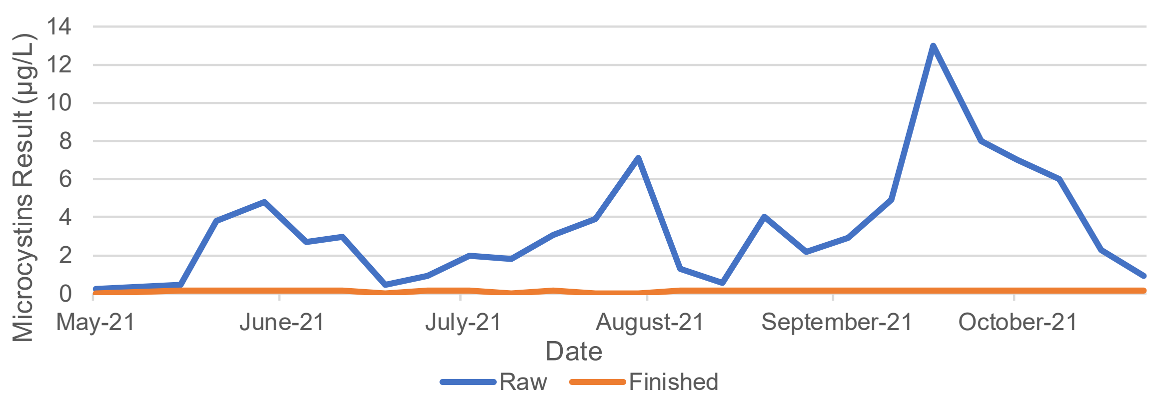


Figure 6.18.2: WMHP Microcystins Monitoring Results (2021)

pH, Disinfection & Coagulation

The WMHP does not regularly track coagulant and disinfection dosages, therefore, a relationship between harmful algal blooms and chemical additives cannot be determined.

Ammonia

The WMHP does not regularly monitor for ammonia. Monitoring regularly for ammonia in the future may help the WMHP better manage chlorine dosages and chloramine formation.

7- CLEAR LAKE LITERATURE REVIEW

7.1 - CLEAR LAKE LIMNOLOGY

Clear Lake is a large, shallow, warm polymictic lake[1] with a Mediterranean climate that consists of three interconnected but fundamentally distinct basins: the Upper Arm, the Lower Arm, and the Oaks Arm. The basins are connected by a mile long strait called the Narrows. Its limnology has been studied extensively due to the seasonal development of harmful algal blooms (HABs) in the spring and late summer. During bloom season, they form thick mats of noxious cyanobacteria that cover vast surface areas of the lake. When blooms decay, they release potent cyanotoxins and emit a smell similar to untreated sewage (McCosker, 2020). Clear Lake's shallow depth, unstable thermal stratification, sedimentation, residence time, wind patterns and climate favor the growth of cyanobacteria.

There are three toxin-producing species of cyanobacteria that are abundant in Clear Lake: *Aphanizomenon, Anabaena,* and *Microcystis*. *Aphanizomenon* dominates Clear Lake between the months of January until the end of August with a peak concentration associated with HABs in May, June and July. *Microcystis* and *Anabaena* dominate Clear Lake between the months of August and December with a peak concentration associated with HABs in September and October. Both *Aphanizomenon* and *Anabaena* are diazotrophic (nitrogen-fixing[2]) bacteria. When nitrogen levels decrease, *Aphanizomenon* and *Anabaena* can use nitrogen in the atmosphere to fuel their metabolic processes. It is estimated that roughly 50% of the nitrogen in Clear Lake is from diazotrophic bacteria, particularly *Aphanizomenon* and *Anabaena*. Nitrogen (N_2) is likely the limiting factor for *Aphanizomenon* and *Anabaena* growth in Clear Lake. *Microcystis,* on the other hand, is non-diazotrophic and limited by the available combined nitrogen (nitrate and ammonia) for cellular use (Horne, 1975).

Aphanizomenon, Anabaena, and *Microcystis* are photosynthetic and able to regulate their buoyancy throughout the day to convert solar energy into metabolic energy. They have small vacuoles that allow them to adjust their position in the water column. Overnight, their vacuoles fill with gas which causes the organisms to float to the surface. When the sun rises, the organisms use solar energy in photosynthesis. The sugars produced during photosynthesis collapse the vacuoles and the organism sinks in the water column where there is an abundant supply of nutrients. In a resting state, usually in the afternoon, the organism is deep enough in the water column to protect itself from intense solar energy. Under normal conditions, the additional nutrient mixing from buoyancy regulation will not cause a nuisance algal bloom. However, when there are high winds or disturbances that lead to low light conditions for prolonged periods of time, a large number of cells will float to the surface all at once (Mioni, 2011). In addition, if the organisms are unable to collapse their vacuoles during the day, intense light will kill the organism, causing a nuisance bloom decay (Horne, 1975).

The unique properties of cyanobacteria present in Clear Lake aid in nutrient cycling throughout the lake on daily time scales even when waters are quiescent. The ability for cyanobacteria to regulate buoyancy in the water column moves phosphorus from the hypolimnion towards the epilimnion. Diazotrophic cyanotoxins (*Aphanizomenon* and *Anabaena*) introduce additional nitrogen into the

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[1] A lake that is too shallow to maintain regular thermal stratification. Clear Lake undergoes periods of intermittent thermal stratification but is relatively well mixed throughout the year.

[2] Nitrogen fixation is the process of converting atmospheric nitrogen gas into cellular nitrogen used for algal growth.

lake. Non-diazotrophic cyanotoxins (*Microcystis*) are able to facilitate the release of sediment-bound phosphorus, which increases the amount of available phosphorus in the lake. Finally, cyanobacteria are able to store excess phosphorus intercellularly. They contain a specific metabolic process that increases the uptake of phosphorus when phosphorus is scarce. The ability for cyanobacteria to aid in nutrient cycling allows them to access pools of nitrogen and phosphorus that would otherwise be unavailable for other phytoplankton species. These unique properties ensure their survivorship and the increase the probability of cyanobacterial blooms (Cottingham, 2015).

Aphanizomenon, Anabaena, and *Microcystis* are not usually toxic during growth and development. They contain toxins that exist intracellularly or extracellularly by natural excretion or release via cell lysis. The toxin concentration may become harmful for human, animal, and ecosystem health during cellular decomposition of blooms containing *Aphanizomenon, Anabaena,* and *Microcystis*. Four classes of toxins are released by *Aphanizomenon, Anabaena,* and *Microcystis*. They include: microcystins, cylindrospermopsin, anatoxins, and saxitoxins. The majority of anatoxins and saxitoxins exist intracellularly (>95%), roughly 70% of microcystins remain intracellular, and 50% of cylindrospermopsin is remains intracellular (Westrick, 2010; Schmidt et al., 2002).

7.1.1 - Aphanizomenon

Aphanizomenon is most abundant in the Oaks Arm with concentrations that reach roughly 660ml/m^2 during the spring bloom, followed closely by the Lower Arm with concentrations of roughly 520ml/m^2. The Upper Arm trails far behind the other basins with concentrations reaching about 270ml/m^2 (Horne, 1975). High concentrations found in the Oaks Arm is most likely due to intense wind activity that keeps the nutrients mixed year round. Overall, the abundance of *Aphanizomenon* in Clear Lake far outweighs the presence of both *Anabaena* and *Microcystis* combined. Not only is it the most abundant species in the lake by biomass, it is also present year round. It does not spore; therefore, some biomass must be present in the waters throughout the year to ensure its survival.

Aphanizomenon is the dominant species of cyanobacteria in Clear Lake during the winter. The lack of solar energy causes many organisms to die, however, a significant biomass survives overwintering because increased tributary inflow brings phosphorus into the lake which *Aphanizomenon* uses to fuel metabolic processes. The spring bloom is mostly composed of *Aphanizomenon;* however, a small portion of the bloom is *Anabaena*. During the spring, solar energy increases, and phosphorus levels decrease. Anoxic conditions during the spring and summer promote sediment phosphorus release, but the rate of loss by algal biomass consumption and decreased inflow from tributaries results in a drop in phosphorus availability (Cottingham, 2015).

Aphanizomenon remains dominant in the spring because of its ability to fix nitrogen from the atmosphere. However, *Aphanizomenon* can only fix nitrogen when there is ample solar energy and phosphorus because it is an energy-intensive process (Horne, 1975). Ultimately, the spring *Aphanizomenon* bloom collapses because the solar energy becomes too intense and there is a need for nitrogen that is not compensated by nitrogen-fixation. Nitrogen-fixation requires sunlight and available phosphorus so as phosphorus levels decrease, so does nitrogen fixation. The limiting factors for *Aphanizomenon* in Clear Lake are presumed to be nitrogen and solar energy. However, it should be noted that iron has been shown to stimulate nitrogen-fixation, therefore, iron may be limiting in nitrogen-constrained environments (Horne, 1975).

During cell lysis, *Aphanizomenon* releases several toxins including saxitoxins, anatoxins, and cylindrospermopsin. The short-term health effects of these toxins are relatively well documented, but some of the long-term health effects are still under investigation. The health effects for the toxins released by *Aphanizomenon* are summarized below in Table 1. There are currently no regulatory decisions regarding the concentrations of the abovementioned contaminants in drinking water, however, all three are on the contaminant candidate list (CCL) to be considered for regulatory action (CCL5, 2022).

Saxitoxins are a group of 57 hydrophilic alkaloid neurotoxins (organic compounds originating from plants that target the brain) that are collectively called "paralytic shellfish toxins" because they are the main cause of shellfish poisonings (Wiess, 2010). Short-term symptoms emerge within 30 minutes of ingestion and include tingling, numbness or burning of the esophagus, tongue, lips, and mouth which may be accompanied by vomiting, heavy sweating, and diarrhea. High concentrations of saxitoxins may result in fatigue, paralysis, and death. The long-term effects of saxitoxins are unknown (He et al., 2016). Saxitoxins are released by both *Aphanizomenon* and *Anabaena*.

Anatoxins are potent neurotoxins with three variants: anatoxin-a, homoanatoxin-a, and anatoxin-a(s) (USEPA, 2020). They are slightly hydrophobic bicyclic amines (a derivative of ammonia with two ringed molecule structures) that rank among the smallest of cyanotoxins weighing only 165 Daltons (He et al., 2016). Anatoxin-a is the most abundant and widespread variant of the anatoxin group in freshwaters throughout the world and is released by both *Aphanizomenon* and *Anabaena* (Cheung, 2013). The short-term symptoms of anatoxin poisoning mirror those of saxitoxins, however, the long-term health effect of anatoxins is cardiac arrhythmia that leads to death.

Cylindrospermopsin is a cyanotoxin with two known variants, 7-epicylindro-spermopsin and 7-deoxycylindrospermopsin. They are slightly hydrophilic tricyclic alkaloids (nitrogenous three ring compounds of plant origin) that target the liver and kidneys. Short-term exposure symptoms vary and include vomiting, kidney damage, headache, bloody diarrhea, and pneumonia (USEPA Drinking Water Health Advisory, 2015). Long-term exposure can cause anorexia and kidney damage leading to death (Cheung, 2013).

7.1.2 - Anabaena

Anabaena is dominant during the fall bloom but may also coexist with *Microcystis*. These blooms are abundant in the Oaks and Lower Arm and are mostly absent in the Upper Arm. *Anabaena* is the second most abundant toxin-producing species of cyanobacteria in Clear Lake with its highest concentrations reaching around 200mg/m^2 in late summer (Horne, 1975). *Anabaena* is similar to *Aphanizomenon* in that they are both single-celled filamentous nitrogen-limited diazotrophic species. Decreases in light intensity around October allow the *Anabaena* bloom to peak. *Anabaena* biomass does not overwinter; they collapse with the bloom in late October (Horne, 1975). Their ability to spore allows them to continue blooming annually. During cell lysis, they release anatoxins, saxitoxins, and *microcystins*. The health effects for the toxins released by *Anabaena* are summarized below in Table 1.

Of the toxins explored in this section, *microcystins* are the most well-studied due to their widespread occurrence throughout the United States (Cheung, 2013). *Microcystins* are hydrophobic cyclic heptapeptides (molecules arranged in a circular pattern consisting of hepta- [seven] amino acids) that have over 100 variants. They are stable and water soluble molecules whose main biological function is to mitigate oxidative stress on *Anabaena* and *Microcystis* species (He et al., 2016) Each variant is named after its configuration of amino acids (Westrick, 2010). For example, the most common variant, Microcystin-LR is named because it contains leucine (L) and arginine (R).

In surface waters, roughly 30% of microcystin concentration is extracellular. The remaining 70% is contained within the cyanobacterial cell and released during cell lysis. *Microcystins* undergo photochemical breakdown in direct sunlight and their toxicity is recorded to be the highest during periods of low sunlight and high turbidity (Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins, 2015). Short-term symptoms of microcystin poisoning are heavy breathing, weakness, vomiting a diarrhea. *Microcystins* concentrate in the liver and inhibit the enzymes required for proper liver function which can lead to hemorrhaging and breakdown of liver tissue. *Microcystins* are known tumor promoters; long-term health risks are liver cancer and death from respiratory arrest (Falconer, 1999).

7.1.2 - Microcystis

Of the three toxin-producing species of cyanobacteria abundant in Clear Lake, *Microcystis* are the least abundant with a maximum concentration of less than 100ml/m^2 (Horne, 1975). *Microcystis* are non-diazotrophic single-celled organisms that exist in a gelatinous matrix. *Microcystis* only grows where there is an abundance of available nitrogen which explains their relative temporal distribution. Small amounts of *Microcystis* are present in the Lower and Oaks Arm starting in August but are absent in the Upper Arm until October. The Oaks and Lower Arms have available nitrogen in the late summer while the Upper Arm does not (Cottingham, 2015).

Unlike *Aphanizomenon* and *Anabaena, Microcystis* facilitates internal phosphorus loading. *Microcystis* blooms occur in the late fall, which is characterized by oxygenated water from wind mixing and storm inflow. The oxygenated water stimulates sediment release of nitrate and ammonia, essential to *Microcystis* growth, but the concentrations of phosphorus, also needed for *Microcystis* growth, continues to decrease. *Microcystis* aids the release of sediment bound phosphorus to ensure its survival year round (Cottingham, 2015). Unlike *Anabaena, Microcystis* do not spore. Rather, similar to *Aphanizomenon,* they overwinter by sinking to the sediment level where they have enough nutrients to survive (Ma et al., 2016). When water temperatures drop below 10℃, much of the *Microcystis* biomass dies, signaling the collapse of the fall bloom. During cell lysis, they release *microcystins* (Cheung, 2013). The health effects of *microcystins* are summarized below in table 7.1.1. Refer to figure 7.1.1 for a visual representation of the toxins released by *Aphanizomenon, Anabaena,* and *Microcystis.*

Table 7.1.1: Short and Long-Term Health Effects of Toxins Released by Aphanizomenon, Anabaena and Microcystis (modified from Cheung, 2013)

Cyanobacteria	Toxin Released	Short-Term Health Effects	Long-Term Health Effects
Aphanizomenon & Anabaena	Saxitoxins	Burning, tingling, numbness, incoherent speech, drowsiness, respiratory paralysis leading to death	Unknown
Aphanizomenon & Anabaena	Anatoxins	Burning, tingling, numbness, incoherent speech, drowsiness, respiratory paralysis, death	Cardiac arrhythmia leading to death
Aphanizomenon	Cylindrospermopsin	Gastrointestinal, liver inflammation and hemorrhage, pneumonia, dermatitis	Malaise, anorexia, liver failure leading to death
Anabaena & Microcystis	Microcystins	Heavy breathing, vomiting, weakness, diarrhea, gastrointestinal liver inflammation, and hemorrhage and liver failure leading to death, pneumonia, dermatitis	Tumor promoter, liver failure leading to death

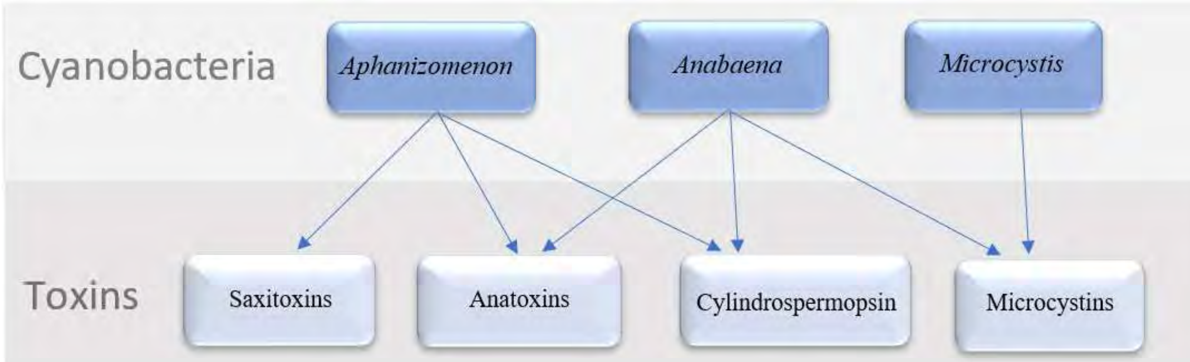

Figure 7.1.1: Cyanotoxins Released by Aphanizomenon, Anabaena, and Microcystis

7.2 - PHYSICAL TREATMENT TECHNOLOGIES

Treating cyanobacterial blooms containing toxins is inherently complex. HABs increase chemical demand, produce taste and odor (T&O) problems, and promote the formation of disinfection byproducts (DBPs). In addition, cell lysis can be induced by conventional water treatment practices, therefore, special care is taken to avoid cell lysis during the treatment process (Westrick, 2010; Cheung et al., 2013; Schmidt et al., 2002). Physical and chemical removal processes vary in effectiveness depending on the specific toxin. Water treatment operators must be familiar with the characteristics of the toxin they are treating before selecting a treatment technique (Westrick, 2010). The treatment facilities in Clear Lake are faced with treating three species of cyanotoxins and four classes of dissolved toxins, all of which behave differently during conventional treatment.

There are two stages to treat algal blooms in raw source water, each stage containing various configurations of treatment units and processes. The first stage is to physically remove intact algal cells from raw water through conventional treatment, direct filtration, or an alternative treatment process. The second stage of treatment is chemical oxidation and inactivation of microbiological contaminants, including extracellular cyanotoxins (Westrick, 2010). The success of chemical inactivation depends largely on the characteristics of the toxin including its hydrophobicity, molecular size, and functional groups susceptible to oxidation (Westrick, 2010). Oxidation chemicals are always added at the end of surface water treatment, but many treatment plants apply oxidizers both at the headworks and after treatment. Many treatment plants also utilize advanced oxidation techniques like ultraviolent light (UV) and ozone (O_3) to inactivate extracellular toxins. The combination of physical treatment and chemical oxidation removes intact cyanobacterial cells and extracellular toxins in drinking water (USEPA Health Advisory, 2015; Westrick, 2010; He et. al., 2016; Cheung et. al., 2013). With changing water quality conditions across the globe from climate change and environmental degradation, treatment facilities should incorporate flexibility into the plant design to allow auxiliary treatment units to be added as needed to comply with state and federal regulations (Westrick, 2010).

7.2.1- Conventional Treatment-

Although each treatment facility in Clear Lake draws from the same source, there is no equivalent of a "one size fits all" or a "magic bullet" for water treatment. Water treatment processes are dynamic and highly dependent on other unit processes. Most surface water treatment plants can be optimized using existing infrastructure to effectively remove intact cyanobacterial cells. Auxiliary physical treatment processes may be added to provide redundancy in the event of toxin breakthrough or to address other water quality concerns. When raw water quality changes, all unit processes must be adjusted accordingly to accommodate for those changes. See table 7.2.1below for a list of conventional treatment processes and some of their associated modifications.

Table 7.2.1Conventional Treatment Plant Unit Processes and Modifications

Unit Process	Types	Options
Coagulation	Traditional Enhanced	Primary coagulants: aluminum sulfate, ferrous sulfate, polyaluminum chloride, ferric sulfate, polyferric sulfide, ferric chloride, cationic polymers Coagulant aids (if needed): bentonite clay, calcium carbonate, sodium silicate, anionic, nonionic polymers
Flocculation	Horizonal mixing Vertical mixing	Flocculant aids (if needed): aluminum sulfate, nonionic polymers, iron salts
Sedimentation	N/A	Rectangular Basin Upflow Clarifier/ Solid Contact Unit Dissolved Air Flotation (DAF)
Filtration	Direct Conventional	Filtration units: Slow sand, rapid sand, pressure filters Media types: sand, anthracite, green sand, mixed media, garnet
Auxiliary process: Membrane filtration	Microfiltration (MF) Nanofiltration (NF) Ultrafiltration (UF) Reverse Osmosis (RO)	Membranes of varying sizes
Auxiliary process: Activated Carbon	Granulated (GAC) Powdered (PAC)	Wood, coal, seashells, coconut, bones

The accumulation of cyanobacterial cells during the physical removal process decreases the efficacy of subsequent chemical inactivation during the final stage of treatment (Zamyadi et. al., 2013). If chemical inactivation is not adequate, there is a risk of toxin exposure through drinking water. Treatment facilities have contingencies and multiple barriers for contamination, but they are highly dependent on the other treatment processes. For example, if the coagulation process is inadequate, flocculation and sedimentation will be less effective, and the bulk of removal is reserved for the filters, which can result in reduced filter run times, decreased performance, and increased risk of toxin breakthrough. Table 7.2.2 below outlines recommendations for conventional treatment unit process optimization in Clear Lake.

Table 7.2.2 Physical Treatment Processes

Unit Process	Method	Recommendation	Justification
Coagulation	Enhanced Coagulation	Recommended	Enhanced coagulation agglomerates more NOM and intact cyanobacterial cells, increasing treatment efficacy. Aphanizomenon is the most resistant to coagulation.
Sedimentation	Rectangular Sedimentation Basin	Recommended	Recommended for conventional treatment due to their ability to accommodate for vast changes in water quality.
	Upflow clarifiers/ solid contact units	Not Recommended	Not recommended for use in Clear Lake due to its inability to compensate for vast changes in water quality.
	Dissolved Air Flotation (DAF)	Recommended	DAF is recommended as a replacement for sedimentation basins or used as an auxiliary treatment process during algal blooms
Filtration	Direct Filtration	Not Recommended	Direct filtration should not be used in waters with high turbidity.
	Rapid Sand Filtration	Recommended	Recommended for use in conjunction with conventional treatment
	Membrane Filtration	Recommended	Recommended to replace conventional particle filtration, if possible.
	Granulated Activated Carbon (GAC)	Recommended	Recommended for use after conventional treatment to mitigate T&O and facilitate partial removal of extracellular toxins
	Powdered Activated Carbon (GAC)	Recommended	Recommended for use during sedimentation for partial removal of extracellular toxins if GAC cannot be used.

7.2.2- Coagulation

Coagulation is a chemical reaction that takes place by adding a coagulant to water containing suspended particles. This is often the first step of treatment but may be preceded by pre-treatment oxidation methods and/or pH adjustment. The coagulant chemical agglomerates solids into flocculant that can be removed during sedimentation. Vigorous mixing is required in order to thoroughly disburse the coagulant into the raw water flow. Mixing can be created with mechanical mixers, diffusers, or pumped blenders (Zamyadi et. al., 2013). Since colloidal particles have a weak negative charge, they repel one another and become evenly distributed throughout the water column. Coagulants cause insoluble microfloc to precipitate from solution. Microfloc formation during the coagulation stage allows for flocculation and sedimentation of the suspended particles (Zamyadi et. al., 2013). Many colloidal clay particles are so small that they pass right through a conventional gravity or pressure filter, therefore, the colloids must be coagulated to facilitate removal by sedimentation and filtration (Wendele, 2020).

Coagulant chemicals are separated into two groups: primary coagulants and coagulant aids. The most common primary coagulants include metallic salts such as aluminum sulfate, ferrous sulfate, ferric sulfate, and ferric chloride. Cationic polymers are also classified as primary coagulants. Metallic salts and cationic polymers exhibit a positive electric charge making them ideal for destabilizing colloidal particles. Coagulant aids include bentonite clay, calcium carbonate, sodium silicate, anionic and nonionic polymers. The purpose of coagulant aids is to form interparticle bridges which aid in building floc for turbidity removal (Wendele, 2020).

Cyanobacterial cells are larger than colloidal particles but also have relatively low densities and have a slight negative charge. Coagulation agglomerates intact cyanobacterial cells into insoluble floc but does not remove extracellular toxins. Vigorous mixing during coagulation basins may cause cell lysis; monitoring of extracellular toxins is recommended during coagulation to determine if coagulation causes cell lysis. Several studies have shown that *Microcystis* resist cell lysis even under rigorous mixing, but little is known about the effect of rapid mixing on *Aphanizomenon* and *Anabaena* (He et al., 2016).

The strain of cyanobacteria being treated is an important consideration for optimizing the physical removal of algal cells during the conventional treatment process. Polyaluminum chloride has been shown to be effective in removing *Anabaena* and *Microcystis*, although natural organic matter (NOM) may interfere with successful coagulation. Aluminum sulfate, polyferric sulfate, and ferric chloride are less effective for coagulating *Anabaena* and *Microcystis*. *Aphanizomenon* cells are the most resistant to coagulation and do not easily settle in sedimentation basins (Zamyadi, et. al., 2013). See table 7.2.3 for coagulant effectiveness on *Aphanizomenon, Anabaena* and *Microcystis*.

Table 7.2.3 Coagulant Effectiveness

Cyanobacterium	Polyaluminum chloride	polyferric sulfate	Aluminum sulfate	Ferric sulfate
Anabaena	Effective	Moderately Effective	Moderately Effective	Moderately Effective
Aphanizominon	Not effective	Not effective	Not effective	Not effective
Microcystis	Effective	Moderately Effective	Moderately Effective	Moderately Effective

- Enhanced coagulation is a process undertaken by utilities to minimize the formation of known carcinogenic disinfection byproducts (DBPs) (He et al., 2016). DBPs are formed when chlorine-based disinfectants (namely, sodium hypochlorite) are exposed to NOM (USEPA DBPR, 2020). By the time water gets to the disinfection stage, it should be relatively clear of NOM to prevent the formation of DBPs (Kerri, 2008). Relatively turbid surface water supplies often opt for enhanced coagulation whereby the coagulant dose is increased to agglomerate more suspended matter early in the treatment train so there is less NOM in the water during disinfection (He, et. al., 2016). Enhanced coagulation is recommended for treating drinking water in Clear Lake.

7.2.3- Flocculation

Flocculation is a physical stirring process that facilitates collisions of microfloc to produce insoluble pinfloc. Pinfloc is a macroscopic accumulation of agglomerated colloids, intact algal cells, and coagulant chemicals with enough density to settle out of solution. The best flocculation results are achieved in compartmentalized basins. In this setup, there are usually three compartments separated by baffles to prevent short-circuiting. Generally, the stirring speed is highest in the first compartment with gradual decreases in stirring speed in the second and third compartments (Kerri, 2008). The first compartment contains mostly microfloc so high speed mixing is still required to increase the density of the floc. The second and third basins contain pinflocs and require reduced mixing speeds to prevent shearing.

Flocculant chemicals, such as aluminum sulfate, iron salts, or nonionic polymers may be added during flocculation to aid the development of pinfloc. Aluminum sulfate has been shown to be an effective flocculant in waters with high algal concentrations. Iron salt flocculants have only shown to be moderately effective at removing cyanobacterial cells, however, ferrate III has shown to aid in flocculation, decrease T&O compounds, and partially remove extracellular toxins without contributing to cell lysis (He et al., 2016). Due to the low density of cyanobacteria, pinflocs are often of similar density to water, causing them to remain suspended. The addition of polymers during flocculation help to settle the floc (Zamyadi, et. al., 2013).

