California Regional Water Quality Control Board

San Francisco Bay Region

Ten Year Implementation Status of the Guadalupe River Watershed Mercury Total Maximum Daily Load

by

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Cover photograph: Mine Hill, New Almaden, located in Almaden Quicksilver County Park (photographic image from 1996 provided by Santa Clara County Parks)

Mine Hill was cleaned up in 1999 and is visible on satellite images like the below image from Google Earth (acquired on January 2022; latitude 37.174894, longitude: -121.844167).

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Glossary

Calcines	Roasted mercury ore (one form of mercury mining waste)
Control	Stevens Creek Reservoir is the positive control reservoir for Valley Water’s oxygenation pilot tests
REI	Remediation effectiveness indicator (biosentinel) fish
Reference	Lexington Reservoir was the reference reservoir for the TMDL
TMDL	Guadalupe River Watershed Mercury Total Maximum Daily Load

Units

cy	cubic yards
mg/kg ww	milligrams per kilogram (parts per million) wet weight
mg/L	milligrams per liter (parts per million)
ng/L	nanograms per liter (parts per billion)
sq ft	square feet
ug/g ww	micrograms per gram (parts per million) wet weight
ug/g – mm, ww	length-normalized fish mercury in micrograms per gram per millimeter fish length, wet weight

1 Executive Summary

New Almaden mercury mining district is located at the top of the Guadalupe River Watershed in south San Jose (see Figure 1). New Almaden was the largest-producing mercury mine in North America. Although it has been closed since 1975, historic mining practices left a legacy of mercury contaminated waste that continues to pollute downstream reservoirs, lakes, creeks, the Guadalupe River, and San Francisco Bay. Fish in these reservoirs and lakes have some of the highest mercury levels in fish in California. These mercury levels make it unsafe to consume fish and consequently these waters are posted with “no consumption” advisory signs.

Consequently, the San Francisco Bay Regional Water Quality Control Board (Water Board) adopted the Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL) in 2008. TMDL implementation was planned for two 10-year phases: Phase 1 (2009–2018), and Phase 2 (2019–2028), with a review after Phase 1 and fish mercury targets to be met at the 20-year mark. The TMDL states that within ten years of the effective date of this TMDL project (by December 31, 2018), the Water Board will consider amending this TMDL project and implementation plan as necessary to ensure attainment of fish targets in a timely manner. This requirement for a review at ten years is the impetus for this report.

TMDL Phase 1 implementation (mining waste cleanup in upslope locations and pilot tests in reservoirs to reduce methylmercury production) has proceeded more slowly than anticipated. Consequently, Water Board staff delayed the 10-year review by a few years. Thus, herein we summarized all TMDL implementation actions to date in the watershed, analyzed current water and fish tissue data, and determined that the TMDL is adequate to protect water quality and does not need to be amended.

At this time, staff recommends that no changes be made to the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan for this TMDL, including no changes to: two site-specific mercury water quality objectives (in the form of fish tissue mercury concentrations); two TMDLs; load and wasteload allocations; and TMDL fish targets (equal to the site-specific mercury water quality objectives). However, implementation is proceededing at a slightly slower pace than anticipated in the TMDL. Consequently, in this report, we formally recognize that Phase 2 of implementation will start with a 10-year delay and begin in 2029. Phase 2 of implementation includes mercury cleanup in creeks and Guadalupe River, and methylation controls in shallow impoundments (i.e., waterbodies smaller than lakes or reservoirs) in creeks. The goal for Phase 2 remains the same (attainment of the watershed fish tissue targets and the San Francisco Bay mercury TMDL allocations to urban stormwater runoff and legacy mercury sources in the Guadalupe River watershed) but the date is extended by 10 years to December 31, 2038.

We have made measurable progress in Phase 1 TMDL actions to clean up priority mines and implement pilot tests to evaluate whether reservoir oxygenation can effectively reduce mercury methylation and bioaccumulation. There are some indications that fish mercury levels have declined in some reservoirs, but the signal was not consistent across all water bodies. Therefore, the Santa Clara Valley Water District (Valley Water) is continuing its pilot tests to reduce bioaccumulation in Calero, Almaden, and Guadalupe Reservoirs (from east to west, see Figure 1).

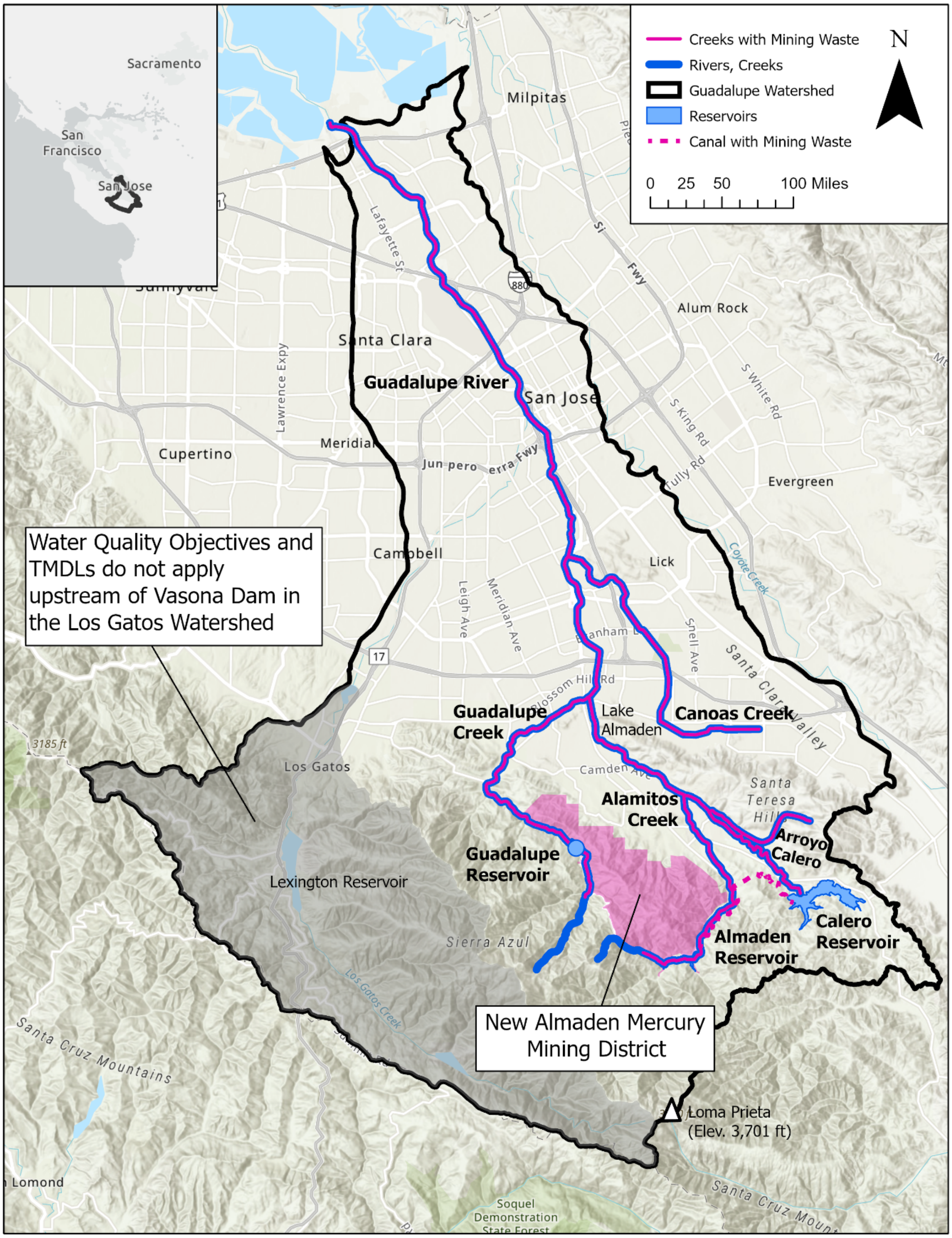

Figure 1. Map of the Guadalupe River Watershed

The Guadalupe River Watershed Mercury TMDL addresses waters downstream of mercury mines, notably New Almaden, one of the world's largest-producing mercury mines.

1.1 Mine Cleanups

Landowners completed several mine site cleanup projects in Phase 1 (see Figure 2) as described in the next few paragraphs. Mercury mining wastes include calcines (process mercury ore that still contains environmentally relevant mercury concentrations), mercury-contaminated soil, sediment, and equipment, elemental mercury that spilled, and furnace dust. Calcines were used to pave mining roads because when wetted they form a light cement that is a good road surface.

Figure 1 (prior page) indicates the locations of previous and pending mercury cleanups. Prior to the TMDL, the Santa Clara County Parks and Recreation Department (County Parks) cleaned up the most mercury-polluted sites (Figure 2, sites 2, 3, 5, 6, 7) in Almaden Quicksilver County Park. Specifically, County Parks removed elemental mercury and furnace dust, the most toxic mining wastes, from several sites and over 300,000 cubic yards (cy) of calcines. Also prior to the TMDL, Valley Water cleaned up mining waste in Jacques Gulch (Figure 2, site 8). This creek drains into Almaden Reservoir and mercury is transported in water flowing in the Almaden-Calero Canal to Calero Reservoir.

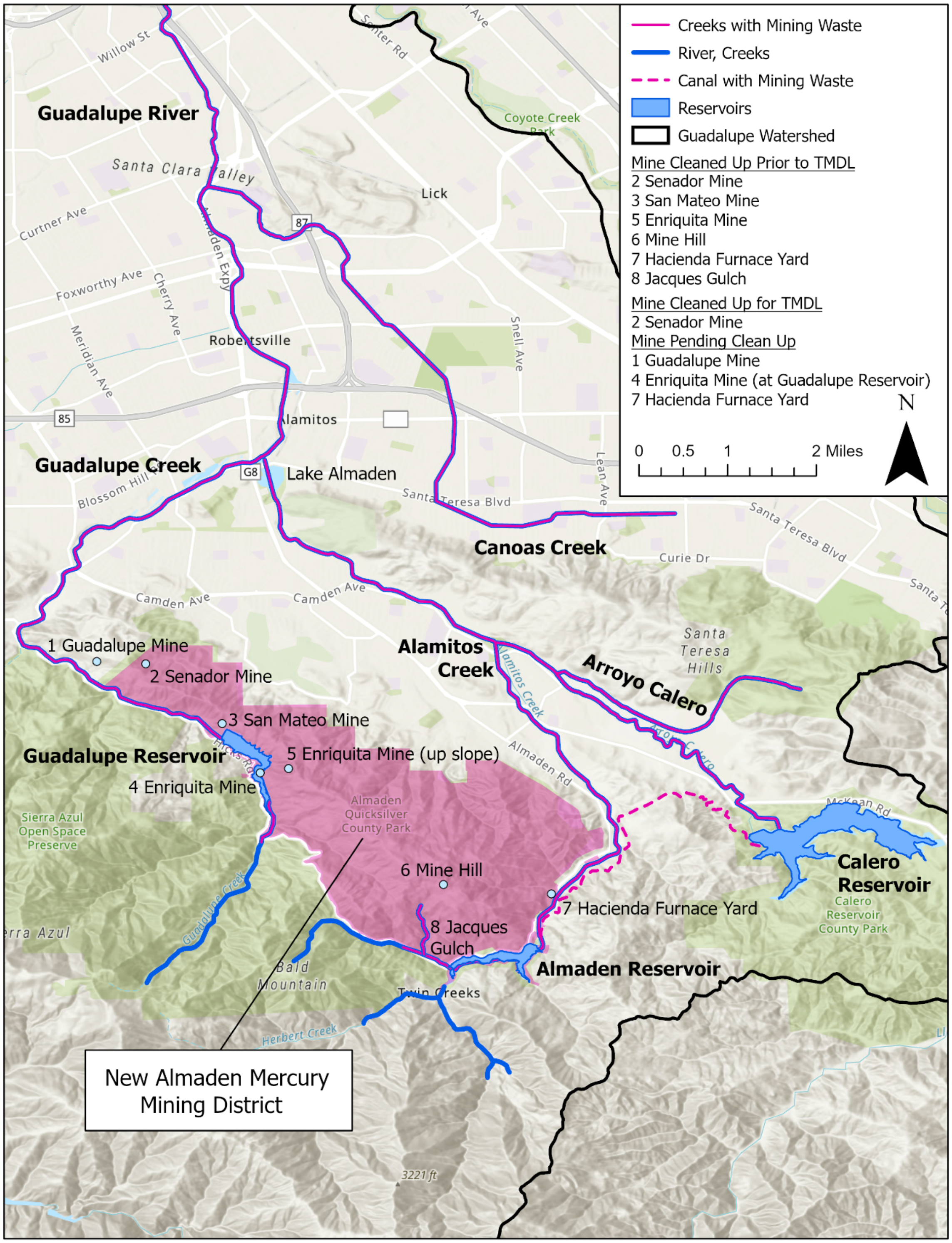

Figure 2. Map of the New Almaden Mercury Mining District

The 7 sites in Almaden Quicksilver County Park shown on Figure 2 had (or still have) large quantities of mercury mining waste but are a small subset of the 230 sites with mining features (Santa Clara County Parks 2011).

For compliance with the TMDL, the Midpeninsula Regional Open Space District and San Francisco Estuary Partnership jointly received a grant from the Water Board and U.S. EPA Clean Water Act Section 319(h) funds. In fall 2014, the grantees reduced one source of mercury to the watershed by stabilizing an eroding slope of mercury mining waste at Hicks Flat (not mapped, near Guadalupe Mine). County Parks also joined with the San Francisco Estuary Partnership and won grant funding from the U.S. EPA's San Francisco Bay Water Quality Improvement Fund. They did additional cleanup at Senador Mine (Figure 2, site 2) and cleaned up approximately four miles of calcine-paved roads (not mapped, roads near Mine Hill).

County Parks has another major cleanup project at Hacienda Furnace Yard and Deep Gulch (Figure 2, site 7) because the earlier project did not remove all of the calcines. This project is settlement of a lawsuit dating from prior to TMDL adoption. That will be the next-to-last feasible cleanup of calcines in Almaden Quicksilver County Park, although other mining wastes remain at the Park and elsewhere (see Section 3.6). The last feasible cleanup of calcines in Almaden Quicksilver County Park is small, ~200-ft-long stretch of calcine-paved road near the north shore of Guadalupe Reservoir (Santa Clara County Parks and Recreation, URS 2011[1]).

In addition to the mine clean ups described above, a restoration project for Lake Almaden will both reduce the mercury problem in the Lake and improve habitat and passage for anadromous fish. The Lake Almaden project, too, is long delayed and still in the planning and permitting stage. Once these projects are in construction, Water Board staff will next address (see Section 3.6) mercury mining waste in Alamitos Creek. On the west side of New Almaden, the future Guadalupe Dam Seismic Retrofit Project will include cleanup of mining waste at Enriquita Mine on the shoreline of Guadalupe Reservoir (Figure 2, site 4). Once that project is in construction, Water Board staff will next address downstream mercury mining waste at Guadalupe Mine (Figure 2, site 1) and subsequently in Guadalupe Creek.

Several responsible parties coordinate for monitoring of mercury loads and fish mercury levels in the creeks and Guadalupe River. Additionally, the San Francisco Bay Regional Monitoring Program monitored a large January 2017 storm to estimate the mass of mercury transported by the storm from the Guadalupe River Watershed to the San Franciso Bay, which is also impaired by mercury and subject to the San Francisco Bay Mercury TMDL. This storm peaked at 5,400 cfs, which is a little below a one in five year return interval of 6,000 cfs. They estimated that this *one storm* transported a whopping 70 kilograms (kg) of mercury (McKee et al. 2018). (The San Francisco Bay Mercury TMDL allocation to the Guadalupe River is less than 10 kg *per year*, and in the Walker Creek watershed in Marin County a discharge of 82 kg of mercury over *two months* [Whyte and Kirchner 2000] was so concerning that U.S. EPA SUPERFUND emergency response cleaned up the Gambonini Mercury Mine [Kirchner et al. 2011].) Clearly, TMDL implementation to ensure cleanup of mercury at mines and downstream is still necessary.

[1] Feature WS9 on Figure 1, Tile 2 in Santa Clara County Parks and Recreation, prepared by URS, 2011.

1.2 Notable Findings After a Decade of Implementation

The notable findings are that:

- Fish mercury levels remain highly elevated and greatly exceed the TMDL targets in all TMDL waters (Almaden, Calero, and Guadalupe Reservoirs, Lake Almaden, and in the creeks and Guadalupe River downstream of New Almaden) (see Section 6.4);
- Cleanup of mercury mines—not oxygenation—was likely the primary agent for a significant decrease (40 and 50 percent) in fish mercury levels in two reservoirs (see Section 6.2);
- Line diffuser oxygenation systems were not effective in reducing methylation or fish mercury levels in reservoirs because their bubbles caused mixing of reservoir water and methylmercury throughout the reservoir water column (see Section 0);
- Other types of oxygenation systems (i.e., Speece cone) or other mercury control actions (i.e., sorbents) might work in these shallow, bottom discharge reservoirs (see Section 4); and
- Water column mixing—not suppression of methylation—from consistent operation of line diffuser oxygenation systems reduced discharges of methylmercury to downstream by more than 80% (see Sections 4.3.4 and 6.4).

1.2.1 Mine cleanup and fish mercury levels

The first notable finding is that mine cleanup reduced fish mercury levels. Figures 3 and 4 show lower mercury levels in both young and several-year-old (sport-size) fish in Almaden and Calero Reservoirs downstream of cleanup of mercury mining waste in Jacques Gulch, a creek that drains Mine Hill (Figure 2, site 8). In contrast, there is no reduction in Guadalupe Reservoir that still has mining waste on its shore (Figure 2, site 4) although mining waste upslope was cleaned up (Figure 2, site 5). Valley Water oxygenated all three reservoirs (see Section 0).

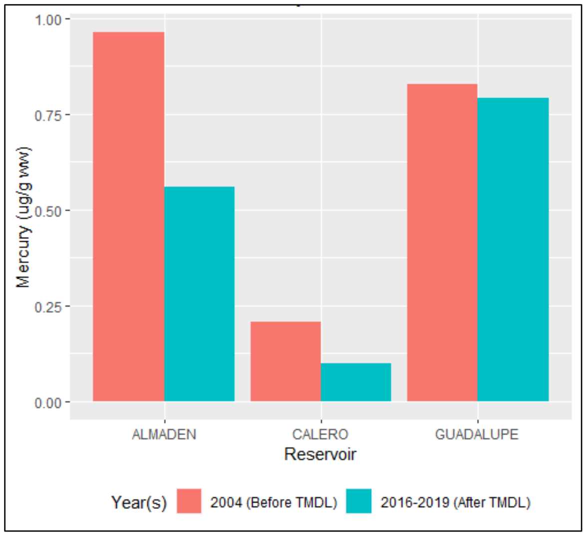

Figure 3. Mine Cleanup Decreased Mercury Levels in Biosentinel Fish (REIs)

Both Almaden and Calero Reservoirs have statistically significant decreases in mercury in REIs (biosentinel) fish, most likely due to mine cleanup (see Section 6.2). The TMDL REIs fish are age-1 (young-of-year) Largemouth bass (whole fish, mercury in wet weight).

