Guadalupe River Watershed

Mercury
Total Maximum Daily Load (TMDL)
Project Report

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California Regional Water Quality Control Board
San Francisco Bay Region

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Acknowledgements

The scientific basis for this TMDL was greatly enhanced by the numerous and extensive data collection efforts and development of a conceptual model (described in Sections 3.1 & 3.2). Water Board staff would like to thank the Santa Clara Valley Water District for its generous funding of the Tetra Tech contract and District staff time.

The Guadalupe Mercury Work Group first began meeting in 1999, and has had consistent participation over the years by Dave Drury (Water District), Michael Cox (local resident, mercury mine expert, and New Almaden historian), and Kristin Kerr (of EOA, Inc., representing SCVURPPP). Special thanks to Luisa Valiela of USEPA and Trish Mulvey (CLEAN South Bay) for assistance with group process. Active participants and consistent attendees include James Downing (City of San Jose, and Work Group liaison to the Santa Clara Basin Watershed Management Initiative), Terry Cooke (URS), Diane Fleck (USEPA), Bill Grimes (County Parks), Tom Grieb (Tetra Tech), Jim Kuwabara (USGS), Kirk Lennington (Mid-Peninsula Open Space), Lester McKee (SFEI), Eddie Pettit (Guadalupe Rubbish and Disposal), Dan Russell (USFWS), and Andria Ventura (Clean Water Fund).

I would especially like to thank my Work Group co-chair, Dave Drury. Actions to reduce methylmercury production and bioaccumulation require innovative measures, such as adapting reservoir nutrient controls, and he has the foresight and leadership to pursue these innovations. I wish him success in these developments and salute his watershed stewardship.

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SUMMARY

Overview

This report provides the technical background and basis for a future amendment to the Water Quality Control Plan, San Francisco Bay Region, addressing mercury contamination in the Guadalupe River watershed, a 170-square-mile region containing numerous creeks and reservoirs and draining the historic New Almaden mercury mining district into San Francisco Bay (see Figures S-1 and S-2). This report contains analyses by staff of the San Francisco Bay Regional Water Quality Control Board (Water Board) of mercury impairment and sources, recommends mercury load allocations, and proposes a preliminary plan to implement the allocations. If adopted as a future Basin Plan amendment, it would 1) establish a Total Maximum Daily Load (TMDL) for mercury in the Guadalupe River Watershed pursuant to Section 303(d) of the Clean Water Act, and 2) establish an implementation strategy to achieve and support the TMDL.

This summary highlights and explains four central points that have emerged from the technical studies and regulatory work undertaken in drafting this TMDL:

- The largest source of mercury contamination in this watershed is mining waste—which can be reduced by “low-tech” erosion control methods.
- Most of the production of methylmercury, the chemical form of mercury most harmful to fish, and to the humans and wildlife that eat them, occurs in summer in the oxygen-depleted depths in impoundments (engineered structures such as reservoirs that cause water to pond) in the watershed.
- There is a link between the amount of contamination in the fine sediments at the bottom of these impoundments and the amount of methylmercury present in the tissues of the fish living in them. This link provides the basis of the allocation of loads to the New Almaden Mining District proposed in this TMDL.
- Curbing the production of methylmercury in the watershed—primarily by innovative changes in reservoir management currently under development by engineers at the Santa Clara Valley Water District—will help solve the problem of bioaccumulation in fish and protect human health and wildlife.

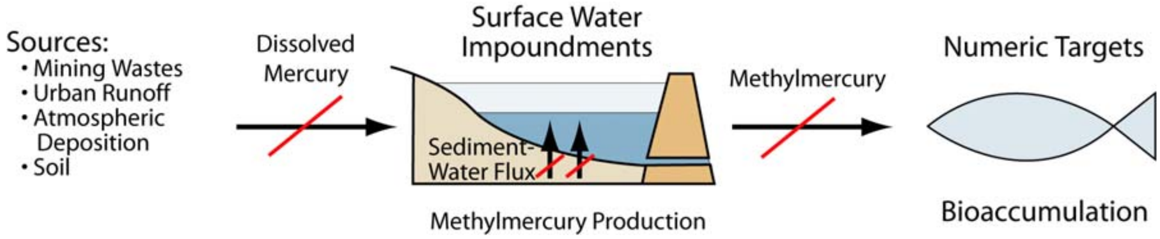

Figure S-1 Solving the Mercury Problem

Citation: prepared by Tetra Tech under contract to Water Board

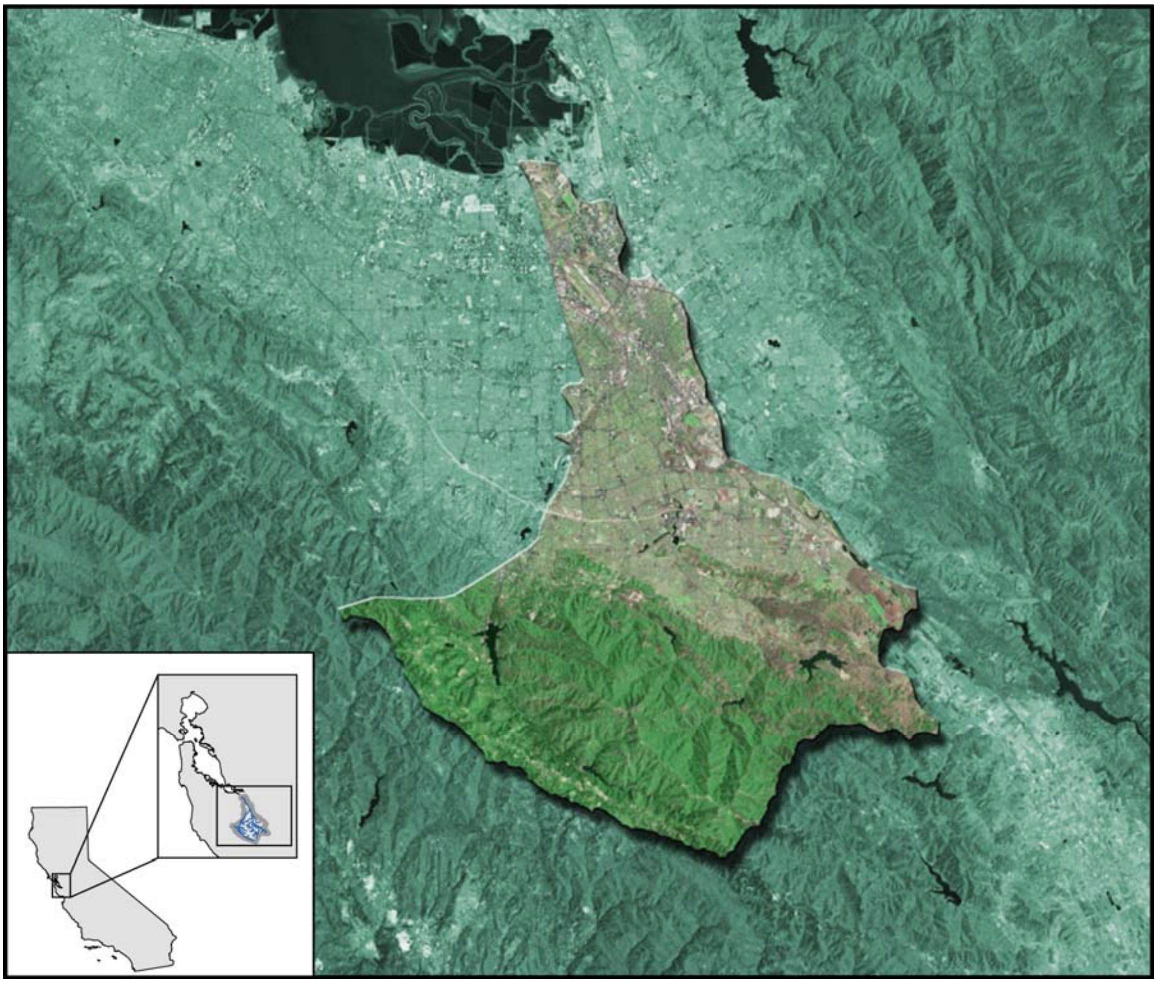

Figure S-2 Location of Guadalupe River Watershed

Citation: Figure ES-1 Final Conceptual Model Report (Tetra Tech 2005c)

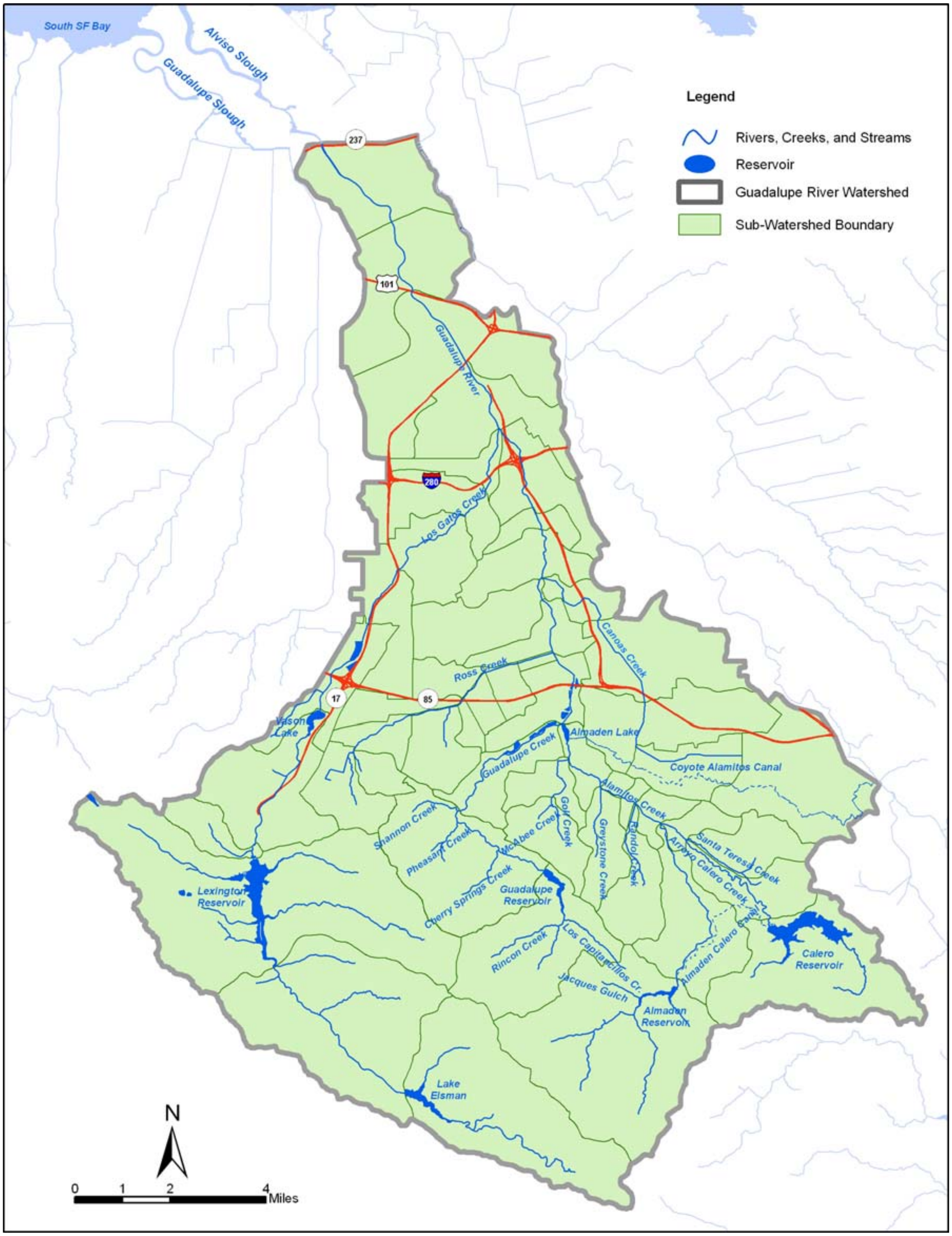

Figure S-3 Guadalupe River Watershed

Citation: Figure 2-2 Final Conceptual Model Report (Tetra Tech 2005c)

Background

Mercury, also known as “quicksilver,” is a naturally occurring metal commonly found in such items as thermometers, was also used as an amalgam in dental fillings, industrial processes, and gold mining. California’s miners placed mercury in their gold sorting and washing trays because it forms a heavy amalgam with the gold, making it easier to separate the gold from the waste rock. The U.S. Geological Survey estimates that gold mining activities added an estimated 13 million pounds of mercury to the creeks, rivers, and delta draining into San Francisco Bay.

Additions to the Bay’s mercury load also came from the south. The South Bay’s New Almaden Mining District, located in the hills above San Jose (Figures S-2 and S-3), was the fifth-largest mercury mine in the world. Between 1845 and 1975, New Almaden produced 38.4 million kilograms of mercury, about five percent of all the mercury mined on the planet. Only four other mines worldwide extracted more mercury than New Almaden, top among these being its namesake in Spain.

New Almaden included five large and numerous small mine sites and tunnels, one big furnace yard, and a number of other yards, retorts, and mobile furnaces used to roast and process the ore. Miners placed most of the roasted waste, called calcines, in or near creeks so winter flows would sweep the materials downstream—a mining practice common at the time. As a result of such practices, a substantial amount of waste material and mercury ended up in the district’s myriad creeks and the 19-mile-long Guadalupe River, as well as in two reservoirs and several other artificial ponds and lakes.

Production of the specific form of mercury most easily passed up to humans through fish is particularly significant in the watershed’s reservoirs and other impoundments. It is in the oxygen-depleted depths of these impoundments that bacteria convert garden-variety (inorganic) mercury into (organic) methylmercury in a process called “methylation.” Methylmercury is of much greater concern than other chemical forms of the metal because it concentrates as it moves up the food chain from algae to zooplankton to prey fish and to predator fish (concentrations in fish can be millions of times higher than in the water in which they live). This astonishing intensification of methylmercury as it moves up the food chain is among the largest “biomagnifications” of all known chemical compounds (see Section 6, Figure 6.8).

Studies leading up to this TMDL compared mercury levels in fish from reservoirs and lakes downstream of the New Almaden Mining District to those from elsewhere in the San Francisco Bay Area. Although largemouth bass from many of the Bay region’s water bodies have elevated mercury concentrations (in the range of 0.8-1.4 parts per million, ppm), the concentrations are markedly higher in Guadalupe and Almaden reservoirs and Almaden Lake (2.1-5.8 ppm). In reservoirs inhabited by fish considered safe for human consumption, such as nearby Lexington Reservoir and Alameda County’s Lake Chabot, levels are closer to 0.6 ppm.

Comparisons were also made between the Guadalupe watershed and another stretch of the Central Coast Range mined for mercury—the Cache Creek watershed about 80 miles upstream of the Bay. Cache Creek is one of the largest contributors of mercury to the Sacramento River system. Comparing 40-cm-long largemouth bass (a size large enough to be consumed by humans) from both watersheds, the Guadalupe Reservoir’s bass had more than 10 times (6.1 ppm) the amount of methylmercury in their bodies as Cache Creek's Clear Lake bass (0.6 ppm). Such data show that the Guadalupe watershed is a larger producer and bioaccumulator of methylmercury than Cache Creek and other Bay Area watersheds, and therefore should be of concern to the State and to Bay Area residents, and particularly to local anglers putting fish from this watershed on their family dinner plates.

Consumption of fish containing mercury is the principal route of human exposure to this metal. In humans, mercury is neurotoxic, affecting the brain and spinal cord, and interfering with nerve function. Pregnant women and nursing mothers can pass mercury to their fetuses and infants through the placenta and breast milk. In children, particularly those under age six, mercury can decrease brain size, delay physical development, impair mental abilities, cause abnormal muscle tone, and result in coordination problems. Substantial mercury exposure is also associated with birth defects and infant mortality. Adults exposed to mercury may experience abnormal sensations in their hands and feet, tiredness, or blurred vision. Higher levels of mercury exposure can impair hearing and speech. In summary, the main human health concern is for the fetus and young children. The young, and reproductive problems, are also of concern for wildlife consuming mercury-laden fish. In and around the Guadalupe River, wildlife sensitive to mercury include ducks, kingfishers, herons, terns, osprey, mink, and otter; among them the least tern is the only listed rare and endangered species.

Contamination

Within the Guadalupe River watershed, those waterways listed as impaired by mercury under section 303(d) of the Clean Water Act are: Almaden Reservoir, Alamitos Creek, Calero Reservoir, Guadalupe Reservoir, Guadalupe Creek, and the Guadalupe River. Other water bodies in and downstream of the historic New Almaden Mining District are also considered impaired due to the presence of mining wastes but have not yet been listed—these water bodies are, however, addressed by this TMDL.

For those waters listed as impaired, states are required to establish TMDLs. This report provides the basis for the TMDL. It discusses background conditions and current mercury loads. It also describes how the TMDL will ensure attainment of water quality objectives and protect beneficial uses of water bodies in the Guadalupe River watershed consistent with state and federal antidegradation policies. Of the many beneficial uses recognized by the State (which range from municipal water supply to recreation and groundwater recharge), only human and wildlife consumption of fish are impaired by mercury. It is for this reason that mercury in fish is the focus of the Guadalupe River Watershed TMDL.

Warnings about not eating the fish from the Guadalupe region's reservoirs and lakes pre-date this TMDL. In 1987, Santa Clara County issued an advisory warning anglers and their families not to consume any fish from water bodies containing mining wastes. During the same year, the state ordered a Superfund cleanup of the New Almaden mines property, which the County had purchased in 1975 to create the 4,000-acre Almaden Quicksilver County Park. The County began cleanup in 1990, and worked to bury, cover, and re-vegetate waste piles, and to control erosion and runoff at five sites that posed the greatest threat to people visiting the park. Although progress was made in the effort to clean up New Almaden's mercury legacy, a great deal more remains to be done both within and downstream of the New Almaden Mining District. This TMDL offers some next steps.

As a first step, the Water Board, together with stakeholders, commissioned and conducted many technical studies examining the sources and effects of current mercury contamination in the watershed. These studies provide a strong scientific basis for the TMDL (the more technically inclined readers are urged to read both the *Data Collection Report* and the *Final Conceptual Model Report*).

TMDL studies identified four sources of mercury in the Guadalupe River watershed: mining wastes, urban runoff, naturally occurring mercury in the soil, and atmospheric deposition. Whatever the source, once mercury enters the water column, most of it is bound to particles. Studies suggest that not every source contributes to every water body. Lexington Reservoir, for example, does not receive mining wastes or urban runoff and therefore serves as the "reference reservoir" indicative of natural background conditions. Based on measurements of total mercury transported downstream during the 2003-2004 wet season, mining waste is by far the largest source (see Section 4, Figures 4.1 and 4.2, and Tables 4.1 and 4.3).

Mercury loads are not only influenced by their primary source of origin and physical form (solid, suspended, liquid, or airborne), but also by seasonal changes and the resulting changes in water chemistry from thermal stratification (layering) within reservoirs. TMDL studies indicate that the wet season is largely a time of transport of the garden-variety inorganic particulate mercury, whereas the more problematic methylation and bioaccumulation largely occur in the dry season. As explained above, this is because during the dry season, oxygen levels in the water become very low (anoxic) down in the deeper waters of impoundments (a layer known as the "hypolimnion") and in the upper few centimeters of sediment—conditions that enhance methylation.

A 2004 study of Guadalupe and Almaden reservoirs indicates that large amounts of methylmercury were produced in the dry season, and more was transported downstream to Guadalupe and Alamitos creeks and the Guadalupe River than was retained in these reservoirs (see Section 4, Figure 4.8). Although there may be sites for methylation in the stream and river channels, their total contribution to methylmercury production is much smaller than the exports from the reservoirs and Almaden Lake during the dry season. This suggests that reducing methylmercury production in impoundments in the New Almaden Mining District and Almaden Lake will likely also reduce contamination of downstream waters.

Once produced in the depths of the watershed's reservoirs, and/or discharged downstream, the methylmercury may find its way into resident fish. TMDL studies found that mercury concentrations in fish samples collected in 2004 were greatest in Guadalupe and Almaden reservoirs located immediately downstream of the mining district. In contrast, adult largemouth bass in nearby Lexington Reservoir are safe for human consumption (see Section 2, Figure 2.1 for results of fish samples collected from throughout the watershed in 2004).

Proposed Targets

To demonstrate attainment of water quality standards, TMDLs must specify "numeric targets" that reflect measurable conditions. Targets are the amount of mercury (solid, suspended, liquid, or airborne) allowed in a certain amount of water, fish tissue, or sediment. For the Guadalupe River Watershed TMDL, the Water Board proposes three targets for methylmercury in fish to protect human health and wildlife, as shown in Table S-1 below.

Table S-1 Fish Targets (ppm methylmercury, wet weight)

Protection of Wildlife	Protection of Wildlife	Protection of Human Health
TL3 Fish* 50 – 150 mm	TL3 Fish* 150 – 350 mm	Typical Size and Species of Fish Consumed
0.05 ppm	0.10 ppm	0.3 ppm

** TL3 refers to the two sizes of smaller fish considered to be at the third trophic level (TL3) in the aquatic food web.*

The fish targets for wildlife are more stringent than the human health targets and therefore provide additional protection of human health (strong controls on smaller fish at the base of the food chain will reduce accumulation in the larger fish that humans consume). Achieving these targets will protect the Guadalupe River Watershed's wildlife and recreational (fishing) beneficial uses, attain the Basin Plan narrative objective for bioaccumulation, and attain all applicable numeric water quality objectives.

Proposed TMDL and Allocations

The Guadalupe River Watershed proposed TMDL consists of concentration- and mass-based allocations, which are not strictly additive but in combination protect against the adverse effects of mercury that occur through long-term bioaccumulation. The allocations are based on the goals of a) eliminating inputs of mercury caused by human activities, particularly mining and urban runoff, and b) minimizing the transformation of mercury to methylmercury caused by human activities, particularly the construction and operation of impoundments.

The allocations are listed on Table S-2 (see next page).

Table S-2 Allocations

Concentration-based allocations

Impoundment Methylmercury Allocation

- 3.0 ng/l (parts per trillion) seasonal maximum of methylmercury in the hypolimnion of Guadalupe, Almaden, and Calero reservoirs and Almaden Lake

Mining Waste Total Mercury Allocations

- 0.1 ppm mercury (annual median, dry weight) in erodable soil fines transported from the portion of the New Almaden Mining District that drains to Guadalupe, Almaden, and Calero reservoirs and Almaden Lake; and
- 0.2 ppm mercury (annual median, dry weight) in erodable soil fines transported from the remaining 10 percent of the New Almaden Mining District; and from sediments suspended from Guadalupe, Alamitos, and Calero creeks and the Guadalupe River

Definition of impoundments: engineered structures that pond water. They include dams (i.e., reservoirs), former quarries (i.e., lakes and percolation ponds), flood control structures, other engineered features (such as drop structures), and non-native invasive vegetation that ponds water.

Definition of erodable soil: soil that is transported by storm runoff ***to receiving waters***; soil fines (i.e. particulates, suspended sediment) are less than 63 microns in diameter.

Mass-based allocations

Urban Runoff Total Mercury Allocation

- 11 kilograms per year of total mercury to be attained within 10 years, and 7.2 kilograms per year of total mercury to be attained within 20 years

Background Soil Total Mercury Allocation

- 0.5 kilograms per year of total mercury

Atmospheric Deposition Total Mercury Allocation

- 0.1 kilograms per year of total mercury

Outreach and Implementation

This TMDL report represents a major step forward in the state's efforts to address public concerns about mercury contamination in their fish and waterways, and to implement the broader 2004 San Francisco Bay Mercury TMDL. It also offers an opportunity for the public to provide input and feedback on the regulatory direction. As it has at all key milestones in the TMDL process, the Water Board will actively solicit and consider stakeholder comments and concerns on this report.

The Water Board also extends an opportunity to the Guadalupe Mercury Work Group to provide detailed, specific feedback and suggestions on the Implementation, Adaptive Implementation, Risk Management, and Monitoring Plans for this TMDL. Implementation to reduce methylmercury production and bioaccumulation requires innovative measures—currently underway for the first time ever in the world by engineers at the Santa Clara Valley Water District—to adapt reservoir nutrient controls for methylation. Other implementation actions will likely entail erosion control in areas where mining waste is present, removal of contaminated sediments from stream beds, banks, and floodplains, and storm drains. Monitoring to document progress made in reducing mercury methylation, transport, and discharge into the Bay, and uptake by fish and wildlife, will also be critical to the success of cleaning up and managing mercury within the Guadalupe River watershed.

Conclusion

Based on the large body of data collected and technical analysis undertaken in support of this TMDL, the Water Board is now prepared to take regulatory action. The Guadalupe River Watershed Mercury TMDL will be the primary regulatory vehicle for achieving water quality goals in the watershed and will simultaneously reduce the load of mercury to the Bay in accordance with the San Francisco Bay Mercury TMDL.

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1. Introduction

This report provides the technical background and basis for a future amendment to the *Water Quality Control Plan, San Francisco Bay Region* (Basin Plan; SFBRWQCB 1995) addressing mercury contamination of the Guadalupe River watershed (Figure 1.1), a 170-square-mile region containing numerous creeks and reservoirs and draining the historic New Almaden mercury mining district into South San Francisco Bay (Figure 1.2). This report contains analyses by staff of the San Francisco Bay Regional Water Quality Control Board (Water Board) of mercury impairment and sources, recommended mercury load allocations, and a preliminary plan to implement the allocations. If adopted as a future Basin Plan amendment, it would 1) establish a mercury Total Maximum Daily Load (TMDL) in the Guadalupe River Watershed pursuant to Section 303(d) of the Clean Water Act, and 2) establish an implementation strategy to achieve and support the TMDL.

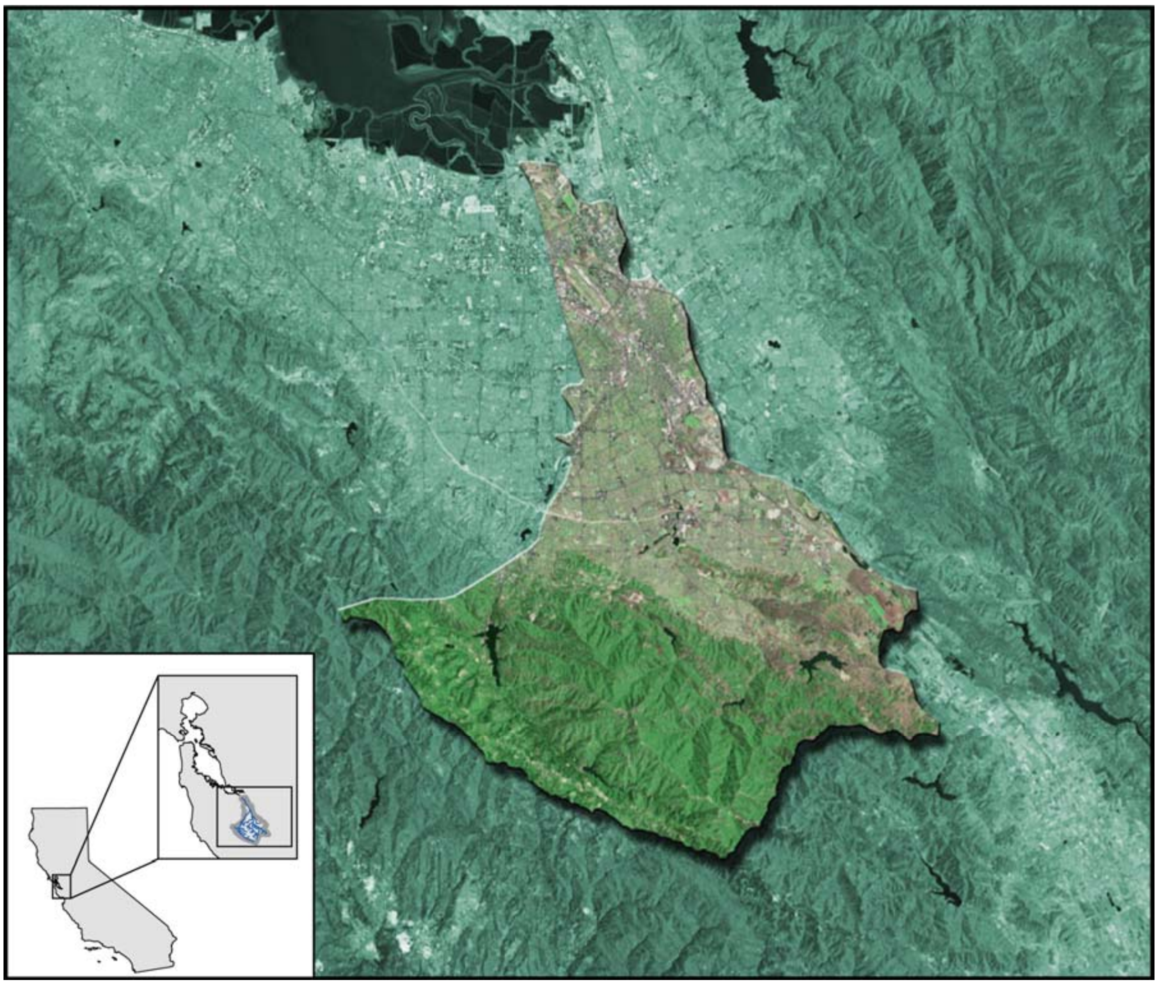

Figure 1.1 Location of Guadalupe River Watershed

Citation: Figure ES-1 Final Conceptual Model Report (Tetra Tech 2005c)

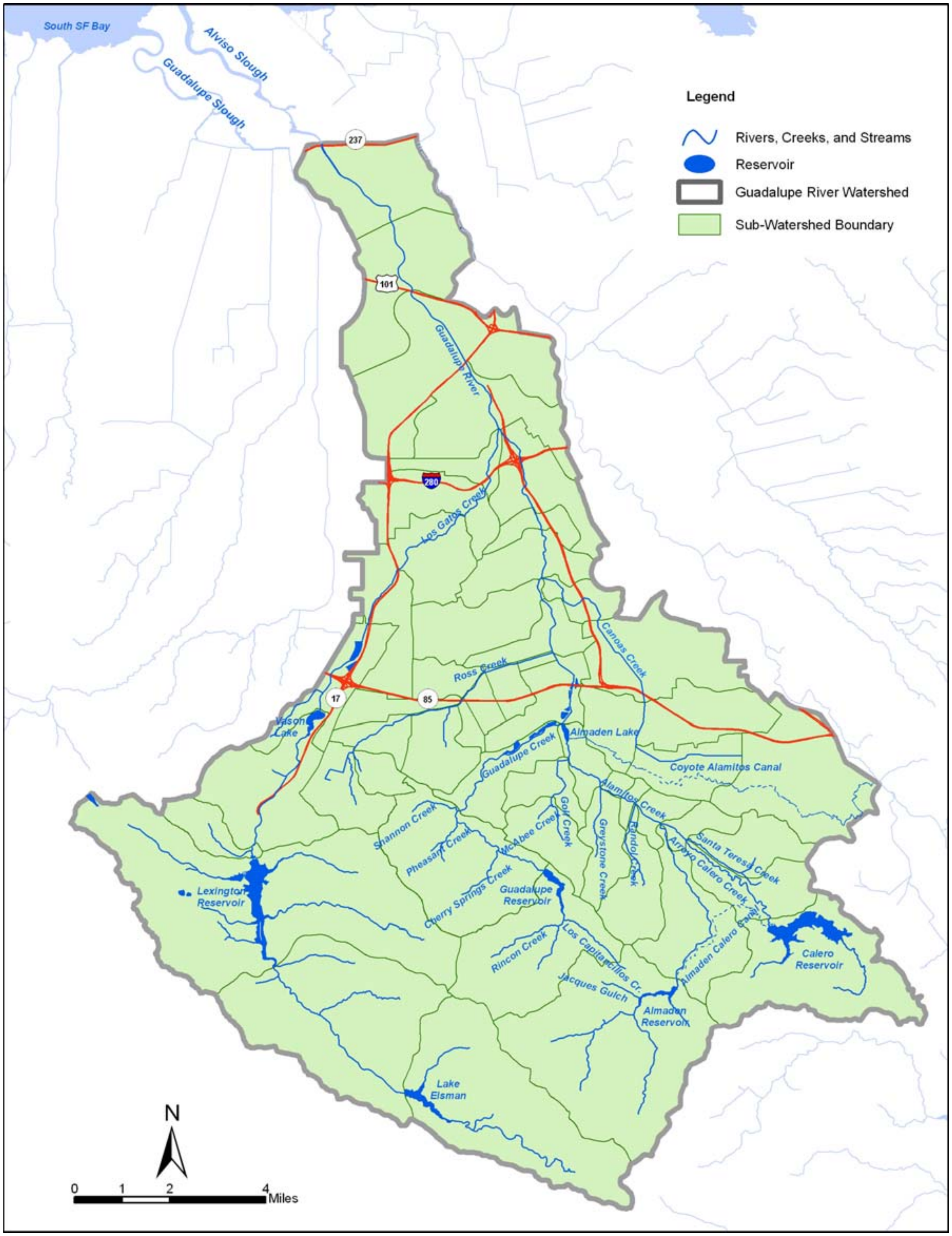

Figure 1.2 Guadalupe River Watershed

Citation: Figure 2-2 Final Conceptual Model Report (Tetra Tech 2005c)

The Basin Plan contains water quality standards applicable to the San Francisco Bay region. A water quality standard defines the water quality goals for a water body by designating the uses for the water (beneficial uses), setting numeric or narrative water quality objectives necessary to protect these uses, and preventing degradation of water quality through antidegradation provisions. The Basin Plan delineates these standards by identifying beneficial uses of water bodies, numeric and narrative water quality objectives to protect those uses, and provisions to enhance and protect existing water quality.

Section 303(d) of the Clean Water Act (CWA) requires states to compile a list of "impaired" water bodies that do not meet water quality standards. For these impaired waters, states are required to establish TMDLs for the pollutants responsible for impairment. TMDLs are to be established at whatever level is necessary to attain water quality standards. The TMDLs are to account for seasonal variations and include a margin of safety that accounts for uncertainties.

This report provides the basis for the TMDL and an associated implementation plan for the Guadalupe River watershed. It discusses background conditions and current mercury loads. It also describes how the TMDL will ensure attainment of water quality objectives and protect beneficial uses of water bodies in the Guadalupe River watershed consistent with state and federal antidegradation policies.

1.1 Impaired Waters and Applicable Water Quality Standards

The listed waters impaired for mercury in the Guadalupe River watershed (Figure S-2) under CWA Section 303(d) are: Almaden Reservoir, Alamitos Creek, Calero Reservoir, Guadalupe Reservoir, Guadalupe Creek, and the Guadalupe River. Other water bodies in and downstream of the historic New Almaden Mining District (creeks in the Mining District, Calero Creek, and Almaden Lake) are also considered impaired due to the presence of mining wastes, but have not yet been listed as impaired under CWA Section 303(d). The impaired water bodies are shown in red on Figure 4.1.

The water quality standards for the Guadalupe River watershed include beneficial uses, narrative water quality objectives, numeric water quality objectives, and antidegradation provisions. The beneficial uses of the watershed include: Cold Freshwater Habitat (COLD); Freshwater Replenishment (FRSH); Groundwater Recharge (GWR); Fish Migration (MIGR); Municipal and Domestic Supply (MUN); Preservation of Rare and Endangered Species (RARE); Water Contact Recreation (REC1); Noncontact Water Recreation (REC2); Fish Spawning (SPWN); Warm Freshwater Habitat (WARM); and Wildlife Habitat (WILD). Of the many beneficial uses listed above, only human consumption of fish (REC1) and wildlife consumption of fish (RARE and WILD) are impaired by mercury.

The Basin Plan mercury water quality objectives include narrative objectives for bioaccumulation and toxicity. They also include the following numeric water quality objectives: for municipal supply (Table 3-5 of the Basin Plan), 2,000 nanograms of mercury per liter of water (ng/l, parts per trillion); and for toxic pollutants (Table 3-4), 25 ng/l four-day average and 2,400 ng/l one-hour average. The California Toxics Rule (Code of Federal Regulations, Title 40, §131.38) limits mercury in surface water to 50 ng/l 30-day average.

The U.S. Environmental Protection Agency (USEPA) has promulgated a methylmercury criterion of 0.3 milligrams methylmercury per kilogram of fish tissue (i.e., parts per million, ppm) because the consumption of fish is the most important route of mercury exposure to humans (USEPA 2001). This criterion has not yet been formally adopted for California.

The water quality objectives applicable to waters impaired by mercury in the Guadalupe River watershed are the Basin Plan narrative objective for bioaccumulation and numeric water quality objectives for toxic pollutants (both 25 ng/l 4-day and 2,400 ng/l 1-hour), and the California Toxics Rule (0.050 ppb 30-day). The numeric objectives are based on the USEPA *Ambient Water Quality Criteria for Mercury – 1984* (USEPA 1985). The Basin Plan bioaccumulation objective states:

> *Many pollutants can accumulate on particles, in sediment, or bioaccumulate in fish and other aquatic organisms. Controllable water quality factors shall not cause a detrimental increase in concentrations of toxic substances found in bottom sediments or aquatic life. Effects on aquatic organisms, wildlife, and human health will be considered.*

1.2 Integration with the San Francisco Bay Mercury TMDL

The Guadalupe River Watershed Mercury TMDL will be the primary regulatory vehicle for achieving water quality goals in the watershed and will simultaneously reduce the load of mercury to the Bay in accordance with the requirements of the San Francisco Bay Mercury TMDL (Looker & Johnson 2004). In accordance with State Board guidance, the two TMDLs are being carefully integrated in terms of load allocations, interim milestones toward the load allocations, and evaluating compliance with the allocations (see Section 7.6).

1.3 Next Steps

The next step in this project is for Water Board staff to conduct a CEQA scoping meeting and open the public comment period on this preliminary report. Staff will also solicit public comments on two important supporting references, the *Final Conceptual Model Report* (Tetra Tech 2005d) and the *Derivation of Numeric Wildlife Targets for Methylmercury in the Development of a Total Maximum Daily Load for the Guadalupe River Watershed* (USFWS 2005).

Subsequently, staff will develop a proposed Basin Plan Amendment and Staff Report. Both the proposed Amendment and Staff Report will take into consideration public comments on this preliminary report. Staff will then submit the proposed Basin Plan Amendment and Staff Report for technical peer review, revise as appropriate based on peer review, and finally present the two documents to the Water Board for consideration and possible adoption (authorized under California Water Code §13240). If adopted, the State Water Resources Control Board will consider the Basin Plan Amendment for adoption (authorized under California Water Code §13170). At all key milestones in the process outlined above, the Water Board will actively solicit and consider stakeholder comments and concerns. After State Board adoption, the California Office of Administrative Law will review the amendment. If the Office of Administrative Law approves the amendment, the U.S. Environmental Protection Agency will consider this TMDL for final approval.

1.4 Report Organization

The process for establishing a TMDL includes compiling and considering available data and information, conducting appropriate analyses relevant to defining the impairment problem, identifying sources, and allocating responsibility for actions to resolve the impairment. This staff report is organized into sections that reflect the key technical elements of the TMDL:

1) Introduction—provides background on this report and the TMDL process.
2) Problem Statement—describes the basis for concluding that mercury impairs beneficial uses in the Guadalupe River Watershed.
3) Background—provides context, such as the watershed setting, and encourages technically inclined readers of this TMDL report to read both the Data Collection Report and the Final Conceptual Model Report.
4) Source Analysis—identifies and quantifies the various contributions of watershed mercury sources.
5) Numeric Targets—expresses the condition desired for the watershed by proposing numeric targets, which, if met, would ensure attainment of water quality standards.
6) Linkage Analysis—describes the relationship between mercury sources and the proposed targets.
7) TMDL, Allocations and Implementation Strategy—proposes allocations for mercury sources and describes the margin of safety afforded by the analysis.
8) Preliminary Implementation Plan—proposes mercury pollution prevention and control actions necessary to reach the targets.
9) Preliminary Monitoring Strategy—specifies monitoring mechanisms to evaluate progress and describes how new information will be gathered and considered as it becomes available.
10) References—lists all information sources cited and relied upon to prepare this report.

Appendices—Provide data and supporting calculations relied upon to prepare this report.

Key Points

- The 303(d) waters listed as impaired for mercury in the Guadalupe River watershed are: Almaden Reservoir, Alamitos Creek, Calero Reservoir, Guadalupe Reservoir, Guadalupe Creek, and the Guadalupe River. Other water bodies in and downstream of the historic New Almaden Mining District are also considered impaired due to the presence of mining wastes, but have not yet been listed.
- Of the many beneficial uses, only human consumption of fish (COMM and REC1) and wildlife consumption of fish (RARE and WILD) are impaired by mercury.
- The water quality objectives applicable to waters impaired by mercury in the Guadalupe River watershed are the Basin Plan narrative objective for bioaccumulation and numeric water quality objectives for toxic pollutants (both 25 ng/l 4-day and 2,400 ng/l 1-hour), and the California Toxics Rule (0.050 ppb 30-day).
- The Guadalupe River Watershed Mercury TMDL will be the primary regulatory vehicle for achieving water quality goals in the watershed and will simultaneously reduce the load of mercury to the Bay in accordance with the San Francisco Bay Mercury TMDL.
- At all key milestones in the TMDL process, the Water Board will actively solicit and consider stakeholder comments and concerns.

2. Problem Statement

The New Almaden Mining District was the largest-producing mercury mine in North America. Typical of the time, waste management practices largely consisted of dumping roasted ores (calcines) into creeks for large winter storms to wash downstream. Consequently, fish downstream of the mining district have significantly elevated mercury concentrations. Fish from Guadalupe Reservoir contain the highest fish tissue mercury concentrations in California.

This section provides a description of the main environmental concern with mercury in this watershed: mercury in fish. The *Guidance for Developing TMDLs in California* (USEPA 2000) recommends that the problem statement contain additional information. In order to avoid duplication within this report, the additional information can be found in the following sections: 1. Introduction—name(s) and locations(s) of water body segments for which the TMDL is being developed; specific applicable water quality standard(s); and, 1. Introduction, 2. Problem Statement, and 3. Conceptual Model—adequate background information about the watershed setting for the TMDL to help the reader understand key water quality, pollutant discharge, land use, and resource protection issues in the watershed.

