2.0 WATERSHED CHARACTERIZATION

This section provides a general description of the watershed. The topography, precipitation, hydrology, geology, land uses and mercury sources are described to provide essential background information to those who are not familiar with the watershed.

2.1 WATERSHED DESCRIPTION AND SYSTEM CHARACTERISTICS

2.1.1 TOPOGRAPHY

The Guadalupe River headwaters are in the eastern Santa Cruz Mountains near the summit of Loma Prieta (elevation 3,790 feet). As seen in Figure 2-1, the upper portion of the watershed is mountainous with several ridges extending out into the alluvial valley. The Guadalupe River begins at the confluence of Alamitos and Guadalupe Creeks, below Almaden Lake, and flows 19 miles through heavily urbanized portions of San Jose, ultimately discharging into South San Francisco Bay through Alviso Slough (Figure 2-2). Three urban creeks: (1) Ross, (2) Canoas, and (3) Los Gatos Creeks, join the river as it flows toward San Francisco Bay. Guadalupe River has a total drainage area of approximately 170 square miles south of Highway 237. The river then flows into a 5-mile tidally-influenced reach through Alviso Slough to San Francisco Bay. Prior to 1866, when the south Bay salt ponds began to be developed, the river flowed into Guadalupe Slough.

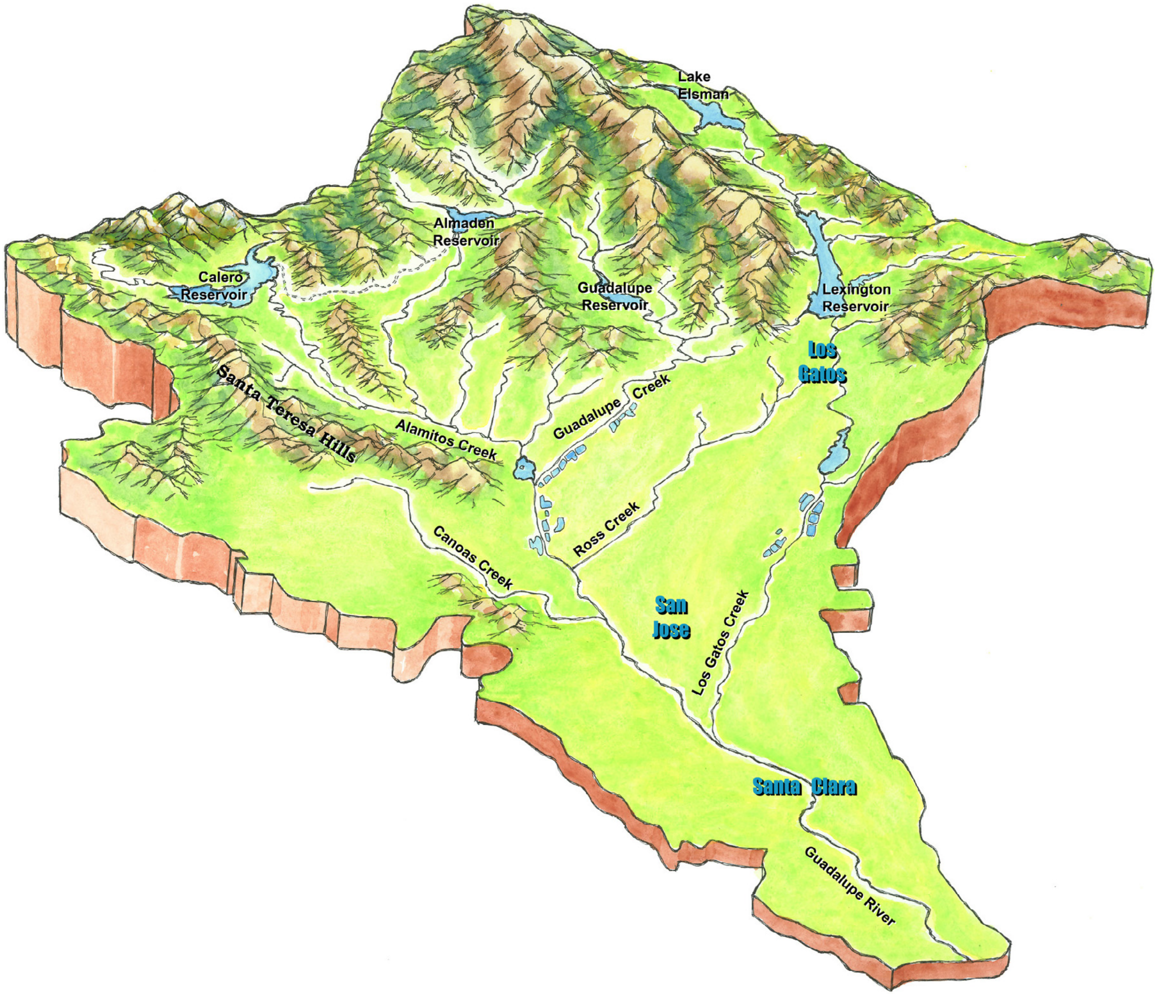


Figure 2-1. General topography of Guadalupe River Watershed.

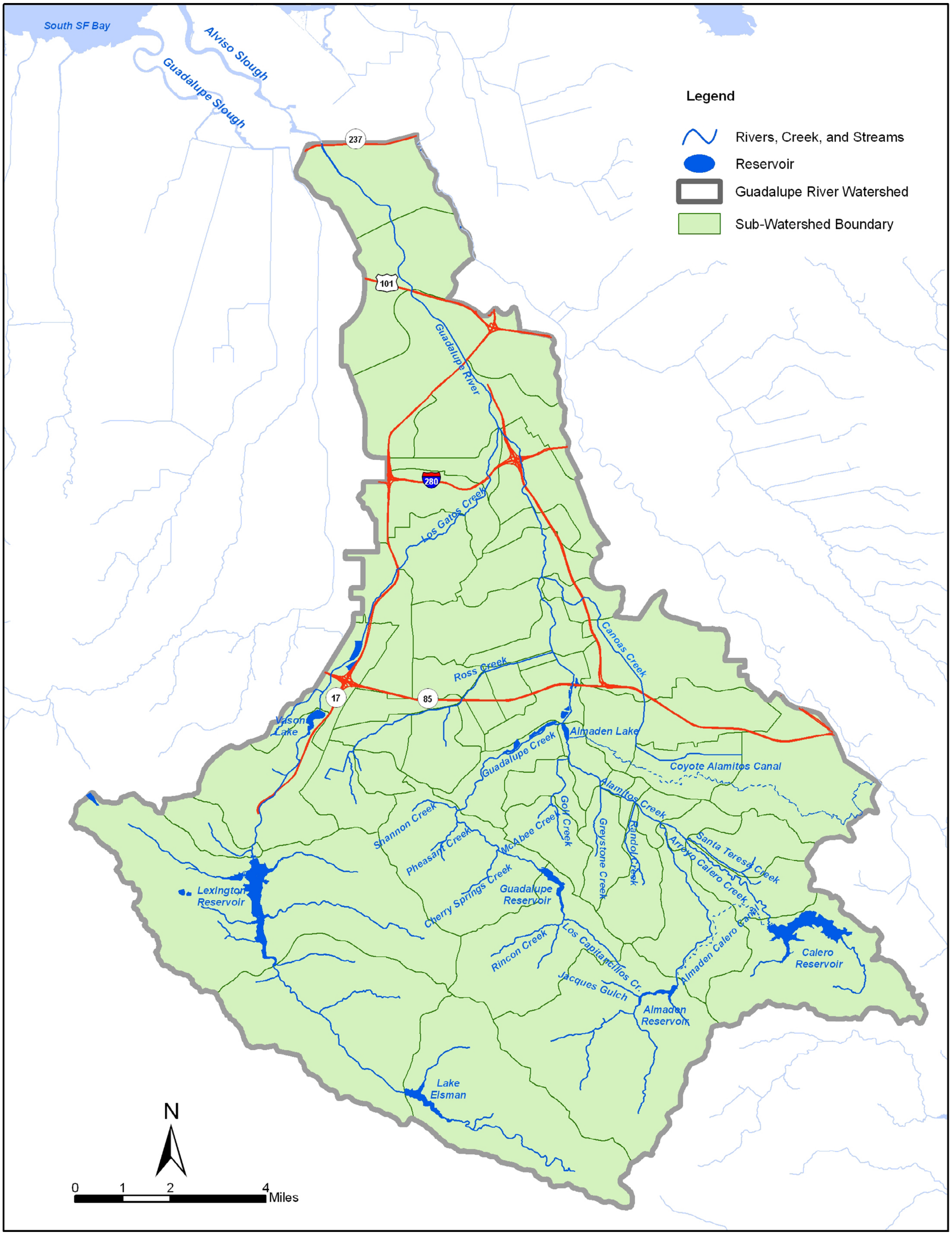


Figure 2-2. Major waterbodies and subwatersheds of Guadalupe River system.

2.1.2 METEOROLOGY

The watershed has a Mediterranean-type climate generally characterized by moist, mild winters and dry summers. The measurable precipitation is in the form of rainfall, 85 percent of which 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 gauge (station 131). Figure 2-3 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.