7.2.4- Sedimentation

The primary purpose of coagulation, flocculation, and sedimentation is to remove suspended solids and to reduce particulate loading during filtration. Sedimentation is a physical settling process that allows floc to settle into sludge for later removal. Settled water should have relatively low turbidity levels before it enters the filters. Rectangular sedimentation basins are highly recommended in Clear Lake for utilities performing conventional treatment because they have a high tolerance for shock loading, are cost-effective, have little maintenance requirements, have predictable performance, and minimize short-circuiting (Kerri, 2008).

Another common design for sedimentation basins are upflow clarifiers and solid contacts units. These units combine coagulation, flocculation, and sedimentation into a single basin. Upflow clarifiers are capable of producing excellent effluent quality, however they are easily upset by changes in flow rate or water quality (Wendele, 2020). Due to their sensitivity to water quality changes, upflow clarifiers and solids contact units are not generally recommended for Clear Lake water supplies.

7.2.4- Dissolved Air Flotation

Conventional water treatment processes normally include coagulation, flocculation, and sedimentation. However, coagulation, flocculation, and dissolved air flotation (DAF) has shown to be more successful in removing algal cells, specifically *Microcystis*, than conventional treatment. DAF units may replace the sedimentation step or act as an auxiliary treatment unit during cyanobacterial blooms to aid in removal after sedimentation. DAF has not been shown to contribute to cell lysis (Westrick, 2010).

Originating in the oil and gas industry as a method to separate oil from wastewater, DAF units have become recognized by the USEPA as a method for removing intact cyanobacterial cells from drinking water supplies (USEPA Health Advisory, 2015). DAF works by saturating water with micro air bubbles. The air bubbles float flocculant to the top of the basin where it is then sloughed off into a sludge tank. Pretreatment in the coagulation and flocculation process is required to make the floc slightly hydrophobic (Water World, 2013). Since cyanobacterial floc is typically less dense than floc consisting of mainly colloidal material, the floc is better able to float, making DAF units highly effective at removing cyanobacterial floc. DAF units are recommended for use in Clear Lake.

7.2.5- Filtration

Filtration is the last physical treatment process in a conventional or direct filtration treatment plant. Most suspended solids should be removed by this point. High solids concentrations lead to reduced filter performance, contaminant breakthrough, short-circuiting, and more frequent backwashing. The previous physical treatment processes should clarify the water to a point where it is easily filtered. There are two types of filtration configurations in surface water treatment plants: conventional filtration and direct filtration. Direct filtration combines sedimentation and filtration into one step and is often used for water with low turbidity. Since many areas in Clear Lake undergo heavy silting, direct filtration is not a reliable option for some areas around the lake. Conventional filtration is the most effective filtration mechanism for areas of Clear Lake that are subject to heavy silting.

Filter media roughness and pore size, as well as cyanobacterial cell size and chemical composition are important for determining an optimal filter media (USEPA Health Advisory, 2015). Most conventional filtration units are particle filters composed of a combination of anthracite, sand, and gravel. The filter can either be fed by gravity (rapid sand filtration) or filtered under pressure. They remove suspended solids but do not remove small compounds like viruses and ions. Since cyanobacterial cells are relatively large, particle filters successfully remove intact cells. Conventional treatment using particle filters in conjunction with optimized chemical oxidation yields successful removal of cyanobacterial cells and extracellular toxins (He et al., 2016).

Although water quality goals can be attained by particle filtration, many utilities in Clear Lake opt to use membrane filtration. Membrane filtration has been shown to be successful in removing both cyanobacterial cells and extracellular toxins. However, due to their small pore size, pretreatment is required to prevent the filters from clogging (USEPA Health Advisory, 2015). Membrane filtration processes include microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. Both micro- and nanofiltration processes are commonly used to remove cyanobacterial cells. These processes usually replace conventional filtration units (Westrick, 2010).

Microfiltration and ultrafiltration achieve more than 98% removal of cyanobacterial cells, including intracellular microcystins. However, extracellular release of toxins has been reported from shear stress from the membrane. Ultrafiltration was able to remove 35-70% of extracellular microcystins, and therefore cannot be solely relied upon to remove extracellular toxins (Westrick, 2010). Nanofiltration and reverse osmosis were able to remove both cyanobacterial cells and extracellular toxins by greater than 90%. Most cyanobacterial cells should be removed from solution prior to reverse osmosis because their small membranes are easily clogged. These values are dependent on a variety of factors including initial concentration and membrane size (USEPA Health Advisory, 2015). The molecular size and weight of cyanotoxins vary; larger toxins like cylindrospermopsin are effectively removed by membrane filtration, whereas smaller toxins like saxitoxins will pass through membrane filtration (He et al., 2016).

7.2.5- Activated Carbon

Activated carbon is a physical treatment processes that removes hundreds of contaminants from effluent waters including organic taste and odor (T&O) causing compounds, extracellular cyanotoxins, volatile organic compounds (VOCs) including disinfection byproducts (DBPs), herbicides, pesticides, and perfluorinated compounds via adsorption (Continental Carbon Group, 2020). Activated carbon cannot remove intact cyanobacterial cells, which constitutes roughly 80% of microcystin concentrations, but they are moderately successful at removing extracellular toxins. Activated carbon is used in water treatment processes as either granulated activated carbon (GAC) stationary units or powdered activated carbon (PAC) added during treatment. Activated carbon is not used in all conventional treatment plants and is not considered a core component to conventional treatment. However, it is a powerful tool for water treatment operators and its use may be mandatory if regulated contaminants are not removed during conventional treatment processes.

Both PAC and GAC can be successful in removing extracellular toxins, so the choice of using one over the other is based on treatment plant configuration, raw water quality, and budget. PAC addition is normally used as a temporary treatment method for discrete events or infrequent contaminant problems. Water treatment operators sometimes prefer PAC over GAC because it does not have to be used continuously and does not require extensive infrastructure. However, PAC is expensive and cannot be regenerated unlike GAC. Large scale water treatment plants can go through $200,000 of PAC per month (He et al., 2016). GAC, on the other hand, is a stationary, continuous treatment mechanism. Utilities in Clear Lake face chronic cyanobacteria blooms, therefore, the use of GAC over PAC is recommended.

Activated carbon removes contaminants via adsorption. As water passes through the media, contaminants physically attach to the surface area of the media, effectively removing it from effluent water (Continental Carbon Group, 2020). Adsorptive action results from electrostatic and hydrophobic interactions. Ionic functional groups in cyanotoxins react with the charged functional groups within the carbon to generate electrostatic interactions. Stronger ionic functional groups adsorb more rapidly onto the carbon surface because electrostatic repulsions decrease. Van der Waals forces attract the cyanotoxin molecules to the nonpolar carbon surface, creating a hydrophobic reaction. Relative hydrophobic properties of cyanotoxins influence its rate of adsorption. For example, hydrophobic variants of microcystin, such as microcystin-LF, adsorb quicker than less hydrophobic variants like microcystin-LY (He et al., 2016). In general, polar (soluble) compounds are less likely to adsorb onto the media than nonpolar compounds. Contaminants with a high molecular weight are more likely to adsorb (Continental Carbon Group, 2020).

Biofilm accumulation on GAC media has influenced toxin removal differently on several occasions. In some instances, biofilms blocked or clogged pore space, which lead to a decrease in toxin removal. In other cases, biofilm accumulation further helped to degrade toxins resulting in an increase of toxin removal. The latter scenario is names biologically active carbon (BAC). The use of GAC in conjunction with subsequent BAC has shown some success in pilot studies but it has not been tested in full scale treatment plants (He et. al., 2016). The concept of biologically active carbon has also shown success in slow sand filtration applications with >95% dissolved microcystin removal during summer months. Biologically active slow sand microcystin removal is highly dependent on temperature. Decreases in temperature during autumn decreased removal efficiency to less than 65% (Westrick, 2010)

7.3 - CHEMICAL INACTIVATION

Cyanobacteria and cyanotoxins are susceptible to inactivation via oxidation, but each strain reacts differently. Of the cyanobacteria present in Clear Lake, *Aphanizomenon* is the most susceptible to oxidation followed by *Anabaena*. *Microcystis* is the most resistant to oxidation. No oxidant will inactivate all cyanobacteria and toxins. Instead, treatment facilities utilize several different oxidants to mitigate cyanobacteria blooms (He et al., 2016). Of the toxins potentially present in Clear Lake, anatoxins and saxitoxins have two functional groups that are susceptible to oxidation whereas cylindrospermopsin has one functional group susceptible to oxidation. Microcystins have three functional groups that are susceptible to oxidation, however, microcystins are stable molecules whose biological function within cyanobacterial cells is to resist oxidation. Therefore, microcystins are the most resistant to chemical oxidation (Mioni, 2011; Westrick, 2010; He et al., 2016).

The use of some disinfectants, such as chlorine and ozone, cause cell lysis. Therefore, the order and combination of oxidants used in drinking water treatment facilities should be carefully considered to minimize the damage caused to intact cyanobacterial cells (He et al., 2016). It is often necessary for treatment plants to utilize more than one oxidant for effective treatment of cyanotoxins (He, et. al., 2016). See table 7.3.1 for a summary of oxidant effectiveness for the toxins present in Clear Lake

Table 7.3.1 Oxidant Effectiveness for Toxins Present in Clear Lake (Cheung, et. al., 2013)

Oxidant	Toxin			
	Anatoxin-a	Cylindrospermopsin	Microcystin	Saxitoxin
Chlorine	Not Effective	Effective (pH 7-9)	Effective	Somewhat Effective
Chloramine	Not Effective	Not Effective	Not Effective within normal operating parameters	Inadequate information
Chlorine Dioxide	Not Effective within normal operating parameters	Not Effective	Not Effective within normal operating parameters	Inadequate information
Potassium Permanganate	Effective	Not Effective	Effective	Not Effective
Ozone	Effective	Effective	Effective	Not Effective
UV	Effective	Effective	Not Effective	Inadequate information

7.3.1- Chlorine

Chlorine, in the form of sodium hypochlorite (NaOCl) or chlorine gas, is an effective oxidant for microcystins and cylindrospermopsin, but is ineffective for oxidizing anatoxins and saxitoxins. Despite its widespread use in surface water treatment systems, it is an aggressive chemical that has shown significant cyanobacterial cell damage resulting in the release of intracellular toxins. Conventional treatment should take place before chlorination to minimize the number of cyanobacterial cells in the water during disinfection (USEPA Health Advisory, 2015). Oxidation chemicals that cause cell lysis, such as chlorine, should not be used as a pre-treatment oxidant in Clear Lake.

Chorine is effective at oxidizing extracellular microcystins at a dose of 3mg/L when the pH is below 8 and a 30 minute contact time (CT) is maintained. Cylindrospermopsin is successfully oxidized at a dose of 1mg/L, pH of 7-9, and a CT of 30 minutes (Westrick, 2010). During bloom events, the pH of the raw water can reach above 9, therefore, water treatment facilities may have to implement a pH adjustment mechanism, such as the addition of muriatic or sulfuric acid, to decrease the pH to be within 7-9. Chlorine is only somewhat effective for the inactivation of saxitoxins and not effective for the inactivation of anatoxins.

7.3.2- Chloramines

The use of chloramines has little to no impact on cylindrospermopsin within a reasonable CT for drinking water purposes and has shown to be ineffective for the inactivation of microcystins and anatoxins (USEPA Health Advisory, 2015; He et. al., 2016). There is insufficient information to determine if chloramines are successful for the inactivation of saxitoxins (He, et. al., 2016). Choramination is a powerful tool for water systems that are confronted with significant DBP formation, however, since they do not inactivate the extracellular cyanotoxins in Clear Lake, utilities in Clear Lake are not recommended to use chloramines as a disinfectant. The physical treatment of cyanotoxins does little to remove extracellular toxins so there must be a robust disinfection system that works to inactivate extracellular toxins.

7.3.3- Chlorine Dioxide

Chlorine dioxide has been found to be useful in drinking water applications because it is a stronger oxidizer than chlorine, its effectiveness for most compounds does not depend on pH, and it does not undergo hydrolysis, meaning it does not dissociate in water and the oxidation potential remains constant. Despite its oxidative potential, chlorine dioxide has not been shown to inactive microcystins nor cylindrospermopsin within typical operating conditions. The reaction of chlorine dioxide and microcystins and cylindrospermopsin is slow and requires large dosages. Chlorine dioxide is ineffective for inactivating anatoxins, and there is insufficient evidence to indicate if it successfully inactivates saxitoxins (He, et. al., 2016). Due to its inability to inactivate extracellular toxins present in Clear Lake, chlorine dioxide is not recommended for use in Clear Lake surface water treatment facilities.

7.3.4- Potassium Permanganate

Potassium permanganate ($KMnO_4$) is often used as a pre-oxidant injected at intake structures for the purpose of reducing biological growth an intake structures, inhibit DBP formation, iron and manganese removal, and T&O mitigation. $KMnO_4$ can be added at the intake at doses between 1-5mg/L without significant cell lysis (Cheung, 2016; USPEA Health Advisory, 2015; He et al., 2016). Doses in excess of 5mg/L produce measurable release of intracellular toxins (He et al., 2016). In addition, it helps to coagulate intact cyanobacterial cells for more efficient removal during conventional treatment (Westrick, 2010).

Although $KMnO_4$ is an unselective oxidant, not all reaction rates are the same. $KMnO_4$ can oxidize microcystins and anatoxins within 40-60 minutes of CT. Since $KMnO_4$ is applied at the intake, $KMnO_4$ is given ample time to react and degrade microcystins and anatoxins (Laszakovits and MacKay, 2019; Rodriguez, et. al., 2007; He et al., 2016). However, it can take up to 28 days to degrade cylindrospermopsin and anywhere between 3-700 days to degrade saxitoxins, depending on the toxin. Therefore, $KMnO_4$ is only practical for degrading microcystins and anatoxins under normal operating conditions (Laszakovits and MacKay, 2019; Sharma, et. al., 2012; USPEA Health Advisory, 2015; He et al., 2016). A dose of 1.0mg/L $KMnO_4$ can degrade microcystins within a pH of 6-9, even with varying levels of alkalinity. The same dosage degrades anatoxins between a pH of 8 and 10. Temperature affects the reaction rate, with fast reactions happening during the summer months and slower reactions during winter. Since the majority of algal blooms in Clear Lake occur during warm months, $KMnO_4$ reaction rates are optimized for use in Clear Lake (Laszakovits and MacKay, 2019).

Microcystins compete with dissolved organic matter (DOM), and to a lesser extent cyanobacteria cells, for $KMnO_4$ oxidation. When there is DOM present in raw water, $KMnO_4$ reacts with DOM to a stronger extent than microcystins. High concentrations of DOM can result in significant concentrations of microcystins remaining in effluent waters. DOM has a high electron donating capacity, meaning that it gives electrons freely to $KMnO_4$ which fuels the reaction with DOM and $KMnO_4$. To mitigate this issue, sequential dosing of $KMnO_4$ is recommended. The first $KMnO_4$

chemical addition typically happens at the intake. After DOM and $KMnO_4$ have enough time to react, the electron donating capacity of DOM significantly decreases because it has already undergone oxidation. A subsequent dose of $KMnO_4$ somewhere else in the treatment train can be added to optimize microcystin inactivation. Subsequent dosing has shown to decrease microcystin levels from 126μg/L to less than 10μg/L. The final concentrations of microcystins can then be inactivated via the final disinfection step (Laszakovits and MacKay, 2019).

7.3.5- Ozone

Ozone (O_3) is an advanced oxidation treatment technique that is used to destroy pathogens and oxidize metals, such as iron, into insoluble metal oxides that can be later filtered out of solution. O_3 is unstable and cannot be transported to treatment facilities. Instead, treatment facilities using O_3 must use an onsite ozone generation technology at their facility. O_3 may support DBP formation such as bromate, chlorite and chlorate so care should be taken to minimize DBP formation with O_3 is in use (USEPA Health Advisory, 2015).

Ozone is effective at oxidizing microcystins (>90%), cylindrospermopsin (>95%) and anatoxins at low dosages (0.5mg/L) but is dependent on water quality parameters such as alkalinity, dissolved organic carbon, temperature, pH and CT (USEPA Health Advisory, 2015; He et al., 2016). O_3 is not effective at oxidizing saxitoxins (He et al., 2016). Several studies note that O_3 is the most effective oxidant for inactivating microcystins and cylindrospermopsin as compared to potassium permanganate, chlorine, chloramines, and chlorine dioxide (He et. al., 2016; Schmidt, 2010; Wert, et al., 2013) O_3 causes 90% cell lysis within 30 seconds at a dose of 6mg/L, which indicates a need to incorporate O_3 after filtration (He et al., 2016). Likewise, water must be filtered after O_3 injection to filter out insoluble metal oxides which creates a need to filter before and after ozonation (USPEA Health Advisory, 2015; Schmidt, 2010; He et al., 2016).

7.3.6- Ultraviolet Light

Ultraviolent Light (UV) is a form of advanced oxidation that is used in treatment facilities to inactivate pathogens. Subjecting cyanobacterial cells to intense solar energy is a successful way to destroy the organisms. UV can successfully oxidate cylindrospermopsin and anatoxins but is inadequate for microcystin degradation (USPEA Health Advisory, 2015). There is insufficient information to determine if it can degrade saxitoxins (Cheung, 2013).

Water treatment systems have a range of UV dosages from 10-40mJ/cm^2 using a low to medium pressure lamp to treat giardia, viruses, total coliform, and other common microorganisms found in raw water. However, doses required to degrade cylindrospermopsin and anatoxins are significantly higher, ranging from 1,500-20,000mJ/cm^2, therefore, high pressure lamps are required to degrade cyanotoxins (Westrick, 2010). The energy demand from increased UV dosages is a significant cost for water treatment facilities and should be carefully considered before implementing UV treatment for the degradation of cyanotoxins. UV must be installed after filtration and before final disinfection. UV causes cell lysis; therefore, it should be placed after filtration to minimize the number of intact cells being treated (Westrick, 2010).

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    - Chapter 3D: Road Management. May 2005,
    - Chapter 3E: Timber Harvesting. May 2005,
    - Chapter 3G: Fire Management. May 2005,
    - Chapter 3H: Revegetation of Disturbed Areas. May 2005,
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59. USGS, UC Davis: Summary Report on Metals and Metalloids in Clear Lake Based on Historical Data. June 2022
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62. USGS: Webpage, Mine Drainage. https://www.usgs.gov/mission-areas/water-resources/science/mine-drainage#overview
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ATTACHMENT A

RECENT WETLAND RESTORATION PROJECTS IN THE CLEAR LAKE BASIN

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

RECENT WETLAND RESTORATION PROJECTS

IN THE CLEAR LAKE BASIN

Project Implemented	Description of Project	Goals of Project	Results of Project	Sources
Middle Creek Flood Damage Reduction and Ecosystem Restoration Project	Connecting the area adjacent to Rodman Slough that was reclaimed for levee construction back to Scotts and Middle Creek.	Scotts and Middle Creek contribute 71% of Phosphorus loading to Clear Lake. This project would reduce 40% of the entering Phosphorus.	847 acres of property have been acquired, and 19 residences and associated infrastructure have been demolished. Two residences and approximately 1,000 acres of land remain to be purchased.	Lake County (2012) (lakecountyca.gov) Lake County Land Trust (2017/2018) (lakecountylandtrust.org)
Scotts Creek Project	Establishing wetland environment in Scotts Creek stream bank.	To prevent sediment erosion and improve water quality.	1,300 lineal feet of willow mattresses and 800 willow sprigs were planted. A control structure was implanted.	Forsgren (2012) 04 A Sanitary Survey_red.pdf
Big Valley Wetlands Project	Purchasing exisiting wetlands located in Big Valley.	To protect wetlands from being destroyed from agriculture and development.	Land Trust purchased 32 acres of wetland, and the Natural Resources Conservation Service purchased 153 acres of conservation easements.	Lake County Land Trust (2017/2018) (lakecountylandtrust.org)
Tule Lake Project	Purchasing conservation easements in Tule Lake.	To restore wetlands that were reclaimed in 1903 for agriculture.	788 acres of conservation easements in the Tule Lake area were purchased. The easements prohibit intensive agriculture and allow at least 588 acres of agricultural land to be restored to wetlands.	Lake County Land Trust (2017/2018) (lakecountylandtrust.org)
Wright Wetlands Preserve and Keithly Property	Reconnecting Clear Lake to wetlands in Wrights preserve and connecting Manning Creek to its delta in Wright Wetlands Preserve.	To remove levee sections, revegetate the area with native plants, relocate or remove fence lines, breach existing roadbed sections, and remove abandoned agricultural water pumps.	Wright Wetlands Preserve Project is still underway and will begin its operational period between August 15th and October 15th. Land is still being acquired for the Keithly Property.	City of Lakeport (cityoflakeport.com)

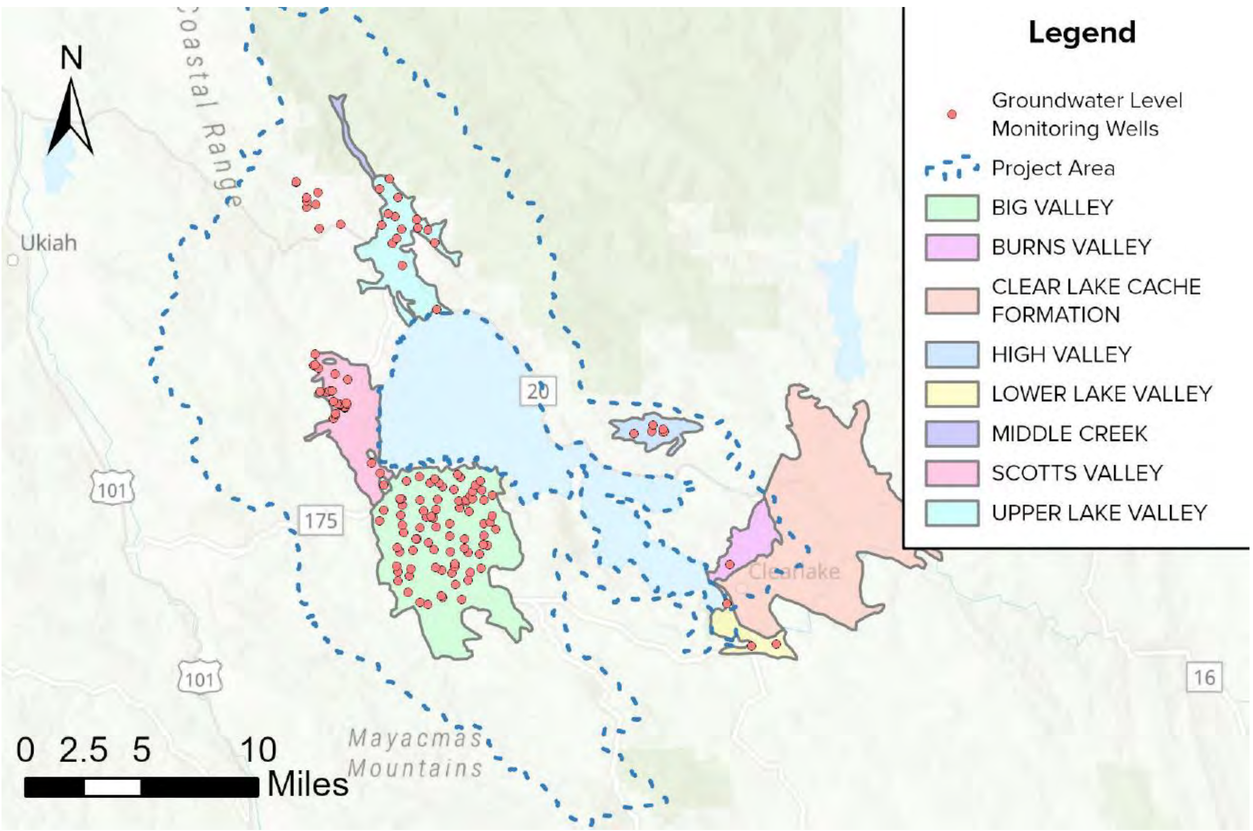
ATTACHMENT B

SUPPLEMENTAL GROUNDWATER INFORMATION

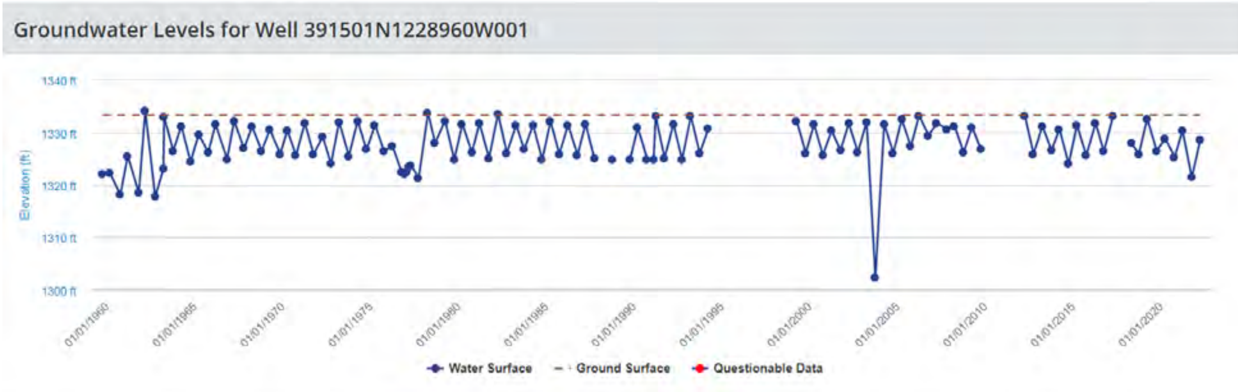
CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

ATTACHMENT B: SUPPLEMENTAL GROUNDWATER INFORMATION

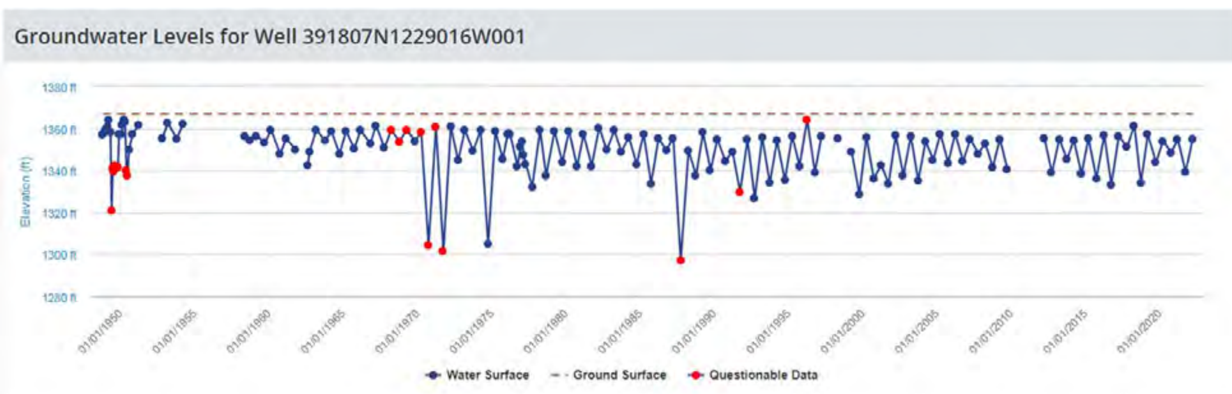
Basin Groundwater Levels (EXCLUDING QUALITY AND STREAM FLOW)
Water level data for basins in the study area were obtained from DWR (https://wdl.water.ca.gov/waterdatalibrary/Map.aspx). The number of monitoring wells per basin varied from none to several dozen with basins at the south end of the lake generally having the least data. The primary criteria for representative wells wee wells with lengthy data histories extending to present. The exceptions were basins with no wells or only wells not fitting these parameters. Both the Middle Creek and Clear Lake Cache Formation Groundwater basins have no DWR wells. Burns Valley has only a single well and Lower Lake Valley has three wells of which none have data more recent than 1995. The following figure depicts the basins and respective DWR monitoring wells.