2.1 Fish Consumption and Human Health

In humans, mercury is neurotoxic, affecting the brain and spinal cord, and interfering with nerve function. Pregnant women and nursing mothers can pass mercury to their fetuses and infants through the placenta and breast milk. In children, particularly those under age six, mercury can decrease brain size, delay physical development, impair mental abilities, cause abnormal muscle tone, and result in coordination problems. Substantial mercury exposure is also associated with birth defects and infant mortality. Adults exposed to mercury may experience abnormal sensations in their hands and feet, tiredness, or blurred vision. Higher levels of mercury exposure can impair hearing and speech. Long-term exposure can damage the kidneys (D'Itri 1991; Davies 1991; COEHHA 1997; USDHHS 1999; USEPA 1997c). In summary, the main human health concern is for the fetus and young children.

In humans, the principal route for mercury exposure is through the consumption of mercury-containing fish (USEPA 2001). The Toxics Substances Monitoring Program collected about 100 fish from the watershed in 1986 (TSMP 1978-2000). Mercury in 70percent of these samples exceeded 1 part per million (ppm), the U.S. Food and Drug Administration's (USFDA) action level. To protect human health, in 1987 Santa Clara County issued a fish consumption advisory to not consume any fish from Guadalupe, Almaden, and Calero reservoirs; Alamitos and Guadalupe creeks; Guadalupe River; and percolation ponds on these creeks and river. In 1988, the 303(d) list of impaired waters was first released, and these water bodies were included. In January 2001, USEPA issued a methylmercury criterion in fish tissue for the protection of human health of 0.3 ppm (more stringent than the USFDA action level).

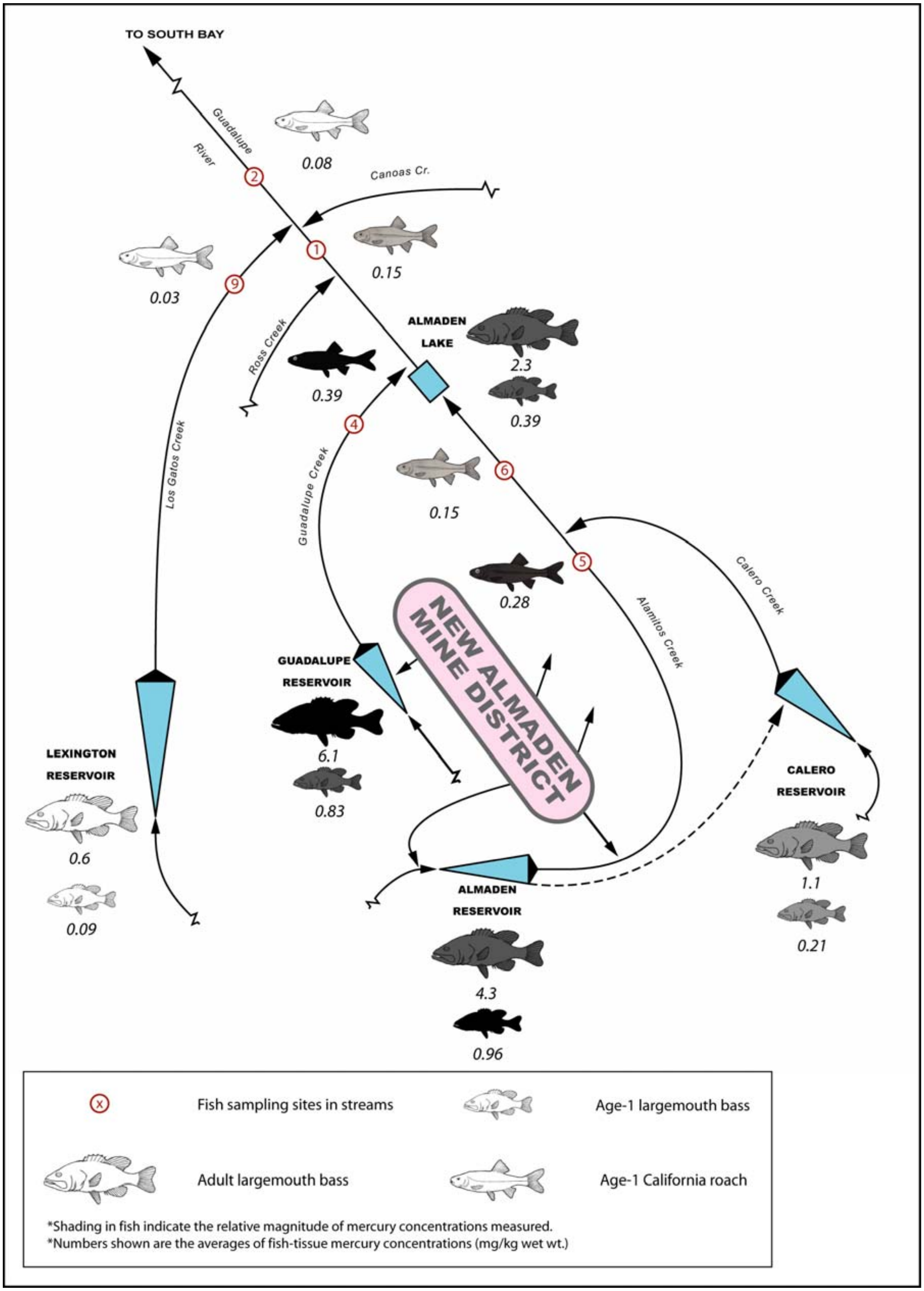

Figure 2.1 Summary of 2004 Fish Sampling Results

Citation: Figure 3-25 Final Conceptual Model Report (Tetra Tech 2005c)

Results of fish samples collected from throughout the watershed in 2004 are shown on Figure 2.1. The adult largemouth bass were about 40 centimeters (cm) in length, which is believed to be representative of the size consumed by humans. (There are no fish consumption surveys for this or similar and nearby watersheds that could provide fish consumption information.) Mercury concentrations in adult largemouth bass were greatest in Guadalupe and Almaden reservoirs located immediately downstream of the mining district, and were still elevated in Almaden Lake and Calero Reservoir, which are farther downstream. In contrast, adult largemouth bass in Lexington Reservoir, which does not receive mining waste or urban runoff, are safe for human consumption (given certain assumptions discussed in Numeric Targets, Section 5).

Three decades of fish mercury data from Guadalupe Reservoir are shown on Figure 2.2 (see Table A.1 in Appendix A for data and references). Because the different species have different consumption habits (i.e., different trophic levels – see Section 5), they are not directly comparable to one another; nonetheless, this data illustrate that mercury in fish has been, and remains, elevated.

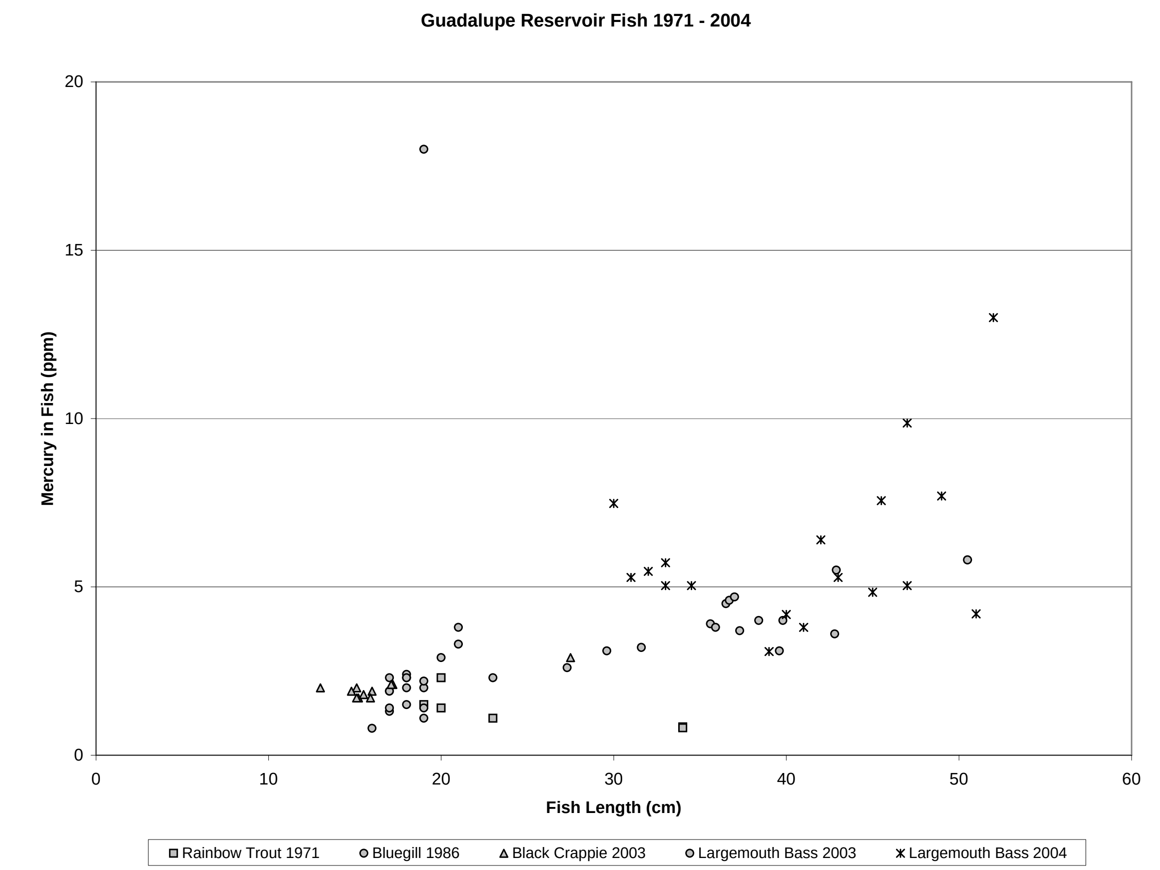

Figure 2.2 Guadalupe Reservoir Fish 1971 – 2004

Mercury in fish from reservoirs and Almaden Lake downstream of the New Almaden Mining District are compared to data from throughout the San Francisco Bay area in Table 2.1. Although largemouth bass from many water bodies have elevated mercury concentrations, the concentrations are markedly higher in Guadalupe and Almaden reservoirs and Almaden Lake.

Table 2.1 Mercury in Fish from San Francisco Bay Area

Citation: Table 8-3, Data Collection Report (Tetra Tech 2005a)

Water Body Downstream of New Almaden Mining District	Other Water Bodies in San Francisco Bay Area (not downstream of mercury mines)	Mercury Standardized 40 cm Largemouth Bass (ppm, wet weight)
Fish Unsafe for Human Consumption		
Guadalupe Reservoir		5.8
Almaden Reservoir		3.6
Almaden Lake		2.1
	Stevens Creek Reservoir, Stevens Creek watershed, Santa Clara County	1.4
	Anderson Reservoir, Coyote Creek watershed, Santa Clara County	1.3
Calero Reservoir		1.2
	Soulajule Reservoir, Marin County	1.1
	Del Valle Reservoir, Alameda County	0.9
	Nicasio Reservoir, Marin County	0.8
Fish Safe for Human Consumption (given assumptions discussed in Numeric Targets, Section 4)		
	Lexington Reservoir, Guadalupe River watershed, Santa Clara County	0.6
	Lake Chabot, Alameda County	0.6
	Lafayette Reservoir, Contra Costa County	0.4

2.2 Fish Consumption and Wildlife

Mercury poses potential hazards to birds, mammals, and other wildlife. Birds and mammals that consume fish and other aquatic organisms can be exposed to significant quantities of mercury. In birds, mercury can adversely affect survival. It can affect cell development and reproductive success, and cause developmental problems in the young. It can cause reduced feeding, weight loss, lack of coordination, hyperactivity and hypoactivity, and liver and kidney damage. In mammals, mercury can reduce speed and agility, making it more difficult to obtain food and avoid predation (USEPA 1997d). The embryos of birds and other vertebrates are more sensitive to mercury exposure than adults (Wiener et al. 2003).

As in humans, the principal route for mercury exposure in wildlife is through the consumption of mercury-containing fish (USFWS 2005). Fish of smaller sizes, typical of wildlife consumption, were sampled throughout the watershed, and results are shown on Table 2.2 and Figure 2.1. The age-1 largemouth bass, about 9 cm in length, were collected from reservoirs and Almaden Lake . Like the adult largemouth bass, mercury concentrations in age-1 largemouth bass were greatest in Guadalupe and Almaden reservoirs located immediately downstream of the mining district and were still elevated in Almaden Lake and Calero Reservoir, which are farther downstream. The lowest mercury concentrations in age-1 largemouth bass were in Lexington Reservoir.

The age-1 California roach, about 50 cm in length (SCVWD 2005), were collected from several creeks and the Guadalupe River. Like the largemouth bass, mercury concentrations in age-1 California roach were greatest in the water bodies closest to the mining district, Guadalupe and Alamitos creeks, and were elevated in the Guadalupe River. Samples were collected from two locations in both Alamitos Creek and the Guadalupe River. In both cases, the upstream samples had higher mercury concentrations than the downstream samples. The lowest mercury concentrations in age-1 California roach were found in Los Gatos Creek at a downstream location that receives urban runoff, but like all locations in this sub-watershed, does not receive mining waste.

Table 2.2 Mercury in Age-1 Fish

Citations: Figure 8-5, Tables 8-4 and 8-5, Data Collection Report (Tetra Tech 2005a)

Water Body Downstream of New Almaden Mining District	Largemouth Bass Average Mercury (ppm, wet weight)	California Roach Average Mercury (ppm, wet weight)
Guadalupe Reservoir	0.83	
Guadalupe Creek		0.39
Almaden Reservoir	0.39	
Alamitos Creek (Site 5)		0.28
Alamitos Creek (Site 6)		0.15
Almaden Lake	0.96	
Guadalupe River (Site 2)		0.15
Guadalupe River (Site 1)		0.08
Calero Reservoir	0.21	
Water Body Outside of New Almaden Mining District	**Largemouth Bass Average Mercury (ppm, wet weight)**	**California Roach Average Mercury (ppm, wet weight)**
Lexington Reservoir	0.09	
Los Gatos Creek		0.03

Mercury in fish is a useful measure of bioaccumulation, which is the main environmental concern with mercury. Several studies have been conducted to better understand mercury in this watershed, including bioaccumulation. These studies provide the scientific basis of this TMDL, and are described in the next section.

Key Points

- The main environmental concern with mercury in this watershed is mercury in fish. To protect human health, in 1987 Santa Clara County issued a fish consumption advisory to not consume any fish from water bodies containing mining wastes.
- Mercury concentrations in fish samples collected in 2004 were greatest in Guadalupe and Almaden reservoirs located immediately downstream of the mining district. In contrast, adult largemouth bass in Lexington Reservoir, which does not receive mining waste or urban runoff, are safe for human consumption (given certain assumptions discussed in Numeric Targets, Section 5)

3. BACKGROUND

The purpose of this background section is to provide context, such as mercury production information and watershed setting, and encourage technically inclined readers of this TMDL report to read both the *Data Collection Report* and the *Final Conceptual Model Report*.

California's New Almaden Mining District was one of the largest mercury producers in the world. About 5 percent of all the mercury mined on the planet came from New Almaden. Only four other mines worldwide extracted more mercury than this historic South San Francisco Bay district, top among these being New Almaden's namesake in Spain (see Table 3.1).

New Almaden mined one of 51 major mercury deposits in the 400 km mineral belt extending up and down California's Coast Range. Each of these 51 deposits was large enough to have produced in excess of 1,000 flasks of mercury (a flask equals 76 pounds or 34 kg). The two largest producers were the deposits within the New Almaden Mining District in the hills above the city of San Jose and New Idria near Coalinga on the southwest hillsides of the Central Valley. Numerous smaller deposits with elevated concentrations of mercury are also present in the mineral belt.

Due to the size of the mine and the complexity of mercury in the environment (described in Section 6, Linkage), the New Almaden Mining District warrants detailed study and a conceptual model of mercury behavior in the Guadalupe River watershed.

Table 3.1 World Production of Mercury

Citation: Total World Production Through 1977 (Cox 1999)

	Mercury Produced (million kilograms)	**Percent of World Production**
Almaden, Spain	271	33%
Rest of World	188	22%
Monte Amiata, Italy	104	12%
Idria, Yugoslavia (Slovenia)	102	12%
Rest of U.S.	64	8%
Huancavelica, Peru	52	6%
New Almaden, U.S.	38	5%
New Idria, U.S.	20	2%
Total	839	100%

3.1 Data Collection

PRELIMINARY STUDIES

In 1999, the Guadalupe Mercury Work Group was convened by the Santa Clara Basin Watershed Management Initiative (WMI), partly to assist with the technical basis of this TMDL. It is co-chaired by staff from the Water Board and Santa Clara Valley Water District (Water District), and its membership includes watershed residents and representatives from USEPA, environmental advocacy organizations, and local agencies. In 2000, the Guadalupe Mercury Work Group produced two documents: *Work Plan to Develop and Implement a Total Maximum Daily Load (TMDL) For Waterbodies in the Guadalupe River Watershed Listed as Impaired Due to Mercury* (June 29, 2000), and *Guadalupe River Mercury TMDL Workgroup's Recommended Interim Sampling and Monitoring Plan* (final December 7, 2000).

Implementing these recommendations for sampling and monitoring required funding. In November 2000, the voters of Santa Clara County approved a ballot measure that created a special countywide 15-year parcel tax to fund the Clean, Safe Creeks and Natural Flood Protection Program, which is being implemented by the Water District. This bond measure includes $1 million per year for impaired water bodies. One year's funding was used for data collection and development of the conceptual model of mercury behavior in the Guadalupe River watershed. USEPA contributed reservoir fish sampling, the Water District contributed creek and river fish sampling, and USGS collected phyto- and zooplankton samples.

The consultant selected (through a competitive bid process) to conduct much of this data collection and to develop the conceptual model was Tetra Tech, Inc. The Guadalupe Mercury Work Group reviewed Tetra Tech's draft sampling plan, reports, and conceptual model. A Technical Review Committee of recognized mercury experts was also convened to review key draft documents. Members of this committee were Dr. Gary A. Gill from Texas A&M University at Galveston, Dr. Donald B. Porcella from Environmental Science and Management, Dr. James Rytuba from the U.S. Geological Survey, and Dr. James G. Wiener from the University of Wisconsin-La Crosse. The following is an overview of some of the key documents reviewed by either the work group or the committee. Each document—the problem statement, surveys, sampling plan, and data collection report—was a step toward developing the *Final Conceptual Model Report* of mercury behavior in the Guadalupe River watershed.

PRELIMINARY PROBLEM STATEMENT

The *Preliminary Problem Statement* was an important first step in the development of the Guadalupe River Watershed Mercury TMDL. The purpose of this document is to provide a concise description of the current understanding of the processes or factors that are most relevant to controlling mercury in the watershed.

The *Technical Memorandum 1.2 Preliminary Problem Statement* is available on the Water District's website (www.valleywater.org) at:

http://www.valleywater.org/Water/Watersheds_-_streams_and_floods/Watershed_info_&_projects/Guadalupe/_Guadalupe_River_TMDL_project/index.shtm

SYNOPTIC SURVEY

The *Synoptic Survey* was designed to meet two primary objectives. The first objective was to provide a general view of mercury contamination in the watershed. To accomplish this objective, the survey included sampling and chemical analyses at 24 different locations over a wide spatial area, and used a consistent set of sampling and analytical methods. The second objective was to identify where key mercury transformations of solid phase mercury to bioavailable mercury occur in the Guadalupe watershed.

This report included a preliminary load estimate and extensive documentation of surveys of mining wastes in and downstream of the New Almaden Mining District. Among Tetra Tech's findings were that Alamitos Creek warranted additional mining waste field surveys, and that mercury is methylated in reservoirs and other impoundments (Tetra Tech 2003a). The mining waste survey findings are discussed below in Section 3.3. Together with the *Preliminary Problem Statement*, the findings were used to develop hypotheses for the Data Collection Plan.

The *Technical Memorandum 2.2 Synoptic Survey Report* is available on the Water District's Web site (www.valleywater.org) at the URL cited above.

ALAMITOS CREEK SURVEY

With the continent's largest mercury mine and a furnace yard on its banks, Alamitos Creek probably has the most mining waste of any creek in California and warranted its own survey. Most of the ore from Mine Hill, New Almaden's largest mine, was processed at the Hacienda Furnace Yard on Alamitos Creek just above the confluence with Deep Gulch Creek. Waste disposal practices largely consisted of piling the roasted ore (calcines) into creeks for winter rains to wash downstream. The findings are discussed below in Section 3.3.

The *Survey of Alamitos Creek from McKean Road to Almaden Reservoir* (Tetra Tech 2003b) provides extensive written and photographic documentation of mining wastes in Alamitos Creek.

The *Addendum to Technical Memorandum 2.2 Synoptic Survey Report, Survey of Alamitos Creek from McKean Road to Almaden Reservoir,* is available on the Water District's Web site (www.valleywater.org) at the URL cited above.

DATA COLLECTION PLAN AND REPORT

The Data Collection Plan (i.e., sampling plan) for the Guadalupe River watershed has two primary objectives. The first is to identify those data that are essential for the development of a TMDL for mercury in the Guadalupe River watershed. Each data requirement is discussed in terms of its use in the preparation of the TMDL and its contribution to the reduction of uncertainty in our understanding of the biogeochemical processes controlling mercury transport, fate, and bioavailability in the Guadalupe River watershed. The second objective is to develop and describe an efficient sampling plan for the collection of these data. The sampling plan describes the objectives for each major element, including hypotheses, identifies the parameters to be measured, and describes the overall sampling approach.

The scope of the proposed sampling did not include developing estimates of the volume of mining waste in the watershed or performing a geomorphic assessment. Both the Technical Review Committee and Guadalupe Mercury Work Group reviewed and commented on the draft sampling plan.

Tetra Tech conducted sampling (i.e., data collection) in the 2003-2004 wet season and 2004 dry season. The sampling yielded estimates of wet season loads and fish tissue data from impoundments, creeks, and the river, and revealed high rates of methylmercury production in Guadalupe and Almaden reservoirs during the dry season (Tetra Tech 2005a). **The *Data Collection Report* includes not only the results of these sampling**

efforts, but also results of hypothesis testing and comparisons with previously collected data. Because it includes such in-depth analysis, the more technically inclined readers of this TMDL report may wish to peruse the *Data Collection Report*.

The sampling results and findings formed the basis of the conceptual model and now provide the scientific basis for this TMDL and report. The Source Analysis and Linkage (Sections 4 and 6 herein) largely excerpt information from the *Data Collection Report* (as refined by the *Final Conceptual Model Report)*.

Both the *Technical Memorandum 5.2.3 Data Collection Plan* and the *Technical Memorandum 5.3 Data Collection Report* are available on the Water District's Web site (www.valleywater.org) at the URL cited above.

3.2 Final Conceptual Model

The problem statement, surveys, sampling plan, and data collection were each steps toward developing the *Final Conceptual Model Report* of mercury behavior in the Guadalupe River watershed (Tetra Tech 2005c.) The *Final Conceptual Model Report* includes:

- "Watershed characterization," which provides a general description of the watershed and is such essential background information that it is included herein;
- "Data summary," a succinct presentation of the data collection findings, although **Water Board staff urges those with a more technical interest in this TMDL report to read the *Data Collection Report***;
- "Estimated mercury loads," which form the TMDL source analysis (Section 4 herein); and
- "Conceptual model of mercury behavior in the Guadalupe River watershed," which is the basis for our Linkage (Section 6).

The *Final Conceptual Model Report* was completed under contract to the Water Board. Due to budget constraints, the previous version, the *Final Draft Conceptual Model Report*, was not submitted to the Technical Review Committee. Therefore, the Water Board will circulate the *Final Conceptual Model Report* for public review and comment concurrently with this report, and comments will be considered and reflected in the subsequent TMDL report. The *Final Conceptual Model Report* is available on the Water Board's Web site (www.waterboards.ca.gov) at:

http://www.waterboards.ca.gov/sanfranciscobay/guadaluperivermercurytmdl.htm

3.3 Watershed Description and System Characteristics

The "watershed characterization" section of the *Final Conceptual Model Report* (Tetra Tech 2005c) provides a general description of the landscape and special conditions of the watershed that this TMDL must address. Because the report provides such essential background information about interactions among the watershed's creeks, rivers, soils, climate, and mining activities, it is summarized herein.

TOPOGRAPHY

The headwaters of the Guadalupe River spring from the eastern Santa Cruz Mountains near the summit of Loma Prieta (elevation 3,790 feet). The Guadalupe River begins at the confluence of Alamitos and Guadalupe creeks, below Almaden Lake (the names Almaden Lake and Lake Almaden are used interchangeably in the watershed, on signage, and on maps), and flows 19 miles through heavily urbanized portions of San Jose, ultimately discharging into South San Francisco Bay through Alviso Slough (Figure 3.1). Three urban creeks—Ross, Canoas, and Los Gatos creeks—join the river as it flows toward San Francisco Bay. The Guadalupe River has a total drainage area of approximately 170 square miles south of Highway 237. Tides influence the lower reach of the river as it flows for five miles through Alviso Slough to San Francisco Bay. When development of the salt ponds in the South Bay began in 1866, lower river flows were diverted from their original course through Guadalupe Slough to Alviso Slough. There are no natural deep lakes in the watershed; all reservoirs and percolation ponds (i.e., former gravel quarries, including Almaden Lake) are engineered impoundments.

SUBWATERSHED DESCRIPTIVE TERMS

A number of key terms are used in this TMDL. The first term is "reference reservoir." In this case, the Guadalupe River's largest subwatershed is Los Gatos Creek, which is largely undeveloped in its headwaters above two reservoirs, Lake Elsman and Lexington Reservoir. Lexington Reservoir is readily accessible to the public (and for sampling), and due to the lack of mining in this subwatershed, was selected as the reference reservoir for the data collection and conceptual model development efforts.

Undeveloped and non-mining headwater areas for Calero, Alamitos, Guadalupe, and Los Gatos creeks are referred to as "background" areas, a second key term.

A third term, the "mining" area, refers to everything "in and downstream" of the New Almaden Mining District to the Guadalupe River, which begins at the confluence of Alamitos and Guadalupe creeks, below Almaden Lake (see Figure 4.1—"mining district" in dark green and "creeks with mining waste" in red). The mining district drains to Guadalupe and Alamitos creeks both above and below the reservoirs on these creeks (Guadalupe and Almaden reservoirs).

A fourth term defines the "urban" area as outside of the mining and background areas: Los Gatos Creek below Lexington Reservoir, and Ross and Canoas creeks, although lower portions of the Guadalupe and Alamitos creeks subwatersheds are urbanized.

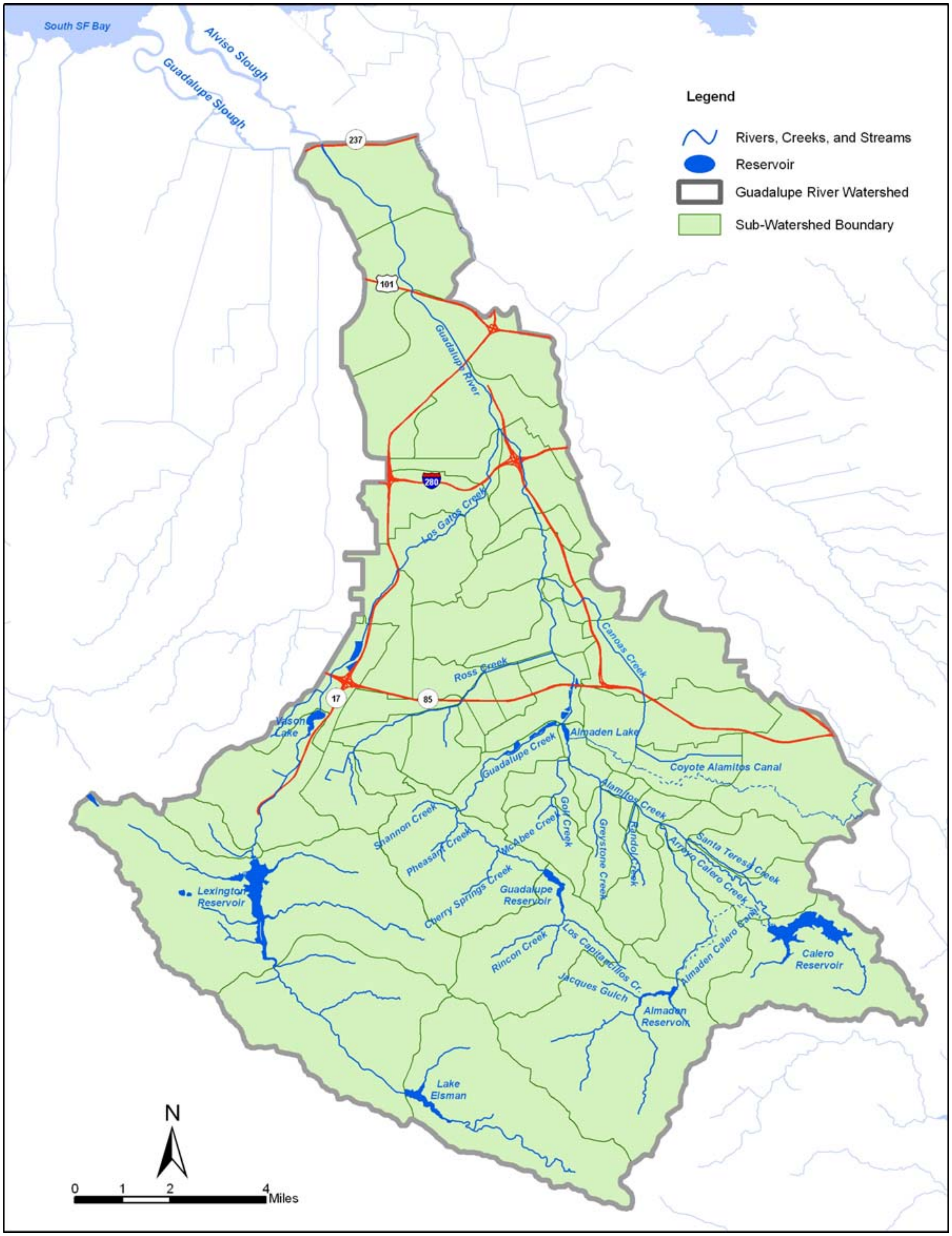

Figure 3.1 Major Water Bodies and Subwatersheds

Citation: Figure 2-2 in Final Conceptual Model Report (Tetra Tech 2005c)

CLIMATE

The watershed has a Mediterranean-type climate generally characterized by moist, mild winters and dry summers. About 85 percent of the measurable precipitation, rainfall, occurs between November and April. Mean annual precipitation ranges from 48 inches in the headwaters above the Guadalupe and Almaden reservoirs to 14 inches at the Central San Jose rain gage (station 131). Figure 3.2 shows the variation in rainfall between the upper and lower parts of the watershed. Temperatures range from below freezing in the mountains for a few days in winter to nearly 100°F in the hottest parts of the valley in the summer.

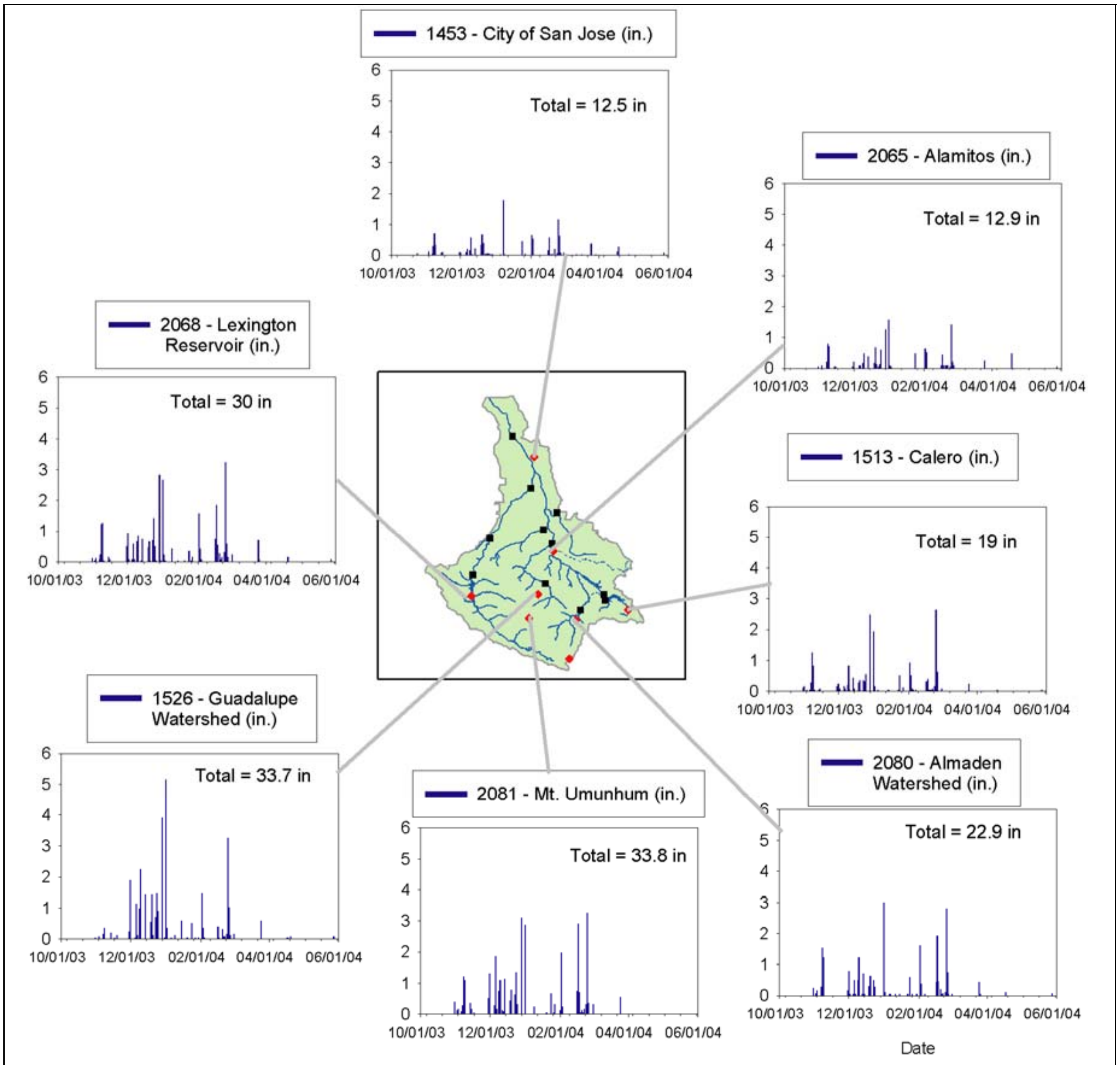

Figure 3.2 Measured Rainfall at Selected Rain Gages

Citation: Figure 2-3 in Final Conceptual Model Report (Tetra Tech 2005c)

HYDROLOGY – OVERVIEW

The watershed's Mediterranean-type climate produces different flow characteristics for the Guadalupe River in the dry and wet seasons. During the wet season, flows can be large and episodic, while in the dry season, flows are lower but more uniform. This pattern is also observed in the urban creeks, and differs with the more managed and less variable outflows from the reservoirs.

Figure 3.3 shows the flow gages used in the loading analysis for this watershed and flow data for each gage from October 2003 through May 2004. The long-term flow record from 1930 to 2002 comes from the old USGS gaging station at St. John's Street in San Jose, which was decommissioned due to channel modifications on April 30, 2003. USGS set up a replacement gaging station which began recording data on May 23, 2002 downstream near the San Jose Airport by Highway 101.

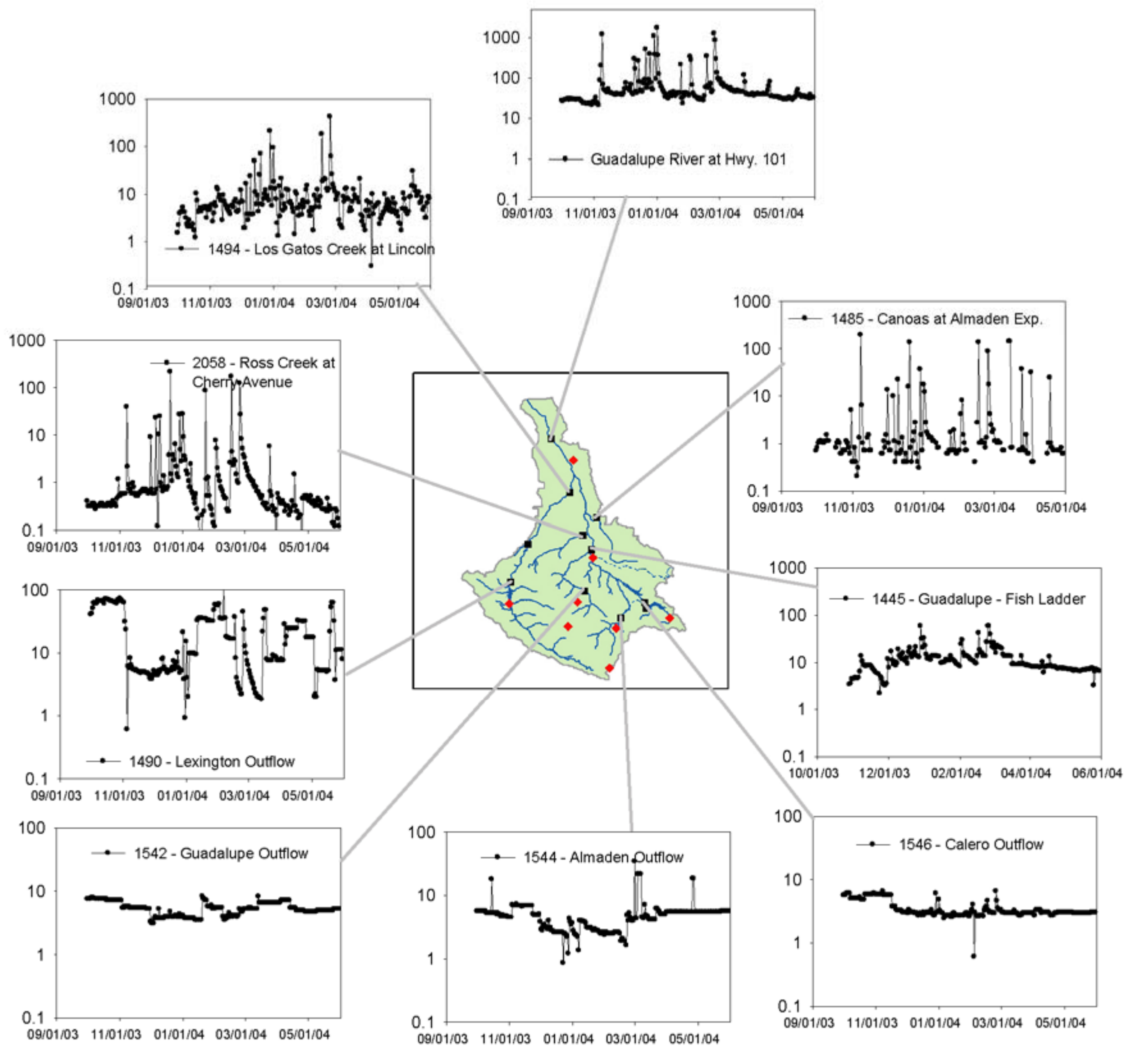

Figure 3.3 Measured Flow at Selected Gages

Citation: Figure 2-4 in Final Conceptual Model Report (Tetra Tech 2005c)

According to data from the older gage, the median flow in the Guadalupe River at St. John's Street was 4.5 cubic feet per second (cfs) between 1960 and 2002. The maximum daily flow was 7,870 cfs, while the average daily flow was 54.3 cfs over this same period of record. In the wet season, flows increase substantially during storm events. Between 1930 and 1998, peak flows at the old USGS gage varied from 125 cfs in 1960 to 10,500 cfs on March 10, 1995. The large flows, such as in 1995 and 1998, flooded downtown San Jose. In addition, flows in the lower river (just below the confluence with Los Gatos Creek) increased between the 1950s and the 1990s, as seen in Figure 3.4, partly as a result of urbanization.

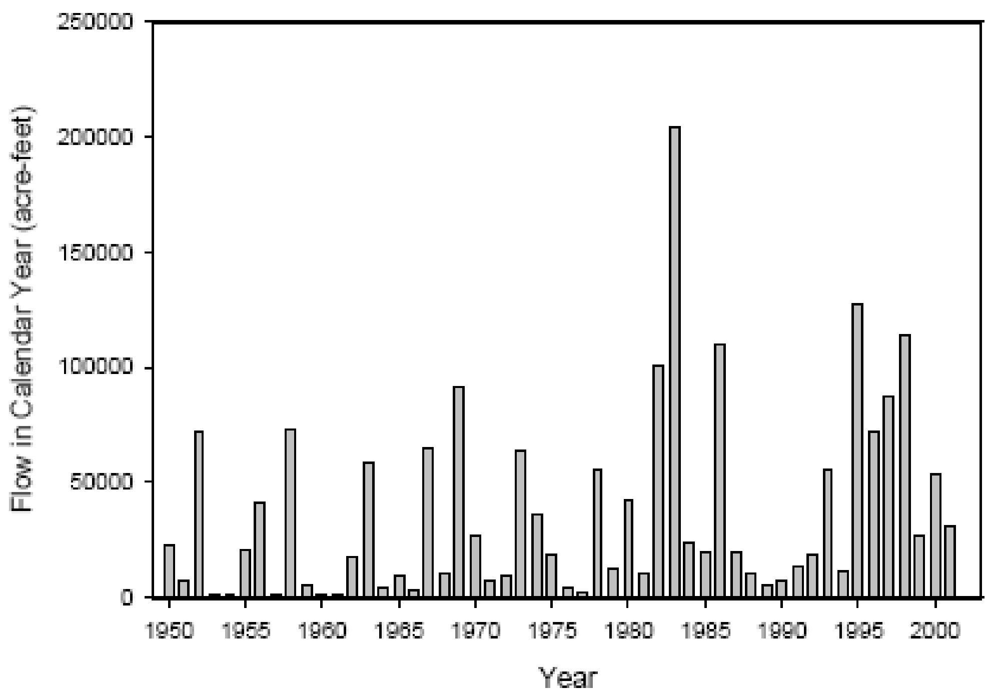

Figure 3.4 Flows in Guadalupe River

Citation: Figure 2-5 in Final Conceptual Model Report (Tetra Tech 2005c)

HYDROLOGY – MODIFICATIONS TO GUADALUPE RIVER

Interested parties have been modifying the river to control flooding since 1866, about the time the river was diverted from Guadalupe Slough to Alviso Slough. In 1963, local agencies channelized the lower Guadalupe River and added new levees along Alviso Slough out to South San Francisco Bay. In the early 1960s, they also rerouted Canoas and Ross creeks to flow into the Guadalupe River at different locations, and channelized the lower reaches of both creeks. More recently, highway engineers modified the river channel to facilitate construction of the 1975 Almaden Expressway. These modifications involved widening and moving about 3,000 feet of channel to the east and filling the original channel.

