DRAFT TECHNICAL MEMORANDUM NO. 2A - MINE DRAINAGE
CALIFORNIA URBAN WATER AGENCIES
STUDY OF DRINKING WATER QUALITY IN DELTA TRIBUTARIES

November 5, 1993

The impacts of mine drainage were determined to be of relatively little concern to drinking water supplies in the Sacramento and San Joaquin basins in the State Water Project (SWP) Sanitary Survey. Metals concentrations in mine drainage are typically well below current drinking water standards although they often exceed the Inland Surface Waters Plan (ISWP) objectives for aquatic life (California State Water Resources Control Board, 1991). Additional information collected on mine drainage in the Central Valley since completion of the SWP Sanitary Survey was reviewed to reassess the potential impacts on drinking water quality of Delta tributaries. The purpose of this technical memorandum is to address the significance of mine drainage as a source of contaminants of concern relevant to this study and as a source of concern to drinking water quality in general.

BACKGROUND INFORMATION ON MINES IN THE CENTRAL VALLEY WATERSHED

Mining operations in central and northern California have been primarily for the recovery of 1) copper, zinc, and other nonferrous metals from sulfide ore bodies, 2) gold, and 3) mercury. Mining of sulfide ore bodies has occurred primarily in the Lake Shasta area and also in the foothills of the Sierra Nevada. Mining for gold has centered in the Sierra Nevada foothills. Mercury mining has been primarily in the Coast Ranges.

Regulation of Mines in the Central Valley

The Central Valley Regional Water Quality Control Board (Regional Board) manages active and inactive mines in the Central Valley under the Waste Discharge Requirement program, the National Pollutant Discharge Elimination System permitting program, and on a case-by-case basis. Permit conditions for active mines allow only inert or non-hazardous waste releases. Active mining operations meet these conditions by controlling the acidity of their discharges and by other best management practices.

Several thousands of mines have been worked and later abandoned. Discharges from these inactive mines constitute a significantly greater threat to water quality than discharges from active mines. Therefore, only inactive mines are discussed further.

Historically, the Regional Board has had difficulty in addressing inactive mines due to insufficient resources and concern over the state assuming liability for the clean-up. Many inactive mines have either no principle responsible party (PRP) or no PRP willing to accept the financial consequences of mine discharge abatement. In addition, in the instance of Penn Mine, where the Regional Board initiated abatement, subsequent litigation from The Friends of the Mokelumne River to force the Regional Board to assume comprehensive liability for abatement of Penn Mine discharges to meet water quality standards, has delayed further Regional Board sponsored abatement projects.

As directed under the Pollutant Policy Document (California State Water Resources Control Board, 1990), the Regional Board must limit mass loadings of arsenic, cadmium, copper, mercury, selenium, silver, and polynuclear aromatic hydrocarbons to the Delta (State Water Resources Control Board, 1990). The Regional Board has added lead and zinc to this list. In developing their mass loading reduction strategy, the Regional Board has developed load estimates for five of these pollutants from the major sources in the Central Valley (see Table 1). Because inactive mines are the principle source of several of these pollutants, mine abatement projects are now receiving renewed attention.

In addition, the State Inland Surface Waters Plan (ISWP), adopted in April 1991, lists numeric water quality objectives for a variety of pollutants (including metals) which must be met in nonpoint sources (such as inactive mines) as well as in point source discharges. The fact that inactive mines are the principle source of several of the metals (cadmium, copper, and zinc) for which the ISWP objectives are exceeded in the Sacramento River at Freeport will further focus Regional Board attention on mine discharge abatement (Larry Walker Associates, 1992).

In addition to state regulation, two of the major inactive mine sites in the Central Valley (Iron Mountain Mine and Sulfur Bank Mine) are federal Superfund sites.

Table 1. Source of Metals Loadings in the Central Valley Prelim #'s needs additional refinement

Source	Estimated percent of total load in the Sacramento River at Freeport				
	As	Cd	Cu	Pb	Zn
Inactive mines	11	72	59	2.5	60
Urban runoff	24	12	11	80	20
Agricultural drainage [1]	61	15	28	15	17
NPDES discharges	4	1	2	2.5	3
Unknown ?					
Total	100	100	100	100	100

Source of information: California Regional Water Quality Control Board, Central Valley Region. 1993. Report on Mass Emission Strategy Load Estimates.