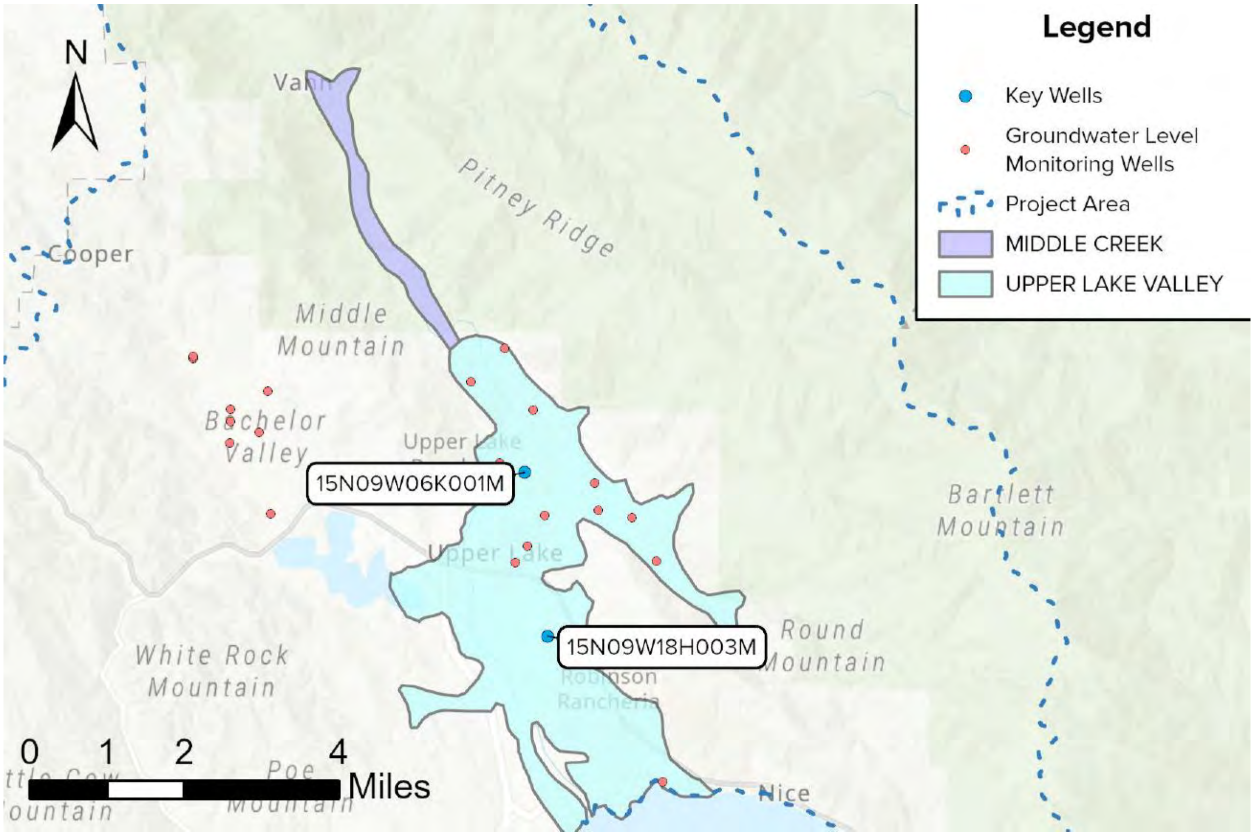


Upper Lake Valley Groundwater Basin
The key wells selected in the basin as are centrally located in both the southern and northern portions of the basin. Data for well 15N9W18HO3M begins in 1959 and ends in 2022 as shown on the hydrograph below. Seasonal highs reach the approximate land surface during the annual winter recharge cycle. Over the observation period, the aquifer has remained fully recharged with the exception of a brief period at the inception of data collection and the most recent period. The overall trend is that of a basin in equilibrium and not exhibiting signs of overdraft even with the recent drought.



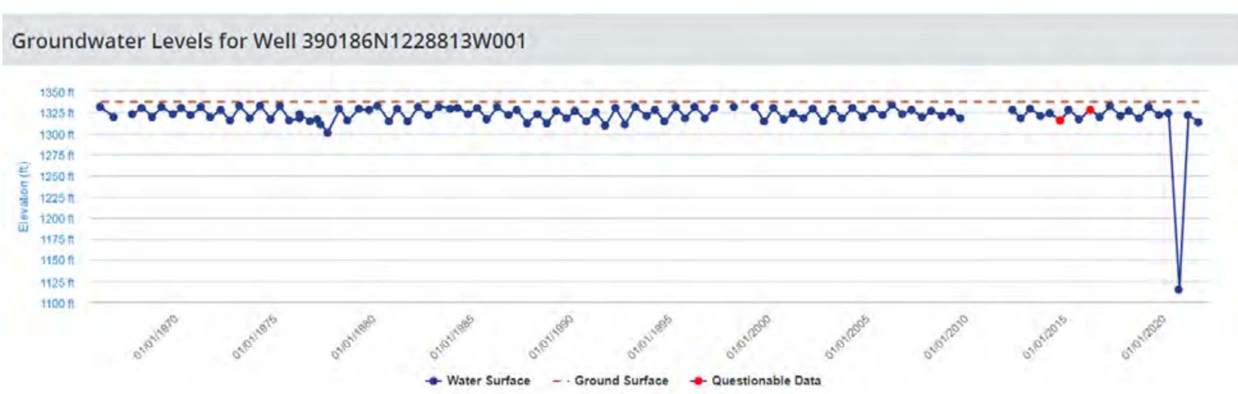
Data for well 15N09W06K001M begins in 1948 and ends in 2022 as shown below. Seasonal highs rarely reach the approximate land surface with most highs about 10 feet shy of the surface. Over the observation period, the aquifer has remained fully recharged with the recent drought. Seasonal lows can reach as much as 40 feet below land surface.



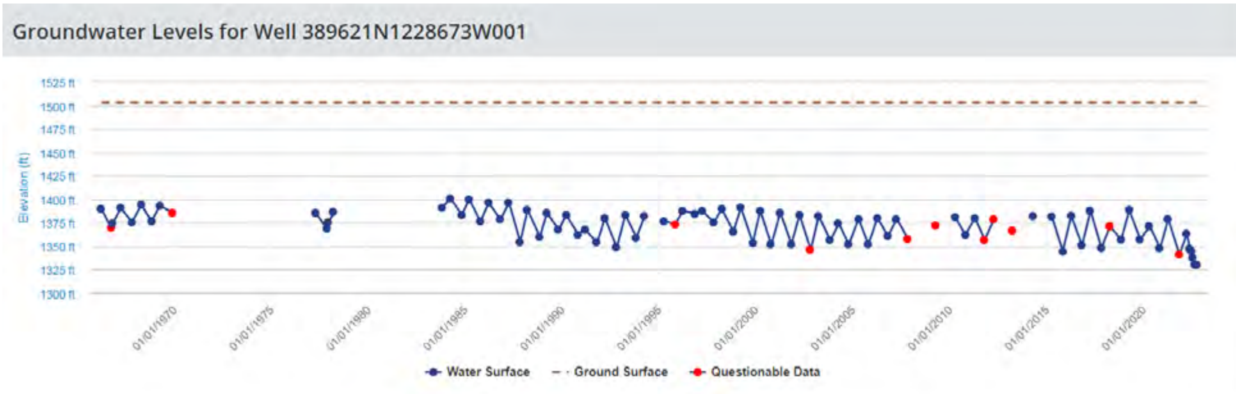


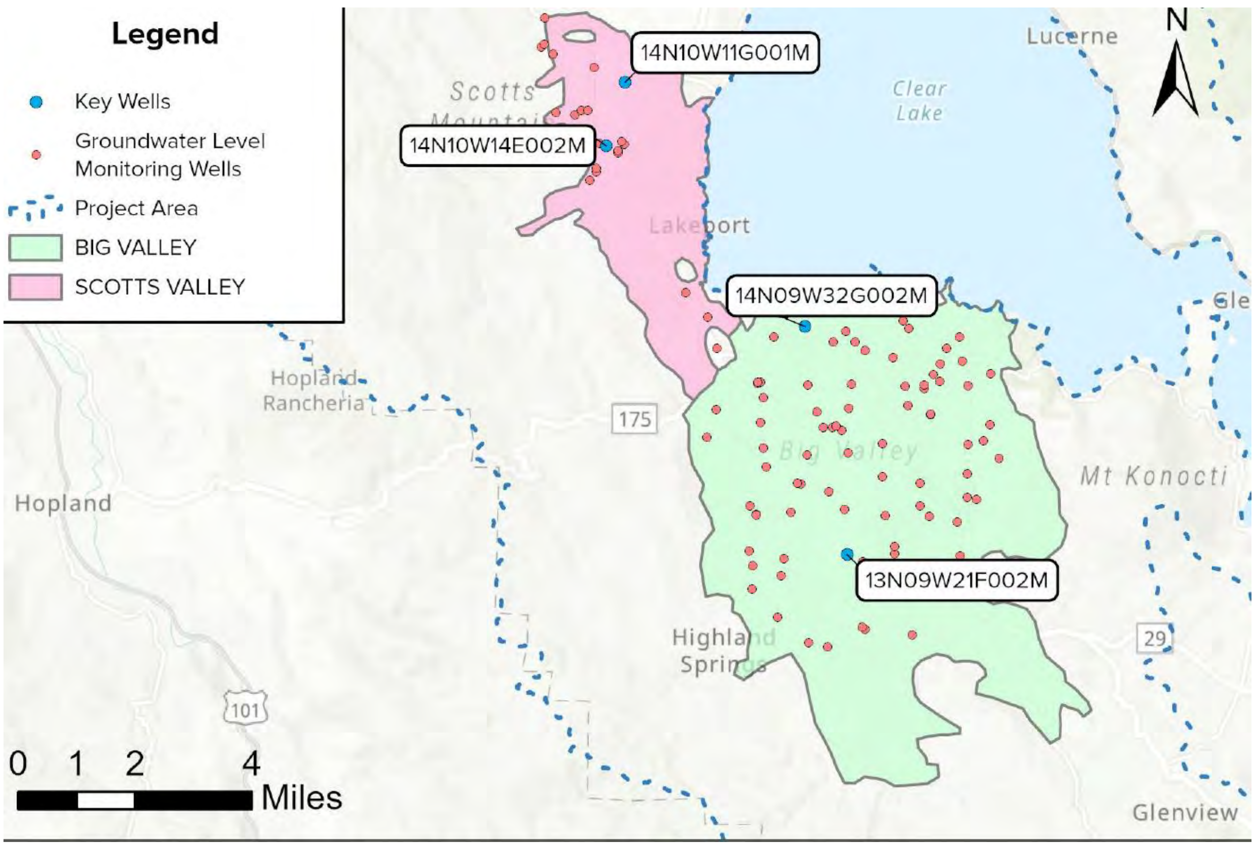
Big Valley Groundwater Basin

The key wells selected in the basin are centrally located in the extreme northern portion of the basin and south central. Data for well 14N09W32G002M (extreme north) begins in 1966 and ends in 2021 as shown on the hydrograph below. Seasonal highs consistently reach the approximate land surface during the annual winter recharge cycle. Over the observation period, the aquifer has remained fully recharged with modest seasonal lows possibly as a result of near continuous recharge from nearby Clear Lake.



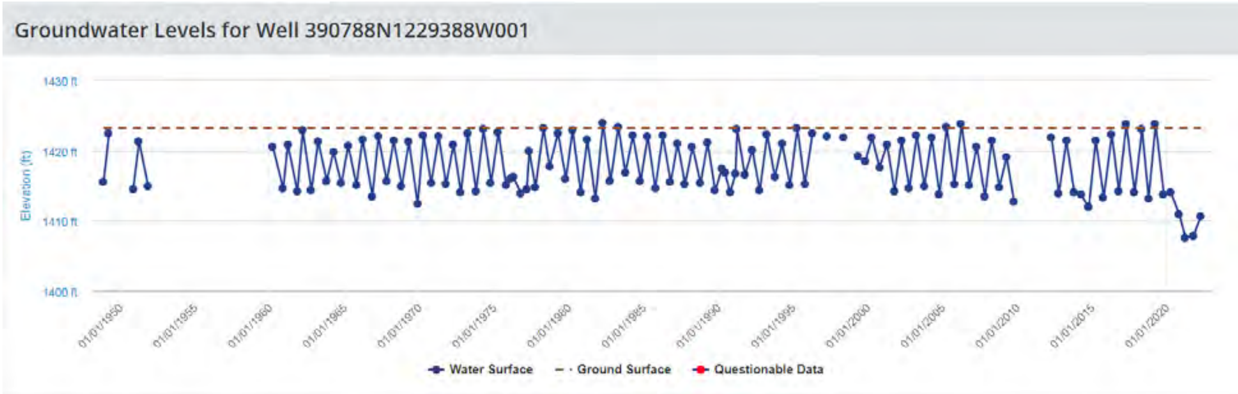
Data for well 13N09W21F002M, as shown on the hydrograph below, begins in 1966 and ends in 2022. Seasonal highs essentially reach the same level during the annual winter recharge cycle which is approximately 110-115 feet below the surface. Over the observation period, the aquifer has remained fully recharged with the exception of 1991 and the most recent period. The overall trend is that of a basin in equilibrium and not exhibiting signs of overdraft even with the recent drought.



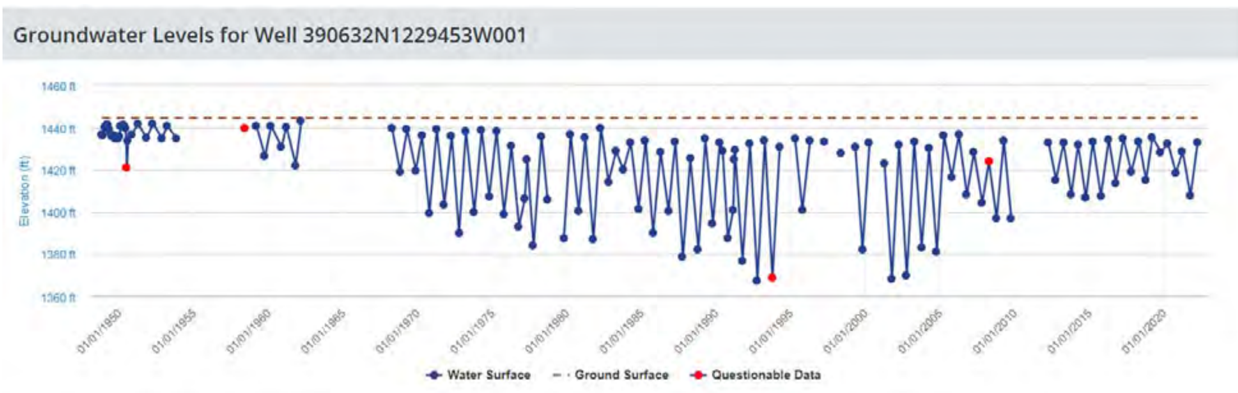


Scotts Valley Groundwater Basin

The key wells selected in the basin are centrally located in the northern southern portion of the basin. Data for well 14N10W11G001M (extreme north) begins in 1948 and ends in 2022 as shown on the hydrograph below. Seasonal highs consistently reach the land surface during the annual winter recharge cycle. Over the observation period, the aquifer has remained fully recharged with modest seasonal lows. The current drought is evident in record lows posted in 2021.

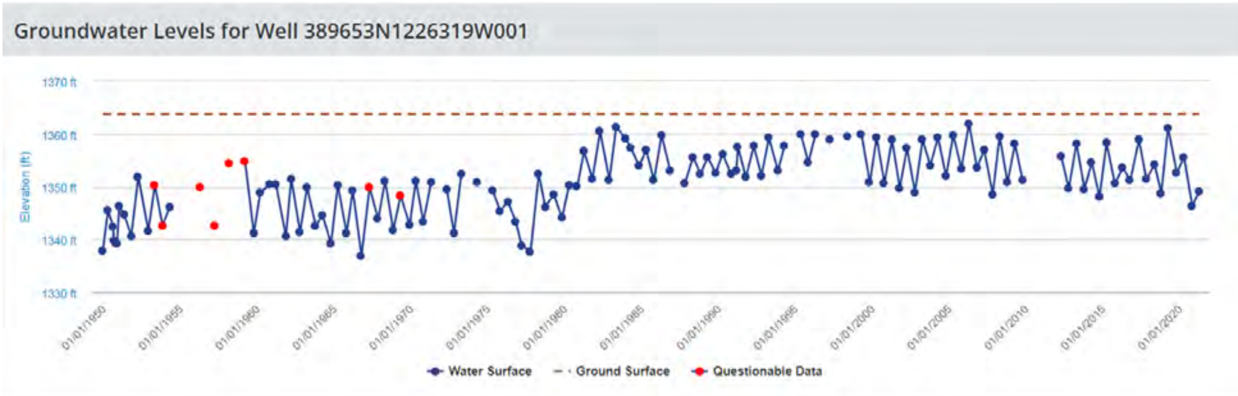


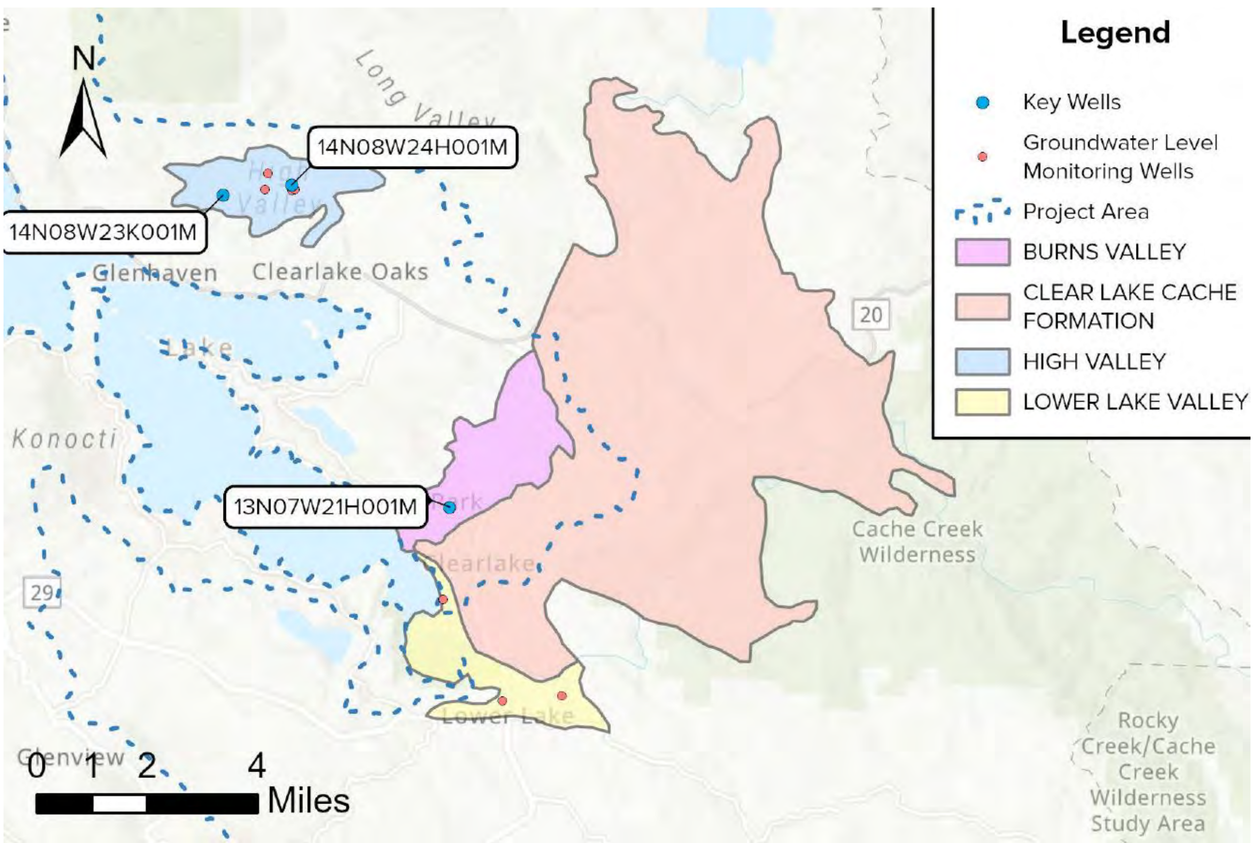
Data for well 14N10W14E002M, as shown on the hydrograph below, begins in 1948 and ends in 2022. Seasonal highs essentially reached the land surface early in the observation period but since 1968 water levels remained 8-10 feet below the surface. Seasonal lows can be 70 feet below the surface. Despite the somewhat lower seasonal highs since 1968 the aquifer has remained fully recharged and the recent drought is not affecting overall basin health.



Burns Groundwater Basin

Data for 13N07W21H001M, as shown on the hydrograph below, begins in 1949 and ends in 2021. There are not other DWR wells in the basin. Seasonal highs have remained elevated since 1982 essentially reaching the land surface and seasonal lows are typically 15 feet below the surface. The abrupt change in both seasonal lows and highs appears to reflect reduced basin usage after 1982 placing the basin in balance with annual recharge cycles. The current drought is evident as the last two entries are depressed relative to recent history although the duration of the drought affect has yet to span a meaningful period of time.



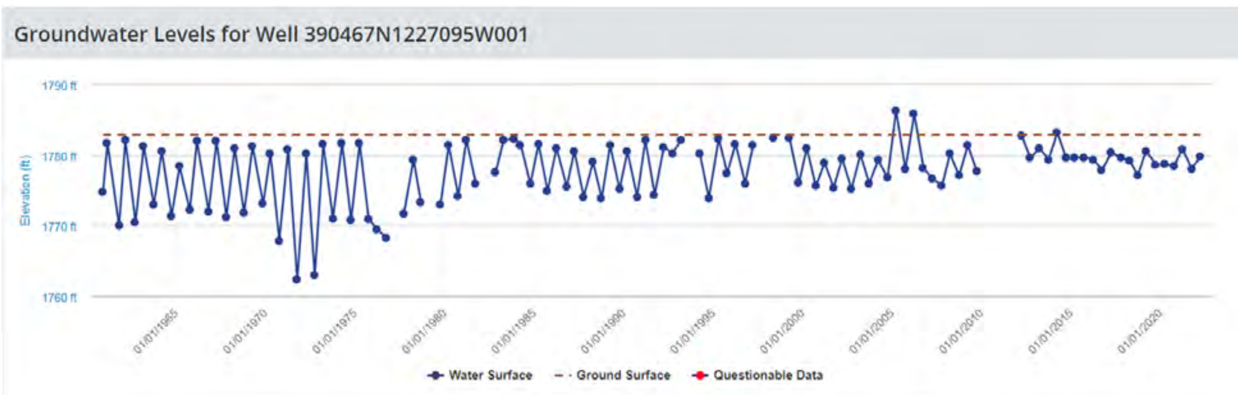


Lower Lake Valley Groundwater Basin
No wells with extended data sets exist in the basin; only three wells are mapped. The most recent data ends in 1995.

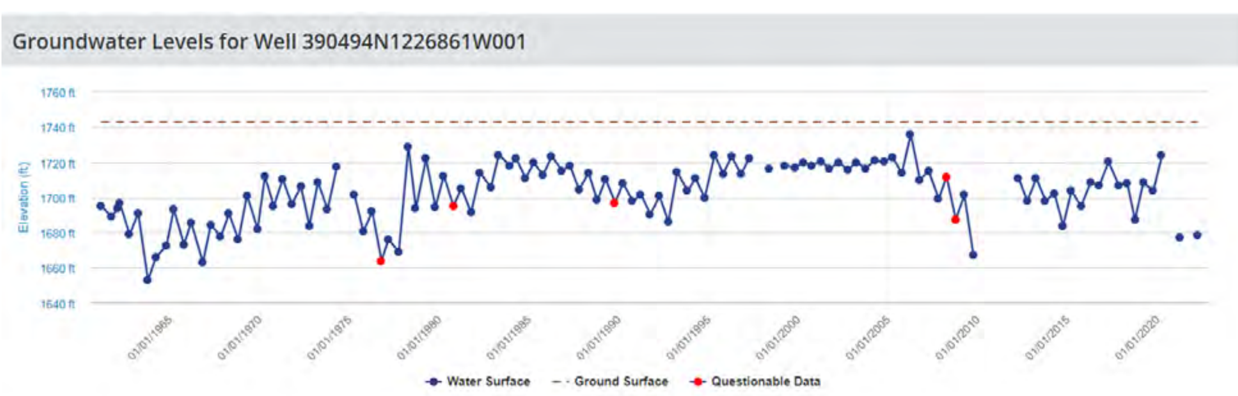
Burns Groundwater Basin
No wells with extended data sets exist in the basin; only one well is mapped. The most recent data ends in 1974.

Clear Lake Cache Formation Groundwater Basin
No wells with extended data sets exist in the basin; only one well is mapped. The most recent data ends in 1974.

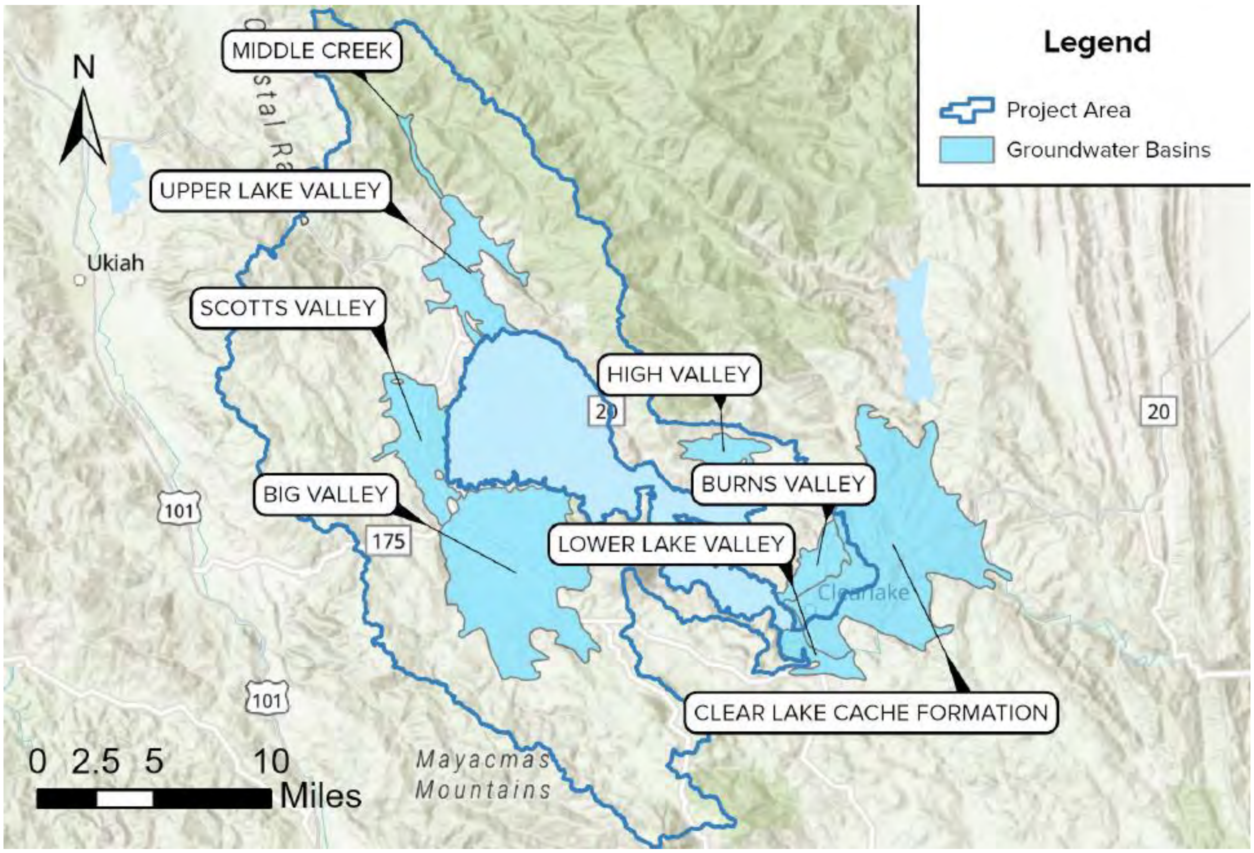
High Valley Groundwater Basin
The number of monitoring wells is limited to six. The key wells selected are on the western perimeter and the central east portion of the basin. Data for well 14N08W23K001M (extreme west) begins in 1960 and ends in 2022 as shown on the hydrograph below. Seasonal highs consistently reached the land surface during the annual winter recharge cycle although since 2014, coincident with the current drought, water levels have failed to reach historic annual highs. It is clear that basin management has become more efficient as the seasonal lows have become less pronounced over time with the period since 2014 showing annual highs and lows swing over a four foot range compared to as much s 20 feet in 1971. Over the observation period, the aquifer remained fully recharged until 2014 when the current drought muted the annual recharge highs.