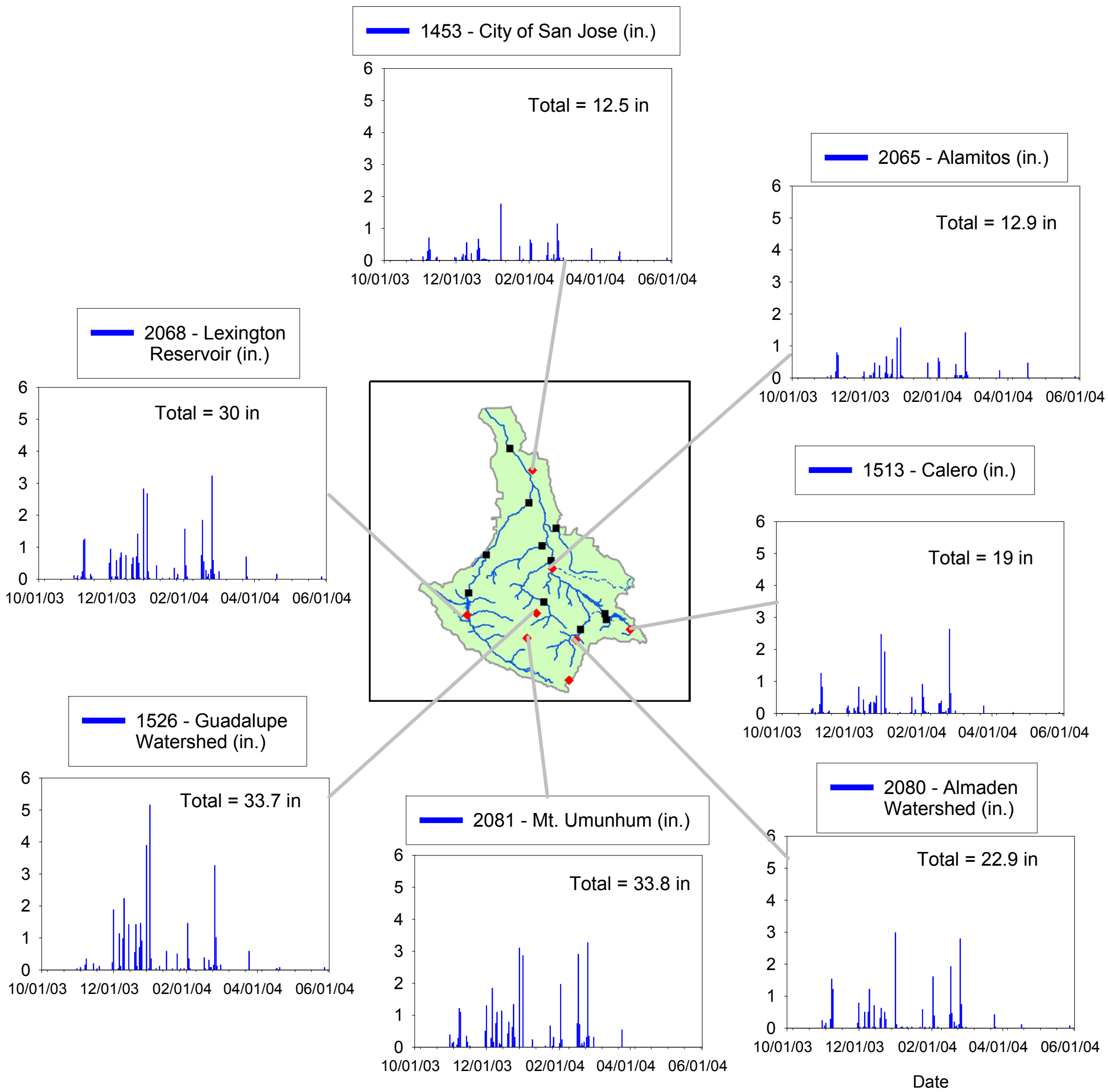


Figure 2-3. Measured rainfall for selected rain gauges in the Guadalupe River Watershed. The numbers at the top of each plot are the identifiers for the individual gauges. Data were obtained from the SCVWD ALERT system (http://alert.valleywater.org/). The y-axis in each plot shows rainfall in inches and the x-axis shows the date between 10/1/2003 and 5/31/2004.

Limited information is available in the San Jose and greater San Francisco Bay Area on wet and dry deposition of mercury. The closest air monitoring station for mercury to the Guadalupe River Watershed is the one at Moffett Field in Sunnyvale. The annual rainfall at this monitoring station during a 1999-2000 pilot study was 14.33 in, and the volume-weighted average total mercury concentration in the rain was 9.7 ng/L (SFEI, 2001). The computed wet deposition flux was 3.5 $\mu g/m^2/yr$ in the South Bay. The total mercury concentration in ambient air at the South Bay station was 2.2 ng/m^3. The total mercury in the air was divided into 95 percent Hg^0, 2 percent RGM (reactive gaseous mercury considered to be Hg^{2+}), and 3 percent particulates based on literature values. An estimate of total deposition flux was made by multiplying the concentration of each species by the appropriate deposition velocity. The total dry deposition flux was estimated to be 19 $\mu g/m^2/yr$. Wet and dry deposition is expected to be higher in the upper parts of the watershed because of the higher rainfall (e.g., up to 48 in/yr) and higher dry deposition due to increased capture in the forested areas. Due to retention of deposition in the watershed, the portion of the total deposition flux that actually reaches surface water is less than the above estimates.

Methylmercury is found at low concentrations in wet deposition (e.g., 0.015-0.35 ng/L) as summarized for samples from the United States and Canada by St. Louis et al., 1995. No local data for methylmercury in rainfall are currently available.

2.1.3 Hydrology

The Guadalupe River has different flow characteristics in the dry and wet seasons. This pattern is also observed in the urban creeks, compared to the less variable outflows from the reservoirs. Figure 2-4 shows the flow gauges used in the loading analysis for this watershed and flow data for each gauge from October 2003 through May 2004. The long-term flow record from 1950 to 2002 comes from the old USGS gauging station at St John's Street, which was removed due to channel modification after May 2002. A new USGS gauging station was set-up downstream near the San Jose Airport by Highway 101. The median flow in the Guadalupe River at the old USGS gauge at St. John's Street was 4.5 cfs between 1960 and 2002 (ALERT, 2003). 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 gauge varied from 125 cfs in 1960 to 10,500 cfs on March 10, 1995. The large flows, such as in 1995 and 1998, resulted in flooding of the downtown area of San Jose. There has been an increase in flows from the 1950s and 1960s to the 1990s in the lower part of the river as seen in Figure 2-5, partly as a result of the increased urbanization.

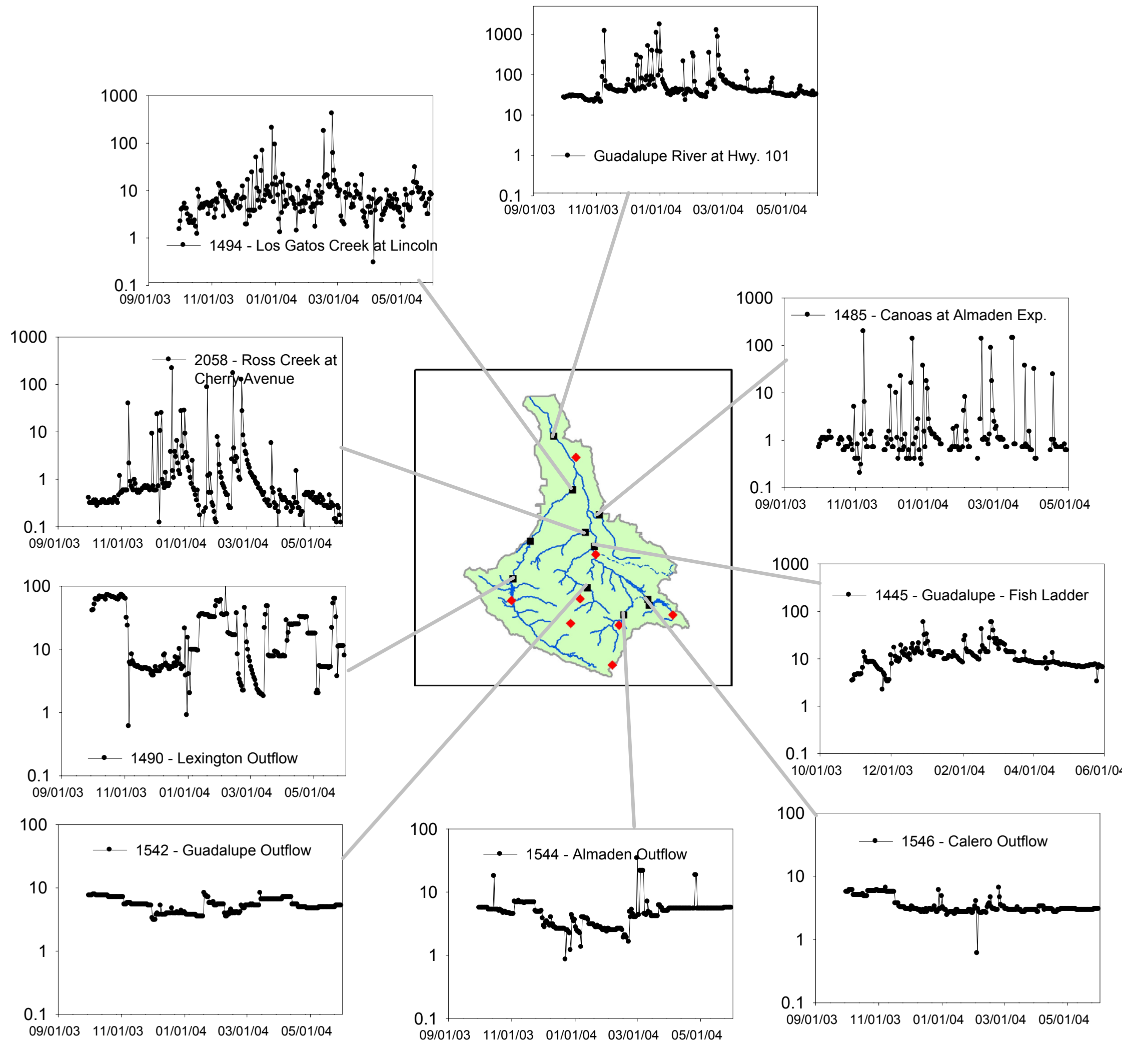


Figure 2-4. Measured flow for selected gauges in the Guadalupe River Watershed. Data were obtained from the SCVWD ALERT system (http://alert.valleywater.org/). The y-axis in each plot shows flows in cfs and the x-axis shows the date between 10/1/2003 and 5/31/2004. The red symbols identify rain gauges and data from them is plotted in Figure 2-3.