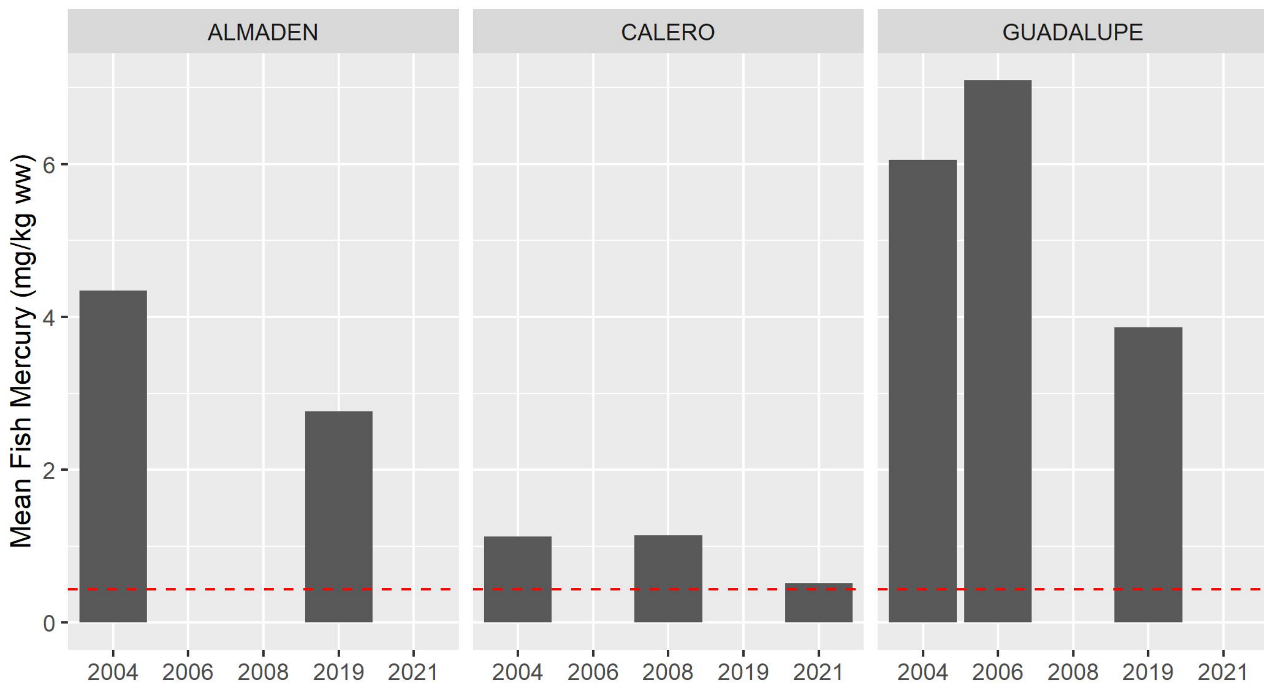

Figure 4. Elevated Mercury Levels in Sport-size Largemouth Bass

Largemouth bass mercury levels are highly elevated in comparison to the California no consumption level[2] of 0.44 ug/g (dotted red line). This comparison is to no consumption level because there is no TMDL target for sport fish and the statewide mercury water quality objectives do not apply (see Section 2.2). Note that both Almaden and Calero Reservoirs had a statistically significant reduction in mercury levels over time (see Section 6.5 for normalized fish mercury and time trend evaluation). This figure provides annual average mercury in sport-size (200 mm or longer) Largemouth bass (skinless fillet, wet weight). Citations: 2003, 2005, 2004 and 2006: TMDL Staff Report; 2007–08 SWAMP BOG 2007–2008 Lakes Survey 2010 Report; 2019 and 2021SWAMP BOG data transmittals.

Regarding use of fish, biosentinel fish (see Figure 3) are a useful measure of recent changes in methylmercury bioaccumulation provided the fish are young and they have high site fidelity, so that we know when and where they accumulated their mercury. This TMDL calls its biosentinels “Remediation Effectiveness Indicators” (REIs) and are age-1 (young-of-year) Largemouth bass, which have high site fidelity. In contrast, sport fish are used to measure the threat to human health (for consumers of local fish). The statistically significant decrease in mercury in both REIs and sport-size fish in Almaden and Calero Reservoirs is most likely due to mine cleanup (see Section 6.2).

Figure 4 provides mean mercury levels in sport-size Largemouth bass. (See Section 6.5 for size-normalized data.) Guadalupe Reservoir has the highest fish mercury levels in California. Protection

[22] California’s Office of Environmental Health Hazard Assessment establishes consumption levels to protect human health from contaminants in fish and publishes fish consumption advisories.

of human health has long been underway. In 1987, Santa Clara County issued a “no consumption” advisory to inform people to not consume any fish caught from downstream of New Almaden. Signs with no consumption advisory are posted and catch-and-release fishing is allowed.

1.2.2 Reservoir oxygenation

The second notable finding is that these line diffuser oxygenation systems were not effective in reducing methylation or fish mercury levels in these shallow, bottom discharge reservoirs (Section 4.3). Valley Water determined that the bubbles from line diffuser systems mix reservoir water. Mixing dilutes the methylmercury in bottom water rather than oxygen suppressing methylation (see Section 4.3.2). An unintended consequence of line diffuser oxygenation in these shallow reservoirs was mixing nutrients up to the photic zone, increasing cyanobacteria by 25 to 60 percent, i.e., worse reservoir water quality. Moreover, mixing raised the temperature of water discharged downstream, including into creeks where cold water is needed to protect anadromous fish. Valley Water is considering new and innovative methylmercury control methods such as mercury sorbents and possibly supersaturation, a different method of applying oxygen (Section 4.4).

1.3 Conclusions and Next Steps

TMDL Phase 1 implementation has proceeded more slowly than anticipated. Water Board staff recommends that no changes be made to the TMDL except to recognize that Phase 1 will take 20 years (twice as long as originally anticipated) so that Phase 2 of implementation will start with a 10-year delay and begin in 2029. Water Board staff will prioritize the following actions to complete Phase 1:

- Cleanup of mercury mining waste shall be sequenced from upslope to water’s edge and from upstream to downstream, starting with Guadalupe Mine and prioritizing sites at Almaden Quicksilver County Park (see Section 3.6)
- Support and direct Valley Water’s reservoir pilot tests (see Section 4.5)
- Direct and track coordinated monitoring (see Section 5.3)
- Evaluate and report on fish mercury levels (see Section 6)

2 Introduction

The historical New Almaden mercury mining district is located at the top of the Guadalupe River Watershed in south San Jose (see Figure 1). Mining in the New Almaden Mining District began in 1846, peaked in the 1860s, and continued until 1975. In accordance with mining practices common at the time, workers disposed of roasted mercury ore (calcines) and other mining wastes in or near the creeks, so the materials would be transported downstream by winter flows. New Almaden was the largest-producing mercury mine in North America, and it continues to pollute downstream reservoirs, lakes, creeks, the Guadalupe River, and San Francisco Bay with mercury. These reservoirs and lakes have some of the highest mercury levels in fish in California. Consequently, they are posted with “no consumption” advisory signs.

To address this mercury pollution, the San Francisco Bay Regional Water Quality Control Board (Water Board) adopted the Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL) in 2008. The TMDL can be found in Chapter 7.7.1[3] of the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan). TMDL implementation was planned for two 10-year phases from 2009 to 2018 and 2019 to 2028, with a review after Phase 1 and fish mercury targets to be met at the 20-year mark. However, TMDL Phase 1 implementation has proceeded more slowly than anticipated. Consequently, Water Board staff delayed the 10-year review for several years. At this time, staff recommends that no changes be made to the TMDL.

2.1 TMDL Phasing

We planned for TMDL implementation in two phases, beginning promptly after TMDL adoption by the Regional Water Board in October 2008. The goals for the first 10-year phase include: implementing effective source control measures for mining waste at mine sites; completing studies to reduce discharge of mining waste accumulated in Alamitos Creek; and completing studies of methylmercury and bioaccumulation controls in reservoirs and lakes, by December 31, 2018. The goal for the second 10-year phase of implementation is the attainment of the watershed fish tissue targets and the San Francisco Bay mercury TMDL allocations to urban stormwater runoff and legacy mercury sources in the Guadalupe River watershed, by December 31, 2028.

The first phase is taking longer than planned because work is proceeding slower than anticipated:

- Santa Clara County Parks and Recreation is still working on the “Hacienda Furnace Yard and Deep Gulch” project in Almaden Quicksilver County Park. This is a large mercury mining waste cleanup project that County Parks committed to in 2005 (prior to and separate from the TMDL). After several delays, planning and permitting for this project are again underway.
- Studies for Alamitos Creek are pending Valley Water’s Lake Almaden Improvement Project. After several delays, construction of the Lake project is scheduled for 2022.
- Reservoir methylmercury and bioaccumulation studies are ongoing and show modest but significant declining trends in fish mercury levels in Guadalupe Reservoir (Seelos et al., 2021).

Although slower than planned, the sequence of mining cleanup actions is appropriate. The TMDL phases mercury mining waste control actions so that mercury discharges from upstream will be eliminated or significantly reduced before downstream projects are undertaken. This sequence ensures that erosion and transport of upstream mining wastes is eliminated before downstream areas are cleaned up. The “Hacienda Furnace Yard and Deep Gulch” project is located far upstream on Alamitos Creek, so it should be completed prior to cleanup of Alamitos Creek. Planning and permitting for the Lake Almaden project has taken considerably longer, and hence more of Valley Water’s staff resources, than anticipated. We anticipate that Valley Water will have

[3] Available on the Water Board’s website at: https://www.waterboards.ca.gov/sanfranciscobay/basin_planning.html

staff availability for studying and planning cleanup in Alamitos Creek once construction of the Lake Almaden project is underway.

Also slower than planned are Valley Water's efforts to address mercury cycling in their reservoirs. There are some indications that fish mercury levels have declined in reservoirs, but we do not yet know what levels are achievable. Therefore, Valley Water is continuing its pilot tests and studies of mercury controls in Calero, Almaden, and Guadalupe Reservoirs (from east to west, see Figure 1).

2.2 TMDL Elements and Portion of Watershed

The Guadalupe River watershed mercury TMDL includes site-specific mercury water quality objectives and TMDL elements (e.g., allocations and targets).

2.2.1 Site-specific water quality objectives and TMDL targets

This TMDL includes two site-specific water quality objectives and two TMDL targets equal to the objectives. These objectives and targets are expressed as mercury concentrations in fish to protect wildlife that consume local prey fish. These objectives and targets also protect human health for the consumption of local sport fish. The water quality objectives can be found in Basin Plan Chapter 3, Table 3-4A and the TMDL targets can be found in Basin Plan Chapter 7.7.1.

Subsequent to adoption of this TMDL, the State Water Resources Control Board established statewide mercury water quality objectives expressed as mercury concentrations in fish to protect wildlife and people who consume local fish. However, these statewide objectives do not supersede the Guadalupe site-specific objectives. Moreover, the Guadalupe objectives are consistent with the more recent statewide objectives. For convenience, the applicable table from the Basin Plan is provided below. The TMDL staff report (in Section 9.9, Fish Tissue Monitoring) describes that "prey fish methylmercury concentrations may be estimated as ninety percent of the total mercury in whole fish," because fish is often analyzed for total mercury concentration rather than methylmercury concentration.

Basin Plan Table 3-4A. Protection of Aquatic Organisms and Wildlife[a]

Water Quality Objective	Applicability
0.05 mg[b] methylmercury per kg[c] fish	Average wet weight concentration measured in whole trophic level 3 fish 5 to 15 cm in length
0.1 mg methylmercury per kg fish	Average wet weight concentration measured in whole trophic level 3 fish 15 to 35 cm in length

a. The freshwater water quality objectives for the protection of aquatic organisms and wildlife also protect humans who consume fish from the Walker Creek and Guadalupe River watersheds.

b. mg = milligram

c. kg = kilogram

2.2.2 TMDLs and Allocations

This Project includes: 2 TMDLs, 1 wasteload allocation, and 5 load allocations in Basin Plan Chapter 7.7.1. The 2 TMDLs are expressed as annual peak methylmercury concentrations in reservoir hypolimnion water and annual median mercury concentrations in sediment. The one wasteload allocation is to urban stormwater runoff discharges and it is the same as and implemented through the San Francisco Bay mercury TMDL (Basin Plan Chapter 7.2.2). There are several load allocations that are equivalent to the two TMDLs. These load allocations are expressed as methylmercury concentrations in reservoir water and mercury concentrations in erodible mining waste, erodible sediment, and suspended sediment. Additionally, there is a load allocation to atmospheric deposition to water surface. For convenience, the applicable tables from the Basin Plan are provided below.

Basin Plan Table 7.7.1-1: Total Maximum Daily Loads

Waters	**TMDLs**
Creeks and river: • Guadalupe Creek • Alamitos Creek • Guadalupe River	0.2 mg[a] mercury per kg[b] suspended sediment (dry wt., annual median)
Reservoirs and lakes: • Guadalupe Reservoir • Almaden Reservoir • Calero Reservoir • Lake Almaden	1.5 ng total methylmercury per liter water (seasonal maximum, hypolimnion)

a. mg = milligram
b. kg = kilogram

Basin Plan Table 7.7.1-2: Load and Wasteload Allocations

Source	Load Allocation	Wasteload Allocation
Total Mercury Sources:		
Mercury mining waste discharged from the New Almaden Mining District, and Guadalupe, Santa Teresa, and Bernal mercury mines	0.2 mg mercury per kg erodible mercury mining waste (dry wt., median)[a, b, c]	
Mercury-laden sediment discharged from depositional areas in Alamitos Creek, Guadalupe Creek, Los Gatos Creek downstream of Vasona Dam[d], Canoas Creek, Ross Creek, Guadalupe River, tributaries to these creeks that drain mercury mines, and percolation ponds along these creeks	0.2 mg mercury per kg erodible sediment (dry wt., median)[a, b]	
Urban stormwater runoff discharges[e]: Santa Clara Valley Water District, County of Santa Clara, Town of Los Gatos, cities of Campbell, Monte Sereno, San José, Santa Clara, and Saratoga		0.2 mg mercury per kg suspended sediment (dry wt., annual median)[f]
Nonurban stormwater runoff discharges[g]	0.1 mg mercury per kg suspended sediment (dry wt., annual median)[h]	
Atmospheric deposition	0.02 mg mercury per square meter of water surface (per year)[i]	
Methylmercury production in reservoirs and lakes: [j]		
Guadalupe Reservoir, Almaden Reservoir, Calero Reservoir, and Lake Almaden	1.5 ng total methylmercury per liter water (seasonal maximum, hypolimnion)[b]	

Notes continued on next page:

Notes:

a. Allocations to mercury mining waste and mercury-laden sediment are not cleanup standards. These allocations are equal to the mercury suspended sediment TMDLs in Table 7.7.1-1.

b. “Erodible” means material readily available for transport by stormwater runoff to surface waters.

c. The mercury mining waste allocation shall be measured in fines less than 63 microns in diameter.

d. This allocation applies to the Los Gatos Creek watershed between Vasona Dam and Lenihan Dam.

e. Urban stormwater runoff is subject to an NPDES permit. At the time of adoption, the permit no. was CAS029718

f. The urban stormwater runoff allocation is proportionally equivalent to the mass allocation (7.2 kg mercury per year) in the San Francisco Bay mercury TMDL. The urban stormwater runoff allocation is the fraction of the Santa Clara Valley Urban Runoff Pollution Prevention Program allocation attributed to the Guadalupe River watershed. The urban stormwater runoff allocation implicitly includes all current and future permitted discharges within the geographic boundaries of municipalities and unincorporated areas including, but not limited to, California Department of Transportation (Caltrans) roadways and non-roadway facilities and rights-of-way, atmospheric deposition, public facilities, properties proximate to stream banks, industrial facilities, and construction sites.

g. This allocation applies to waters that do not drain areas mined for mercury upstream of Lenihan Dam, Guadalupe Reservoir, Almaden Reservoir, and Calero Reservoir.
h. The nonurban stormwater runoff allocation is proportionally equivalent to the mass allocation (0.5 kg mercury per year) in the San Francisco Bay mercury TMDL. The nonurban stormwater runoff allocation is the fraction of the regionwide allocation attributed to the Guadalupe River watershed. The background mercury concentration in non-urban and non-mined areas is equal to the nonurban stormwater runoff allocation (0.1 mg mercury per kg suspended sediment), and includes mercury from both naturally occurring mercury in soil and atmospheric deposition.
i. The atmospheric deposition allocation to water surfaces in the Guadalupe River watershed is equal to the rate in the San Francisco Bay mercury TMDL.
j. The methylmercury allocation to reservoirs and lakes is equal to the methylmercury TMDL in Table 7.7.1-1.

2.2.3 Portion of Watershed Addressed by the TMDL

This TMDL Project addresses about 80 percent of the Guadalupe River watershed, see Figure 1. The portion of the Guadalupe River watershed that is addressed by this mercury TMDL is the portion downstream of the New Almaden mercury mining district and areas with urban stormwater runoff. Both the TMDL and site-specific water quality objectives apply to this large portion. Notably, the area upstream of Vasona Dam on Los Gatos Creek is not addressed by this TMDL and the statewide mercury water quality objectives apply to this area of the Guadalupe River watershed.

2.3 Report organization

This report is organized as follows. Section 1 is a summary that can be used as a standalone document. Section 2 introduces the TMDL and its implementation requirements. Sections 3 and 4 describe the progress on TMDL implementation requirements for cleanup of mining wastes and reservoir pilot tests, respectively. Section 5 describes coordinated monitoring. Section 6 describes fish mercury levels and explores whether they are lower due to TMDL implementation. Section 7 provides the status of special studies and answers to TMDL adaptive implementation questions. Lastly, Section 8 (References) lists information sources cited and relied upon to prepare this report, and Appendix A provides supporting data, figures, and calculations relied upon to prepare this report.

3 Mercury Cleanups

The first implementation action required by the Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL) is source control to reduce mercury loads both in the Guadalupe River watershed and to San Francisco Bay. The TMDL protects surface waters by requiring that mercury mining waste be cleaned up, i.e., stop polluting. Mercury mining waste control actions are phased, so mercury discharges from upstream will be eliminated or significantly reduced in Phase 1 before downstream projects are undertaken in Phase 2. We had planned that mercury mine cleanup, particularly at New Almaden, would be completed within the first 10 years (Phase 1), but despite much progress it is not yet completed.

We estimate that cleanup of mercury mining waste in New Almaden Quicksilver County Park is about 70 percent complete. Our estimate is based on surface area of mine features (Santa Clara County Parks and Recreation 2011), which admittedly is a poor approximation of volume. To date, sites with the worst erosion problems and calcines (processed ore) were cleaned up (Mine Hill, San Francisco Open Cut, Hacienda Furnace Yard, Deep Gulch, San Mateo Mine, Enriquita Mine upslope, Senador Mine, and calcine-paved roads) (Table A-1). Together, these sites covered about 1.4 million square feet (sq ft). Water Board staff have identified 22 high-priority sites in New Almaden Quicksilver County Park for investigation for threat to water quality. Of these 22 sites, 7 sites may potentially contain calcines and total about 330,000 sq ft. The remaining 15 sites total about 700,000 sq ft and it is likely that many of them will not need cleanup.

Phase 1 also calls for Valley Water to begin planning for downstream cleanup in Alamitos Creek between Hacienda Furnace Yard and Lake Almaden. We had expected that Lake Almaden would be completed within a few years of TMDL adoption. However, Lake Almaden has taken much longer than anticipated, so creek cleanup planning is also delayed.

The following sections explain the expected benefits from cleanup of mercury mining wastes, what cleanups have been completed, and what cleanups are pending (see Figure 1).

3.1 Expected Benefits from Mercury Cleanups

This section explores the expected benefits from cleanup of mercury mining wastes: location, pace, and degree of improvement as measured by lower fish mercury levels. In short, we estimate that effective mercury cleanups above reservoirs should reduce reservoir biosentinel fish mercury levels by 50 percent within a few years following upstream cleanup and subsequent large storm events that transport low-mercury soils to the reservoir that bury mercury mining. Section 6.2 describes improvement in Almaden and Calero Reservoirs likely as a result of cleanup of upstream mercury mining waste.

3.1.1 Effective mercury cleanups

Effective mercury cleanups upstream of or within surface waters means both:

- Substantially reduced mercury loading to the surface water body, and
- Mercury already in the surface water body will soon be buried, either by low-mercury sediment transported by storms or by an engineered clean cover

The scientific literature provides some evidence that mercury source reduction (i.e., mercury cleanups) reduces methylmercury bioaccumulation. Unfortunately, the evidence is scarce largely because (1) many cleanups focus on mercury concentrations in soil and sediment rather than on biota methylmercury concentrations, and (2) biota data sets generated prior to clean up are often too small to support before-and-after comparisons with statistical significance.

Evidence in San Francisco Bay of Lower Biota Mercury Levels

A study in San Francisco Bay provides some evidence that mercury in biota downstream of New Almaden has declined since closure of the mine. University of San Francisco Professor Allison Luengen (et al. 2016) was the first to report long-term decline in methylmercury in biota in San Francisco Bay. Luengen’s team obtained mussels from museum archives that had been collected in the vicinity of the Dumbarton Bridge in South San Francisco Bay. Lower South San Francisco Bay is polluted by mercury from New Almaden and mercury from other sources. Consequently, prey fish near the Guadalupe River in Lower South San Francisco Bay have elevated mercury levels (Greenfield et al. 2010). Luengen's team determined that mussel methylmercury concentrations have decreased nearly four-fold since mine closure (1970 to 2012). They noted that this decline in mercury concentrations in biota was consistent with previously observed declines in Bay sediment mercury concentrations and not caused by food web changes or museum preservation practices.

Unfortunately, no such decline is seen in sport fish mercury levels in San Francisco Bay. The San Francisco Bay Regional Monitoring Program has evaluated Striped bass mercury levels but does not find any changes over more than four decades.

Declines but Mercury Levels Likely to Remain Above Targets

A literature review by U.S. EPA scientist Chris Eckley and others (2020) provides evidence that mercury source reductions have decreased methylmercury concentrations in biota but cautions us that although methylmercury

> … concentrations in biota may initially respond relatively quickly to a remediation action at a highly contaminated site, these levels may still be above targeted criteria concentrations. Further declines in fish [*methylmercury*] concentrations to meet criteria levels can occur slowly and may take several decades or longer, particularly as the distance from the initial point of release increases.