Data for well 14N08W24H001M, as shown on the hydrograph below, begins in 1961 and ends in 2022. Seasonal highs have varied widely with the period of greatest basin recharge being constrained to the period from 1978 – 2006. Both before and after the 1978 – 2006 period, winter watertable highs were lower with some dramatic periods of short term overdraft that were subsequently reversed. The most recent water levels (2021, 2022) are depressed relative to historic norms.



Major and Minor Aquifers
Clear Lake is surrounded by a patchwork of groundwater basins interspersed with non-basin terrain as shown on the following map. The Sustainable Groundwater Management Act (SGMA) Dashboard (https://gis.water.ca.gov/app/bp-dashboard/final/) maps seven DWR defined groundwater basins in the study area. Both the major and minor aquifers feeding domestic wells and the one public water system (City of Lakeport) still using wells are found in these basins. DWR describes each basin as listed below.



Middle Creek Groundwater Basin
DWR(a) (2004) states the following: *The Middle Creek Groundwater Basin is a north-trending basin located west of Pitney Ridge and east of Middle Mountain. The basin consists of Quaternary alluvium and is likely in hydraulic continuity with the Upper Lake Groundwater Basin. Faulting may extend the length of the western boundary. The basin is bounded to the north and east by the Franciscan Formation. Much of the western portion of the basin is bounded by Lower Cretaceous marine deposits.*

Hydrogeologic information was <u>not available</u> for the following:
Water-Bearing Formations
Groundwater Storage

Upper Lake Groundwater Basin

DWR(a) (2004) states the following: *The Upper Lake Basin is an irregularly shaped basin at the north end of Clear Lake that includes Middle Creek Valley, Clover Valley, and Bachelor Valley, all of which extend to a main central valley opening to the south to Clear Lake. Middle Creek Valley and Clover Valley are bounded by Middle Mountain to the west and Pitney and Hogback Ridges to the east (Jennings, 1969). Precipitation in the basin ranges from 35- to 43-inches annually, increasing to the north.*

The aquifer system in the Upper Lake Basin is composed primarily of Quaternary alluvial deposits and Pliestocene terrace, lake, and floodplain deposits. The alluvium, lake, and floodplain deposits fill the valleys and contain nearly all water yielded to wells. The contact between the bedrock bounding the unconsolidated alluvium generally defines the basin boundary. Bedrock units in the area include the Franciscan Formation and the Great Valley Sequence (Earth Sciences Associates 1978).

The average specific yield for the depth interval of 0 to 100 feet is estimated to be 8 percent based on review and analysis of well logs for the Upper Lake Basin (DWR, 1957). The storage capacity for the basin is 10,900 acre-feet (DWR, 1957). DWR (1975) estimates the useable storage capacity to be 5,000 acre-feet.

Recharge Areas

Groundwater recharges the basin from the mouths of canyons and around the periphery of the basin. Recharge also occurs along Middle Creek, Clover Creek, and Alley Creek (ESA, 1978). Groundwater recharge occurs from the stream channels during the early part of the wet season, and the basin fully recharges and contributes to stream flow during most wet seasons. Lesser amounts of recharge occur to the groundwater basin through percolation of smaller streams and direct rainfall. Additional recharge results from irrigation return flow and septic system percolation.

Scotts Valley Groundwater Basin

DWR(b) (2004) states the following: *The Scotts Valley Basin lies adjacent to the west side of Clear Lake and extends northwesterly along Scotts Creek north to Hidden Lake. The valley is bordered to the east by the shoreline of Clear Lake and bounded on the west and the north by the Jurassic-Cretaceous Franciscan complex of metamorphic and sedimentary rocks which constitute the basement rock in the basin (Jennings, 1969). The basin shares a boundary with the Big Valley Basin to the south and may be hydrologically contiguous. Annual precipitation in the basin ranges from 31- to 35-inches, increasing the northwest.*

The aquifer system in Scotts Valley Basin is composed primarily of Quaternary alluvial and terrace deposits, and Plio-Pleistocene to Pleistocene lake and floodplain deposits. Plio-pleistocene Cache Formation sediments overlie bedrock.

The average specific yield for the depth interval of 0 to 100 feet is estimated to be 8 percent based on review and analysis of well logs (DWR, 1957). The storage capacity for the basin is estimated to be 5,900 acre-feet based on the above depth interval and estimate of specific yield (DWR, 1957). DWR (1960) estimates the useable storage capacity to be 4,500 acre-feet.

Recharge Areas

Recharge to the confined aquifer takes place in the forebay or unconfined zone in the southern portion of the valley. Percolation from Scotts Creek is the principal source of recharge with minor amounts from precipitation and applied irrigation water.

Big Valley Groundwater Basin

DWR(c) (2004) states the following: *The Big Valley Basin is located in the west-central portion of Lake County. The basin has been referred to as the Kelseyville Basin in previous versions of Bulletin 118. The basin name has been changed from Kelseyville Basin to the Big Valley Basin in this bulletin update to reflect past investigative work and to avoid any confusion with references to the Kelseyville Subbasin – an aquifer system within Big Valley. Plio-Pleistocene extrusive rocks of Mt. Konocti and Camelback Ridge border the basin to the east and southeast. The Jurassic-Cretaceous Franciscan Formation borders the basin to the west and south and constitutes the basement rock (SMFE 1967). The north side of the basin is open to Clear Lake. The basin shares a boundary with the Scott Valley Basin to the northwest and may be hydrologically contiguous. Precipitation in the basin ranges from 22 to 35inches annually, decreasing to the northeast.*

Previous work conducted in the valley identified eight subbasins based on geologic structure, geologic material, and aquifer conditions (perched or confined conditions) (SMFE 1967). For the purpose of this basin summary, the valley has been divided into five subbasins based on geologic conditions, groundwater boundaries, and topography. These areas are referred to as the Western Upland, the Adobe Creek-Manning Creek Subbasin, the Kelseyville Subbasin, the Central Upland and Upper Big Valley Subbasin, and the Cole Creek Upland.

The Western Upland is a one-half to one-mile wide topographic bench located along the western margin of the basin. The Adobe Creek - Manning Creek Subbasin is located east of the Western Upland, extends north to the Big Valley Fault, and is hydrologically connected to the Kelseyville Subbasin. The Kelseyville Subbasin is located north of the Big Valley Fault and extends north to Clear Lake. The Central Upland and Upper Big Valley Subbasin includes the eastern half of the basin south of the Big Valley Fault and is geologically similar to the Western Upland but is separated topographically by the Adobe Creek – Manning Creek Subbasin and separated structurally by the Adobe Creek Fault system. The Cole Creek Upland is located east of the Central Upland and Upper Big Valley system and is bounded to the north by the Mt. Konocti volcanics and to the south by Camel Back Ridge.

The Big Valley Basin is comprised of extensive Quaternary to late Tertiary alluvial deposits, including fan deposits, lake bed and flood plain deposits, and terrace uplands. The primary water-bearing formations in the basin are Quaternary alluvium, lake, and terrace deposits and Upper Pliocene to Lower Pleistocene volcanic ash deposits.

DWR (1960) estimates storage capacity to be 105,000 acre-feet for a saturated depth interval of 10 to 100 feet. Useable storage is estimated to be 60,000 acre-feet.

Recharge Areas

Recharge in the northern portion of the Big Valley Basin is primarily infiltration from Kelsey Creek and by underflow from the Adobe Creek-Manning Creek Subbasin. Underflow occurs mainly from more permeable zones at depths of 25- to 45-feet and 70- to 90-feet. A limited amount of underflow probably enters the basin from the Central Upland system and from Mt. Konocti. Some recharge by infiltration of rain, applied water, and creek water occurs in areas other than the Kelsey Creek flood plain; however, direct surface recharge is inhibited by clayey soil and the near surface clay layer (SMFE 1967).

Recharge within the Adobe Creek-Manning Creek Subbasin is from percolation from the channels of Highland and Adobe Creeks and from underflow from the Western Upland and Central Upland areas.

Lower Lake Valley Groundwater Basin

DWR(d) (2004) states the following: *Lower Lake Basin is located at the southeast end of Clear Lake and includes the alluvial plains of Cache, Herndon, and Seigler Canyon Creeks. Copsey Creek also drains to Cache Creek from Excelsior Valley located to the south. The basin is bounded on the south by Plio-Pleistocene Cache Formation, Tertiary bedrock, and rocks of the Great Valley Sequence; on the north by the Cache Formation and Quaternary volcanics; and on the east by Tertiary rock of the Martinez and Tejon formations. Surficial Cache Formation and Martinez Formation deposits are located within the middle third of the basin north and northeast of the city of Lower Lake. Annual precipitation in the basin is approximately 27 inches.*

The aquifer system of Lower Lake Basin is primarily composed of deposits of Quaternary alluvium and the Plio-Pleistocene Cache Formation (Upson, 1955).

Storage capacity is estimated to range from 3,000 to 4,000 acre-feet (Upson, 1955). Additional storage capacity is available as part of the Cache Formation; however, thickness and specific yield of that formation is unknown.

Recharge Areas

Groundwater recharge is derived from precipitation and from seepage from Herndon Creek and Clear Lake (Upson, 1955). Recharge also likely occurs from Copsey and Seigler Canyon creeks. Recharge of groundwater in the Cache formation is likely derived from the infiltration of rain that falls on the outcrop area (Upson, 1955).

Clear Lake Cache Formation Groundwater Basin

DWR(e) (2004) states the following: *The Clear Lake Cache Formation Groundwater Basin is located east of Clear Lake and shares a basin boundary with the Burns Valley Groundwater Basin to the southwest. The basin is bounded to the south by lower Cretaceous marine and Knoxville Formation deposits and Mesozoic ultra-basic intrusive rocks. The basin is bounded on the east by lower Cretaceous marine deposits and to the north and west by rocks of the Franciscan Formation. The basin is drained by the North Fork Cache Creek and by Cache Creek. Faulting is observed along portions of the western and southern boundaries. Precipitation ranges from 25 to 29 inches.*

The primary water-bearing formation is the Cache Formation. The Cache Formation is largely made up of lake deposits. The formation consists of tuffaceous and diatomaceous sands and silts, limestone, gravel, and intercalated volcanic rocks. In some areas the general lithology includes up to 400 feet of blue clay and shale with alternating strata of shale and limestone below 400-feet (DWR, 1957). The permeability of the formation is generally low.

Burns Valley Groundwater Basin

DWR(f) (2004) states the following: *Burns Valley Basin is located along the southeastern edge of Clear Lake and consists of low-lying alluvial plains and upland terrace deposits. The basin is bounded by basalt flows to the northwest and the Plio-Pleistocene Cache Formation on all other* *sides with the exception of Olivine basalt to the southeast. The west side of the basin opens to Clear Lake. The Cache Formation underlies the majority of the basin. Assuming that there is hydraulic continuity between the alluvium and the Cache Formation, groundwater is in hydraulic continuity in all directions beyond the alluvial plain with the exception being to the northwest. The Jurassic-Cretaceous Franciscan Formation and volcanics constitute the basement rock (USBR 1976). Almost all of the groundwater of Burns Valley is derived from rain that falls within a 12.5 square mile drainage area (Upson 1955). Annual precipitation in the basin is approximately 27 inches.*

Quaternary alluvium and upland terrace deposits and the Plio-Pleistocene Cache Formation are the primary water-bearing deposits in the valley.

Storage capacity is estimated to be 4,000 acre-feet based on an area of 1,000 acres, a saturated thickness of 50 feet, and a specific yield of 8 percent (Upson 1955). DWR (1960) estimates the useable storage capacity to be 1,400 acre-feet.

High Valley Groundwater Basin

DWR(g) (2004) states the following: *High Valley Basin is a small, poorly drained, isolated valley about 2 miles north of Clearlake Oaks in the Coast Ranges. It is nearly a closed basin, with the only outlet being the narrow gorge of Schindler Creek in the southeast corner. The valley consists of a flat alluvial plain about 3 miles long and 1 mile wide, surrounded by a narrow band of high, steeply sloping hills. The contact between the Jurassic-Cretaceous Franciscan Formation bounding the valley alluvium generally defines the basin boundary to the north, west, and south. Baldy Mountain is located to the west and High Valley Ridge boarders the valley to the north. Quaternary Holocene volcanics border the basin to the east (Jennings 1969). Annual precipitation in the valley ranges from 27 to 35 inches, decreasing to the east.*

The aquifer system in High Valley Basin is comprised primarily of Quaternary alluvial deposits and Holocene volcanic deposits. The alluvium overlies a confined volcanic aquifer of Holocene age. Below the volcanic aquifer are older alluvial deposits about which there is little information.

Information with respect to the hydrogeology of the basin is limited. Little is known in regards to the lithology of the deeper alluvium and it's believed that the extents of the alluvium may be several miles to the east underneath the younger volcanics. DWR (1960) estimates the storage capacity to be 9,000 acre-feet for a saturated depth interval of 10 to 10 feet. Usable storage capacity is estimated to be 900 acre-feet.

Groundwater flow direction typically mirrors the land surface barring barriers such as concealed bedrock, faults, pumping depressions to name a few. Groundwater modeling in the study area was recently done for the Big Valley Groundwater Basin Sustainability Plan (County of lake, 2022) as depicted below. None of the other six groundwater basins have groundwater basin sustainability plans. Note that groundwater flow is towards the lake conforming to expectation.

In winter months after heavy precipitation the groundwater table can approach the land surface especially in areas nearer to the lake and at topographic lows. Stream channels represent topographic lows which can intercept the groundwater table causing the discharge of groundwater into the stream channel. Active stream channels also represent hydrologic highs which can alter the flow direction of groundwater. Dissolved phase contaminant migration will conform to the local gradient of groundwater flow or surface flow.

Source; Big Valley Groundwater Basin Sustainability Plan (County of lake, 2022)

Characterization of Aquifer Chemistry
Groundwater quality data as available from DWR is summarized for each Basin. Additionally, Big Valley Groundwater Basin collects and disseminates data through their Groundwater Sustainability Agency

Middle Creek Groundwater Basin
DWR(a) (2004) does not provide water chemistry data rather a summary of well types with depths and typical yields as summarized below. No public water systems are reported to extract groundwater from this basin.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	1-3	75	54-100, 70 average
Domestic	31	--	31-250, 108 average

Upper Lake Groundwater Basin
DWR(a) (2004) states the following: *Magnesium bicarbonate and calcium bicarbonate water are the predominant groundwater types in the basin. Total dissolved solids (TDS) range from 180 to 615 mg/L, averaging 500 mg/L. Boron has been detected is some wells in the basin; however, high boron is not a prevalent condition (DWR 1957). Water quality analyses show high iron, manganese, EC, calcium, ASAR, and TDS.*

No public water systems are reported to extract groundwater from this basin. A summary of well types with depths and typical yields as summarized below.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	129	15-900	50-308, 129 average
Domestic	89	--	20-390, 89 average

Scotts Valley Groundwater Basin
DWR(b) (2004) states the following: *Calcium-magnesium bicarbonate is the predominant groundwater type in the basin (SWRCD 1978). TDS range between 140 to 175 mg/L, averaging 158 mg/L (DWR unpublished data). Iron, manganese, and boron concentrations exceed EPA maximum acceptable concentrations for continuous irrigation for selected wells (SWRCB 1978).*

The City of Lakeport public water system relies on four wells to extract groundwater from this basin. A summary of well types with depths and typical yields as summarized below.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	132	6-1200	28-600, 127 average
Domestic	497	--	5-408, 125 average

Big Valley Groundwater Basin
DWR(c) (2004) states the following: *Magnesium bicarbonate is the predominant groundwater type in the basin. TDS range from 270 to 790 mg/L, averaging 535 mg/L (DWR unpublished data). Boron is present in groundwater at concentrations that may be injurious to crops (SMFE 1967).*

The County of Lake Water Resources (2021) states that the *Widespread presence of contaminants at undesirable levels (concentrations that exceed applicable regulatory limits) has not been reported in groundwater samples in the Basin.* Concentrations of TDS, nitrate, arsenic, and boron

No public water systems are reported to extract groundwater from this basin. A summary of well types with depths and typical yields as summarized below.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	285	30-1470	48-524, 162 average
Domestic	414	--	20-660, 103 average

Lower Lake Valley Groundwater Basin
DWR(d) (2004) states the following: *Bicarbonate type waters with mixed cationic character are found in the basin. TDS concentrations range from 290 to 1,230 mg/L, averaging 568 mg/L (DWR unpublished data). Groundwater in the basin has localized high iron, manganese, calcium, sodium, ASAR, sulfate, and TDS. High boron concentrations may be an issue for irrigation.*

No public water systems are reported to extract groundwater from this basin. A summary of well types with depths and typical yields as summarized below.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	17	3-100	26-340, 113 average
Domestic	86	--	22-230, 78 average

Clear Lake Cache Formation Groundwater Basin
No public water systems are reported to extract groundwater from this basin. A summary of well types with depths and typical yields courtesy of DWR(e) (2004) is summarized below.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	23	11-245	58-380, 162 average
Domestic	113	--	23-450, 103 average

Burns Valley Groundwater Basin
No public water systems are reported to extract groundwater from this basin. A summary of well types with depths and typical yields courtesy of DWR(e) (2004) is summarized below.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	3	30	68-175, 134 average
Domestic	65	--	30-335, 108 average

High Valley Groundwater Basin
DWR(g) (2004) states the following: *Groundwater in the basin consists of magnesium bicarbonate type waters. TDS range from 480 to 745 mg/L, averaging 598 mg/L (DWR unpublished data). Impairments to water quality include locally high ammonia, phosphorus, chloride, iron, and manganese. High boron may be an issue for agricultural uses.*

No public water systems are reported to extract groundwater from this basin. A summary of well types with depths and typical yields is summarized below.

Well Characteristics Summary

Well Type	**Number of Well Logs**	**Yield** (gpm)	**Depth** (ft)
Municipal/Irrigation	17	3-100	26-340, 113 average
Domestic	86	--	22-230, 78 average

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ATTACHMENT C

SUPPLEMENTAL CLEAR LAKE WATER QUALITY INFORMATION

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

Attachment C: Clear Lake Water Quality

This section summarizes data collected by the California Department of Water Resources (DWR) and the County of Lake Department of Water Resources from 2015 to 2022. The DWR collected samples from locations throughout the lake from 2002-2020 (California Department of Water Resources Water Data Library, 2022). When DWR ceased their monitoring program in 2020, the County of Lake Department of Water Resources took over monitoring at the same locations in 2021. Funding for the continuation of the County of Lake's monitoring program is not guaranteed for subsequent years (DePalma-Dow, 2022). Data collected by the County of Lake Department of Water Resources is uploaded to the California Environmental Data Exchange Network (CEDEN). Some data from drinking water intakes are included in this section, however, most intake water quality data is summarized in section 8. Drinking water intake data was obtained through the California Safe Drinking Water Information System (SDWIS).

The DWR/CEDEN monitoring locations summarized in this section are as follows:

- Upper Arm CL-1 (0.5 Meters)
- Oaks Arm CL4 (0.5 Meters)
- Lower Arm CL3 (0.5 Meters)

The DWR monitored for the constituents found in Table 1. Of these constituents, those that were detected at levels close to regulatory limits (maximum contaminant level [MCL] or secondary maximum contaminant level [SMCL]), as well as other constituents of concern, are summarized in this section.

Table 1: DWR Monitoring Constituents

Constituent			
Aluminum	Copper	Nitrate	Sodium
Alkalinity	Dissolved Oxygen	Nitrate + Nitrite	Specific Conductance
Ammonia	Hardness	Orthophosphate	Sulfate
Arsenic	Iron	pH	Temperature
Boron	Lead	Phosphorus	Total Dissolved Solids
Cadmium	Magnesium	Potassium	Total Suspended Solids
Calcium	Manganese	Secchi Depth	Total Kjeldahl Nitrogen
Chloride	Mercury	Selenium	Turbidity
Chromium	Nickel	Silver	Zinc

Primary and Secondary Standards

Raw water detections, either in-lake or at drinking water intakes, that approach, meet, or exceed regulatory limits are summarized below. Additional discussions of MCL exceedances and compliance for individual utilities are addressed in Section 8.

Total Aluminum

Aluminum concentrations in Clear Lake are presumed to be both naturally occurring with a potential influence from the Sulphur Bank Mercury Mine. The volcanic rock types surrounding Clear Lake, such as shale, basalt, chert, and other igneous rock types, are known to be naturally rich in metals such as arsenic, aluminum, and antimony (McNitt, J.R., 1968). Most significant enter via the Upper Arm, which consistently has the highest concentration of aluminum. This indicates that the aluminum concentrations are primarily a result of natural deposits and erosion. Additionally, Waters with high concentrations of organic matter, like Clear Lake, tend to have naturally higher concentrations of aluminum (Aluminum in Drinking-water, 1998).

High concentrations of aluminum, arsenic, and mercury were found in sediment samples taken from the Sulphur Bank Mercury Mine in 2008 (Shipp & Zierenberg, 2008). Runoff from the Sulphur Bank Mercury Mine has not flowed into Clear Lake since 2000 but sediment transport is possible (Sulphur Bank Mercury Mine Clearlake Oaks CA Cleanup Activities, 2022). The World Health Organization found that water effected from acid mine drainage tends to have higher concentrations of aluminum, arsenic, and other heavy metals (Aluminum in Drinking-water, 1998).

Samples taken at monitoring locations throughout the lake show a range from non-detect (ND) to 370 micrograms per liter (µg/L) with an average value of 40.5 µg/L (Figure 1). The data from 2015-2019 show a slight trend of higher concentrations in April. No such trend can be found in 2021. Samples collected before 2020 were collected by the California Department of Water Resources whereas samples collected after 2020 were collected by the County of Lake Department of Water Resources. The same EPA method 200.8 was used for analysis but the two agencies used different labs. It is unclear whether the difference in results is due to the difference in lab, or if there is an increase in aluminum concentrations in the lake after 2020. Of the 141 data points, five were detected above the SMCL of 200 µg/L, all during 2021.

Samples from drinking water intakes show a range of ND to 1700 µg/L with an average value of 103.3 µg/L. The data shows a similar trend of increased aluminum concentrations in April (Figure 2). Drinking water intake data does not show a trend of increased aluminum concentrations in 2021. Of the 126 data points, 17 exceeded the SMCL of 200 µg/L and 1 exceeded MCL of 1,000 µg/L. All systems that exceed the SMCL for aluminum must monitor quarterly and determine compliance based on the running annual average per 22 CCR § 64449.

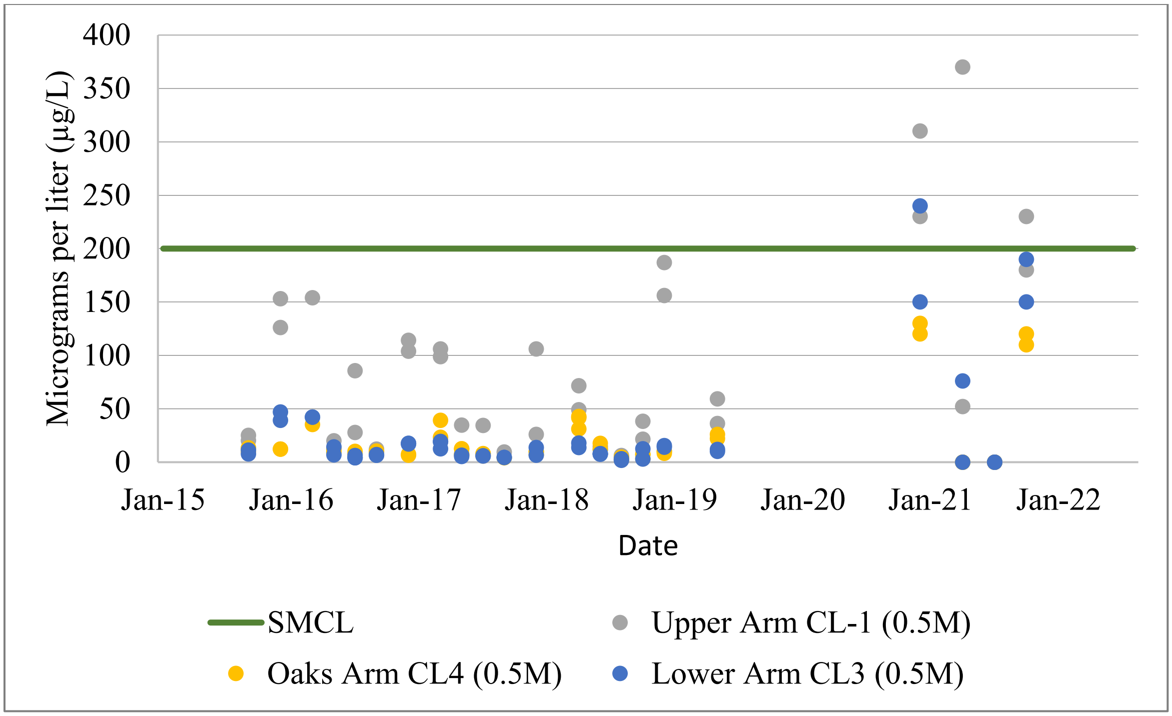

Figure 1: Total Aluminum - In-Lake Monitoring

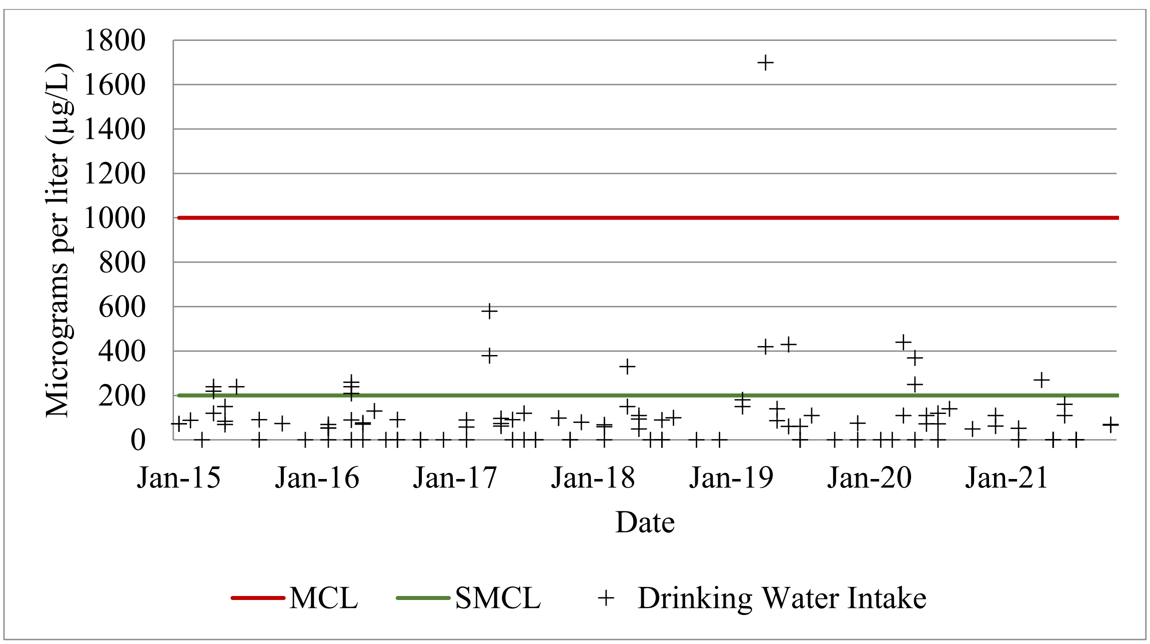

Figure 2: Total Aluminum - Drinking Water Intakes

Total Arsenic

Similar to total aluminum concentrations, total arsenic concentrations are presumed to be both naturally occurring and potentially influenced by the Sulphur Bank Mercury Mine via sediment transport. Samples taken at monitoring locations throughout the lake show a range from ND to 12.6 µg/L (Figure 3). The data shows higher concentrations in the fall with an overall downward trend from year to year. The high of 2015 was 12.6 µg/L, whereas the high in 2021 is 0.98 µg/L. Of the 128 data points, 4 exceeded the MCL of 10 µg/L. The highest and lowest concentrations are within the Upper Arm, indicating that the primary source of arsenic in Clear Lake is from natural deposits and erosion. Data from utility intakes show a weaker seasonal trend (Figure 4). Of the 124 data points, none exceeded the MCL. Systems who exceeded the MCL for arsenic must monitor quarterly and determine compliance based on the running annual average per 22 CCR § 64432.