In the late 1970s, flood control engineers modified channels in the lower reaches of Randol, Greystone, and Golf creeks and built levees along Alamitos Creek from the

Harry Road bridge to the confluence with Almaden Lake. Some of these flood control projects may have decreased the extent of erosion along stream banks by installing bank protection and changing the energy gradient to reduce water velocity in fast-flowing segments. Others may have shifted erosion and associated sediments and mercury to elsewhere in stream corridors.

In 1999, in an effort to help fish migrate above the Alamitos Drop Structure, the Water District added a fish ladder below Almaden Lake. (A drop structure is one of many engineered structures designed to prevent channel incision or down-cutting by slowing down the water velocity; sediment accumulates behind structures that slow water).

Currently, three flood control projects are underway for the Guadalupe River. The Lower Guadalupe River Project is designed to increase the capacity of the river channel between Highway 101 and the Union Pacific Bridge in Alviso so that it can better handle a 100-year flood. The recently completed Downtown Project is designed to make channel improvements along a three-mile stretch from Interstate Highway 880 to Interstate Highway 280. The next project to be constructed is the Upper Guadalupe Project, which extends from I-280 to Blossom Hill Road along the Guadalupe River and from I-880 to U.S. Highway 101 along Ross and Canoas creeks. In 2004, the construction of a 3,000 cfs bypass channel to route flood flows underground, instead of through the natural river channel, was completed as part of the Downtown Project.

As mitigation for the Downtown Project, in 2001 the flood control agencies modified channels to improve stream habitat along a portion of Guadalupe Creek above its confluence with Alamitos Creek and below Masson Dam. Sediment was also removed from the creek in conjunction with this project and an earlier 1999 project involving construction of a fish ladder to bypass Masson Dam.

HYDROLOGY – MAINTENANCE

Flood control measures have included the removal of sediment for routine maintenance from the various drop structures and flood control structures from various parts of the Guadalupe River watershed (see Table 2-1 in *Final Conceptual Model Report).* The sediment removal activities confirm sediment accumulation in the tributaries. Sediment removal also removes mercury and prevents it from reaching San Francisco Bay. The Water District has also conducted stream bank protection projects to prevent erosion. For example, in the Guadalupe River watershed, engineers reworked about 13,000 linear feet of bank between 1986 to 1995. In the future, an additional 12,000 linear feet is slated for bank protection.

HYDROLOGY – RESERVOIRS

The watershed contains six water conservation and storage reservoirs (Figure 3.1). These reservoirs are Calero Reservoir on Calero Creek; Guadalupe Reservoir on Guadalupe Creek; Almaden Reservoir on Alamitos Creek; and Lake Elsman, Lexington Reservoir, and Vasona Lake on Los Gatos Creek. The three reservoirs in or near the former mining area, Almaden, Guadalupe, and Calero, were built in the creek canyons. Water is transferred to Calero Reservoir from Almaden Reservoir via the Almaden-Calero Canal and from the Central Valley Project (CVP). The volume of water retained in the reservoirs changes over the year, depending on precipitation, releases to the streams and evaporation. Vasona Lake is small, and spills when large storms occur, such as from

February 25-27, 2004. The other reservoirs rarely spill. Hydraulic modeling for Almaden Reservoir estimated that it would spill 6 percent of the time in 100 years. The four other reservoirs (besides Vasona) may spill in a 100-year flood event, but did not spill in 2003 or 2004.

GEOLOGY

The Guadalupe River watershed can be divided into three regions: 1) an upland region with bedrock outcrops, 2) an alluvial plain, and 3) a baylands region. Sedimentary and metamorphic rocks underlie most of the upland region, chiefly belonging to the Franciscan Formation. The formation includes common sedimentary rock types laid down on ancient seafloors, such as sandstone, shale, graywacke, limestone, and conglomerates, and common metamorphic and volcanic rocks, such as chert, serpentinite, greenstone, basalt, and schist. The river's alluvial plain—the area where it has long flowed, flooded, and deposited sediments—overlies a deep structural basin filled with up to 1,500 feet of Plio-Pleistocene and Quaternary unconsolidated alluvial materials. The alluvial deposits consist of well-graded, interbedded fine sands and silts with some gravels. Coarse gravel deposits are present in some reaches of the Guadalupe River where it flows across the ancestral channel, rather than in relocated channels. The portion of the watershed south of California State Highway 237 is underlain by Bay muds and fine-grained silts and clays.

For the following description of the uplands mineralized geology from the *Final Conceptual Model Report*, Tetra Tech relied primarily on the definitive tome: *Geology and Quicksilver Deposits of the New Almaden District, Santa Clara County, California, Geological Survey Professional Paper 360* (Bailey & Everhart 1964). Mercury mineralization in the South San Francisco Bay region is chiefly associated with serpentine intrusions into the Franciscan Formation, where the serpentine has been hydrothermally altered to silica carbonate. The naturally occurring mercury is principally in the form of the mineral cinnabar (mercury sulfide) in the silica carbonate. Because the rock types in the Franciscan Formation contain limestone and carbonates, soils derived from these deposits are alkaline, as is the runoff and mine seeps. The alkaline seeps are in contrast to other mining areas with acid-mine drainage, where the ore was associated with pyrites and other sulfide minerals, such as the gold mines in the Sierra Nevada and the New Idria Mine, where the mercury ore was formed due to hot springs solution deposits.

The Franciscan Formation and its related serpentine beds underlie the New Almaden Mining District of the upper Guadalupe River watershed. Silica carbonate bedrock is found in scattered areas of the New Almaden Mining District. To extract the ore from these rocks, miners dug and blasted deep underground shafts and tunnels. New Almaden is the deepest mercury mine in the world—just over 2,000 feet deep. Over 99 percent of the ore was extracted from underground. A small percentage was extracted via open cuts and surface mines in Mine Hill and around the Enriquita fault zone, which cuts through the Guadalupe Reservoir. In addition, a placer deposit (surface mineral deposit formed by mechanical and weathering processes) in thick gravels was found in the lower portion of Deep Gulch Creek. The average cinnabar content was an amazingly high 75 percent; this deposit was mined nearly to exhaustion.

Dispersed cinnabar may also be present in small, never-mined silica carbonate outcrops and in the remaining unexplored subsurface veins. Elevated total mercury levels have been found in soils overlying the silica carbonate deposits. Other rock types and locations containing some cinnabar include graywacke and shale in the Harry area and altered greenstone and tuff in the nearby upper Cora Blanca and Los Angeles areas of the New Almaden Mining District (all near Mine Hill).

Recently produced geologic maps for the Los Gatos area show isolated, small silica carbonate deposits in the Limekiln Canyon area of the Lexington watershed. There were no other potential mercury deposits identified in the Lexington Reservoir watershed. The Limekiln Canyon did not have elevated total or particulate mercury when sampled in the wet season of 2004 (Tetra Tech 2005a). Other silica carbonate deposits outside the New Almaden Mining District include small deposits along the route of the Almaden-Calero Canal near its discharge point to Calero Reservoir and in several places east of the reservoir, and in small areas near Cherry Creek on the west side of the reservoir. The Santa Teresa Hills between Canoas and Calero creeks also have limited areas with silica carbonate formations; mining operations were limited in these hills.

3.4 Mining Operations

An excellent and brief history of the New Almaden Mining District is presented in the same document mentioned above: *Geology and Quicksilver Deposits of the New Almaden District, Santa Clara County, California, Geological Survey Professional Paper 360* (Bailey & Everhart 1964). The introductory paragraph provides sufficient historical context with such great appeal to a wide range of interests that we repeat it here:

> *"The recorded history of the great quicksilver mines on the New Almaden property extends through a period of more than 100 years and encompasses the transition of California from a sparsely populated Mexican territory to a rich and populous State—a transition that profoundly affected the mines, the miners, and the methods of mining and reducing ores. Many of the resultant changes that influenced the development of quicksilver mining in the United States are emphasized, whereas others only mentioned briefly will be of interest to persons specializing in different fields of historical research. The geologists, for example, will perhaps be most interested in the changing concept of the ore gangue, from an early belief that it was an extremely wide fissure filling to the present realization that it is the silicified and carbonatized border of intrusive serpentine. The mining engineer will be more interested in the development of methods of mining. In the early days of the district, ore was carried in leather bags by Mexicans who climbed up notched poles from stopes hundreds of feet underground, whereas in later times the mines had powerful hoists and pumps; and such new techniques as the methods of timbering large horizontal stopes were first developed at the New Almaden mine. The metallurgist's interest will center around the development of quicksilver-reduction equipment from crude retorts made of gun barrels to modern Herreshoff and rotary furnaces. A lawyer will find much of interest in the fact that many laws concerning ownership of land formerly held under grant from a foreign country were first tested in the legal battles over the New Almaden property, and he might diligently follow the cases through State and district courts to the U.S. Supreme Court, and to a final settlement by international arbitration. A sociologist will perhaps be surprised to learn of a mining community, half Mexican and half American, wherein as early as 1870*

> *medicine, dentistry, entertainment, and educational lectures were provided for all through compulsory monthly payroll deductions. The history of the mine contains much of interest to a historian, especially the part relating to the critical Civil War period, when the quicksilver so necessary for the operation of the precious-metal mines of the Mother Lode and the Comstock Lode was nearly lost to the Northern States, through statewide feeling against the governmental seizure of the New Almaden mine ordered by President Lincoln."*

The appeal of New Almaden extends beyond the professions mentioned above (geologists, engineers, metallurgists, lawyers, sociologists, and historians) to fiction writers—notably novelist Wallace Stegner, who included a character based on his grandfather (the chief engineer at New Almaden Mining District at the height of production) in his epic novel *Angle of Repose*, winner of the 1972 Pulitzer Prize.

For this description of mining operations from the *Final Conceptual Model Report*, Tetra Tech again relied primarily on the Bailey & Everhart 1964 book. American Indians and Mexicans discovered the mercury deposits sometime before 1845. Mining in the New Almaden Mining District began in 1846 and continued until 1975. Figure 3.5 (an oversized figure at the end of this section) shows the major mine-related features in the upper Guadalupe River watershed.

The district produced a total of about 38.4 million kilograms of mercury; about 70 percent of this was mined before 1875, and about 80 percent before 1935. The early mined veins contained rich ore of up to 20 percent mercury, which was hand-sorted prior to processing in furnaces and retorts. In later years, the amount of mercury in the ore declined to 0.5 percent. The average grade of the ore processed over the 130-year life of the mines was nearly 4 percent, about a flask (76 pounds) of mercury per ton of rock. Most of the ore came from Mine Hill. Miners roasted the ore in retorts or furnaces at a temperature of 700°F – 1,200°F; the efficiency of the equipment varied, resulting in varying mercury content in the waste calcines. Large furnaces and retorts were present in Hacienda Yard and on Mine Hill, which generated significant waste deposits. On the banks opposite the Hacienda Yard stood an additional group of 14 small furnaces. Mining wastes from these retorts are still present on the slopes above Alamitos Creek. Retorts, used for shorter periods of time, were present at the Guadalupe, Senador, Enriquita, and San Mateo mines, resulting in smaller waste dumps at these sites. Small retorts, often portable units, were used at the Day Tunnel, upper Deep Gulch Creek, and San Cristobal Tunnel.

In accordance with common mining practices at the time, workers disposed of roasted mining wastes, called calcines, and other waste in or near the creeks so the materials would be transported downstream by winter flows. Guadalupe and Almaden reservoirs were constructed in 1935 in creek canyons containing calcines, and Guadalupe Reservoir reportedly covers a former processing area. Calcines and other mining wastes are still present along the banks of Alamitos Creek, and along Deep Gulch, Jacques Gulch, and Guadalupe Creek above Camden Avenue. The ore derived from silica carbonate deposits that can also be mined and roasted to produce cement, as it is in other areas of the world. Mining wastes are thus sometimes found as cemented deposits along the creek banks, particularly in long stretches of Alamitos Creek.

Field surveys conducted in the summer of 2003 as part of TMDL development identified the locations of reaches of the creeks—on readily accessible lands—where calcines were observed. Survey results appear in Figure 3.6 (a second oversized figure at the end of this section). Photographs of creek reaches with cemented and loose calcines, and other mining waste deposits, are shown in Figure 3.7 (the third oversized figure at the end of this section). For example, above the Hacienda Furnace Yard along Alamitos Creek, there are large non-cemented deposits of calcines on the slopes above the creek. Present on the banks are both early calcines composed of cobble-sized material and later calcines from the Scott furnaces composed of smaller material. Below the Hacienda Furnace Yard, in the reach of Alamitos Creek between Bertram Road and Harry Road, there are small calcine deposits along the banks, some of which are cemented and some loose. Many of these deposits are above the low flow channel. A small area of furnace dust is present under the Almaden Road Bridge. The survey also pinpointed numerous other waste sites: On Alamitos Creek downstream of Harry Road, there are areas with calcines, which are often cemented and limited in extent, such as six sites between Harry Road and Greystone Lane. Survey workers also observed calcines in the gravel bars along the entire reach of Alamitos Creek, and along the banks of upper Guadalupe Creek near the former Guadalupe Mine outside of the Almaden Quicksilver County Park. A partly vegetated mining waste pile is present at Hicks Flat on the opposite side of Guadalupe Creek from the main mine.

Mercury extraction operations in the area also extended to two much smaller mines in the Canoas Creek watershed: the Santa Teresa and Bernal mines. Mining companies operated the Santa Teresa Mine as an underground mine from three main adits (horizontal passages from surface to mine). In 1903, they installed a 40-ton Scott furnace, which produced nine flasks of mercury. The Bernal Mine was an underground mine with two shafts and an adit by 1902. In 1942, miners drilled two new holes, and in 1946, extended the adit and installed a retort. The mine was idle by 1947, and no evidence of mercury production was found in the abandoned retort.

Another mine called Hillsdale Mine lies outside the watershed boundary of the Canoas Creek (and hence Guadalupe River) watershed, but its operation may have affected the creek as a result of quarrying and regrading operations. The Hillsdale Mine produced 30 to 40 flasks in spring 1871, and small amounts up to 1874, idled from 1875 to 1892, and from 1907 to 1915, and produced another few flasks in 1915. Operators returned to rework Hillsdale from 1939 to 1946. Sometime later the Hillsdale mine area became a gravel quarry, and the quarry operators excavated part of Hillsdale Mine in the early 1980s . In the 1960s, engineers rerouted the lower portion of Canoas to enter the Guadalupe River farther upstream, and channelized its side slopes with concrete.

DEFINITION OF NEW ALMADEN MINING DISTRICT FOR TMDL

For the purposes of the Guadalupe River watershed mercury TMDL, the New Almaden Mining District is defined as the Los Capitancillos ridge and its extensions, and the processing areas on adjacent hillsides (Figure 4.1). Such processing areas, for example, include both sides of Alamitos Creek next to the Hacienda Furnace Yard, and mining waste piles at Hicks Flat. Notably different from historical descriptions, but important for the purposes of this TMDL, which addresses the entire watershed, Guadalupe Mine, located on an extension of Los Capitancillos Ridge, is included in the New Almaden Mining District.

As described above and extensively in the *Data Collection Report* (Tetra Tech 2005a), no mercury mining waste sources have been identified in the following areas of the watershed: the landscape along the route of the Almaden-Calero Canal near its discharge point to Calero Reservoir and several places east of the reservoir; small areas near Cherry Creek on the west side of the reservoir; the Santa Teresa Hills between Canoas and Calero creeks; and the Hillsdale Mine. Therefore, for the purposes of this TMDL, these areas are not included in the New Almaden Mining District.

NEW ALMADEN COMPARED TO CALIFORNIA'S OTHER MINES

In preparing the conceptual model and surveying the watershed, it was useful to compare the geology and landscape conditions of New Almaden with other California mercury and gold mines, and to examine data collected on their mercury output and pollution problems. One thing that California mercury and gold mines have in common is nearly all drain to San Francisco Bay. Three basic factors, apart from management of waste materials, which seems to be equally bad everywhere, influence the extent of the mercury pollution problem from these different mines: amount of production, the presence of alkaline or acid conditions associated with the mineral deposits, and methylmercury production.

The amount of mercury produced has not yet been reliably correlated to downstream concentrations of total mercury. In the *Final Conceptual Model Report*, Tetra Tech compared the mercury concentrations in runoff and creeks below various California gold and mercury mines. The highest total mercury concentrations in nanograms of mercury per liter of water (ng/l, parts per trillion) were (Tables 2-6 and 2-9, Tetra Tech 2005c):

1,040,000	Gambonini Mercury Mine, Walker Creek (tributary to Tomales Bay in western Marin County), collected by Water Board staff in a large storm event
110,000	New Almaden Mining District sample from Alamitos Creek collected by county parks staff in a storm event that occurred when the soil was already saturated
38,304	Downstream of (unspecified) gold mine
464	Guadalupe River sample collected by Tetra Tech during a storm in wet season 2004
191	New Almaden Mining District creek sample collected by Tetra Tech in a very small storm event in wet season 2004

The Gambonini Mercury Mine data were collected in a two-month period in 1998 with great precision during a large winter storm and resulted in an accurate load estimate of an alarming 82 kilograms of mercury discharged in these two months (Whyte & Kirchner 2000). None of the data from the other gold and mercury mines discussed above or in Section 2.2 of the *Final Conceptual Model Report* even approach the level of accuracy of the Gambonini Mercury Mine load study. Therefore, the available data are insufficient to support any conclusions based on the range of known mercury concentrations downstream of mines. Conclusions can be drawn, however, based on the relative size of the mines, their acid or alkaline conditions, and methylmercury production.

Between 1940 and 1970, there were seven active mercury mines operating in western Marin County, of which Gambonini was the largest and produced about 5,000 flasks (New Almaden produced 200 times more mercury than Gambonini——about 1.1 million flasks). All ore from West Marin was processed at Gambonini (most of the ore from New Almaden was processed at Hacienda Furnace Yard). Following major storms in 1982, the sediment dam that had contained the Gambonini mining wastes failed. USEPA reacted quickly to the 1998 load estimate by undertaking a Superfund cleanup action, completed within nine months. From 1999 to 2000, USEPA and the Water Board remediated a large part of the Gambonini Mine site. Remediation actions included the use of geotechnical engineering techniques and biostabilization practices to stabilize the waste piles. These are virtually the same measures the Santa Clara County Parks Department used in the Almaden Quicksilver County Park cleanup effort discussed below.

Acid mine drainage—which compounds mercury pollution problems with other pollutant issues—differs greatly among California mines as a result of local geology. Not only are highly acidic waters toxic to most living creatures, but acid dissolves much more mercury and other toxic metals out of the mining wastes than alkaline conditions. This results in higher concentrations of dissolved mercury which, under the right conditions, is readily methylated and bioaccumulated. In terms of mercury mines, the two major types of mercury deposits are silica-carbonate deposits and thermal springs. Thermal springs vary greatly in mineral content. Cinnabar is the dominant mercury form in both types, but secondary mercury compounds are more prevalent in thermal spring areas. Acid mine drainage is not as prevalent at mercury mines as at gold mines, since gold deposits are typically associated with larger quantities of iron sulfide minerals that generate sulfuric acid.

Methylmercury production and bioaccumulation are also important factors in this comparison of different California mines. Median annual methylmercury downstream of mercury mines and mineral springs in the Cache Creek watershed (in the Central Coast Range mineral belt) are commonly about 0.5 ng/l (Table B.1, *Cache Creek, Bear Creek, and Harley Gulch TMDL for Mercury*, November 2004), but much higher in some locations. For example, in summer most of the water in Sulphur Creek comes from mineral springs high in dissolved total mercury and reaches an astoundingly high 20 ng/l methylmercury. Mercury sources in Bear Creek are mining waste and natural springs, which produce high fish concentrations of up to 6 ppm in Sacramento pikeminnow. Mercury in 40 cm largemouth bass in Clear Lake is 0.6 ppm on average, where the highest open water methylmercury concentrations are 1.4 ng/l.

In contrast, methylmercury in creeks downstream of New Almaden ranged up to 0.2 ng/l in a reservoir tributary in the wet season, but methylmercury in the hypolimnion of Guadalupe Reservoir reached a stunning concentration of nearly 13 ng/l in the 2004 dry season. Not surprisingly, fish in Guadalupe Reservoir have the highest mercury concentrations in the watershed, up to 13 ppm, with an exceptionally high average concentration of 6.1 ppm in 40 cm largemouth bass.

In conclusion, New Almaden is of significant concern relative to California's other mercury and gold mines due to its much larger mining and methylmercury production and bioaccumulation. On the other hand, conditions at New Almaden are alkaline, hence the acid mine drainage problems associated with other mercury mines in the Coast Range do not occur at New Almaden.

3.5 Cleanup In and Downstream of New Almaden Mining District

CLEANUP OF ALMADEN QUICKSILVER COUNTY PARK

Santa Clara County purchased most of the New Almaden mines property in 1975. Pursuant to California Superfund authority, the Department of Toxic Substances Control (DTSC) issued a Remedial Action Order to the County in October 1987. The County undertook an extensive response, including site assessment, risk assessment, remedial design, and construction. The scope of this effort was at least equal to this TMDL's data collection and conceptual model effort. The five sites that presented the greatest threat human health from direct exposure were identified and cleaned up: Mine Hill, the Hacienda Furnace Yard, and the Senador, Enriquita, and San Mateo mines. While this effort went a long way toward addressing the most significant hazards to human health within the park, the issues of soil erosion and transport of mercury to water bodies and bioaccumulation were not addressed.

The County's major cleanup effort began in 1990. The County removed mercury-laden calcines and furnace dust piles around the main retort sites at Hacienda Yard, on top of Mine Hill, and near the Senador, Enriquita, and San Mateo mines, and then covered, re-graded, and re-vegetated the removal sites. The County placed most of the calcines in the San Francisco Open Cut on Mine Hill, where they too were covered with soil and revegetated. A two-foot soil cap was added over the remaining calcines at the Hacienda Furnace Yard. Calcines present on the opposite bank of Alamitos Creek from the Furnace Yard were not within the park and therefore were not addressed. The County buried those calcines removed from the Enriquita and San Mateo mines near the former retort sites.

The County also undertook erosion control measures on the steep slopes around the former furnaces and retorts. On the Hacienda Yard next to Alamitos Creek, workers installed a concrete cutoff wall and gabion and rock slope protection on the western bank. Cleanup proceeded to design specifications and visual confirmation of removal of mining wastes, but unlike most hazardous waste cleanup actions, no post-excavation samples were collected to confirm mercury concentrations.

More recently, observations from site visits to the former mines suggest that the calcine disposal areas within Almaden Quicksilver County Park are largely being protected from erosion by the vegetation and runoff control measures. Maintaining vegetation in this dry climate remains a challenge. Mining waste piles at former mines, such as near the Senador Mine, were seeded with grass, but the vegetative cover is thin, and active erosion is occurring in places. Gabions statewide have turned out not to be a long-term slope stabilization measure, and the upstream gabion at the Hacienda Furnace Yard is no exception to the rule—it is failing. These small maintenance problems will likely need to be addressed in future remedial actions under the TMDL.

REMAINING CLEANUP CHALLENGES IN NEW ALMADEN

Several contaminated locations within the Almaden Quicksilver County Park did not make it into the first substantial cleanup endeavor described above. The locations of known mine seeps and many remaining mining wastes are shown in Figure 3.6. Because the previous cleanup efforts were confined to the then-current park boundary, adjacent contaminated mining sites in the New Almaden Mining District were not sampled or remediated.

As previously discussed, calcines on the opposite bank of Alamitos Creek from the Hacienda Furnace Yard lie outside the park boundary, and thus remain to be addressed (two downstream sections are proposed to be addressed under the Natural Resources Damages Assessment cleanup action described below). Within the park, overburden piles remain near some of the mines, including the Providencia and Senador mines. Calcines and other mining wastes are present in Jacques Gulch, which discharges into Almaden Reservoir. They are also present in Deep Gulch, which discharges into Alamitos Creek. Both Jacques and Deep gulches are proposed to be addressed under the Natural Resources Damages Assessment cleanup action described below.

Other potential problem areas include the many miles of former mine roads in the park where mining wastes are evident in the larger cobble- and gravel-sized materials, which are actively eroding. Runoff in some of these areas could reach Jacques Gulch. Other old mine roads drain areas into both North Los Capitancillos Creek, which discharges into Guadalupe Reservoir, and directly into this reservoir. Mine seeps are present from former tunnels and adits, such as at the Day Tunnel and above Randol Creek, which both ultimately could reach Randol Creek, and then Alamitos Creek (also shown in Figure 3.6).

Figure 3.8 (an oversized figure at the end of this section) provides a summary, based on pre-remediation site assessments, of the total mercury concentrations in the Almaden Quicksilver County Park that were not removed or buried. If these areas erode into waters, they cause unacceptably high mercury loads.

PRE-CLEANUP SOIL MERCURY CONCENTRATIONS

Prior to remediation, mercury concentrations in the mining wastes within the boundaries of Almaden Quicksilver County Park ranged from 10 – 1,000 ppm; the median of 37 sites was 84 ppm. Sediment samples from Deep Gulch Creek had total mercury ranging from 2 – 590 ppm on a wet weight basis. Sediment samples from Alamitos Creek collected below the reservoir had total mercury ranging from 1.5 – 95 ppm on a dry basis. A tributary of Randol Creek had total mercury of 5.1 – 230 ppm on a wet weight basis. Guadalupe Creek above Camden Avenue was sampled from 1980 to 1989; here total mercury ranged from 0.04 – 70 ppm on a dry basis. These data illustrate the high mercury concentrations present in soils and sediment in the mining district prior to the remediation efforts.

POST-CLEANUP WATER MERCURY CONCENTRATIONS

Though the County did not collect any post-remediation soil mercury samples, some water data are available from the two sets of stormwater samples collected each year as required by the Industrial Stormwater National Pollutant Discharge Elimination System General Permit required for industrial activities, including active and inactive mines and mineral processing. The Santa Clara Parks and Recreation Department (SCPRD) stormwater data from 1994 to 2003 (presented in the *Final Conceptual Model Report*) are samples from creeks that drain the park. These data illustrate the high mercury concentrations remaining in stormwater post-cleanup.

Tetra Tech evaluated a subset of SCPRD's data, the more recent data from 2000 – 2003. The highest mercury concentrations (up to 4,000 ng/l) occurred in January 2000 at most sites when the suspended solids were relatively high (several hundred milligrams of sediment per liter of water [mg/L]) during a large storm event (total rainfall was 2.52 inches the day before sampling and 3.11 inches the day of sampling). The single highest total mercury concentration (110,000 ng/l) was detected in a sample from Alamitos Creek just below the Hacienda Furnace Yard (Site D) on February 25, 2004, when rainfall was 0.12 inches the day before sampling and 2.6 inches the day of sampling, which had especially high suspended solids (2,000 mg/L).

NATURAL RESOURCES DAMAGE(S) ASSESSMENT

Federal statutes establish liability for natural resources damages to compensate the public for injury, destruction, and loss of federal, state, and tribal resources and their services resulting from hazardous substance releases. Natural resource trustees are authorized to act under those statutes, on behalf of the public, to assess and recover natural resource damages and to plan and implement actions to restore natural resources and resource services injured or lost as a result of the releases. USFWS was the lead trustee for a recently settled Natural Resources Damage(s) Assessment (NRDA). The planned restoration projects, which will reduce mercury discharges, include: two 150-foot sections of Alamitos Creek on the bank opposite Hacienda Furnace Yard, a 300-foot section of Deep Gulch Creek, and two areas in Jacques Gulch (which drains Mine Hill to Almaden Reservoir). More information on the NRDA is available at:
http://www.fws.gov/pacific and
http://www.dfg.ca.gov/ospr/organizational/scientific/nrda/NRDA.htm

WATER DISTRICT MITIGATION, MAINTENANCE, AND RESTORATION PROJECTS

A half-mile stretch of Guadalupe Creek was restored as mitigation for the downtown San Jose flood control project (see "Hydrology – Modifications to Guadalupe River"). Restoration included removal of mercury-contaminated sediments and recreation of a meandering stream course with native vegetation. Sediment-removal maintenance activities undertaken by the Water District for flood control purposes also remove mercury-contaminated sediment (see "Hydrology – Maintenance" above). Some of the restoration projects undertaken by the Water District include fish passage improvements (see "Hydrology – Modifications to Guadalupe River") and have included removal of mercury-contaminated sediments.

The Water District was awarded a USEPA 319(h) nonpoint source pollution reduction grant for mercury load reductions. The Water District removed mercury-contaminated mining wastes at four sites on Alamitos Creek. They removed a total of 3,725 cubic yards of contaminated soil—permanently removing 165 kg of mercury from the watershed, and restored 2,570 square feet of riparian habitat by replanting the creek banks with native vegetation. Based on these projects, they produced a "*Stream-bank Repair Guidance Manual for the Private Landowner: Guadalupe and Alamitos Creeks,*" which will useful for local residents needing to stabilize their creek banks.

CLEANUP AND ABATEMENT ACCOUNT

The Water District submitted a request for $3 million in Cleanup and Abatement funds from the State Water Resources Control Board in August 2002. Funding is dispersed as it becomes available and upon approval of the State Water Board. Recently, the fund balance has increased, although several other requests submitted prior to the Water District's will be considered first.

Key Points

- California's New Almaden Mining District was the fifth-largest mercury mine in the world. Typical of its time (1845 – 1975), waste disposal practices largely consisted of piling the roasted ore (calcines) into creeks for winter rains to wash downstream. Consequently, downstream mercury methylation and bioaccumulation into fish is a significant problem relative to other mercury and gold mines in California.
- A strong scientific basis for this TMDL is provided by the many technical studies. We urge the more technically inclined readers of this TMDL report to read both the Data Collection Report and the Final Conceptual Model Report.
- The New Almaden Mining District is defined, for the purposes of this watershed-wide TMDL, as the Los Capitancillos ridge and its extensions and the processing areas on adjacent hillsides.
- Although progress has been made to clean up mercury from New Almaden, vastly more remains to be cleaned up in and downstream of the mining district.

4. Source Analysis

Mercury in the Guadalupe River watershed comes from mining waste, urban runoff, naturally occurring mercury in the soil, atmospheric deposition, and some other potential sources. Not every source contributes to every water body. Only water bodies receiving mining waste are included on the 303(d) list of impaired water bodies (SWRCB 2003). Table 4.1 (below) describes mercury sources to both impaired and non-impaired water bodies.

Table 4.1 Sources and Water Bodies

Impaired Water Body	Drains to	Source of Mining Waste	Other Mercury Sources
Calero Reservoir	Arroyo Calero Creek (1), then Alamitos Creek	Canal from Almaden Reservoir	Atmospheric deposition and background soil
Almaden Reservoir	Alamitos Creek	New Almaden Mine District	Atmospheric deposition and background soil
Alamitos Creek	Alamitos and Guadalupe creeks join below Almaden Lake[1] to become the Guadalupe River	New Almaden Mine District and Almaden Reservoir	Urban runoff, atmospheric deposition, and background soil
Guadalupe Reservoir	Guadalupe Creek	New Almaden Mine District	Atmospheric deposition and background soil
Guadalupe Creek	Guadalupe River	New Almaden Mine District and Guadalupe Reservoir	Urban runoff, atmospheric deposition, and background soil
Guadalupe River	South San Francisco Bay	Alamitos and Guadalupe creeks	Urban runoff, atmospheric deposition, and background soil

Note: [1]Not listed as impaired.

Non-Impaired Water Body	Sources (no mining wastes)
Upper Los Gatos Creek, Lake Elsman, and Lexington Reservoir	Atmospheric deposition and background soil
Los Gatos Creek below Lexington Reservoir, Vasona Lake, and percolation ponds	Urban runoff, atmospheric deposition, and background soil
Ross and Canoas Creeks	Urban runoff, atmospheric deposition, and background soil

The map in Figure 4.1 shows mining wastes discharged from the New Almaden Mining District in red, and urban runoff in brown. How these and other sources contribute to methylmercury production is an important concern, particularly in the dry season. Seasonal variations in source inputs and methylmercury production are discussed below.

The following sections (4.1 through 4.5) on wet season total mercury and dry season methylmercury loads are based on Section 4 of the *Final Conceptual Model Report* (Tetra Tech 2005c.) As described in Section 3 (Conceptual Model), the Santa Clara Valley Water District retained Tetra Tech, Inc., as technical consultants to develop the conceptual model of mercury in the Guadalupe River watershed. The mercury loading analysis presented in Sections 4.1 through 4.5 (below) was first presented in the *Data Collection Report* (Tetra Tech 2005a) and again in the *Final Conceptual Model Report* (Tetra Tech 2005c).

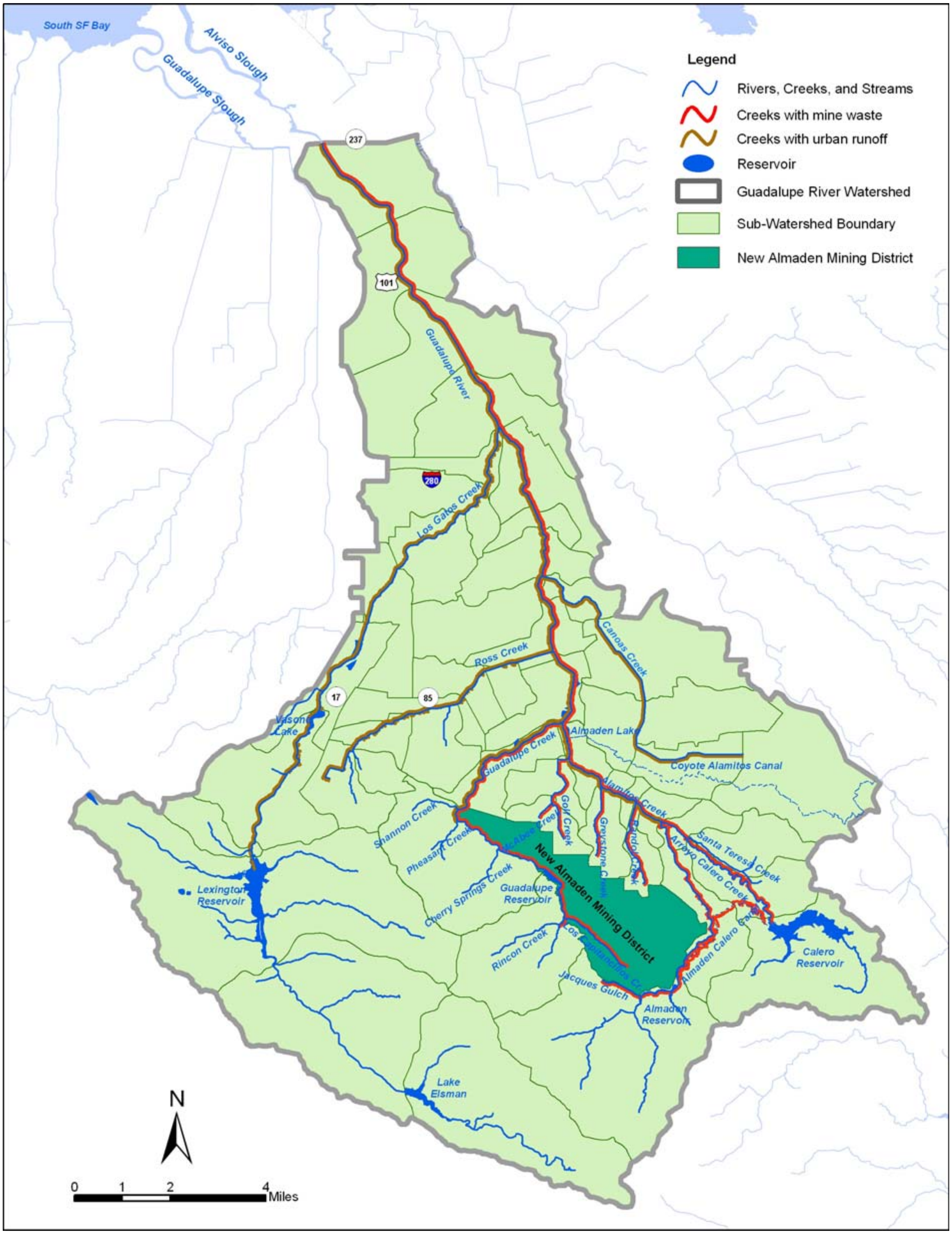

Figure 4.1 Locations of Primary Mercury Sources

Citation: prepared by Tetra Tech under contract to Water Board

Tetra Tech's estimates are based on the knowledge that whatever the source, once mercury enters the water column, most of it is bound to particles (see Section 6, Linkage Analysis). Therefore, the mercury loads can be quantified on the basis of sediment loads and mercury concentrations in suspended sediment (particulate mercury), as shown in Equation 4.1, which is used below to calculate the mining waste load.

Equation 4.1
Mercury Concentration in Water = (Particulate Mercury) x (Total Suspended Solids)

The following three equations are used in the methodology sections below to calculate each of the loads.

Equation 4.2
Daily Mercury Load = (Daily Flow) x (Mercury Concentration in Water)

Equation 4.3
Unit Area Mercury Load = (Seasonal Mercury Load) / (Representative Area)

Equation 4.4
Drainage Area Load = (Unit Area Mercury Load) x (Drainage Area)

Loads transported downstream from one water body to another can be estimated on the basis of mercury concentrations in water samples and flow volumes as shown in Equation 4.5.

Equation 4.5
Load of Mercury = (Volume of Water) x (Mercury Concentration in Water)

4.1 Methodology Overview: Wet Season Load Estimates

To develop the conceptual model, Tetra Tech assessed loads for the wet and dry seasons separately, based on the knowledge that most mercury transport occurs during the wet season, and most methylmercury production occurs during the warm, dry season. Tetra Tech focused a large part of the wet season data collection effort on measuring flow and mercury at different locations and different times in the watershed. Tetra Tech indirectly inferred loads transported from land surface to water from the measured concentrations, and from modeled and gaged flows in streams in the watershed. Using sub-watersheds affected principally by one source, they estimated the contribution of the wet season unit area for mining waste, urban runoff, and background (soil and atmospheric deposition) in units of micrograms of mercury per square meter of land surface ($\mu g/m^2$). Tetra Tech also indirectly inferred loads from multiple sources transported downstream (i.e. from one water body to another) by relationships between flow and concentrations of total mercury, dissolved mercury, and methylmercury, in units of grams per day (g/d).

For the warm, dry season, Tetra Tech focused sampling efforts on measuring mercury at different depths in the two reservoirs most affected by mining (Almaden and Guadalupe). Typical of large, deep water bodies, these two reservoirs undergo thermal stratification in the dry season. Stratification results in an upper warm layer (epilimnion), a cool lower layer (hypolimnion), and a transitional zone between them (thermocline). Depth measurements from surface to thermocline, and from thermocline to bottom, coupled with bathymetry, yielded epilimnion and hypolimnion volumes over the dry season.

Concentration, multiplied by volume, yields mass. The data were used to infer methylmercury production in units of g/d.

For the purpose of this analysis, Tetra Tech estimated all loads as net loads (sources minus losses) at the point of interest. Examples of losses include deposition of mercury-laden sediment on creek and river floodplains, banks, and bottoms; and photodemethylation. (Deposition may result in a temporary loss, as nearly all sediments are likely to be scoured and transported at a later date; photodemethylation of methylmercury to gaseous inorganic mercury may be a permanent loss, however, as the mercury can then be transported out of the watershed.)

METHODOLOGY FOR MINING WASTE LOADS

The mining waste load calculated herein includes mercury from three sources: mining waste, atmospheric deposition, and naturally occurring mercury in soil. The Los Capitancillos Creek watershed was used to estimate the unit area mining waste load using the following steps.

1) Select Representative Area
   Tetra Tech selected Los Capitancillos Creek to estimate the unit area mining waste load because its watershed is almost entirely within the New Almaden Mining District.

2) Collect Available Data on Flows, Total Suspended Solids, and Mercury
   In developing this load, Tetra Tech had little actual flow data to draw on. There are no flow gages in the New Almaden Mining District. In the absence of actual data, Tetra Tech used a hydrologic model to estimate daily wet season flows in creeks draining the mining district. This model, called the Soil and Water Assessment Tool Version 2000 (SWAT 2000), was developed by the U.S. Department of Agriculture, Agricultural Research Service, and the Texas A&M Spatial Sciences Laboratory (Tetra Tech 2005a). SWAT is a long-term, continuous watershed simulation model. Widely used in the United States, this model simulates land cover impacts together with weather, soil, topography, and vegetation data. Because of the absence of flow gage information at any of the subwatersheds modeled, the SWAT model could not be calibrated, which is considered a source of uncertainty (see Section 4.3).

   Data on total suspended solids and mercury in Los Capitancillos Creek were collected on two dates: March 3 and 26, 2004. Because this is such a small data set, Tetra Tech used total suspended solids and mercury data from all New Almaden Mining District creeks sampled in the wet season to undertake the next steps in developing the mining waste loads (see "creeks draining historic mercury mining areas" section of Table 6-1 in *Data Collection Report* (Tetra Tech 2005a)). These district-wide samples were collected from March 2 to April 23, 2004. However, the last large storm (and high creek flow) of the season occurred in late February. Lack of high flow sample data may lead to an underestimation of the load, which is discussed in the uncertainty section (4.3), below.

3) Relate Flow to Total Suspended Solids
   Tetra Tech developed a linear regression relationship between daily modeled flow

for Los Capitancillos Creek and available total suspended solids data from all creeks in the mining district; see Figure 6-1 in *Data Collection Report* (Tetra Tech 2005a). This regression was applied to the modeled daily flows to estimate daily total suspended solids concentrations in the creek. Because data was only available from smaller storms, the regression was applied to higher creek flows than those sampled (i.e., extrapolated beyond the data set). This source of uncertainty in the load estimates is discussed in Section 4.3, below.