Mine Drainage Quality

Sulfide ore mines produce acid mine drainage. Acid mine drainage is formed primarily from the oxidation of pyrite sulfide ores within mine tunnels and at the surface of waste rock piles. This reaction produces sulfuric acid with a pH of about 3. The low pH dissolves metals in the surrounding rock generating a discharge containing high dissolved metals concentrations. Acid mine drainage can contain elevated levels of copper, cadmium, and zinc and, usually lower concentrations of other metals such as nickel, lead, and chromium. Acid mine drainage may also carry radionuclides. Radionuclide levels in Central Valley acid mine drainage have not been

1 doesn't subtract out loading coming on to the ag fields

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studied. Drainage from gold mines can contain elevated levels of arsenic and mercury (once used in the gold amalgamation process). Drainage from mercury mines can contain elevated levels of mercury.

Mine drainage is carried out of the mine when infiltrating water floods the interior to the level of the lowest adit. Mine drainage is also discharged from waste rock piles when rainfall or streamflow contact the pile.

KEY MINE DISCHARGES

The Regional Board ranked the largest inactive mines according to their threat to downstream water quality (Buer et. al., 1978). Inactive mines with high and medium rankings are listed in descending order in Table 2. The locations of these mines are shown on Figures 1 and 2. Eleven of the inactive mines listed in Table 2 are located upstream of reservoirs. Some unknown percent of the contaminants in the mine drainage from these mines will be entrained within the sediments of the downstream reservoirs.

Table 2. Major Inactive Mines in the Watersheds Rated as High or Medium Threat to Water Quality

Mine	Watershed location
Iron Mountain	Sacramento
Mammoth	Sacramento
Penn	San Joaquin
Balaklala	Sacramento
Keystone	Sacramento
Afterthought	Sacramento
Mt. Diablo	San Joaquin
Bully Hill, Rising Star	Sacramento
Walker	Sacramento
Sulfer Bank	Sacramento
Newton	San Joaquin
Greenhorn	Sacramento
New Idria	San Joaquin
Corona	Sacramento
Manzanita	Sacramento
Cherokee	Sacramento

Source of information: California Regional Water Quality Control Board, Central Valley Region. 1985. Mass Loading Assessment of Major Point and Nonpoint Sources Discharging to Surface Waters in the Central Valley.