The Guadalupe River plays an important role in flood control for the Santa Clara Basin and has been subject to modification since 1866. In 1963, the lower Guadalupe River was channelized including adding new levees along Alviso Slough, out to its confluence with South San Francisco Bay. In the early 1960s, Canoas and Ross Creeks were rerouted to flow into Guadalupe River at different locations, and both lower creek sections were channelized. More recently, the river channel was modified as part of the 1975 Almaden Expressway construction project, where approximately 3,000 feet of channel was widened and moved eastward; the original channel was filled to allow construction of the northbound expressway. In 1999, a fish ladder was added to bypass the Alamitos Drop Structure below Lake Almaden.

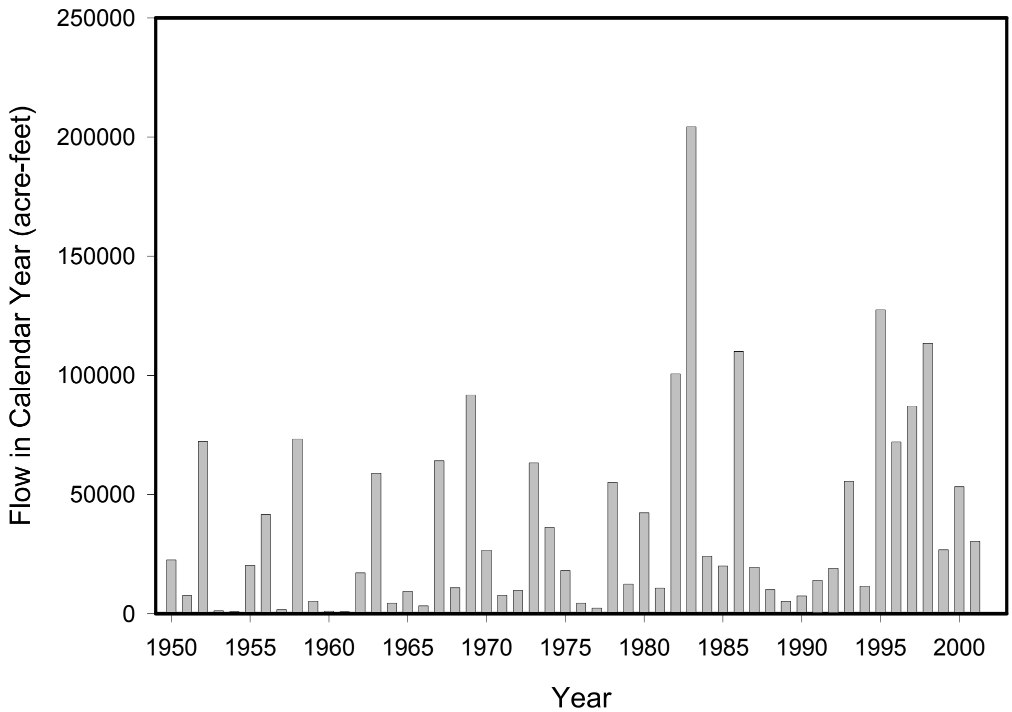


Figure 2-5. Year-to-year variability in total wet weather outflows from the Guadalupe River Watershed, based on the USGS gauge station just below the confluence of Guadalupe River and Los Gatos Creek. Note that there is an increase in total outflows possibly as a result of greater urbanization.

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 to handle the one-in-a-100-year flood between Highway 101 and the Union Pacific Bridge in Alviso. The Downtown Project is designed to make channel improvements along a 3-mile stretch from Highway I-880 to I-280. The Upper Guadalupe Project extends from I-280 to Blossom Hill Road along the Guadalupe River and from I-880 to Highway 101 along Ross and Canoas Creek. In 2004, the construction of a 3,000 cfs bypass channel to route flood flows underground, instead of in the natural river channel, was completed as part of the Downtown project.

Channel modifications to improve stream habitat were made in 2001 along a portion of Guadalupe Creek above its confluence with Alamitos Creek and below Masson Dam. Sediment was also removed in conjunction with this project and a 1999 project to improve fish passage along Guadalupe Creek where a fish ladder was built to bypass Masson Dam. In the late 1970's, channel modification was done on the lower reaches of Randol, Greystone, and Golf Creeks to provide improved flood protection, and levees were built along Alamitos Creek from the Harry Road bridge to the confluence with Almaden Lake. Flood control projects can also decrease the extent of erosion along stream banks by installing bank protection measures and by changing the energy gradient to reduce high velocity segments.

As part of flood control measures, the SCVWD removes sediment from the various drop structures and flood control structures for routine maintenance as shown for various parts of the Guadalupe River watershed in Table 2-1. The sediment quantities removed by the District provide confirmation of sediment accumulation in the tributaries. Removal of sediment also removes mercury and prevents it from reaching San Francisco Bay. Additional data are needed to quantify sediment transport in the various creeks and to evaluate the reduction in mercury loading due to the District's sediment removal activities. In addition to the removal operations, stream bank protection projects have also been conducted. For example, in the Guadalupe River watershed, about 13,000 linear feet of bank was reworked from 1986 to 1995, and the estimated amount of future bank protection work in this watershed is 12,000 linear feet.

Table 2-1
Past Sediment Removal Operations in Guadalupe River Watershed

Creek	Sediment Removed 1980 - 89 (cu yds)	Sediment Removed 1990 - 98 (cu yds)	Sediment Removal for Next 10 Years (cu yds)
Alamitos Creek	NA	NA	NA
Canoas Creek	38,056	3515	48,000
Guadalupe Creek	330	NA	1,500
Almaden-Calero Canal	NA	NA	NA
Coyote-Alamitos Canal	NA	NA	NA
Greystone Creek	3630	15	5,000
Randol Creek	7,110	NA	3,000
Guadalupe River	12,107	33,062	94,000
Ross Creek	6,720	3,462	8,000
Golf Creek	2090	200	NA
Lone Hill Creek	NA	20	NA
Los Gatos Creek	350	NA	NA

Data are from SCVWD, 2002.
NA = Data not available at time of printing.

There are six water conservation and storage reservoirs in the watershed. These reservoirs are Calero Reservoir on Calero Creek; Guadalupe Reservoir on Guadalupe Creek; Almaden Reservoir on Alamitos Creek; and Vasona Reservoir, Lexington Reservoir, and Lake Elsman on Los Gatos Creek, the latter above Lexington Reservoir. The three reservoirs in or near the former mining area, Almaden, Guadalupe and Calero, were built in the creek canyons. Mine wastes and merury-contaminated sediment are present in the sediments of Almaden and Guadalupe Reservoirs. The storage capacity of the reservoirs is provided in Table 2-2. 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 the releases to the streams and evaporation. Vasona Reservoir is small, and spills when large storms occur such as for Feb 25-27, 2004. The other reservoirs rarely spill. Hydraulic modeling for Almaden Reservoir using the HEC-5 model estimated that it would spill 6 percent of the time in 100 years (Saah, 1994). The four reservoirs, besides Vasona, may spill in a 1 in a 100 year flood event, but did not spill in 2003 or 2004.

Table 2-2
Reservoir Capacity and Drainage Area of Reservoirs of Guadalupe River System (ALERT, 2003)

Reservoir (Creek)	Drainage Area Above Reservoir (sq miles)	Reservoir Capacity (acre-ft)	Year Built
Almaden (Alamitos)	12	1,586	1935
Guadalupe (Guadalupe)	6	3,228	1935
Calero (Calero)	7	10,050	1935
Lexington (Los Gatos)	37.5	19,834	1952
Vasona (Los Gatos)	44	400	1935
Lake Elsman (Los Gatos)	9.9	6,280	1951

The Guadalupe River system has 15 subwatersheds, as shown in Figure 2-2. Guadalupe Creek and Alamitos Creek subwatersheds, which drain the former mining areas comprise 26,206 acres, representing 24 percent of the entire Guadalupe River watershed (108,911 acres) (see Table 2-3). The area of these watersheds above the reservoirs is 16,000 acres or 14.7 percent of the total watershed. Streamflow decreases in the summer downstream of the reservoirs due to percolation through the stream bottom and diversion to recharge facilities.

Table 2-3
Size of Subwatersheds in Guadalupe River Watershed

Creek	Acres
Alamitos Creek	11,808
Calero Creek	6,762
Santa Teresa Creek	1,285
Randol Creek	1,416
Greystone Creek	1,116
Golf Creek	844
McAbee Creek	1,232
Guadalupe Creek	9,489
Ross Creek	3,197
East Ross Creek	1,311
Short Creek	519
Lone Hill Creek	1,276
Canoas Creek	11,899
Los Gatos Creek	35,261
Guadalupe River	21,496
Total Guadalupe Watershed	**108,911**

2.1.4 LAND USES

The Guadalupe River Watershed is located in the Santa Clara Basin and is largely undeveloped in its upper zone above the reservoirs, with pockets of high-density residential areas. Three-quarters of this area is protected. Virtually all headwaters drain from the protected areas, except for Upper Los Gatos Creek. The lower zone is typical of watersheds in the Santa Clara Basin, with high-density residential use predominating and commercial and public/quasi-public developments being interspersed. The lower zone is atypical of other watersheds in the area due to the continued presence of agriculture (Santa Clara Basin Watershed Management Initiative, 2000) (Table 2-4).