4) Relate Total Suspended Solids to Total Mercury
   The average particulate mercury concentration in creeks in the New Almaden Mining District in these 2003-2004 wet season samples was 17.5 milligrams of mercury per kilogram of soil (mg/kg, parts per million, ppm), see Table 4.2. From Equation 4.1, average particulate mercury multiplied by estimated daily total suspended solids (from Step 3), yields estimated average daily total mercury concentrations.

5) Relate Total Mercury to Dissolved Mercury and Methylmercury
   Tetra Tech developed linear regression relationships between estimated concentrations of total mercury (from Step 4) and both dissolved mercury and methylmercury; see Figure 6-5 in *Data Collection Report* (Tetra Tech 2005a). These regressions were applied to the estimated daily total mercury (from Step 4) to estimate daily concentrations of dissolved mercury and methylmercury.

6) Calculate Wet Season Unit Area Loads
   Loads are developed by multiplying flow by mercury concentration (Equation 4.2). Modeled daily flow (from Step 2), multiplied by estimated daily concentrations of total mercury (from Step 4) and dissolved mercury and methylmercury (from Step 5), yields daily loads. The sum of the product of daily loads yields the seasonal load for each type of mercury measured: total mercury, dissolved mercury, and methylmercury. The unit area mining waste load was calculated (see Equation 4.3) by dividing the seasonal load (for total mercury, dissolved mercury, and methylmercury) by the area of the Los Capitancillos Creek watershed, yielding a unit area mining waste load of 54.5 $\mu g/m^2$ for total mercury, 14.8 $\mu g/m^2$ for dissolved mercury, and 0.11 $\mu g/m^2$ for methylmercury in the 2003-2004 wet season.

Based on the methodology above, the 2003-2004 wet season unit area loads developed for Los Capitancillos Creek are more than 40 times greater than background total and dissolved mercury loads, and about 10 times greater than background methylmercury loads.

In the load diagrams in Section 4.2 (Figures 4.2 through 4.4), arrows pointing to (not between) each water body indicate loads calculated from Equation 4.4. (Arrows pointing from one water body downstream to the next are discussed below in "Methodology for Loads Transported Downstream"). Each drainage area is assigned a type (mines, urban runoff, or background), and its area multiplied by its unit area load. These drainage area loads come from multiple sources, which are indicated where applicable. For example, in Figure 4.2 a large portion of the New Almaden Mining District, which drains to Alamitos Creek between the reservoir and Calero Creek, contributed an estimated load of 120 grams of mercury from mining waste, atmospheric deposition, and naturally occurring mercury in soil. In this same wet season, the area on the opposite side of Alamitos Creek contributed an estimated load of 9.6 grams from background sources (atmospheric deposition and naturally occurring mercury in soil), and 1.7 grams from urban sources as discussed at the end of "methodology for urban runoff loads."

Table 4.2 Mining Waste Particulate Mercury

Sample ID	Total Suspended Solids (TSS; mg/l)	Particulate Mercury (ng/g)	Particulate Mercury (mg/kg)
Citation: Table 3-3 (Tetra Tech 2005a)			
Mine Hill Tributaries			
E1-6	2.4	29,463	
E1-7	0.4	61,257	
E1-7	0.4	46,725	
North Los Capitancillos Creek			
E1-9	3.2	2,128	
E1-9A	18.9	1,421	
E1-9B	18.4	630	
Citation: Table 3-10 (Tetra Tech 2005a)			
Deep Gulch Creek			
E2-8	1.1	7,190	
Greystone Creek			
E2-15	2.8	7,786	
Randol Creek			
E2-16	1.1	1,152	
Average:		17,528	17.5

METHODOLOGY FOR URBAN RUNOFF LOADS

The load calculated herein includes mercury from three sources: urban runoff, atmospheric deposition, and naturally occurring mercury in soil. The Ross Creek watershed was used to estimate the unit area urban runoff load using the following steps:

1) Select Representative Area
Tetra Tech selected the Ross Creek watershed to estimate the unit area urban runoff load because this watershed is almost entirely urbanized and has no history of mining activities.

2) Collect Available Data on Flows, Total Suspended Solids, and Mercury
Tetra Tech obtained wet weather daily flows from the gage near the downstream end of Ross Creek, but little data on total suspended solids and mercury in the creek was available. Because this is such a small data set, Tetra Tech added total suspended solids and mercury data from other creeks draining similar urban areas, and with no mining history, to its limited data from Ross Creek to develop the

waste loads for urban runoff (see Table 6-1 in *Data Collection Report* (Tetra Tech 2005a). The samples were collected from a wide range of storm and flow events from February 27 to April 20, 2004.

3) Relate Flow to Total Suspended Solids
This is the same as step 3 for mining waste; Tetra Tech developed a linear regression relationship between daily measured flow and available total suspended solids data (see Figure 6-1 in *Data Collection Report* (Tetra Tech 2005a)). This regression was applied to the measured daily flows to estimate daily total suspended solids concentrations.

4) Relate Total Suspended Solids to Total Mercury
Tetra Tech developed a linear regression relationship between daily estimated total suspended solids and measured total mercury (see Figure 6-4 in *Data Collection Report* (Tetra Tech 2005a)). This regression was applied to estimated daily total suspended solids concentrations (from Step 3) to estimate daily total mercury concentrations.

5) Relate Total Mercury to Dissolved Mercury and Methylmercury
This is the same as step 5 for mining waste; Tetra Tech developed linear regression relationships between measured concentrations of total mercury and both dissolved mercury and methylmercury (see Figure 6-5 in *Data Collection Report* (Tetra Tech 2005a)). These regressions were applied to estimated daily total mercury (from Step 4) to estimate daily concentrations of dissolved mercury and methylmercury.

6) Calculate Wet Season Unit Area Loads
Loads are developed by multiplying flow by mercury concentration (Equation 4.2). Measured daily flow (Step 2), multiplied by estimated daily concentrations of total mercury (Step 4) or dissolved mercury and methylmercury (Step 5) yields daily loads. The sum of the product of daily loads yields the seasonal loads for total mercury, dissolved mercury, and methylmercury, respectively. Tetra Tech calculated the unit area urban runoff load using Equation 4.3 by dividing the seasonal load (for total mercury, dissolved mercury, and methylmercury) by the area of the Ross Creek watershed, yielding unit area urban runoff loads of 1.6 $\mu g/m^2$ for total mercury, 0.61 $\mu g/m^2$ for dissolved mercury, and 0.02 $\mu g/m^2$ for methylmercury.

Tetra Tech multiplied these unit area loads by the corresponding urban drainage area (Equation 4.4) to calculate the estimated urban runoff loads discharged to creeks below reservoirs, urban creeks (Canoas and Ross creeks), and the Guadalupe River. By comparing the background (below) and urban runoff unit area total mercury loads of 1.16 and 1.6 $\mu g/m^2$ respectively in 2003-04 wet season, it appears that urban sources contributed about 25 percent of the total mercury load from urbanized areas, while the remaining 75 percent came from atmospheric deposition and naturally occurring mercury in soil. However, this method underestimates the urban runoff contribution because it does not account for first flush mercury loads in urban runoff, which are significant (Soller et al. 2003).

In the load diagrams in Section 4.2 (Figures 4.2 through 4.4), each drainage area is assigned a type (mines, urban runoff, or background), and its area multiplied by its unit area load. These drainage area loads are from multiple sources, which are indicated where applicable. For example, in Figure 4.2, the urbanized portion of the Alamitos Creek subwatershed between the reservoir and Calero Creek contributed an estimated load of 1.7 grams of mercury in the 2003-2004 wet season from urban runoff, atmospheric deposition, and naturally occurring mercury in soil. In this same wet season, the rural portion of this subwatershed outside of the New Almaden Mining District contributed an estimated load of 9.6 grams from background sources (atmospheric deposition and naturally occurring mercury in soil).

METHODOLOGY FOR BACKGROUND LOADS

The background load was calculated in a manner similar to that for the urban runoff load. The background load is from two sources: naturally occurring mercury in soil and atmospheric deposition. The Soda Spring watershed was used to estimate the unit area background load using the following steps:

1) Select Representative Area
   Tetra Tech selected the Soda Spring watershed to estimate the unit area background load because this watershed has practically no development and no mercury mines.

2) Collect Available Data on Flows, Total Suspended Solids, and Mercury
   Little flow, total suspended solids, and mercury data currently exists for background areas, where no gages have been installed to date. Therefore, Tetra Tech estimated daily wet season flows in Soda Spring using the SWAT 2000 model (see "Methodology for Mining Waste Loads" above). Tetra Tech then added total suspended solids and mercury data from other creeks draining similar undeveloped background areas and with no mining history to its limited data from Soda Spring to develop the background load (see Table 6-1 in *Data Collection Report* (Tetra Tech 2005a)). The samples were collected from March 2 to April 14, 2004. However, the last large storm (and high creek flow) of the wet season occurred in late February. Lack of high flow sample data is discussed in the uncertainty section (4.3) below.

3) Relate Flow to Total Suspended Solids
   This is the same as step 3 for mining waste and urban runoff; Tetra Tech developed a linear regression relationship between daily modeled flow and available total suspended solids data (see Figure 6-1 in *Data Collection Report* (Tetra Tech 2005a)). This regression was applied to the modeled daily flows to estimate daily total suspended solids concentrations. Because data was only available from smaller storms, the regression was applied to higher creek flows than were sampled (i.e., extrapolated beyond the data set). This source of uncertainty in the load estimates is discussed in Section 4.3 below.

4) Relate Total Suspended Solids to Total Mercury
   This is the same as step 4 for urban runoff; Tetra Tech developed a linear regression relationship between daily estimated total suspended solids and measured total mercury (see Figure 6-4 in *Data Collection Report* (Tetra Tech

2005a)). This regression was applied to the estimated daily total suspended solids concentrations (from Step 3) to estimate daily total mercury concentrations.

5) Relate Total Mercury to Dissolved Mercury and Methylmercury
   This is the same as step 5 for mining waste and urban runoff; Tetra Tech developed linear regression relationships between measured concentrations of total mercury and both dissolved mercury and methylmercury (see Figure 6-5 in *Data Collection Report* (Tetra Tech 2005a)). These regressions were applied to the estimated daily total mercury (from Step 4) to estimate daily concentrations of dissolved mercury and methylmercury.

6) Calculate Wet Season Unit Area Load
   Loads are developed by multiplying flow by mercury concentration (see Equation 4.2). Modeled daily flow (Step 2), multiplied by estimated daily concentrations of total mercury (Step 4) or dissolved mercury and methylmercury (Step 5) yields daily loads. The sum of the product of daily loads yields the seasonal loads for total mercury, dissolved mercury, and methylmercury. The unit area background load was calculated (Equation 4.3) by dividing the seasonal loads (total mercury, dissolved mercury, and methylmercury) by the area of the Soda Spring watershed, yielding unit area background loads of 1.16 $\mu g/m^2$ for total mercury, 0.33 $\mu g/m^2$ for dissolved mercury, and 0.012 $\mu g/m^2$ for methylmercury.

Rainfall in the vicinity of Lexington Reservoir (including Soda Spring) was approximately 30 inches from October 2003 through May 2004. The background unit area loads were scaled proportionally to the amount of rainfall in each location, which was as high as 48 inches in the headwaters above Guadalupe and Almaden reservoirs. Tetra Tech multiplied the resulting unit area loads by each drainage area (Equation 4.4) to calculate the estimated background (soil and atmospheric deposition) loads discharged to each water body in the watershed.

METHODOLOGY FOR LOADS TRANSPORTED DOWNSTREAM

Tetra Tech estimated loads from multiple sources transported downstream from one water body to another using daily gaged flow and measured concentrations of total mercury, dissolved mercury, and methylmercury (Equation 4.5). Linear regressions were developed using gaged flow and measured mercury concentrations. These were applied to the daily wet season flows to estimate daily total mercury, dissolved mercury, and methylmercury concentrations. Daily flow, multiplied by daily concentrations, yields daily loads, which were summed to arrive at the seasonal total load.

By design, reservoirs contain a substantial amount of storage, and because their outflows are controlled, it is likely that mercury concentrations in their outlets are less variable than in creeks, especially during the wet season. For this reason, loads discharged from reservoirs were computed in a manner simpler than that applied to streams: Gaged outflows were multiplied by the wet season average mercury concentration.

An exception was made for transport from Almaden Reservoir to Calero Reservoir because, unlike the other discharges, the canal flows only part of the time. Tetra Tech multiplied the average daily wet season flow of 7.1 cubic feet per second (cfs) by the average concentration (measured at the outlet of the Almaden-Calero Canal) to obtain the estimated seasonal load of total mercury, dissolved mercury, and methylmercury.

ATMOSPHERIC DEPOSITION LOADS

As mentioned above, loads from atmospheric deposition are included in the background loads. Tetra Tech provided the following information regarding atmospheric deposition in Section 4.1.1 of the *Final Conceptual Model Report* (Tetra Tech 2005c). Atmospheric deposition includes wet and dry deposition, and transport of past dry deposition in stormwater runoff from land surface to water bodies. Tetra Tech estimated the atmospheric deposition input of total mercury as a daily load using wet and dry deposition data collected by the San Francisco Estuary Institute (SFEI) at various locations around San Francisco Bay. Tetra Tech estimated wet deposition using a rainfall concentration of 9.7 nanograms of mercury per liter of water (ng/l), a rainfall amount of 48 inches in the watersheds above the reservoirs, and a rainfall amount of 14 inches for the rest of the watershed. Annual wet deposition was estimated as 12 micrograms per square meter per year ($\mu g/m^2/yr$) in the upper watershed, and 3.4 $\mu g/m^2/yr$ in the lower watershed. The annual dry deposition was estimated as 19 $\mu g/m^2/yr$ throughout the system. Thus, the total deposition is approximately 30 $\mu g/m^2/yr$.

Tetra Tech noted that only a small portion (about 5 percent as supported by recent literature review) of atmospheric deposition is exported from land into waters. Tetra Tech rounded the estimated background unit area load of total mercury to one significant digit, 1 $\mu g/m^2$, which is 3 percent of the 30 $\mu g/m^2/yr$ from atmospheric deposition. The background unit area load includes mercury from two sources: atmospheric deposition and naturally occurring mercury in soil. It is not possible from this data set to determine what proportion of the background load is from atmospheric deposition.

4.2 2003-2004 Wet Season Loads

This section is taken from Section 4.3 of the *Final Conceptual Model Report* (Tetra Tech 2005c). Total mercury, methylmercury, and dissolved methylmercury wet season loads from October 1, 2003, through May 31, 2004, for the major water bodies in the Guadalupe River watershed are shown in graphic form in Figures 4.2 through 4.4. The wet season loads were calculated for the following sources: background (naturally occurring mercury in soil and atmospheric deposition combined), mines (mining waste, naturally occurring mercury in soil, and atmospheric deposition combined), and urban (urban runoff, naturally occurring mercury in soil, and atmospheric deposition combined). Not every source contributes to every water body (e.g., mining wastes discharged from the New Almaden Mining District are shown in red on Figure 4.1).

For total mercury loads, shown in Figure 4.2 and Table 4.3, all reservoir outflows appear to be of roughly the same magnitude, except Calero Reservoir. Although concentrations flowing out of Lexington Reservoir are lower than from Guadalupe and Almaden reservoirs, the low concentration is counterbalanced by the substantially larger volume of outflows, which results in nearly equal loads from Lexington Reservoir outside the mining district as compared to the two reservoirs (Guadalupe and Almaden) immediately downstream from the mining district.

Farther downstream, the largest loads to Guadalupe River originate from Alamitos Creek, followed by Los Gatos and Guadalupe creeks. Alamitos Creek loads, upstream of Calero

Creek, are substantially higher than Almaden Reservoir outflow loads, indicating the mobilization of internal sediment loads. Although the Los Gatos Creek watershed does not contain any mines, the relatively high loads are a consequence of its larger watershed, and therefore larger background load, compared to Guadalupe Creek.

The 2003-04 wet season loads exiting the Guadalupe River to San Francisco Bay (10,000 g) are far higher than the total loads entering the river from all its tributary creeks and from its watershed (800 g). This is a strong indication of uncertainties in the upstream contributing loads, in loads from the highly urbanized area, and in the mobilization of internal sediment loads. Uncertainties in loads are discussed in more detail below.

Table 4.3 Wet Season Total Mercury Loads (10/01/03 – 05/31/04)

Sources	Annual Load (g)	Total Annual Load (g)	Uncertainty
Mining waste (includes atmospheric deposition and naturally occurring mercury in soil)			
New Almaden Mining District (NAMD) [1] Creeks Draining to Guadalupe Reservoir	220		(3, 4)
NAMD Creeks Draining to Almaden Reservoir [2]	190		(4)
NAMD Creeks Below Reservoirs	465		
Total		875	
Urban runoff, atmospheric deposition, and naturally occurring mercury in soil			
NAMD Creeks Below Reservoirs	27		
Urban Creeks	115		(5)
Guadalupe River	89		
Total		231	
Table 4.3 continued on next page			
Background (atmospheric deposition and naturally occurring mercury in soil)			
NAMD Creeks Draining to Guadalupe Reservoir	20		
NAMD Creeks Draining to Almaden Reservoir	28		
Calero Reservoir	14		
Lexington Reservoir	110		
NAMD Creeks Below Reservoirs	45		
Urban Creeks	62		
Guadalupe River	41		
Total		320	

Table 4.3 Wet Season Total Mercury Loads (10/01/03 – 05/31/04)

Notes:

1) A substantial portion of the mining waste load to reservoirs is accumulated as sediment in the reservoirs; in the 2003-2004 wet season exports from Guadalupe and Almaden reservoirs to NAMD creeks below reservoirs were 150 g and 110 g, respectively.

2) 190 g of mercury were transported from Almaden Reservoir via the Almaden-Calero Canal to Calero Reservoir; 28 g were exported from Calero Reservoir to Calero Creek.

3) The load estimates for the upper watershed are biased low because they are based on sampling conducted during small storm events. Infrequent high-rainfall-intensity storms result in much higher loads. Based on stormwater sampling results from Almaden Quicksilver County Park on February 25, 2004, the mercury load to Guadalupe Reservoir was 490g in one day, nearly twice the estimated annual total.

4) The dissolved mercury load estimates are based on sampling conducted during small storm events. Dissolved mercury in samples from NAMD creeks ranged from 15 percent to 60 percent of total mercury. However, in a large storm event on February 25, 2004, dissolved mercury ranged from 0.4 percent to 12 percent in stormwater samples from Almaden Quicksilver County Park (see calculation in Appendix B).

5) The load estimates for urban runoff did not include samples from storm drains. Mercury concentrations in urban creeks ranged from 2.0 to 29.8 ng/l, and in Guadalupe River ranged from 14.5 to 464.4 ng/l (TetraTech 2005a). Mercury concentrations in samples from storm drains collected between 1997-1999 ranged from 23 to 1,370 ng/l (Soller et al. 2003).

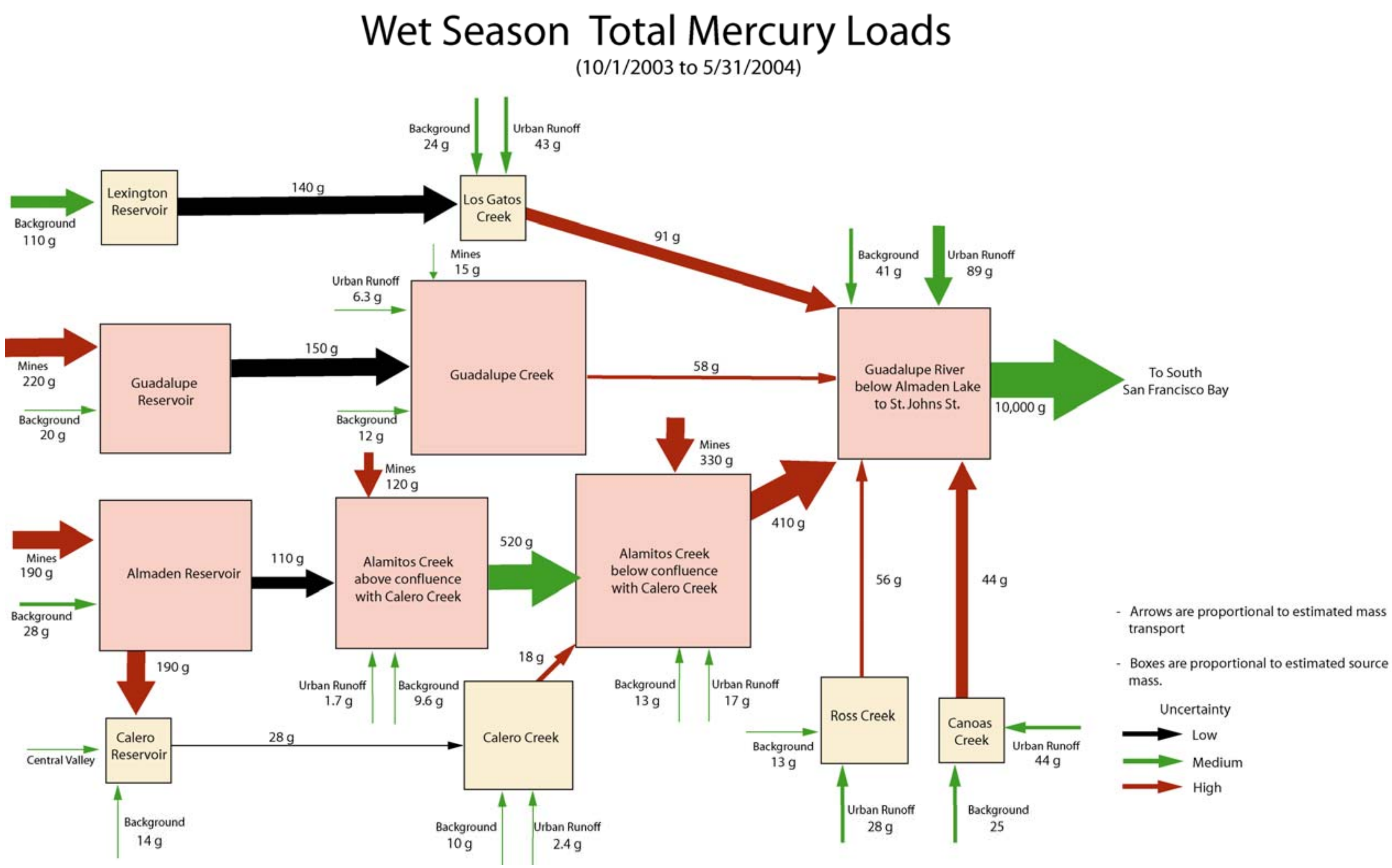

Figure 4.2 Wet Season Total Mercury Loads

Citation: Figure 4-1 in Final Conceptual Model Report (Tetra Tech 2005c)

For methylmercury loads, shown in Figure 4.3, Guadalupe Reservoir (1.4 g) is the largest contributor in the wet season, followed by Lexington and Almaden reservoirs at somewhat lower levels, with Calero Reservoir (0.3 g) being the lowest. Farther downstream, with the exception of Alamitos Creek (2.0 g), the methylmercury loads to the Guadalupe River from the different creeks are not too dissimilar (0.5 – 1.0 g), indicating that even small amounts of total mercury can produce substantial amounts of methylmercury if the right aquatic chemistry conditions are present. As with total mercury, the methylmercury loads exiting the Guadalupe River to San Francisco Bay (27 g) are somewhat higher than the total loads (6.7 g) entering the river from all its tributary creeks and from its watershed.

4.3 Range in 2003-2004 Wet Season Load Estimates

Loads of contaminants over defined time periods are generally obtained as a product of the flow volumes and the concentrations. The loads are estimated rather than exact because there is inherent variability in the sampling and measuring techniques. Therefore, it is common practice to describe the range (i.e., uncertainty) in the load estimates.

When both flow and concentrations are highly variable over short durations, as is the case during storm events in the Guadalupe River watershed, accurate load estimates require very frequent sampling. Although there was a large effort to obtain mercury and flow data throughout the watershed in the wet season for purposes of mercury sampling for the TMDL, the data are still not sufficient to precisely quantify the loads at all locations sampled, i.e., define the average loads and the variability associated with each load. Therefore, the numerical values of the loads presented in this section are best considered only as estimates useful in comparing the relative magnitudes of different sources in the watershed.

To facilitate interpretation of the data, Tetra Tech classified the uncertainty in the estimated loads into three categories (see Figures 4.2, 4.3, and 4.4):

- **High Uncertainty:** when flow data were limited to field estimates of creek flow at the time mercury samples were collected, and calculations were based on modeled flow
- **Medium Uncertainty:** when continuously gaged flow data were available
- **Low-Medium Uncertainty:** when continuously gaged flow *and* continuous turbidity data were available

Lower Guadalupe River load estimates fell into the low-medium uncertainty category because of the presence of a multi-decade continuous flow record and an independent station where the San Francisco Estuary Institute conducted monitoring for total suspended solids (continuous turbidity monitoring) and mercury (grab samples).

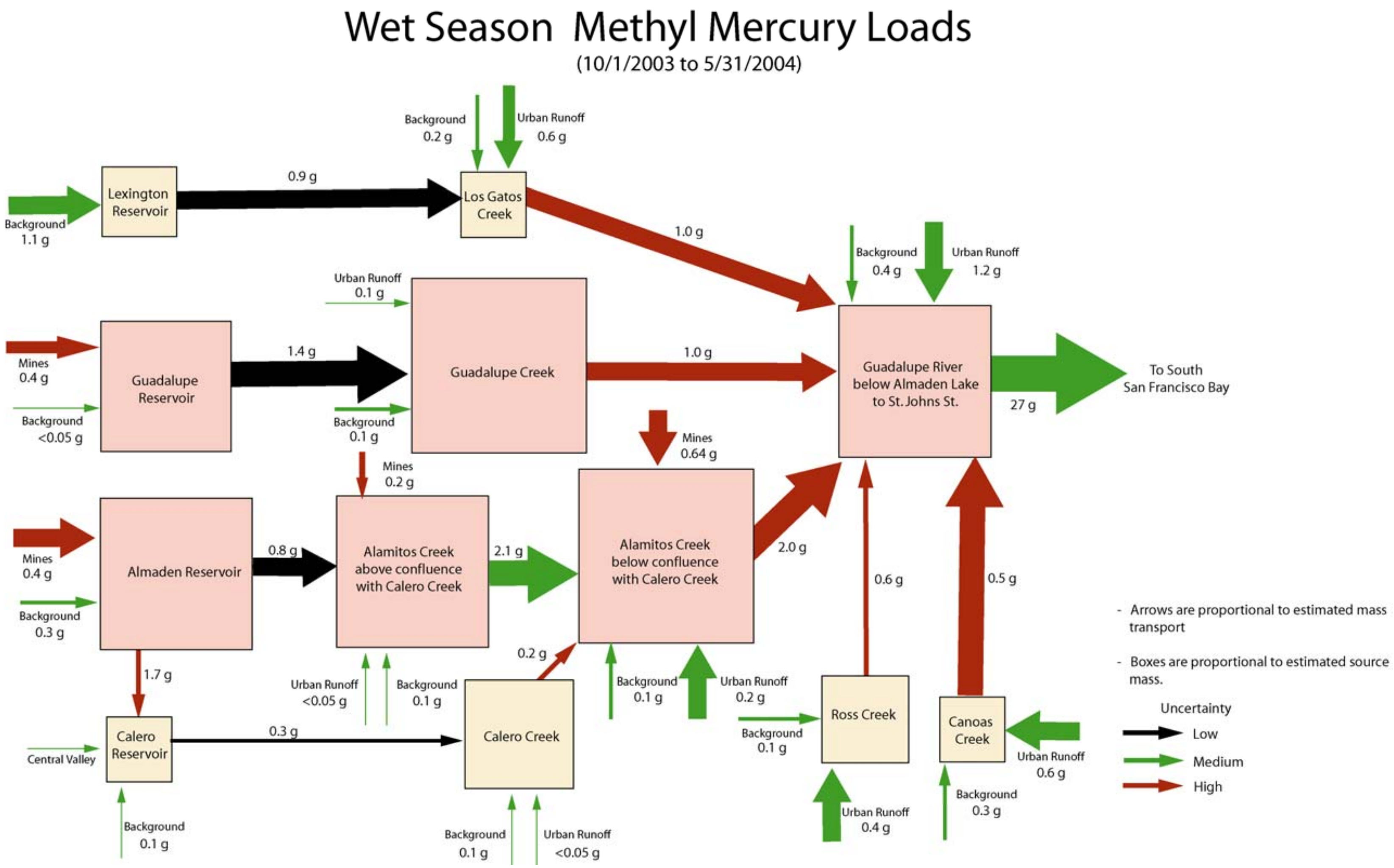

Figure 4.3 Wet Season Methylmercury Loads

Citation: Figure 4-3 in Final Conceptual Model Report (Tetra Tech 2005c)

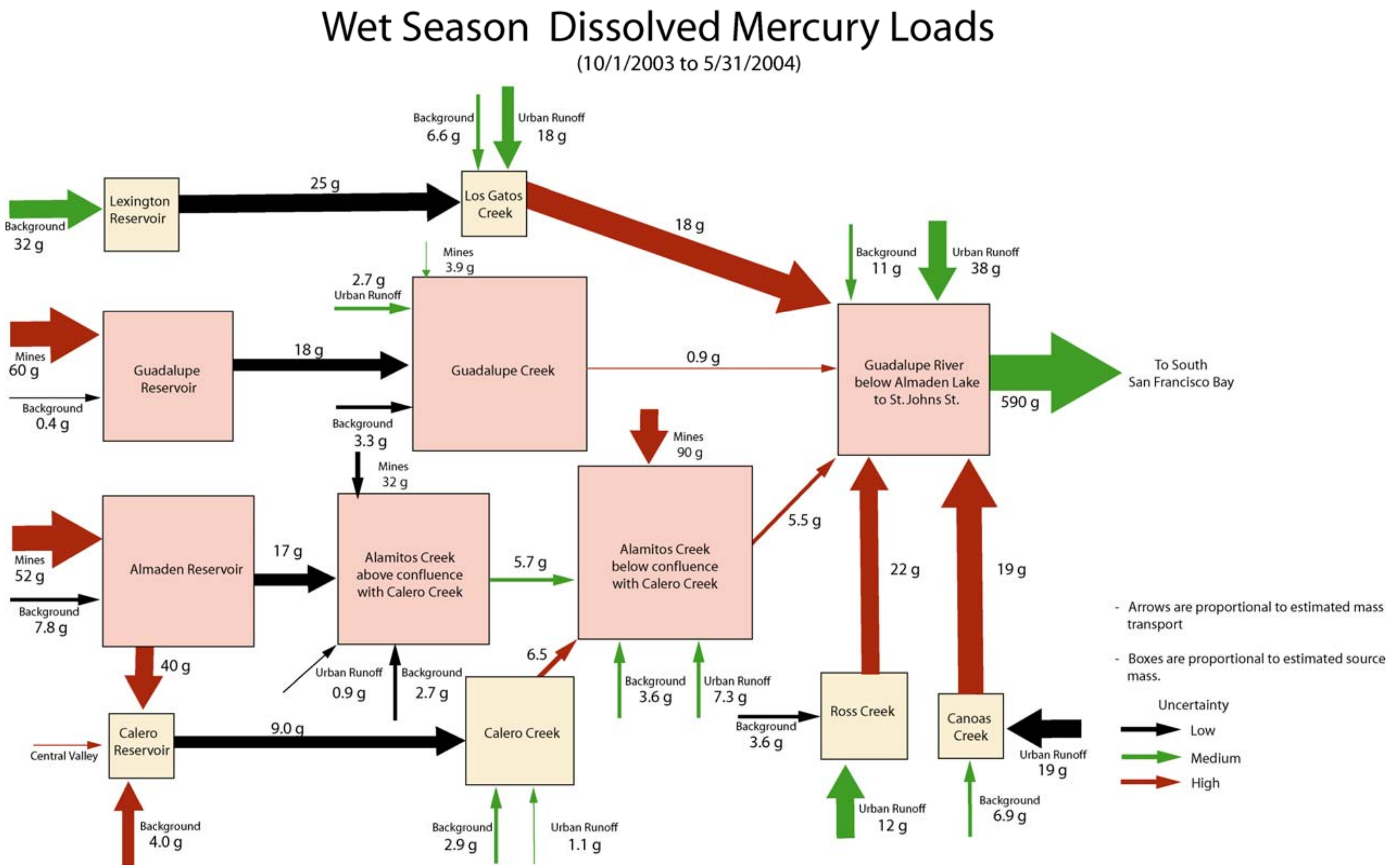

Figure 4.4 Wet Season Dissolved Mercury Loads

Citation: Figure 4-2 in Final Conceptual Model Report (Tetra Tech 2005c)

RANGE IN UPPER WATERSHED LOAD ESTIMATES

The upper watershed background and mining waste loads fell into the high uncertainty category because most 2003-2004 wet season samples were collected after the last large storm event in late February 2004. This precluded high flow sampling in the upper watershed. The loads presented above must be considered in light of these constraints in the existing data set. As a general rule, increased flows result in higher suspended solids and, therefore, higher mercury transport. This process was accounted for by using flow-total suspended solids correlations (linear regression) to estimate total suspended solids levels at flows higher than those physically sampled (i.e., extrapolated beyond the data set). It is highly likely that these correlations were not accurate, and perhaps underestimated the load, especially at higher flows. Additionally, because of the absence of flow gage information from any of the upper subwatersheds modeled, the SWAT model could not be calibrated. This lack of calibration adds to the uncertainty, and there is insufficient information to determine whether it might contribute to under- or overestimating the load.

Calculations using data from the Almaden Quicksilver County Park illustrate the significance of high flow events with high total suspended solids. Measurements made at the park on Los Capitancillos Creek on February 25, 2004, indicated total suspended solids values of 8,890 mg/l, and mercury values of 5,300 ng/l, see Table 2-6 of the *Final Conceptual Model Report* (Tetra Tech 2005c). Flow measurements were not made during this sample collection event. However, based on modeled flow data computed using rainfall in the 2003-2004 wet season, the average estimated flow on this date is 58 cfs. Assuming that the peak flow is approximately four times the average daily flow, and that this flow lasts for four hours, the transported load from the Los Capitancillos Creek during this storm event is estimated to be 490 grams, a value much higher than the estimated annual load of mercury from mines to the Guadalupe Reservoir (220 grams).

Although approximate, this calculation highlights the significance of the storm event loads in the upper watershed, and indicates a major source of uncertainty in the estimated loads presented here: the contribution of large winter storms. Based on this assessment, it appears that the calculated loads presented here are more likely to be underestimates than to be overestimates. Tetra Tech strongly recommended further quantification of the upper watershed loads through additional wet weather data collection in future stages of this project. Tetra Tech also noted that the numerical values of the loads presented in this section are best considered only as estimates useful in comparing the relative magnitudes of different sources in the watershed. Water Board staff concurs that these load estimates are useful in comparing the relative loads from different sources and in different locations in the watershed, and do not currently anticipate a need for more precise load estimates from the upper watershed.

RANGE IN LOADS TO SAN FRANCISCO BAY

Tetra Tech sought to quantify the range in its load estimate of the total mercury entering San Francisco Bay from the Guadalupe River by accounting for the residual error in the regressions using Monte Carlo analysis. The analysis provides an estimate of the likely ranges of loads, given imperfect knowledge about the needed inputs, particularly flow-concentration relationships and inter-year variability in flows. Monte Carlo analysis is performed by assuming probability distributions for the key inputs, and performing the load calculations multiple times where values of inputs are drawn from a specified probability distribution. Each Monte Carlo trial results in an estimate of the load. When this process is repeated many times (typically several hundred or thousand times), a distribution of the loads is obtained that is consistent with the uncertainty in input parameters.

For the specific case of developing the uncertainty-based load estimates of mercury for the Guadalupe River watershed, where flows are related to total suspended solids, and the total suspended solids to mercury concentrations, a method was needed to provide probability distributions such that, given a specific value of flow, the method provides a probabilistic estimate of total suspended solids, and a probabilistic estimate of the total mercury concentrations. The method Tetra Tech used is a statistical approach that uses the residual errors in the regressions to develop Monte Carlo estimates of key input parameters.[1] This approach was implemented in Microsoft Excel, using the Crystal Ball program. Crystal Ball is a specialized tool for performing Monte Carlo simulations.

The Monte Carlo estimate of wet weather loads was computed using the following steps:

1) The flows, obtained from the USGS flow gage in the downstream portion of the Guadalupe River, were assumed to be accurately known, i.e., there was no uncertainty associated with them.

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[1] The statistical approach for doing this is to assume that the linear regression models developed by Tetra Tech are expressed as $y = \alpha + \beta x$, where y is the dependent variable and x is the independent variable, and α and β are the intercept and slope. Using N pairs of observed data (X_i, Y_i), a least-squared error estimator was used to determine α and β. Our goal is to develop a Monte Carlo procedure that will generate random values of the dependent variable y for specified values of the independent variable x. The variance of the model error will be computed using the N data samples. An unbiased variance estimator s_m^2 is computed (Bhattacharyya & Johnson 1977, pages 341-357) as follows:

$$s_m^2 = \frac{SSE}{(N-2)}$$

where *SSE* is the residual sum of squares using *N* data pairs (X_i, Y_i):

$$SSE = \sum_{i=1}^{N} (Y_i - \alpha - \beta X_i)^2 .$$

The Monte Carlo algorithm generates random deviates of the linear model by assuming the dependent y variable of the model has Gaussian distribution $N(\mu_y, \sigma_y)$. The variance of the dependent y variable is assumed to be the same for any value of the independent variable x. The j[th] deviate y_j of the dependent variable can be generated for the specified dependent value x^* as follows:

$$y^* = \alpha + \beta x^*, \text{ where } y_j \in N(y^*, s_m).$$

2) For a specific day, the flow rate was used to obtain a probabilistic estimate of the TSS using the regression equation for stations on the river, and using the statistical approach above.
3) Using the probabilistic estimate of TSS, a similar probabilistic estimate was obtained for total mercury concentration using the mercury-TSS correlation for the river stations.
4) Multiplying the flow and mercury concentration for each day provided an estimate of the daily load.
5) The entire wet weather load was calculated by summing the daily loads from October 1, 2003, to May 31, 2004.
6) Steps 1 through 5 were repeated 1,000 times to obtain a distribution of the wet weather load for 2004.

Steps 1 through 6 result in a quantitative estimate of uncertainty in the load in one wet season (October 2003 through May 2004). Daily average flows in this wet season ranged from 21 cfs to 1,730 cfs (Tetra Tech 2004), and as described in Step 1, Tetra Tech made the reasonable assumption of no uncertainty in the flow measurement. Total suspended solids and mercury samples were collected between February 26 and April 20, 2004, with a maximum daily average flow of 851 cfs on February 26 (Tetra Tech 2004). This was the fifth-highest average daily flow in this wet season. Consequently, there are no residual error values to estimate the uncertainty for the four days with highest flow. Because the largest loads of mercury occur with the highest flows, this quantitative estimate of uncertainty is biased low.

The Monte Carlo simulated distribution of wet season loads for 2003-2004 is shown in Figure 4.5. The distribution shows a somewhat skewed bell curve, with a longer tail on the right side than on the left side, as a consequence of some of the variables being log-transformed in the regressions. Total loads range from approximately 8 to 20 kg. The midpoint of the distribution is about 12 kg.

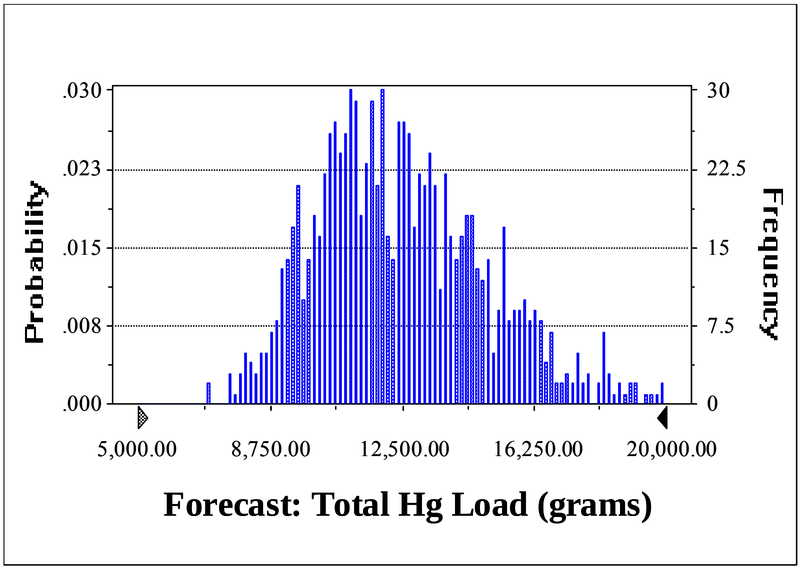

Figure 4.5 Uncertainty in Single-Year Loads to South San Francisco Bay

Citation: Figure 4-7 in Final Conceptual Model Report (Tetra Tech 2005c)

Although loads for a given year are uncertain, it is known that there is significant year-to-year variability in the flows out of the Guadalupe watershed. Because flows and mercury loads are related, it is likely that multi-year uncertainty will be significantly greater than the single-year uncertainty estimate. To assess the multi-year uncertainty, Tetra Tech performed a Monte Carlo analysis using daily average flows from 1960-2002 from the former USGS gaging station at St. John's Street. The maximum daily flow was 7,870 cfs. A single year (2004) from the new gaging station at California State Highway 101 was randomly sampled to compute total wet weather loads from October through May, during which the maximum daily flow was 1,730 cfs. The distribution of loads for the multi-year analysis is shown in Figure 4.6. It can be seen that the multi-year uncertainty is considerably greater than the single-year uncertainty, with values ranging from near zero for the extremely low flow years to almost 100 kg for the high flow years. Although this is not an unexpected result, the Monte Carlo analysis permits quantification of the process, and can be used to relate individual year loads, and potential load reductions, to the overall distribution of loads. Like the Monte Carlo simulation for one year, the Monte Carlo simulation for 1960 – 2001 wet seasons (Figure 4.6) is also biased low due to lack of data for high flow events, when the greatest loads occur.