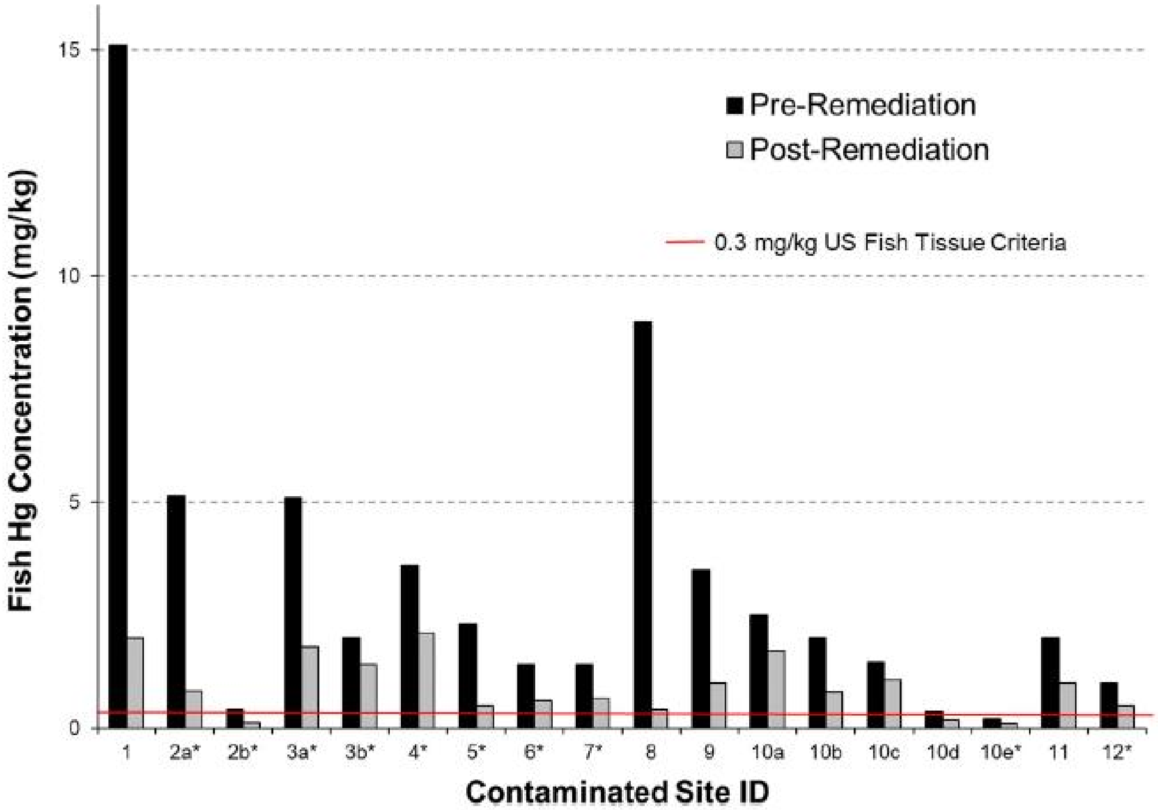

Figure 5. Fish Mercury Concentrations Before and After Site Cleanup

This figure shows that site cleanup reduces fish mercury (mean or median) levels downstream. Sites 2 and 7 are lakes polluted by mercury mines where cleanup reduced fish mercury levels by 50 to 85 percent. Site 2 had erosion control then natural burial of contaminated sediment. Site 7 had more extensive cleanup (excavation of soil at mill site and sediment in lake downstream). Sites 1 through 7 and 10 are lakes or reservoirs. Sites 8 through 12 had more extensive cleanup actions than the other sites. The asterisks (*) next to the site ID represents samples where pre- and post-remediation fish concentrations have been length normalized.
Citation: Figure 6 in and supplemental for Eckley et al. 2020.

3.1.2 Location of improvement

We expect that reservoirs are the first surface water bodies that will show improvement from mercury cleanup as measured by lower fish mercury[4] levels. Moreover, we expect that Almaden and Calero reservoirs are the first location that will show improvement because:

- Only one creek drains from a mined area into Almaden Reservoir (and then mercury and water are transferred via Almaden-Calero Canal into Calero Reservoir)

[4] Note that we use “fish mercury” rather than fish methylmercury” levels because although most of the mercury in fish is in the form of methylmercury the laboratory analysis is for “total mercury” for cost savings.

- Mercury mining waste was cleaned up at the mine site and in the creek that drains the mine site that flows into Almaden Reservoir (Mine Hill in 1990 and Lower Jacques Gulch in 2009, respectively; Figure 2, sites 6 and 8); and
- A fast burial rate in Almaden Reservoir due its large upstream watershed with highly erosive and low-mercury soils

In contrast, improvement will be much slower to achieve at Guadalupe Reservoir and Lake Almaden. Guadalupe Reservoir has mercury mining waste on its shoreline (see Figure 2, Site 4) and many mine sites in its watershed (not shown on Figure 2). Lake Almaden is located far downstream of Hacienda Furnace Yard, which likely processed the most mercury ore of any facility in North America. Although much of Hacienda Furnace Yard was cleaned up previously, additional cleanup is still pending. Consequently, Alamitos Creek between Hacienda Furnace Yard and Lake Almaden is heavily polluted with mercury mining waste. Planning to cleanup Alamitos Creek is long delayed (see Section 2.1). Therefore, storms will continue to transport upstream mercury mining waste into Lake Almaden for many more years.

We expect that creeks and the Guadalupe River will be slower even than reservoirs and Lake Almaden to show improvement. Numerous mercury mines pollute many miles of creeks, including but not limited to Guadalupe Creek downstream of Guadalupe Mine; numerous tributaries to Alamitos Creek on the east side of New Almaden; and Alamitos Creek. To achieve improvement in the creeks requires that first the upslope mercury mines be cleaned up and then the creeks – all of which will take many years.

3.1.3 Pace of improvement

The pace of improvement as measured by lower mercury levels in young fish (Remedial Effectiveness Indicator “REI” fish, see Figure 3 and Section 4) should be within a few years following upstream cleanup and large storm events that transport low-mercury soils to the reservoir and bury mercury mining wastes. This estimate is based on quick reductions in prey fish in Onondaga Lake (USEPA 2020) and our knowledge of mercury transport (Kirchner et al. 2011). We expect that it will take a few years longer to see a reduction in sport fish mercury levels because it takes time for these older (five or more years) fish to lose their previously accumulated mercury. This estimate for sport fish is based on our knowledge from working with the statewide and San Francisco Bay fish monitoring. Further, we expect that sport fish will have a somewhat smaller reduction in mercury levels because food chain dynamics are complicated and provide many pathways for bioaccumulation.

3.1.4 Degree of improvement

The degree of improvement in young fish mercury levels could be 50 percent reduction. We based our young fish estimate on data from Onondaga Lake (USEPA 2020; see Section 6.1.5). The degree of improvement in sport fish mercury levels could be 50% reduction (and note this would not occur until 5 to 10 years after reductions are observed in young fish). We based our sport fish estimate of degree of improvement on data from two mercury mine cleanups and subsequent lower mercury levels in lakes (see Sites 2 and 7 in Figure 5).

3.2 Summary and Status of TMDL Cleanup Requirements

The TMDL required, and Water Board staff or responsible parties completed, the following:

- Requirement: Water Board to issue, within six months of adoption of the TMDL, California Water Code § 13267 orders to compel investigation of New Almaden and the Guadalupe, Santa Teresa, and Bernal mercury mines
- Status: Water Board issued the investigation orders in June 2009 for New Almaden and the Guadalupe and Bernal mercury mines; Water Board staff completed an investigation of the Santa Teresa mine in 2009 because it is located on a private, residential parcel; the investigation reports were completed by July 2009
- Requirement: Water Board to issue, within six months of approval of the investigation reports, California Water Code § 13304 orders
- Status: The Water Board issued a California Water Code § 13304 order for Guadalupe Mine in June 2013 (R2-2013-0024) and the landowner implemented erosion control measures and continues to monitor and maintain them
- Status: Cleanup orders were not needed for two public agency property owners (County Parks and Midpeninsula Regional Open Space District) because they obtained grants and cleaned up several sites, as described in the next section

3.3 Mercury Mining Waste Cleanups Completed Due to the TMDL

The following are sites with mercury mining waste that were cleaned up under the TMDL:

- Alamitos Creek – Cleanup of several hundred meters of calcine deposits and mercury-laden sediment (3,700 cy containing 165 kg of mercury) was completed in 2004 by Valley Water
- Hicks Flat – Remediation of an eroding slope of mercury mining waste (800 cy containing approximately 4.5 kg of mercury) was completed in 2014 at Hicks Flat by the landowner, Midpeninsula Regional Open Space District
- Senador Mine in Almaden Quicksilver County Park – Mining waste cleanup (approximately 313 cy of calcines[5] were removed) and erosion control was completed in 2016 by the landowner, Santa Clara County Parks and Recreation
- Calcine-paved roads in Almaden Quicksilver County Park – Mining waste cleanup (over 3,800 cy of calcines were removed) and erosion control was completed in 2017 by the landowner, Santa Clara County Parks and Recreation

[5] In keeping with previous County Parks' cleanups, for this 2016 cleanup they describe accomplishments in terms of volume of calcines removed rather than mass of mercury removed.

- Upper Jacques Gulch in Almaden Quicksilver County Park – A 2017 engineering study determined that it is not feasible to cleanup mining waste in this steep section of creek, consequently there was no cleanup
- Guadalupe Mine – Erosion control measures (no removal) were implemented and are monitored and maintained by the landowner, Guadalupe Rubbish and Disposal Company, Inc.
- Additionally, Hillsdale Mine (Communications Hill, San Jose) – Mining waste cleanup (no volume or mass removed is readily available in documents in GeoTracker) was compelled by the Water Board’s mines program and was largely completed in 2018 by KB Home South Bay, Inc., who is constructing a residential development in several phases

The above cleanups by public agencies had grant funding that covered a portion of the costs.

3.4 Mercury Mining Waste Cleanups Outside of the TMDL

Several cleanups were completed outside of the TMDL. Santa Clara County purchased most of the New Almaden mines property in 1975 (prior to the TMDL). In the late 1990s, Santa Clara County Parks and Recreation cleaned up the five sites in Almaden Quicksilver County Park that presented the greatest threat to human health from direct exposure: Mine Hill, the Hacienda Furnace Yard, and the Senador, Enriquita, and San Mateo mines (see Figure 2, sites 2–3, 5–7). Importantly, this over $6 million cleanup action safely disposed of more than 300,000 cy (DTSC 1999) of calcines in an on-site landfill, and disposed of furnace dust and elemental mercury[6]. Nonetheless, several of these sites required additional cleanup actions, so they are also listed in the previous and following sections.

The U.S. Fish and Wildlife Service brought a Natural Resource Damage Assessment (NRDA) lawsuit against several parties. The parties reached agreement in 2008 (prior to the TMDL). Valley Water agreed to cleanup lower Jacques Gulch, which drains Mine Hill into Almaden Reservoir; cleanup of approximately 15,000 cy of calcines was completed in 2009 (DTSC 2009). Santa Clara County Parks and Recreation agreed to further cleanup of Hacienda Furnace Yard and Deep Gulch (removal of 3,000 cy of calcines); after several delays, this project is in the final planning and permitting stage. The Hacienda Furnace Yard and Deep Gulch project will mark an important milestone: the completion of all feasible cleanups of furnace dust and elemental mercury, and all but one calcine site, in Almaden Quicksilver County Park.

Additionally, Valley Water regularly undertakes creek maintenance activities including removal of mercury-contaminated sediments from waterways downstream of New Almaden.

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[6] This landfill is visible on satellite photos. The former San Francisco Open Cut mine was filled will excavated calcines and covered with clean fill (37.176088, -121.845522). The terraced slope below consists of calcines from the former Mine Hill processing facility that are capped in place (37.173722, -121.844742).

3.5 Cost of Mine Cleanups

In this section, we provide cost estimates developed for the 2008 TMDL staff report and subsequent cost information. Mine cleanups are costly endeavors partly because they involve disposal of hazardous waste. The California Department of Toxic Substances Control permits mining waste disposal sites in Almaden Quicksilver County Park. These local sites have kept transportation costs and greenhouse gas emissions lower than if wastes were disposed offsite. However, these disposal sites are nearing capacity, which could increase costs for future mine cleanups.

3.5.1 TMDL Staff Report

The Guadalupe TMDL staff report, in Section 10.5 Economic Considerations, has cost estimates in 2008 US dollars, as follows:

- One-time costs for cleanups of mining waste on 70 acres: $68 million
- Annual costs for mine cleanups: $10,000 to $50,000 per year
  (annual costs such as operations and maintenance of erosion control measures and monitoring required by the TMDL)

3.5.2 Other Cleanup Cost Information

The following is available cost information for the mercury mining waste cleanups described in Sections 3.3 and 3.4, using then-current U.S. dollars, as follows:

- Late 1990s: Santa Clara County Parks and Recreation cleaned up the five worst sites in Almaden Quicksilver County Park: $6 million
  (Guadalupe TMDL Staff Report Section 10.5)
- Early 2000s: Valley Water cleaned along Alamitos Creek: $410,000
  Citation: Weiss Associates 2005
- 2009: Jacques Gulch in Almaden Quicksilver County Park: $3.2 million
  Citation: Almaden Quicksilver Restoration Plan and Environmental Assessment Final Report, by U.S. FWS and CDFG, October 1, 2008, available at:
  https://wildlife.ca.gov/OSPR/NRDA/New-Almaden-Mine
- 2013 Hicks Flat by Midpeninsula Regional Open Space District: $225,000
  Citation: Hicks Flat Final Project Report, by Midpeninsula Regional Open Space District, December 2013
- 2016 Senador Mine in Almaden Quicksilver County Park: $1 million
  Citation: Phase II: Senador Mine Restoration Project, Final report, by Santa Clara County Parks Department, October 2016
- 2017 Calcine-paved roads in Almaden Quicksilver County Park: $1.6 million
  Citation: Remediating Calcine-paved Roads and Upper Jacques Gulch, by San Francisco Estuary Partnership, April 2018

- 2022, Hacienda Furnace Yard and Deep Gulch in Almaden Quicksilver County Park: $7.25 million
  Citation: Flynn, personal communication, 2022

3.6 Next Steps for Mercury Cleanups Under the TMDL

The following are known sites with mercury mining waste that still need to be cleaned up, which we expect will occur due to Water Board staff implementing the TMDL. These sites are listed in the order in which they should be addressed, from upslope down to the water's edge and from upstream to downstream.

3.6.1 Almaden Quicksilver County Park

Water Board staff will evaluate the need for cleanup of other mercury mining waste after the Hacienda Furnace Yard and Deep Gulch project breaks ground. Water Board staff will reference the TMDL Staff Report (particularly Sections 3.5 and 10.5) and the 2011, Santa Clara County Parks report, "Almaden Quicksilver County Park and Santa Teresa County Park Mine Material Evaluation." This report identified 230 features that could potentially erode and discharge mercury.

The main strength of the County Parks 2011 report is that it relied on excellent desktop analysis of historical maps and then-current LiDAR images to support field investigation of 240 features ranging in size from 313 to over 600,000 sq ft. The main weakness of this report is lack of mercury concentration data (only 11 samples were submitted for laboratory analysis and no field instruments were used). County Parks has mercury concentration data from the late 1980s when about 1,000 samples from Almaden Quicksilver County Park were analyzed for mercury. To assess current mercury concentrations, Water Board staff has access to a hand-held x-ray fluorescence meter for field measurements of dry soil mercury concentrations. When their evaluation is complete, Water Board staff will encourage (or compel if needed) County Parks to cleanup mercury mining wastes that present a threat to water quality.

Water Board staff reviewed the site descriptions in the County Parks 2011 report (Tables 1 and 2) and assigned high, medium, and low priority for field investigation to each of the features based on our best professional judgment of whether the features are likely to, might, or are unlikely to contain mining waste. Based on this assessment, Water Board classified 22 features as high priority for field investigation to determine their mercury concentration and current erosion potential. We acknowledge these scored between a high of 4.51 to a low of 2.20 in the County Parks report, but only 12 of the 22 have mercury concentration data. Because of data limitations associated with the County Parks report, our prioritization process considered additional factors. As an example, the Enriquita Mine waste on the shoreline of Guadalupe Reservoir (URS ID WS65) scored 3.37 and had a mercury concentration of 45 mg/kg (dry weight). However, the Water Board's 2019 samples submitted for laboratory analysis had 5 times higher mercury concentrations (mean 268 mg/kg) (Water Board 2020). Further, the reservoir water level was low during our site visit and we observed a discharge from a pipe that had a mercury concentration of 32 ng/L. An additional 16 features are medium priority for field investigation, and the remaining 192 are low priority. A listing of the feature priority rankings is provided in Table A-1(a separate MS Excel file).

3.6.2 Alamitos Creek

Alamitos Creek is highly polluted along the stretch from Hacienda Furnace Yard to Lake Almaden (Tetra Tech 2003). Hacienda Furnace Yard on Alamitos Creek was arguably the largest mercury processing facility in North America because Mine Hill produced 90 percent of the ore for New Almaden and most of this ore was processed at Hacienda Furnace Yard. Consequently, in the early 2000s, the Water Board awarded Valley Water grant funding under Clean Water Act Section 319(h) to clean up calcine deposits totaling several hundred meters in length in Alamitos Creek (see Sections 1.1, 3.3, and 3.5.2; see Section 4 in Weiss Associates 2005). Valley Water likely has removed mercury-laden sediments and calcines from other areas of Alamitos Creek as part of their stream maintenance program.

Once Valley Water breaks ground at Lake Almaden and County Parks breaks ground at Hacienda Furnace Yard and Deep Gulch, Water Board staff shall encourage (or compel if needed) Valley Water to undertake studies and planning for cleanup of the highly polluted Alamitos Creek. Timing may be before, during, or after Enriquita Mine (see next section).

3.6.3 Guadalupe Mine

Water Board staff will evaluate the need for cleanup of mercury mining waste at Guadalupe Mine before Valley Water breaks ground for the Guadalupe Reservoir dam and Enriquita Mine projects. There are extensive dumps of mining waste along Guadalupe Creek at this mine site (see Figure 2, site 1), which is owned by Guadalupe Rubbish and Disposal Company, Inc. Water Board staff will evaluate, or compel the mine landowner to have a geomorphic and geotechnical evaluation of whether seismic events or large, episodic storm flows have the potential to cause failure of the creek banks and large discharges of mercury mining waste, or if the creekbanks are stable.

3.6.4 Enriquita Mine in Guadalupe Reservoir

Mining waste cleanup of Enriquita Mine and possibly other areas within Guadalupe Reservoir to be undertaken by the reservoir owner, Valley Water, during the dam seismic retrofit project (Water Board letters of April 9, 2018 and January 23, 2019 to Valley Water). As of December 2020, this project was scheduled for construction in 2026.

3.6.5 Guadalupe Creek downstream of Guadalupe Mine:

Water Board staff to evaluate need for cleanup of downstream mercury mining waste after Guadalupe Rubbish and Disposal Company, Inc. breaks ground for Guadalupe Mine cleanup (or the Water Board determines that there is no further need for cleanup of Guadalupe Mine). The downstream parcels near Guadalupe Mine are owned by Guadalupe Rubbish and Disposal Company, Inc. on the east and Midpeninsula Regional Open Space District on the west. Farther downstream, it is likely that Valley Water and others own the parcels along Guadalupe Creek.

3.6.6 Santa Teresa Mine

Water Board staff will evaluate the need for cleanup of mercury mining waste from this residential parcel.

3.6.7 Cleanup and Abatement Orders

As mentioned above, Water Board staff will consider whether to issue cleanup and abatement orders to compel private landowners and public agencies to cleanup mercury mining wastes and mercury-laden sediment. Regarding compelling public agencies, note that such orders preclude grant funding from the Water Board or U.S. EPA for cleanup; previously, grants offset cleanup costs of several sites owned by public agencies.

3.6.8 Selective Sequential Extraction

Water Board staff may also want to consider selective sequential extraction (SSE) to aid in prioritization for cleanup. SSE could be used to prioritize for cleanup sites with more leachable mercury. The following describes that SSE results from the earlier of several extraction steps (fractions F0 to F3) may be used instead of total mercury concentrations. However, the SSE technique is expensive, especially compared to total mercury analysis, so it is challenging to obtain a robust or sufficient dataset.

SSE is a commercially available multi-step chemical extraction method. Leaching of mercury can occur naturally in the aquatic environment because different forms of inorganic mercury species have different solubilities. SSE assesses the “extractability” of inorganic mercury by a series of leaching treatments that mimic anticipated environmental and biological conditions. Results from the earlier steps (fractions F0 to F3) can be interpreted as environmentally available forms of mercury whereas results of the last two steps (fractions F4 and F5) are considered recalcitrant and not available for methylation. (The SSE and other extraction techniques and their applications for site cleanup evaluations is described by Water Board geochemist Lindsay Whalin in Eckley et al. 2020.) Previously, a few samples in the Guadalupe River watershed were analyzed for mercury SSE and reported in Tetra Tech 2005 Data Collection Report and Santa Clara County Parks’ 2011 report (see Almaden Quicksilver County Park above).

This concludes the status report on mercury source control. The next section discusses implementation actions to address the more toxic form of mercury, methylmercury.