Table 2-4
Acreage of Existing (1995) Land Uses for the Guadalupe River Watershed

Land Use	Acreage
Residential	32,230
Commercial	4,888
Public/Quasi-Public	2,777
Industry-Heavy	3,397
Industry-Light	2,049
Transportation/Communication	1,700
Utilities	15
Landfills	–
Mines, Quarries	28
Agriculture	3,120
Forest	37,810
Rangeland	16,859
Vacant, Undeveloped	1,145
Wetlands	–
Bays, Estuaries	–
Freshwater	399
Total Acres	108,900

Adapted from: Santa Clara Basin Watershed Management Initiative. Table 4-2. (2000).

2.1.5 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. The upland region is underlain by sedimentary and metamorphic formations, chiefly belonging to the Franciscan Formation. Common sedimentary rock types include sandstone, shale, graywacke, limestone, and conglomerates. Common metamorphic and volcanic rocks include chert, serpentinite, greenstone, basalt, and schist. The alluvial plain 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 Highway 237 is underlain by Bay muds and fine-grained silts and clays.

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 (Bailey and Everhart, 1964). 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 (Alpers and Hunerlach, 2000) and the New Idria Mine, where the mercury ore was formed due to hot springs solution deposits (Ganguli et al., 2000).

The Franciscan Formation and its related serpentine beds underlie the New Almaden Mining District of the upper Guadalupe River Watershed (reference Plate 1 from the Bailey and Everhart, 1964 report and the new geologic maps in McLaughlin et al, 2001). Silica carbonate bedrock is found in scattered areas of the New Almaden Mining District, the largest mercury mine in North America. Over 99 percent of the ore was extracted from deep underground shafts and tunnels (Bailey and Everhart, 1964). The mines where silica carbonate outcrops were at the surface include the Mine Hill area with multiple mines and open-cuts on Los Capitancillos Ridge.The Providencia Mine, and the Guadalupe and Senador Mines were located along the extension of Los Capitancillos Ridge. Smaller outcrops were associated with the Enriquita fault zone that cuts across the present location of Guadalupe Reservoir. This zone was exploited by three small mines: San Mateo, San Antonio, and Enriquita. There were other small outcrops along the eastern portion of Los Capitancillos Ridge. A placer deposit in thick gravels was found in the lower portion of Deep Gulch Creek. However, dispersed cinnabar may be present in small silica carbonate outcrops and in the remaining unexplored subsurface veins. Soils overlying the silica carbonate deposits have elevated total mercury. The range of five soil sampling areas within the former mining area had total mercury concentrations ranging from 3.2 to 570 mg/kg; the median total mercury concentrations were 17 to 200 mg/kg (Dames and Moore, 1989). Other rock types that had some cinnabar in a few locations, as noted in the report on the New Almaden Mining District (Bailey and Everhart 1964) include graywacke and shale in the Harry area and altered greenstone or 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 shows isolated, small silica carbonate deposits in the Limekiln Canyon area of the Lexington watershed (McLaughlin et al, 2001). There were no other 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. 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.

2.1.6 Mining Operations and Existing Conditions

The mercury deposits were first discovered by Indians and Mexicans prior to 1845. The New Almaden Mining District (a group of seven adjacent mines, most underground, in the upper part of the Guadalupe Creek and Alamitos subwatersheds) operated from 1846 to 1975. Figure 2-6 shows the major mine-related features in the

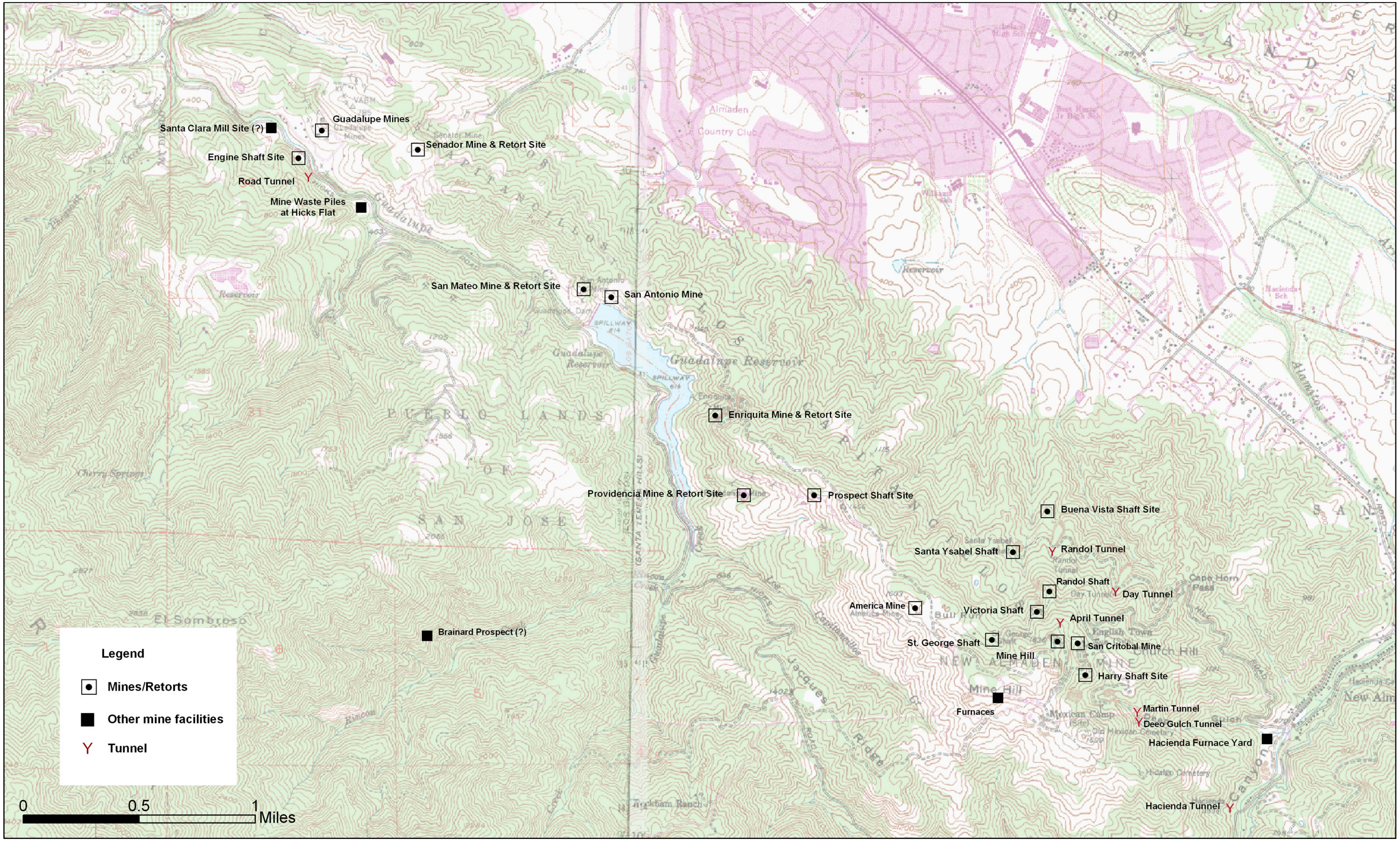


Figure 2-6. Map of major mine-related features (Mine Hill had multiple shafts and open-cut operations, not shown here).

upper Guadalupe River Watershed. Most of the ore was derived from cinnabar in silica carbonate deposits, but there was some native mercury in the underground veins such as in the Harry area near Mine Hill. A placer deposit of cinnabar nuggets in stream gravels was mined from 1945 to 1947 in lower Deep Gulch Creek where it joined Almaden Canyon (Bailey and Everhart, 1964).

A total of about 38.4 million kilograms of mercury was produced; about 70 percent of the production came before 1875, and about 80 percent before 1935. Prior to construction of the Guadalupe and Almaden Reservoirs in 1935, roasted mine wastes, called calcines, and other mine wastes were disposed of in or near the creeks so the materials would be transported downstream by winter flows. Calcines and other mine wastes are still present along the banks of Alamitos Creek on the opposite slope from Hacienda Yard and in some downstream reaches of Alamitos Creek from Bertram Road to Greystone Lane, Deep Gulch, Jacques Gulch, and Guadalupe Creek above Camden Avenue. Because the ore was from silica carbonate deposits, the mine wastes are sometimes found as cemented deposits along the creek banks.