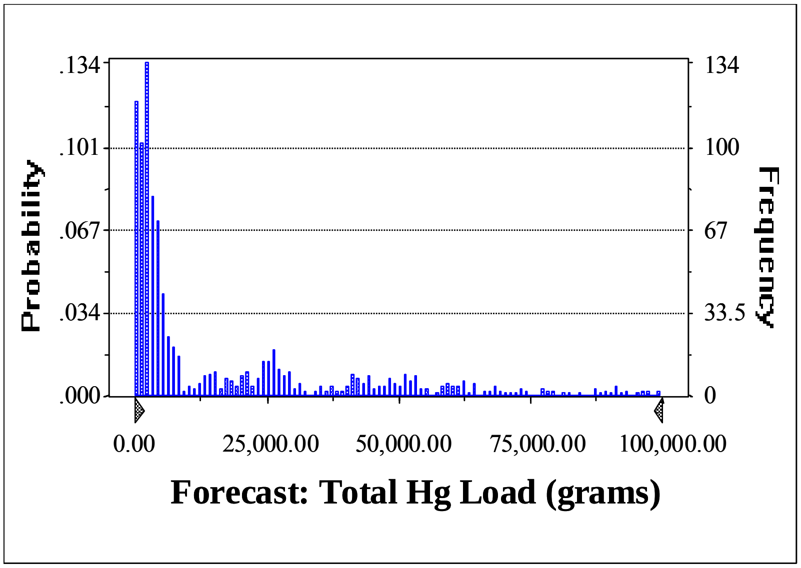

Figure 4.6 Uncertainty in Multi-Year Loads (1960-2001) (Tetra Tech)

Citation: Figure 4-8 in Final Conceptual Model Report (Tetra Tech 2005c)

The San Francisco Estuary Institute also developed a long-term load estimate, but using a different methodology. The San Francisco Estuary Institute methodology (McKee et al. 2004) has the benefit of being based on a continuous record of flow and turbidity for two entire wet seasons. The loads estimated between the 1960 wet season and the 2001 wet season for the Tetra Tech and SFEI relationships are shown in Figure 4.7. It is clear from these plots that continuous monitoring (SFEI) compared to infrequent grab sampling (Tetra Tech) can make a large difference in the estimates of mercury loads. In general, the greatest discrepancies occur in the high flow years, and the loads estimated using the SFEI approach are consistently higher.

4.4 2004 Dry Season Methylmercury Loads

To estimate dry season loads of methylmercury, Tetra Tech used data from monthly to biweekly sampling of Almaden and Guadalupe reservoirs conducted between May and August, 2004. Load calculations considered the measured mercury concentrations and the reservoir-stored water volumes, both of which changed over time. Besides the mercury concentration data, other data required for the load calculations are the volumes of water stored in the reservoir in the hypolimnion and the epilimnion, and the outflows from the reservoirs. The depth of the hypolimnion was estimated from the temperature and dissolved oxygen profiles that were taken during the mercury sampling. The calculations of the hypolimnion and epilimnion volume were based on detailed bathymetric maps of the reservoirs. The reservoir-stored water volumes were obtained from automated gages that are associated with Santa Clara Valley Water District's online ALERT system. The concentrations over the sampling period were multiplied by the volume of the hypolimnion or the epilimnion to determine the mass of total or methylmercury in either compartment. Because concentration data were obtained less frequently than depth data, concentrations at dates without measurements were estimated by interpolation from the two nearest values with measurements.

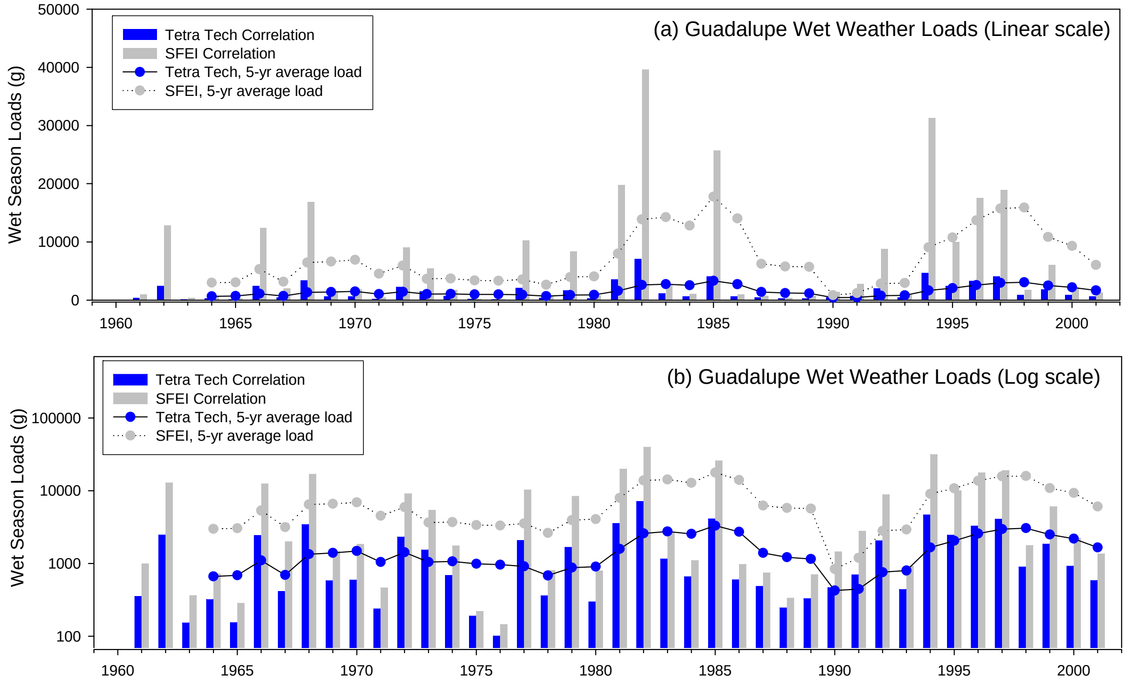

Figure 4.7 Comparison of Uncertainty in Multi-Year Loads (1960-2001)

Citation: Figure 4-9 in Final Conceptual Model Report (Tetra Tech 2005c)

The loads of mercury exported to Guadalupe Creek and Alamitos Creek were calculated as the product of mercury concentrations in the reservoir outflows and the flow rate data routinely collected by the Santa Clara Valley Water District and reported on the ALERT system. Daily average flow data were used (computed from 24-hourly values). Actual measured total and methylmercury concentration data were used when available; for dates without mercury data, values were interpolated from the nearest two dates of sampling.

The methylmercury produced in and exported from Guadalupe and Almaden reservoirs is shown on Figures 4.8 and 4.9. Depending on the reservoir, there is three to 10 times as much methylmercury accumulated in the hypolimnion (lower cooler layer) than in the epilimnion (upper warmer layer). There is a substantial increase in methylmercury concentrations beginning in July, particularly for Guadalupe Reservoir. Methylmercury exports from Almaden Reservoir were similar to those from Guadalupe Reservoir (7.2 and 5 grams, respectively). In both instances, more of the methylmercury produced was exported than retained in the reservoirs. More methylmercury is exported during the dry season than during the wet season (Table 4.4).

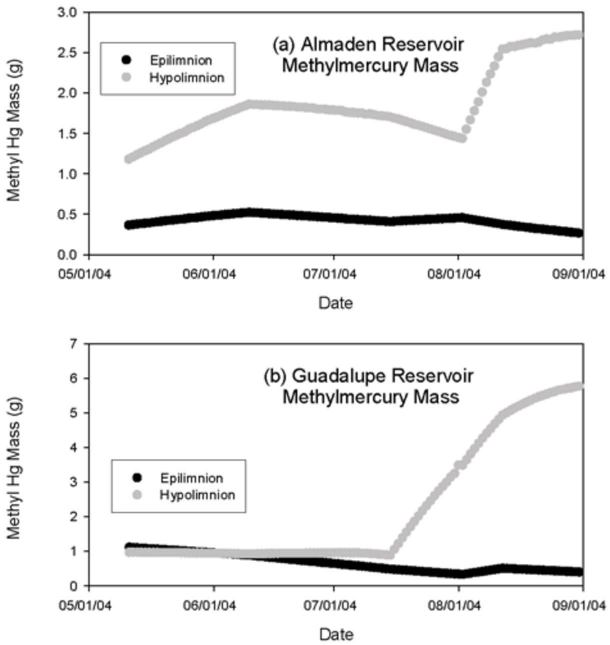

Figure 4.8 Methylmercury Production Estimates in 2004 Dry Season

Citation: Figure 4-4 in Final Conceptual Model Report (Tetra Tech 2005c)

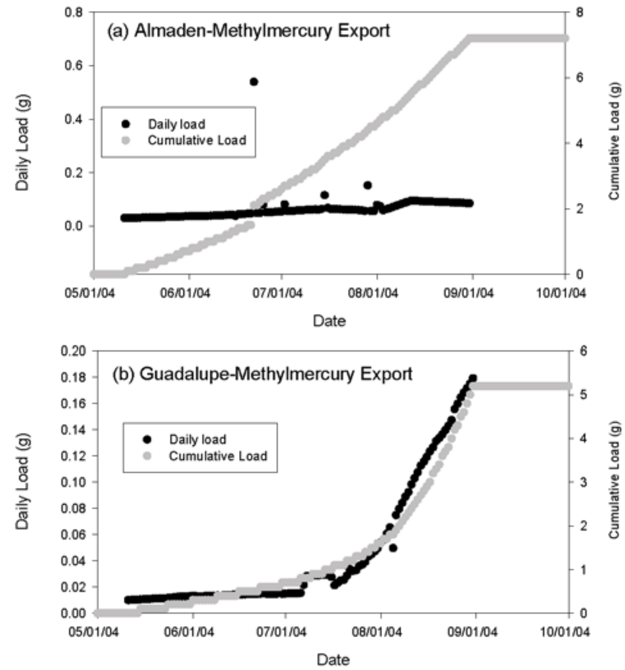

Figure 4.9 Downstream Methylmercury Exports from Two Reservoirs

Citation: Figure 4-5 in Final Conceptual Model Report (Tetra Tech 2005c)

Table 4.4 Seasonal Reservoir Exports

Reservoir	Wet Season		Dry Season	
	Total Mercury Exported (g)	Methylmercury Exported (g)	Total Mercury Exported (g)	Methylmercury Exported (g)
Almaden	110	0.8	21	7.2
Calero	28	0.3	No data	No data
Guadalupe	150	1.4	37	5.0
Lexington	140	0.9	No data	No data
Citations:	*Figure 4.2*	*Figure 4.3*	*Table 4-6 in Final Conceptual Model Report (Tetra Tech 2005c)*	

The loads considered to this point are for one season. It is helpful to put these in the context of long-term loads, which is the subject of the next section.

4.5 Long-Term Load Estimates

The San Francisco Bay Mercury TMDL Implementation Plan for the Guadalupe River watershed (Looker & Johnson 2004) requires dischargers to demonstrate progress toward a) the interim loading milestone, or b) attainment of the allocation by using one of three methods listed below.

1) Quantify the annual average mercury load reduced by implementing a) pollution prevention activities, b) source and treatment controls, and c) if applicable, other efforts to reduce methylation or mercury-related risks to humans and wildlife. The Water Board will recognize loads reduced resulting from activities implemented after 1996 (or earlier if actions taken are not reflected in the 2001 load estimate) to estimate load reductions.
2) Quantify the mercury load as a five-year annual average mercury load using data on flow and water column mercury concentrations.
3) Quantitatively demonstrate that the mercury concentration that best represents sediment discharged from the watershed to San Francisco Bay is below the suspended sediment target (0.2 ppm).

The load estimates discussed above are for the 2003-2004 wet season and 2004 dry season. The purpose of this section is to evaluate whether the five-year averaging period in Method 2, above, is appropriate for the Guadalupe River watershed.

The remainder of this section is taken from Section 4.12, "Recommended Averaging Time for Guadalupe River Loads to San Francisco Bay," of the *Final Conceptual Model Report* (Tetra Tech 2005c). Mercury loads exiting the Guadalupe River watershed vary substantially depending on the volume of flow. Given the historical variability of flows in the river, it is appropriate to define an averaging period and an associated baseline for loads against which any future loads must be considered. The averaging period must be chosen based on local site and climate characteristics. An averaging period that is too long will be insufficient to detect trends in changing loads, whereas an averaging period that is too short will be overwhelmed by year-to-year variability.

As a starting point, the Water Board has proposed a five-year averaging period. Figure 4-10 shows a comparison of the estimated loads as a function of the averaging period (three years, five years, seven years, and 10 years) for the Tetra Tech and SFEI correlations used in Figure 4-9. The use of longer averaging periods has the benefit of smoothing out peaks caused by occasional very high flow years, which are typical of this watershed. However a long averaging period (e.g., 10 years) has the effect of elevating the average load for a long period of time. It is conceivable that watershed changes could occur over timeframes shorter than 10 years, particularly those associated with modification of the flow channel, as proposed in San Jose, or removal of sediments containing high levels of mercury from dams and river channels. For this reason, a 10-year averaging period is rejected as being too long, and a five- to seven-year averaging period is considered acceptable.

4.6 Other Potential Sources

Other potential sources of mercury include off-gassing from mining wastes and re-deposition, and water imports from the Central Valley. Note that industrial discharges are included in urban runoff loads, so they are not another potential source.

Mercury is volatile; mercury off-gassing from uncovered mining wastes and mercury-enriched surface soil is a local atmospheric source that may re-deposit in the Guadalupe River watershed. Natural off-gassing from mercury-enriched surface soil is included in the background source category (atmospheric deposition). The potential to reduce this source is limited. Previous and future vegetation or excavation and capping of mining wastes in the watershed are anticipated to reduce atmospheric inputs from local and regional sources, but no estimates are available.

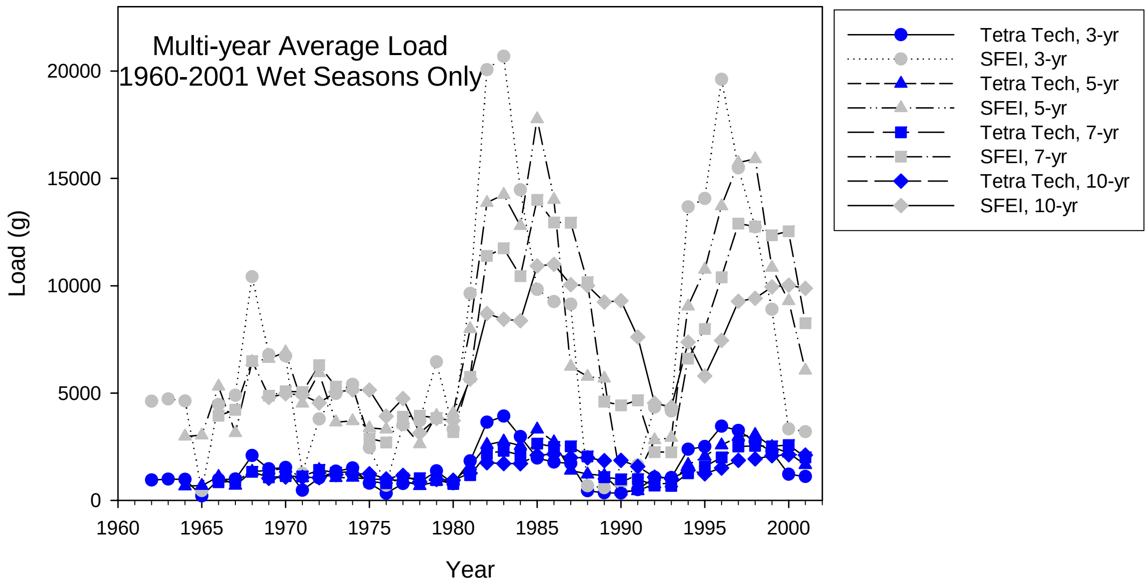

Figure 4.10 Average Annual Mercury Loads as a Function of Averaging Period

Citation: Figure 4-10 in Final Conceptual Model Report (Tetra Tech 2005c)

Central Valley water transfers to Calero Reservoir are a potential, albeit small, source of mercury. However, there is no impairment of beneficial uses related to Central Valley water transfers to Calero Reservoir.

Industrial facilities are regulated by Waste Discharge Requirements (WDRs) and/or general industrial stormwater NPDES permits. Guadalupe Rubbish Disposal Company, Inc., owned by Waste Management, Inc., occupies the site of the former Guadalupe Mine and is the only industrial facility in the New Almaden Mining District. Landfill operations are subject to Waste Discharge Requirements Order No. 01-050 and General Industrial NPDES Stormwater Permit No. 97-03-DWQ. Discharges from landfill property which contain mining waste or practices which result in the discharge of mining waste from the landfill property are addressed by this TMDL.

Key Points

- There are four sources of mercury in the Guadalupe River watershed: mining wastes, urban runoff, naturally occurring mercury in the soil, and atmospheric deposition; not every source contributes to every water body (see Table 4.1 and Figure 4.1).
- Loads of total mercury transported in the 2003-2004 wet season (see Figure 4.2 and Table 4.3) are useful to compare the relative magnitudes of different sources in the watershed; mining waste is by far the largest source.
- Large amounts of methylmercury were produced in Guadalupe and Almaden reservoirs in the 2004 dry season, and more was transported downstream to Guadalupe and Alamitos creeks and the Guadalupe River than was retained in these reservoirs (Figure 4.8).
- Essentially, in the wet season, total mercury is transported in stormwater, whereas methylation and bioaccumulation largely occur in the dry season when and where the critical condition of low oxygen (anoxic conditions) occurs.

5. Numeric Targets

"Numeric targets" are measurable conditions that demonstrate attainment of water quality standards. Targets are the maximum amount of mercury (solid, suspended, liquid, or airborne) allowed in a certain amount of water, fish tissue, or sediments. A numeric target can be a 1) numeric water quality objective, 2) numeric interpretation of a narrative objective, or 3) numeric measure of some other parameter necessary to meet water quality standards. The USEPA human health criterion (0.3 milligrams of methylmercury per kilogram of fish) is an example of a numeric interpretation of the bioaccumulation narrative objective. A regional background mercury sediment target (0.2 milligrams total mercury per kilogram of sediment) is an example of an alternative parameter (*Draft Sulphur Creek Mercury TMDL*, August 2004).

To protect human health and wildlife in the Guadalupe River Watershed, Water Board staff proposes three methylmercury fish targets (see Table 5.3). The proposed targets are intended to protect beneficial uses of waters impaired by mercury. The targets are based on available information and are intended to be at least as protective as established water quality objectives. Other targets could also be equally protective of beneficial uses and could be considered in the future through the adaptive implementation process described in Section 8 (Implementation Plan).

In addition to numeric targets, Water Board staff proposes age-1 fish tissue mercury concentrations as remediation effectiveness indicators. A description of age-1 fish and corresponding mercury data are provided in the *Data Collection* and *Final Conceptual Model Reports* (Tetra Tech 2005a & 2005c), and the remediation effectiveness indicators are described in Section 9.2.

5.1 Development of Targets

Water Board staff considered mercury in various media (sediment, water, and fish) and various forms (total and dissolved, methylmercury, and inorganic mercury), and considered corresponding target options and their advantages and disadvantages. Developing a fish tissue methylmercury target for the protection of human health based on the USEPA's recent criterion appears to be the best approach, partly because it relies on an established and peer-reviewed criterion, but mainly for the following reasons summarized in the criterion document (USEPA 2001):

> *(The) EPA believes a fish tissue residue water quality criterion is appropriate for many reasons. Such a criterion integrates spatial and temporal complexity that occurs in aquatic systems and that affects methylmercury bioaccumulation. A fish tissue residue water quality criterion is more closely tied to the (Clean Water Act) goal of protecting the public health because it is based directly on the dominant human exposure route for methylmercury. The concentration of methylmercury is also generally easier to quantify in fish tissue than in water and is less variable over the time periods in which water quality standards are typically implemented… Thus, the data used in permitting activities can be based on a more consistent and measurable endpoint. A fish tissue residue criterion is also consistent with how fish advisories are issued. … The methylmercury water quality criterion is, thus, a concentration in fish tissue."*

Similarly, developing a fish tissue methylmercury target for the protection of wildlife appears to be the best approach. The USFWS developed the targets (described below) and noted (USFWS 2005):

> *Wildlife currently thought to be most likely at risk from mercury in an aquatic environment are terrestrial species that are primarily or exclusively piscivorous, ingesting methylmercury that has bioaccumulated and biomagnified in their aquatic prey (Wiener et al. 2002).*

5.2 Human Health Target

The method used to develop a target for fish tissue from the Guadalupe River watershed is derived from the method USEPA used to develop its national criterion for methylmercury in fish tissue (USEPA 2001): 0.3 milligrams methylmercury per kilogram of fish tissue (i.e., parts per million, ppm) using Equation 5.1:

Equation 5.1

$$\text{Criterion} = \frac{\text{Body Weight x (Reference Dose – Relative Source Contribution)}}{\text{Fish Intake}}$$

USEPA assumed an adult human body weight of 70 kilograms. The reference dose in the equation is 0.0001 milligrams methylmercury per kilogram of body weight per day (ppm/day). The reference dose represents a lifetime daily exposure level at which no adverse effect would be expected. It is derived from studies showing at what level methylmercury causes toxic effects in children exposed to methylmercury before birth. Adverse developmental effects are the most sensitive indicators of methylmercury's effects. USEPA's approach for developing its fish tissue criterion includes several additional conservative assumptions, including the incorporation of a factor of 10 in the reference dose to account for uncertainties related to methylmercury's health effects and its metabolism within the body. The relative source contribution (0.000027 ppm/day) accounts for other sources of methylmercury exposure (USEPA 2001).

The USEPA default fish intake is calculated for freshwater and estuarine fish after subtracting 12.5 grams of marine fish with a weighted average methylmercury concentration of 0.157 ppm. USEPA environmental standards typically protect at the 90^{th} percentile level. Ninety percent of the U.S. population eats from zero to 17.5 grams of freshwater and estuarine fish per day. Therefore, USEPA used 17.5 grams per day as the default intake (consumption) rate in the human health methylmercury criterion for freshwater and estuarine fish.

To protect human health, Water Board staff proposes a fish methylmercury target of 0.3 ppm average concentration in fish typically consumed by humans.

Species, size of fish, and consumption rate affect methylmercury intake. The relative location of the species in the food chain is called the trophic level (TL). Trophic level 1 plants are consumed by trophic level 2 herbivores, which are consumed by trophic level 3 predators, which are then consumed by trophic level 4 top predators. The USEPA default consumption rates for the general population by fish trophic level are: TL2 = 3.8 grams of fish per day (g/d); TL3 = 8.0 g/d; and TL4 = 5.7 g/d.

The resulting methylmercury concentrations by trophic level are: TL2 = 0.029 milligrams of methylmercury per kilogram of fish (mg/kg, part per million, ppm); TL3 = 0.165 ppm; and TL4 = 0.660 ppm (USFWS 2003).

The fish data set in the Guadalupe River watershed consists primarily of data for largemouth bass, which is a TL4 fish. Initially, the human health numeric target will be monitored in 400 mm TL4 largemouth bass and compared to the USEPA default TL4 methylmercury concentration of 0.66 ppm.

However, the wildlife targets proposed below for TL3 fish are estimated to result in no more than 0.43 ppm methylmercury in 400 mm TL4 largemouth bass (see calculations in Appendix B). This concentration is lower than the USEPA default safe concentration. Therefore, the fish targets for wildlife provide additional protection of human health.

Staff proposes actions to refine the fish consumption rate and, if warranted, revise the human health target through the adaptive implementation process described in Section 9 (Monitoring and Adaptive Implementation). Actions to help manage the risk of mercury-contaminated fish from the Guadalupe River watershed to consumers are described in Section 8 (Implementation Plan). Initially, the human health numeric target will be monitored in 400 mm TL4 largemouth bass and compared to the USEPA default TL4 methylmercury concentration of 0.66 ppm. If, as a result of the fish consumption data, the human health target is changed, monitoring may be changed accordingly.

5.3 Wildlife Targets

Whereas fish consumption accounts for only a portion of most human diets, some wildlife depend entirely on fish or other aquatic organisms for their food. As noted in the San Francisco Bay Mercury TMDL, numerous studies document mercury accumulation within the aquatic food web and its toxic effects on birds (Wiener et al. 2003). In the Bay Area, birds feeding on fish and other aquatic organisms are among the most sensitive wildlife mercury receptors (CDFG 2002; Davis et al. 2003).

The U.S. Fish and Wildlife Service (USFWS) developed the fish mercury targets discussed in this section with assistance from biologists at the Santa Clara Valley Water District regarding species present in the watershed. This section, "Wildlife Targets," is largely based on *Derivation of Numeric Wildlife Targets for Methylmercury in the Development of a Total Maximum Daily Load for the Guadalupe River Watershed* (USFWS 2005). USFWS determined that a wildlife target that protects birds is also expected to protect other wildlife that rely on the Guadalupe River watershed for food.

Wildlife most likely at risk from mercury in the aquatic environment are terrestrial species that are primarily or exclusively piscivorous—they consume methylmercury that has bioaccumulated in their aquatic prey. Aquatic-dependent terrestrial species include reptiles, amphibians, mammals, and birds. State or federally listed threatened and endangered species in the Guadalupe River watershed include amphibians (e.g., red-legged frog), fish (e.g., Central California coast steelhead), and birds (e.g., California least tern and bald eagle). The fall-run chinook salmon is not listed; however it is regulated by NOAA Fisheries under the Magnuson-Stevens Fishery Conservation and Management Act.

Research into the effects of mercury on wildlife has generally focused on higher trophic level predators, such as piscivorous birds and mammals, rather than on reptiles and amphibians. The higher the trophic level, the greater the amount of methylmercury ingested from aquatic prey. Two piscivorous mammals, mink and river otter, are likely to be present in this watershed. Based on dietary analysis of piscivorous mammals and birds for the Cache Creek watershed, USFWS concluded that safe methylmercury targets for birds would be protective of these mammals. Therefore, targets protective of wildlife were developed for piscivorous birds (USFWS 2005).

Table 5.1 Fish Species Potentially Consumed by Piscivorous Birds

TL2	TL3	TL4
None	Small bullheads, carp, small catfishes, black crappie, white crappie, goldfish, killifish, bigscale logperch, mosquitofish, California roach, golden shiner, inland silverside, Sacramento sucker, sunfishes (including bluegill, redear, and green), and steelhead/rainbow trout	Largemouth bass, large bullheads, large catfishes, anadromous steelhead

Note: Trophic levels are approximate and simplified to primary trophic level.

Many piscivorous bird species frequent the watershed during the year. Because reproductive effects are the most sensitive indicators of mercury toxicity, the target species are those that forage in the watershed or are resident in or around the watershed during their breeding seasons. The five piscivorous species most vulnerable to mercury in the breeding season in the Guadalupe River watershed are common merganser (*Mergus merganser*), osprey (*Pandion haliaetus*), belted kingfisher (*Ceryle alcyon*), great blue heron (*Ardea herodias*), and Forster's tern (*Sterna forsteri*). Bald eagles visit only in winter and are not known to breed near or in the watershed. California least terns forage in South San Francisco Bay and are addressed in the San Francisco Bay Mercury TMDL.

The USFWS methodology for deriving wildlife targets recognizes that piscivorous birds obtain most of their methylmercury from fish in their diet, and that reproductive effects are the most sensitive indicators of adverse impacts from mercury. Previously published results of feeding studies on mallards were used to estimate the safe daily exposure to methylmercury. A margin of safety was applied to estimate a no-observable-adverse-effects concentration (NOAEC).

To better assess what types and sizes of fish birds in the watershed consume, USFWS reviewed published literature and determined that there are four main dietary preferences: TL3 fish less than 50 millimeters (mm) in length, 50-150 mm in length, and 150-350 mm in length; and TL4 fish 150-350 mm in length. Note that the fourth size is smaller than the TL4 fish evaluated for human health (400 mm). The fish consumption rate, fish size, and fish trophic level were evaluated for each of these five bird species. Transfer of mercury between fish trophic levels was also considered. USFWS determined safe levels of prey fish methylmercury for wildlife in the Guadalupe River watershed as listed in Table 5.2.

USFWS determined that the target for belted kingfisher (0.05 ppm TL3 fish between 50-150 mm long) is sufficient to protect the great blue heron and should also be protective of the Forster's tern. Similarly, the target for common mergansers (0.10 ppm TL3 fish between 150-350 mm long) is also protective of osprey. Based on the USFWS work, **Water Board staff proposes fish methylmercury targets of 0.05 ppm in TL3 fish between 50-150 mm long and 0.10 ppm in TL3 fish between 150-350 mm long to protect wildlife.**

USFWS recommends that a fish tissue monitoring plan be developed to determine whether the assumptions it relied on to develop the targets are valid for the watershed (see Monitoring Plan in Section 8). Furthermore, should its assumptions hold, it proposes that it would be reasonable to assign one target concentration (i.e., 0.10 ppm in 150-350 mm TL3 fish) that would be protective of all wildlife species in the watershed. Such a change in targets could be considered in the future through the adaptive implementation process described in Section 9 (Monitoring and Adaptive Implementation).

Table 5.2 Safe Prey Fish Methylmercury Levels

	TL3 Fish < 50 mm	TL3 Fish 50-150 mm	TL3 Fish 150-350 mm	TL4 Fish 150-350 mm
	(ppm, wet weight)			
Great Blue Heron		0.12		
Osprey			0.10	0.20
Common Merganser			0.10	
Forster's Tern	0.05			
Belted Kingfisher		0.05		

5.4 The Three Proposed TMDL Targets

Staff proposes two TL3 fish targets to protect wildlife, and one TL4 fish target to protect human health (Table 5.3). These targets apply where birds and/or humans obtain fish for consumption. The five piscivorous bird species forage throughout the watershed (USFWS 2005). Therefore, the wildlife targets are applicable in all water bodies. Humans, however, prefer large fish for eating, not the tiny minnows and suckers in the upper watershed creeks. Therefore, the human health target applies to the reservoirs and downstream creeks and river.

Table 5.3 Fish Targets (ppm methylmercury, wet weight)

Protection of Wildlife	Protection of Wildlife	Protection of Human Health
TL3 Fish 50 – 150 mm	TL3 Fish 150 – 350 mm	Typical Size and Species of Fish Consumed
0.05 ppm	0.10 ppm	0.3 ppm

Although the targets were developed for methylmercury, because nearly all mercury in fish tissue is methylmercury (Grieb et. al. 1990), fish samples may be analyzed for total mercury. This and other fish sampling considerations are described in the Monitoring Plan (Section 9).

5.5 Anti-Degradation

The numeric targets proposed in this TMDL (see Table 5.3) must be consistent with antidegradation policies. Title 40 of the Code of Federal Regulations (§131.12) contains the federal antidegradation policy. State Water Resources Control Board Resolution 68-16 contains California's antidegradation policy. These antidegradation policies are intended to protect beneficial uses and the water quality necessary to sustain them. When water quality is sufficient to sustain beneficial uses, it cannot be lowered unless doing so is consistent with the maximum benefit to the citizens of California. Even then, water quality must sustain existing beneficial uses.

To be consistent with the antidegradation policies, the numeric targets proposed in this TMDL, taken together, cannot be less stringent than existing water quality objectives. As described in "Water Quality Standards Attainment" (see Section 6.7), the proposed numeric targets together are as protective as the Basin Plan narrative water quality objective for bioaccumulation. Because mercury concentrations already exceed the bioaccumulation objective, meeting the numeric targets would improve current water quality conditions and resolve the bioaccumulation impairment. Therefore, the proposed targets are consistent with the antidegradation policies and the protection of water quality and beneficial uses.

Key Points

- "Numeric targets" are measurable conditions that demonstrate attainment of water quality standards. Achieving these targets will attain the REC1, COMM, and WILD beneficial uses, the Basin Plan narrative objective for bioaccumulation, the Basin Plan numeric water quality objectives, and the California Toxics Rule numeric water quality objective.
- To protect human health, Water Board staff proposes a fish methylmercury target of 0.3 ppm average concentration in fish typically consumed by humans.
- Water Board staff proposes fish methylmercury targets of 0.05 ppm in TL3 fish between 50-150 mm long and 0.10 ppm in TL3 fish between 150-350 mm long to protect wildlife. The fish targets for wildlife are more stringent and therefore provide additional protection of human health.

6. LINKAGE ANALYSIS

The main purpose of the linkage analysis is to describe the links between sources and targets (fish tissue methylmercury concentrations) and to determine appropriate allocations (Section 7). These links include the transport of mercury from sources to water bodies, the chemical transformations that occur in water, and the bioaccumulation of mercury. The linkage analysis is presented in the following sections:

6.1 Qualitative Linkage from Sources to Targets
6.2 Conditions in Guadalupe Watershed Reservoirs
6.3 Mercury Transport and Linkage
6.4 Quantitative Linkage from Methylmercury in Water to Targets
6.5 Implications for TMDL
6.6 Mercury in Reference Reservoir
6.7 Water Quality Standards Attainment

This analysis describes the four sources of mercury in this watershed: mining waste, urban runoff, atmospheric deposition, and naturally occurring mercury in soil. But the linkage between these sources and the numeric targets (fish tissue methylmercury concentrations) is not direct. As illustrated in the diagram below (Figure 6.1), the sources and the numeric targets are linked by the sites where methylmercury is produced.

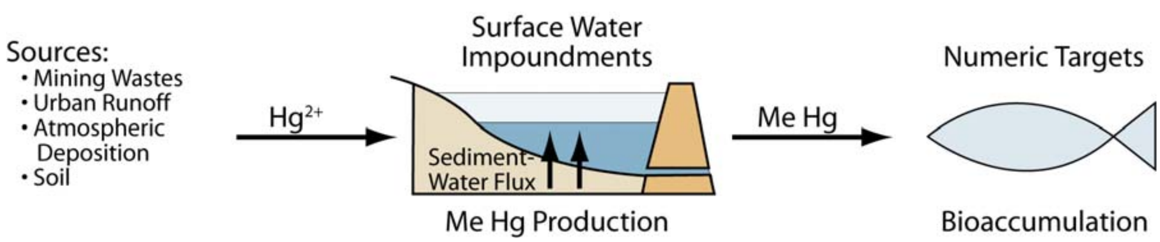

Figure 6.1 Linkage Between Sources, Methylmercury, and Targets

Citation: Prepared by Tetra Tech under contract to Water Board

Impoundments are engineered structures, such as dams, drop structures, and former quarries, that cause water to pond. In the Guadalupe River watershed, the largest impoundments on the creeks and river—Guadalupe, Almaden, and Calero reservoirs and Almaden Lake—have been identified as the primary sites of methylmercury production and bioaccumulation. Data supporting the linkage from mercury sources to fish tissue targets is described in the next section.

6.1 Qualitative Linkage from Sources to Targets

The largest source of mercury in the Guadalupe system is mining waste (see Table 4.3). Mines discharge mercury-laden sediment, some of which accumulates in impoundment bottom sediments. It is not surprising, then, that the strongest evidence of the linkage between sources and targets in the watershed is reservoir sediment and corresponding fish tissue mercury concentrations. Figure 6.2 illustrates 2005 sediment and 2004 fish data from three reservoirs (Tetra Tech 2005b and 2005a, respectively, and Appendix B). There is a clear trend toward higher mercury concentrations in fish tissue with higher reservoir sediment mercury concentrations. The median reservoir bottom sediment total mercury concentrations range from 0.1 milligrams of mercury per kilogram of sediment (mg/kg, parts per million, ppm) in Lexington to 3.0 ppm in Guadalupe Reservoir. Corresponding fish tissue mercury concentrations in standardized 40 cm largemouth bass range from 0.6 ppm in Lexington to 5.8 ppm in Guadalupe Reservoir.

Another strong indication of the linkage between sources and targets in the watershed is the high fish tissue mercury concentrations in close proximity to the New Almaden Mining District, and the lower fish tissue concentrations both farther downstream from the mining district and in Los Gatos Creek outside the mining district, as illustrated on Figure 6.3, below.

The data collection efforts and *Final Conceptual Model Report* that provide the scientific basis of this TMDL are described in Section 3 (Conceptual Model). Sections 6.2 through 6.5 herein are taken largely from the *Final Conceptual Model Report* which provides a detailed explanation of the linkage between sources and targets, particularly in Section 5.0, which includes mercury transport, transformation, and biological uptake and bioaccumulation in fish (Tetra Tech 2005c). The *Conceptual Model Report* references studies described in the literature which show that in order for mercury to bioaccumulate in fish tissue, it must first be converted into the organic methylmercury form. The conditions in reservoirs in the watershed that lead to methylmercury production and bioaccumulation are described in the next section.

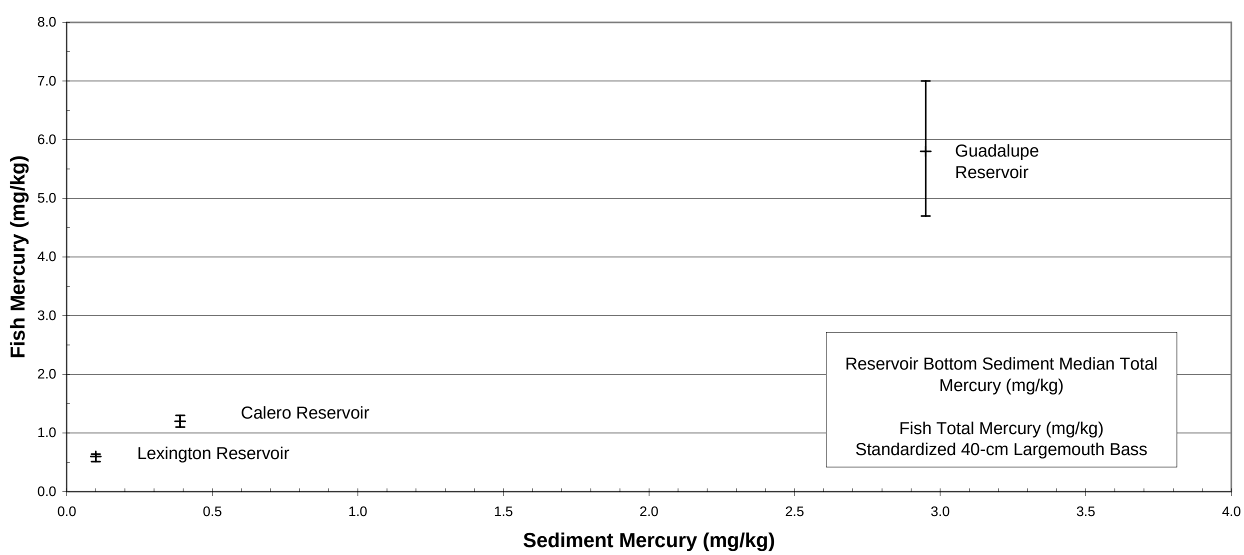

Figure 6.2 Fish and Reservoir Sediment Mercury Results

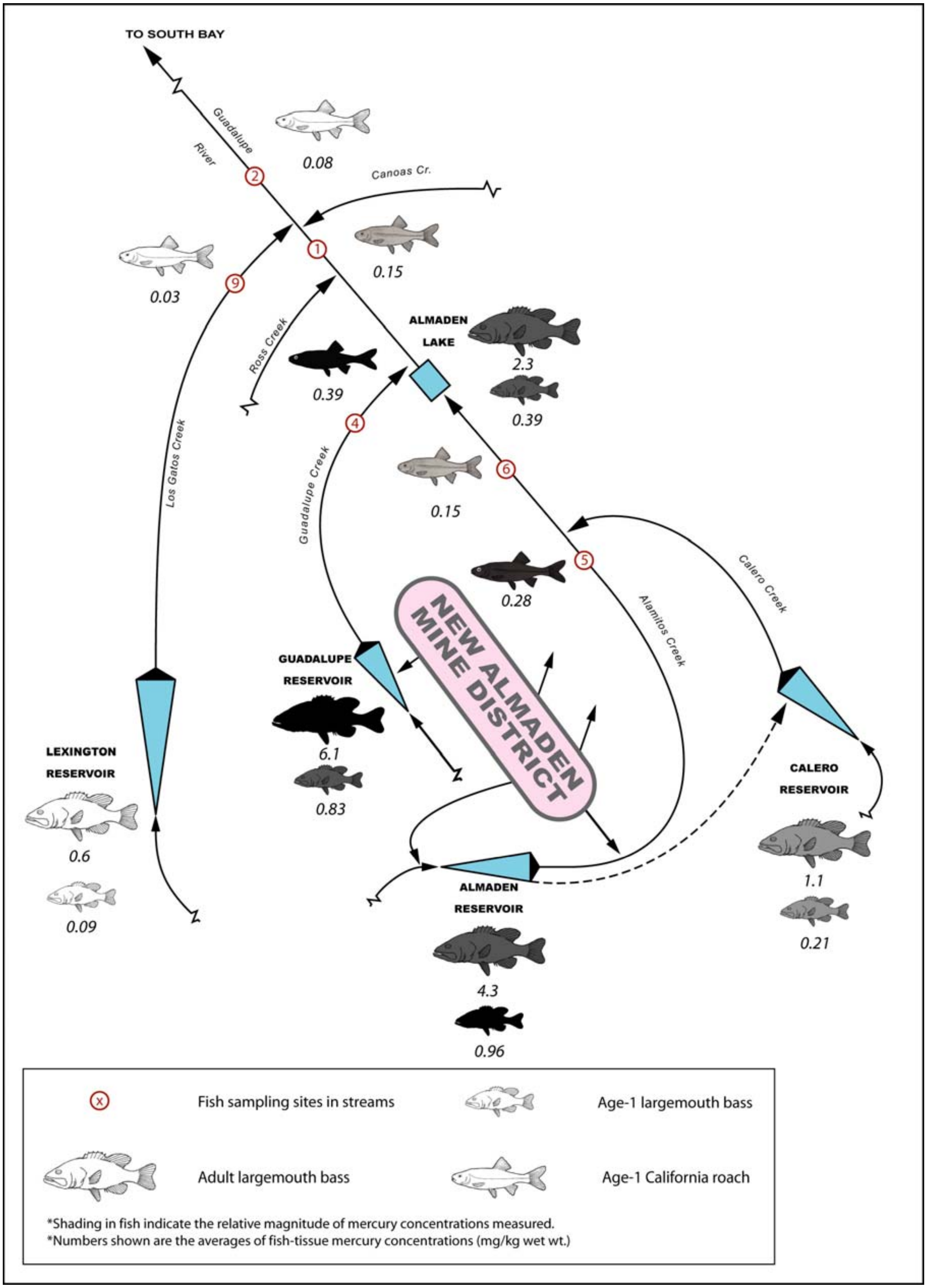

Figure 6.3 Summary of 2004 Fish Data

Citation: Figure 3-25 Final Conceptual Model Report (Tetra Tech 2005c)

6.2 Conditions in Guadalupe Watershed Reservoirs

Mercury's transformations from one chemical form to another (including methylation), and within water, air, or sediments, involve complicated interactions among biological, physical, and chemical factors that defy simplification. For the purposes of this TMDL, however, the following paragraphs cover some relevant basics of these interactions.