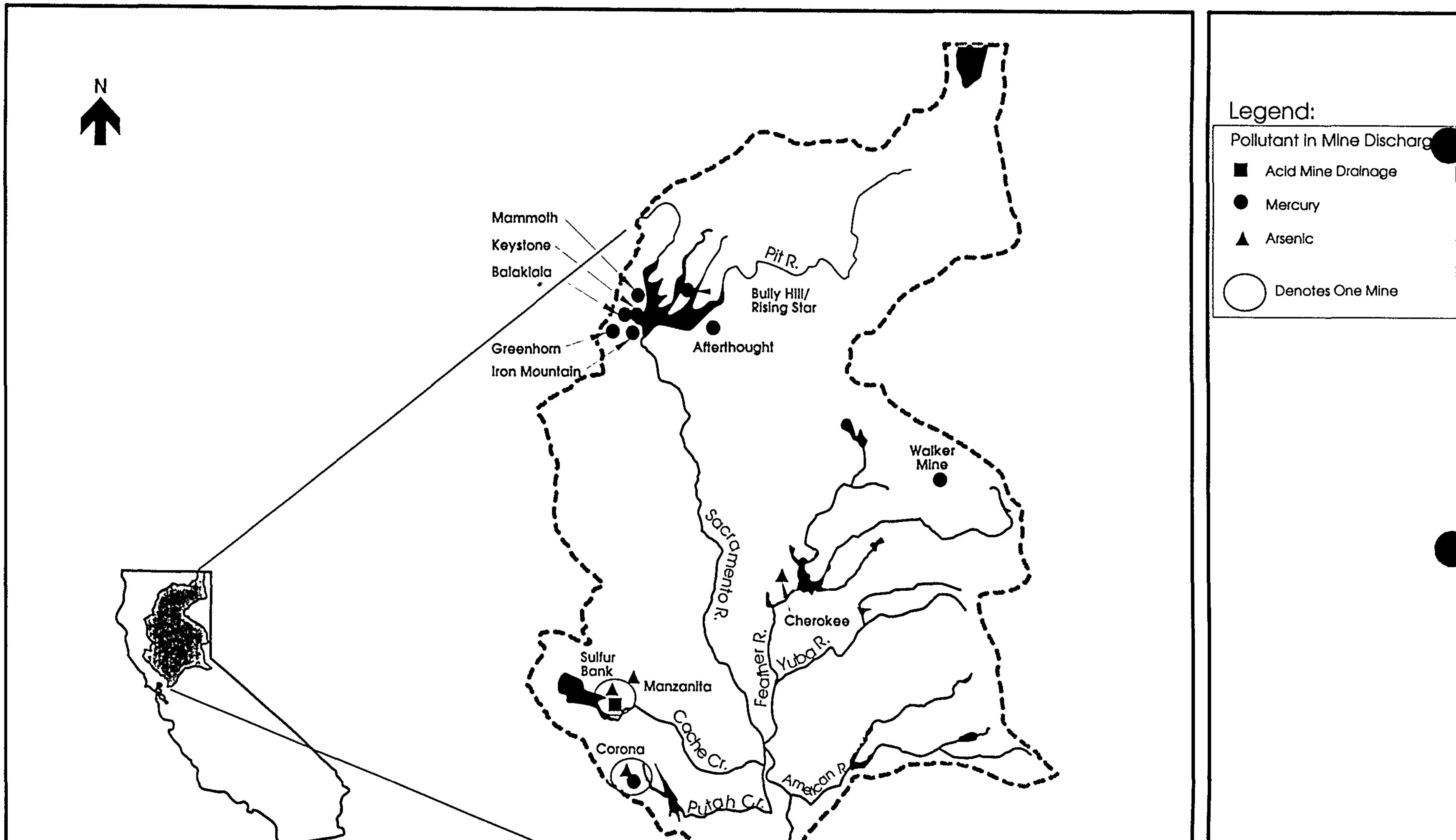

Figure 1.
Major Inactive Mines
in the Sacramento Basin

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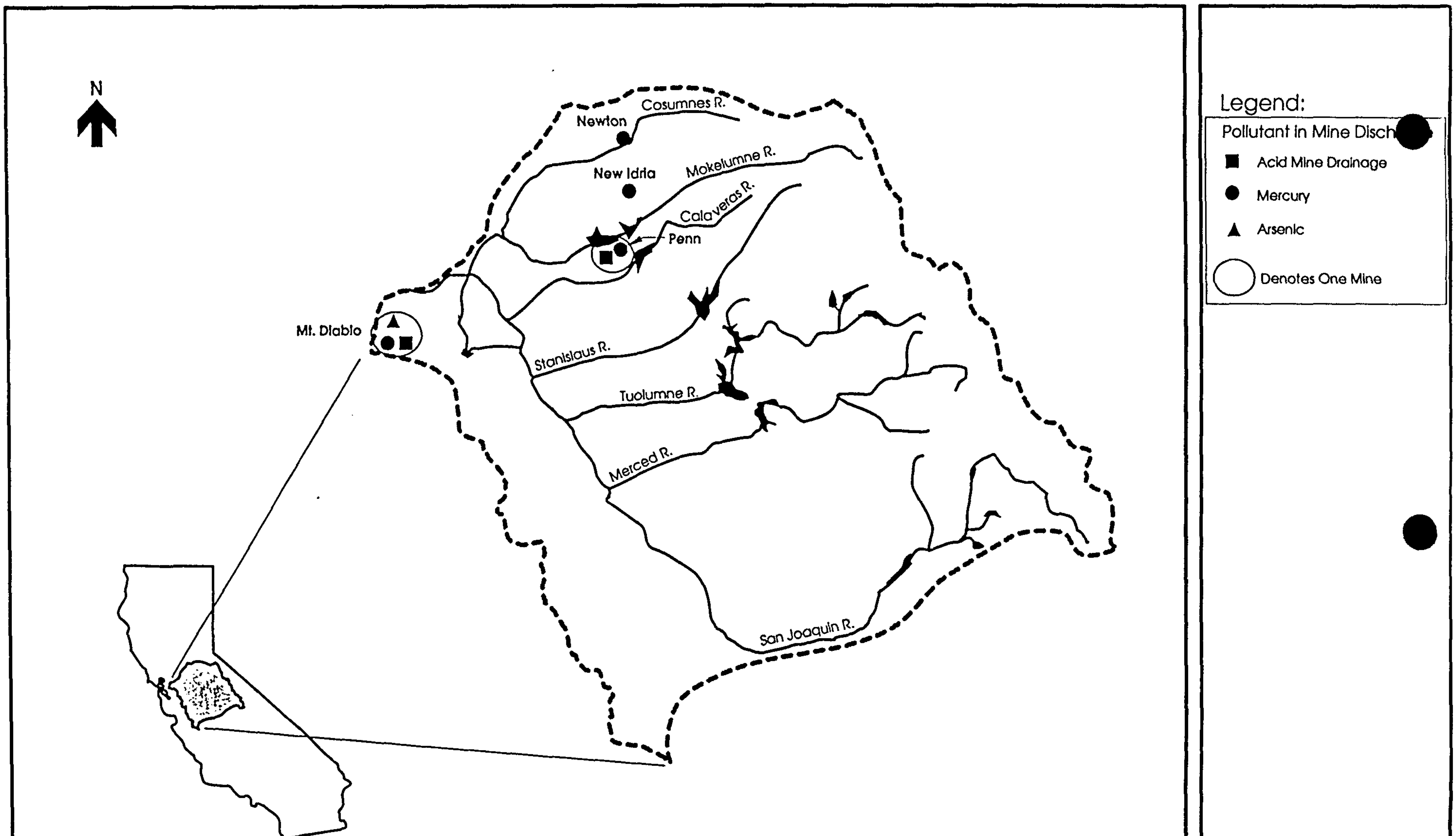