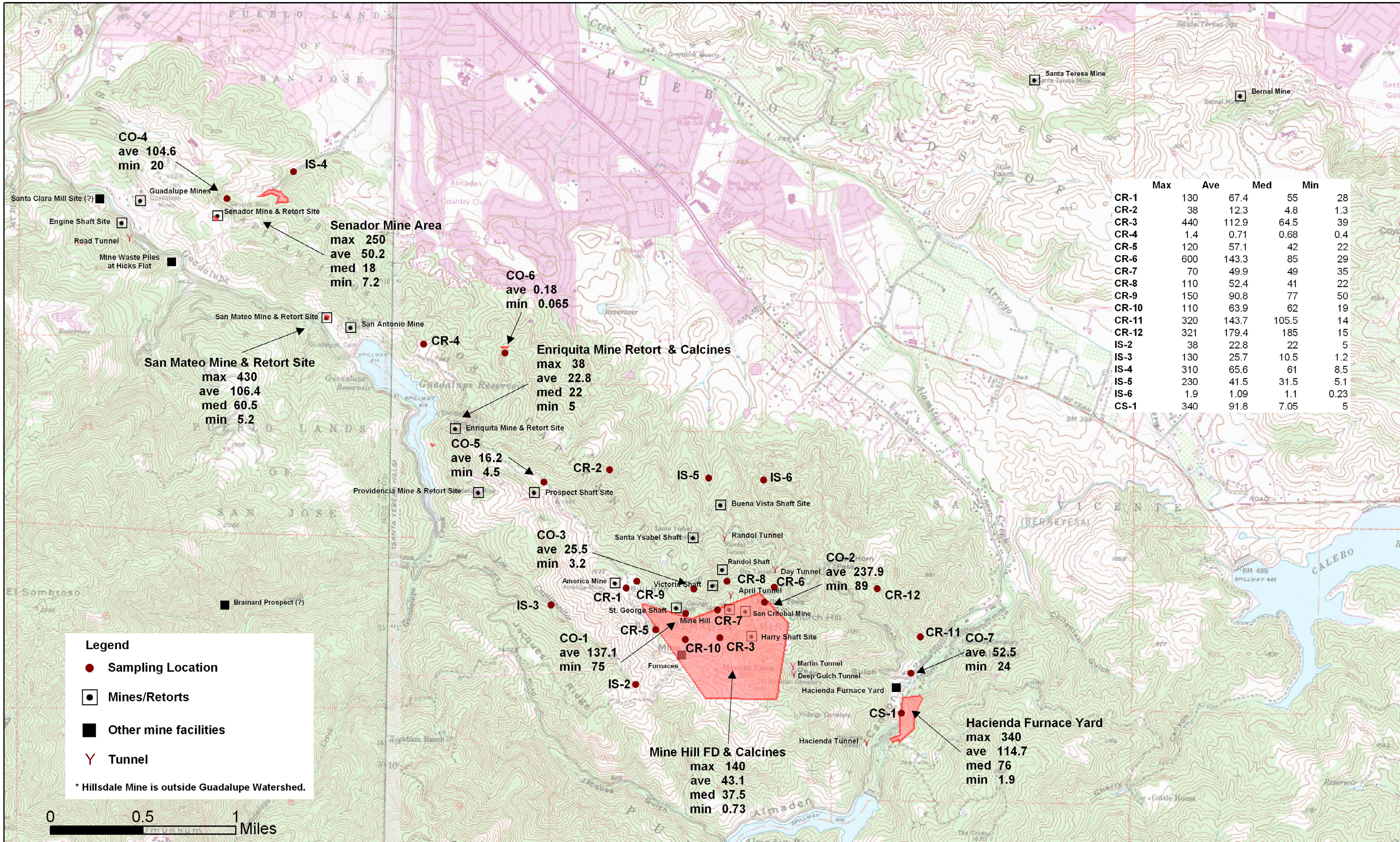
The production activities at the New Almaden Mining District are well characterized, and there is considerable information regarding concentrations of total mercury remaining in the soils. The early veins mined had rich ore of up to 20 percent mercury, which was hand-sorted prior to processing in furnaces and retorts (Bailey and Everhart, 1964). In later years, the percent mercury in the ore declined to 0.5 percent. The average grade of the ore processed over the 100-year life of the mines was nearly 4 percent, about a flask of mercury per ton of rock. As seen in Table 2-5, most of the production came from the mines on Mine Hill within the New Almaden Mining District. The ore was roasted in retorts or furnaces at a temperature of 700 to 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. A group of 14 small furnaces were used on the banks opposite the Hacienda Furnace Yard. Mine wastes from these retorts are present on the slopes opposite the Hacienda Furnace Yard 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, which were sometimes portable units, were used at the Day Tunnel, upper Deep Gulch Creek, and San Cristobal Tunnel. Visible waste dumps were not observed at the latter site (WCC, 1992).

Table 2-5
Production of Mercury from Major Mines in New Almaden Mining District
(Bailey and Everhart, 1964 and Cox, 2000)

Mine	Period of Operation	Mercury Produced (Flasks)
New Almaden Mines	1846 to 1975	1,096,411
America Mine	1800s to 1960s	<2,500
Guadalupe Mine	1846, 1920-1930 & 1947-75	112,623
Enriquita	1859-75,1892, 1927-1935	10,571 by 1865, then <100
San Mateo	1860-70s, 1890-1901,1915-1917, 1935-40	At least 1,000
San Antonio	1848, 1915-1917	Small amounts
Providencia	1860-1870,1882, 1909,1942	<2,000
Senador	1860-1900, 1916-1926, 1940s	About 24,500

Prior to remediation, mercury concentrations in the mine wastes within the boundaries of Almaden Quicksilver County Park ranged from 10 to 1,000 mg/kg; the median of 37 sites was 84 ppm (CDM, 1992). Samples of calcines and waste piles around the major mines were collected, along with the unpaved roads, exposed soil overlying silica carbonate and other types of bedrock, streambed sediment, and mine seeps (Dames and Moore, 1989). A summary of the total mercury concentrations in the AQC Park that were not removed or buried is provided in Figure 2-7. 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 were removed in 1990, covered with soil, re-graded, and re-vegetated. Most of the calcines were placed in the San Francisco Open Cut on Mine Hill, where they were covered with soil, and revegetated. The remaining calcines at the Hacienda Furnace Yard were covered with a 2-foot soil cap (DTSC, 2002). Calcines present on the opposite bank of Alamitos Creek from the Yard were not removed or covered. Calcines at Enriquita and San Mateo were buried near the former retort sites. Overburden piles remain at some of the mines such as near the Providencia and Senador Mines. Erosion control measures were implemented on the steep slopes around the former furnaces and retorts. On the Hacienda Yard next to Alamitos Creek, a concrete cutoff wall and gabion and rock slope protection were installed on the western bank.

Observations from recent site visits to the former mines show that the calcine disposal areas within Almaden Quicksilver County Park are being protected from erosion by the vegetation and runoff control measures implemented. Mine waste piles at former mines; such as near the Senador Mine, have been seeded with grass, but there are places where active erosion is occurring. Runoff from the Senador Mine reaches McAbee Creek, which discharges into Golf Creek, and then into Alamitos Creek. For the boundaries of the subwatersheds within Almaden Quicksilver County Park, see Figure 2-10, which is included in Section 2.1.7 as part of the discussion on the runoff data from the streams in the AQC Park. Calcines and other mine wastes are present in Jacques Gulch, which discharges into Almaden Reservoir, and Deep Gulch, which discharges into Alamitos Creek. The location of known mine seeps and mine wastes are shown in Figure 2-8. Within Almaden Quicksilver County Park, there are former mine roads where isolated mine wastes are evident in the larger cobble and gravel size materials, which are actively eroding. Runoff in some of these areas could reach Jacques Gulch, which discharges into Almaden Reservoir. Other areas would discharge into 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 2-8.



	Max	Ave	Med	Min
CR-1	130	67.4	55	28
CR-2	38	12.3	4.8	1.3
CR-3	440	112.9	64.5	39
CR-4	1.4	0.71	0.68	0.4
CR-5	120	57.1	42	22
CR-6	600	143.3	85	29
CR-7	70	49.9	49	35
CR-8	110	52.4	41	22
CR-9	150	90.8	77	50
CR-10	110	63.9	62	19
CR-11	320	143.7	105.5	14
CR-12	321	179.4	185	15
IS-2	38	22.8	22	5
IS-3	130	25.7	10.5	1.2
IS-4	310	65.6	61	8.5
IS-5	230	41.5	31.5	5.1
IS-6	1.9	1.09	1.1	0.23
CS-1	340	91.8	7.05	5

Figure 2-7. Map of former mining area with summary of total mercury data following remediation in AQC Park in 1994-1996 (Dames and Moore, 1989 and CDM, 1994) CO = colluvium, CR = road samples, IS = intermittent streambed sediments. CS-1 was collected from Alamitos Creek sediment.