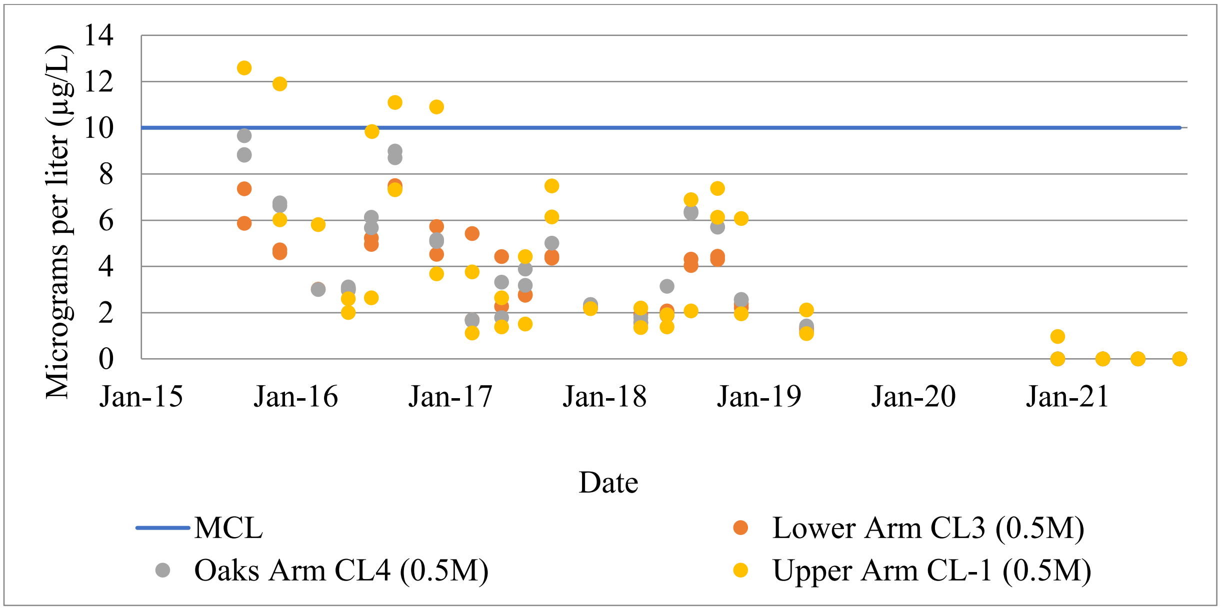

Figure 3: Total Arsenic - In-lake Monitoring

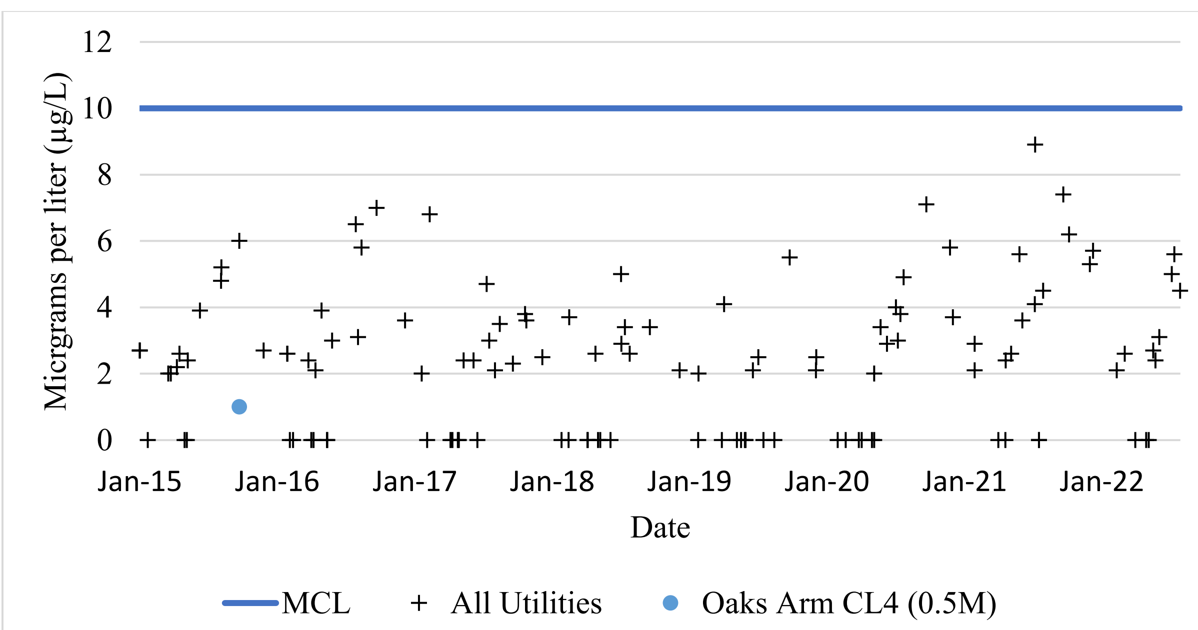

Figure 4: Total Arsenic - Drinking Water Intakes

Total Manganese

Manganese in Clear Lake is naturally occurring from natural deposits and erosion. It is the twelfth most abundant element in earth's crust and is particularly concentrated in volcanic rocks and soils. In-lake monitoring data does not show any trends in manganese concentrations (Figure 5). Results range from 2 µg/L to 294 µg/L. Of the 110 data points, 14 exceeded the SMCL of 50 µg/L. Similarly, no data trends can be discerned from drinking water intake data (Figure 6). Results range from ND to 1,300 µg/L. Of the 211 data points, 89 exceeded the SMCL of 50 µg/L and 10 exceeded the notification level of 500 µg/L. Systems who exceeded the SMCL for manganese must monitor quarterly and determine compliance based on the running annual average per 22 CCR § 64449.

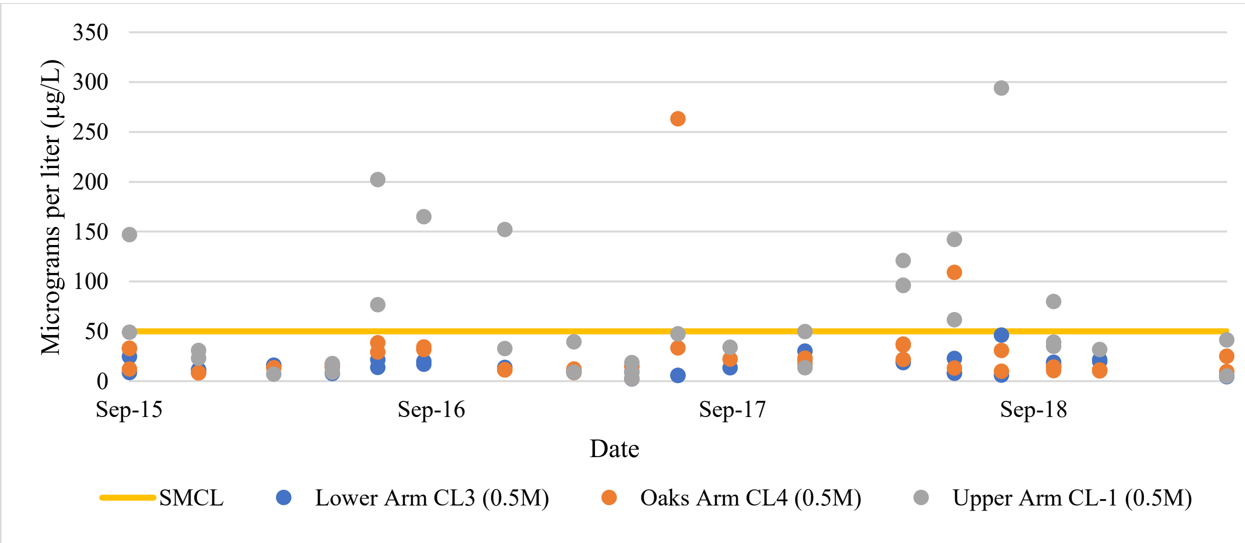

Figure 5: In-Lake Total Manganese Concentrations

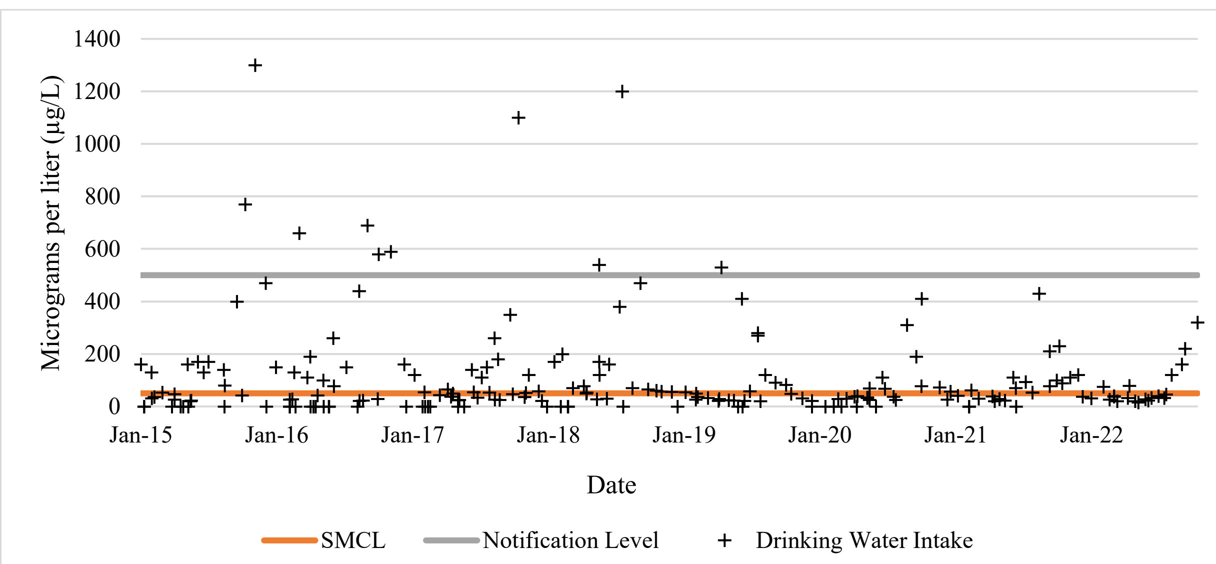

Figure 6: Total Manganese - Drinking Water Intakes

Iron

Iron in Clear Lake is naturally occurring from natural deposits and erosion. In-lake monitoring data does not show any discernible trends. Results range from ND to 410 µg/L (Figure 7). Data collected by the California Department of Water Resources before 2020 shows a high of 220 µg/L. Data collected after 2020 was collected by the County of Lake Department of Water Resources. The same EPA method 200.8 was used for analysis but the two agencies used different labs. It is unclear whether the difference in results is due to the difference in lab, or if there is an increase in iron concentrations in the lake after 2020.

Drinking water intake monitoring shows no discernable trends. Results range from ND to 3,300 µg/L with an average result of 319 µg/L. Of the 213 data points, 65 exceeded the SMCL of 300 µg/L. All systems that exceed the SMCL for iron must monitor quarterly and determine compliance based on the running annual average per 22 CCR § 64449.

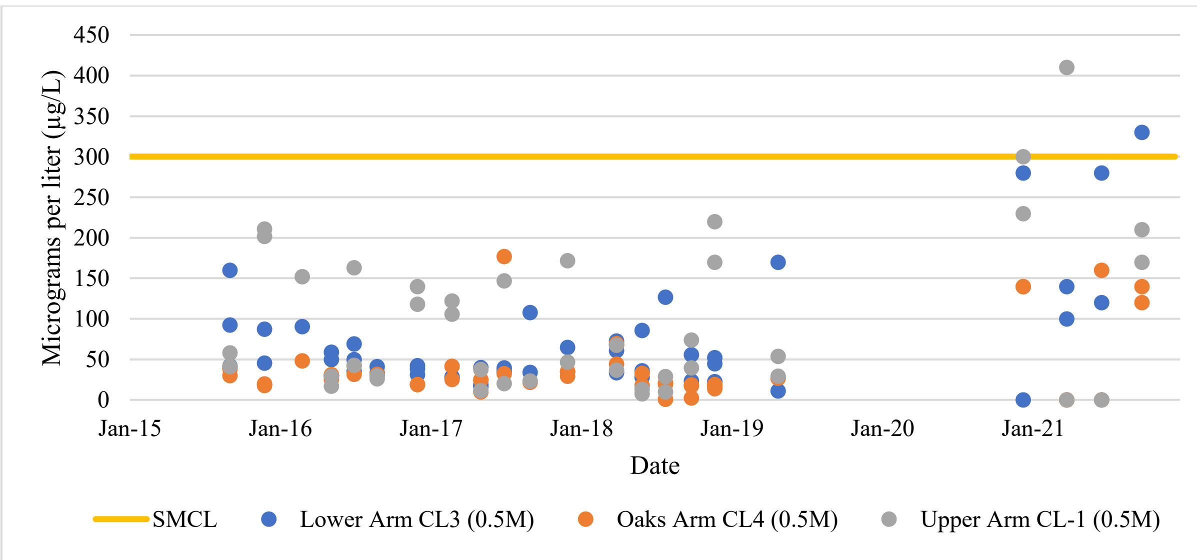

Figure 7: In-Lake Total Iron Concentrations

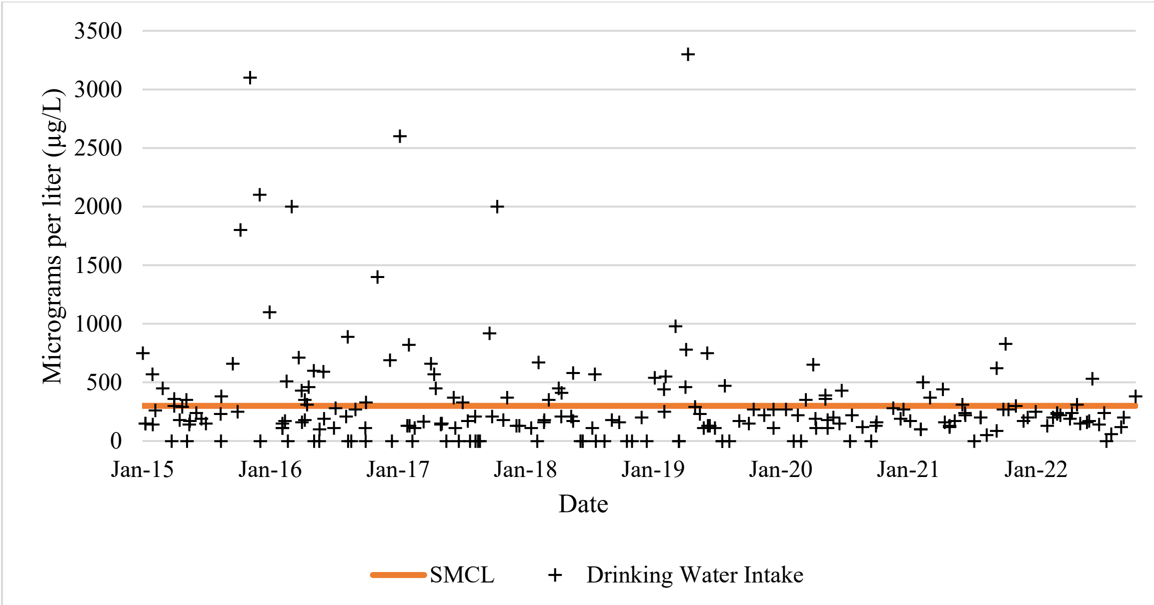

Figure 8: Total Iron - Drinking Water Intakes

Turbidity

Turbidity is a measure of the degradation of clarity. Clarity is typically degraded by suspended colloids and fine solids such as clay, organic particulates, and microorganisms. Increased turbidity levels are typically the result of erosion and sediment transport during precipitation and high flow events. High turbidity levels are a challenge for water purveyors because they may mask the presence of microorganisms and interfere with disinfection. Turbidity is a good measure of the efficiency of the treatment process. It is a regulated constituent with which water utilities must comply. Depending on the type of surface water treatment technology employed, turbidity standards may be as low as 0.1 NTU per the Surface Water Treatment Rule. The SMCL for turbidity is 5 Nephelometric Turbidity units (NTU). Turbidity is removed via the conventional surface water treatment process.

In-lake monitoring shows a range from 0.88 NTU to 49.8 NTU (Figure 9). Generally, turbidity in Clear Lake has two main sources: rain events (in winter), and algae blooms (in summer). It is difficult to ascertain any trends and to reach any conclusions from the data because spikes in the data depend largely on precipitation. Years of heavy rainfall typically show turbidity spikes during the winter and more mild concentrations in the summer whereas drought years typically show turbidity spikes in the summer and more wild spikes in the winter. Algal concentrations intensify during years with low precipitation because there is less water in the lake to dilute the concentration.

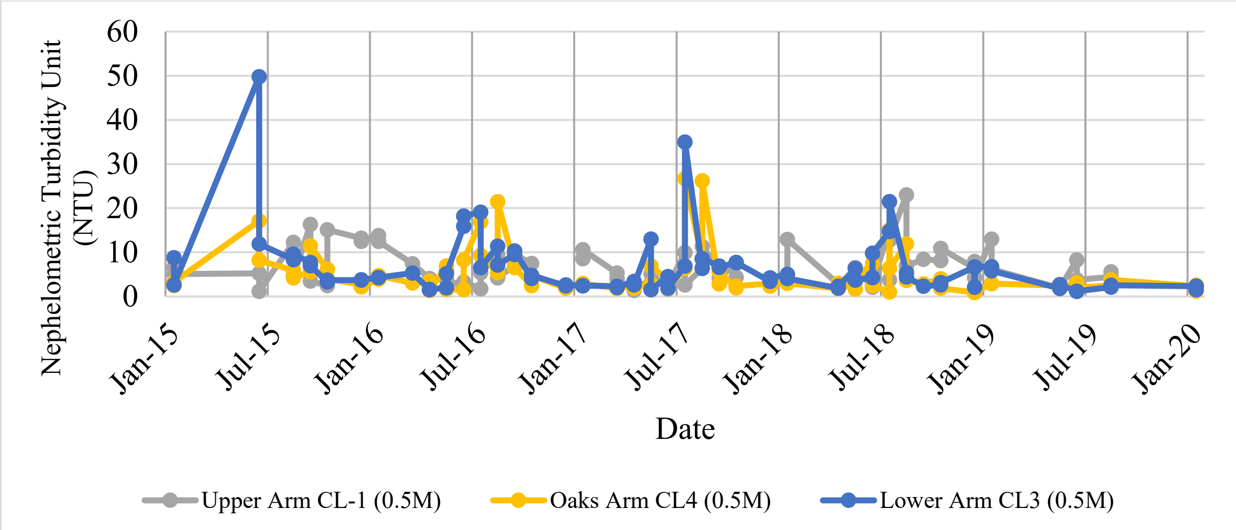

Figure 9: In-Lake Turbidity Monitoring

Other Constituents

Other constituents measured by the California Department of Water Resources and the County of Lake Department of Water Resources but not regulated by the Safe Drinking Water Act are summarized below. These constituents are of specific interest because of their relationship to the development of harmful algal blooms in Clear Lake.

Dissolved Ammonia

Ammonia concentrations are cyclical with the highest concentrations between June and October, which correspond to the months when harmful algal blooms are most abundant (Figure 10). Increased ammonia in the lake is an indication of algal dieoffs. When blooms decay as they do during the mid-to-late summer, cyanobacterial cells release ammonia into the lake (Wang, et. al., 2020). Ammonia is the most bioavailable form of nitrogen for cyanobacterial cells. Any form of nitrogen in the lake such as nitrate, nitrite, or sediment bound nitrogen, must be converted to ammonia within the cell before it can be used for metabolic activity (Great Lakes HABs Collaboratory, 2017). As a result, each cell contains some amount of ammonia that is released when the cell decays.

Increased ammonia concentrations in the lake create challenges for drinking water disinfection. When chlorine is introduced to water containing ammonia, chloramines are developed. While many systems purposely use chloramines as a disinfectant, chloramines do not inactivate cyanotoxins and therefore are not used in Clear Lake. As a result, chlorine dosages must be increased significantly to reach breakpoint chlorination.

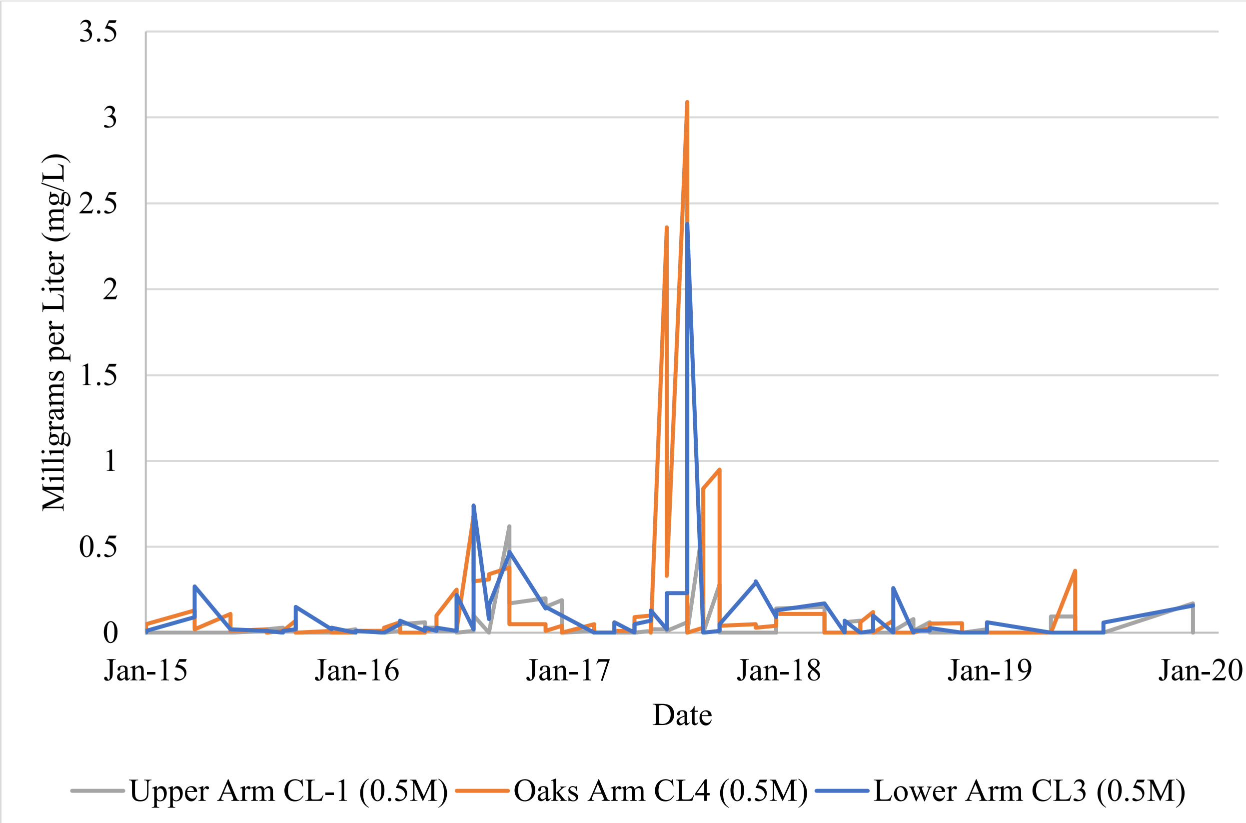

Figure 10: In-Lake Ammonia Concentrations

pH

The data shows increased pH during the summer months (Figure ###). When cyanobacteria are present in the lake, they photosynthesize during daylight hours, increasing lake pH. The pH decreases overnight when the algae are no longer photosynthesizing and atmospheric carbon dioxide is being added to the lake. Algae increase pH because they extract carbon dioxide from the water column during photosynthesis. When carbon dioxide (CO_2) is added to water (H_2O), the water dissociates into bicarbonate (HCO_3^-) and hydrogen atoms ($H+$) which causes the pH to decrease. As carbon dioxide is removed from water, as in the case when cyanobacteria are photosynthesizing, the reaction does not dissociate into bicarbonate and hydrogen ions but rather stays as carbonic acid (H_2CO_3), causing the pH to increase (Tucker & D'Abramo, 2008).

High pH interferes with successful coagulation. The coagulation process is pH dependent; most coagulants react optimally between a pH of 6-7.5. Harmful algal blooms increase pH, which can significantly decrease the effectiveness of coagulation. In response, water treatment operators increase coagulant doses to force the coagulation reaction to happen. The highest coagulant dose at the Golden State Water Company – Clearlake System's treatment plant between 2016-2020 was 30mg/L, however, coagulant dosages reached new heights during the summer of 2021. Keith Ahart, Operations Superintendent for the Golden State Water Company – Clearlake System increased the coagulant dosage to 60mg/L in 2021 to overcome charge imbalances from raw water pH (Ahart, Personal Communication 2022). Similarly, Frank Costner, General Manager with Konocti County Water District, increased the coagulant doses to above 120mg/L to overcome the raw water pH changes (Costner, Personal Communication 2022). The variability in coagulant dosages around the lake is attributed to the distinct chemistry of the water at their intakes. The highest coagulant dosages correspond with the systems located in the Lower and Oaks Arm of Clear Lake because those sections have the most abundant harmful algal blooms.