For mercury to be methylated, it must first be available in its dissolved form to sulfate-reducing bacteria, which occur naturally in the environment. Mercury dissolves into this form through solubilization from inorganic particles. In the water column, where sulfate reduction takes place, mercury in the dissolved phase exists primarily as aqueous complexes associated with sulfides, natural organic matter, and other ligands.

The forms of mercury most likely to be taken up by bacteria and methylated are uncharged mercury-sulfide complexes (mercuryS^0 and mercury $(SH)_2^0$), according to recent experimental and field studies. Other aqueous complexes of mercury also have the potential to be taken up by bacterial cells. Limited data indicate that there is a range of sulfate concentrations over which methylation is stimulated, and concentrations greater than or less than this range tend to suppress methylation. Sulfate-reducing bacteria convert sulfate to sulfides for energy, and in the process methylate mercury, converting it from dissolved inorganic to dissolved organic mercury (i.e., methylmercury). Relative to the primary activity of bacterial conversion of sulfate to sulfides, methylation is generally hypothesized to be an incidental activity. The increased concentrations of sulfides resulting from natural bacterial activity accelerate weathering of mercury solids which, coupled with methylation, appears to be a significant means of bringing methylmercury into solution in these waters. Methylation can occur in the sediment or anywhere in the water column where sulfate reduction occurs. Demethlyation can also occur in the environment, as a result of different physical and biological processes.

Because a large quantity of mining waste was present in the creek canyons prior to construction of Almaden and Guadalupe reservoirs, the bottom sediments in these reservoirs are a significant source of mercury. In addition, particulate and dissolved mercury loads continue to be transported to Almaden and Guadalupe reservoirs during each wet season (and to Calero Reservoir via the Almaden-Calero Canal). Following thermal stratification early in the dry season, low dissolved oxygen levels in the lower layer (hypolimnion) promote the activity of sulfate-reducing bacteria and therefore sulfide production. Sulfide production enhances the solubility of particulate mercury both in the sediments and suspended in the water column. The sulfate-reducing bacteria take up the solubilized mercury and form methylmercury (Figure 6.4). Methylmercury enters algal cells at the base of the food chain (Figure 6.5).

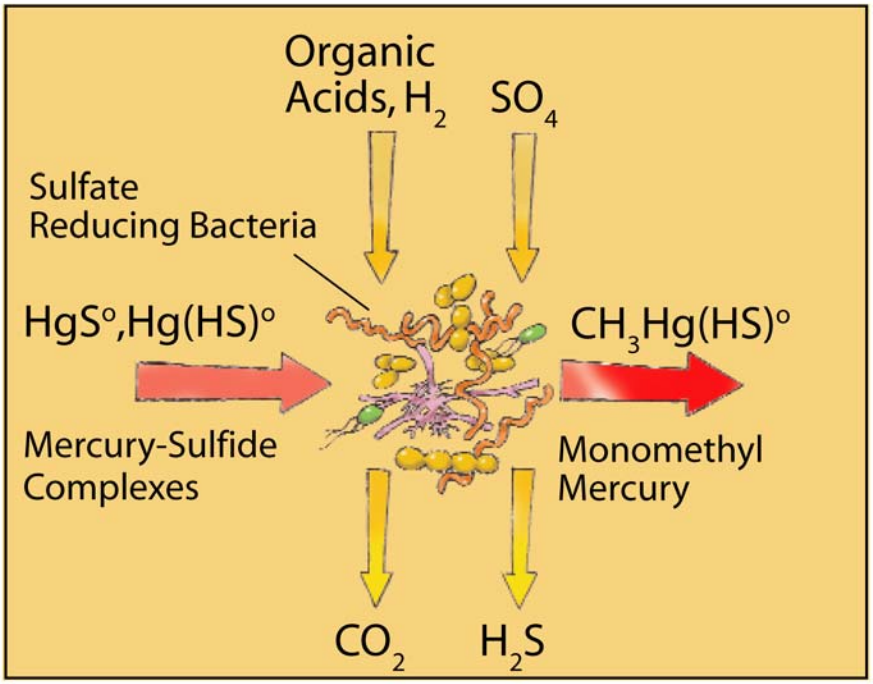

Figure 6.4 Mercury Methylation by Sulfate-Reducing Bacteria

Citation: Figure 5-5 Final Conceptual Model Report (Tetra Tech 2005b)

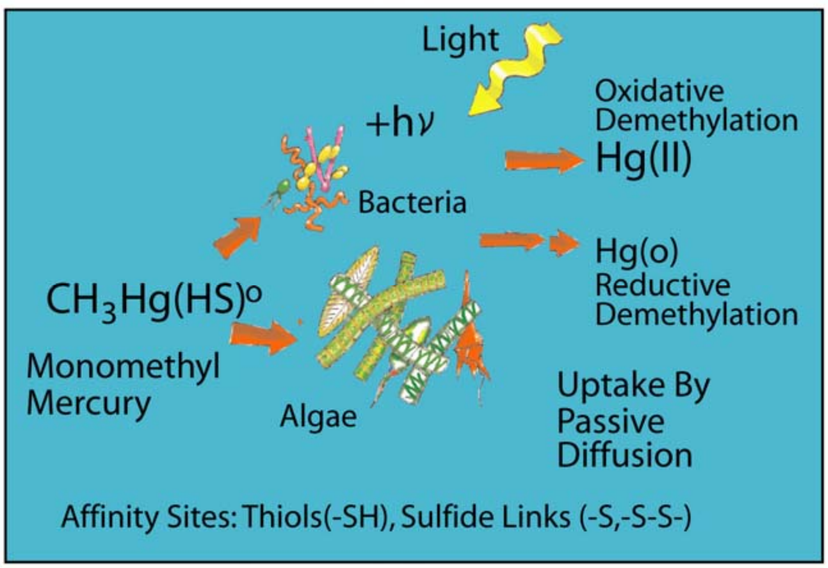

Figure 6.5 Methylmercury Uptake and Loss Processes

Citation: Figure 5-6 Final Conceptual Model Report *(Tetra Tech 2005b)*

The annual hydrologic cycle in the reservoirs and the observed behavior of methylmercury cycling in the Guadalupe and Almaden reservoirs are summarized on Figure 6.6, below.

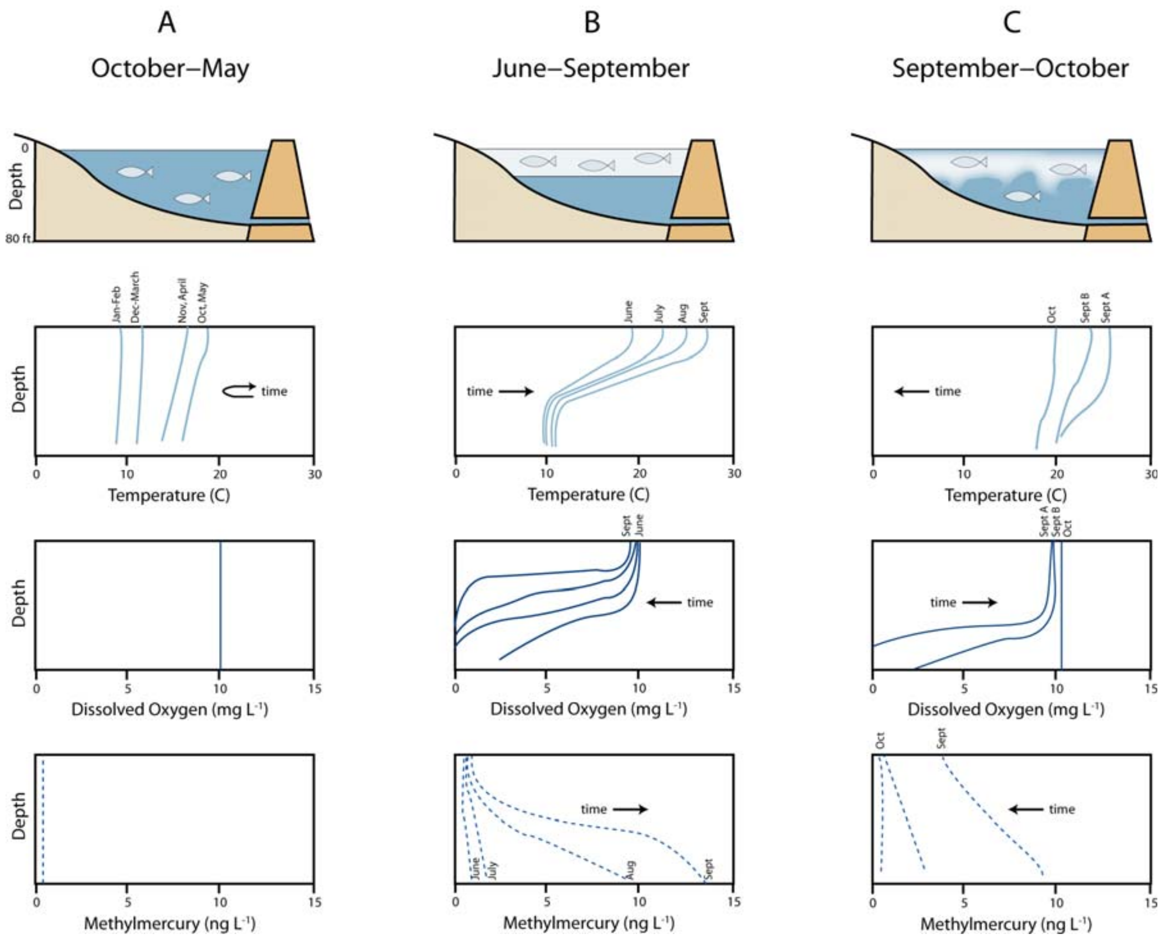

Figure 6.6 Annual Hydrologic Cycle in Reservoirs

Citation: Figure 5-13 Final Conceptual Model Report (Tetra Tech 2005b)

PANEL A (FIGURE 6.4): OCTOBER – MAY

During most of the year, the reservoirs are well mixed, and fish and other aquatic organisms are found throughout the water column. The temperature decreases as the wet season and winter period commence, and increases again in the spring, but the temperature and the dissolved oxygen concentrations (at near-saturation levels; oxygen gas dissolves from air into water, and the equilibrium concentration is called "saturation") remain relatively unchanged with depth. From October through May, methylmercury concentrations are at low levels (less than 1.0 nanogram of methylmercury per liter of water [ng/l, part per trillion]) for this watershed and are also constant with depth.

PANEL B (FIGURE 6.4): JUNE – SEPTEMBER

Like most deep water bodies, Almaden and Guadalupe reservoirs become thermally stratified between late spring and early fall (June - September, although the exact timing varies from year to year). The stratification period is characterized by an upper layer (epilimnion) of uniformly warm (20^o - 26^oC), well-mixed water. The water in the lower layer (hypolimnion) is cold (10^o - 14^oC). Dissolved oxygen becomes depleted by the bacterial decomposition of organic matter in the water column, as well as at the sediment-water interface where bacterial decomposition is at its maximum. As shown in Figure 6.4, both the thermal stratification and dissolved oxygen depletion increase over the dry season. During thermal stratification, fish are restricted to the epilimnion.

A number of studies have shown noteworthy increases in methylmercury concentrations in the hypolimnion during the stratification period (Herrin et al. 1998; Sellers et al. 2001; Watras & Bloom 1992). In Guadalupe and Almaden reservoirs, the increase in the concentration of methylmercury in the hypolimnion is pronounced. From concentrations of less than 1 part per trillion in the unstratified period (October - May), the concentrations of methylmercury in the hypolimnion near the bottom increase to greater than 10 ng/l during the stratification period.

PANEL C (FIGURE 6.4): SEPTEMBER - OCTOBER

In the early fall, declining air temperatures result in a loss of heat from surface waters, and solar radiation cannot make up for the heat loss. The surface waters cool and sink as they become denser than the underlying epilimnion. The continual cooling of the surface waters leads to progressive deepening of the epilimnion and increased circulation throughout the water column. The increased circulation leads to a breakdown of stratification and the restoration of oxygen concentrations (at near saturated levels) throughout the water column.

Several investigators have shown that the introduction of methylmercury produced in the hypolimnion during stratification and its uptake by phytoplankton represents an important internal source of methylmercury in lakes or reservoirs, and also a significant entry point of mercury into the food web (Herrin et al. 1998; Gorski et al. 1999; Sellers et al. 2001; Slotton et al. 1995). Methylmercury produced in the hypolimnion during stratification is quickly taken up by phytoplankton during the mixing at the end of the stratification period (Herrin et al. 1998). The uptake of methylmercury in zooplankton and fish increased dramatically during the fall mixing of California's Davis Creek Reservoir, which is contaminated by mercury mining activities (Slotton et al. 1995). These studies also show that biotic uptake of mercury is both rapid and short-lived. The decrease in water-column methylmercury is equally rapid (within a period of days to weeks). In addition to biological uptake, methylmercury can be lost from, or degraded in, the water column as it adsorbs to particles, settles in sediments, or degrades in sunlight.

6.3 Mercury Transport and Linkage

The largest source of mercury in the Guadalupe system is mining waste, which is located in three general areas:

- Waste materials in the New Almaden Mining District; particularly poorly managed waste that is easily eroded and transported in stormwater runoff,
- Wastes previously transported into Guadalupe and Almaden reservoirs and their tributary creeks, and
- Wastes previously transported into the river system below Guadalupe and Almaden reservoirs.

Because of the higher rates of methylation in impoundments, and the efficiency with which biota take up methylmercury, wastes that have been transported to impoundments are of particular significance with respect to mercury bioaccumulation.

In the Guadalupe River watershed, much of the rainfall, and most of the streamflow volume, occur during the wet months (October through May). Mercury transport is closely tied to water flows, and the most significant transport occurs in the wet months. Mercury is transported predominantly in the inorganic particulate form, with two important exceptions: a) dissolved mercury mobilized by small storms and b) methylmercury produced in impoundments during the dry season.

In the upper part of the watershed that drains the New Almaden Mining District, dissolved mercury loads during small storms in the wet season can be significant, and represent a quarter or more of the total mercury load. The proportion of dissolved mercury is much less in large storm events that transport most of the load (see note 4 on Table 4.2). This corresponds to wet season findings from the Gambonini Mercury Mine in the Coast Range where particulate mercury represented over 99.97% of the total mercury transported (Whyte & Kirchner 2000). Nonetheless, the load of dissolved mercury imported from the upper watershed to each of the Guadalupe and Almaden reservoirs (60 and 52 grams, Figure 4.4) is about 10 times the amount of methylmercury exported from each of these reservoirs (Figure 4.6). In other words, the dissolved mercury load entering the reservoirs from the mining district during the wet season is sufficient to account for all the methylmercury produced within the reservoir, and later exported from the reservoir.

Methylmercury production and export are much greater in the two reservoirs adjacent to the mining district than in other impoundments in the watershed. Given the greater degree of contamination in these two reservoirs, Guadalupe and Almaden, Tetra Tech evaluated their contribution to the watershed's total load separately

The 2004 dry season study of Guadalupe and Almaden reservoirs documented a substantial increase in methylmercury beginning in July, particularly for Guadalupe Reservoir. In both impoundments, more of the methylmercury produced was exported than was retained in the reservoirs. This is a key finding of the dry season monitoring—reservoirs are net producers and exporters of methylmercury to downstream waters.

Monitoring results also indicate that late in the dry season, a significant fraction (more than 30 percent) of the total mercury in the hypolimnion of Guadalupe and Almaden reservoirs was comprised of methylmercury. In many instances, total methylmercury concentrations were higher than the dissolved mercury concentrations, indicative of a very high methylation efficiency in the system during the dry season. This observation may be linked to the fact that conditions that enhance dissolution of solid-phase mercury (elevated sulfide concentrations) also enhance the production of methylmercury, as explained in more detail below.

In the dry season, both total and dissolved methylmercury concentrations in the creeks flowing from the reservoirs decrease with distance downstream from the reservoirs (see July 2003 data on Figure 6.7). This decrease in dissolved methylmercury also holds true for Guadalupe River, where it decreased from 1.72 ng/l in Almaden Lake to 0.113 ng/l in the Guadalupe River downstream of the Alamitos Drop Structure (Tetra Tech 2003).

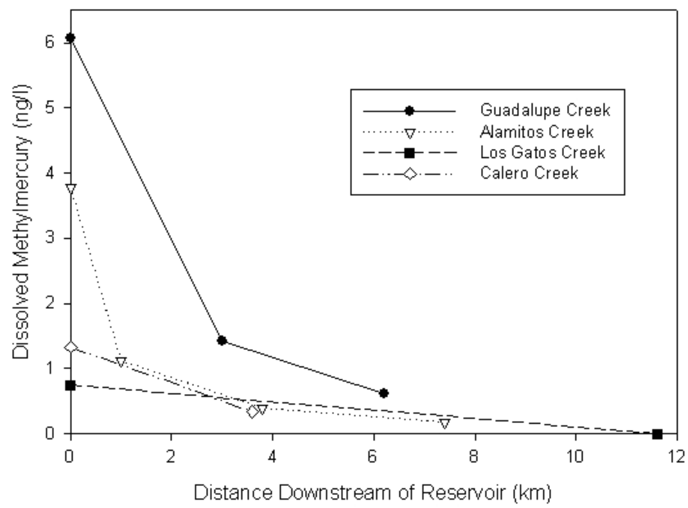

Figure 6.7 Dissolved Methylmercury Below Reservoirs, July 2003

Citation: Figure 5-10 Final Conceptual Model Report (Tetra Tech 2005c)

Fish samples from two locations both Alamitos Creek and the Guadalupe River had higher mercury concentrations in the upstream samples than in the downstream samples. The samples were collected at Sites 5 and 6 on Alamitos Creek (see Figure 6.3) (average concentrations of 0.28 and 0.26 ppm, respectively), and in the Guadalupe River at Sites 1 and 2 (average concentrations of 0.15 and 0.08 ppm, respectively). Although there may be sites for methylation in the stream and river channels, it appears that their total contribution to methylmercury production and bioaccumulation is much smaller than the reservoir exports during the dry season.

To sum up mercury transport on a watershed scale, at most locations in the wet season, the quantity of methylmercury and dissolved total mercury being transported is a small fraction of the total mercury. In the dry season when methylmercury production peaks, however, a significant fraction of the total mercury in outflows from the more contaminated impoundments is methylmercury (more than 30 percent). The amount of methylmercury decreases with distance downstream from these reservoirs. Methylation is much greater in these impoundments than in stream and river channels. But in general, methylation can occur wherever sulfate-reducing bacteria are active, although the deeper waters in impoundments and the upper few centimeters of sediment appear to be the most important zones.

The main points in linkage and transport are that the wet season is largely a time of transport of inorganic particulate mercury from the four sources in this watershed, ; mining waste, urban runoff, atmospheric deposition, and naturally occurring mercury in soil. In contrast, the dry season is characterized by mercury methylation by naturally occurring bacteria. Methylation principally occurs in the oxygen-depleted depths of impoundments, which are engineered structures. Methylmercury is the most bioavailable form of mercury. Bioaccumulation is the subject of the next section.

6.4 Quantitative Linkage from Methylmercury in Water to Targets

Methylmercury bioconcentrates as it moves up the food chain from algae to zooplankton to prey fish and to predator fish (Figure 6.8). The largest single jump in concentration occurs from the water to algae. The biomagnification of methylmercury is among the largest biomagnifications of all known chemical compounds. Concentrations in fish muscle tissue can be millions of times higher than in water. Unlike the qualitative linkage above, the link from methylmercury in water to fish tissue targets can be quantified as a bioaccumulation factor.

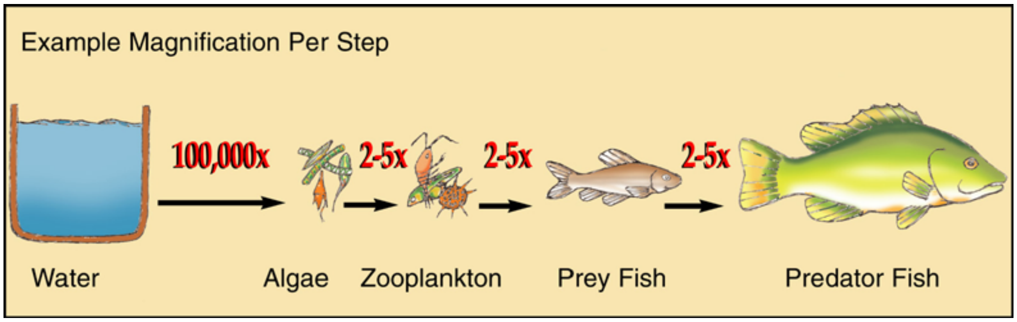

Figure 6.8 Food Chain Biomagnification of Methylmercury

Citation: Figure 5-7 Final Conceptual Model Report (Tetra Tech 2005c)

A summary of the 2004 fish sampling results is shown in the Figure 6.3 schematic diagram of the Guadalupe River watershed. The figure depicts the range of measured concentrations of mercury in the fish tissue for each sampling location. The shading of the fish symbols indicates the relative magnitude of the measured concentrations. The highest concentrations of mercury in adult largemouth bass muscle tissue were measured at Guadalupe Reservoir in the New Almaden Mining District, where the range of values was 3.1-13.0 ppm wet weight (wt.) muscle tissue for adults, and 0.64-1.1 ppm wet wt. whole-body samples for age-1 fish. The lowest mercury concentrations in both the adult and age-1 largemouth bass were measured at Lexington Reservoir outside of the New Almaden Mining District, where the ranges of mercury values were 0.4-1.0 ppm wet wt. muscle tissue for adults, and 0.06-0.14 ppm wet wt. whole-body samples for age-1 fish.

The stream sampling sites, where the California roach tissue samples were collected, are also shown on the watershed diagram. The highest concentrations in the whole-body California roach samples were measured at Guadalupe Creek in the New Almaden Mining District (Site 4), where the range of mercury concentrations was 0.31-0.48 ppm wet wt. The lowest concentrations in the California roach were measured at Los Gatos Creek outside of the New Almaden Mining District (Site 9), where the range of values was 0.02-0.04 ppm wet wt.

The differences in the fish tissue mercury concentrations exhibited in Figure 6.6 were examined further to establish a quantitative linkage between water column methylmercury concentrations and fish tissue mercury concentrations (numeric targets).

The bioaccumulation factor (BAF) is the ratio of the fish tissue mercury concentration to the water column mercury concentration in units of liters of water per kilogram of fish:

Equation 6.1

$$\text{Bioaccumulation Factor (BAF)} = CT/CW * 10^{-6}$$

where:

CT = Methylmercury concentration in the fish tissue, ppm
CW= Methylmercury concentration in the water, ng/l

Available data for the calculation of the bioaccumulation factors (BAFs) at different trophic levels in the aquatic ecosystem include measurements of mercury concentrations in the water, plankton, and fish between 2003 and 2005. The following paragraphs present the BAFs for a) zooplankton in impoundments, b) adult largemouth bass and age-1 largemouth bass in impoundments, and c) California roach in streams and the river.

Zooplankton BAFs were calculated based on measurements of total and methylmercury concentrations in the water column, phytoplankton, and zooplankton collected in September 2004 (Kuwabara et al. 2005). The BAF calculated with the epilimnion average total methylmercury concentration (0.36 ng/l) and zooplankton average methylmercury concentration (0.90 nanograms of methylmercury per gram of zooplankton, ng/g, parts per billion, dry wt.) at Guadalupe Reservoir is greater than 2 million (Tetra Tech 2005d; SFBRWQCB 2005e). Because the zooplankton methylmercury concentrations are reported on a dry-weight basis, this number is not directly comparable to the BAF values for the fish samples from these same waters, but it demonstrates the high uptake of methylmercury at the lower trophic levels. The zooplankton BAFs in this study are consistent with mercury trophic-transfer factors in literature published on other lakes and show the importance of the uptake of methylmercury by the lower trophic levels. BAFs were not calculated for phytoplankton because methylmercury was detected in phytoplankton in only two of the five impoundments.

To support development of fish BAFs and other TMDL work, measurements of total mercury in fish throughout the watershed were collected in 2004. Nearly all mercury in fish is methylmercury (Grieb et al. 1990). USEPA collected adult and age-1 largemouth bass from five impoundments (Guadalupe Reservoir, Almaden Reservoir, Calero Reservoir, Lexington Reservoir, and Almaden Lake). The Santa Clara Valley Water District collected age-1 California roach (*Lavinia symmetricus*) at six creek and river locations.

Adult largemouth bass BAFs were developed from average total mercury concentrations in fish and unfiltered (total) methylmercury concentrations in the surface and hypolimnion of the five largest impoundments (Tetra Tech 2005d; SFBRWQCB 2005e). The water concentrations are averages of measurements at Almaden and Guadalupe reservoirs on one date in July 2003 and six dates between May 11 and August 31, 2004. These measurements were taken at both the surface and at the reservoir outlet (referred to as hypolimnetic samples, since water is released from the bottom of the reservoirs below the thermocline). The mercury concentrations at Almaden and Guadalupe reservoirs are well characterized. A single value is used for the surface-water methylmercury concentration at Almaden Lake. This value is the average of two samples collected at the outlet in April 2004 as part of the Wet Weather Sampling under Part 1 of the Data Collection Plan (Tetra Tech 2005a). There is no measurement for the hypolimnion at

Almaden Lake. The surface-water and hypolimnion values for Calero and Lexington reservoirs are from samples collected on one date in July 2003.

The BAFs for adult fish compared to hypolimnion methylmercury range from 400,000 to 1,000,000. The BAFs for adult fish compared to surface total methylmercury range from 3.2 million to 12 million.

Similarly, age-1 largemouth bass BAFs were calculated from measurements of total mercury in the fish and the same set of impoundment methylmercury data used for the adult BAFs. The BAFs for age-1 fish compared to hypolimnion methylmercury range from 80,000 to 200,000. The BAFs for age-1 fish compared to surface total methylmercury range from 400,000 to 2 million.

California roach BAFs were developed from mercury concentrations measured in fish sampled at six creek and river locations in 2004, and in surface samples from five nearby sites in 2003. The calculated BAF values are consistent with observations in other systems where methylmercury is taken up rapidly in the water column by algae and transferred by ingestion to zooplankton and planktivorous fish (Tetra Tech 2005d). The concentration of methylmercury in the California roach is approximately 300,000 to 600,000 times higher than the methylmercury levels in the water column. The results of the fish sampling and measurements of mercury in tissue samples provide valuable new information to support the use of fish tissue as a numeric target for the TMDL.

6.5 Implications for TMDL

The research and analysis described in the preceding linkage sections suggest that a) both dissolved and total mercury loads must be reduced, and b) reducing methylmercury production to attain targets in reservoirs in the mining district may also attain targets in downstream waters.

There are three hypotheses (*H*) about the source(s) of methylmercury in the impoundments, and the relative contribution of each source to methylmercury loads and bioaccumulation. Current data from the watershed are inadequate to evaluate the validity of these hypotheses.

H_1: particulate mercury in bottom sediments in the dry season is solubilized due to high sulfide concentrations; dissolved mercury diffuses out of the sediment into the hypolimnion where it is methylated.

H_2: particulate mercury in bottom sediments in the dry season is solubilized due to high sulfide concentrations, methylated in the sediment, and methylmercury diffuses from the sediment to the hypolimnion.

H_3: dissolved mercury transported to the impoundments in the wet season is methylated in the hypolimnion in the dry season.

Based on current data from the Almaden and Guadalupe reservoirs, the relative contributions of the sediments or the water column are yet to be discerned. However, given that substantially more mercury exists in the sediment, it is reasonable to assume that the sediments are the larger source. (For a given volume, sediments at 1 ppm of mercury may contain three orders of magnitude more mercury than water at 100 ng/l.)

The implications for the TMDL are that both dissolved and total mercury loads must be reduced. In Section 8 (Preliminary Implementation Plan), actions are proposed to prevent mining waste and reduce urban runoff from entering water bodies and/or continuing to be transported downstream. These actions will reduce both particulate mercury concentrations in impoundment sediments and loads of dissolved mercury to impoundments.

Although there may be sites for methylation in the stream and river channels, as discussed in “mercury transport and linkage” above, their total contribution to methylmercury production is much smaller than the exports from the reservoirs and Almaden Lake during the dry season. This suggests that that reducing methylmercury production to attain TMDL targets in reservoirs in the mining district and Almaden Lake will likely also attain targets in downstream waters.

6.6 Mercury in Reference Reservoir

Previous linkage sections explained mercury transport, transformation to methylmercury, and bioaccumulation. Now we examine how these concepts apply under background conditions (no mining waste or urban runoff) and whether numeric targets are achieved. If so, this may provide options to consider as allocations in the next section.

The upper portion of the Los Gatos Creek subwatershed (from the headwaters to Lenihan Dam, i.e. Lexington Reservoir) is considered background because it receives no mining waste or urban runoff. Two sources contribute mercury to the background area: naturally occurring mercury in soil and the other anthropogenic source, atmospheric deposition. Consequently, the readily accessible reservoir (Lexington) was selected as the reference reservoir for this TMDL.

Fish tissue mercury concentrations are the best measure of bioaccumulation and consequently were selected as the targets for this TMDL. Two sets of fish tissue data were collected from Lexington Reservoir in 2004 (Tetra Tech 2005a). The first step is to compare the fish data to targets.

The target to protect human health is 0.3 ppm average in fish typically consumed (Table 5.3). The adult fish sampled were largemouth bass, which are trophic level four (TL4) as opposed to “typically consumed.” As noted in Numeric Targets (Section 5), TL4 data should be compared to 0.66 ppm, the USEPA equivalent concentration for TL4 fish (with the assumption that the USEPA default fish consumption rate is applicable). Average mercury in adult largemouth bass, average length of 408 millimeters (mm), was 0.6 ppm. We conclude that the human health target is met in Lexington Reservoir.

The 50 – 150 mm TL3 fish target to protect wildlife is 0.05 ppm average (Table 5.3). Again, the fish sampled were largemouth bass, age-1 in this case, but still TL4. The increase of mercury from one trophic level to the next is described by the “trophic level ratio.” The trophic level ratio from TL3 to TL4 is approximately 2 (USFWS 2005.) Average mercury in age-1 largemouth bass, average length 89 mm, was 0.09 ppm. Dividing the mercury concentration by 2 yields the equivalent mercury concentration in TL3 of 0.045 ppm, which is lower than the target of 0.05 ppm for both TL3 fish of less than 50 mm and between 50 – 150 mm (Table 5.2). We conclude that the wildlife target is met in Lexington Reservoir.

Methylmercury is a particular focus of this TMDL because it is the most bioavailable form of mercury. As described above in detail, in the warm dry season under low oxygen conditions, inorganic mercury is converted to methylmercury by naturally occurring bacteria. Methylmercury concentrations increase notably in the deep portions of thermally stratified impoundments (hypolimnion), until the seasons change (see Figure 6.6 Panel B.) As explained in the discussion of Figure 6.6 Panel C, the greatest uptake of methylmercury in impoundments occurs as water levels mix and turn over each fall.

Lexington Reservoir hypolimnion methylmercury concentrations from late May 2004 through mid-October 2004 are illustrated on Figure 6.9 (LAS 2004; Table A.3). Hypolimnion methylmercury reached 2.7 nanograms of methylmercury per liter of water (ng/l, parts per trillion) on September 17, 2004, but a lower concentration of 1.75 ng/l was measured on October 11. Based on our linkage analysis, it is reasonable to assume that methylmercury concentrations continued to rise for several more weeks up until turnover, which the Water District estimates occurred between October 29 and November 24, 2004 (SCVWD 2005). A linear regression of methylmercury concentrations in Lexington Reservoir from May to turnover yields the estimated seasonal peak hypolimnion methylmercury concentration in 2004 of 3.0 ng/l.

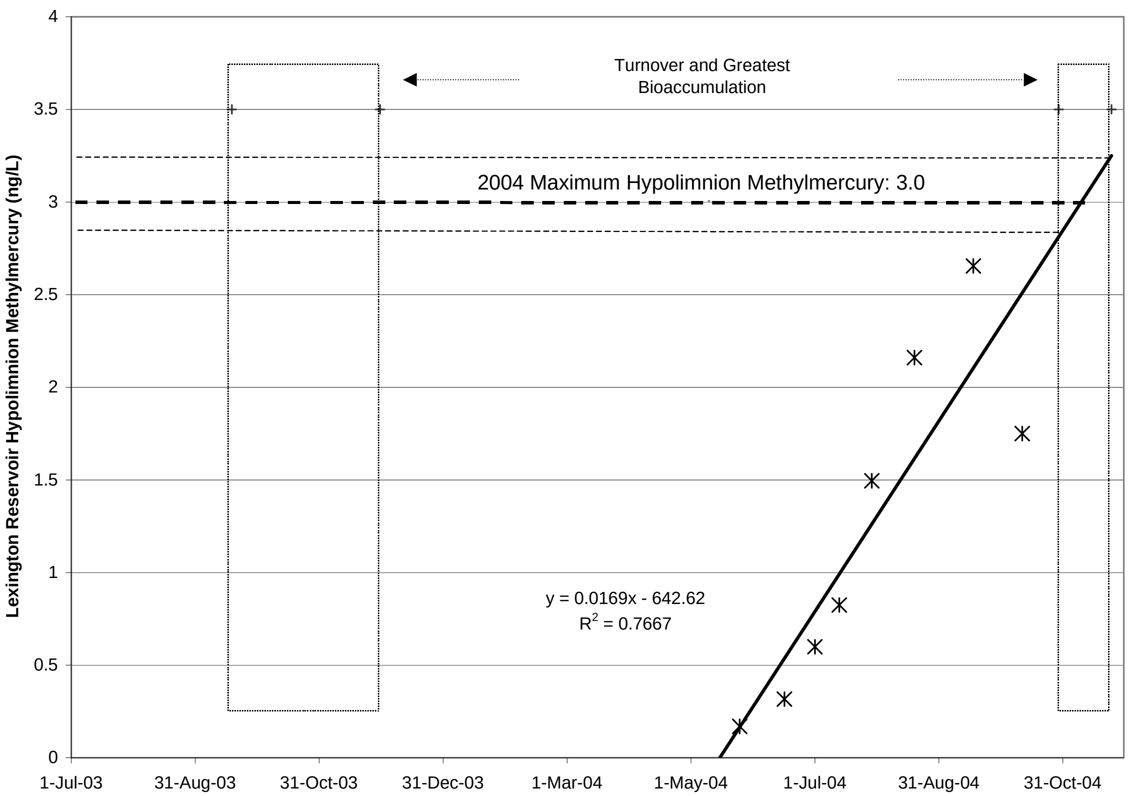

Figure 6.9 Maximum Hypolimnion Methylmercury

As noted above, both human health and wildlife targets are met in Lexington Reservoir, so we conclude that a maximum hypolimnion methylmercury concentration of 3.0 ng/l will meet targets. If hypolimnion methylmercury is assumed to be a controllable water quality factor, and the related management questions in Section 9 (methylmercury monitoring plan) are resolved, then a seasonal maximum of 3.0 ng/l methylmercury in the hypolimnion of deep impoundments may be an appropriate allocation for this TMDL.

Mining waste eroded by storms and transported to receiving waters is the largest source of mercury. This is the same erosion and transport process of background soil into the reference reservoir. Both contribute inorganic mercury, primarily in particulate form. Three measures are available: mass loads of total and dissolved mercury, and bottom sediment mercury concentrations. Mass loads were estimated in the *Final Conceptual Model Report* (Tetra Tech 2005c) with low precision (a high precision monitoring program was cost-prohibitive and unnecessary for the conceptual model). In contrast, a statistically robust set of impoundment bottom sediment samples were collected (see Figure 6.2) and provide a qualitative linkage from sources to targets (Section 6.1).

Mercury concentrations in Lexington Reservoir bottom sediment samples (Tetra Tech 2005b; Table A.2) had a small range from 0.07 – 0.18 ppm dry weight, with average mercury of 0.1 ppm. As noted above, both human health and wildlife targets are met in Lexington Reservoir, so we conclude that a maximum of 0.1 ppm average total mercury in impoundment bottom sediments will meet targets. More than half of the samples were 100% fines (silts and clays of less than 63 microns); percent fines ranged from 85 – 100%. These soil fines were transported as suspended sediment in storm water runoff, which is best characterized by the annual median. If erosion is assumed to be controllable and “erodable soil” is defined as soil that is transported by storm runoff to receiving waters, then a maximum of 0.1 ppm (annual median, dry weight) total mercury in erodable soil fines (less than 63 microns) may be an appropriate allocation for this TMDL.

6.7 Water Quality Standards Attainment

Natural erosion and sediment deposition may eventually wash the mining waste out of the Guadalupe River watershed, or bury it. In the Cache Creek watershed, which contains much less mining waste but extends a longer distance to San Francisco Bay compared to Guadalupe, it is estimated that this natural process will take at least 500 years (Cooke & Morris 2004). Consequently, in the Cache Creek Mercury TMDL, Central Valley Water Board staff proposes extensive implementation actions to stop discharges of mining waste and reduce methylmercury production, hence restoring the watershed in fewer than 500 years.

Similarly, San Francisco Bay Water Board staff proposes in this TMDL to require extensive implementation actions to stop discharges of mining waste and reduce methylmercury production. These actions will restore impaired beneficial uses and attain applicable water quality objectives in a timeframe that is more reasonable and acceptable to the public, dischargers, and, presumably, wildlife.

The mercury TMDL must comply with the federal Clean Water Act, and result in attainment of the Basin Plan narrative objective for bioaccumulation, the Basin Plan numeric water quality objectives, and the USEPA California Toxics Rule numeric water quality objective. The Clean Water Act requires that a TMDL and associated waste load and load allocations be set at levels that attain all applicable water quality standards, which include beneficial use protections, narrative water quality objectives, numeric water quality objectives, and anti-degradation policies (see below). As described in the Introduction (Section 1), to protect beneficial uses, the applicable water quality objectives are those related to mercury impairment and include the following:

- Beneficial uses for human consumption of fish: Water Contact Recreation (REC1)
- Beneficial uses for wildlife consumption of fish: Preservation of Rare and Endangered Species (RARE), and Wildlife Habitat (WILD)
- Basin Plan narrative water quality objective for bioaccumulation
- Basin Plan numeric water quality objectives
- California Toxics Rule numeric water quality objective (30-day average)

The proposed fish methylmercury targets provide a numeric interpretation of the Basin Plan narrative objective for bioaccumulation, and are protective of human health and wildlife. Achieving these targets will attain the REC1, RARE, and WILD beneficial uses and the Basin Plan narrative objective for bioaccumulation.

Both of the Basin Plan numeric water quality objectives (25 ng/l four-day average and 2,400 ng/l one-hour average) are derived from the USFDA's action level for mercury in commercial fish and shellfish (1.0 ppm) and a bioconcentration factor of 40,000 (the relative methylmercury concentration found in the Eastern oyster compared to the total mercury concentration in the water in which the Eastern oyster lives) (USEPA 1985). Because the proposed fish tissue target of 0.3 ppm is substantially lower than the USFDA's action level of 1.0 ppm, it is more stringent than the Basin Plan numeric water quality objectives.

Both the USEPA human health criteria, a) 0.3 ppm methylmercury criterion (not yet adopted for California) and b) the California Toxics Rule numeric water quality objective (adopted) use the same reference dose and body weight (see Equation 5.1), and nearly the same fish consumption rate (18.73 and 17.5 grams per day, respectively). Equation 5.1 is solved directly to result in the fish tissue value in the methylmercury fish tissue criterion. The California Toxics Rule takes this calculation one step further by dividing the fish tissue value by a bioconcentration factor, which results in a water column value. In other words, the fish tissue criterion and the California Toxics Rule value are essentially the same, except they are expressed for different media (fish tissue vs. water column, respectively). Therefore, the proposed human health fish tissue target is consistent with the California Toxics Rule.

In summary, the three proposed fish methylmercury targets are protective of human health and wildlife. Achieving these targets will attain the REC1, COMM, and WILD beneficial uses, the Basin Plan narrative objective for bioaccumulation, the Basin Plan numeric water quality objectives, and the California Toxics Rule numeric water quality objective.

Key Points

- The linkage between sources (mining waste, urban runoff, atmospheric deposition, and naturally occurring mercury in soil) and the numeric targets (fish tissue methylmercury concentrations) is not direct. As illustrated in the diagram below (Figure 6.1), the sources and the numeric targets are linked by the sites where methylmercury is produced.
- The strongest evidence of the linkage between sources and targets in the watershed is reservoir sediment and corresponding fish tissue mercury concentrations. Reference reservoir bottom sediment concentrations of 0.1 ppm total mercury in fines (less than 63 microns) correspond to acceptable fish mercury concentrations. We define "erodable soil" as soil that is transported by storm runoff to receiving waters and derive a load allocation for mining waste discharges of 0.1 ppm (annual median, dry weight) total mercury in erodable soil fines. One implication of the linkage is that both dissolved and total mercury loads must be reduced, so that measures designed to prevent soil erosion must also consider transport of dissolved mercury.
- The wet season is largely a time of transport of inorganic particulate mercury, whereas methylation and bioaccumulation largely occur in the dry season when and where the critical condition of low oxygen (anoxic conditions) occurs. Methylation principally occurs in the oxygen-depleted depths of impoundments. "Impoundments" are engineered structures, such as dams, drop structures, and former quarries, that cause water to pond – and are very different from natural conditions as there are no natural deep lakes in this watershed. The reference reservoir reached a seasonal maximum of 3.0 nanograms of methylmercury per liter of water (ng/l, parts per trillion) methylmercury in the hypolimnion with acceptable fish mercury concentrations. From the reference reservoir we derive a load allocation of 3.0 ng/l methylmercury in the hypolimnion of deep impoundments.
- Methylmercury bioconcentrates as it moves up the food chain from algae to zooplankton to prey fish and to predator fish (Figure 6.8). The largest single jump in concentration occurs from the water to algae. The biomagnification of methylmercury is among the largest biomagnifications of all known chemical compounds.
- Although there may be sites for methylation in the stream and river channels, as discussed in "mercury transport and linkage" above, their total contribution to methylmercury production is much smaller than the exports from the reservoirs and Lake Almaden during the dry season. This suggests that that reducing methylmercury production to attain TMDL targets in impoundments in the mining district and Almaden Lake will likely also attain targets in downstream waters.