4 Reservoir Methylmercury and Bioaccumulation Pilot Tests

The Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL) addresses methylation of mercury. Mercury from mining (see Section 3) is in the inorganic form. Methylation of inorganic mercury occurs in low-oxygen conditions in the aquatic environment. Reservoirs and lakes have low oxygen particularly in bottom waters in the dry season whereas their waters are mixed and well-oxygenated in the wet season. Naturally occurring bacteria methylate mercury, thereby creating methylmercury, which is highly toxic and readily bioaccumulated up the food web. Methylmercury in fish is a health threat for human and wildlife consumers of fish. The TMDL “anticipates the development of new and innovative methylmercury control methods” (Basin Plan Section 7.7.1.6).

The Water Board recognized in the TMDL that Valley Water (formerly Santa Clara Valley Water District) “is a leading researcher in methods of controlling methylmercury production and bioaccumulation in reservoirs and lakes” (Basin Plan 7.7.1.6). Accordingly, the TMDL requires

Valley Water to continue the pilot testing of methylmercury and bioaccumulation controls that they began in 2006 (before TMDL adoption). Water Board staff recommends continuing the pilot test program until there is more certainty about achievable fish mercury levels.

The following sections explain the status of required actions, and explain reservoir pilot tests, results, and next steps.

4.1 Expected Benefits from Reservoir Pilot tests

Water Board staff estimated in the 2008 TMDL staff report that mercury levels in REI (biosentinel) fish (see Section 6.1) would reach TMDL target levels relatively quickly after cleanup of mercury mining waste and deploying methylation controls in reservoirs (TMDL Staff Report page 9-33). However, fish mercury levels are still much higher than the TMDL targets (see Section 6.4).

Recent scientific literature has shed more light on the expected pace of change. For example, Onondaga Lake in Syracuse, New York was polluted by the chemical industry. Mercury was cleaned up (at the chemical plant sites, along drainages to the Lake, and by dredging and capping in Onondaga Lake) and in-lake actions (nitrate applications) are on-going to suppress methylation of mercury. These source control and water chemistry actions are parallel to actions required by the TMDL. Prey fish mercury levels declined in Onondaga Lake by 50 percent within two years of oxidant addition to suppress methylation and mercury source removal and 67 percent within seven years of these actions (USEPA 2020). A recent publication corroborates the Onondaga recovery timing (Blanchfield 2022).

4.2 Summary and Status of TMDL Reservoir Requirements

The TMDL required, and Valley Water voluntarily completed, the following:

- Requirement 1: Valley Water shall conduct technical studies of methylmercury production and control in reservoirs.
- Status of requirement 1: Valley Water has continued their technical studies of methylmercury production and control in reservoirs.
- Requirement 2: Valley Water shall continue to operate, maintain and improve the performance of, or replace with newer technology, existing methylmercury controls already in place on Lake Almaden, Almaden Reservoir, and Guadalupe Reservoir. The District shall install methylmercury controls in Calero Reservoir, if necessary, by December 31, 2017.
- Status of requirement 2: Valley Water has continued to operate and maintain the solar-powered circulators in Lake Almaden. Valley Water plans to discontinue mercury methylation controls in Lake Almaden once construction commences. In the reservoirs, Valley Water replaced the solar-powered circulators in Almaden and Guadalupe Reservoirs with line-diffuser (porous hose) hypolimnetic oxygenation systems, and installed this type of system in Calero Reservoir.
- Requirement 3: Valley Water shall report to the Water Board, by December 31 of odd years until directed to stop, on the operation and effectiveness of the methylmercury controls.
- Status of requirement 3: Valley Water has submitted the required reports every other year and in 2021, published these findings in Environmental Pollution, a peer-reviewed scientific

journal (see Section 4.3). The next biennial report will cover 2022/2023 and is due by December 31, 2023.

- Requirement 4: Where the Water Board finds it is feasible to reduce methylmercury production and/or bioaccumulation, the Water Board will issue cleanup and abatement orders to Valley Water to undertake actions to reduce fish mercury concentrations to attain the targets.
- Status of requirement 4: The reservoir oxygenation systems have decreased methylmercury production and there are some indications that fish mercury levels have declined in reservoirs. However, we do not yet know what fish mercury levels are achievable. Therefore, Valley Water is continuing to implement reservoir pilot tests, and Water Board staff have not issued a cleanup and abatement order to Valley Water.
- Requirement 5: Valley Water is required to monitor and determine the loads of mercury discharged annually by reservoirs and monitor mercury in fish tissue. Valley Water is also required to conduct a special study to answer, “How do the reservoirs and lakes in the Guadalupe River watershed differ from one another?” Valley Water and other responsible parties are required to monitor, and are encouraged to coordinate monitoring, fish mercury levels to assess progress in attaining TMDL targets and mercury load to San Francisco Bay to assess progress in attaining the legacy and urban stormwater runoff mass load allocations assigned by the San Francisco Bay mercury TMDL.
- Status of requirement 5: Valley Water monitors and reports on reservoir mercury loads and fish mercury levels in its biennial reports. Valley Water has a comprehensive monitoring program to support their pilot test program. This monitoring program allowed them to complete and report their answers on how reservoirs and lakes differ from one another in their 2016/2017 Progress Report on Methylmercury Production and Control Measures. Valley Water participates in and currently leads the coordinated monitoring program (see Section 5).

4.3 Reservoir Pilot Tests

Valley Water began pilot tests (technical studies of methylmercury production and control) before TMDL adoption by installing solar-powered circulators in Lake Almaden in 2006 and in Almaden and Guadalupe Reservoirs in 2007. The circulators in Lake Almaden reduced average hypolimnetic (bottom water) methylmercury concentrations by 76 percent. Valley Water will continue to operate the circulators in Lake Almaden until the year in which construction begins on a major lake reconfiguration project (see Section 2.1). The reconfiguration project will separate Lake Almaden from Alamitos Creek, that mercury from New Almaden will no longer enter Lake Almaden.

The solar-powered circulators were not effective in Almaden and Guadalupe Reservoirs in reducing water methylmercury concentrations. Therefore, Valley Water installed more powerful oxygenation systems in Calero (2011) as well as in Almaden (2014) and Guadalupe (2013) Reservoirs.

These more powerful oxygenation systems apply oxygen at the bottom of these three reservoirs to suppress methylation of mercury. Valley Water generates pure oxygen gas on site and distributes it through a line diffuser (porous hose) anchored to the reservoir bottom. These systems were operated consistently in the dry season in these three reservoirs from 2016–2019. Valley Water reservoir monitoring data confirm that from 2016–2019 oxygenation decreased methylmercury concentrations in bottom water with mean reductions of 63 to 85 percent below pre-oxygenation concentrations (Seelos et al. 2021). However, the reduction was not due to suppression of methylation but rather due to mixing and dilution with reservoir surface water.

The COVID-19 pandemic, drought, and mechanical failures reduced operations in 2020–2021. In 2020, all oxygenation systems were started late due to mechanical failures that took months to repair. Consequently, oxygen was applied after reservoir stratification began (Almaden and Calero in May and Guadalupe in June). It is very difficult to apply sufficient oxygen to overcome oxygen demand after stratification begins to achieve at least 3 mg/L dissolved oxygen. The extended duration for repairs was due to the pandemic because hospital oxygenation systems had highest priority for repairs. In 2021, Almaden and Calero oxygenation systems again had mechanical failures. Almaden and Calero systems operated consistently after June 15 and 3, respectively. The Guadalupe system was not operated in 2021 and 2022 due to mechanical failures, low water levels that preclude system maintenance, and concerns about discharged water with elevated temperature. The following sections describe the effects of the oxygenation systems.

4.3.1 Methylmercury Allocation

Figure 6 shows reservoir bottom water methylmercury concentrations from 2016 through 2019 when the oxygenation systems operated consistently in the dry season.

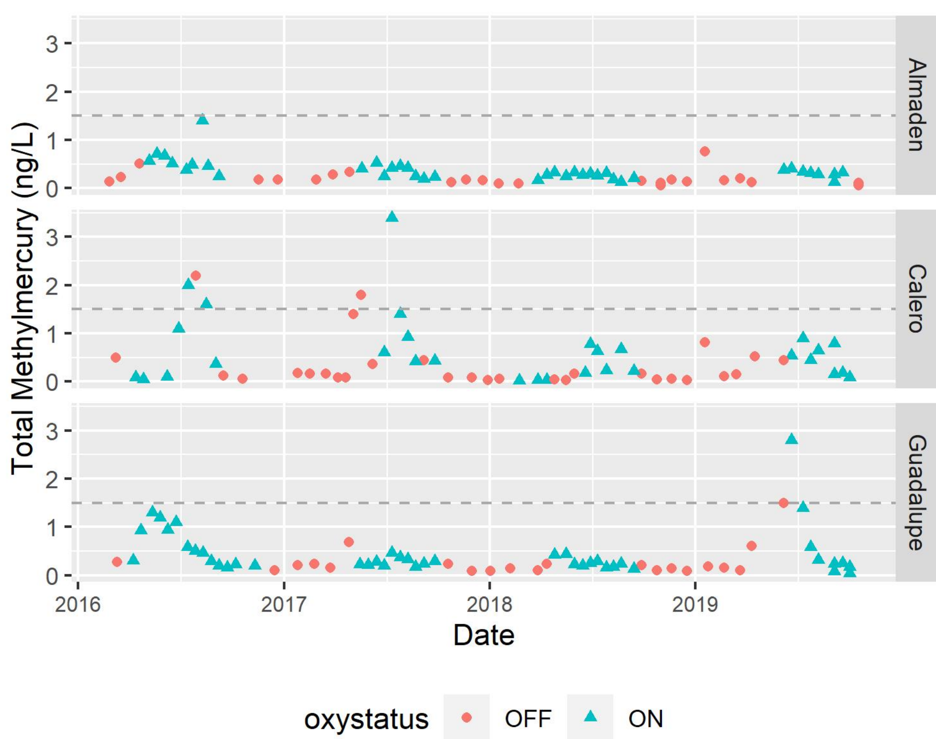

Figure 6. Reservoir Bottom Water Methylmercury Concentrations During Oxygenation

This figure shows that during the dry seasons of 2016 through 2019, during consistent oxygenation (green triangles), the reservoirs nearly always met the methylmercury allocation (dotted grey line) of a seasonal peak of 1.5 nanograms per liter (ng/L). However, they met the allocation by mixing and dilution not by suppressing methylation of mercury.

Almaden Reservoir met the methylmercury allocation consistently during oxygenation (whereas prior to oxygenation it regularly exceeded 5 ng/L, not shown). Calero Reservoir had excursions above the allocation in two years during oxygenation (whereas prior to oxygenation it often reached 5 ng/L). Guadalupe Reservoir had an excursion above the allocation in one year during oxygenation (whereas prior to oxygenation it often reached above 20 ng/L). This figure also shows that with oxygenation there is much variation and no time trend in methylmercury concentrations in the dry season[7]. The few sample results below the laboratory detection limit are not shown. (Citation: data provided by Valley Water and discussed in Seelos et al. 2021.)

The line diffuser oxygenation systems put out fine bubbles that cause mixing. The reservoirs appear to have met the methylmercury allocation, but this occurred from dilution and mixing not by suppressing methylation of mercury. Oxygenation ended the seasonal trend of increasing methylmercury, which allowed the reservoirs to meet the TMDL allocation for methylmercury. The TMDL methylmercury allocation was calculated to achieve the fish tissue targets, but the targets are not yet met (see Section 6.4). However, there are no new data yet to support changing the allocation.

4.3.2 Discharge Point and Mixing

The TMDL conceptual model envisioned that reservoir bottom water methylmercury concentrations increase over the dry season until fall turnover, when mixing of nutrients and methylmercury from bottom waters into surface waters can cause an algae bloom and a spike in methylmercury bioaccumulation. To reduce bioaccumulation, the TMDL assigns an allocation to the seasonal peak in reservoir bottom water methylmercury concentrations. However, the conceptual model is based on studies of a lake that naturally discharges from the surface and a reservoir that in retrospect we now understand also—surprisingly—discharges from the surface.

Valley Water has greatly enhanced our understanding of methylmercury cycling in reservoirs. Valley Water identified the important difference between lakes (or reservoirs) that discharge from the surface and these three reservoirs that all release from the bottom. They informed us that bottom release is a common practice to remove nutrients to control algae blooms. They calculated that these three TMDL reservoirs discharge so much of the bottom water—and methylmercury—prior to fall turnover that fall mixing only increases surface water methylmercury concentrations by 1 to 3 percent (Seelos et al., 2021), which is not enough to cause a spike in bioaccumulation. They concluded that these line-diffuser oxygenation systems did not suppress methylation but rather caused mixing of the reservoir water that in effect diluted bottom water methylmercury concentrations. Mixing due to line diffuser oxygenation in lakes had been reported by Dent and others (2014) but several years after Valley Water had initiated their studies.

Valley Water also determined that oxygenation worsened reservoir surface water quality because the bubble plume transported nutrients from bottom to surface waters. These nutrients increased

[7] Prior to oxygenation, all three reservoirs had a consistent trend during the dry season of increasing methylmercury concentrations (not shown).

algae by 20 to 35 percent as measured by chlorophyll-a (but no increase in Guadalupe Reservoir), and increased cyanobacteria by 60 percent in Calero (and 25 percent in Almaden and 40 percent in Guadalupe Reservoirs) as measured by phycocyanin. Further, Valley Water found that oxygenation raised the temperature of water discharged downstream. Cold water bottom releases are needed to protect anadromous fish. The bubble plume caused mixing between cold bottom and warm surface water that increased the temperature of discharged water 2.5 to 5.5 °C (mean, dry season, but no increase in Almaden Reservoir). The oxygenation system was not effective in Calero Reservoir in oxygenating bottom water. Valley Water determined that its ineffectiveness was due to incorrect sizing. Valley Water has continued to operate the Calero oxygenation system.

Valley Water reports on their reservoir pilot tests to the Water Board every other year. In 2021, Mark Seelos (Valley Water) also published a manuscript that shows modest but significant declining trends in fish mercury levels in Guadalupe Reservoir from oxygenation (Seelos et al., 2021; see Figure 9). Dr. Seelos' next manuscript will focus on methylmercury transfers that occur low in the food web—the most important transfers. Water Board staff recommends that Valley Water continue their pilot tests and consider methods other than line-diffuser oxygenation until there is more certainty about achievable fish mercury levels in these reservoirs located downstream from New Almaden.

In addition to the above-mentioned work, Valley Water has funded numerous studies[8] to quantify water column methylation; evaluate mercury sorbents; and identifying local mercury emissions and deposition at New Almaden through lichen mercury concentrations. They have partnered with US Geological Survey, UC Merced, UC Santa Cruz, and have ongoing university and federal collaborations.

See also Section 6.2, which includes an evaluation of "before and after" fish mercury for effectiveness of reservoir pilot tests and mercury mine cleanup.

[8] For more information on these studies, contact Mark Seelos mseelos@valleywater.org

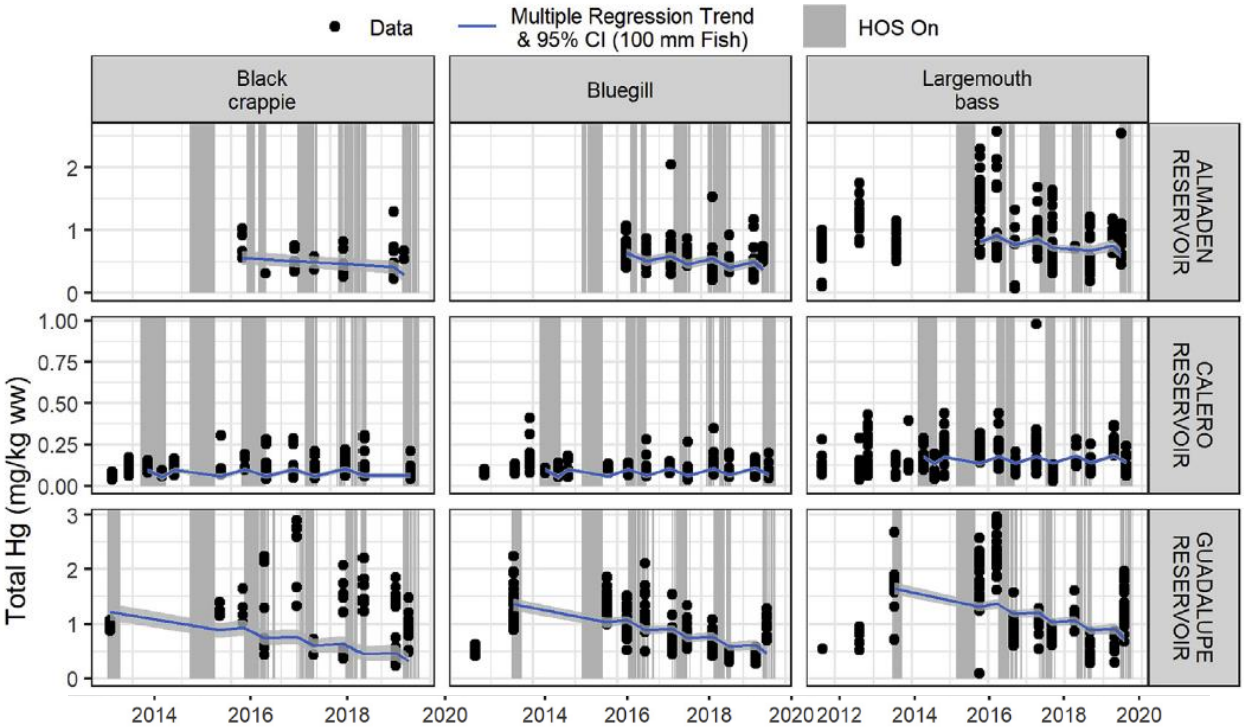

Figure 7. Reservoir Fish Mercury Levels Over Time During Oxygenation

Statistically significant decreases in mercury levels in 100-mm size standardized fish were found in Largemouth bass (right column) in two reservoirs – one comparing before and treated and the other over the course of treatment. In Almaden Reservoir (first row), comparing before treatment to during four years of consistent oxygenation, there was an average decrease of 35 percent. In Guadalupe Reservoir (third row), over seven years including during four years of consistent treatment, there was about a 55 percent decrease. There were no statistically significant decreases in any of the three fish species in Calero Reservoir where oxygenation was not effective in maintaining dissolved oxygen in deep water.

This figure provides raw fish mercury data (black dots) and multiple regression model fitted to 100 mm fish length. Gaps in monitoring, e.g., from 2013 through 2015, were due to drought.

Citation: Figure 6 from Seelos et al., 2021

4.3.3 Drawdown and Sulfate Limitation

Extreme reservoir water drawdown occurs uncontrollably during drought or in a controlled fashion to allow maintenance or construction. Extreme drawdown exposes a large “bathtub ring” to air, which converts sulfide to sulfate. Upon subsequent refill, the water commonly has higher sulfate concentrations that fuels mercury methylation and increases fish mercury levels. Valley Water’s extensive reservoir water quality monitoring program includes sulfate and shows that these Guadalupe Watershed reservoirs are not sulfate limited.

4.3.4 Methylmercury discharged from reservoirs

Herein we explore whether lower methylmercury concentrations in bottom reservoir water has translated to less methylmercury being discharged from the reservoirs. For the TMDL conceptual model, Tetra Tech (2005) estimated mass of methylmercury discharged from Almaden and

Guadalupe Reservoirs in the 2004 dry season. Subsequently, Valley Water has estimated mass of methylmercury discharged.

Table 1. Methylmercury Discharged from Reservoirs

Year	Reservoir	Methylmercury (g/season)	Million gallons water discharged	MeHg (g) / 1,000 gallons Comments
2004	Almaden	7.2	389	18.6 g / 1,000 gal; 4 mos. May - Aug
2016	Almaden	1.88	1,610	0.73 to 1.9 g / 1,000 gal; annual
2017	" "	9.59	10,330	" "
2018	" "	0.72	980	" "
2019	" "	9.58	5,083	" "
2004	Guadalupe	5	389	12.9 g / 1,000 gal; 4 mos. May - Aug
2016	Guadalupe	2.93	1,247	0.54 to 2.3 g / 1,000 gal; annual
2017	" "	3.03	4,804	" "
2018	" "	0.36	671	" "
2019	" "	1.57	2,428	" "

Citations:

2004: (Tetra Tech 2005 Conceptual Model) we estimate discharge was 5 cfs based on Figure 7-4;
2016–2017: Valley Water's Guadalupe River Watershed Mercury TMDL: 2016-2017 Progress Report on Methylmercury Production and Control Measures;

2017–2018: Valley Water's 2019 Progress Report on Methylmercury Production and Control Studies

It appears that oxygenation was effective in greatly reducing the amount of methylmercury discharged downstream. It reduced mass of methylmercury discharged from Almaden Reservoir by 90 to 96 percent and from Guadalupe Reservoir by 82 to 96 percent. (As previously noted, this was due to mixing and dilution of bottom water, not from suppression of methylmercury production.) It is likely that there is an environmental benefit of less methylmercury flowing downstream. These benefits may be realized closer to the discharge point rather than farther downstream because the scientific literature indicates that bacteria or sunlight can rapidly demethylate methylmercury in oxygenated water. Ideally, creek fish monitoring would have quantified the environmental benefit – we would expect to see lower mercury concentrations in creek fish. We explore the creek fish data and discuss whether to add more or revise existing fish collection locations in Section 6.4.