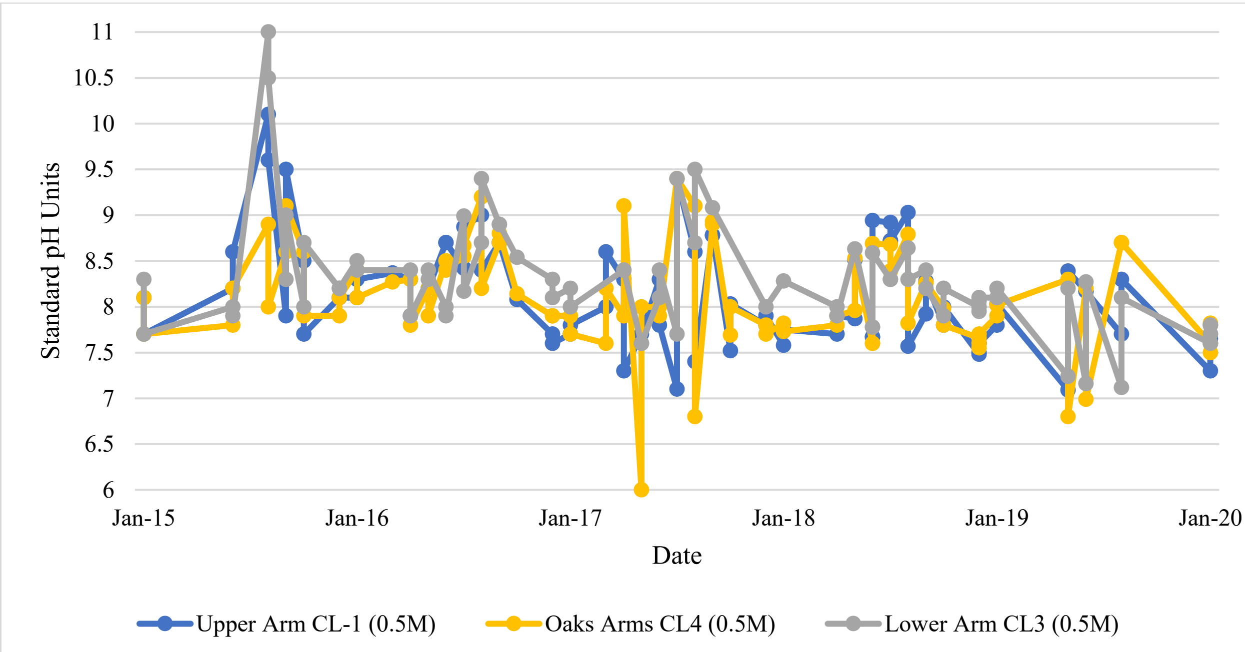

Figure 11: In-Lake pH Monitoring

Total Phosphorus

Total phosphorus concentrations have a cyclical pattern with peaks in the late summer and early fall, which correspond to the months when harmful algal blooms are most abundant in Clear Lake (Figure 12). The cause of this cyclical pattern results from several contributing factors. Phosphorus and nitrogen are the main nutrient sources that cyanobacterial cells use for metabolic functions. Excess phosphorus and nitrogen in waterbodies often results in harmful algal blooms. However, the harmful algal blooms themselves also increase the concentration of phosphorus in the lake.

Harmful algal blooms deplete dissolved oxygen in the lake, creating hypoxic and anoxic conditions. Low oxygen conditions catalyze internal phosphorus loading via the release of sediment bound phosphorus and ammonia, increasing the concentration of phosphorus and further fuels the development of harmful algal blooms. In addition, of the three species of toxin-producing cyanobacteria in Clear Lake (*Aphanizomenon*, *Anabaena,* and *Microcystis*), *Microcystis* facilitate the release of sediment-bound phosphorus, which increases the amount of available phosphorus in the lake. Finally, cyanobacteria are able to store excess phosphorus intercellularly. They contain a specific metabolic process that increases the uptake of phosphorus when phosphorus is scarce. Therefore, when the algal cells decay, they release phosphorus into the lake.

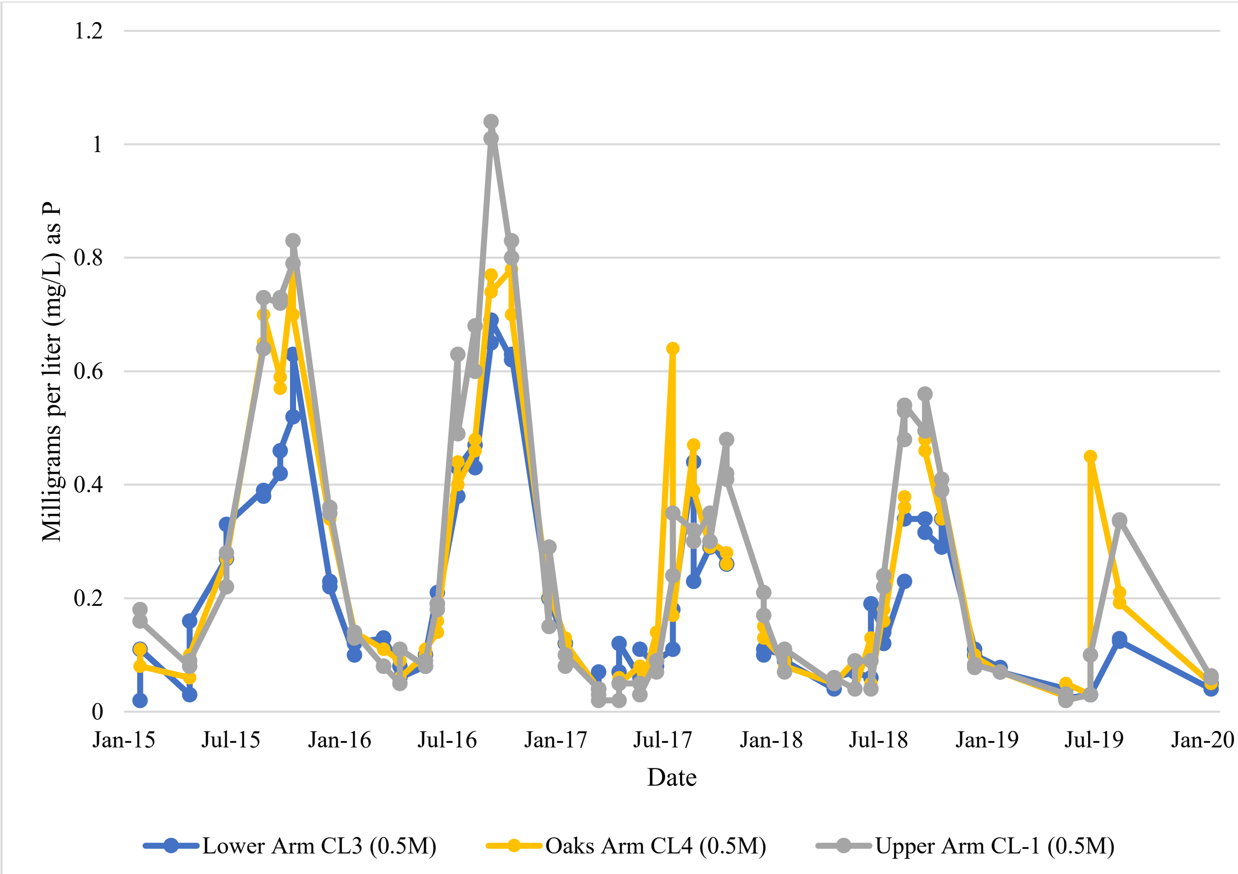

Figure 12: In-Lake Total Phosphorus Concentrations

Dissolved Oxygen

Oxygen availability in Clear Lake tends to deplete during the summer months, but some peaks in dissolved oxygen can be seen in the Lower Arm during the summer (Figure 13). These results are generally consistent with our understanding of Clear Lake limnology. Oxygen availability decreases during the months when algal blooms are present. When algal cells die, as they do in mass numbers during a bloom, the algae sinks in the water column where they are degraded by heterotrophic bacteria. This biodegradation process consumes dissolved oxygen and releases carbon dioxide (USEPA Dead Zones and Harmful Algal Blooms, 2022).

Large blooms can deplete dissolved oxygen concentrations creating hypoxic or anoxic conditions, which result in fish kills and the release of sediment bound constituents like iron, manganese, phosphorus, and ammonia. Excess iron and manganese create taste and color problems in finished drinking water and excess ammonia interferes with disinfection. Most utilities use granulated activated carbon (GAC) units to mitigate taste and odor concerns. However, during years when harmful algal blooms are particularly severe, some systems are still faced with taste and odor problems after the use of GAC.

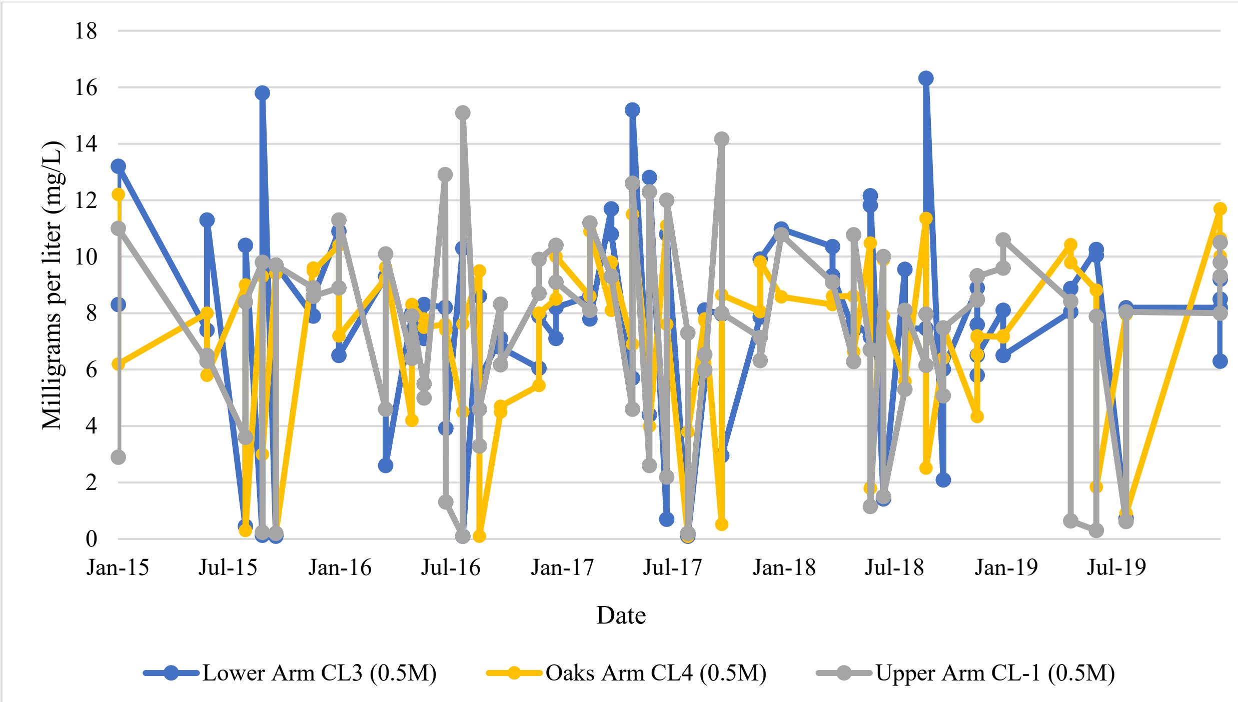

Figure 13: In-Lake Dissolved Oxygen Monitoring

Temperature

The water temperature is consistent in Clear Lake and follows seasonal weather patterns. Clear Lake is warm and shallow, which can create taste, odor and disinfection problems in water treatment plants. Generally taste and odor problems get more severe in warmer weather and is exacerbated by the presence of harmful algal blooms. Additionally, chlorine reactions are quicker in warmer environments, which may increase chlorine demand during the warmer months.

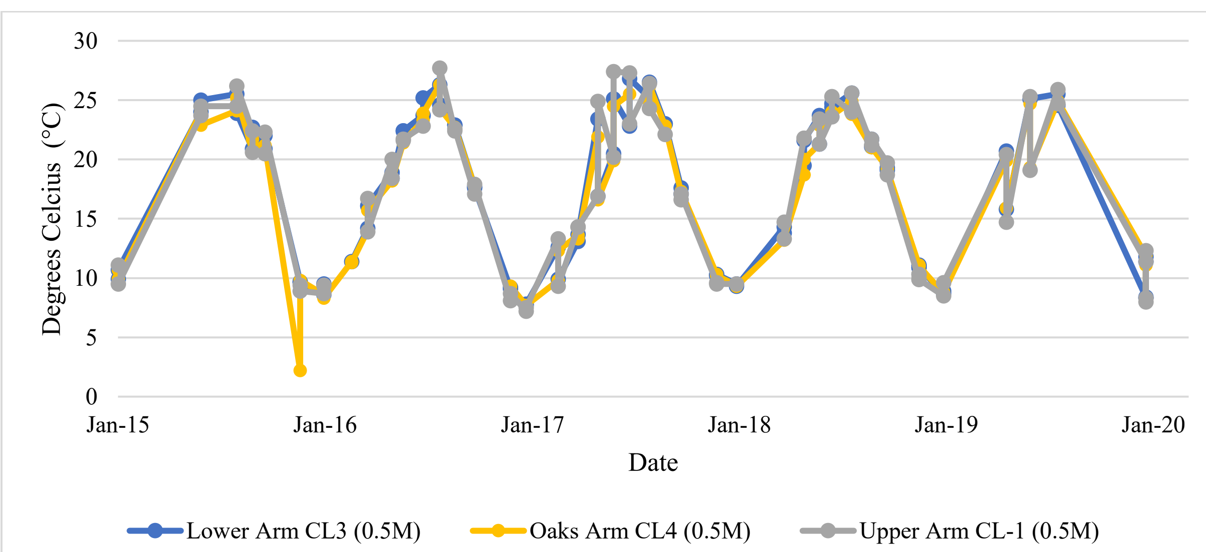

Figure 14: In-Lake Temperature Monitoring

Boron

There is no established MCL or SMCL for boron, however, the State of California issued a notification level of 1mg/L (Groundwater Information Sheet Boron (B), 2017). In-lake monitoring results show a multi-year decline in boron concentrations until the start of 2017. From 2017 until 2019 the data shows a gradual increase in boron concentrations followed by another decrease at the start of 2019. The data also shows a gradual trend of higher results in the fall and early winter with lower results in the spring and summer. Most data points are above the notification level of 1 mg/L. It is recommended that surface water purveyors monitor regularly for boron and notify customers if results exceed the notification level.

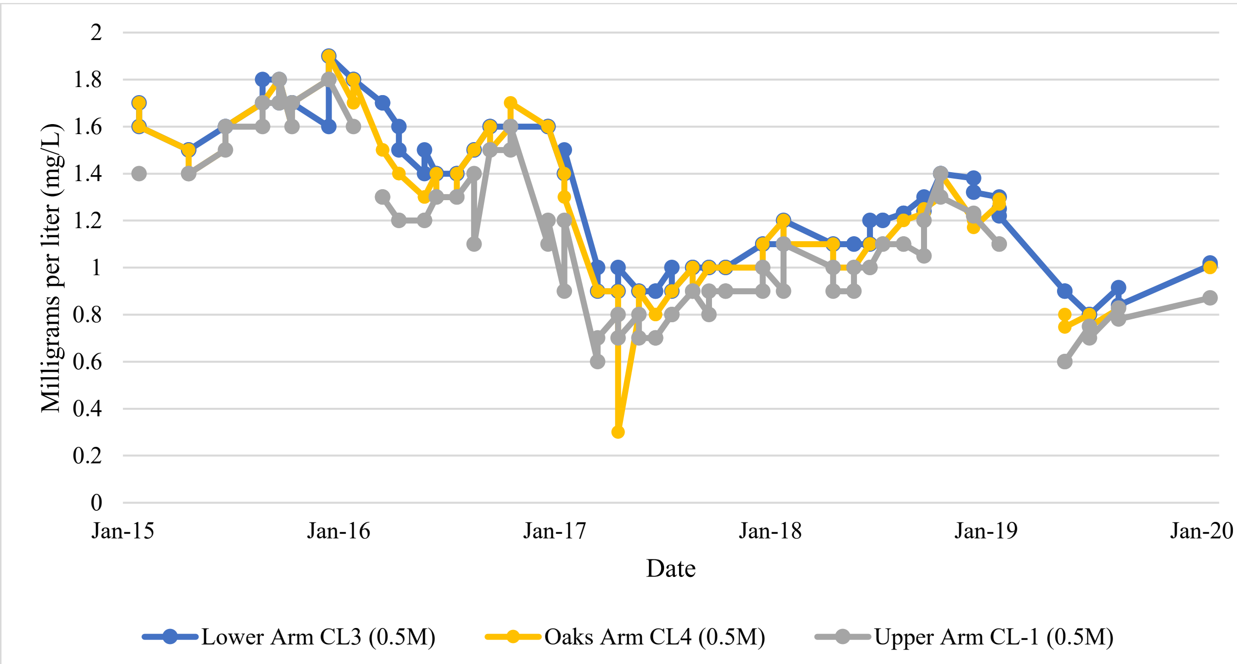

Figure 15: In-Lake Dissolved Boron Concentrations

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ATTACHMENT D

RAW WATER SAMPLING SCHEDULE

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

Typical Raw Water Intake Sampling Schedule for Potable Water Utility					
Analyte Name	**RL**	**Unit**	**MCL**	**DLR**	**Frequency (months)**
ANTIMONY, TOTAL	6	UG/L	6	6	12
ARSENIC	2	UG/L	10	2	12
ASBESTOS	0.2	MFL	7	.2	108
BARIUM	100	UG/L	1000	100	12
BERYLLIUM, TOTAL	1	UG/L	4	1	12
CADMIUM	1	UG/L	5	1	12
CHROMIUM	10	UG/L	50	10	12
FLUORIDE	0.1	MG/L	2	.1	12
MERCURY	1	UG/L	2	1	12
NICKEL	10	UG/L	100	10	12
PERCHLORATE	2	UG/L	6	2	12
SELENIUM	5	UG/L	50	5	12
THALLIUM, TOTAL	1	UG/L	2	1	12
NITRATE	0.4	MG/L	10	.4	12
NITRITE	0.4	MG/L	1	.4	36
GROSS ALPHA PARTICLE ACTIVITY	1.4	PCI/L	15	3	108
1,1,1-TRICHLOROETHANE	0.5	UG/L	200	.5	36
1,1,2,2-TETRACHLOROETHANE	0.5	UG/L	1	.5	36
1,1,2-TRICHLOROETHANE	0.5	UG/L	5	.5	36
1,1-DICHLOROETHANE	0.5	UG/L	5	.5	36
1,1-DICHLOROETHYLENE	0.5	UG/L	6	.5	36
1,2,4-TRICHLOROBENZENE	0.5	UG/L	5	.5	36
O-DICHLOROBENZENE	0.5	UG/L	600	.5	36
1,2-DICHLOROETHANE	0.5	UG/L	.5	.5	36
1,2-DICHLOROPROPANE	0.5	UG/L	5	.5	36
1,3-DICHLOROPROPENE	0.5	UG/L	.5	.5	36
P-DICHLOROBENZENE	0.5	UG/L	5	.5	36
BENZENE	0.5	UG/L	1	.5	36
CARBON TETRACHLORIDE	0.5	UG/L	.5	.5	36
CIS-1,2-DICHLOROETHYLENE	0.5	UG/L	6	.5	36
DICHLOROMETHANE	0.5	UG/L	5	.5	36
ETHYLBENZENE	0.5	UG/L	300	.5	36
CHLOROBENZENE	0.5	UG/L	70	.5	36
STYRENE	0.5	UG/L	100	.5	36
TETRACHLOROETHYLENE	0.5	UG/L	5	.5	36
TOLUENE	0.5	UG/L	150	.5	36
TRANS-1,2-DICHLOROETHYLENE	0.5	UG/L	10	.5	36
TRICHLOROETHYLENE	0.5	UG/L	5	.5	36
TRICHLOROFLUOROMETHANE	0.5	UG/L	150	5	36
TRICHLOROTRIFLUOROETHANE	0.5	UG/L	1200	10	36
VINYL CHLORIDE	0.5	UG/L	.5	.5	36
XYLENES, TOTAL	0.5	UG/L	1750	0.5	36
1,2,3-TRICHLOROPROPANE	0.005	UG/L	0.005		36
2,4,5-TP	1	UG/L	50	1	108
2,4-D	10	UG/L	70	10	108
ATRAZINE	0.5	UG/L	1	.5	36
CARBOFURAN	5	UG/L	18	5	36
DALAPON	10	UG/L	200	10	36
DINOSEB	2	UG/L	7	2	36

DIQUAT	4	UG/L	20	4	36
ENDOTHALL	45	UG/L	100	45	36
ETHYLENE DIBROMIDE	0.02	UG/L	.05	.02	108
HEPTACHLOR	0.01	UG/L	.01	.01	108
HEPTACHLOR EPOXIDE	0.01	UG/L	.01	.01	108
BHC-GAMMA	0.2	UG/L	.2	.2	108
METHOXYCHLOR	10	UG/L	30	10	108
OXAMYL	20	UG/L	50	20	36
PENTACHLOROPHENOL	0.2	UG/L	1	.2	36
PICLORAM	1	UG/L	500	1	36
SIMAZINE	1	UG/L	4	1	12
TOXAPHENE	1	UG/L	3	1	108
ALKALINITY, TOTAL	5	MG/L			12
BROMATE	5	UG/L	10	5	3
ALKALINITY, BICARBONATE	5	MG/L			12
CALCIUM	1	MG/L			12
ALKALINITY, CARBONATE	5	MG/L			12
CHLORIDE	5	MG/L	500		12
COLOR	5	UNITS	15		12
COPPER, FREE	50	UG/L	1000	50	12
FOAMING AGENTS (SURFACTANTS)	0.05	MG/L	.5		12
HARDNESS, TOTAL (AS CACO3)	5	MG/L			12
HYDROXIDE AS CALCIUM CARBONATE	5	MG/L			12
IRON	100	UG/L	300	100	12
MAGNESIUM	1	MG/L			12
MANGANESE	20	UG/L	50	20	12
ODOR	1	TON	3	1	12
PH	1.68	pH			12
SILVER	10	UG/L	100	10	12
SODIUM	1	MG/L			12
CONDUCTIVITY @ 25 C UMHOS/CM	20	UMHO/CM	1600		12
SULFATE	5	MG/L	500	.5	12
TDS	10	MG/L	1000		12
TURBIDITY	0.1	NTU	5	.1	12
ZINC	50	UG/L	5000	50	12
ALUMINUM	50	UG/L	1000	50	12
METHYL TERT-BUTYL ETHER	3	UG/L	13	3	12
THIOBENCARB (BOLERO)	0.24	UG/L	70	1	12
TOTAL HALOACETIC ACIDS (HAA5)	1	UG/L	60		3
TTHM	1	UG/L	80		3
TOTAL HALOACETIC ACIDS (HAA5)	1	UG/L	60		3
TTHM	1	UG/L	80		3
RL – Reporting Level means the level to which the laboratory reported the presence of an analyte. For radionuclides, Reporting Level is the MDA95.					
DLR – Detection Limit for purposes of Reporting (DLR) means the designated minimum level at or above which any analytical finding of a contaminant in drinking water resulting from monitoring required under Chapter 15 of Title 22 shall be reported to the State Board (California Code of Regulations Section § 64400.34)					

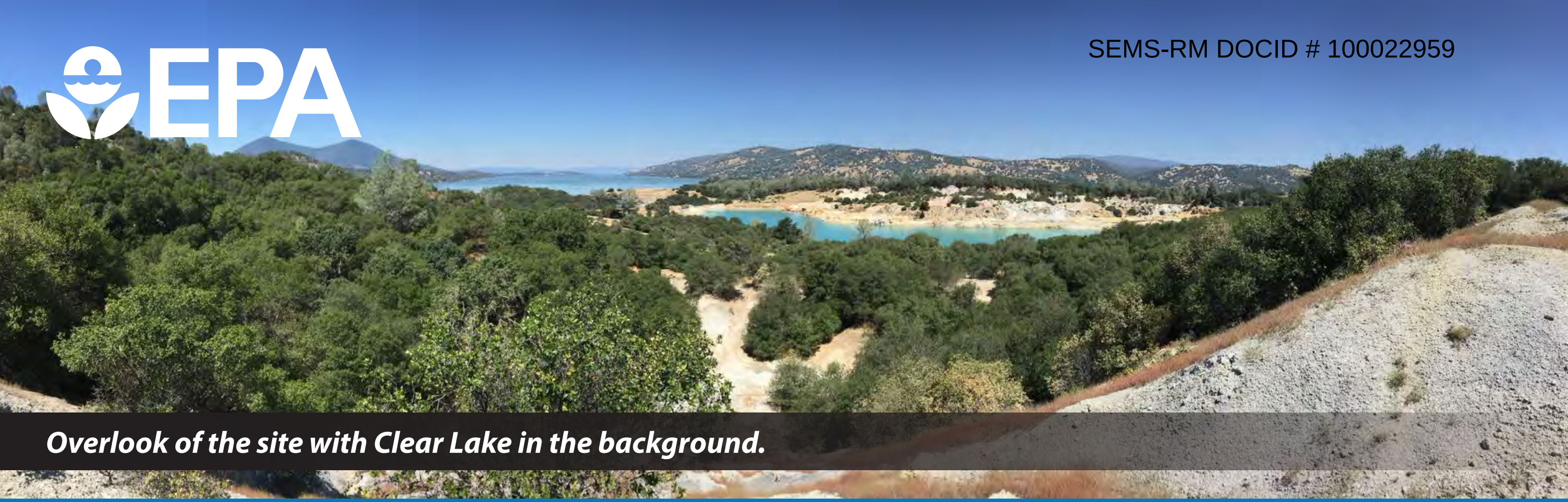
ATTACHMENT E

EPA SULPHUR BANK CLEANUP UPDATE

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

LAKE COUNTY

NRCS



Overlook of the site with Clear Lake in the background.

U.S. Environmental Protection Agency • Pacific Southwest Region (Region 9) • February 2021

2021 Sulphur Bank Superfund Site Cleanup Update

The U.S. Environmental Protection Agency (EPA) added the Sulphur Bank Mercury Mine Site to its Superfund cleanup program in 1990. The site is large (about 160 acres) and is polluted with arsenic and mercury from historic mining activities. EPA has completed eight short-term cleanup projects at the site to prevent community members and the environment from coming into contact with highly contaminated mine waste (pollution). EPA has also been researching options for a long-term cleanup for the site. For more information view the site webpage at: www.epa.gov/superfund/sulphurbankmercury

This update covers

- How the site affects Clear Lake community health;
- Options for the long-term site cleanup; and
- Timeline and goals for cleanup.

Also Inside:

- How to reduce contact with site pollutants (*pg. 4*)
- How to stay involved (*pg. 8*)

Map in upper-left indicates the location of the site with a red dot.