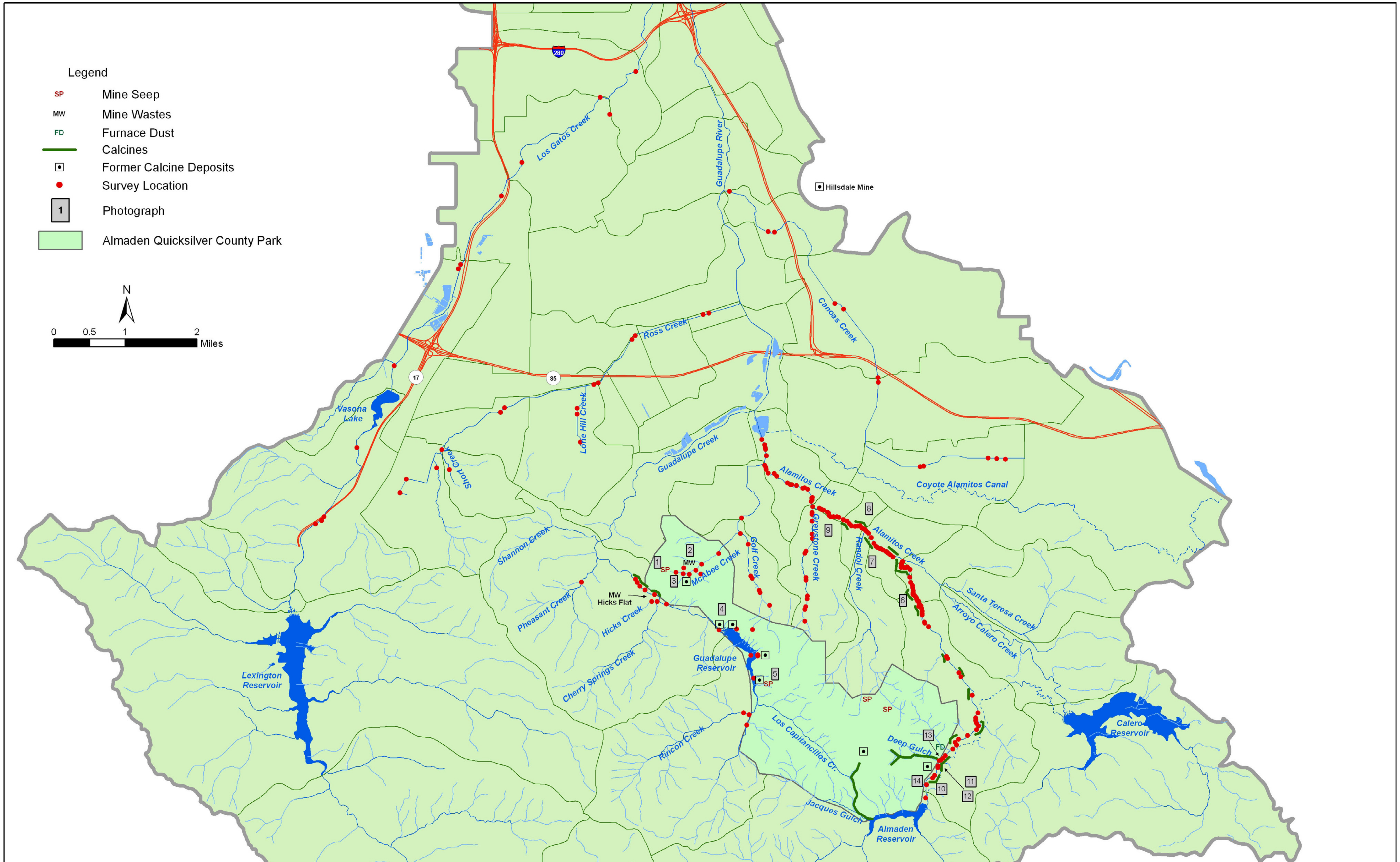


Figure 2-8. Location of exposed mine wastes and seeps along the tributaries to the Guadalupe River.

The locations of reaches of the creeks where calcines were observed during the field surveys in summer 2003 are identified in Figure 2-8. Example photographs of the creek reaches with cemented and loose calcines and other mine waste deposits are shown in Figure 2-9. For example, above the Hacienda Furnace Yard along Alamitos Creek, there are large non-cemented deposits of calcines on the slopes above the creek. Both early calcines composed of cobble-sized material and later calcines from the Scott furnaces composed of minus 3-inch material are present. A site visit indicated that the gabion wall along the creek is now failing (Austin, 2005). 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, of which some are cemented and some are loose. Many of these deposits are above the low flow channel. A small area of furnace dust is present under the Almaden Road bridge. On Alamitos Creek downstream of Harry Road, there are calcine areas, which are often cemented and limited in extent, such as six sites between Harry Road and Greystone Lane. Calcines are observed in the gravel bars along the entire reach of Alamitos Creek.

Along Guadalupe Creek outside of the Almaden Quicksilver County Park, possible calcine deposits were observed along the banks of upper Guadalupe Creek near the former Guadalupe Mine. A partly vegetated mine waste pile is present at Hicks Flat on the opposite side of Guadalupe Creek from the main mine.

There are two much smaller mines in the Canoas Creek watershed, the Santa Teresa and Bernal Mines. The Santa Teresa mine was operated as an underground mine from 3 main adits. In 1903, a 40-ton Scott furnace was installed, which produced 9 flasks of mercury (Bailey and Everhart, 1964). The Bernal Mine was an underground mine with 2 shafts and an adit by 1902. In 1942, two new holes were drilled, and in 1946, the adit was extended, and a retort was installed. The mine was idle by 1947, and no evidence of mercury production was found in the abandoned retort. The Hillsdale Mine is outside the watershed boundary of the Canoas Creek watershed, but due to quarrying and regrading operations it may have affected Canoas Creek. The Hillsdale Mine produced 30 to 40 flasks in spring 1871, and small amounts up to 1874; it was idle from 1875 to 1892 and from 1907 to 1915 (Cox, 2000). A few flasks of mercury were produced in 1915; the mine was reworked from 1939 to 1946. The gravel quarry started after 1947 and excavated part of the mine in the early 1980’s. The lower portion of Canoas Creek was rerouted in the 1960’s to enter the Guadalupe River further upstream, and it was channelized with concrete partway up the side slopes.

2.1.7 Water and Sediment Data from Almaden County Quicksilver Park

From 1994 to 2003, water samples have been collected in the wet season from creeks that drain the Almaden Quicksilver County Park by the Santa Clara Parks and Recreation Department (SCPRD). The sites are shown in Figure 2-11. The total mercury in the 2000-2003 water samples was analyzed using EPA Method 1631, as summarized in Table 2-6. The Senador Mine site drains to McAbee Creek, which joins Golf Creek, then Alamitos Creek. The Mine Hill tributary to Jacques Gulch site drains into Jacques Gulch, then into Almaden Reservoir. Deep Gulch drains to

Photographs of Exposed Mine Wastes, Seeps, etc.


Photo 1 **Mine Seep at Senador mine**


Photo 2 **Mine Waste Piles at Senador Mine**


Photo 3 **Senador Mine Reduction Works**


Photo 4 **Silica carbonate outcrop at San Mateo Mine**


Photo 5 **Mine wastes and seeps near Enriquita Mine and seeps**


Photo 6 **Cemented calcine on Alamitos Creek**


Photo 7 **Cemented layers on Alamitos Creek**


Photo 8 **Undercut calcines on Alamitos Creek**


Photo 9 **Cemented calcines on Alamitos Creek**


Photo 10 **Calcines along the edge of Alamitos Creek**


Photo 11 **Calcines on the upper flood plain above Alamitos Creek**


Photo 12 **Close-up of calcines above Alamitos Creek**


Photo 13 **Furnace dust beneath an Alamitos Creek bridge on New Almaden Road below Hacienda Furnace Yard**


Photo 14 **Calcine deposits on hill below road slip above Alamitos Creek**

Figure 2-9. Examples of calcine deposits and other mine wastes in or near creeks.

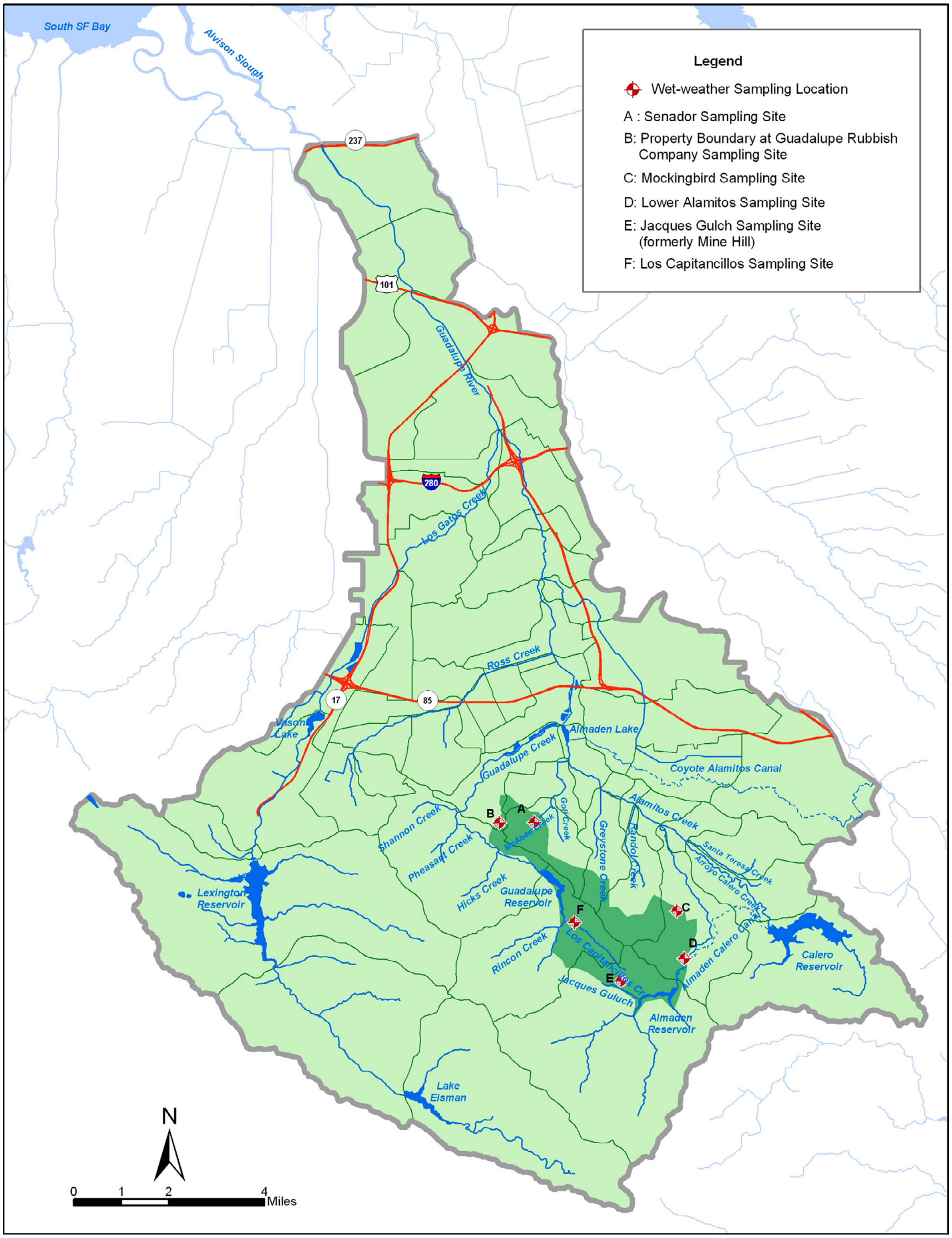


Figure 2-10. Wet-weather sampling locations used in 2003 for Almaden Quicksilver County Park by SCPRD.