7. TMDL, Allocations and Implementation Strategy

The total maximum daily load of mercury in the Guadalupe River Watershed is the combination of concentration and mass load allocations proposed herein. Additionally, this section describes the implementation strategy for the Guadalupe River Watershed Mercury TMDL. The Water Board extends to the Guadalupe Mercury Work Group (convened by the Santa Clara Basin Watershed Management Initiative partly to assist with the technical basis of this TMDL) the opportunity to contribute to the development of the Final Implementation Plan by June 30, 2006 which incorporates the goals and schedules provided below.

As shown by the Linkage Analysis (Section 6), mercury bioaccumulation in the Guadalupe River watershed cannot be reduced unless loads of dissolved and total mercury and methylmercury production are reduced. Reductions in total mercury are also necessary to meet the load allocation that the San Francisco Bay Mercury TMDL assigns to the watershed. This section presents recommended allocations for mercury reduction among the sources in the Guadalupe River watershed. Allocations are based on goals of a) eliminating inputs of mercury caused by anthropogenic activities, particularly mining and urban runoff, and b) minimizing the transformation of mercury to methylmercury caused by anthropogenic activities, particularly construction and operation of impoundments.

A TMDL need not be stated as a daily load (Code of Federal Regulations, Title 40, §130.2[i]). Other measures are allowed if more appropriate. The allocations proposed below combine concentration limits within the watershed and annual mass loads for discharges to San Francisco Bay. This combination of annual loads and concentration limits was selected to protect against the adverse effects of mercury that occur through long-term bioaccumulation. Mass loads and concentrations of total mercury are expected to fluctuate with the magnitude of precipitation, flow, and resulting soil erosion from the land surface and from the banks, floodplains, and bottoms of creeks and rivers. The allocations are intended to represent long-term averages and account for long-term variability, including seasonal variability. As discussed in Section 7.2 below, the proposed allocations involve an implicit margin of safety.

Achieving the load allocations detailed below will be part of a two-phase TMDL implementation process described in the Preliminary Implementation Plan (Section 8. In general, the goals for the first phase of implementation are to a) implement effective source control measures for mining waste in the New Almaden Mining District, b) complete studies to reduce discharge of mining waste accumulated in downstream beds, banks, and floodplains, and c) attain the urban runoff interim loading milestone of 11 kilograms per year. The goal for the second 10-year phase of implementation is to achieve the watershed fish tissue targets and the total mercury load allocation assigned by the San Francisco Bay Mercury TMDL. Throughout both phases, the mercury load, concentrations, and bioaccumulation will be monitored to ensure that total and methylmercury levels have adequately declined. As described in Section 9 (Monitoring Plan), monitoring may be undertaken in a coordinated effort by many entities. Guiding both phases, and remaining central to the implementation process, will be the allocations for each source described below.

7.1 Impoundment Methylmercury Allocation

Impoundments are engineered structures that pond water. They include dams (i.e., reservoirs and artificial lakes), flood control structures, other engineered features (such as drop structures), and non-native invasive vegetation that ponds water. As described in Section 4 (Source Analysis), prior to the mining era, there were no lakes or other large natural impoundments in the Guadalupe River watershed. This allocation is intended to reduce methylmercury production in deep impoundments impaired by mercury, where seasonal thermal stratification results in water chemistry that enhances methylmercury production (see Section 6), to a level that attains targets. As shown by Section 6.9, the maximum hypolimnion methylmercury concentration at Lexington Reservoir of 3.0 nanograms of methylmercury per liter of water (ng/l, parts per trillion) results in fish safe for consumption by people and wildlife. **Therefore, the impoundment allocation is a seasonal maximum of 3.0 ng/l methylmercury in the hypolimnion of Guadalupe, Almaden, and Calero reservoirs and Almaden Lake**.

PHASE 1: IMPLEMENTATION STRATEGY FOR METHYLMERCURY IN DEEP IMPOUNDMENTS

- Applicable to methylmercury production in Guadalupe, Almaden, and Calero reservoirs and Almaden Lake
- Responsible parties will conduct appropriate technical analyses of hypolimnion methylmercury controls. The technical analyses will be presented in a report shall to be submitted for Water Board approval.
- If the technical analyses indicate it is possible to control hypolimnion methylmercury, responsible parties shall develop and submit for Water Board approval feasibility studies to control methylmercury production.
- The technical analyses and feasibility studies, and deployment of control measures in Guadalupe, Almaden, and Calero reservoirs and Almaden Lake shall be completed within the 10-year duration of Phase 1.

Potential Actions

- Adapt nutrient controls developed for reservoirs (e.g., oxygenate hypolimnion) for control of methylmercury
- Deploy methylmercury controls in Guadalupe, Almaden, and Calero reservoirs and Almaden Lake and evaluate whether fish tissue mercury levels will meet targets
- Subsequently, measure downstream aqueous methylmercury and fish tissue mercury levels

PHASE 2: IMPLEMENTATION STRATEGY FOR METHYLMERCURY IN ALL IMPOUNDMENTS

- Responsible parties shall implement methylmercury production controls in shallow impoundments if warranted based on Water Board evaluation (to be conducted during the five-year Basin Plan review cycle in the middle of Phase 2).

7.2 Mining Waste Total Mercury Allocations

Mining waste is defined in the California Water Code §13050 (q)(1) as "all solid, semisolid, and liquid waste materials from the extraction, beneficiation, and processing of ores and minerals. Mining waste includes, but is not limited to, soil, waste rock, and overburden, as defined in Section 2732 of the Public Resources Code, and tailings, slag, and other processed waste materials…" The mining waste allocations apply to mining waste as defined above, including ore piles, soil under processing sites, stormwater runoff from processing facilities and equipment, and other process areas and equipment impacted by mine operations and exposed to stormwater such that mercury may be transported to receiving waters.

Mining waste is located in the New Almaden Mining District (defined in Section 3.4; notably for purposes of this TMDL, it includes the former Guadalupe Mine), and due to wet season transport over more than a century, mining waste is also located in the downstream bed, banks, and floodplains of Guadalupe, Alamitos, and Calero creeks and Guadalupe River. The goal for the mining waste allocation is to eliminate inputs of mercury caused by anthropogenic activities (i.e., mining) to restore beneficial uses. This goal is consistent with the Basin Plan's Implementation Plan goals for mines and mineral producers to "…restore and protect beneficial uses of receiving waters now impaired or threatened with impairment resulting from past or present mining activities." It is also consistent with the Clean Water Act requirement that "the TMDL and associated waste load and load allocations must be set at levels necessary to result in attainment of all applicable water quality standards… 40CFR130.7(c)(1)."

Water Board staff considered forms of mercury appropriate for this allocation. The principal concern with mining waste is wet season stormwater transport of inorganic mercury to receiving waters. We assume that implementation actions taken to address total mercury in mining waste will effectively address dissolved mercury from mining waste; methylmercury production is addressed as a separate allocation above. Therefore, the mining waste allocation is for total mercury. We also considered several options for the mining waste allocations and associated compliance monitoring, such as a mass load, restoring to pre-mining conditions, and a sediment mercury concentration. Examples and evaluations of these allocations and compliance monitoring are provided below.

Examples of mass load allocations are the total maximum annual load that the San Francisco Bay Mercury TMDL assigns to the Guadalupe River watershed (Looker & Johnson 2004), and the 95 percent mass load reduction assigned to mines in the Cache Creek watershed (Cooke & Morris 2004.) However, the Guadalupe Linkage Analysis (see Section 6) for inorganic mercury is qualitative, so it does not provide a scientific basis for a mass load in the Guadalupe River watershed. Additionally, compliance monitoring for a mass load would require considerable precision for discharges from many creeks in the several-thousand-acre New Almaden Mining District, and separately from downstream creek beds, banks, and floodplains. Due to the wide range in annual precipitation, monitoring would be required over several years. Presumably, the 95 percent mass load reduction approach to allocations would require even greater monitoring precision. We propose that the funding for these monitoring efforts would be better spent on implementation to restore beneficial uses.

Examples of allocations to restore the landscape to pre-mining conditions include establishing pre-mining surface soil mercury concentrations to use as mine site cleanup goals (Cooke & Morris 2004), or mineralized zone perimeter sediment mercury concentrations to use as mine site cleanup goals (Stanish & Cooke 2004). It is reasonable to assume that the inefficient processing methods—and lack of air pollution controls—widely distributed mercury onto surface soils in the New Almaden Mining District. Therefore, the main difficulty with these approaches is determining pre-mining mercury concentrations and production for the New Almaden Mining District. Compliance monitoring would be based on the simple and immediate approach used for hazardous waste cleanups—collect a statistically valid set of samples, determine average mercury, and complete remediation when the cleanup goal is met.

Lastly, we considered an allocation based on background sediment mercury. As described in Section 6.9, for the purposes of this TMDL, Lexington Reservoir is a background impoundment. The average impoundment bottom sediment mercury concentration in Lexington Reservoir is 0.1 ppm (average, dry weight), which attains the targets to protect human health and wildlife in deep impoundments, the water bodies with the highest methylmercury concentrations in the watershed. The deep impoundments downstream of the New Almaden Mining District are Guadalupe, Almaden, and Calero reservoirs, and Almaden Lake. The majority (about 90 percent) of the New Almaden Mining District drains to these deep impoundments.

The remaining 10 percent of the New Almaden Mining District, Guadalupe Creek, and the Guadalupe River do not drain to deep impoundments. The Linkage Analysis (Section 6) does not provide a quantitative linkage for this segment of the watershed, but it does explain that the methylmercury discharged from the deep impoundments is much greater than the in-stream production (Section 6.3). The San Francisco Bay Mercury TMDL, however, proposes a suspended sediment mercury target of 0.2 ppm (annual median, dry weight) to meet the proposed fish tissue and bird egg targets protective of wildlife beneficial uses. **Therefore, Water Board staff proposes two mining waste allocations as follows:**

- **0.1 ppm mercury (annual median, dry weight) in erodable soil fines transported from the New Almaden Mining District to Guadalupe, Almaden, and Calero reservoirs and Almaden Lake ; and**
- **0.2 ppm mercury (annual median, dry weight) in suspended sediments eroded from the remaining 10 percent of the New Almaden Mining District; Guadalupe, Alamitos, and Calero creeks; and the Guadalupe River.**

Water Board staff proposes to evaluate attainment of the mining waste allocations through Water Board oversight of selection, design, construction, and operations and maintenance of best management practices for erosion control. This is the same method as proposed for the 95 percent mercury load reduction from mines in the Cache Creek watershed, and for pathogens in the Tomales Bay Pathogens TMDL.

PHASE 1: IMPLEMENTATION STRATEGY FOR MINING WASTE FROM UPPER WATERSHED

- Applicable to mercury-contaminated sediments from mining wastes transported from the New Almaden Mining District to receiving waters (not just those draining to deep impoundments; the purpose is to ensure effective upstream source control before downstream projects are undertaken), and seeps that discharge mercury to receiving waters

- Responsible parties shall develop and submit for Water Board approval plans to control mining waste discharges.
- Remedial actions shall be completed within the 10-year duration of Phase 1.

<u>Potential Actions</u>

- Assess mining waste erosion potential
- Develop and implement erosion control plan as follows:

  Excavate mining waste in and within __#__ feet of water bodies and revegetate

  Stabilize creek banks with biotechnical methods, such as laying back banks and planting native riparian vegetation

  Easily eroded mining waste on steep slopes requires a) excavation or re-grading resulting in run-on routed around stable waste piles and b) establishing and maintaining vegetation on the stable waste piles

  easily eroded mining waste on moderate to flat slopes requires a) excavation or re-grading resulting in run-on routed around stable waste piles

PHASE 1: IMPLEMENTATION STRATEGY FOR DOWNSTREAM MINING WASTE

- Applicable to mining waste discharges from Guadalupe, Alamitos, and Calero creeks and the Guadalupe River (including shallow impoundments on these water bodies)
- Responsible parties shall conduct appropriate technical analyses of the erosion potential of mining wastes accumulated in the bed, banks, and floodplains. The technical analyses will be presented in a report, which responsible parties shall submit for Water Board approval.
- Where it is possible to control erosion of mining wastes, responsible parties shall develop and submit for Water Board approval feasibility studies to control mining waste discharges.
- The technical analyses of the erosion potential and feasibility studies to control mining waste discharges shall be completed within the 10-year duration of Phase 1.

<u>Potential Actions</u>

- Assess mining waste erosion potential from bed, banks, and floodplains
- Develop and implement erosion control plan as follows:

  Stabilize creek banks with biotechnical methods, such as laying back banks and planting native riparian vegetation

- Remove sediments where mercury exceeds the applicable allocation (0.1 or 0.2 ppm) accumulated in small impoundments (e.g., Alamitos Drop Structure and other flood control structures) or accumulated in the Guadalupe River

PHASE 2: IMPLEMENTATION STRATEGY FOR DOWNSTREAM MINING WASTE

- Responsible parties shall implement control actions for mining waste discharges from Guadalupe, Alamitos, and Calero creeks and Guadalupe River (including all impoundments on these water bodies), if warranted based on Water Board evaluation (to be conducted during the five-year Basin Plan review cycle near the end of Phase 1).

7.3 Urban Runoff Total Mercury Allocation

The mercury in urban stormwater runoff results in part from controllable urban sources, such as improperly discarded fluorescent lights, electrical switches, thermometers, and other mercury-containing devices, and from historical and ongoing industrial activities. Atmospheric deposition and naturally occurring mercury in background soils, which are assumed to be difficult to control, also contribute to the mercury in urban runoff. The estimated suspended sediment load discharged from the Guadalupe River watershed to San Francisco Bay is 44 million kilograms per year (M kg/yr), of which 36 M kg/yr is from urban runoff (Looker & Johnson 2004). Sediment load multiplied by the San Francisco Bay Mercury TMDL target concentration of 0.2 ppm total mercury in suspended sediment (Looker & Johnson 2004) yields the **urban runoff wasteload allocation of 7.2 kilograms per year total mercury to be attained within 20 years. The interim wasteload allocation to urban runoff is halfway between the current load and the allocation, 11 kilograms to be attained within 10 years.**

PHASE 1: IMPLEMENTATION STRATEGY FOR URBAN RUNOFF

- Applicable to storm drain discharges to creeks and the river in the Guadalupe River watershed. Urban runoff management agencies represent the communities that operate the storm drains and are responsible for storm drain discharges through National Pollutant Discharge Elimination Permits. The water Board has issued countywide permit CAS029718 to the Santa Clara Valley Urban Runoff Pollution Prevention Program. This allocation implicitly includes any construction or industrial (e.g., California Department of Transportation [Caltrans]) discharges that discharge to creeks and the river in the Guadalupe River watershed.

- Conduct investigation and surveillance for industrial facilities and construction sites mercury hot spot cleanup. Review available mercury data, land use information, historical activity, and other relevant information to identify where contamination is likely.

- Identify stormwater conveyance mercury hot spots. Evaluate sediment best management practices options for stormwater funoff treatment retrofits for fine sediment control (detention basins, sand filters, infiltration basins, wetlands, etc.).

- Evaluate stormwater treatment by publicly-owned treatment works (POTWs), particularly "first-flush" discharge. Evaluate drainage areas, flow volume and timing needs. Identify potential partnerships between urban stormwater agencies and POTWs, including trading credits for partners.

- Complete above studies within five years; cleanup (remedial) actions shall be completed within the 10-year duration of Phase 1.

Potential Actions

- Sample and analyze total and methylmercury in urban runoff throughout the watershed; use the data to compute the annual median sediment total mercury concentration and annual load to San Francisco Bay and the methylmercury load
- Sample and analyze total and methylmercury in sediments accumulated in stormwater conveyances, including storm drains
- Identify areas where mercury in accumulated sediment exceeds the Guadalupe allocation (and Bay sediment target) of 0.2 ppm and remove that sediment; evaluate areas of high methylmercury production and discharge to receiving waters and remove that sediment
- Establish a dry season storm drain maintenance program to check for and remove sediment accumulated in stormwater conveyance systems (stormwater inlets, catch basins, pump stations, and street curbs; program can be targeted to specific areas depending on such factors as land use and size of the drainage area, and previous sediment mercury and methylmercury concentrations)
- Cleanup (remediate) industrial facilities and construction sites mercury hot spots. Determine potential for off-site migration, identify oversight agency and potentially responsible parties (PRPs), and select remedy.

PHASE 2: IMPLEMENTATION STRATEGY FOR URBAN RUNOFF

Potential Actions

- Responsible parties shall implement continued and improved urban runoff control actions.

7.4 Background Soil Total Mercury Allocation

Erosion of background, non-mineralized soil is a source of mercury. This source, naturally occurring mercury in soil, is different from mining waste. Because erosion from non-urban background areas of the watershed may be exacerbated by grazing, road cuts, or other anthropogenic activities, the loads are somewhat controllable. In the San Francisco Bay Mercury TMDL, the Guadalupe River watershed's suspended sediment load was estimated to be 44 M kg/yr, of which 8.5 M kg/yr is derived from non-urban runoff (Looker & Johnson 2004). The estimated mercury sediment concentration in Bay Area open space today of 0.06 ppm is close to the estimated pre-mining background concentration of 0.08 ppm, and well below the San Francisco Bay Mercury TMDL target of 0.2 ppm (Looker & Johnson 2004). **Therefore, the background soil load allocation**

is the current load. Sediment load multiplied by estimated open space mercury concentration of 0.06 ppm total mercury in suspended sediment yields the background soil load allocation of 0.5 kilograms per year of total mercury.

7.5 Atmospheric Deposition Total Mercury Allocation

Deposition from the atmosphere is minimal relative to other loads in the watershed. As described in Section 4 (Source Analysis), the load of mercury from atmospheric deposition onto land surface has not been quantified separately from the background soil load, and therefore is included in the background soil load allocation above. However, **there is also direct atmospheric deposition onto waters, which is addressed by this load allocation**. No reductions are called for partly because this load is reflected in the mining waste allocations of 0.1 & 0.2 ppm mercury (annual median, dry weight) in erodable soil fines (see Sections 6.6 and 7.2).

Mercury in the atmosphere enters the watershed during dry weather (dry deposition) and rainy weather (wet deposition). To determine the mercury load associated with dry and wet deposition, the Regional Monitoring Program for Trace Substances collected ambient air and precipitation samples at three Bay Area sites. The study estimated the average dry and wet deposition rate to be 23.2 micrograms of mercury per square meter per year (SFEI 2001). About 1 percent of the 170-square-mile watershed is water surface, which is approximately 4.8 million square meters.

The deposition rate multiplied by the area yields the existing load of 0.1 kilograms per year of total mercury. Because the potential to reduce deposition by controlling local sources is believed to be limited, and because reductions in the global atmospheric pool are beyond the scope of this TMDL, the atmospheric deposition load allocation is the existing load. It is anticipated that remediation of the New Almaden Mining District will reduce atmospheric inputs from local and regional sources, but no estimates are available.

PHASE 1: IMPLEMENTATION STRATEGY FOR ATMOSPHERIC DEPOSITION

- Refer to Section 8 of the San Francisco Bay Mercury TMDL Report (Looker & Johnson 2004) for an in-depth discussion of implementation strategy for atmospheric deposition in the San Francisco Bay Area.
- The Bay Mercury TMDL proposed that the Bay Area Air Quality Management District (Air District) should conduct a local mercury emission inventory, investigate the significance of local mercury air emission, evaluate the effectiveness of existing control measure, and the feasibility of additional controls. The Water Board will request that the Air District conduct a Guadalupe River watershed-specific mercury emission inventory.

7.6 Integration with San Francisco Bay Mercury TMDL

As mentioned in Section 1.2, the Guadalupe River Watershed Mercury TMDL will be the primary regulatory vehicle for achieving water quality goals in the watershed and will simultaneously reduce the load of mercury to the Bay in accordance with the requirements of the San Francisco Bay Mercury TMDL (Looker & Johnson 2004). In accordance with State Board guidance, the two TMDLs are being carefully integrated in terms of load allocations, interim milestones toward the load allocations, and evaluating compliance with the allocations.

The San Francisco Bay Mercury TMDL assigns allocations to the Guadalupe River watershed as listed in Table 7.1.

Table 7.1 Bay Mercury TMDL Allocations to Guadalupe River Watershed

Description	Existing Load (kg/yr)	Allocation (kg/yr)	Load Reduction
Mining Legacy	92	1.7	98%
Non-Urban Runoff	0.5	0.5	None
Urban Runoff	14	7.2	49%
Bay TMDL total:	**106.5**	**9.4**	**- -**

The two TMDLs are integrated in the following ways:

1) Urban runoff is assigned the same interim allocation (11 kg to be achieved within 10 years), and the final allocation (7.2 kg to be achieved within 20 years), in both the Bay and Guadalupe TMDLs.
2) Non-urban runoff in the Bay TMDL is called naturally occurring mercury in soil in the Guadalupe TMDL, and is assigned the same allocation (0.5 kg/yr) in both the Bay and Guadalupe TMDLs to be achieved within 20 years.
3) Water Board staff proposes in both TMDLs that dischargers demonstrate progress toward a) the interim loading milestone, or b) attainment of the allocation by using one of three methods listed below:
    - Quantify the annual average mercury load reduced by implementing a) pollution prevention activities, b) source and treatment controls, and c) if applicable, other efforts to reduce methylation or mercury-related risks to humans and wildlife. The Water Board will recognize loads reduced resulting from activities implemented after 1996 (or earlier if actions taken are not reflected in the 2001 load estimate) to estimate load reductions.
    - Quantify the mercury load as a five-year annual average mercury load using data on flow and water column mercury concentrations.
    - Quantitatively demonstrate that the mercury concentration of suspended sediment that best represents sediment discharged from the watershed to San Francisco Bay is below the suspended sediment target (0.2 ppm).
4) There is an extensive transition zone from the Guadalupe River through the tidal Alviso Slough to San Francisco Bay. The two TMDLs will be coordinated to ensure that the fate and transport of mercury-laden sediments from the river will be addressed, particularly in the hundreds of acres of soon-to-be-restored salt ponds adjacent to, and near the mouth of, Alviso Slough.

7.7 Seasonal Variations & Critical Conditions

Federal regulations require TMDLs to account for seasonal variations and critical conditions. The possible factors to consider for seasonal variability include pollutant loads, beneficial use impairment, and ambient concentrations of total mercury and methylmercury in water and sediment. Seasonal variability in loads is a key feature in the Guadalupe River watershed, and it is discussed extensively in this section. Essentially, in the wet season, total mercury is transported in stormwater, whereas methylation and bioaccumulation largely occur in the dry season when and where the critical condition of low oxygen (anoxic conditions) occurs. The allocations proposed in Section 7 are intended to address seasonal variations and critical conditions.

7.8 Margin of Safety

TMDL analyses must incorporate a margin of safety to address potential uncertainties. The margin of safety is intended to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality.

The margin of safety can be derived either explicitly or implicitly. Providing an explicit margin of safety would involve reserving a specific mercury load allocation for the margin of safety. Alternatively, an implicit margin of safety involves using conservative assumptions (assumptions more likely to be over-protective than under-protective) throughout the analysis. This report relies on several conservative assumptions to derive targets and allocations, and thereby provides the margin of safety implicitly.

Conservative assumptions were made in developing targets. The method USEPA used to develop its fish tissue criterion (from which the human health fish tissue target is derived) includes several conservative assumptions, including the incorporation of a factor of 10 in the reference dose to account for uncertainties related to mercury's health effects and its metabolism in the body. These conservative assumptions were retained for the fish tissue target; therefore, the target reflects a conservative estimate of the lifetime daily exposure level at which no adverse effects would be expected (USEPA 2001). Similarly, the method USFWS used to develop its fish tissue criterion (from which the wildlife fish tissue targets are derived) includes several conservative assumptions (USFWS 2005).

The largest margin of safety is provided by methylation controls. This TMDL indicates that source control actions for mining waste and urban runoff are needed throughout the New Almaden Mining District and downstream to the mouth of Guadalupe River. Safe levels of mercury in impoundment bottom sediments would likely require cleanup of mining waste to lower-than-background concentrations of mercury. An alternative, but similarly impractical, method for achieving fish tissue targets is to remove all impoundments from operation. Therefore, Water Board staff has proposed an alternative strategy of adapting nutrient controls developed for reservoirs (e.g., oxygenate the hypolimnion) for methylation control. Consequently, even if the mining waste allocations cannot be met everywhere they are applicable, methylation control provides a sufficient margin of safety so that, as explained in Section 6.5, the fish tissue targets are likely to be met in and downstream of Guadalupe, Almaden, and Calero reservoirs and Almaden Lake (i.e., targets are likely to be met in Guadalupe and Alamitos creeks and the Guadalupe River).

Key Points

<u>*Concentration-based allocations*</u>

Impoundment Methylmercury Allocation

- 3.0 ng/l (parts per trillion) seasonal maximum of methylmercury in the hypolimnion of Guadalupe, Almaden, and Calero reservoirs and Almaden Lake

Mining Waste Total Mercury Allocations

- 0.1 ppm mercury (annual median, dry weight) in erodable soil fines transported from the portion of the New Almaden Mining District that drains to Guadalupe, Almaden, and Calero reservoirs and Almaden Lake; and
- 0.2 ppm mercury (annual median, dry weight) in erodable soil fines transported from the remaining 10 percent of the New Almaden Mining District; and from sediments suspended from Guadalupe, Alamitos, and Calero creeks and the Guadalupe River

<u>*Definition of impoundments*</u>*: engineered structures that pond water. They include dams (i.e., reservoirs), former quarries (i.e., lakes and percolation ponds), flood control structures, other engineered features (such as drop structures), and non-native invasive vegetation that ponds water.*

<u>Definition of erodable soil</u>: soil that is transported by storm runoff ***to receiving waters***; soil fines (i.e. particulates, suspended sediment) are less than 63 microns in diameter.

<u>*Mass-based allocations*</u>

Urban Runoff Total Mercury Allocation

- 11 kilograms per year of total mercury to be attained within 10 years, and 7.2 kilograms per year of total mercury to be attained within 20 years

Background Soil Total Mercury Allocation

- 0.5 kilograms per year of total mercury

Atmospheric Deposition Total Mercury Allocation

- 0.1 kilograms per year of total mercury

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8. Preliminary Implementation Plan

This section provides an outline of the Implementation Plan for the Guadalupe River watershed mercury TMDL. The Santa Clara Basin Watershed Management Initiative has convened the Guadalupe Mercury Work Group. The Water Board extends to the Guadalupe Mercury Work Group the opportunity to contribute to the development of the Final Implementation Plan by June 30, 2006 which incorporates the goals and schedules provided in Section 7.

8.1 Risk Management

The highest priority human health risk management activity for the Guadalupe TMDL is a consumption study which may include estimation of rates and patterns of fish consumption, characterization of groups with potentially high levels of exposure, identification of effective methods for communicating advice, and evaluation of effectiveness of fish-consumption advisories (note that water bodies downstream of the mining district have been posted for over two decades warning readers to not consume the fish.) We seek input from the Guadalupe Mercury Work Group on the priorities and components of the risk management plan.

8.2 Phase 1: First 10 Years

The goals of Phase 1 are to:

- implement effective source control measures for mining waste in the New Almaden Mining District, thereby attaining the mining waste allocations for total mercury in erodable soils in the New Almaden Mining District,
- evaluate the need to control discharges of mining waste which has accumulated in downstream bed, banks and floodplains; and
- attain the urban runoff interim loading milestones of 11 kilograms per year, halfway between the current load of 14 kg/yr and the allocation of 7.2 kg/yr.

8.3 Phase 2: Second 10 Years

The goal of Phase 2 is to attain all allocations and more importantly, attain the fish tissue methylmercury targets for human health and wildlife.

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9. PRELIMINARY MONITORING STRATEGY

This section provides an outline of the strategy from which the Monitoring, Risk Management and Adaptive Implementation Plan will be developed for the Guadalupe River watershed mercury TMDL. The Water Board extends to the Guadalupe Mercury Work Group the opportunity to contribute to the development of the Final Monitoring, Risk Management and Adaptive Implementation Plan to be completed by June 30, 2006.

9.1 Adaptive Implementation

Adaptive implementation outlined in this report includes: a) two-phase implementation strategy, b) monitoring fish tissue targets and possibly assigning one target concentration (rather than the current two) that would be protective of all wildlife species in the watershed, c) following the lead of the Water District by proposing they continue to develop methylation controls for deep impoundments, d) continued monitoring of downstream conditions to determine whether methylmercury allocations are appropriate, e) geomorphic assessment of downstream conditions to determine whether erosion control measures are needed and whether they would be effective in reducing mining waste discharges, and f) evaluating changes to the human health fish tissue target if studies indicate different consumption rates than the USEPA default national rates. Staff propose to use the adaptive implementation section from the San Francisco Bay mercury TMDL as a basis for the Guadalupe TMDL, to be modified based on a) – f) and input from the Guadalupe Mercury Work Group.

9.2 Monitoring Framework

This report proposes fish tissue targets, a seasonal maximum hypolimnion methylmercury concentration, effective erosion control measures, and mass-based allocations. Water Board staff propose that the dischargers in the watershed undertake this monitoring effort in a coordinated, watershed-wide, fashion (similar to the Regional Monitoring Program for San Francisco Bay) . The monitoring should be designed to answer the issues and questions outlined below – we seek Guadalupe Mercury Work Group input on the appropriate issues and questions to be resolved, and the resulting monitoring program.

EVALUATION OF FISH TISSUE TARGET

USFWS recommends that a fish tissue monitoring program be developed to determine whether the assumptions they relied on to develop the targets are valid for the watershed (see Section 5). Furthermore, should their assumptions hold, it proposes that it would be reasonable to assign one target concentration (i.e., 0.10 ppm in 150-350 mm TL3 fish) that would be protective of all wildlife species in the watershed.

Conduct bi-annual monitoring of fish targets in all impaired water bodies to evaluate progress toward attainment of the fish tissue targets in Phase 1 of implementation (at a later date establish the frequency for Phase 2.) Conduct fish sampling on the same frequency in the reference reservoir to better understand inter-annual variations in methylmercury production and bioaccumulation.

AQUEOUS METHYLMERCURY MONITORING

A comparison of methylmercury production rates in three of the deep impoundments (see Figure 9.1 and Table A.6) indicates wide variation in 2004. Conduct dry season monitoring of hypolimnion methylmercury and ancillary water quality parameters to better understand methylmercury production, the controlling factors, and potential control measures; and to evaluate whether the current allocation – one number applied to all deep impoundments – should be a different number (higher or lower), or whether site-specific allocations are needed in each impoundment. Conduct dry season monitoring downstream of the deep impoundments to evaluate whether downstream methylmercury allocations and controls are needed to attain targets.

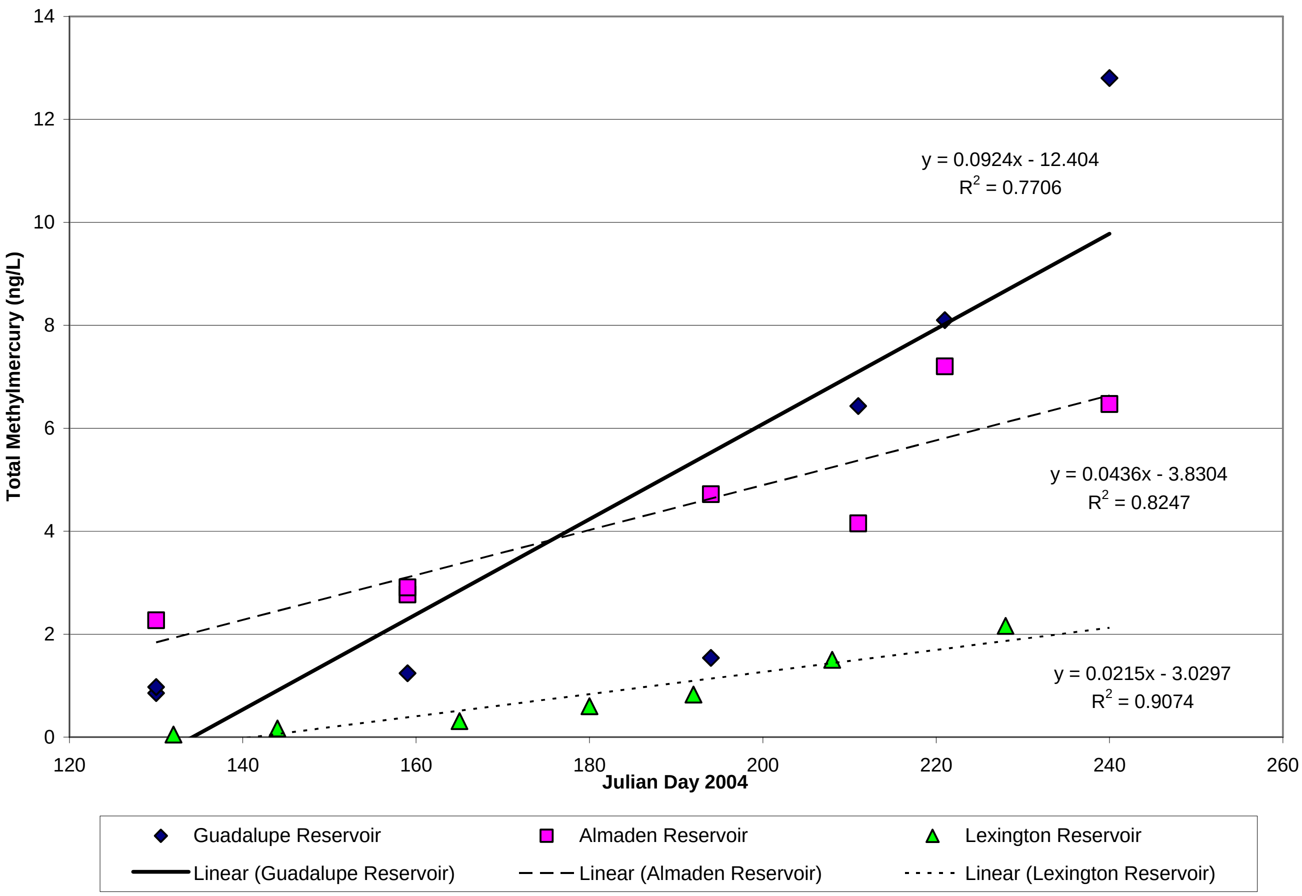

Figure 9.1 Comparison of Methylmercury Production Rates

Prepared by Tetra Tech under contract to Water Board

Fish Tissue Methylmercury Monitoring

Develop a watershed fish sampling protocol which addresses relevant sampling issues, including the following.

Although the targets for this TMDL were developed for methylmercury (Section 5), because nearly all mercury in fish tissue is methylmercury (Grieb et. al. 1990), fish samples may be analyzed for total mercury. Ideally, the timing of fish sampling to evaluate attainment of wildlife targets should occur during the belted kingfisher and common mergansers breeding season. Similarly, the timing of fish sampling to evaluate attainment of human health targets should occur when angling reaches the annual peak. Fish sampling should be conducted for a sufficient duration to describe year-to-year variability in mercury uptake.

EFFECTIVENESS OF MINING WASTE EROSION CONTROL MEASURES

Erosion control effectiveness evaluations should document the degree to which an action results in reduced sediment and/or mercury loads, downstream methylation and/or bioaccumulation, along with any information about site-specific factors relevant to the applicability of the action throughout the watershed. Reductions in downstream bioaccumulation are best evaluated by changes in mercury concentration in age-1 fish "remediation effectiveness indicators" described below. Some erosion control measures may be designed to achieve the naturally-occurring concentration of mercury in local surface soil; methods to estimate this concentration are discussed below.

MONITORING PROGRESS TOWARD MASS ALLOCATIONS

As described in Section 7.6, Water Board staff propose in both TMDLs that dischargers demonstrate progress toward (a) the interim loading milestone, or (b) attainment of the allocation by using one of three methods listed below:

1) Quantify the annual average mercury load reduced by implementing (a) pollution prevention activities, (b) source and treatment controls, and (c) if applicable, other efforts to reduce methylation or mercury-related risks to humans and wildlife. The Water Board will recognize loads reduced resulting from activities implemented after 1996 (or earlier if actions taken are not reflected in the 2001 load estimate) to estimate load reductions.
2) Quantify the mercury load as a five-year annual average mercury load using data on flow and water column mercury concentrations.
3) Quantitatively demonstrate that the mercury concentration of suspended sediment that best represents sediment discharged from the watershed to San Francisco Bay is below the suspended sediment target (0.2 ppm).

Option (1)(c) may be best monitored in age-1 fish "remediation effectiveness indicators." (see 9.3, below), in which case this monitoring effort may also be useful to monitor progress toward concentration allocations.

9.3 Remediation Effectiveness Indicators

Whereas grab water methylmercury samples provide an instantaneous and site-specific measure of methylmercury, age-1 fish provide an integrated measure of methylmercury over time (one year) and space (their forage area within a given water body). Sampling of age-1 largemouth bass in impoundments in 2004 confirmed low sample variability, and therefore excellent utility for measuring environmental response to implementation actions. Similar to fish from the impoundments, age-1 California roach in creeks and the river had low sample variability. The roach, too, provides excellent utility for measuring environmental response to implementation actions.

Water Board staff assumes that it will take several years to reach equilibrium in the water column (i.e. decreases in methylmercury production due to less mining waste) after mining waste source control implementation (remediation) actions are undertaken. During the period between completion of mining waste remediation actions and attaining equilibrium, the best method for evaluating mining waste remediation effectiveness may be to compare newly collected age-1 fish mercury concentrations to the 2004 baseline age-1 data (see Table 9.1, below). Staff expects that several years after mining waste source control implementation actions are completed, after methylmercury production controls are formulated, and within months of deploying methylmercury production controls that mercury concentrations in age-1 fish will attain the TL3 wildlife target of 0.05 ppm (applicable both to fish less than 50 mm length and those between 50 to 150 mm length). Water Board staff expects that it will take several more years of methylmercury production controls before mercury in older fish attain the TL3 wildlife target of 0.10 ppm in 150-300 mm fish, and TL4 human health target of 0.66 ppm as measured in 40 cm largemouth.

Therefore, staff proposes to use the 2004 baseline age-1 fish data to evaluate remediation effectiveness in the years before the targets are attained.

Table 9.1 Remediation Effectiveness Indicator: Age-1 Fish	
Purpose: Remediation effectiveness indicator of improvements compared to baseline Description: • Average mercury in age-1 fish • Location-specific • Applicable immediately after undertaking implementation actions; See time schedule in Implementation Plan	Impoundments: Largemouth Bass • Guadalupe Reservoir: 0.83 ppm • Almaden Reservoir: 0.96 ppm • Almaden Lake: 0.9 ppm • Calero Reservoir: 0.21 ppm Creeks & River: California Roach • Alamitos Creek at Harry Road: 0.28 ppm • Alamitos Creek at Greystone Lane: 0.15 ppm • Guadalupe Creek at Meridian Ave.: 0.39 ppm • Guadalupe River at Foxworthy Ave.: 0.15 ppm • Guadalupe River at Coleman Ave.: 0.08 ppm

9.4 Mining Waste Cleanup Goal

The Implementation Plan (Section 8) describes that the mining waste allocations in New Almaden Mining District are expected to be met by erosion control actions. Some erosion control measures may be designed to attain natural mercury concentrations (e.g., surface soil concentrations equal to pre-mining concentrations of naturally occurring mercury.) Therefore, this section provides preliminary ideas on how dischargers may calculate these mercury concentrations for review and approval by Water Board staff prior to implementing mining waste source control actions.

One method is described in the Sulphur Creek Mercury TMDL, where Central Valley Water Board staff used the concept of a mineralized zone surrounding mercury deposits to propose a preliminary cleanup goal for mercury in eroded soil fines. Based on mercury concentrations found at the periphery of the mineralized zone in the lower Sulphur Creek watershed, staff proposed a goal of no more than 3 ppm of mercury from eroded soil fines in runoff and the stream below mine sites – a goal that is approximately double the concentration found at the periphery (Stanish & Cooke 2004).

The periphery of the mineralized zone of the New Almaden Mining District has not been mapped in the same detail as in the Sulphur Creek area. Dischargers may undertake a monitoring program to establish a perimeter surface soil mercury concentration in the New Almaden Mining District. The sampling and analysis plan shall describe how sampling locations will be selected to avoid contamination by mining waste and historic local deposition from ore roasting. The sampling and analysis plan shall be submitted to the Water Board staff for review and approval prior to sampling.

To plan cleanup and excavation work, some understanding of local soil and rock types, their relationships to mercury concentrations, and how historic mining operations processed and used mined materials is essential. Silica carbonate is the host rock for cinnabar mercury ore in the New Almaden Mining District (Bailey & Everhart 1964). Other soil types include Franciscan sandstone, Franciscan greenstone, chert, and serpentine. Data from pre-remediation mercury samples collected in Almaden Quicksilver County Park from each of these soil types in non-mined areas are plotted on Figure 9.2 (Dames & Moore 1989) (see Tables A.4 and A.5). Median mercury concentrations in these soil samples were 24 ppm in silica-carbonate soils and 0.84 ppm in other soils (indicated as "All NonMineNonSiCarb" on Figure 9.2; medians ranged from 0.16 ppm at CO-6, the hillside north of Randol Trail, to 3.4 ppm at CR-2 in native road base). In contrast, mercury concentrations in Franciscan greenstone downwind of the Hacienda Furnace Yard (where roasting cinnabar led to mercury emissions into the air) ranged from 23-79 ppm.

The principal clue that miners used to locate ore bodies in the New Almaden Mining District was surface outcrops of silica-carbonate soils, many of which they excavated. Many of the silica-carbonate outcrops still standing today likely are located in close proximity to former ore-roasting facilities, whether permanent or mobile furnaces. Dames & Moore collected surface soil samples from the remaining outcrops from 0-2 inches below surface, and therefore these results likely included mercury from local deposition from nearby ore-roasting chimneys. Consequently, the samples of silica-carbonate soils described above are likely to contain elevated mercury from nearby ore roasting facilities and therefore they do not adequately represent natural soil mercury concentrations.