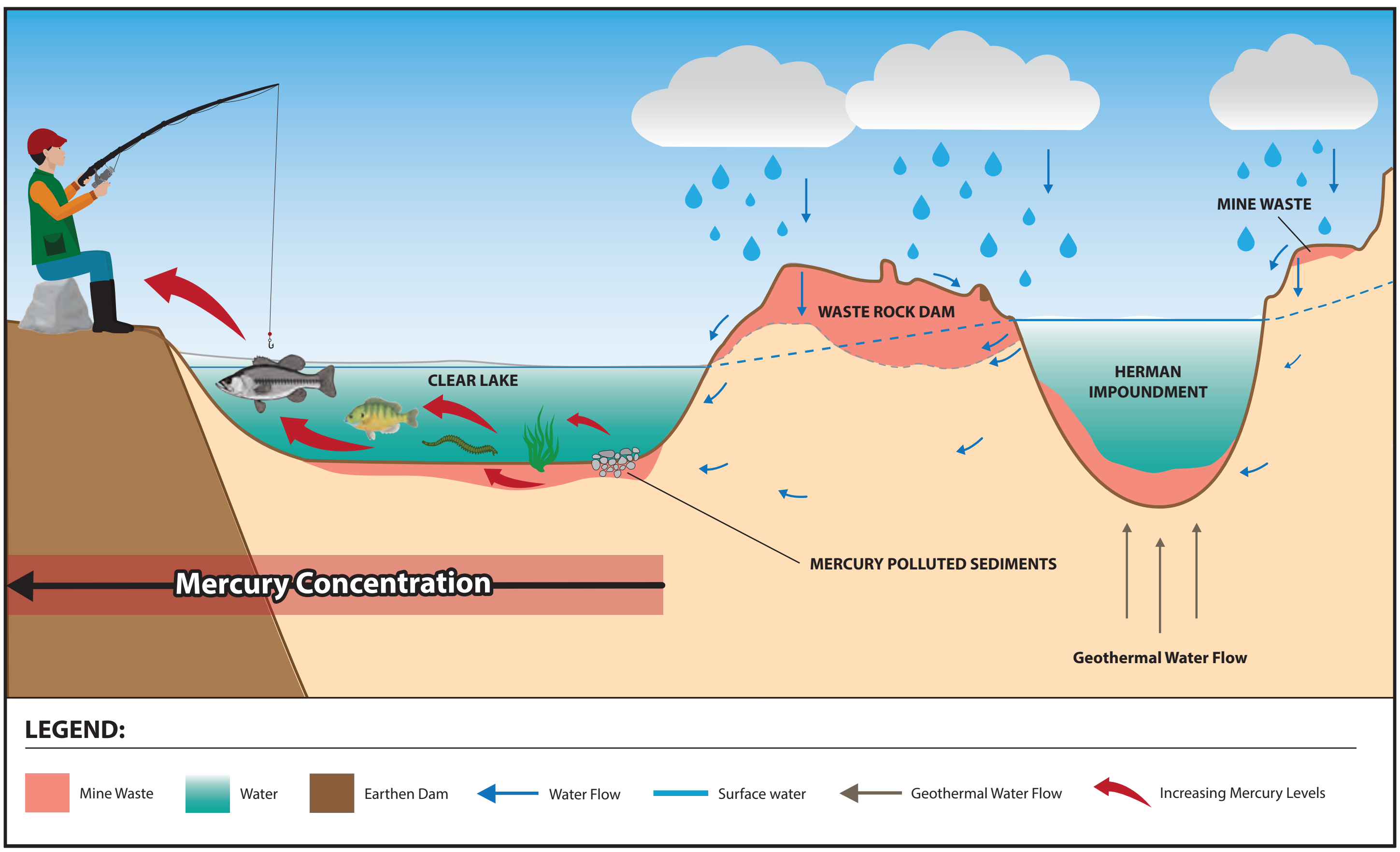
Brief Description of the Sulphur Bank Mercury Mine Superfund Site

For definitions of the **bolded terms** please go to page 7 of the fact sheet to find the glossary.

The 160-acre Sulphur Bank Mercury Mine site is an abandoned **open pit mercury mine** located on the shoreline of Clear Lake in Lake County, California. The Sulphur Bank Mercury Mine was mined for sulphur and mercury between 1865 and 1957. About 150 acres of **mine tailings** and waste rock and a flooded open pit mine (called the **Herman Impoundment**) are located on the property (*see map*). Approximately two million cubic yards of mine waste and tailings remain on the mine site. The Herman Impoundment is filled with acidic water and is 750 feet from the shore of Clear Lake. The Elem Indian Colony is on a portion of the site. Tribal members use the land and resources on and near the site for traditional cultural activities.

The geology of the area naturally contains high levels of mercury. The mining activity in the area brought it to the surface where it has **contaminated** the soil and Clear Lake **sediments**. **Mercury** in the lake sediments gets absorbed by algae and builds up in fish (*see graphic below*). The levels of mercury in the fish in Clear Lake led the state to issue an **advisory** to limit consumption of fish caught in Clear Lake. For more information view the state's webpage at: oehha.ca.gov/advisories/clear-lake

Close-up of Herman Impoundment water onsite.



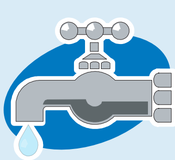
Graphic showing how mercury from ***mine waste (pollution)*** *moves with groundwater flow from Herman Impoundment, through the* ***waste rock dam****, and into Clear Lake where it further contaminates lake sediments.*

SECTION 1
How the Mine Affects Clear Lake Community Health

How does EPA evaluate the risk to human health?

EPA did a study—called a **Human Health Risk Assessment**—to see how pollution from the mine may affect human health. In this assessment, EPA looked at how toxic the chemicals from the mine are and the different ways the Clear Lake community could come into contact with the pollutants **(exposure)**. EPA also worked with the Elem Indian Colony to consider how traditional practices contribute to exposure to the pollution.

EPA gathering soils from the site.



Please note that no one is drinking or using groundwater polluted by the site. Drinking water provided to residents and businesses in the area is safe to drink.

What did EPA study in the area?

- Waste materials and soils on the site.
- Residential soils within the Elem Indian Colony (EIC) and other residential areas along Sulphur Bank Mine Road affected by mining waste.
- Sediment samples along the Clear Lake shoreline and upstream from the site.
- Surface water samples onsite and from nearby wetlands.
- Fish tissue (black crappie, bluegill sunfish, channel catfish, common carp, largemouth bass, redear sunfish, Sacramento sucker, silverside, threadfin shad, and tule perch) in different parts of Clear Lake.
- Wild plants (including acorns, tule roots, tule stalks, cattail roots, and cattail stalks) around the site and EIC.

Who was considered for the Human Health Risk Assessment?

- Traditional tribal users of the land;
- Clear Lake residents;
- Recreational users, including fishermen; and
- Trespassers on the site.

What tribal exposures were considered?

- Traditional practices using the land/soil on the Elem Indian Colony;
- Drinking water from Clear Lake; and
- Eating fish, plants (acorns, tules, and cattails), and waterfowl.

How to Reduce Your Contact with Pollution From the Site?

What pollutants from the site are most risky to community members? What are the ways community members come into contact with them?

Signage onsite informing about trespassing risks.

Arsenic poses the greatest risk, but only to those who may trespass on the site and in some way eat or breathe in surface soils. Arsenic is highly toxic and has a high cancer risk if eaten/breathed in. The site and the land that surrounds it naturally has metals, which is why it was mined for many years. The Clear Lake area has more arsenic in soils than in other parts of the country.

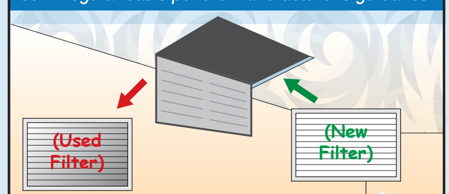
Mercury poses a risk to those in tribal communities and in the general public who may eat more fish than the state recommends. It can cause permanent damage to the nervous system and might result in disabilities for developing fetuses and children.

How can I reduce my contact with arsenic in soil?

Remove your shoes before entering the house.

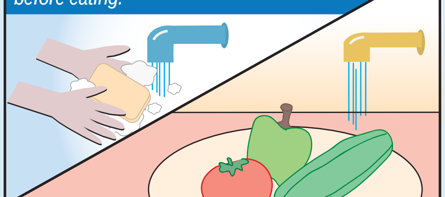
Dust from outside can be tracked in on your shoes and lodge in carpets and upholstery in small amounts that add up over time.

Change heating/cooling system intake filters on a semi-regular basis per the manufacturer's guidance.



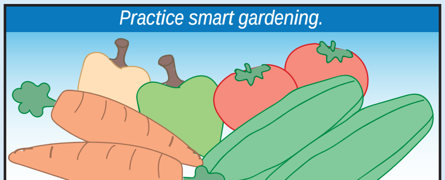
If possible, ensure your filter has a high Minimum Efficiency Reporting Value (MERV) of 13 or higher. This will minimize soils and dust from the outside that can collect in ducts.

Wash your hands and your children's hands before eating.



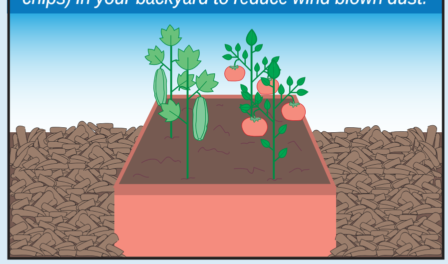
Also, wash your homegrown vegetables and fruit before eating. This will ensure that soils or dust on your hands/food do not get on your food or directly into your mouth.

Practice smart gardening.



Lettuce, radishes, broccoli, brussel sprouts, kale, and cabbage accumulate more arsenic from soils than other garden plants. Consider eating a limited amount of these vegetables from local gardens. Avoid growing sticky plants, such as the ones above or marijuana, that can accumulate more arsenic dust.

Consider growing plants in raised beds with purchased/clean soil and lay ground cover (like wood chips) in your backyard to reduce wind blown dust.



How can I avoid mercury pollution in fish?

The California Office of Environmental Health and Hazard Assessment (OEHHA) issued a limit on eating fish from Clear Lake. It is based on mercury found in edible Clear Lake fish tissue. OEHHA is the agency responsible for evaluating health impacts from eating polluted fish and recommend safe limits on eating polluted fish. This fish advisory can be viewed at: www.oehha.ca.gov/advisories/clear-lake

If the fish are polluted, can I safely swim in the lake?

Pollution from the site does not make it unsafe to swim in Clear Lake. Levels of mercury in the lake water consistently meet state and federal standards. However, there are occasional and naturally occurring algal and cyanobacteria blooms that occur in Clear Lake that can make the water unsafe to swim in. These usually occur in mid to late summer. We advise the community to follow information and instructions from the State of California and the County of Clear Lake on cyanobacteria blooms.

SECTION 2
Options to Address Pollution from the Site

Since 2017, EPA has studied long-term cleanup options for the Sulphur Bank Mine site. This study is detailed in EPA's **Focused Feasibility Study** document. EPA is finalizing this study and will use it to help make a final decision on how to clean up the site. The next step in the process is the publishing of a proposed cleanup plan (Proposed Plan) for the mine portion of the site. EPA plans to issue this Proposed Plan on the mine site cleanup for public comment in the mid-late Summer of 2021.

Also, EPA continues to study the lake and its sediment to understand how it might reduce the mercury contamination in the lake. Clear Lake's geology and the way mercury moves through the food chain makes the site's pollution in Clear Lake very difficult to clean up. Before cleaning up the lake EPA must determine how each cleanup option would affect levels of mercury in fish. EPA must also understand how mine-related mercury contamination in the lake differs from mercury that is naturally occurring in the area. EPA anticipates the Proposed Plan for the lake and sediment cleanup to be several years away.

Site monitoring work in progress.

SECTION 3
EPA Cleanup Timeline and Goals

EPA is committed to create the site clean up plan (Proposed Plan) for the mine portion of the site this year. To do this, EPA has been working with stakeholders from:

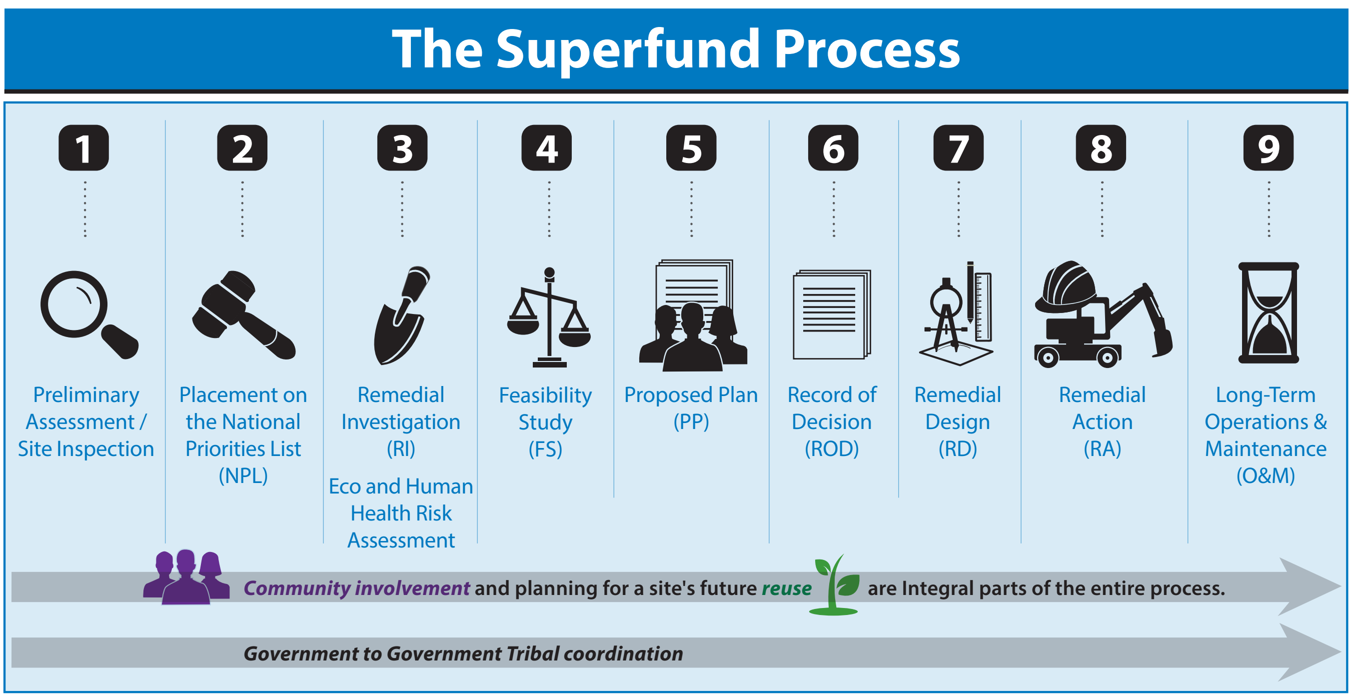
- EPA Headquarters;
- the Elem Tribal Colony;
- California Department of Toxic Substances Control; and
- Central Valley Regional Water Quality Control Board.

The stakeholder group has developed goals for the site team for both the near term (next five years) and long term (through 2037). The cleanup plan for the lake and its sediment and wetlands will require further investigation. On the next page there is a site specific timeline that shows where different parts of the site will be in the cleanup process during the next eight years. These are approximate years and subject to delays or change.

Site Timeline

	Mine Site 4	Clear Lake and Sediment 3	North Wetlands 1
2020	Update Human Health Risk Assessment and Focused Feasibility Study 3/4	Evaluate lake data and coordinate study with USGS on mercury in fish tissue 3	Review existing site data
2021	Interim Proposed Plan 5	Refine Site Strategy and collect data 3	Designate new Operable Unit
2022	Interim Record of Decision 6		Remedial Investigation/ Feasibility Study (RI/FS) 3/4
2023 - 2028	Interim Record of Decision Phase 1 Remedial Design (RD) 7	Remedial Investigation/ Feasibility Study (RI/FS) 3/4	Proposed Plan Record of Decision Remedial Design (RD) Remedial Actions (RAs) 5/6/7/8
	Interim Record of Decision Phase 1 Remedial Actions (RAs) 8		

Above is a site specific timeline that notes *(with numbers that connect to the Superfund Process Graphic below)* where different parts of the site will be in the process during the next eight years.



Timeline Definitions

Human Health Risk Assessment: An evaluation of how the site impacts human health.

Focused Feasibility Study: An evaluation of cleanup options for a specific portion of the site

Feasibility Study: An evaluation of cleanup options.

Interim Proposed Plan: A proposed cleanup plan for only the mine portion of the site.

Public Comment: An opportunity for the community / stakeholders to provide comments / concerns about the proposed cleanup.

Record of Decision: A document detailing the final cleanup plan selected for the site.

Remedial Design: Design specifics for executing the cleanup plan.

Remedial Actions: Executing the cleanup.

Site Strategy: Strategies and goals to ensure the cleanup progresses.

Operable Unit: During cleanup, a site can be divided into a number of distinct areas depending on the complexity of site problems. These areas are called operable units (OUs). OUs can address a specific geographical area where a unique action is required.

Parcel Transfer Criteria: Parcel cleanup goals intended to ensure their transfer to the Bureau of Indian Affairs.

Cleanup Goals

- **Ensure site documents and data are easily accessible to the public.** EPA will ensure site related information is accessible through the site's webpage.
- **Reduce mercury going from the site into Clear Lake.** The cleanup efforts will focus on the historic mine waste to decrease the amount of mercury continuing to enter Clear Lake.
- **Promptly address unacceptable human exposure to site pollutants.** Mining wastes have been found in areas used by the Elem Indian Colony and neighbors south of the mine. EPA's prior cleanup actions have reduced human health risks, and future actions will complete the cleanup of pollution in these areas.
- **Reduce mercury in Clear Lake fish tissue.** Since 1970, various investigations in Clear Lake have found high levels of mercury in fish tissue. Although mercury comes from many sources, the primary source of mercury in fish tissue is the Sulphur Bank Mercury Mine site. EPA's cleanup plans for the mine site will reduce mercury contributions to Clear Lake. EPA is working to determine what additional cleanup may be needed.
- **Facilitate timely transfer of parcels to Bureau of Indian Affairs (BIA).** EPA is working with BIA to assist in transferring ownership of parcels previously held by the company that mined Sulphur Bank to the Elem Indian Colony (EIC). These parcels have ancestral significance to EIC. While some of the parcels are clean, others have some site related pollution.

Glossary

Exposed Acid Generating Rock: Naturally contaminated rock that is highly acidic.

Exposure: Community members coming into contact with pollutants.

Feasibility Study: An evaluation of cleanup options.

Focused Feasibility Study: An evaluation of cleanup options for a specific portion of the site.

Herman Impoundment: See open pit mercury mine.

Human Health Risk Assessment: An evaluation of how the site impacts human health.

Lake Sediment: Lake sediments are comprised mainly of particles of clay/ silt/ sand, organic debris, chemicals, or combinations of these that settle into the bottom of a lake.

Mine Tailings: Contaminated materials left over after the mining process.

Open Pit Mercury Mine / Herman Impoundment: Mining technique in which a hole is dug to take out minerals that are close to the surface. The open pit on the site is called Herman Impoundment.

Residential Soils: Soils located on private properties with homes and residential use.

State Fish Advisory: A recommendation to limit or avoid eating certain species of fish or shellfish caught from specific water bodies.

Waste Rock: Contaminated mine waste.

Waste Rock Dam: A pile of contaminated waste rock that was unofficially constructed as a dam to prevent water flow from Herman Impoundment into Clear Lake.

How to Stay Informed/Involved

EPA is committed to developing a clean up plan for the mine portion of the site this year. As a part of the process, EPA hired public participation contractor Triangle Associates. Their staff are supporting EPA in providing transparent communication and engagement with the public about the ongoing cleanup efforts. This includes holding a virtual community forum in 2021.

March 2021 Community Forum Planning Meetings

EPA will support two community forum planning meetings: (1) A tribal-specific meeting; and, (2) a local government and general community-specific meeting. These meeting groups will work with EPA to decide an agenda for the Community Forum that will:

- give the community the opportunity to discuss their concerns relating to the site;
- help EPA to get an understanding of how lake health affects different communities;
- make the EPA team available to answer and respond to questions and concerns; and
- help EPA prioritize resources related to lake health and fish consumption outreach.

More information on this will be provided soon.

Spring/ Summer 2021 Virtual Community Forum

- EPA is planning to hold both tribal and general Community Forum meetings via Zoom in spring 2021.
- EPA invites the community to join and share their perspectives on the site cleanup. Community input will inform future cleanup work at the site and prioritize our outreach.
- As part of the planning process for the Community Forum, EPA is contacting tribal members, tribal representatives, community members, government agencies, and stakeholders to hear their concerns about the site and understand how to best communicate with the community at large.
- More information on the date, time and software platform will be provided soon.

Where to find more information and who to contact

Visit the site website (https://www.epa.gov/superfund/sulphurbankmercury) or contact the site's Community Involvement Coordinator or Remedial Project Manager.

Community Involvement Coordinator

Gavin Pauley
Public Affairs Division
U.S. EPA Region 9
75 Hawthorne Street
(Mail Code: OPA-2)
San Francisco, CA, 94102
pauley.gavin@epa.gov
(415) 535–3725

Remedial Project Manager

Carter Jessop
jessop.carter@epa.gov
(628) 223–3524

Scan the QR code with your camera or favorite app.

ATTACHMENT F

CLEAR LAKE FOOD WEB TABLE

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

Number	Species Name	Diet	Predator
A. ALGAE			
1	Aulacosira sp.	nutrients only	22, 36-38 (4)
2	Stephanodiscus sp.	nutrients only	22, 29-34, 36-38 (10)
3	Fragilaria sp.	nutrients only	22, 38 (2)
4	Navicula sp.	nutrients only	23, 25-34, 36-38 (14)
5	Ankistrodesmus sp.	nutrients only	22, 29-34, 38 (9)
6	Oocystis sp.	nutrients only	22, 24, 29-34, 38 (9)
7	Spirogyra sp.	nutrients only	22, 25-27, 36-38, 40, 41,44 (10)
8	Zygnema sp.	nutrients only	22, 25-27, 36-38, 40, 41,44 (10)
9	Microcystis sp.	nutrients only	22, 38, 40, 41,44 (5)
10	Anabaena circinalis	nutrients only	22, 25-28, 38, 40, 41,44 (9)
11	Aphanizomenon ovafisporum Forti	nutrients only	22, 25-28, 38, 40, 41,44 (9)
12	Aphanizomenon flos-aquae	nutrients only	22, 25-28, 38, 40, 41,44 (9)
13	Ceratium sp.	22, 23 (2)	22, 35, 38 (3)
B. MACROPHYTES			
14	Ceratophyllum demersum (Coon tail)	nutrients only	23 (1)
15	Ludwigia peploides (Water primrose)	nutrients only	23 (1)
16	Myriophyllum spicatum	nutrients only	23 (1)
17	Phragmites australis (= communis)	nutrients only	23 (1)
18	Potamogeton natens	nutrients only	23 (1)
19	Scirpus acutus (tule)	nutrients only	23 (1)
20	Scirpus californicus	nutrients only	23 (1)
21	Typha latifolia	nutrients only	23 (1)
C. MONERA, PROTISTA			
22	Planktonic bacteria/detritus	1-3, 5-13, 22 (13)	22, 24, 29-34, 38, 40, 41,44 (12)
23	Benthic bacteria/detritus	4, 14-21, 23 (10)	23-34, 37, 38, 40, 41 (16)
24	Zooflagellates	6, 22, 23 (3)	29-34, 37, 38 (8)
D. INVERTEBRATES			
25	Branchiura sowerbyi	4, 7, 8, 10-12, 23 (7)	38, 40, 43 (3)
26	Ilyodrilus frantzi	4, 7, 8, 10-12, 23 (7)	38, 40, 43 (3)
27	Potamothrix bavaricus	4, 7, 8, 10-12, 23 (7)	38, 40, 43 (3)
28	Asplanchna girodi	4, 10-12, 23 (5)	29-35 (7)
29	Bosmina longirostris	2, 4,-6, 22-24, 28 (8)	35, 43-45, 47, 48 (6)
30	Chydorus	2, 4-6, 22-24, 28 (8)	35, 43-45, 47, 48 (6)
31	Daphnia galeata mendotae	2, 4-6, 22-24, 28 (8)	35, 39, 4345, 46-48 (8)
32	Daphnia pulex	2, 4-6, 22-24, 28 (8)	35, 39, 4345, 46-48 (8)
33	Diacyclops bicuspidatus thomasi	2, 4-6, 22-24, 28 (8)	43-45, 48 (4)
34	Diaptomus franciscanus	2, 4-6, 22-24, 28 (8)	35, 43-45, 48 (5)
35	Chaoborus astictopus	13, 28-32, 34 (7)	38-40, 42, 43, 45 (6)
36	Chironomus plumosus	1, 2, 4, 7, 8 (5)	3841, 4345 (6)
37	Corisella decolor (fain. Corrixidae)	1, 2, 4, 7, 8, 23, 24 (7)	none
E. FISHES			
38	Cyprinus carp* (Carp)	1-13, 22-27, 35, 36 (21)	56 (1)
39	Gambusia affinis (Mosquitofish)	31, 32, 35, 36 (4)	56 (1)
40	Ictalurus catus (White catfish)	7-12, 22, 23, 25-27, 35, 36, 45 (14)	56 (1)
41	Ictalurus nebulosus (Brown bullhead)	7-12, 22, 23, 36, 44, 45 (11)	56 (1)
42	Ictalurus punctatus (Channel catfish)	35, 44, 45, (3)	56 (1)
43	Lavinia exilicauda (Hitch)	25-27, 29-36 (11)	56 (1)
44	Lepomis macrochirus (Bluegill)	7-12, 22, 29-34, 36, 45 (15)	41, 42, 46, 56(4)
45	Menidia beryllina (Inland silverside)	29-36 (8)	40, 41,44,46, 47 (5)
46	Micropterus salmoides (Largemouth bass)	31, 32, 44, 45 (4)	56(1)
47	Pomoxis annularis (White crappie)	29-32, 45 (5)	56(1)
48	Pomoxis nigromaculatus (Black crappie)	29-34 (6)	56(1)
49	Orthodon microlepidotus (Blackfish)		56 (1)
F.			
50	Frogs	Aquatic Invertebrates	54, 55 (2)
51	Cormorants	Fish	none
52	Herons	Fish	none
53	Osprey	Fish	none
54	Mink	50, Fish	none
55	Otter	50, Fish	none
56	Humans	Fish	none

Table 3.3 Proposed food web for Clear Lake, showing major aquatic and terrestrial species, and their feeding relations. The numbers found under the headings "Diet" and "Predator" correspond with those under the heading "Number." The values in brackets are counts for each grouping of numbers.

ATTACHMENT G

SUPPLEMENTAL LAKE TAHOE WATER QUALITY INFORMATION

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

ATTACHMENT G: SUPPLEMENTAL LAKE TAHOE WATER QUALITY INFORMATION

Runoff from developed land in the Lake Tahoe basin is recognized as one of the largest sources of fine sediments and other pollutants in the Lake. As a result, the Lahonton Regional Water Quality Control Board has set total maximum daily loads (TMDLs) in the Tahoe basin in a similar manner to the TMDL established for Clear Lake.

The following points were noted from the 2022 State of the Lake Report:

- Clarity continues to decrease in the summer months.
- A six-fold increase was identified for algae production in 2021.
- There exists a rapidly evolving shoreline algae problem.
- A dramatic decline in zoo plankton that consume algae could be concerning.
- The cyanobacteria population was the most abundant species in 2021.
- Steam bed nitrogen and phosphorus were the lowest in record in 2021.

Projects being implemented in the Tahoe Basin, as documented on the related EPA website, include:

- Retrofitting roads, highways and streets with stormwater infrastructure that captures and treats runoff including curbs, gutters, and filtration technology.
- Installation of rock-lined channels, bioswales, and stormwater infiltration basins.
- Vegetating hillsides, installation of retaining walls and other erosion control improvements.
- Decommissioning Forest Service roads which no longer serve important as recreational, or forest management uses.
- Installation of area-wide treatment and pump treatment facilities.
- Reduction and improved collections of sand and cinders applied for traction control in winter months.
- Retrofitting public and private parcels with Best Management Practices (BMPs).
- Assisting public and private property owners with BMP inspections, installations, and certifications.

Several tools have been developed by the Water Board and the Nevada Division of Environmental Protection to aid with the projects listed above. These tools include:

- A road inspection and assessment method and associated tracking system.
- A stormwater treatment BMP inspection and assessment method and associated tracking system.
- The Lake Clarity Crediting Program credit registration, award, and declaration system.

- The credit calculator is based on estimating reductions of nitrogen and phosphorus loading with an emphasis on the reduction in fine particle loading (1-5 microns).