4.4 Cost of Valley Water Reservoir Pilot Tests

In this section we provide 2008 cost estimates and subsequent cost information provided by Valley Water in their biennial reservoir pilot test reports.

4.4.1 TMDL Staff Report: Cost Estimates

The Guadalupe TMDL staff report, in Section 10.5 Economic Considerations, has cost estimates in 2008 US dollars, as follows:

- One-time costs for reservoir oxygenation ranges from $1.5 million to $15 million

- Annual costs for reservoir oxygenation ranges from $40,000 to $400,000

4.4.2 Valley Water Actual Cost Information

Valley Water provided the following cost information in their March 13, 2020 cover letter for the 2019/2020 biennial report:

> Costs for the hypolimnetic oxygenation systems included about
> $600,000 in construction costs per system,
> $44,000 per system for power hookups,
> $25,000 in electricity costs per system per year,
> ongoing maintenance costs, and
> significant sampling and analysis costs.

Based on this information, Water Board staff estimates that Valley Water's costs of compliance with the Guadalupe TMDL in 3 TMDL reservoirs are the following:

- One-time costs for line-diffuser oxygenation in 3 TMDL reservoirs: $1.9 million
- Annual costs for reservoir oxygenation and monitoring in 3 TMDL reservoirs: $300,000

These costs do not include Valley Water's special studies (see Section 7.1).

4.5 Next Steps for Reservoir Pilot Tests

Valley Water is considering new and innovative methylmercury control methods to comply with the TMDL and requirements by other agencies to maintain cool water temperature downstream. Valley Water is considering several options for methylmercury controls. At Guadalupe Reservoir, they found it necessary to not oxygenate in 2021, due to severe drought conditions. Not oxygenating preserved cold water in Guadalupe Reservoir for as long as possible. Here, Valley Water was balancing a legal requirement to preserve downstream cold-water fish habitat with the mercury TMDL requirements. Consequently, Valley Water is exploring other possible methylation control actions in Guadalupe Reservoir, such as using adsorbents. In the future, Valley Water will dewater Guadalupe Reservoir when they undertake seismic retrofit of Guadalupe Dam. Dewatering will facilitate access for cleanup of mercury mining wastes, such as the wastes at Enriquita Mine on the reservoir shoreline.

At Calero Reservoir, Valley Water is considering raising the dam and changing the outlet structure and type of oxygenation system when they undertake seismic retrofit of Calero Dam. Valley Water is considering changing the outlet structure from a single discharge point at the bottom to a multiport outlet with discharge from several depths. Valley Water is also considering changing the oxygenation system from the current line diffuser to a saturation system (e.g., Speece cone) for better control of drinking water issues (e.g., taste and odor, manganese, and iron). Whereas the line diffuser puts out fine oxygen bubbles that cause mixing, saturation systems discharge oxygen-supersaturated reservoir water at low flow with essentially no change in temperature (or density) and hence minimal mixing. We expect that a saturation system will be more effective than line diffusers to address drinking water issues and also for controlling mercury methylation. Therefore, in the Clean Water Act Section 401 certification that we will issue for the dam seismic retrofit we plan to encourage Valley Water to consider installing a saturation system.

Almaden Reservoir, too, needs a dam seismic retrofit. All dam seismic retrofits are several years in the future because Valley Water resources have been redirected toward the urgent seismic retrofit of Anderson Dam.

Additionally, Water Board staff will consider whether, how, and when to add creek fish monitoring sites closer to reservoir discharge points (see Sections 6.4 and 7.2.2 for rationale). In the future, Water Board staff will consider this additional creek fish monitoring when reviewing Valley Water's biennial reports and proposed monitoring plans. The next biennial report will cover 2022 and 2023.

This concludes the status report on methylmercury and bioaccumulation controls. The next section discusses the coordinated mercury monitoring efforts.

5 Coordinated Monitoring

The Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL) requires monitoring and encourages a coordinated approach for fish tissue and mercury loads monitoring between Valley Water, Santa Clara County Parks and Recreation, Midpeninsula Open Space District, and Guadalupe Rubbish Disposal Company, Inc. Valley Water's reservoir pilot test monitoring is discussed in Section 4.2.

5.1 Summary and Status of TMDL Monitoring Requirements

The TMDL requires that parties responsible for mercury discharges from mercury mines, urban stormwater runoff, and reservoirs and lakes monitor mercury loads discharged and fish mercury levels. The TMDL encourages these parties to coordinate their monitoring efforts because fish integrate methylmercury over time and space and because the mercury load to San Francisco Bay is from a combination of sources and responsible parties. The parties have been coordinating and are in their second 5-year monitoring cycle, as follows:

- Requirement 1: The Water Board will compel the responsible parties to conduct monitoring.
- Status of 1: The Water Board promptly issued, on November 23, 2009, monitoring requirements to Valley Water, Santa Clara County Parks and Recreation, Midpeninsula Open Space District, and Guadalupe Rubbish Disposal Company, Inc., under California Water Code Section 13267. Subsequently, the Water Board has issued monitoring requirements. The current requirements were issued on October 24, 2018, and require monitoring from 2018 through 2023. The draft five-year report is due by January 30, 2024.
- Requirement 2: Participating parties shall submit a coordinated watershed monitoring plan.
- Status of 2: The coordinated parties submitted a coordinated watershed monitoring plan for five years that the Water Board approved. The parties conducted coordinated monitoring for 2011 through 2016, provided interim reports as requried, and in March 2017 provided a 5-year report. The coordinated parties again submitted a 5-year monitoring plan that the Water Board approved. They are proceeding with monitoring for the 5-year period of 2018 through 2023 and have provided interim reports.

5.2 Monitoring Results

The largest loads of mercury occur when heavy precipitation falls on the New Almaden mercury mining district after the soils are saturated. In the first 5-year period of coordinated monitoring from 2011 through 2015, there was relatively little rainfall. Water year 2011 was the wettest and had 180 percent of normal discharge from the Guadalupe River at Highway 101. The mercury load in 2011 was an estimated 18.3 kg (AECOMM 2017). In contrast, water year 2017 was a very wet year, and unfortunately the Guadalupe TMDL coordinated monitoring program was planning its next steps and not in the field for monitoring. Happily, the San Francisco Bay Regional Monitoring Program had a contingency program to monitor loads of mercury to San Francisco Bay during an exceptionally large storm. Such a storm occurred in January 2017 and the Regional Monitoring Program monitored it. They estimate that this *one storm* transported a whopping 70 kg of mercury (McKee et al. 2018). (The Bay mercury TMDL allocation to the Guadalupe River is 2 kg *per year*.) Another even larger storm occurred in February 2017, but it was not monitored for mercury load.

In February 2019, the coordinated parties sampled two storms in compliance with the 2018 through 2023 sampling plan. The coordinated parties continue to assess rainfall and sampling criteria during each wet season. The loading from 2018 through 2023 will be reported in the 5-year monitoring report that is due by January 30, 2024.

Fish mercury data from 2011 through 2016 is discussed in Section 6. Fish mercury data from 2018 through 2023 will be reported in the 5-year monitoring report that is due by January 30, 2024.

5.3 Next Steps for Coordinated Monitoring

Water Board staff will track and review monitoring and deliverables, and take the following actions:

- Review and comment on the draft interim coordinated monitoring report (for the period from 2018 through 2023) that is due by January 31, 2023, which will include a detailed outline of the five-year report
- Review and comment on the draft, five-year, coordinated monitoring report due that is due by January 31, 2024
- After receiving and approving a satisfactory final five-year report, issue a CWC §13267 requirement for a monitoring plan for the next cycle of monitoring
- After receiving and approving a satisfactory monitoring plan, issue a CWC §13267 requirement to conduct and report on monitoring

This concludes the status report on coordinated mercury monitoring. The next section discusses fish mercury data and comparison to TMDL targets.

6 Fish Mercury Levels

This section provides an evaluation of fish mercury levels in response to TMDL implementation actions. In Sections 3 and 4 we described expected improvements in the form of lower fish mercury levels resulting from implementation of the Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL).

We conclude that, despite measurably lower fish mercury levels in some reservoirs, these improvements were not as good as expected and not nearly good enough to support consumption of fish by wildlife or humans. Mine cleanup reduced fish mercury levels in Almaden and Calero Reservoirs comparing before (2004) to after (2016 to 2019) (see Section 6.2). Target fish mercury levels still exceed the TMDL targets by 2 to 10 times in reservoirs and 7 to 9 times in creeks (Section 6.4).

Interestingly, although oxygenation did not reduce methylmercury production it decreased fish mercury levels in Guadalupe Reservoir over four years of oxygenation (Section 6.3). Seelos and others (2021) determined this decrease was likely due to increased algal growth that diluted methylmercury at the base of the food web. However, herein we find no decrease in REI fish mercury levels when comparing before to after in Guadalupe Reservoir.

Although sport fish in Almaden and Calero Reservoirs had statistically significant decreases in mercury levels, sport fish (Section 6.5) in the Guadalupe River watershed still have some of the highest mercury levels in California. Consequently, “no consumption” advisory signs are still needed and posted at water bodies and on park websites.

6.1 TMDL Fish: REIs, Targets, 100-mm Size-standardized, and Sport Fish

This section describes the different categories of fish for the Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL).

6.1.1 REIs and Biosentinels

The TMDL Technical Review Committee recommended use of biosentinel fish. This TMDL calls its reservoir biosentinels “Remediation Effectiveness Indicators” (REIs). Biosentinel fish are a useful measure of recent changes in methylmercury bioaccumulation provided the fish are young and have high site fidelity, so that we know when and where they accumulated their mercury. The biosentinels should also be old enough to have replaced maternal mercury with mercury from their diet. For the TMDL conceptual model, the selected REIs are age-1 (young-of-year) Largemouth bass ranging from about 50 to 100 mm total length.

Whole and eviscerated REIs (reservoirs)

REIs were first collected from reservoirs in September 2004 (n = 20; Tetra Tech 2005). These REIs were eviscerated to ensure that the measured mercury concentrations reflected only their body tissues and not mercury-laden sediment in their gastrointestinal tract. Subsequently, REIs collected by Valley Water (n = 67) were analyzed whole. Recently, Water Board staff reviewed the feeding habits of Largemouth bass. By 60 mm length, bass are hunting and largely consuming fish (Moyle 2002), which means a low probability they are also ingesting mercury-laden sediment. Therefore, in 2020 we compared mercury concentrations in eviscerated and whole REIs from Guadalupe Reservoir, the most mercury-contaminated reservoir. There was no statistically significant difference in mean REI mercury concentrations (see Appendix B), which means that it is valid to directly compare 2004 to later REI mercury levels (Water Board 2021).

Creek biosentinels

California roach were first collected from six creek sites between March and May 2004 (AECOMM 2017 Table 3-8; Valley Water 2004). These biosentinel fish were 40 to 55 mm fork length.

California roach are omnivores and filamentous algae is the primary staple in their diet, but they can also feed on small insects and crustaceans (Moyle 2002). The 2004 fish were eviscerated because they may incidentally ingest mercury-laden sediment when they consume algae. The 2004 roach collection sites were selected to evaluate creek conditions. We note that these sites are located too far downstream from oxygenated reservoirs to serve as biosentinels to evaluate effectiveness of reservoir oxygenation to decrease downstream creek fish mercury concentrations.

In May 2016, the Coordinated Monitoring Program (see Section 5) in its first five-year cycle collected and evaluated creek fish mercury levels for biosentinel California roach as planned and were whole fish. The current Coordinated Monitoring Plan covers 2018 through 2023 during which creek biosentinels (whole fish) were planned to be collected twice in separate years. Drought and pandemic have made collection difficult to date.

In the future, Water Board staff and the Coordinated Monitoring Program should jointly consider:

- Undertaking a comparison study of eviscerated and whole California roach mercury levels to determine if evisceration is needed for comparison to 2004 data, and
- Additional locations for collecting California roach to evaluate whether reservoir mercury controls are decreasing methylmercury bioaccumulation in creeks downstream.

Time to reduce prey fish mercury concentrations

Data are scarce on how long after application of mercury controls for fish mercury levels to decline. Blanchfield and others (2022) studied the recovery of mercury-contaminated fish. They mimicked atmospheric deposition by applying isotopically labeled mercury to the lake surface and its surrounding watershed for several years. They then measured watershed, lake, and lake fish mercury levels during and after the years of mercury application. Within three years of ceasing mercury application, forage (prey) fish[9] mercury levels declined by 64 percent and within eight years declined by 85 percent. At Onondaga Lake, prey fish mercury levels declined by 50 percent within two years of oxidant addition to suppress methylation and mercury source removal and 67 percent within seven years (USEPA 2020).

6.1.2 TMDL Targets

The TMDL established two site-specific water quality objectives to protect birds and humans who consume local fish (see Section 2.2). The TMDL also established two targets equal to objectives, in different size trophic level 3 (TL3) fish. For convenience, we use Valley Water’s abbreviations, “TL3A” and “TL3B,” as follows:

[9] Within the first 3 years of mercury application, Blanchfield and others observed a greater decline in spike (isotopically labeled) aqueous methylmercury (85%) than in sediments (35%). Consequently, they note that the magnitude and timing of response in fish to mercury loading reductions could be faster in fish reliant on pelagic food web compared to fish reliant on benthic dietary pathways.

- TL3A = 0.05 mg methylmercury per kg fish, average wet weight concentration measured in whole trophic level 3 fish 50 to 150 mm in length
- TL3B = 0.1 mg methylmercury per kg fish, average wet weight concentration measured in whole trophic level 3 fish 150 to 350 mm in length

Valley Water collects and evaluates reservoir fish mercury levels for both targets.

6.1.3 Target Fish from Reservoirs

Beginning in 2012, Valley Water has aimed for twice-yearly collection of three species of fish from reservoirs. The Black crappie and Bluegill correspond to TMDL targets (both TL3A and TL3B), and Largemouth bass are REIs except Valley Water has also collected larger sizes. Valley Water has all their fish analyzed whole for mercury. Valley Water evaluates fish size-standardized at 100 mm. Valley Water also uses a multiple regression model that controls for the effects of confounding variables such as species and collection season to support robust statistical trend analysis (Seelos et al. 2021).

6.1.4 Sport Fish

The TMDL targets (and site-specific water quality objectives) protect humans who consume local fish (see Section 2.2). However, sport fish mercury levels are so elevated in the Guadalupe River Watershed that we compare them to California's no consumption level of 0.44 ug/g ww (see Section 1.2).

California's largest sport fish pollutant monitoring program is intended to protect human health and is run by the Water Boards. The Water Boards' Surface Water Ambient Monitoring Program's (SWAMP's) fish monitoring was previously called Bioaccumulation Oversight Program (BOG) but has recently been renamed to Safe to Eat Workgroup (STEW). In 2007 and 2008, STEW sampled lakes and reservoirs statewide. Subsequently, STEW returns to sample lakes and reservoirs once a decade. Predatory sport fish, (individual, skinless fillets) are analyzed for mercury, typically Largemouth bass in the Bay Region. Bottom feeder sportfish (composites, skinless fillets) are analyzed for mercury. Prey (whole) fish composites are analyzed for mercury. Since 2017, composite sport and prey fish samples are also analyzed for selenium.

Sport fish were collected for the TMDL in 2003 from Guadalupe Reservoir, in 2004 from Almaden, Calero, Guadalupe, and Lexington Reservoirs, and Lake Almaden. Sport fish were collected for STEW's 2007/2008 statewide lakes and reservoir survey from Lake Almaden and Calero and Stevens Creek Reservoirs. Subsequently for STEW's long-term monitoring of bass lakes and reservoirs, in 2019 and 2021 sport fish were collected from Almaden, Calero, Guadalupe, Lexington, and Stevens Creek Reservoirs.

Time to reduce sport fish mercury concentrations

Like with prey fish (see previous section), data are scarce on how long after mercury controls before fish mercury levels decline. Figure 5 data are nearly all sport fish and demonstrate that mercury controls can result in lower fish mercury levels. However, the timing to achieve this reduction is unclear. The study by Blanchfield and others (2022) of application of isotopically labeled mercury to a lake included long-lived sport fish. Within five years of ceasing mercury application, sport fish mercury levels declined by 50 percent. At Onondaga Lake, sport fish mercury levels declined by 50 percent within three years of oxidant treatment and mercury source removal and have held steady in several subsequent years (USEPA 2020).

6.1.5 Fish Collected by Multiple Parties

In Section 6 we discuss fish collected by multiple parties, including:

- Fish collected for the conceptual model to support TMDL development by Valley Water's contractor (Tetra Tech, Inc.) and by U.S. EPA
- Fish collected from reservoirs by Valley Water for compliance with the TMDL and by the State Water Board's SWAMP STEW program
- Fish collected from Lake Almaden by the Guadalupe Coordinated Monitoring Program and by the State Water Board's SWAMP STEW program
- Fish collected from streams and the Guadalupe River by the Guadalupe Coordinated Monitoring Program

This concludes the description of the four categories of fish for the TMDL and that multiple parties have collected fish mercury data. The next sections explore fish mercury concentrations by TMDL fish category.

6.2 REIs: Decrease in Mercury in Almaden and Calero Reservoirs

In this section we focus on REI fish mercury levels because no time trend was detected in creek biosentinel fish mercury levels (AECOMM 2017).

This is the first trend analysis that includes baseline REI fish collected in 2004[10]. The 2004 data set is robust, i.e., *n* of 20 for each reservoir, and the "treated" data set is also robust, i.e., *n* of 59 to 75 for each reservoir. Water Board staff evaluated REI (Largemouth bass 50 to 100 mm "age-1") collected from Almaden, Calero, and Guadalupe Reservoirs. We constrained the sample dates (between July 15 and September 15) to ensure the fish were of similar age and mercury accumulation. We normalized the fish by length (divided mercury concentration by length) to account for differences in fish size between collection events (as was done for Onondaga Lake in Syracuse, New York [U.S. EPA 2020]; see Appendix B for separate evaluations of mercury concentration and length). It is valid to compare 2004 eviscerated to later whole REIs because we demonstrated with 2020 data from Guadalupe Reservoir that whole and eviscerated REIs have do not have a statistically significant difference in mean mercury concentrations (Water Board 2021, see Appendix B).

[10] Note that Seelos and others (2021) did not use these 2004 baseline data.

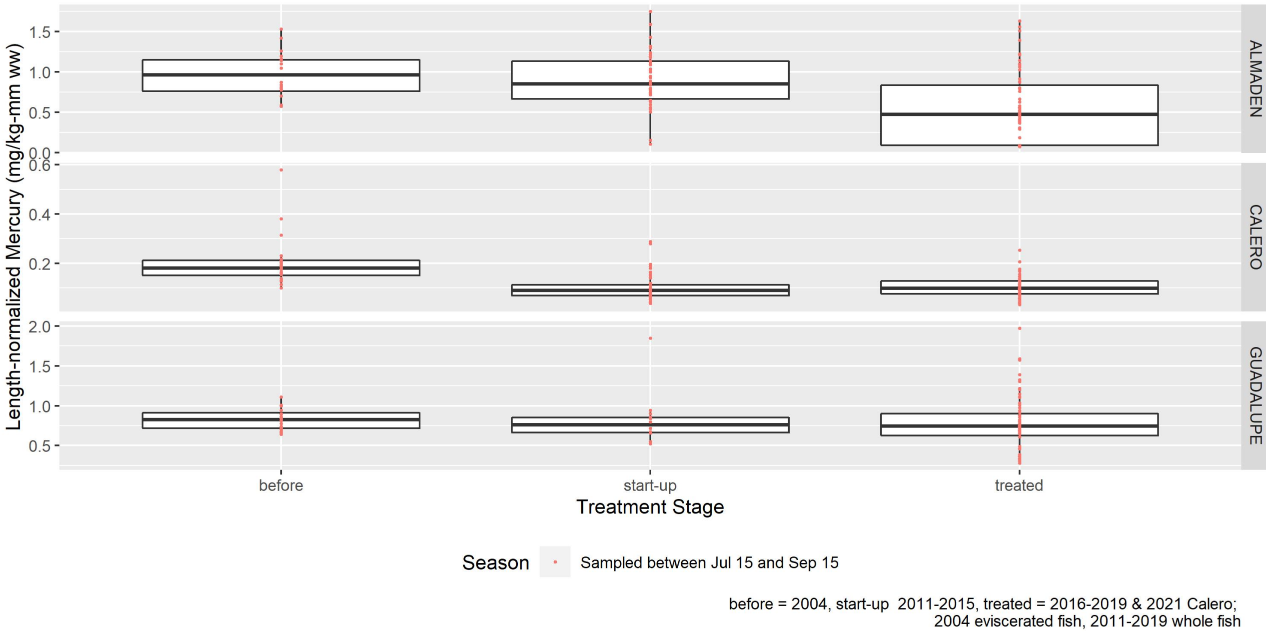

Figure 8. REI Mercury Levels by Oxygen Treatment Stage

> Fish mercury levels decreased from before to treated with oxygen in both Almaden and Calero Reservoirs (statistical significance p << 0.001, see Table A-4 for statistical significance, Figure A-1 for data by year) but there was no significant change in Guadalupe Reservoir. Treatment stages are "before" (before data are from 2004, which is prior to installation in 2007 of solar-powered circulators in Almaden and Guadalupe Reservoirs and 2009 cleanup of Jacques Gulch); "start-up" from 2007 through 2018 (solar powered circulators were tried for a few years, then line-diffuser hypolimnetic oxygenation systems [HOS] were installed and tested); and "treated" (consistent treatment during four consecutive dry seasons using line-diffuser HOS from 2016 through 2019 and in 2021 in Calero).