Alamitos Creek near site D during large storms in the wet season, but percolates underground for the remainder of the year. This site is not shown on Figure 2-10, as it was not sampled in 2003. In 2003, two sites were added: one site at North Los Capitancillos Creek above Guadalupe Reservoir, and a second site at a gully draining part of the Guadalupe Landfill above McAbee Creek. The Deep Gulch and Upper Alamitos Creek sites were dropped, and the Mockingbird site on upper Randol Creek was not sampled. The highest mercury concentrations occurred in January 2000 at most sites when the suspended solids were high during a large storm event (total rainfall was 2.52 in. the day before sampling and 3.11 in. the day of sampling - SCPRD, 2003). High total mercury concentrations also occurred in samples collected on Feb. 25, 2004, when rainfall was 0.12 in. the day before sampling and 2.6 in. the day of sampling, which had especially high suspended solids.

Sediment samples were collected in 1989 at several locations in or near the former mining areas prior to the remediation efforts on Mine Hill and in the lower portions of Deep Gulch Creek within the Hacienda Furnace Yard. Sediment samples from Deep Gulch Creek had total mercury ranging from 2 to 590 mg/kg on a wet weight basis (Dames & Moore, 1989). Sediment samples from Alamitos Creek collected below the reservoir had total mercury ranging from 1.5 to 95 mg/kg on a dry basis (WCC, 1992). A tributary of Randol Creek sampled in 1992 had total mercury of 5.1 to 230 mg/kg on a wet weight basis (WCC, 1992). Guadalupe Creek above Camden Avenue was sampled from 1980 to 1989 by the USGS; total mercury ranged from 0.04 to 70 mg/kg dry (WCC, 1992). These data illustrate the high mercury concentrations present in the mining area prior to the remediation efforts.

Table 2-6
Mercury Concentrations in Stream Water Samples Draining Almaden Quicksilver County Park

Sampling Site and Map Identifier	Dates Sampled (Number of Dates)	Total Suspended Solids (mg/L)	Total Mercury (ng/L)
Deep Gulch Creek	2000-2002 (6)	<1-11	23–2,180
Upper Alamitos Creek	2000-2002 (6)	5.1-19	10.6-71.7
Lower Alamitos Creek (D)	2000-2004 (9)	2.2-26	18-2,900
	2/25/2004	1,790	110,000
Senador Mine (A)	2000-2004 (9)	<0.5-360	21.9-3,692
	2/25/2004	3,230	2,000
Mine Hill Tributary to Jacques Gulch (E)	2000-2004 (9)	<1-680	4.3-6,667
	2/25/2004	440	440
N. Los Capitancillos (F)	2003 (2)	5.4	5.8-26
	2/25/2004	8,890	5,300
Landfill Gully (B)	2003 (2)	1.9-21	79-60
	2/25/2004	3,410	2,500
Mockingbird C	2/2/2004	40	140
	2/25/2004	220	390

Data are from SCPRD, 2003 and 2004. Note samples collected on 2/25/04 were not analyzed using the low level method EPA 1631.

2.2 COMPARISON TO OTHER MERCURY AND GOLD MINES IN CALIFORNIA

Numerous mercury mines are located in the 400 km-long mercury mineral belt of the Coast Range of California. There are 51 mercury mines that each produced more than 1,000 flasks of mercury (34,475 kg) (Rytuba, 2000), while the NAMD alone produced 38.4 Million kg of mercury. Mercury production began in 1846; 70 percent of the NAMD production occurred before 1875 and 80 percent before 1935 (Bailey and Everhardt, 1964). Limited production of open cuts was conducted after 1940. The two major types of deposits are silica-carbonate deposits and hot springs. Cinnabar is the dominant mercury form in both types, but secondary mercury compounds are more prevalent in hot spring areas. Most of the mercury produced was used in the amalgamation process to obtain gold from placer deposits using hydraulic, drift, and dredging methods and crushed hardrock ore deposits. The peak mercury production in the California mercury mines was in 1877 (2,776 M kg), of which most was used in the Sierra Nevada and Klamath-Trinity Mountains (Hunerlach, et al, 1999). The New Almaden Mining District was the largest mercury producer in North America. Characteristics of example mercury and gold mines for comparison to the New Almaden Mining District are presented in Table 2-7a for mercury mines and in Table 2-7b for gold mines. The mines listed are those with ultra-clean mercury measurements in water and/or sediment samples. Data for other mercury and gold mines provides perspective showing the importance of the New Almaden Mining District relative to mercury production in the state. Mercury and methylmercury concentrations in water and sediment samples from nearby waterbodies have been compiled to determine how the data from the Guadalupe River watershed compare to other areas. The data also provide information on other mercury sources to San Francisco Bay, besides the Guadalupe River.

Table 2-7a.
Summary of Mercury Mines in California Used in Analysis

Mine or Mining Area	Type of Mine Deposit and Form of Ore	Years of Production	Mercury Production	Nearest Waterbody Affected
Mercury Mines				
New Almaden Mining District	Silica carbonate - cinnabar	1846 to 1975	38.4 M kg	Almaden/ Guadalupe Reservoirs/Guad River
Gambonini	Hot Springs deposit - cinnabar	1960 to 1970	0.17 M kg	Walker Creek and/Tomales Bay
New Idria	Silica carbonate – cinnabar, metacinnabar	1854 to 1972	17.2 M kg	San Carlos Creek/San Joaquin River*
Knoxville District (Manhattan, Reed and others)	Silica carbonate – cinnabar/metacinnabar; also has gold deposits	1862 to 1970s	Total for district 5.4 M kg	Davis Creek and Reservoir and Cache Creek*
Sulfur Bank	Hot Springs Deposit – cinnabar and secondary mercury of sulfates, chlorides, and oxychlorates	1872 to 1957	4.5 M kg	Clear Lake/Cache Creek*
Sulfur Creek and Manzanita	Geothermal complex	NA	NA	Sulfur Creek/Cache Creek*
Turkey Run and Abbot	Hot springs Deposit	NA	NA	Harley Gulch and Cache Creek*

*These waterbodies ultimately discharge into the Sacramento River and San Francisco Bay. References: Rytuba, 2000/2005; Ganguli et al, 2000; Suchanek et al, 1998; Rytuba and Enderlin, 1999, and Whyte and Kirchner, 2000.

Table 2-7b.
Summary of Gold Mines in California Used in Analysis

Mine or Mining Area	Type of Mine Deposit	Years of Production	Mercury Use	Nearest Waterbody Affected
Gold Mines				
Bodie Mine	Gold hardrock, placer	Peak 1860 to 1880	30-stamp amalgamation plant on creek	East Fork Walker River
Boston/Sailor Flat	Gold placer deposit	NA	Used mercury	Upper Greenhorn Creek/Bear River*
Lower Clear Creek Area	Gold placer deposits	1850 to 1942	Used mercury	Flat, Spring Creek and Lower Clear Creek*
Dutch Flat Mining District	Gold placer deposits	1857 to 1900	>185 M yd3 gravels mined using mercury	Bear River*
McLaughlin	Hot spring gold-mercury (previously Manhattan Hg mine)	1985 to 1996; ore production until 2001	Mercury used to obtain 3 M troy ounces of gold	Clear Lake*

*These waterbodies ultimately discharge into the Sacramento River and San Francisco Bay.
References for table: Rytuba, 2000; Rytuba et al, 2000, Alpers and Hunerlach, 2000, Hunerlach et al, 1999, Ganguli et al, 2000; Suchanek et al, 1998; Rytuba and Enderlin, 1999, and Ashley et al, 2002.

2.2.1 Aqueous Mercury Concentrations in Water Samples near Mines

Total and methylmercury data for water samples of mine drainage and creeks or other waterbodies near mercury and gold mines in California were compiled to compare with data in the Guadalupe River watershed. A summary of mercury concentrations in water samples collected in 2003 and 2004 for the Guadalupe River watershed is provided in Table 2-8. Mercury concentrations in the mine-influenced creeks are considerably higher than the urban creeks and creeks in non-mining areas of the watershed. However, due to the increased suspended sediment load in the Guadalupe River, mercury concentrations are more similar to the mine-influenced creeks than to the urban creeks, and higher than in the reservoir samples. The comparison for methylmercury differs in that the highest concentrations are found in the two reservoirs in the former mining area and Almaden Lake. The median methylmercury concentration in the Guadalupe River samples was higher than for urban creeks, although the maximum concentration was higher for the urban creeks.

A similar table with data for other mercury and gold mines is presented in Table 2-9. The latter table indicates that total mercury and methylmercury are higher in creeks near mercury mines than gold mines, except at some mines where acid drainage occurs. Median concentrations of total mercury in water samples from acid mine drainage at gold mines were higher than at mercury mines. The maximum and mean total mercury concentrations were higher in the mercury mines than the acid mine drainage from gold mines. Acid mine drainage is not as prevalent at mercury mines as gold mines, since gold deposits are typically associated with larger quantities of iron sulfide minerals. The highest methylmercury concentrations were observed in creeks near mercury mines. The increased methylmercury concentrations observed in wetlands near gold mines highlight the importance of waterbody conditions that can favor in-situ methylation.