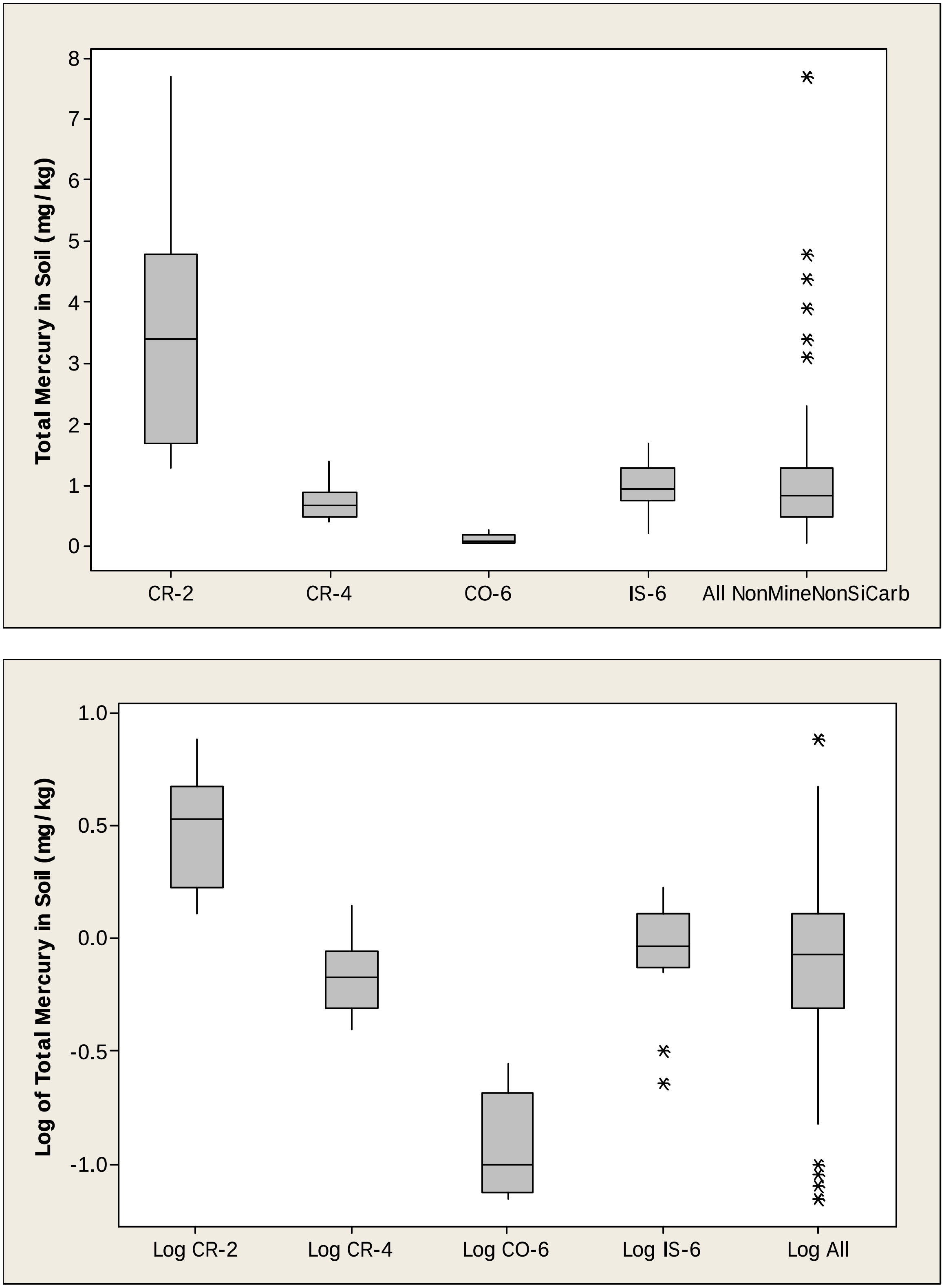

Figure 9.2 Non-mined Area Surface Soil Mercury Concentrations (1989)

Dischargers may conduct a monitoring program to establish natural surface soil mercury concentrations for localized cleanup areas, and by soil type if desired, in the New Almaden Mining District. An initial sampling effort may be necessary to collect depth-profile samples (for example, half-inch increments from 0 – 6 inches below surface) to evaluate historic local deposition from ore roasting, and determine the appropriate sample depth interval. The sampling and analysis plan shall characterize natural variability of mercury concentrations by subwatershed, include a statistical power analysis to support the quantity of samples proposed, and describe how sampling locations will be selected to avoid contamination by mining waste and historic local deposition from ore roasting. The sampling and analysis plan shall be submitted to the Water Board staff for review and approval prior to sampling.

The natural soil mercury concentrations may be applied in at least two ways to source control actions: 1) erosion-control projects in the New Almaden Mining District can be sub-divided by the two soil types. The mercury concentration appropriate to each soil type then applies. 2) A project-specific median mercury concentration may be calculated based on the relative proportions of the two soil types and applied to the entire project site.

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APPENDICES

APPENDIX A – DATA

Table A.1 Data for Figure 2.2: Guadalupe Reservoir Fish 1971 - 2004

Date	Species	Mercury (ppm)	Length (cm)
Jul-71	Rainbow Trout	0.81	34
Jul-71	Rainbow Trout	0.84	34
Jul-71	Rainbow Trout	1.1	23
Jul-71	Rainbow Trout	1.4	20
Jul-71	Rainbow Trout	1.5	19
Jul-71	Rainbow Trout	2.3	20
10/23/86	Blue Gill	0.8	16
10/23/86	Blue Gill	1.1	19
10/23/86	Blue Gill	1.3	17
10/23/86	Blue Gill	1.4	19
10/23/86	Blue Gill	1.4	17
10/23/86	Blue Gill	1.5	18
10/23/86	Blue Gill	1.9	17
10/23/86	Blue Gill	1.9	17
10/23/86	Blue Gill	2.0	18
10/23/86	Blue Gill	2.0	19
10/23/86	Blue Gill	2.2	19
10/23/86	Blue Gill	2.3	23
10/23/86	Blue Gill	2.3	18
10/23/86	Blue Gill	2.3	18
10/23/86	Blue Gill	2.3	17
10/23/86	Blue Gill	2.4	18
10/23/86	Blue Gill	2.9	20
10/23/86	Blue Gill	3.3	21
10/23/86	Blue Gill	3.8	21
05/28/03	Black Crappie	1.7	15.2
05/28/03	Black Crappie	1.7	15.1
05/28/03	Black Crappie	1.7	15.9
05/28/03	Black Crappie	1.8	15.5
05/28/03	Black Crappie	1.9	16.0
05/28/03	Black Crappie	1.9	14.8
05/28/03	Black Crappie	2.0	15.1
05/28/03	Black Crappie	2.0	13.0
05/28/03	Black Crappie	2.1	17.2
05/28/03	Black Crappie	2.1	17.1
05/28/03	Black Crappie	2.9	27.5
05/28/03	Largemouth bass	2.6	27.3
05/28/03	Largemouth bass	3.1	29.6
05/28/03	Largemouth bass	3.1	39.6
05/28/03	Largemouth bass	3.2	31.6
05/28/03	Largemouth bass	3.6	42.8
05/28/03	Largemouth bass	3.7	37.3
05/28/03	Largemouth bass	3.8	35.9
05/28/03	Largemouth bass	3.9	35.6

Table A.1 Data for Figure 2.2: Guadalupe Reservoir Fish 1971 - 2004			
Date	**Species**	**Mercury (ppm)**	**Length (cm)**
05/28/03	Largemouth bass	4.0	38.4
05/28/03	Largemouth bass	4.0	39.8
05/28/03	Largemouth bass	4.5	36.5
05/28/03	Largemouth bass	4.6	36.7
05/28/03	Largemouth bass	4.7	37.0
05/28/03	Largemouth bass	5.5	42.9
05/28/03	Largemouth bass	5.8	50.5

Citations:
1971 data from (Woodward-Clyde 1992)
1986 data (TSMP 1978-2000)
2003 data from (DFG 2003)
2004 data can be found in Volume II of the *Data Collection Report* (Tetra Tech 2005a)

Table A.2a Summary of Reservoir Bottom Sediment Mercury				
Citation: Table 1 Guadalupe River Watershed Reservoir Sediment Sampling (Tetra Tech 2005b)				
	Lexington Reservoir	Calero Reservoir	Guadalupe Reservoir	
	Total mercury (mg/kg, dry basis)			
Mean	0.11	0.42	3.32	
Median	0.10	0.39	2.82	(2.95)*
Minimum	0.07	0.10	0.42	
Maximum	0.18	0.84	7.29	(337.9)*
n	20	18	16	

*One sample was not included in statistical analyses;
the values shown in parentheses include all samples from Guadalupe Reservoir.

Table A.2b Reservoir Bottom Sediment Mercury and Percent Fines

Citation: Appendix Table 1 Guadalupe River Watershed Reservoir Sediment Sampling *(Tetra Tech 2005b)*

Sample ID	Total Mercury mg/kg (dry basis)	Percent Fines*
CR-1-A	0.13	44.3
CR-1-B	0.47	100.0
CR-1-C	0.36	100.0
CR-2-A	0.68	100.0
CR-2-B	0.52	100.0
CR-2-C	0.49	100.0
CR-3-A	0.37	100.0
CR-3-B	0.37	100.0
CR-3-C	0.40	100.0
CR-4-A	0.38	98.8
CR-4-B-1	0.42	100.0
CR-4-B-2	0.31	95.9
CR-4-C	0.29	95.3
CR-5-A	0.25	81.9
CR-5-B	0.55	14.7
CR-5-C	0.10	56.0
CR-7-A	0.61	73.3
CR-7-B	0.84	54.4
GR-1-A	3.32	100.0
GR-1-B-1	3.91	100.0
GR-1-B-2	3.56	100.0
GR-1-C	4.19	96.5
GR-2-A	1.65	100.0
GR-2-B	1.95	100.0
GR-2-C	2.68	100.0
GR-3-A	2.31	100.0
GR-3-B	2.31	100.0
GR-3-C	2.95	100.0
GR-4-A	6.67	20.1
GR-4-B	1.94	72.7
GR-4-C	5.69	96.0
GR-5-B	2.27	23.7
GR-5-C	7.29	72.9
GR-6-A	337.90	29.3
GR-7-A	0.42	75.8
LR-1-A	0.12	98.4
LR-1-B	0.11	100.0
LR-1-C	0.07	100.0
LR-2-A	0.15	85.2
LR-2-B	0.16	95.8
LR-2-C	0.13	100.0
LR-3-A	0.11	100.0
LR-3-B	0.10	100.0
LR-3-C	0.10	100.0
LR-4-A-1	0.10	100.0
LR-4-A-2	0.07	100.0
LR-4-B	0.08	100.0
LR-4-C	0.09	100.0
LR-5-A	0.08	100.0
LR-5-B	0.07	99.5
LR-5-C	0.08	98.0
LR-6-A	0.09	97.3
LR-6-B	0.09	97.9
LR-7-A	0.18	100.0
LR-7-B	0.17	100.0

*Percent Fines means less than 63 microns

Table A.3 Lexington Reservoir Hypolimnion Methylmercury Concentrations

Citation: Data collected by Light, Air, & Space Co. for SCVWD

Lexington Reservoir Outlet (Lenihan Dam)				**Temp**	**pH**	**DO in Outlet**
Date/Time	Res Level	Outlet Flow	Replicate	deg C	st un	mg/L
1/12/2004			A	10.7	8.15	13.98
1:10 PM	607.06	7.1	B			(energy disp)
3/4/2004			A	12.4	8.49	14.24
1:37 PM	624.37	4.2	B			(energy disp)
3/18/2004			A	13.8	8.38	14.6
3:37 PM	626.1	47.4	B			(energy disp)
4/6/2004			A	12.3	8.83	13.52
12:30 PM	626.46	13.4	B			(energy disp)
4/26/2004			A	16	8.2	16.23
1:40 PM	623.32	16.5	B			(energy disp)
5/13/2004			A	14.4	7.95	13.34
1:43 PM	622.41	5.2	B			(energy disp)
5/25/2004			A	15.6	7.74	12.34
2:00 PM	620.65	10.6	B			(energy disp)
6/16/2004			A	14.9	8.09	13.15
11:35 AM	619.6	3.3	B			(energy disp)
7/1/2004			A	14.9	8.21	13.34
12:58 PM	619.62	2.9	B			(energy disp)
7/13/2004			A	17	13.76	14.28
4:11 PM	619.32	2.7	B			(energy disp)
7/29/2004			A	16	8.06	13.27
3:20 PM	619.02	2.7	B			(energy disp)
8/19/2004			A	16.2	8.3	9.6
5:10 PM	618.36	3.2	B			(energy disp)

Table A.3 Lexington Reservoir Hypolimnion Methylmercury Concentrations

Citation: Data collected by Light, Air, & Space Co. for SCVWD

Lexington Reservoir		**Conductivity**	**Turbidity**	**TSS**	**Total Hg**	**Diss Hg**	**MeHg**
Date/Time	Replicate	mmhos/cm3	Ntu	mg/L	ng/L	ng/L	ng/L
1/12/2004	A	0.367	121	20	11.6	10.7	0.125
1:10 PM	B			18	12.1	8.08	0.142
3/4/2004	A	0.319	298	38	4.21	0.28	0.045
1:37 PM	B			48	5.18	0.25	0.045
3/18/2004	A	0.313	242	<10	9.4	10.2	0.05
3:37 PM	B			22	<0.5**	<0.5**	0.061
4/6/2004	A	0.325	61	<10	<200*	<200*	0.064
12:30 PM	B			<10	<200*	<200*	0.045
4/26/2004	A	0.337	60	12	<0.5*	<0.5*	0.106
1:40 PM	B			12	6.25	6.59	0.045
5/13/2004	A	0.338	120	<10	4.8	4.1	0.057
1:43 PM	B			<10	5.02	4.18	0.045
5/25/2004	A	0.331	187	<10	2.72	2.4	0.17
2:00 PM	B			<10	2.57	2.59	0.169
6/16/2004	A	0.251	9	<10	1.94	1.36	0.32
11:35 AM	B			<10	1.87	1.27	0.314
7/1/2004	A	0.256	4	<10	1.65	1.39	0.609
12:58 PM	B			<10	1.65	1.42	0.59
7/13/2004	A	0.288	56	<10	2.04	1.98	0.863
4:11 PM	B			<10	20.1	1.66	0.787
7/29/2004	A	0.392	5	<10	2.56	0.88	1.45
3:20 PM	B			<10	2.49	1.08	1.54
8/19/2004	A	0.328	1	<10	4.52	1.71	2.14
5:10 PM	B			<10	6.8	2.18	2.18

Table A.3 Lexington Reservoir Hypolimnion Methylmercury Concentrations

Citation: Data collected by Light, Air, & Space Co. for SCVWD

Lexington Reservoir		**DOC**	**Sulfate**	**Chloride**
Date/Time	Replicate	mg/L	mg/L	mg/L
1/12/2004	A	3.8	58	14
1:10 PM	B	3.9	56	11
3/4/2004	A	3.5	33	<10
1:37 PM	B	3.9	29	<10
3/18/2004	A	4.2	60	<10
3:37 PM	B	6	49	<10
4/6/2004	A	3.4	50	13
12:30 PM	B	3.8	49	13
4/26/2004	A	3.1	54	10
1:40 PM	B	3.4	50	10
5/13/2004	A	3.3	44	11
1:43 PM	B	3.4	59	20
5/25/2004	A	3.8	51	<10
2:00 PM	B	3.5	50	<10
6/16/2004	A	3.5	52	10
11:35 AM	B	3.4	53	10
7/1/2004	A	3.7	48	<10
12:58 PM	B	3.7	46	<10
7/13/2004	A	3.3	48	10
4:11 PM	B	3.3	44	12
7/29/2004	A	3.4	45	13
3:20 PM	B	3.4	45	14
8/19/2004	A	3.6	44	13
5:10 PM	B	3.3	43	13

*Analyzed using EPA Method 7470A instead of 1631, due to lost samples by courier
**QA concerns
gr means greater than indicated depth
Sample Location same as Station E1-17 used for 2004 wet-weather sampling by Tetra Tech

Table A.4 Silica-Carbonate Mercury Concentrations

	Sample ID	Total Mercury (ppm)	Percent Passing 2mm Sieve	Comments
Non-Mining in Silica-Carbonate				
Area: CR-2				CR-2 Native road base of Franciscan greenstone and silica-carbonate rock colluvium unaffected by mining. Presence of Silica-carbonate rock colluvium was noted in subareas 6 through 15. (Page A-9) Subareas 1 – 10 are mostly in greenstones. (Page 26)
Individual Subarea Samples	CR2.11.1	32	32%	
	CR2.12.1	32	38%	
	CR2.13.1	22	40%	
	CR2.14.1	38	24%	
	CR2.15.1	22	45%	
(duplicate)	CR20.15.1	18	41%	
Area: CO-3				CO-3 Silica-carbonate rock colluvium along a road cut in an unmined area. On the south cut face of the Mine Hill trail, northwestern Mine Hill area, adjacent to the south St. George tunnel. Randomly generated subarea sample locations mostly fell in undisturbed hillslope colluvium above the road cut face, but a few points also fell on the cut face or at ts toe along the road edge. Purpose: Assess the mercury concentrations of colluvium over silica-carbonate rock in an area undisturbed by surface mining activities.
Area Composite Aliquots	CO-3A	19	33%	
	CO-3B	20	33%	
	CO-3C	17	33%	
Individual Subarea Samples	CO3.01.1	24	40%	
(duplicate)	CO30.01.1	23	36%	
	CO3.02.1	12	27%	
	CO3.03.1	33	27%	
	CO3.04.1	28	18%	
	CO3.05.1	19	50%	
	CO3.06.1	23	40%	
	CO3.07.1	24	17%	
	CO3.08.1	42	23%	
	CO3.09.1	38	17%	
	CO3.10.1	27	16%	
	CO3.11.1	42	26%	
	CO3.12.1	24	31%	
	CO3.13.1	18	45%	
	CO3.14.1	25	64%	
	CO3.15.1	3.2	55%	
	CO30.15.1	2.7	60%	
count (n)		26		
min		2.7		
median		24		
mean		24		
max		42		

Table A.5 Mercury Concentrations in Non-Silica-Carbonate Soils

	Sample ID	Total Mercury (ppm)	Percent Passing 2mm Sieve	Comments
Non-Mining, Non-Silica-Carbonate				
Area: CR-2				CR-2 Native road base of Franciscan greenstone and silica-carbonate rock colluvium unaffected by mining. Presence of Silica-carbonate rock colluvium was noted in subareas 6 through 15. (Page A-9) Subareas 1 – 10 are mostly in greenstones. (Page 26)
Individual Subarea Samples	CR2.01.1	3.1	54%	
(duplicate)	CR20.01.1	2.3	40%	
	CR2.02.1	3.4	37%	
	CR2.03.1	1.7	41%	
	CR2.04.1	1.3	39%	
	CR2.05.1	1.3	42%	
	CR2.06.1	3.9	47%	
	CR2.07.1	4.8	47%	
	CR2.08.1	4.4	56%	
	CR2.09.1	7.7	44%	
	CR2.10.1	7.7	61%	
Area: CR-4				CR-4: Road base of Franciscan greenstone and serpentine colluvium, unaffected by mining activity. Mine Hill Trail east of the Guadalupe Dam and the San Antonio Mine. The sampled segment is not shown on published maps compiled before 1957, but it is shown on maps prepared for the New Idria Mining and Chemical Company in 1968.
Area Composite Aliquots	CR-4A	0.51	48%	
	CR-4B	0.58	48%	
	CR-4C	0.93	48%	
Individual Subarea Samples	CR4.01.1	1.2	45%	
(duplicate)	CR40.01.1	1.2	46%	
	CR4.02.1	1.1	38%	
	CR4.03.1	1.4	49%	
	CR4.04.1	0.67	45%	
	CR4.05.1	0.73	49%	
	CR4.06.1	0.72	63%	
	CR4.07.1	0.40	48%	
	CR4.08.1	0.46	50%	
	CR4.09.1	0.68	51%	
	CR4.10.1	0.68	54%	
	CR4.11.1	0.49	54%	
	CR4.12.1	0.49	42%	
	CR4.13.1	0.44	46%	
	CR4.14.1	0.41	41%	
	CR4.15.1	0.75	41%	
(duplicate)	CR40.15.1	0.54	54%	

Table A.5 Mercury Concentrations in Non-Silica-Carbonate Soils

	Sample ID	Total Mercury (ppm)	Percent Passing 2mm Sieve	Comments
Non-Mining, Non-Silica-Carbonate				
Area: CO-6				CO-6: Undisturbed colluvium overlying a typically non-mineralized rock type. Hillside north of Randol Trail and south of the Webb Canyon water tank at the north central Park boundary. CO-6 is about a 20 foot by 100 foot strip located on an undisturbed hillslope near the west end of the Randol Trail. The area is underlain by Franciscan sandstone, but the colluvium is also mixed with chert wasting from a chert-supported knoll upslope.
Area Composite Aliquots	CO-6A	0.20	27%	
	CO-6B	0.12	27%	
	CO-6C	0.15	27%	
Individual Subarea Samples	CO6.01.1	0.15	36%	
(duplicate)	CO60.01.1	0.11	9%	
	CO6.02.1	0.30	32%	
	CO6.03.1	0.23	38%	
	CO6.04.1	0.27	29%	
	CO6.05.1	0.27	29%	
	CO6.06.1	0.26	16%	
	CO6.07.1	0.21	16%	
	CO6.08.1	0.09	31%	
	CO6.09.1	0.07	30%	
	CO6.10.1	0.17	32%	
	CO6.11.1	0.10	23%	
	CO6.12.1	0.08	26%	
	CO6.13.1	0.15	19%	
	CO6.14.1	0.07	23%	
	CO6.15.1	0.25	28%	
(duplicate)	CO60.15.1	0.28	31%	
Area: IS-6				IS-6: Creek sediment unaffected by mining. …location drains a small basin of 36 planimetric acres. The creek received some drainage from park trails, but the trails are based with native colluvium. Franciscan sandstone is the principal rock type in the sediments, with little exception.Organic debris typically covers the sediments. This debris was carefully removed to facilitate sampling of the underlying sediments.
Area Composite Aliquots	IS-6A	1.1	25%	
	IS-6B	1.1	25%	
	IS-6C	1.1	25%	
Individual Subarea Samples	IS6.01.1	1.9	13%	
(duplicate)	IS60.01.1	1.4	20%	
	IS6.02.1	0.84	29%	
	IS6.03.1	1.1	22%	
	IS6.04.1	1.3	49%	
	IS6.05.1	0.67	10%	
	IS6.06.1	1.1	29%	
	IS6.07.1	1.6	54%	
	IS6.08.1	1.2	59%	
	IS6.09.1	0.94	17%	
	IS6.10.1	1.8	36%	
	IS6.11.1	0.62	14%	
	IS6.12.1	0.32	5%	

Table A.5 Mercury Concentrations in Non-Silica-Carbonate Soils

	Sample ID	Total Mercury (ppm)	Percent Passing 2mm Sieve	Comments
Non-Mining, Non-Silica-Carbonate				
(duplicate)	IS60.12.1	0.23	8%	
	IS6.13.1	1.6	40%	
	IS6.14.1	0.72	30%	
	IS6.15.1	1.7	31%	
	IS6.16.1	0.74	28%	
	IS6.17.1	0.9	8%	
	IS6.18.1	1.1	27%	
	IS6.19.1	1.5	39%	
	IS6.20.1	1.3	24%	
	IS6.21.1	1.3	22%	
	IS6.22.1	0.87	20%	
	IS6.23.1	0.97	32%	
	IS6.24.1	1.3	26%	
(duplicate)	IS60.24.1	1.6	26%	
	IS6.25.1	1.1	27%	
	IS6.26.1	1.5	49%	
	IS6.27.1	1.3	20%	
	IS6.28.1	0.84	15%	
	IS6.29.1	0.81	16%	
	IS6.30.1	1.3	14%	
	IS6.31.1	0.87	21%	
	IS6.32.1	1.4	19%	
	IS6.33.1	0.72	10%	
	IS6.34.1	0.86	20%	
	IS6.35.1	0.8	21%	
	IS6.36.1	0.71	21%	
(duplicate)	IS60.36.1	0.72	27%	
count (n)		94		
min		0.07		
median		0.84		
mean		1.1		
max		7.7		

Table A.6 Methylmercury Concentrations in Three Reservoirs

Sample ID	Date Sampled	Julian Day 2004	T MeHg Hypolimnion (ng/L) Guadalupe Reservoir	Almaden Reservoir	Lexington Reservoir
E7-3a	5/11/2004	130	0.853		
E7-3b	5/11/2004	130	0.972		
E7-3	6/10/2004	159	1.240		
E7-3	7/15/2004	194	1.540		
E7-3	8/2/2004	211	6.430		
E7-3	8/12/2004	221	8.100		
E7-3	8/31/2004	240	12.80		
E7-6	5/11/2004	130		2.271	
E7-6a	6/10/2004	159		2.771	
E7-6b	6/10/2004	159		2.909	
E7-6	7/15/2004	194		4.720	
E7-6	8/2/2004	211		4.150	
E7-6	8/12/2004	221		7.200	
E7-6	8/31/2004	240		6.47	
A	5/13/2004	132			0.051
A	5/25/2004	144			0.17
A	6/16/2004	165			0.31
A	7/1/2004	180			0.6
A	7/13/2004	192			0.825
A	7/29/2004	208			1.5
A	8/19/2004	228			2.16

Table A.7 Summary of Adult Largemouth Bass Mercury Data

Citation: Table 8-1 in *Data Collection Report* (Tetra Tech 2005a)

Waterbody	Sample Size	Total Mercury Concentrations (mg/kg wet) Average	Min.	Max.	Coefficient of Variation	Total Length (cm) Average	Min.	Max.	Coefficient of Variation
Guadalupe Reservoir	18	6.1	3.1	13	0.40	41.8	30.7	53.2	0.18
Almaden Reservoir	20	4.3	2.2	7.4	0.30	43.9	33.8	51.2	0.11
Lake Almaden	20	2.3	1.1	3.8	0.34	41.8	31.2	53.2	0.16
Calero Reservoir	20	1.1	0.8	1.6	0.16	36.7	29.7	47.7	0.12
Lexington Reservoir	11	0.6	0.4	1.0	0.27	40.8	35.8	50.2	0.12

Table A.8 Summary of Age-1 Largemouth Bass Mercury Data

Citation: Table 8-4 in *Data Collection Report* (Tetra Tech 2005a)

		Total Mercury Concentrations (mg/kg wet)				Total Length (cm)			
Waterbody	Sample Size	Average	Min.	Max.	Coefficient of Variation	Average	Min.	Max.	Coefficient of Variation
Guadalupe Reservoir	20	0.83	0.64	1.11	0.17	9.0	7.7	9.7	0.07
Almaden Reservoir	20	0.96	0.58	1.53	0.29	6.9	5.6	8.2	0.10
Lake Almaden	20	0.39	0.21	0.53	0.22	9.3	8.0	10.2	0.08
Calero Reservoir	20	0.21	0.10	0.58	0.53	7.4	5.5	10.2	0.22
Lexington Reservoir	20	0.09	0.06	0.14	0.22	8.9	7.1	10.2	0.10

Table A.9 Summary of California Roach Mercury Data

Citation: Table 8-5 in *Data Collection Report* (Tetra Tech 2005a)

			Total Mercury Concentrations (mg/kg wet)			
Site Number	Waterbody and Location	Sample Size	Average	Min.	Max.	Coefficient of Variation
1	Guadalupe R., at Foxworthy Ave.	9	0.15	0.12	0.19	0.17
2	Guadalupe R., at Coleman Ave.	25	0.08	0.04	0.12	0.32
4	Guadalupe Creek, at Meridian Ave.	20	0.39	0.31	0.48	0.11
5	Alamitos Creek, at Harry Road	20	0.28	0.20	0.41	0.21
6	Alamitos Creek, at Greystone Lane	20	0.15	0.10	0.26	0.26
9	Los Gatos Creek, at Linclon Ave.	20	0.03	0.02	0.04	0.24

APPENDIX B – CALCULATIONS

Calculation B.1 Wildlife Target Protective of Human Health

Calculation B.2 Safe Mercury Level at Higher Fish Consumption Rate

Calculation B.3 Bioaccumulation Factors (BAFs)

Calculation B.4 Dissolved Mercury as a Percent of Total Mercury

Calculation B.1 Wildlife Target Protective of Human Health

What would the mercury concentration in 400 mm largemouth bass, a tropic level 4 (TL4) fish be if 50-150 mm TL3 fish meet the wildlife target of 0.05 mg/kg?

Option 1: Assume trophic transfer coefficient (TTC) is irrespective of size

Using TTC of 4: (0.05 x 4) = 0.20 mg/kg (TL4 @ 400 mm)

Using TTC of 5.4: (0.05 x 5.4) = 0.27 mg/kg (TL4 @ 400 mm)

Option 2: Three step calculation:

Step 1: Assume the trophic transfer coefficients are applicable to TL4 at 270 mm and 50–150 mm TL3 (not unlike the Cache Creek watershed).

Step 2: Linear regression on adult largemouth bass data from Lexington yields the following equation:
-0.056 + 0.016(length in cm) = concentration of Hg in mg/kg
calculate concentration of 270 mm (27 cm):
-0.056 + 0.016(27) = 0.376 mg/kg Hg in 27 cm fish

Step 3: Then use the Lexington ratios between age-1 and adult largemouth bass (22.5 cm and 40 cm) to "size up" from 27 cm to 40 cm.

Ratio is 0.6 / 0.376 = 1.6

Step 4: (same as Option 1)

Using TTC of 4: (0.05 x 4) = 0.20 mg/kg (TL4 @ 270 mm)

Using TTC of 5.4: (0.05 x 5.4) = 0.27 mg/kg (TL4 @ 270 mm)

Step 5: -0.056 + 0.016(27) = 0.376 mg/kg Hg in 27 cm fish

Step 6: 0.20 x 1.6 = 0.32; 0.27 x 1.6 = 0.43

Conclusion: When the wildlife target of 0.05 mg/kg mercury in TL3 fish of 50-150 mm is achieved, our best estimate is that the 40 cm TL4 fish will have between 0.20 and 0.43 mg/kg mercury.

Calculation B.2 Safe Mercury Level at Higher Fish Consumption Rate

What would the criterion for protection of human health be at the California consumption rate of 8 ounces uncooked fish per week?

BACKGROUND: USEPA CRITERION

The USEPA criterion for protection of human health from methyl.mercury is 0.3 parts per million (ppm) in fish tissue, rounded to one significant digit from 0.288 ppm (USEPA 2001). This is for consumption of 17.5 grams per day (g/d) of freshwater and 12.5 g/d estuarine fish. Marine fish consumption and mercury level is accounted for separately. The freshwater fish consumption rate of 17.5 g/d is applicable in the Guadalupe River watershed, and equivalent to 4.3 ounces (uncooked) fish per week, as shown below:

17.5 g/d x 7d/wk x 1 oz./ 28.3495g = 4.3 oz/wk

The USEPA default trophic level (TL) breakouts for the general population are:

	TL2	TL3	TL4
grams per day (g/d)	3.8	8.0	5.7
percent (%)	22%	46%	32%

The USEPA methylmercury criterion uses an average trophic level concentration approach, together with default biomagnification factors (TL2:TL3 = 5.7; TL3:TL4 = 4), results in the following methylmercury concentrations TL2 0.029 ppm; TL3 0.165 ppm; and TL4 0.660 (USFWS 2003).

CALCULATION FOR 17.5 g/d (USEPA DEFAULT CONSUMPTION RATE)

Biomagnification factors: TL2:TL3 = 5.7 and TL3:TL4 = 4, so that

TL3 = 5.7 x TL2; and TL4 = 4 x 5.7 x TL2

% consumed by TL are TL2 22% TL3 46%, TL4 32%

0.3 ppm = (22% x TL2 conc) + (46% x TL3 conc) + (32% TL4 conc)

substituting: 0.3 ppm = (22% x TL2 conc) + (46% x 5.7TL2) + (32% 4x5.7xTL2)

simplifying 0.3 ppm = .22TL2 + 2.62TL2 + 7.296TL2 = 10.14TL2

solving for TL2 etc: TL2 = 0.029, TL3 = 0.165, TL4 = 0.661

CALCULATION AT 8 OZ PER WEEK

Consumption rate from OEHHA http://www.oehha.ca.gov/fish/hg/index.html
8 oz/wk x 28.3495 g/oz x wk/7day = 32.4 g/d

(calc new criterion) = Body Weight x (Reference dose – Relative Source Contribution) / Fish Intake

= (70 kg body wt)
x ([0.1 x 10-3 mg MeHg / kg body-wt] – [negligible MeHg from other sources])
/ 0.0324 kg fish/d

= 0.216 ppm; round to one significant digit:

California consumption rate of 8 oz uncooked fish per week yields criterion of 0.2 ppm MeHg in fish

Assume biomagnification factors are same as above, and same % consumed by TL at 32.4 g/d as at 17.5 g/d.

0.2 ppm = (22% x TL2 conc) + (46% x TL3 conc) + (32% TL4 conc)

simplifying 0.2 ppm = .22TL2 + 2.62TL2 + 7.296TL2 = 10.14TL2

solving for TL2 etc:

TL2 = 0.2 / 10.14; TL3 = TL2 x 5.7; TL4 = TL3 x 4

TL2 = 0.019, TL3 = 0.112, TL4 = 0.449

Conclusion: Wildlife targets would provide additional protection of human health at a consumption rate of 8 oz uncooked fish per week, as these targets result in no more than 0.43 mg/kg mercury in TL4 fish, which is lower than 0.45 mg/kg, the average mercury concentration in TL4 fish which is protective of human health.

References:

U.S. Environmental Protection Agency (USEPA) 2001. *Water Quality Criterion for the Protection of Human Health: Methylmercury*, EPA-823-R-01-001, Office of Water, January, page 7-1 to 7-2.

U.S. Fish and Wildlife Service (USFWS) 2003. *Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury*, October, page vi

Calculation B.3 Bioaccumulation Factors (BAFs)

Table B.3a on the following page provides the range of bioaccumulation factors (BAFs) which is the ratio of tissue concentration to water column concentration in units of liters per kilogram (L/Kg). It also provides a check on the average unfiltered methylmercury in surface and hypolimnion samples collected at Guadalupe Reservoir. Tetra Tech had provided averages of 0.46 and 5.61 ng/l respectively without the supporting calculations; Water Board averages were 0.69 and 5.52 ng/l respectively, which is in close accord with the Tetra Tech calculations (Table 8-6 Tetra Tech 2005a).

The BAFs for age-1 largemouth bass range from 80,000 L/Kg at Calero Reservoir to 200,000 L/Kg at Almaden Reservoir for the hypolimnion, and 400,000 L/Kg at Lexington Reservoir to 2 million L/Kg at Guadalupe Reservoir for the surface.

The BAFs for adult largemouth bass range from 400,000 L/Kg at Calero Reservoir to 1 million L/Kg at Guadalupe Reservoir for the hypolimnion, and 3.1 million L/Kg at Lexington Reservoir to 12.6 million L/Kg at Guadalupe Reservoir for the surface.

The BAF tables from Tetra Tech are provided as Tables B.3b, B.3c, and B.3d, below.

Reference

Tetra Tech, Inc. (Tetra Tech 2005a). *Technical Memorandum 5.3.2, Data Collection Report, Volume 1*, Prepared for Santa Clara Valley Water District. February 8. http://www.valleywater.org/Water/Watersheds_-_streams_and_floods/Watershed_info_&_projects/Guadalupe/_Guadalupe_River_TMDL_project/index.shtm

Table B.3a Bioaccumulation Factors

Guadalupe Reservoir (Tetra Tech 2005a)	Sample Date	Surface Unfiltered **MeHg** (ng/L)	Hypolimnion Unfiltered **MeHg** (ng/L)	Average Adult LMB (mg/Kg)	Average Age-1 LMB (mg/Kg)
Table 4-6	7/31/2003	1.05			
		1.67			
		2.14			
			8.27		
Table 4-3	5/11/2004	0.566	0.853		
	6/10/2004	0.472	1.24		
	7/15/2004	0.299	0.965		
	7/15/2004	0.267			
	7/15/2004	0.338			
	8/2/2004	0.204	6.43		
	8/12/2004	0.324	8.1		
	8/31/2004	0.272	12.8		
Table 8-1				6.1	
Table 8-4					0.82
Table 8-6 & 8-7	Average Unfiltered MeHg	0.46	5.61		
Table 8-6	Adult LMB Log (BAF) L/Kg	7.1	6.0		
	convert log value	12,600,000	1,000,000		
Table 8-7	Age-1 LMB Log (BAF) L/Kg	6.3	5.2		
	convert log value	1,995,000	158,000		
Check	Average Unfiltered MeHg	0.69	5.52	Close	
	Adult LMB Log (BAF) L/Kg	7.12	6.04	Correct	
Calculate	Adult LMB BAF (L/Kg)	8,800,000	1,100,000	Close	
	Age-1 LMB BAF (L/Kg)	1,200,000	100,000	Close	
		Adult LMB Log (BAF) L/Kg		Adult LMB BAF (L/Kg)	
		Surface	Hypolimnion	Surface	Hypolimnion
Table 8-6	Guadalupe Reservoir	7.1	6.0	12,600,000	1,000,000
Table 8-6	Almaden Reservoir	6.8	5.9	6,310,000	794,000
Table 8-6	Lake Almaden	6.8	- -	6,310,000	- -
Table 8-6	Calero Reservoir	6.7	5.6	5,010,000	398,000
Table 8-6	Lexington Reservoir	6.5	5.9	3,160,000	794,000
	min			3,160,000	398,000
	max			12,600,000	1,000,000
		Age-1 LMB Log (BAF) L/Kg		Age-1 LMB BAF (L/Kg)	
		Surface	Hypolimnion	Surface	Hypolimnion
Table 8-7	Guadalupe Reservoir	6.3	5.2	1,995,000	158,000
Table 8-7	Almaden Reservoir	6.2	5.3	1,580,000	199,500
Table 8-7	Lake Almaden	6.1	- -	1,260,000	- -
Table 8-7	Calero Reservoir	5.9	4.9	794,000	79,400
Table 8-7	Lexington Reservoir	5.6	5.1	398,000	126,000
	min			398,000	79,400
	max			1,995,000	199,500

Table B.3b Adult Largemouth Bass Bioaccumulation Factors

Citation: Table 8-6 in *Data Collection Report* (Tetra Tech 2005a)

Waterbody	Average Fish Tissue Total Hg *mg/kg wet*	MeHg, ng/L unfiltered		Log(BAF, L kg-1)	
		Surface	Hypolimnion	Surface	Hypolimnion
Guadalupe Reservoir	5.80	0.46	5.61	7.1	6.0
Almaden Reservoir	3.60	0.58	4.57	6.8	5.9
Lake Almaden	2.10	0.30	-	6.8	-
Calero Reservoir	1.20	0.24	2.77	6.7	5.6
Lexington Reservoir	0.60	0.20	0.76	6.5	5.9

Table B.3c Age-1 Largemouth Bass Bioaccumulation Factors

Citation: Table 8-7 in *Data Collection Report* (Tetra Tech 2005a)

Waterbody	Average Fish Tissue Total Hg *mg/kg wet*	MeHg, ng/L unfiltered		Log(BAF, L kg-1)	
		Surface	Hypolimnion	Surface	Hypolimnion
Guadalupe Reservoir	0.82	0.46	5.61	6.3	5.2
Almaden Reservoir	0.96	0.58	4.57	6.2	5.3
Lake Almaden	0.39	0.30	-	6.1	-
Calero Reservoir	0.21	0.24	2.77	5.9	4.9
Lexington Reservoir	0.09	0.20	0.76	5.6	5.1

Table B.3d Age-1 Largemouth Bass Bioaccumulation Factors

Citation: Table 8-9 in *Data Collection Report* (Tetra Tech 2005a)

Site	Waterbody	Fish Total Hg mg/kg wet	Total Hg, ng/L unfiltered	Me Hg, ng/L unfiltered	Log(BAF) (L kg^{-1})	Sed Total Hg (ng/g)	Sed MeHg (ng/g)
1	Guadalupe R., Foxworthy	0.15	105	0.323	5.66	-	-
2	Guadalupe R., Coleman Ave.	0.08	-	-	-	971	1.03
4	Guadalupe Crk, Meridian Ave.	0.39	38.9	0.990	5.60	20,369	1.29
5	Alamitos Crk, Harry Road	0.28	503.2	0.886	5.50	26,586	7.29
6	Alamitos Crk, Greystone	0.15	25.88	0.306	5.68	18,081	0.91
9	Los Gatos Crk, Lincoln	0.03	3.2	0.037	5.83	42	0.04

Calculation B.4 Dissolved Mercury as a Percent of Total Mercury

The sample IDs and calculation of dissolved mercury as a percent of total mercury are presented on the table below.

Table B.4 Dissolved Mercury as a Percent of Total Mercury

Final Data Collection Report *(Tetra Tech 2005a)*				**2003-2004 Annual Report for Storm Water Discharges Associated with Industrial Activities** *WDID No. 243S006793*			
Table 3-3				Sample date: February 25, 2004			
Sample ID	Total Mercury (ng/L)	Dissolved Mercury (ng/L)	Percent Dissolved	Sample ID	Total Mercury (ng/L)	Dissolved Mercury (ng/L)	Percent Dissolved
E1-3	8.74	1.19	14%	Senador	27	0.12	0.44%
E1-3A	2.06	0.79	38%	Mockingbird	0.39	0.046	12%
E1-3B	2.03	0.59	29%	Lower Alamitos	110	0.52	0.47%
E1-6	82.2	11.5	14%	Jacques Gulch	0.44	0.033	7.5%
E1-7	45.6	24.2	53%	Los Capitancillos	5.3	0.034	0.64%
E1-7	42.2	23.5	56%	Landfill Gully	2.5	0.026	1.0%
E1-9	13.4	6.57	49%				
E1-9A	35.1	8.3	24%			min	0.44%
E1-9B	18.2	6.68	37%			max	12%
		min	14%				
		max	56%				