Thus, it appears that reservoir oxygenation (Figure 8) reduced REI fish mercury levels in Almaden and Calero Reservoirs, two of three reservoirs treated with oxygen. However, oxygenation was not the only mercury control action, as described in the following section.

6.2.1 Comparison of effectiveness of mine cleanup to reservoir oxygenation

We applied the following logic to determine that mine cleanup likely was the primary agent—rather than reservoir oxygenation—in reducing fish mercury levels in two reservoirs (Almaden and Calero Reservoirs). All three reservoirs (Almaden, Calero, and Guadalupe Reservoirs) are downstream from mercury mining and had consistent line diffuser hypolimnetic oxygenation from 2016 through 2019.

Mercury mining waste cleanup

Mercury mining wastes have largely been cleaned up upstream of Almaden and Calero Reservoirs but not upstream of Guadalupe Reservoir.

In 2009, Valley Water cleaned up mercury mining waste in Jacques Gulch. This is the only tributary that discharges mining waste from New Almaden mercury mining district into Almaden Reservoir and then to Calero Reservoir via the Almaden-Calero canal. During water transfer and possibly during episodic high-flow storms, mercury-laden suspended sediment from New Almaden flows from Jacques Gulch through Almaden Reservoir and the canal. Evidence of mercury mining waste transport in the canal was provided by Valley Water staff. They told Water Board staff some years ago that periodically they remove accumulated sediment from the canal, and that this sediment has elevated mercury concentrations. Further evidence of transport to and deposit in Calero Reservoir is as shown by elevated mercury levels in bottom sediments in the vicinity of the canal discharge location (Tetra Tech 2005).

Furthermore, Almaden Reservoir receives large amounts of "clean" sediment because most of its highly erosive watershed is not enriched in mercury geology. Clean sediment buries mining waste previously deposited in reservoirs. In contrast, Guadalupe Reservoir has known mining waste present on the shoreline and several other mercury mines are upslope.

Oxygenation from 2016 through 2019

Effective oxygenation maintains dissolved oxygen levels greater than 3 mg/L in bottom water. Dissolved oxygen in deep water was maintained near or exceeded saturation in Almaden and Guadalupe Reservoirs, but failed to raise dissolved oxygen above hypoxia (2 mg/L) in Calero Reservoir.

Conclusion: mine cleanup decreased fish mercury levels in Almaden and Calero Reservoirs

We note that:

- If mine cleanup in Jacques Gulch were effective it would decrease fish mercury levels in both Almaden and Calero Reservoirs, which did occur.
- If oxygenation were effective in maintaining dissolved oxygen levels at 3 mg/L and in reducing production and bioaccumulation of methylmercury it would decrease fish mercury levels in both Almaden and Guadalupe Reservoirs, but not Calero Reservoir. However, fish mercury levels decreased in Almaden and Calero Reservoirs but not Guadalupe Reservoir.

Therefore, Water Board staff conclude that mine cleanup likely was the primary agent—not oxygenation—for a statistically significant decrease in REI fish mercury levels in Almaden and Calero Reservoirs (see Section 6.5 regarding also statistically significant decrease in sport fish mercury levels in Almaden and Calero Reservoirs but not Guadalupe Reservoir). We concur with Valley Water that line diffuser oxygenation is not effective at controlling methylmercury production and bioaccumulation in these shallow, bottom-release reservoirs. However, supersaturation methods of applying oxygen (e.g., Speece cone) or mercury sorbents may be effective in reducing reservoir methylmercury production and bioaccumulation. See Section 4.5 regarding that Valley Water is considering installing a Speece cone in Calero Reservoir in the future and is already undertaking sorbent pilot tests.

6.3 100 mm fish: Decrease in Mercury in

Figure 7 (see Section 4.3.2) provides mercury concentrations in 100 mm size-standardized fish before and during four years (from 2016 through 2019) of consistent oxygenation. Statistically significant decreases in mercury levels in Largemouth bass occurred in Almaden Reservoir, average of 35 percent from before oxygenation to during four years of consistent oxygenation.

In Guadalupe Reservoir, over seven years including during four years of consistent treatment, there was about 55 percent decrease in Largemouth bass mercury levels. There were statistically significant declines in two other species in Guadalupe Reservoir.

Importantly, Seelos and others conclude (2021) that reservoir oxygenation did not suppress methylmercury production “[*r*]esults suggest that oxygenation, rather than directly lowering [*methylmercury*] in water, may have mixed nutrients into surface waters, thereby enhancing primary productivity and indirectly affecting [*mercury*] bioaccumulation by diluting concentrations in phytoplankton.” In other words, increased algal growth diluted methylmercury at the base of the food web, so that less methylmercury accumulated into fish.

6.4 Target Fish

In summary, target fish mercury levels exceed the TMDL targets by 2 to 15 times in both reservoirs and creeks.

Valley Water has been collecting target fish from the reservoirs since 2011. Summary Table 2 (and detailed Table A-2) shows that target fish mercury levels exceed the TMDL targets in reservoirs.

The Coordinated Monitoring Program aims to collect target fish from creeks. However, fish collection is often difficult resulting in collecting different species and sizes than planned. The first collection effort in 2016 obtained fish smaller than the smaller (TL3A) target (see Table A-3). Mean mercury in these fish from two locations on Alamitos Creek and one location on Guadalupe Creek ranged from 0.35 to 0.45 ug/g ww, well above the target of 0.05 ug/g ww (AECOMM 2017, Tables 3-4 and 3-5). Since fish grow in length as they age and continue to accumulate methylmercury, we conclude that target fish mercury levels exceed the TMDL targets in creeks.

Section 4.3.4 described the greater than 80 percent reduction in methylmercury loads to downstream in the dry season and that we would expect to see lower fish mercury levels in creek fish downstream of reservoirs. However, the fish sampling sites are too far downstream to reliably measure effect of reservoir discharges. Therefore, additional fish sampling locations are needed to evaluate effects of oxygenation on downstream biota. This action is listed in Section 4.5 (next steps for reservoir pilot tests) and further discussed in Section 7.2.2 (regarding: how should monitoring efforts be modified to detect trends).

Table 2. Mercury Levels in Reservoir Target Fish

Location TMDL Targets	Years	Target Category	Mean mercury (ug/g ww)
Almaden Reservoir	2016	TL3A	0.56
“ “	2016 - 2017	TL3B	0.75 - 0.87
Calero Reservoir	2012 - 2017	TL3A	0.08 - 0.11
“ “	2014 - 2017	TL3B	0.13 – 0.14
Guadalupe Reservoir	2011 - 2017	TL3A	0.52 - 1.4
“ “	2015 - 2017	TL3B	1.31 - 1.56
TMDL Targets	N/A	TL3A	0.05
“ “	N/A	TL3B	0.1

Citation: Tables 7, 8, and 9 from Valley Water’s 2018 report, Guadalupe River Watershed Mercury TMDL: 2016-2017 Progress Report on Methylmercury Production and Control Measures

6.5 Sport fish

Fish in the Guadalupe River watershed have some of the highest mercury levels in California. Consequently, “no consumption” advisory signs are posted at water bodies and on park websites. Both Almaden and Calero Reservoirs had statistically significant reductions in mercury levels in sport-size Largemouth bass (see Figure 9 and Table A-5). REI fish mercury also decreased in Almaden and Calero Reservoirs (see Section 6.2). We attribute this reduction primarily to mine cleanup of Jacques Gulch in Almaden Quicksilver County Park, the only tributary from New Almaden that drains to Almaden Reservoir.

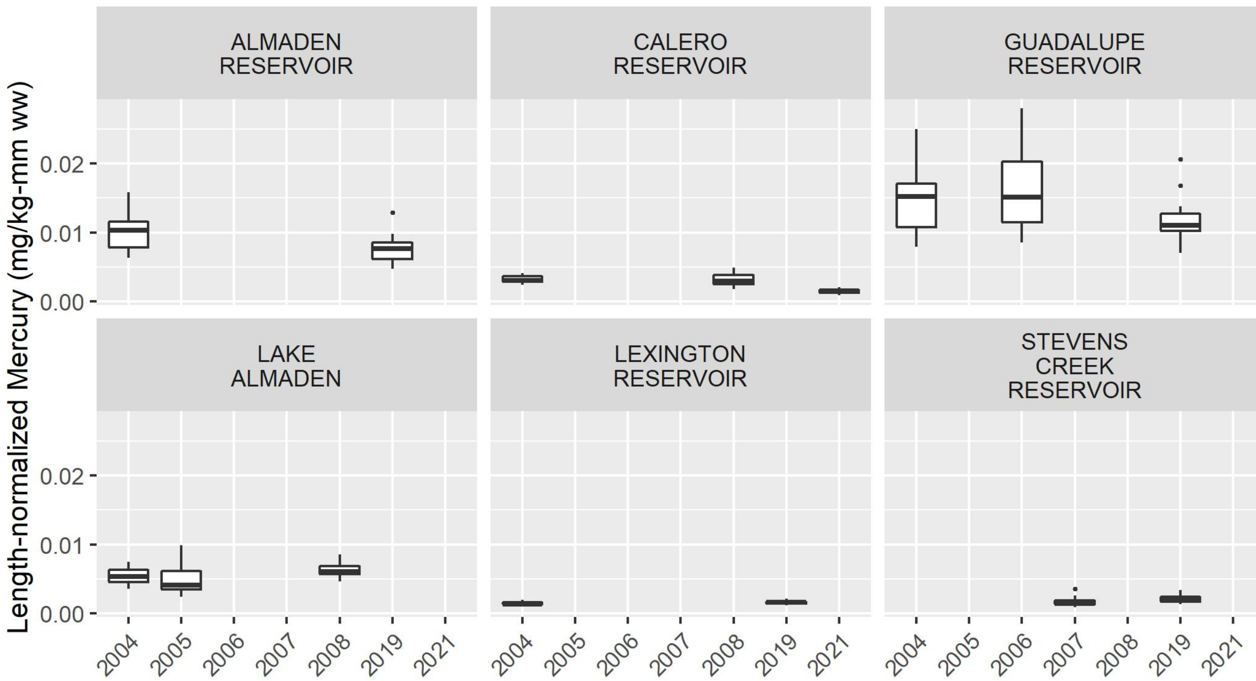

Figure 9. Sport Fish Mercury Levels (Length-Normalized Sport-size Largemouth Bass)

Both Almaden and Calero Reservoirs had a statistically significant reduction in mercury levels. Length-normalized mercury in sport-size (200 mm or longer) Largemouth bass (skinless fillet, wet weight); see Table A-5 for supporting data.

Figure 9 provides mercury levels in sport-size Largemouth bass normalized by fish length. Normalizing by fish length allows for time trend analysis.

Protection of human health has long been underway downstream of New Almaden. In 1987, Santa Clara County issued a "no consumption" advisory to inform people to not consume any fish caught from downstream of New Almaden. Signs with no consumption advisory are posted and catch-and-release fishing is allowed.

Lexington and Stevens Creek Reservoirs are not polluted by mercury mines and are thus not addressed by the TMDL. Data from these two reservoirs located near New Almaden is likely indicative of the best fish mercury levels that can possibly be achieved in the TMDL reservoirs. Lexington Reservoir is the TMDL reference reservoir because it is located away (not downstream) from New Almaden (see Figure 1). Stevens Creek Reservoir is Valley Water's positive control reservoir because it is oxygenated and located away from New Almaden. Even so, mean mercury levels in sport-size Largemouth bass in Lexington and Stevens Creek Reservoirs range from 0.6 to 0.7 and greatly exceed the no consumption level of 0.44 ug/g ww (see Table A-5).

7 TMDL Special Studies and Adaptive Implementation

The Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL) requires special studies and provides for adaptive implementation. Herein we provide a status report on these requirements.

7.1 Special Studies

The purpose of special studies is provided in Basin Plan Section 7.7.1.6, as follows.

> Additional studies may be needed to provide information to improve understanding of mercury cycling in the watershed, and to verify assumptions used in developing these TMDLs. Results of the studies will inform adaptive implementation of these TMDLs and the implementation plan. The special studies should address the following questions.

This section provides the status of each of the study questions.

<u>Study question 1:</u>
How do the reservoirs and lakes in the Guadalupe River watershed differ from one another? Factors to consider include, but are not limited to, area of connected wetlands, food web, water chemistry (phosphorus, pH, acid neutralizing capacity, and dissolved organic carbon), water level fluctuations, and infrastructure (outlet structure). Do outlet samples adequately represent hypolimnetic methylmercury concentrations for each reservoir? How significant are these differences?

<u>Status of study question 1:</u>
Valley Water completed the monitoring and analysis to fully resolve study question 1 (Valley Water 2018). In June 2018, Water Board staff sent a letter to Valley Water to acknowledge that Valley Water has fully resolved study question 1 (Water Board 2018).

<u>Study question 2:</u>
Is it possible to increase the assimilative capacity for methylmercury in reservoirs and lakes? Is it feasible? If it is feasible, will this help to attain the fish tissue targets? How does increasing the assimilative capacity affect the food web: Is the resulting food chain multiplier from large (>15 cm) trophic level 3 (TL3) to large TL4 fish significantly different from 2? If it is significantly different, where and at what frequency should large predator fish (i.e., fish that humans consume) be monitored?

<u>Status of study question 2:</u>
Valley Water's reservoir pilot tests are designed to answer this question, but they are not yet complete. Therefore, extending the duration of Phase 1 by 10 years is warranted because the pilot tests will likely answer this question.

Next, the Basin Plan discusses whether Valley Water has undertaken appropriate effort on study questions 1 and 2 voluntarily or whether the Water Board needs to compel Valley Water to do so. Valley Water has undertaken this work voluntarily and it is of very high quality, not only in the opinion of Water Board staff but also as indicated by publication in peer-reviewed journals.

Study question 3a:
What effect do the reservoir and lake control measures have on methylmercury bioaccumulation downstream? Are the fish targets attained downstream?

Study question 3b:
If not, what factors contribute to methylmercury production and bioaccumulation in creeks and rivers? Factors to consider include, but are not limited to, shallow impoundments, excess nutrients, stagnant pools, shade cover, and aquatic vegetation.

Status of study questions 3a and 3b:
These questions are not yet answered, and Water Board staff plan to address these questions once the reservoir pilot tests near completion. Valley Water's monitoring and biennial reports show that line diffuser oxygenation in reservoirs has reduced the mass of methylmercury discharged downstream (see Section 4.3.4). Section 6.4 describes that fish monitoring in creeks is often difficult resulting in collecting different species and sizes than planned, and that creek fish still have mercury levels many times higher than the TMDL targets. Water Board staff will work to fill this data gap as described in Sections 4.5, 6.4, and 7.2.2.

Next, the Basin Plan discusses whether Valley Water has undertaken appropriate effort on study question 3a voluntarily or whether the Water Board needs to compel Valley Water to do this work. Water Board staff regularly addresses, and will continue to address, voluntary or need to compel every other year when reviewing Valley Water's biennial pilot test reports

Study questions 4 and 5 apply in the future when TMDL targets are achieved. Presently, fish mercury levels remain many times higher than the TMDL targets.

7.2 Adaptive Implementation

This section provides the status of each of the adaptive implementation topics in the same order they are presented in Basin Plan Section 7.7.1.6 for the Guadalupe River Watershed Mercury TMDL.

The TMDL states that within ten years of the effective date of this TMDL project (by December 31, 2018), the Water Board will consider amending this TMDL project and implementation plan as necessary to ensure attainment of fish targets in a timely manner. As mentioned in Section 1, this was the impetus for the current report. In this report we summarized all implementation actions to date in the watershed and analyzed current water quality conditions in impaired waters while also looking for possible decreases in mercury pollution resulting from these efforts. Water Board staff recommends that no changes be made to the TMDL except to recognize that Phase 1 will take 20 years (twice as long as originally anticipated), so Phase 2 of implementation will start with a 10-year delay and begin in 2029.

The TMDL states that reviews will be coordinated through the Water Board's continuing planning program and will provide opportunities for stakeholder participation. Accordingly, Water Board staff is releasing this report for public comment.

The TMDL states that Water Board staff will propose modifications to the targets, allocations, implementation plan actions, or the schedule in this Basin Plan amendment. Water Board staff recommend no changes to to the TMDL other than to extend the schedule of Phase 1.

At a minimum, answers to the following questions will be included in the reviews. Water Board staff will develop additional questions in collaboration with stakeholders during each review. Currently, Water Board staff have no additional questions and we are waiting on answers for some of the following questions.

7.2.1 Question 1

Is there new, reliable, and widely accepted scientific information that suggests modifications to targets, allocations, or implementation actions? If so, how should this TMDL project be modified?

Response: Water Board staff stays current with mercury scientific information and there is no new, reliable, and widely accepted information that suggests modifications to the TMDL targets. As explained in Section 2.2.2, these two TMDL targets are equal to the site-specific mercury water quality objectives for this watershed. Moreover, the targets and site-specific objectives are consistent with the recent (2017) statewide mercury water quality objectives (even though the mercury objectives do not apply to the TMDL area as mentioned in Section 2.2).

As explained in Section 2.2.2, the TMDL allocation to urban stormwater runoff is the same as and implemented through the San Francisco Bay mercury TMDL.

The TMDL allocations to mercury in sediment, soil, and mining wastes were developed based on site-specific conditions (see Chapters 7 and 8 of the 2008 TMDL Staff Report). These site-specific conditions have not changed and implementation is underway, but cleanup of mine sites at the top of the watershed is proceeding slower than anticipated. In the future, after cleanup of the Enriquita Mine and other mercury mining waste in Guadalupe Reservoir commences, Water Board staff should reassess the implementation actions required for Guadalupe Mine. The TMDL requires erosion control of mercury mining wastes at Guadalupe Mine. Although erosion control measures similar to those used at construction sites have been implemented, they require frequent inspection and maintenance. The mine owner is required to inspect frequently and submit inspection reports to the Water Board. Additionally, Water Board staff conduct site inspections, generally timed for after large (i.e., 2-year interval or longer) storms. At the 2022 site inspection, Water Board staff observed erosion of mercury mining waste at 1 of 10 sites along Guadalupe Creek and the landowner indicated they had not inspected or maintained the features in several years. For this reason, and because extremely large storm events could scour the creek banks, Water Board staff should consider requiring permanent measures to prevent erosion and transport of mining waste into Guadalupe Creek. These permanent measures could encompass excavation, backfill with clean soils, and on-site burial, or other measures.

The TMDL allocation to methylmercury production in reservoir hypolimnion water was developed based on site-specific conditions (see Chapters 7 and 8 of the 2008 TMDL Staff Report). Valley Water’s work has improved our understanding of why solar-powered circulators and line-diffuser oxygenation have not reduced methylmercury production in reservoirs. However, Valley Water’s pilot tests are still ongoing (see Section 4) and have expanded to tests of adsorbents and possibly to saturation oxygenation systems in the future (see Section 4.5). Therefore, we do not yet have reliable and widely accepted information that suggests appropriate modifications to the TMDL allocation to methylmercury production in reservoirs. Valley Water’s pilot tests are expected to yield additional valuable information in the next few years and so there is no justification to change the reservoir methylmercury implementation actions.

For all these reasons, Water Board staff recommends no changes at this time to TMDL to targets, allocations, or implementation actions. Moreover, extending the duration of Phase 1 by 10 years is warranted.

7.2.2 Question 2

Is the watershed progressing toward TMDL targets as expected? If progress is unclear, how should monitoring efforts be modified to detect trends? If there has not been adequate progress, how should the implementation actions or allocations be modified?

Response: The monitoring program is adequate to detect progress in reservoir fish mercury targets but not creek fish targets.

Reservoirs are progressing more slowly toward TMDL targets than expected. In Water Board staff's opinion, this is because mine cleanup is proceeding more slowly and reservoir methylmercury controls have been less successful than expected. Nonetheless, progress is being made and valuable information is forthcoming from Valley Water's reservoir pilot tests. Therefore, extending the duration of Phase 1 by 10 years is warranted but no other changes to implementation actions are needed.