Table 2-8.
Summary of Mercury and Methylmercury Data for Water Samples from the Guadalupe River Watershed

Statistic	Runoff Samples from Creeks in the Almaden County Quicksilver Park (2000 through 2003)	Guadalupe River Samples	Mine Area Creeks	Mine-Influenced Downstream Creeks[b]	Urban Creeks	Other Upper Watershed Creeks	Reservoirs in Mining Areas (Almaden and Guadalupe)	Other Reservoirs
Unfiltered Total Hg (ng/L)[a]								
Minimum	1.70	14.48	13.40	3.64	2.04	1.92	2.93	1.37
Maximum	6667.00	464.60	191.10	570.40	29.83	13.54	77.40	19.80
Mean	477.93	161.24	62.61	60.67	13.35	4.44	17.91	7.01
Median	60.00	78.60	42.20	32.99	12.28	3.40	14.30	4.65
Std. Deviation	1268.57	141.86	57.29	106.36	10.20	3.13	14.54	6.31
Count	39	21	9	29	17	16	67	12
Filtered Total Hg (ng/L)[a]								
Minimum	0.90	1.63	1.66	1.38	0.64	0.79	1.00	0.29
Maximum	24.00	22.22	32.91	34.39	18.99	3.94	12.20	5.04
Mean	12.43	10.26	13.53	9.30	5.06	1.59	3.39	2.14
Median	14.00	9.17	8.30	6.34	2.83	1.26	2.65	1.70
Std. Deviation	8.81	6.87	10.65	7.94	5.09	0.98	2.37	1.54
Count	9	21	9	29	17	16	67	12
Unfiltered MeHg (ng/L)[a]								
Minimum	-	0.164	0.031	0.119	0.004	0.014	0.204	0.057
Maximum	-	0.915	0.201	8.266	1.351	0.151	12.800	2.022
Mean	-	0.500	0.111	1.096	0.264	0.057	2.004	0.381
Median	-	0.533	0.086	0.409	0.184	0.039	0.695	0.183
Std. Deviation	-	0.193	0.070	1.833	0.335	0.046	2.822	0.551
Count	-	21	9	29	17	16	67	12
Filtered MeHg (ng/L)[a]								
Minimum	-	0.061	0.101	0.134	0.002	-	0.042	0.010
Maximum	-	0.154	0.169	6.073	1.102	-	8.270	1.253
Mean	-	0.104	0.135	0.942	0.204	-	1.189	0.247
Median	-	0.097	0.135	0.268	0.041	-	0.333	0.094
Std. Deviation	-	0.033	0.048	1.558	0.352	-	1.870	0.372
Count	-	10	2	18	12	-	67	12

[a]Samples were collected for the Guadalupe River Mercury TMDL watershed project and analyzed using ultra-clean methods.
[b]Almaden Lake sample not included in statistical analyses (Tot. Hg - 25.36 ng/L; MeHg - 17.85 ng/L; Filt. Tot. Hg - 4.4 ng/L; Filt. MeHg 1.72 ng/L).

Table 2-9.
Summary of Mercury and Methylmercury Data in Water Samples from Waterbodies near Gold and Mercury Mines in California

Statistic[a]	Creeks Gold Mining	Creeks[c] Mercury Mining	Acid Mine Drainage Gold Mining	Acid Mine Drainage Mercury Mining	Wetlands Gold Mining	Lakes and Reservoirs Gold Mining
Unfiltered Total Hg (ng/L)[b]						
Minimum	0.62	0.30	1.30	5.20	2.10	0.90
Maximum	231.00	38304.00	1330.00	405.00	254.00	2.88
Mean	23.69	502.41	214.24	150.23	41.54	1.76
Median	3.50	16.60	45.00	40.50	7.79	1.02
Std. Deviation	54.03	3183.84	357.65	221.34	93.75	1.00
Count	20	161	23	3	7	7
Filtered Total Hg (ng/L)[b]						
Minimum	<0.40	0.20	0.70	1.64	0.81	0.44
Maximum	196.00	399.00	63.00	1.64	3.96	3.50
Mean	8.16	32.95	14.80	1.64	2.05	1.26
Median	1.09	2.20	7.00	1.64	1.86	0.90
Std. Deviation	33.03	73.36	20.36	-	1.36	0.96
Count	36	159	20	1	6	19
Unfiltered MeHg (ng/L)[b]						
Minimum	<0.04	<0.013	<0.04	0.210	0.040	0.227
Maximum	0.037	20.600	2.330	0.360	6.720	0.479
Mean	0.028	0.723	0.303	0.303	1.841	0.378
Median	0.027	0.180	0.100	0.340	0.454	0.429
Std. Deviation	0.009	2.393	0.645	0.081	2.722	0.133
Count	3	161	12	3	7	3
Filtered MeHg (ng/L)[b]						
Minimum	<0.04	0.011	0.040	0.270	0.033	<0.04
Maximum	0.038	7.130	0.890	0.270	2.280	0.096
Mean	0.025	0.219	0.240	0.270	0.672	0.041
Median	0.020	0.074	0.050	0.270	0.107	0.020
Std. Deviation	0.011	0.619	0.368	-	0.970	0.030
Count	3	159	5	1	5	7

[a]Statistics were calculated using 1/2 the method detection limit.
[b]Samples were collected and analyzed using ultra-clean methods.
[C]Additional creek water samples were collected for mine drainage from the Gambonini Mercury Mine. The range of total mercury concentrations were from 485 to 1,040,000 ng/L (Whyte and Kirchner, 2000).

Many of these creeks eventually flow into the Sacramento River where total mercury samples ranged up to 105 ng/L during a winter storm, and methylmercury concentrations ranged up to 2 ng/L (Domalgalski, 2001). The measured total mercury concentrations in the Guadalupe River are higher than the Sacramento River, which has a much larger watershed and multiple tributaries. Winter methylmercury concentrations were less (maximum of 0.92 ng/L) in the Guadalupe River; summer concentrations in the two mining area reservoirs and downstream creeks were much higher (maximum of 12.8 ng/L and 8.3 ng/L, respectively).

2.2.2 Mercury in Sediment Samples near Mines

Total and methylmercury data for sediment samples in mine wastes and waterbodies near mercury and gold mines in California were also compiled. A summary of mercury concentrations in sediment samples collected in 2003 and 2004 for the Guadalupe River watershed is provided in Table 2-10. Due to the former practice of disposing of mine wastes in Alamitos and Guadalupe Creeks and in their tributaries, the total mercury concentrations in these two creeks are similar to the present-day samples from creeks in the mining area (following remediation efforts). A similar table with data for gold and mercury mines is presented in Table 2-11. This table shows that total mercury concentrations in sediment near gold mines and other mercury mines are generally less than those in the Guadalupe River sediments and mine-influenced creeks. The sediments from the urban creeks had low concentrations of total mercury, compared to the other samples in the Guadalupe River watershed or the creek samples from near other mines. While maximum methylmercury concentrations were higher in the mine-influenced creeks, due to the reservoir inflows, the median concentrations were similar between the Guadalupe River, mine-influenced creeks, and the mine area creeks. The median concentration in the urban creeks was considerably less (0.2 ng/g dry weight), compared to 1.6 ng/g dry weight in the Guadalupe River sediments. The mine area creeks in the Guadalupe system had similar methylmercury concentrations to creeks at other mercury mines, while higher methylmercury concentrations occurred at some of the mine drainage sites from both gold and mercury mines.

Table 2-10.
Summary of Mercury and Methylmercury Data for Sediment from Guadalupe River Watershed

Statistic	Guadalupe River	Mine-Influenced Downstream Creeks	Mine Area Creeks	Urban Creeks
Total Hg (mg/kg dry wt.)[a]				
Minimum	0.065	0.223	1.13	0.042
Maximum	69.51	168.54	143.69	0.112
Mean	10.77	43.51	31.30	0.074
Median	3.0580	19.71	18.12	0.071
Std. Deviation	18.08	55.55	50.10	0.030
Count	18	11	7	4
MeHg (ng/g dry wt.)[a]				
Minimum	0.043	0.065	0.053	0.039
Maximum	3.23	35.85	4.56	1.94
Mean	1.39	5.30	1.52	0.60
Median	1.64	1.76	1.37	0.22
Std. Deviation	0.92	10.46	1.82	0.89
Count	18	11	5	4

[a]Samples were collected for the Guadalupe River Mercury TMDL project and analyzed using ultra-clean methods.

Table 2-11.
Summary of Mercury Data in Sediment from Waterbodies near California Gold and Mercury Mines

Statistic[a]	Creeks Gold Mining Bulk	Creeks[d] Mercury Mining Bulk	Lake/ Reservoir Gold Mining Bulk	Mine Drainage[c] Gold Mining Bulk	Tailings/ Fill Gold Mining Bulk	Tailings/ Fill Gold Mining >2 mm	Tailings/ Fill Gold Mining <2 mm	Wetland/ Pond Gold Mining Bulk	Wetland/ Pond Gold Mining Fines
Total Hg (mg/kg dry wt.)[b]									
Minimum	0.020	0.05	0.0060	0.0044	0.0300	0.0200	0.0400	0.0229	0.1900
Maximum	21.00	50.91	0.0530	6.71	0.2020	0.0400	0.1400	0.1600	0.2950
Mean	3.05	4.50	0.0295	2.65	0.0988	0.0275	0.0728	0.0829	0.2573
Median	0.04	0.58	0.0295	2.40	0.0995	0.0250	0.0556	0.0914	0.2720
Std. Deviation	7.91	11.29	0.0332	2.78	0.0549	0.0096	0.0456	0.0523	0.0462
Count	7	25	2	7	9	4	4	8	4
MeHg (ng/g dry wt.)[b]									
Minimum	0.020	0.056	0.016	<0.015	<0.015	-	0.101	0.225	1.02
Maximum	0.699	7.760	6.11	111.83	0.299	-	0.387	31.10	3.00
Mean	0.302	2.333	3.06	17.94	0.075	-	0.244	5.25	1.82
Median	0.188	1.020	3.06	0.050	0.036	-	0.244	0.588	1.63
Std. Deviation	0.354	2.486	4.31	41.693	0.112	-	0.202	11.45	0.914
Count	3	25	2	7	6	-	2	7	4

aStatistics were calculated using 1/2 the method detection limit.
[b]Samples were collected and analyzed using ultra-clean methods.
[c]Higher mercury concentrations can occur when elemental mercury is present such as the Polar Star Mine in the Dutch Flat area (Hunerlach et al., 1999).
[d]The range of mercury in creek sediment from the New Idria Mine were 4.5 mg/kg to 21.3 mg/kg (Marvin-Dipasquale et al, 2000.