The data for Lake Tahoe suggests that future studies of Clear Lake may lead to identification of similar climatic and biological factors to be considered in the effort to improve water quality. Furthermore, it is expected that long-term reductions in external loading will likely take decades to manifest in the form of direct positive impacts to water quality in the lake.

ATTACHMENT H

NRCS ASSESSMENT INFORMATION

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

NRCS Assessment Information
Clear Lake Source Water Assessment and Sanitary Survey

Section 1

Required data point: An assessment of NRCS' ability to help partners reach the source water protection goals and objectives that partners establish through the planning process.

Below is an estimate, developed with the local NRCS office, of how much conservation we might expect to implement through EQIP projects in a 3-5 year timeframe as a result of this project.

Rangeland/Pastureland: Grazing practices, fencing and livestock watering facilities (to control animal access to waterways), heavy use area protection. 2,000-4,000 ac and 5-10 projects in 5 years. (Up to 0.2% of grazing land)

Forest land: Reduce sediment delivery using unpaved road rehabilitation, stream crossings, and culverts. 5-10 projects in 5 years. Acreage estimate is not available.

Croplands: Reduce sediment, P, and N losses from vineyards, orchards and other farmed lands. Practices will include cover crop, conservation cover, riparian vegetation buffers, nutrient management, irrigation water management, and sediment basins. 1,000-2,000 ac in 5 years. (Up to 6.7% of farmland)

Watershed	Grazing Land	Farmland of Local Importance	Prime Farmland	Farmland of Statewide Importance	Unique Farmland	All Farmland
Adobe Creek	1,924,256.5	373.1	426.6	50.1	369.8	1,219.6
Clover Creek	6,665.4	579.5	238.1		256.8	1,074.4
Cole Creek	29,626.6	1,025.7	897.6	243.0	3,100.0	5,266.4
Kelsey Creek	18,093.2	980.2	225.5	34.0	173.1	1,412.9
Lower Scotts Creek	13,869.7	1,273.7	668.7		278.4	2,220.8
Manning Creek-Frontal Clear Lake	272.1	1,970.0	1,455.7	196.3	968.5	4,590.5
McGaugh Slough-Frontal Clear Lake	45.3	1,377.7	1,677.1	274.7	1,051.3	4,380.9
Middle Scotts Creek	29,616.4	1,374.7	1,081.6		69.4	2,525.7
Rodman Slough-Frontal Clear Lake	300.8	1,255.7	1,580.2	27.2	113.9	2,977.0
Salt Flat Creek-Middle Creek	47,265.6	437.4	490.3		56.6	984.3
Schindler Creek-Frontal Clear Lake	52,813.2	1,947.8	247.0	1.4	952.5	3,148.7
Total	**2,122,824.6**	**12,595.5**	**8,988.6**	**826.6**	**7,390.4**	**29,801.1**

Table: Acres of agricultural land in each watershed surrounding Clear Lake. Watersheds with no agricultural land mapped were excluded from analysis. Data from the Department of Conservation, Farmland Mapping and Monitoring Program, 2018.

Section 4:

Required data points: Current level of treatment in the Source Water Protection Area, and assessment of how treatment is balanced with producer participation.

Producers in the Clear Lake watersheds are already utilizing many of the conservation practices noted above as effective for sediment and nutrient loss reduction. In 2021, the Regional Water Quality Control Board found that irrigated agricultural stakeholders had met the 40% sediment load reduction required by the TMDL (Clear Lake Nutrient TMDL Program Technical Memorandum, Clear Lake Nutrient TMDL Program Technical Memorandum). As vineyards and orchards continue to be developed and replaced, we expect that growers will continue to implement these practices to comply with the TMDL, to comply with the Lake County Grading Ordinance, and to participate in industry sustainability initiatives. As a result, we expect that demand for technical and financial assistance through NRCS for these practices will be steady. In addition, while working with these growers we may be able to incorporate more practices that protect water quality in their conservation plans. These might include riparian buffers, nutrient management plans, reduced tillage strategies, and more complete vegetative cover on steep slopes.

Outreach to grazers and non-industrial private forestland owners will be key to implementing practices on these land uses. Many landowners were made aware of NRCS conservation planning, technical and financial assistance programs due to recent forest fires in Lake County and the rehabilitation and resilience work that has followed. “Return business” from these participants may be important to implementing sediment controls on forest and grazing lands.

EXHIBITS

CLEAR LAKE SOURCE WATER ASSESSMENT AND SANITARY SURVEY

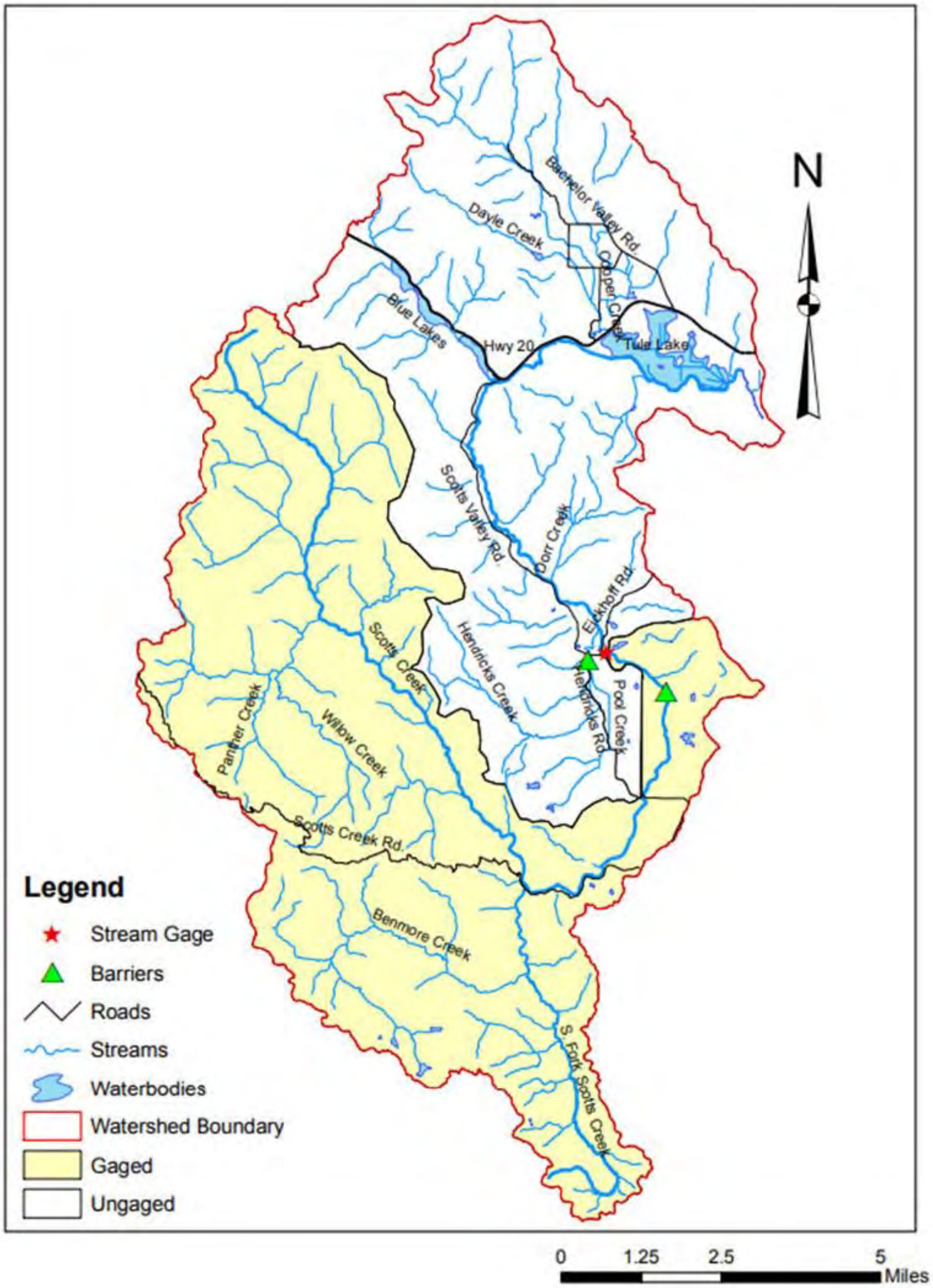


EXHIBIT A

Scott's Creek Watershed Detail Map

This map was reproduced from the Lake County 2010 Scotts Creek Watershed Assessment

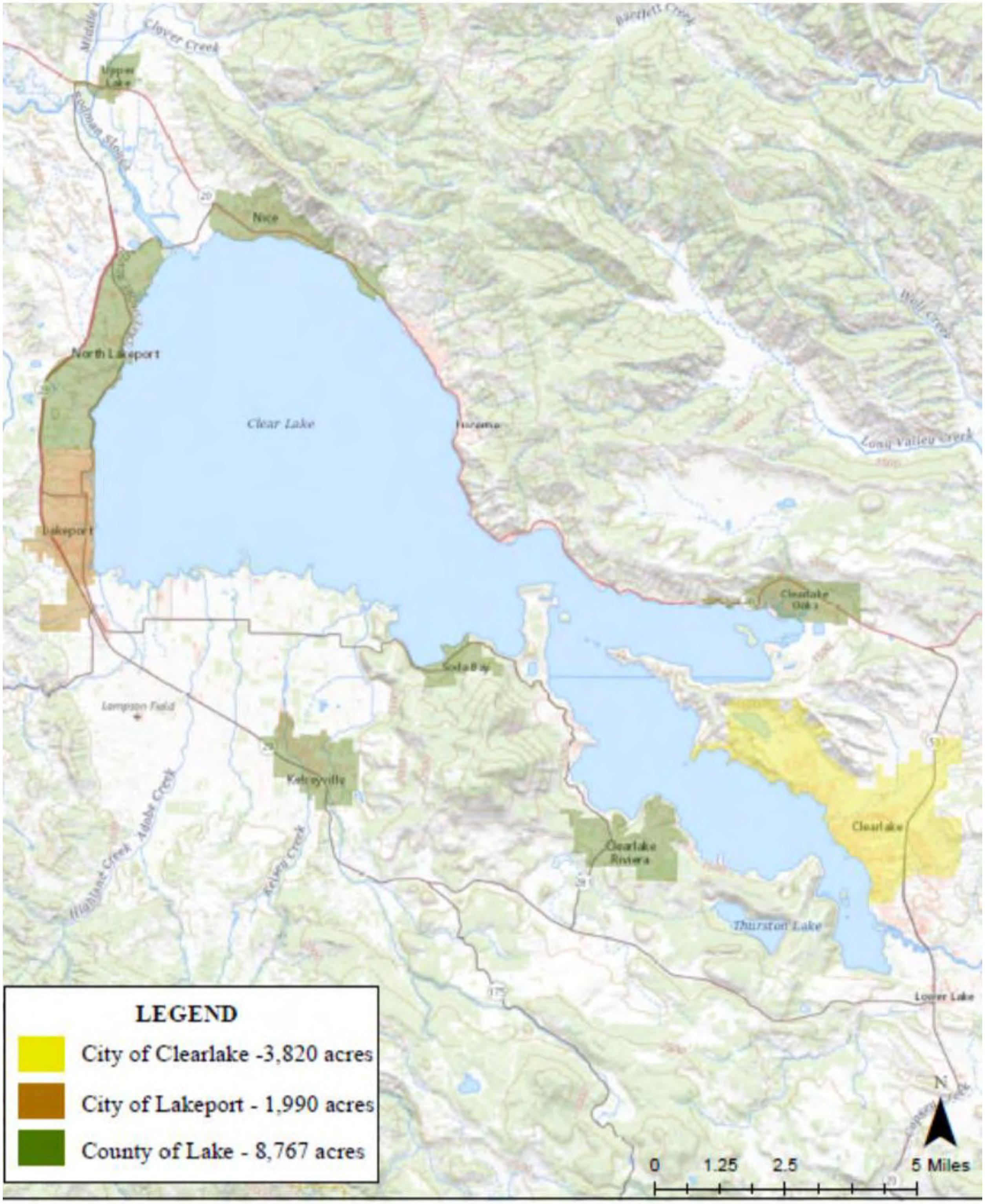


EXHIBIT B

NPDES MS4 Boundaries
Image from CA RWQCB Order R5-2019-1005

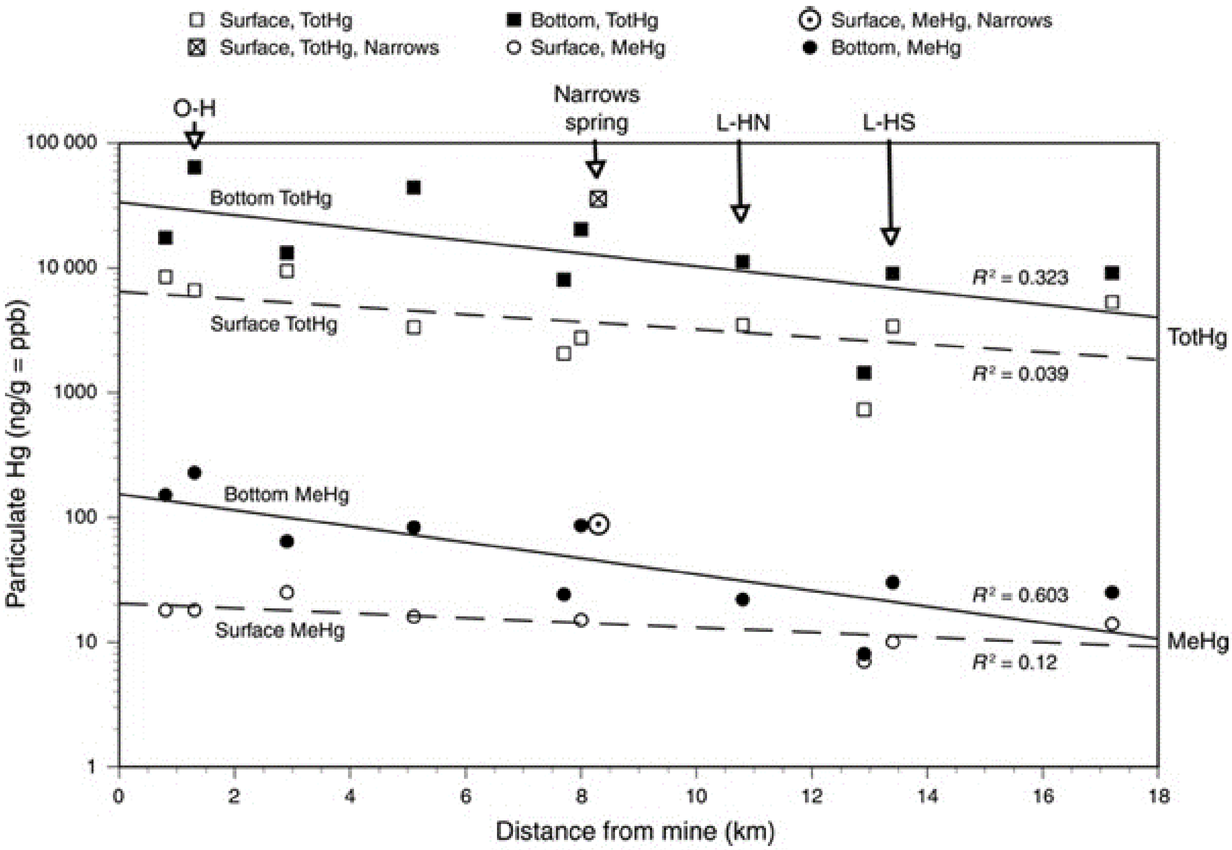


EXHIBIT C

Mercury Concentration in Clear Lake Graph
Image From: "MERCURY IN ABIOTIC MATRICES OF CLEAR LAKE, CALIFORNIA: HUMAN HEALTH AND ECOTOXICOLOGICAL IMPLICATIONS"
By: Suchanek, T.H., Eagles-Smith, C.A., Slotton, D.G., Harner, E.J. and Adam, D.P. (2008)

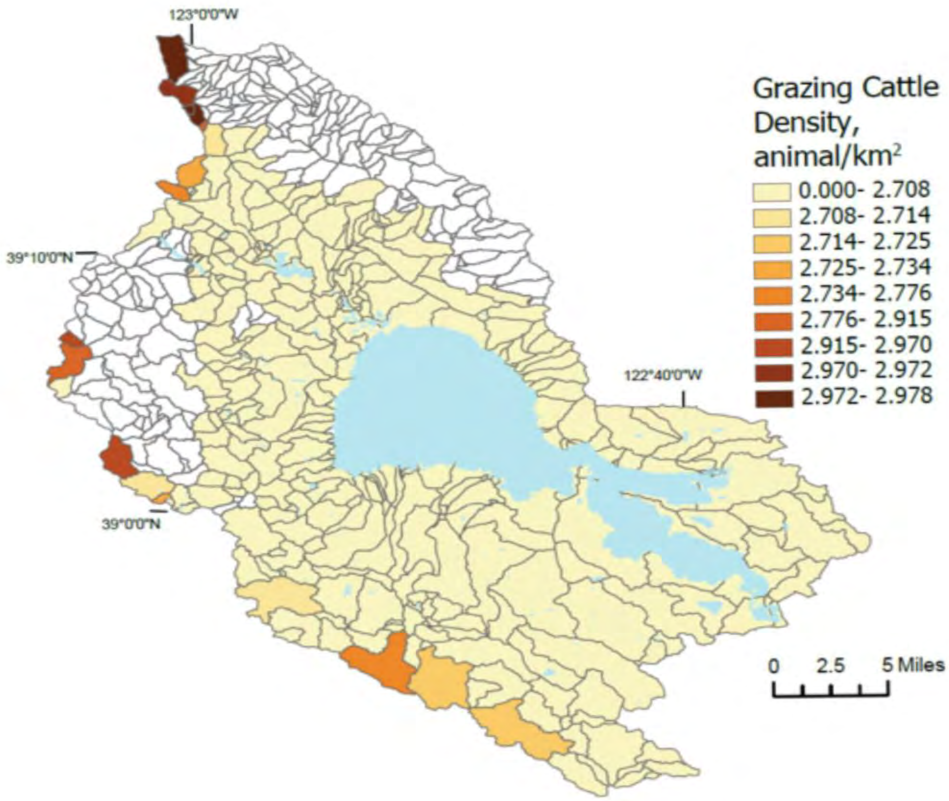


EXHIBIT D

Cattle Grazing Density in Lake County
This image has been reproduced.

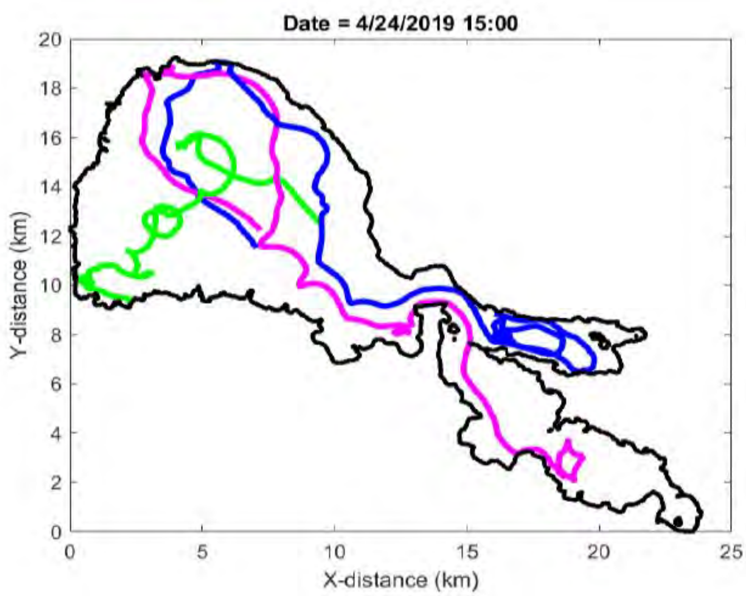
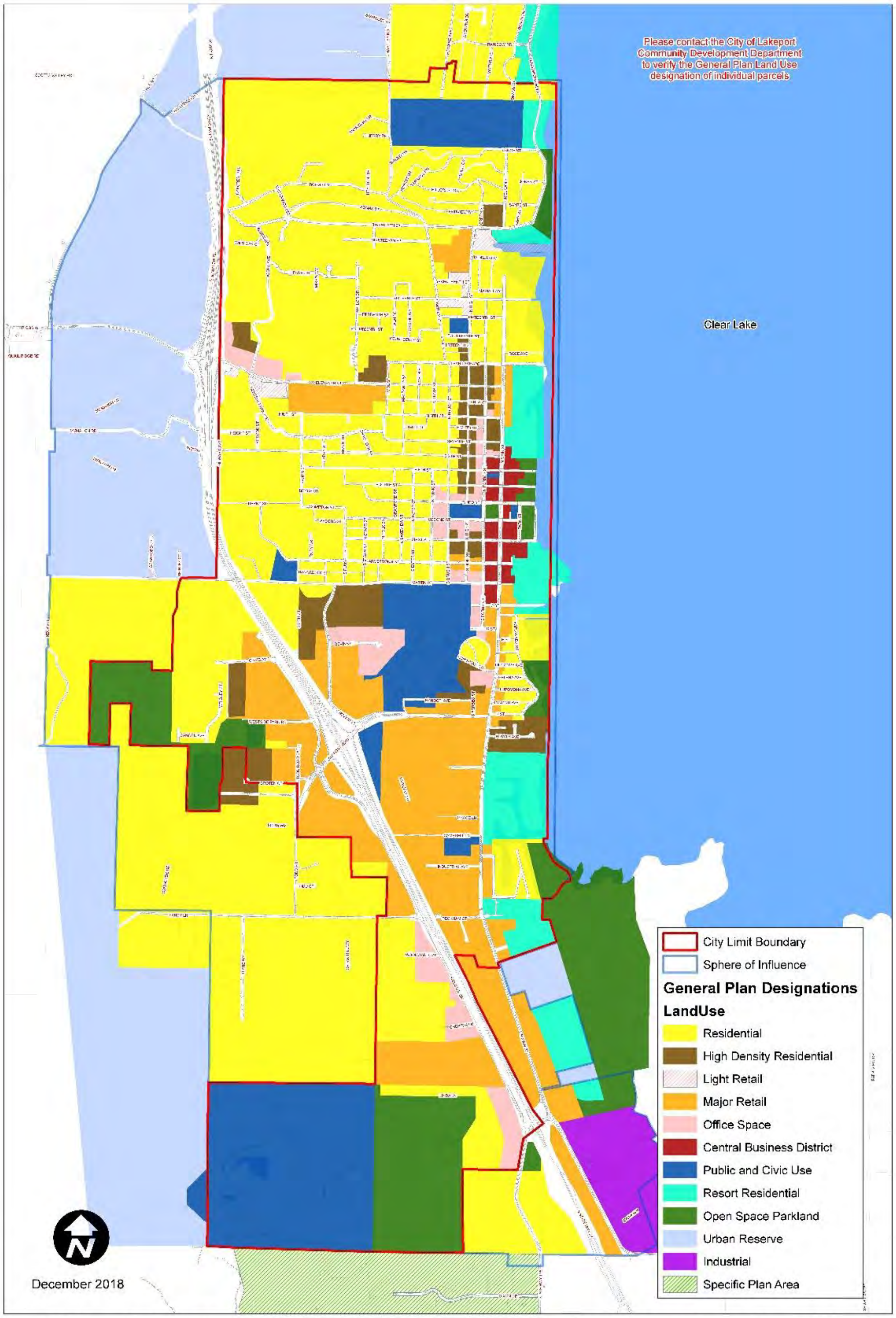


EXHIBIT E

Simulated particle travel, each color represents a different particle.
Developed by UC Davis Tahoe Environmental Research Center



City of Lakeport General Plan Land Use Designation Map

EXHIBIT F

Lakeport General Plan Designations
Map from City of Lakeport Website

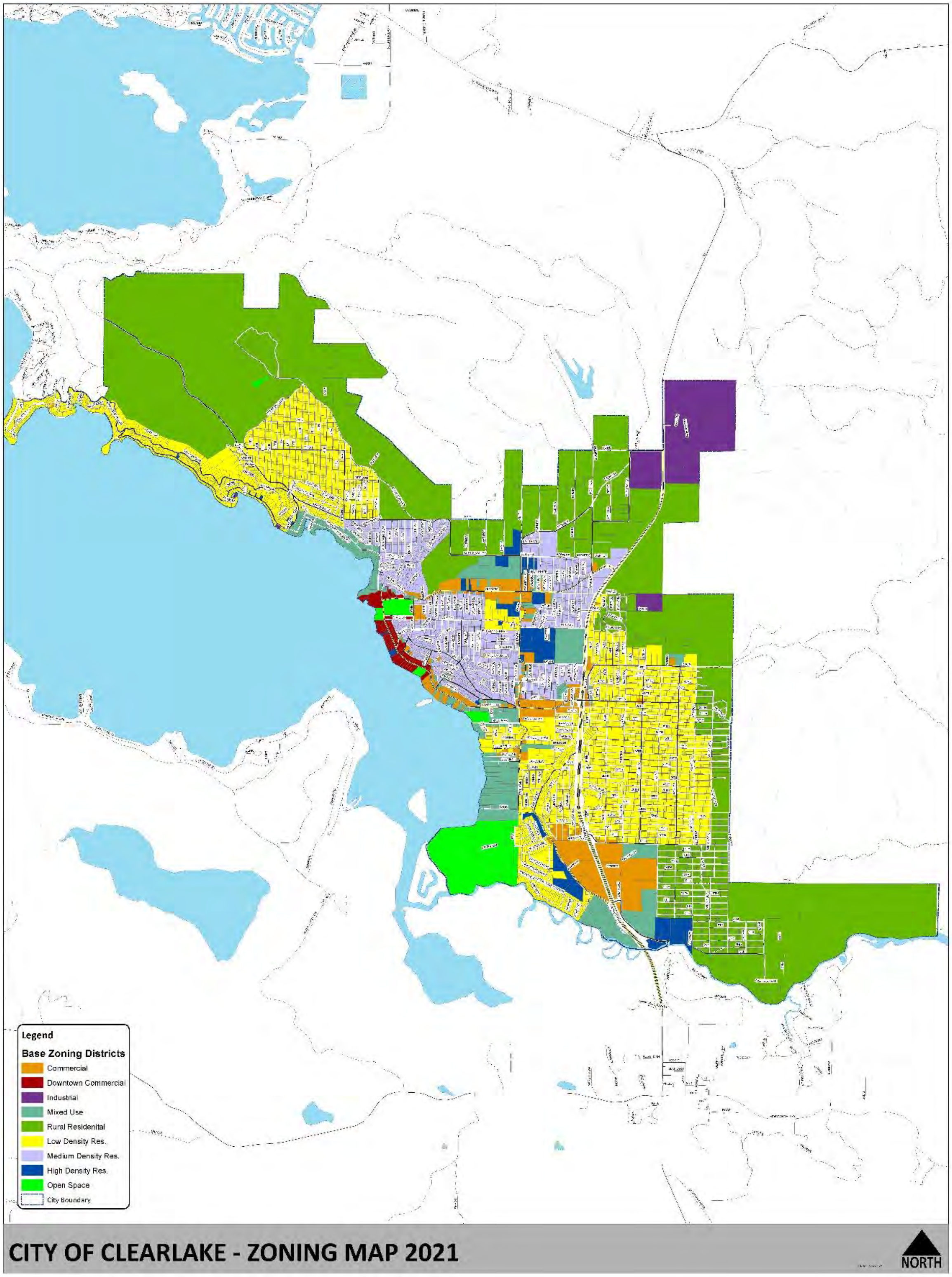


EXHIBIT G

City of Clearlake General Plan Zoning Map from City of Clearlake Website