Regarding creek fish monitoring, Water Board staff will consider whether, how, and when to add monitoring sites closer to reservoir discharge points. Water Board staff will consider this when reviewing Valley Water's biennial report and proposed monitoring plan. The purpose of these monitoring sites would be to assess whether less methylmercury in reservoir discharges measurably reduces creek fish mercury concentrations, i.e., compare downstream creek fish mercury concentrations "treated" to "untreated." Water Board staff will consider whether this monitoring that would be targeted to small, localized areas of improvement is warranted given that we are interested in watershed-wide improvements.

Moreover, no dataset from before reservoir oxygenation exists at these sites, so it will be necessary to take advantage of unplanned oxygenation equipment failures in any of the three reservoirs or drought when Valley Water does not oxygenate Guadalupe Reservoir. That will provide the "untreated" dataset and can be collected either before or after the "treated" dataset. Note that it is challenging to collect consistent fish in creeks due to drought and other factors, so this effort may take a long time (see Section 6.4). Also, timing of fish collection should be considered. In Water Board staff's opinion, it is best to collect late in the dry season or soon after first rains. This timing will capture influence the of methylmercury in reservoir discharges in the immediate prior months. It is harder to interpret results of early spring collections because these fish have overwintered. Overwintering has confounding mercury accumulation and depuration factors.

7.2.3 Question 3

Does additional sediment, water column, or fish tissue mercury or methylmercury data support our understanding of linkages and food webs in the watershed? Does new data suggest an alternative allocation or implementation strategy?

Response: There is no new data that suggests a different understanding of linkages and food webs in the watershed. (See Section 4.3.2 regarding a manuscript in preparation that may suggest a different understanding of linkages and food webs. However, currently, there is no support for an alternative allocation or implementation strategy.)

7.2.4 Question 4

What are the current pollutant loads from the various sources? Have these loads changed over time? Are they meeting the allocations? How might source control measures be modified to further reduce loads?

Response: As expected, the current mercury pollutant loads from mining wastes are extremely high during large storms (see Section 5.2 regarding one storm in January 2017 that transported 35 times more mercury than the annual allocation). Clearly, continued implementation of mercury source control is warranted. The next steps for Water Board staff to take to ensure that mercury cleanups continue are provided in Section 3.6.

7.2.5 Question 5

Are Water Board strategies to encourage and compel implementation actions effective? If not, how should the Water Board revise its strategies to reach the goal of attaining fish tissue targets within 20 years?

Response: Yes, the Water Board strategies are effective in encouraging Valley Water's reservoir pilot tests, use of grant funding to partially offset the cost of County Park's cleanup at Almaden Quicksilver County Park, compelling coordinated monitoring, and compelling erosion control at Guadalupe Mine.

However, TMDL implementation is waiting on two other projects that are outside of the Water Board's authority. County Parks has long been required by a legal settlement, not this TMDL, to undertake another very large cleanup project, (see Section 3.4, Hacienda Furnace Yard and Deep Gulch project). Valley Water, too, has long planned a reconfiguration of Lake Almaden so that mercury from New Almaden will no longer enter Lake Almaden (see Section 2.1). Those projects will reduce transport and bioaccumulation of mercury transport when completed.

7.2.6 Question 6

Can the assimilative capacity for mercury in reservoirs and lakes be increased? If so, how can reservoirs and lakes be managed to reduce bioaccumulation? Should the implementation actions or allocations be modified? If so, how?

Response: Valley Water's reservoir pilot tests are yielding helpful information, we do not yet know if the assimilative capacity for mercury in reservoirs and lakes can be increased, and the pilot tests are still ongoing. Therefore, extending the duration of Phase 1 by 10 years is warranted.

7.2.7 Question 7

Are capital projects like the Lower, Downtown, and Upper Guadalupe Flood Control Projects helping to meet TMDL allocations or are these projects causing increasing loads of mercury and methylmercury to the Guadalupe River and San Francisco Bay? If the loads are increased over pre-project conditions, how might the loads be reduced or their effects be mitigated?

Response: Monitoring of these projects showed they did not increase loads of mercury and methylmercury to the Guadalupe River and San Francisco Bay, thus monitoring was ceased.

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9 Appendices

Appendix A. Supporting Data, Graphics, and Statistical Analysis

Figure A-1 Supporting Length-Normalized Data by Year for Figure 8

Table A-1. Cleanup Priority Rankings at Almaden Quicksilver County Park
Also available as a separate MS Excel file and available from Water Board staff upon request

Table A-2. Supporting Data for Table 1, Target Fish Mercury Levels in Reservoirs

Table A-3. Supporting Data (Section 6.4) Small Fish Mercury Levels in Creeks and Lake Almaden

Table A-4 Supporting Statistics for Figure 8, Length-Normalized REI Fish Mercury

Table A-5 Supporting Statistics for Figure 9

Appendix B. REI Fish Additional Data and Statistical Analysis

Table B-1. Supporting Mercury Concentrations and Fish Length Statistics for Figure 8

9.1 Appendix A. Supporting Data, Graphics, and Statistical Analysis

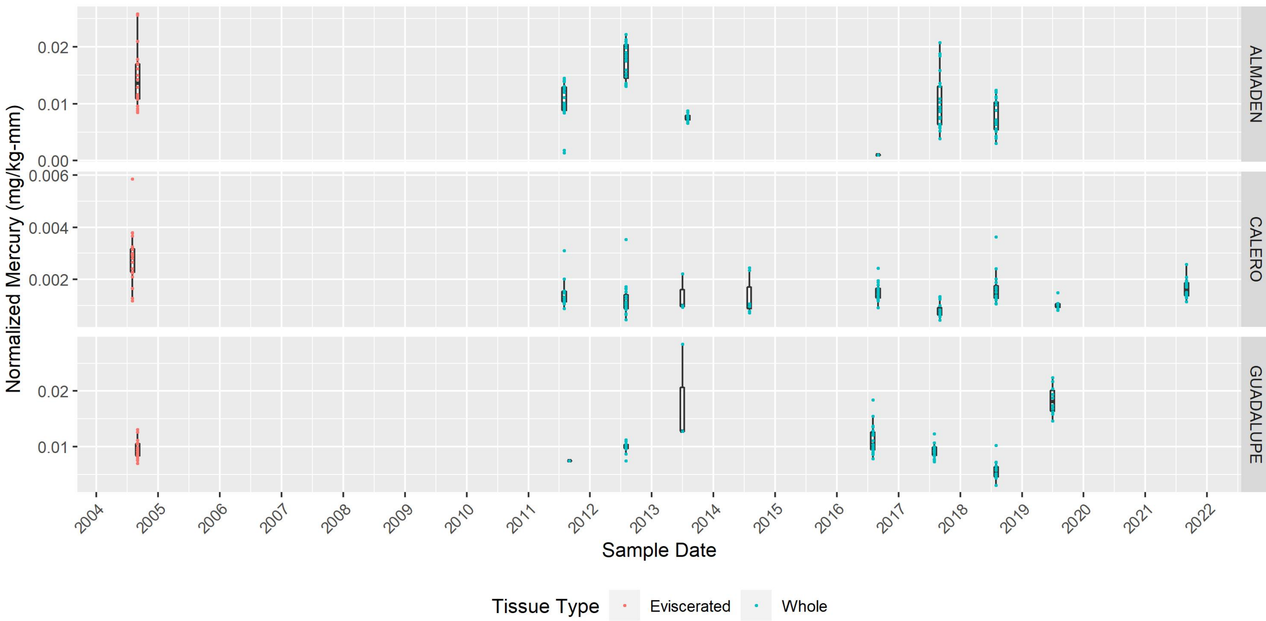

Figure A-1 Supporting Length-Normalized Data by Year for Figure 8

Length-Normalized REI Fish Mercury (ug/g – mm, wet weight)

Sample dates between July 15 and September 15

Table A-1. Cleanup Priority Rankings at Almaden Quicksilver County Park

Table A-1 is very large so it is also packaged as a separate MS Excel file and available from Water Board staff upon request or at https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/guadaluperivermercurytmdl.html.

Citation: For columns "Site Description" through "Map Tile" the source was Almaden Quicksilver County Park and Santa Teresa County Park Mine Material Evaluation, Prepared by URS, Inc., Reports dated December 31, 2010 and May 16, 2011.

Water Board Priority	Water Board Concern	Site Description	Total Mercury (mg/kg)	URS ID	Waste Site Importance Score	Map Tile (URS Figure 1)
	None - cleaned up	Rotory Furnace Ore Stockpile		WS49	2.56	
	None - cleaned up	Satellite Mine Hill Rotory Furnace Calcines Dump		WS50b	3.98	
	None - cleaned up	Mine Hill Furnace Calcines Pile	88	URS_278	4.57	
	None - cleaned up	Mine Hill Furnace Calcines Pile	84	URS_275	4.08	
	None - cleaned up	Mine Hill Rotary Furnace Dust	260	URS_277	4.09	
	None - cleaned up	Senator Mine Calcines Dump	39	WS3	4.06	
	None - cleaned up	Pre-Remediation config of Mine Hill Rotory Furnace Calcines Dump (Mine Hill Rotory Calcines Pile)		WS50	4.65	
	None - cleaned up	Mine Hill Furnace Calcines Pile	88	URS_276	3.89	
	None - cleaned up	Scarp/dump/waste, Unknown Material Type		URS_149	3.21	
	None - cleaned up	Hacienda Calcines Dump		WS57	4.42	
	None - cleaned up	Scarp/dump/waste, Unknown Material Type		URS_120	3.10	
	None - cleaned up	Dump downslope of Mine Hill Opencut		WS67	3.43	
	None - cleaned up	Scarp/dump/waste, Unknown Material Type		URS_177	2.95	
	None - cleaned up	Scarp/dump/waste, Unknown Material Type		URS_182	2.85	
	None - cleaned up	San Mateo Calcines Pile	113	WS7a	3.27	
High	See Section 4. 2 of Water Board's 2022 Report and ask County Parks for photo documentation of maintenance	Erosional Scar, Fill/Slope		ES12	3.45	

High	**Erosion down to calcines is still visible;** located east of URS_176	Drainage eroding western margin of Mine Hill Furnace Calcines Dump		ES1	3.98	
High	Calcine	Scarp/dump/waste, Overburden Soil, Calcines	159	URS_156	4.51	TILES 6 & 7
High	Calcine	Calcine Paved Road at North End of Gaudalupe Reservior		WS9	4.21	TILE 2
High	Calcine	Scarp/dump/waste, Calcines, Soil, Overburden Soil		URS_162	3.81	TILE 7
High	Calcine	Calcines Dump adjacent to dismantled retort from 1950s		WS38	3.53	TILE 7
High	Calcine	San Mateo Calcines Pile	183	WS7b	3.27	TILE 2
High	Calcine	Erosional Scar Below Calcines Paved Road, Soil		ES2	2.20	TILE 2
High	Calcine - see WS13	Enriquita Mine Retort Calcines Pile	420	WS14	2.83	TILE 4
High	Contaminated	Contaminated Creek, South of Los Capitancillos Creek	70	WS59	4.33	TILES 6, 7 & 8
High	Contaminated	Contaminated Colluvium Adjacent to Road, East Side of Juan Vega Opencut Area	233	WS43	3.93	TILES 6 & 7
High	Contaminated	Contaminated Colluvium Adjacent to Haul Road, South Saint George Area	19	WS40	3.58	TILES 6 & 7
High	Contaminated	Contaminated Creek, Deep Gulch Creek	163	WS58	3.51	TILE 7
High	Contaminated	Contaminated Creek, Los Capitancillos Creek to Guadalupe Reservoir	30	WS23	3.47	TILES 4 & 6
High	Contaminated	Contaminated Creek, Map of Area of IS-5 Unnamed Creek near Mockingbird Hil	50	WS20	3.31	TILES 3 & 5
High	Contaminated	Area of Contaminated Colluvium Along Road-Side, Mine Hill Trail Near North America Tunnel	17	WS18	2.93	TILE 4
High	Contaminated	Contaminated Creek, Unnamed Creek North of Cape Horn Pass	1	WS21	2.93	TILES 3 & 5
High	Enriquita - see Water Board Aug 2020 report of 2019 data	Guadalupe Reservoir shoreline overburden	45	WS65	3.37	TILE 2
High	Hacienda	Hacienda Area, Unknown Material Type	56	URS_270	2.80	TILE 7
High	Mine	San Mateo Mine OpenCuts		WS8	2.56	TILE 2
High	Mine site	Senator Mine Furnace Site		WS2	3.34	TILE 1
High	Mine site	Senator Mine Site		WS72	2.51	TILE 1

High	Mine site - furnace dust & calcines visible at furnace	Enriquitta Mine Retort Site		WS13	3.31	TILE 4
Medium	Mine dump	America Mine Dump; Main American Mine Dump Site		WS24	4.05	TILE 6
Medium	Mine dump	Dump West of Mine Hill Opencut		WS68	3.78	TILES 6 & 7
Medium	Mine dump	Buena Vista Shaft, and Randol Dumps		WS61	3.62	TILE 5
Medium	Waste	Waste Site SE of Harry Tunnel		WS70	3.46	TILE 7
Medium	Mine dump	Providencia Opencut, with waste piles downslope		WS15	3.41	TILE 4
Medium	Mine dump	Dump Site East of Almaden Shaft		WS31b	3.28	TILES 6 & 7
Medium	Mine dump	Santa Isabel Shaft Dump		WS60	3.25	TILE 5
Medium	Mine dump	Satellite Dump to Mine Hill Opencuts		WS64d	3.21	TILES 6 & 7
Medium	Mine dump	Victoria Shaft Dump		WS32	3.15	TILES 6 & 7
Medium	Mine dump	Satellite Buena Vista Shaft Dump		WS61b	3.07	TILE 5
Medium	Waste	Waste Site East of Harry Tunnel		WS69	3.06	TILE 7
Medium	Mine dump	Randol Shaft Dump		WS33	3.00	TILES 6 & 7
Medium	Mine dump	Enriquetta Mine Dumps		WS11	2.60	TILE 2
Medium	Mine dump	Yellow Kid Jr. Dumps		WS16	2.47	TILE 4
Medium	Mine dump	American Mine Satalite Portal Dump		WS24h	2.41	TILE 4
Medium	Mine dump	American Mine Satalite Portal Dump		WS24g	1.86	TILE 4
Low		Erosional Scar, Overburden Soil	10	ES6	3.98	TILES 4 & 6
Low	Tunnel/shaft dump	Delgade Tunnel Dump and Opencut	379	WS48	3.87	TILES 6, 7 & 8
Low	Tunnel/shaft dump	China or Main Tunnel Dump, Harry Shafts and Tunnel Dump		WS52	3.87	TILE 7
Low		Erosional Scar, Overburden Soil	26	ES9	3.73	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Overburden Soil		URS_145	3.53	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Overburden Soil		URS_185	3.53	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_154	3.51	TILES 6 & 7
Low		Erosional Scar, Overburden Soil		ES8	3.50	TILES 6 & 7
Low		Unnamed Road West of San Francisco Opencut	60	URS_273	3.50	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Overburden		URS_214	3.47	TILE 7
Low	Dump	Scarp/dump/waste, Overburden Soil		URS_161	3.45	TILES 6 & 7
Low		Soil	40	URS_274	3.41	TILES 6 & 7
Low	Tunnel/shaft dump	Satellite Day Tunnel Dump		WS36b	3.35	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		WS3b	3.33	TILE 1
Low	Dump	Scarp/dump/waste, Soil, Overburden, Ferric Slag		WS39	3.32	TILE 7
Low		Erosional Scar, Overburden Soil		ES5	3.30	TILE 4

Low		Los Capitancillos Creek, Creek at North End of Park near McAbee Road	65	WS5	3.29	TILE 1
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_150	3.27	TILES 6 & 7
Low		Erosional Scar, Overburden Soil		ES18	3.26	TILES 4 & 6
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_139	3.23	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_144	3.21	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_181	3.18	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_102	3.16	TILE 4
Low		Erosional Scar, Unknown Material Type		ES11	3.16	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_212	3.13	TILE 7
Low		Erosional Scar, Soil		ES4	3.13	TILE 6
Low		Colluvium Along Road South of San Cristobal Tunnel	143	URS_272	3.11	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_202	3.11	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_180	3.09	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_109	3.08	TILES 4 & 5
Low		Landslide, Soil		URS_169	3.08	TILE 6
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_178	3.07	TILES 6 & 7
Low		Erosional Scar, Unknown Material Type		ES10	3.06	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_129	3.05	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_138	3.05	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_206	3.05	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_166	3.05	TILE 6
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_167	3.05	TILE 6
Low		Opencut below PG&E Transmission Lines, South Side of Deep Gulch		WS55	3.05	TILES 7 & 8
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_123	3.02	TILE 6
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_179	3.02	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_140	3.02	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_147	3.00	TILES 6 & 7
Low	Dump	Open Cut Dump		WS53b	3.00	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_101	2.99	TILE 4
Low	Tunnel/shaft dump	Satellite Deep Gulch Tunnel Dump		WS54d	2.97	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_157	2.97	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Soil		URS_204	2.97	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_142	2.95	TILES 6 & 7
Low	Tunnel/shaft dump	Day Tunnel Dump		WS36	2.95	TILES 5 & 7
Low	Dump	American Mine Satalite Portal Dump		WS24b	2.95	TILE 6

Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_155	2.94	TILES 6 & 7
Low	Dump	Erosional Scar, Soil	ES3	2.94	TILE 6
Low	Tunnel/shaft dump	April Tunnel Dump	WS66	2.93	TILES 6 & 7
Low		Erosional Scar, Soil	ES14	2.93	TILE 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_211	2.93	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_141	2.92	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_130	2.91	TILES 6 & 7
Low	Tunnel/shaft dump	Satellite Deep Gulch Tunnel Dump	WS54f	2.90	TILES 7 & 8
Low	Tunnel/shaft dump	Satellite Deep Gulch Tunnel Dump	WS54c	2.90	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_119	2.88	TILES 6 & 7
Low		Landslide, Soil	URS_107	2.87	TILE 4
Low		Landslide, Soil	URS_108	2.87	TILES 4, 5 & 7
Low		Landslide, Soil	URS_191	2.87	TILE 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_146	2.86	TILES 6 & 7
Low	Dump	Satellite Dump to Mine Hill Opencuts	WS64c	2.86	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Overburden	WS68b	2.85	TILES 6 & 7
Low	Tunnel/shaft dump	Satellite Deep Gulch Tunnel Dump	WS54e	2.85	TILES 7 & 8
Low	Dump	American Mine Satalite Portal Dump	WS24d	2.83	TILE 6
Low		Erosional Scar, Soil	ES16	2.83	TILE 4
Low	Tunnel/shaft dump	April Tunnel Dump	WS30	2.83	TILES 6 & 7
Low	Dump	American Mine Satalite Portal Dump	WS24e	2.83	TILES 4 & 6
Low	Dump	American Mine Satalite Portal Dump	WS24I	2.83	TILE 6
Low	Tunnel/shaft dump	Satellite Deep Gulch Tunnel Dump	WS54h	2.82	TILE 7
Low		Landslide, Soil	URS_124	2.80	TILES 4, 5, 6 & 7
Low		Landslide, Soil	URS_168	2.80	TILE 6
Low		Landslide, Soil	URS_175	2.80	TILES 6, 7 & 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_207	2.80	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_128	2.80	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_111	2.80	TILES 4 & 6
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_116	2.78	TILE 6
Low		Landslide, Soil	URS_186	2.78	TILES 6 & 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_218	2.77	TILE 7
Low	Dump	Scarp/dump/waste, Overburden	WS68c	2.76	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_137	2.76	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_208	2.75	TILE 7

Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_194	2.74	TILE 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_187	2.73	TILE 8
Low	Dump	Satellite Dump to Mine Hill Opencuts	WS64b	2.73	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_205	2.73	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_118	2.73	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_103	2.72	TILE 4
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_213	2.71	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_184	2.70	TILES 6 & 7
Low	Dump	San Pedro OpenCut Dump	WS28	2.70	TILE 6
Low	Tunnel/shaft dump	Satellite Deep Gulch Tunnel Dump	WS54b	2.70	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_215	2.70	TILE 5
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_117	2.69	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_201	2.68	TILE 7
Low		Landslide, Soil	URS_189	2.68	TILE 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_160	2.68	TILES 6 & 7
Low		Landslide, Soil	URS_100	2.67	TILE 4
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_152	2.67	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	WS3c	2.67	TILE 1
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_151	2.67	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_188	2.66	TILE 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_112	2.66	TILES 4 & 6
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_113	2.66	TILES 4 & 6
Low	Dump	American Mine Satalite Portal Dump	WS24f	2.65	TILES 4 & 6
Low	Tunnel/shaft dump	Roosevelt Tunnel Dump/Carson Tunnel Dump	WS35	2.63	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_183	2.62	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_196	2.61	TILE 8
Low	Tunnel/shaft dump	Deep Gulch Tunnel Dump	WS54	2.61	TILE 7
Low	Tunnel/shaft dump	Great Eastern Tunnel Dump	WS37	2.60	TILE 7
Low		American Mine Satalite Portal Dump	WS24c	2.59	TILE 6
Low	Dump	Erosional Scar, Serpentine	ES17	2.58	TILE 6
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_105	2.58	TILE 4
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_192	2.58	TILES 7 & 8
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_209	2.58	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_106	2.54	TILE 4
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_193	2.54	TILE 8
Low		Landslide, Soil	URS_176	2.54	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_199	2.53	TILE 7

Low	Tunnel/shaft dump	Almaden Shaft-San Pedro Opencut; 10 acre area including San Pedro Opencut dump		WS31	2.51	TILES 6 & 7
Low		Opencut below PG&E Transmission Lines, south side of Deep Gulch and Northwest of Hidalgo Opencut		WS53	2.49	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_126	2.48	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_159	2.47	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_135	2.46	TILES 6 & 7
Low		Landslide, Soil		URS_217	2.45	TILE 5
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_195	2.44	TILE 8
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_148	2.44	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_165	2.43	TILE 7
Low	Tunnel/shaft dump	Senator Mine Shaft Dumps, Senator Mine Area	108	WS4	2.42	TILE 1
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_114	2.42	TILES 4 & 6
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_200	2.42	TILE 7
Low		Landslide, Unknown Material Type		URS_210	2.41	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_110	2.41	TILE 4
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_190	2.41	TILE 6
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_122	2.39	TILE 6
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_134	2.36	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_197	2.36	TILES 7 & 8
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_158	2.35	TILE 7
Low	Tunnel/shaft dump	Senator Mine, 260-foot tunnel entrance dump		WS6	2.35	TILE 1
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_203	2.33	TILE 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_170	2.32	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_127	2.31	TILES 6 & 7
Low		San Francisco Opencut		WS47	2.30	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_216	2.30	TILE 5
Low		Erosional Scar, Soil		ES13	2.30	TILES 6, 7 & 8
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_104	2.30	TILE 4
Low		Area of Bulldozer Trenches adjacent to Mine Hill		WS17	2.29	TILE 4
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_171	2.26	TILES 6 & 7
Low		Ground disturbed by unproductive cuts and trenches in 1920s		WS1	2.26	TILE 1
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_131	2.26	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_143	2.23	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type		URS_198	2.23	TILE 7

Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_115	2.22	TILES 4 & 6
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_136	2.22	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_125	2.20	TILES 6 & 7
Low		Prospect Shaft No.3 waste rock dump	WS12	2.18	TILE 2
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_172	2.14	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_174	2.11	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_163	2.11	TILE 7
Low		Soil	WS65b	2.11	TILES 2 & 4
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_121	2.09	TILE 6
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_153	2.08	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_132	2.06	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_133	2.06	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_173	2.06	TILES 6 & 7
Low	Dump	Scarp/dump/waste, Unknown Material Type	URS_164	2.03	TILE 7
Low		Catharine Opencut	WS29	1.98	TILES 4, 6 & 7
Low	Dump	Encline Railroad Dump	WS51	1.98	TILE 7
Low		Colluvial Soil along Haul Road, Hillside North End of Randol Trail	WS10	1.80	TILE 2
Low	Tunnel/shaft dump	America Mine Satellite Tunnel Dump	WS46	1.76	TILE 6
Low	Tunnel/shaft dump	Santa Rita Shaft Dump, and Juan Vega Opencuts	WS34	1.73	TILES 6 & 7
Low		Mine Hill OpenCuts	WS71	1.46	TILES 6 & 7

Table A-2. Supporting Data for Table 1, Target Fish Mercury Levels in Reservoirs

Location TMDL Targets	Year	Category	Count	Mean mercury (ug/g ww)	StdDev	CV	Mean Length (mm)	Length StdDev (mm)
Almaden Reservoir	2016	TL3A	32	0.56	0.16	0.29	101.53	32.25
" "	2016	TL3B	11	0.75	0.18	0.24	164.64	9.76
" "	2017	TL3B	6	0.87	0.58	0.67	189.33	29.98
Calero Reservoir	2012	TL3A	9	0.08	0.01	0.16	121.22	12.73
" "	2013	TL3A	49	0.11	0.07	0.62	94.31	31.87
" "	2014	TL3A	75	0.09	0.02	0.24	108.23	23.99
" "	2015	TL3A	16	0.1	0.02	0.19	106.88	28.9
" "	2016	TL3A	30	0.09	0.03	0.28	99.2	28.99
" "	2017	TL3A	28	0.08	0.04	0.58	96.54	21.46
" "	2014	TL3B	10	0.13	0.04	0.27	161	6.07
" "	2015	TL3B	7	0.13	0.08	0.58	177	25.79
" "	2016	TL3B	18	0.14	0.07	0.5	195.89	41.92
" "	2017	TL3B	26	0.13	0.05	0.41	190.23	31.32

Location TMDL Targets	Year	Category	Count	Mean mercury (ug/g ww)	StdDev	CV	Mean Length (mm)	Length StdDev (mm)
Guadalupe Reservoir	2011	TL3A	8	0.81	0.2	0.25	73.5	12.06
" "	2012	TL3A	10	0.52	0.08	0.16	67.8	5.73
" "	2013	TL3A	29	1.25	0.37	0.29	107.48	20.81
" "	2015	TL3A	16	1.4	0.22	0.16	101.81	37.2
" "	2016	TL3A	25	0.95	0.28	0.29	84.56	31.41
" "	2017	TL3A	32	0.73	0.14	0.19	95.94	28.78
" "	2015	TL3B	8	1.4	0.23	0.16	175.5	16.45
" "	2016	TL3B	19	1.56	0.44	0.28	182	26.08
Guadalupe Reservoir	2017	TL3B	22	1.31	0.75	0.57	183.05	28.64
TMDL Targets	N/A	TL3A	N/A	0.05	N/A	N/A	N/A	N/A
" "	N/A	TL3B	N/A	0.1	N/A	N/A	N/A	N/A

Notes

SD = Standard Deviation; CV = Coefficient of Variation

Citation: Tables 7,8, and 9 from Valley Water's Guadalupe River Watershed Mercury TMDL: 2016-2017 Progress Report on Methylmercury Production and Control Measures

Table A-3. Supporting Data (Section 6.4) Small Fish Mercury Levels in Creeks and Lake Almaden

Collection Location	Species	Sample Count	Number of fish per sample	Mean Mercury (ug/g ww)	Mean Fork Length (mm)
Alamitos Creek at Harry Road	Age 1+ California roach	20	1	0.45	46
Alamitos Creek at Graystone Lane	Age 1+ California roach	20	1	0.46	49
Guadalupe Creek at Singletree Way	Age 1+ California roach	20	1	0.35	50
Lake Almaden	Age 0+ largemouth bass	20	1 to 3	0.18	37

Note: These fish from 2016 are too small to qualify as TMDL targets (roach) or REIs (bass).

Citation: Tables 3-4 and 3-6 from AECOMM (2017)

Table A-4 Supporting Statistics for Figure 8, Length-Normalized REI Fish Mercury (ug/g – mm, wet weight)

Reservoir	**Stage of Treatment**	**Median**	**Mean**	**StdDev**	**n**	**Comparison**	**Y / N**	**Statistics (Mann-Whitney)**
ALMADEN	before	0.014	0.015	0.005	20	before - start-up	N	W = 604, p-value = 0.1784
ALMADEN	start-up	0.013	0.013	0.005	50	start-up - treat	**Y**	W = 2389, p-value = 2.639e-08
ALMADEN	treated	0.006	0.007	0.005	59	before - treat	**Y**	W = 1026, p-value = 8.198e-07
CALERO	before	0.003	0.003	0.001	20	before - start-up	**Y**	W = 843, p-value = 9.451e-08
CALERO	start-up	0.001	0.001	0.001	46	start-up - treat	N	W = 1404, p-value = 0.08702
CALERO	treated	0.001	0.001	0.001	75	before - treat	**Y**	W = 1354, p-value = 3.605e-08
GUADALUPE	before	0.009	0.009	0.002	20	before - start-up	N	W = 95, p-value = 0.1194
GUADALUPE	start-up	0.010	0.011	0.005	14	start-up - treat	N	W = 581, p-value = 0.1637
GUADALUPE	treated	0.009	0.010	0.004	67	before - treat	N	W = 650, p-value = 0.8441

Notes: Column “Y / N” indicates whether there is a statistically significant difference

Calero “treated” includes 2021 data collected for the Water Boards via the BOG/STEW program

Table A-5 Supporting Statistics for Figure 9, Sport-size Largemouth Bass

Reservoir (Lake)	Date	Sample Size	Statistical Results	Hg Mean	Hg Min	Hg Max	Hg CV	Length-normalized Hg Mean	L Mean	L Min	L Max	L CV
ALMADEN	9/1/2004	20	A	4.35	2.16	7.35	0.30	0.010	429	330	500	0.11
ALMADEN	9/24/2019	14	A	2.77	1.32	5.23	0.40	0.008	356	221	460	0.23
CALERO	8/31/2004	20	B	1.13	0.84	1.56	0.16	0.003	358	290	466	0.12
CALERO	6/25/2008	16	B	1.14	0.49	1.82	0.35	0.003	358	280	470	0.14
CALERO	9/1/2021	14	C	0.51	0.19	0.54	0.41	0.001	341	205	458	0.23
GUADALUPE	9/8/2004	18	D	6.05	3.08	13.00	0.39	0.015	408	300	**520**	0.18
GUADALUPE	11/16/2006	15	D	7.10	2.86	13.42	0.56	0.016	413	305	**530**	0.19
GUADALUPE	9/24/2019	14	D	3.86	2.54	5.04	0.21	0.012	338	238	433	0.19
LAKE ALMADEN	8/31/2004	20	N/A	2.27	1.10	3.78	0.34	0.005	408	305	**520**	0.16
LAKE ALMADEN	8/25/2005	20	N/A	1.98	0.93	4.07	0.48	0.005	405	323	**520**	0.12
LAKE ALMADEN	10/21/2008	11	N/A	2.24	1.34	3.87	0.37	0.006	358	202	**578**	0.30
LEXINGTON	9/8/2004	11	N/A	0.60	0.44	0.97	0.27	0.001	398	350	490	0.12
LEXINGTON	10/22/2019	12	N/A	0.60	0.29	0.80	0.27	0.002	374	247	444	0.17
STEVENS CREEK	7/31/2007	11	N/A	0.60	0.17	1.63	0.73	0.002	318	200	461	0.27
STEVENS CREEK	10/21/2019	14	N/A	0.71	0.50	1.21	0.26	0.002	348	208	462	0.23

Notes

Hg = mercury (ug/g ww); Length-normalized Hg = mercury (ug/g – mm, ww);

CV = Coefficient of variation = measure of data spread relative to the mean (std dev / mean)

Length-normalized mercury = fish mercury concentration divided by length (mg/kg – mm); L = Length (mm)

Bold indicates max length > 500 mm (one fish per date from Lake Almaden and two fish per date from Guadalupe Reservoir)

The statewide sport fish mercury water quality objective of 0.2 ug/g ww applies to Lexington and Stevens Creek Reservoirs

Statistical analysis was performed with R using Wilcox non-parametric test (R wilcox.test); Statistical Comments:

A. Almaden Reservoir, compare 2004 to 2019: Statistically significant difference in both length-normalized mercury (p-value = 0.01234) and mean mercury (0.001361)

B. Calero Reservoir, compare 2004 to 2008: No statistically significant difference between 2004 and 2008 (p-value = 0.7176) by Wilcox non-parametric test in length-normalized mercury (unsurprising as these two years are before Jacques Gulch cleanup and consistent oxygenation)

C. Calero Reservoir, compare 2004 & 2008 (combined) to 2021: Statistically significant difference in both length-normalized mercury and mean mercury (both p value << 0.001)

D. Guadalupe Reservoir: No statistically significant difference between 2004 and 2019 (p-value = 0.06487) by Wilcox non-parametric test in length-normalized mercury. For mean mercury, the statistically significant difference (p-value = 0.0004682) is likely an artifact of shorter fish in 2019.

Citations: 2003, 2005, 2004 and 2006: TMDL Staff Report; 2007–08 SWAMP BOG 2007–2008 Lakes Survey 2010 Report; 2019 and 2021SWAMP BOG data transmittals.

9.2 Appendix B. REI Fish Additional Data and Statistical Analysis

Herein we provide additional data and statistical analysis that support that the preponderance of evidence supports that cleanup of mercury mining waste likely was the primary agent—rather than reservoir oxygenation—in reducing REI fish mercury levels in two reservoirs (Almaden and Calero Reservoirs).

In this section we evaluate REI fish mercury concentrations and length, comparing the before (2004) data set to data collected during treatment (from 2016 through 2019). Both data sets are robust, as before has $n = 20$ for each reservoir and treated has n ranging from 59 to 75. REI are Largemouth bass 50 to 100 mm ("age-1") collected from Almaden, Calero, and Guadalupe Reservoirs. We constrained the sample dates (between July 15 and September 15) to ensure the fish were of similar age and mercury accumulation.

The 2004 fish were eviscerated, and the other fish are whole. Figure B.1 shows mercury concentrations in whole and eviscerated fish from Guadalupe Reservoir in 2020 (these data were not used in the before-to-treated comparison). Based on these data, Water Board staff determined that eviscerating the fish did not appreciably change their mean mercury concentration and that it is valid to proceed with comparing 2004 "before" eviscerated fish to whole fish collected during treatment (from 2016 through 2019).

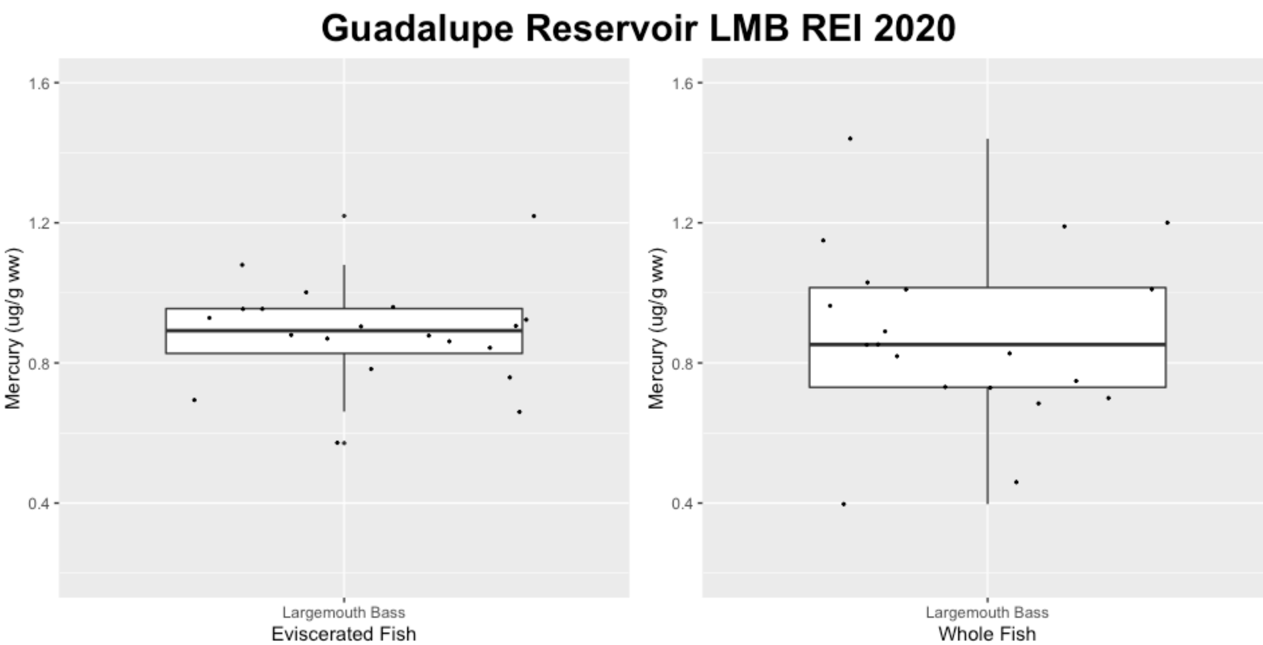

Figure B.1 REI Fish Mercury Concentrations from Guadalupe Reservoir

Based on these data, Water Board staff determined that eviscerating the fish did not make a statistically significant change in their mean mercury concentration (t-test, $t = 0.34326$, $df = 38$, p-value = 0.7333). Citation: Water Board, 2021, Analysis of Guadalupe Reservoir Remediation Effectiveness Indicator Mercury Data

An additional consideration for this before-to-treated comparison, is that we generally expect that longer bass fish have higher mercury concentrations. However, Almaden Reservoir had lower mean mercury concentrations during treatment (decline from 0.96 to 0.56 ug/g ww, before to treated), despite a 10 percent increase in mean fish length (see Table B.1). Oxygenation was effective in Almaden Reservoir as indicated by dissolved oxygen levels at saturation or higher in profundal water (Seelos et al. 2021). Jacques Gulch drains Mine Hill in New Almaden, and this gulch discharges into Almaden Reservoir. The Lower Jacques Gulch mercury mining waste cleanup was completed in 2009.

Similarly, Calero Reservoir had lower mean mercury concentrations during treatment (decline from 0.21 to 0.10 ug/g ww, before to treated), but similar fish length (see Table B.1). Oxygenation was not effective in Calero Reservoir (Seelos et al. 2021). Mercury mining waste in Almaden Reservoir is transferred to Calero Reservoir through the Almaden-Calero Canal (see Section 6.2.1).

In contrast, Guadalupe Reservoir had similar mean mercury concentrations before and during treatment (0.83 and 0.79 ug/g ww), and shorter fish during treatment (decline from mean length of 87.5 to 75 mm). Due to shorter fish, we would expect lower fish mercury levels during treatment, but there was no statistically significant change in fish mercury concentrations. Like Almaden Reservoir, oxygenation was effective in Guadalupe Reservoir as indicated by dissolved oxygen levels at saturation or higher in profundal water (Seelos et al. 2021). Mercury mining waste is present on the shoreline of Guadalupe Reservoir at Enriquita Mine (Water Board 2020).

In summary, both Almaden and Calero Reservoirs had nearly 50 percent declines in fish mercury concentrations, fish of longer or similar length, and effective cleanup of upstream mercury mining waste. In contrast, Guadalupe Reservoir had no measurable change in fish mercury despite shorter fish in the treatment data set and has mercury mining waste on the shoreline. Oxygen was delivered effectively to Almaden and Guadalupe Reservoirs, but not to Calero Reservoir.

The preponderance of evidence supports that cleanup of mercury mining waste likely was the primary agent—rather than reservoir oxygenation—in reducing fish mercury levels in two reservoirs (Almaden and Calero Reservoirs).

Table B.1 REI Fish Mercury Concentrations and Fish Length Statistics

Reservoir	Stage of Treatment	Sample Size	Hg Statistical Results	Hg Mean	Hg Min	Hg Max	Hg CV	Length Statistical Results	L Mean	L Min	L Max	L CV
ALMADEN	before	20	A	0.96	0.58	1.53	0.29	A	65	55	80	0.10
ALMADEN	start-up	50	- -	0.90	0.11	1.75	0.37	- -	70	60	99	0.16
ALMADEN	treated	59	A	0.56	0.08	1.63	0.78	A	85	63	100	0.11
CALERO	before	20	B	0.21	0.10	0.58	0.53	B	66.5	54	100	0.22
CALERO	start-up	46	- -	0.10	0.04	0.29	0.55	- -	75	55	91	0.15
CALERO	treated	75	B	0.10	0.03	0.25	0.39	B	72	54	101	0.17
GUADALUPE	before	20	C	0.83	0.64	1.11	0.17	C	87.5	75	95	0.07
GUADALUPE	start-up	14	- -	0.82	0.52	1.85	0.39	- -	73.5	56	89	0.16
GUADALUPE	treated	67	C	0.79	0.28	1.97	0.44	C	75	57	100	0.15

Notes

Hg = mercury (ug/g ww); CV = Coefficient of variation = measure of data spread relative to the mean (std dev / mean)

Statistical analysis of before (2004) to treated (from 2016 through 2019) was performed with R using Wilcox non-parametric test (R wilcox.test); Statistical Comments:

A. Almaden Reservoir, comparing before to treated, treatment had lower mercury concentrations despite increase in fish length
Statistically significant difference in mercury (p-value = 0.0001073) and length (p-value = 7.651e-08)

B. Calero Reservoir, comparing before to treated, treatment had lower mercury concentrations and similar fish length
Statistically significant difference in mercury (p-value = 7.229e-08) and no significant change in length (p-value = 0.32)

C. Guadalupe Reservoir, comparing before to treated, treated had similar mercury concentrations and shorter length
No statistically significant difference in mercury (p-value = 0.2481) but a statistically significant decrease in length (p-value = 0.0003399)

Citations: 2004 data: TMDL Staff Report; 2016 through 2019 data: Valley Water data transmittal for their Biennial Report; 2021 data for Calero Reservoir: SWAMP STEW data transmittal.

The end.

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