Figure 2.
Major Inactive Mines in the San Joaquin Basin

Abatement Projects at Key Mines

Abatement controls have been or are being implemented at several of the key mines listed in Table 2. These controls are described below. It should be noted that the effectiveness of the controls has not yet been evaluated.

1. Iron Mountain Mine. The most significant abatement project underway is at Iron Mountain Mine. Iron Mountain Mine is the largest inactive mine pollutant source in the Central Valley and is estimated to contribute over 50 percent of the copper, arsenic, cadmium, chromium, zinc and lead loadings from inactive mines to the Sacramento Basin (Montoya et. al., 1989). Existing controls include the Spring Creek Debris Dam, rerouting of drainage, and capping major seep areas. The Spring Creek Debris Dam collects and discharges water from the entire Spring Creek watershed including adit releases, waste rock erosion and seepage, and background stream flow. Work is underway to construct a treatment plant to remove copper, cadmium, and zinc. The Spring Creek Debris Dam is scheduled to be enlarged by 1995-96. The project is projected to reduce copper loads from the mine to the Sacramento River by at least 70 percent (Regional Board Staff Report, 1993).

2. Mammoth Mine. Portal sealing began in 1981 but was interrupted by owner bankruptcy and change in the PRP. Additional portal sealing was completed in 1993. Estimates of copper load reductions from the portals are in the order of 90 percent (Regional Board Staff Report, 1993).

3. Penn Mine. Infiltration ponds were constructed in 1979. The estimated average annual reduction in copper load is about 80 percent. Unfortunately, the ponds concentrate the acid mine drainage so that during very heavy storms, a highly concentrated discharge occurs to Camanche Reservoir. The East Bay Municipal Utility District (EBMUD) constructed a treatment plant in the spring of 1993 that

removes approximately 98 percent of the copper and zinc load (Personal Communication, Richard Sykes, EBMUD). The U.S. Environmental Protection Agency (EPA) issued a draft Consent Order that required EBMUD to finance studies and clean-up activities at the mine. The State Board responded to the Consent Order stating that EPA had no authority under the Clean Water Act to require EBMUD to finance the clean-up activities. EPA has not yet reacted to the State Board response.

4. Balaklala Mine. Abatement projects have included portal sealing and stream diversion (Larry Walker Associates, 1992).

5. Keystone Mine. Portal sealing was completed in 1992. Estimates of copper load reductions from the portal are in the order of 90 percent (Regional Board Staff Report, 1993).

6. Walker Mine. Portal sealing in 1989 resulted in an estimated 98 percent reduction in the copper load from the portal. Abatement of the tailings piles is currently being studied (Regional Board Staff Report, 1993).

7. Sulfur Bank Mine. The existing abatement project involves a diversion dam (Larry Walker Associates, 1992).

Additional mines (not shown in Table 2) where abatement projects are existing or underway include Early Bird Mine, Shasta King Mine, and Stowell Mine (Larry Walker Associates, 1992). These mines are all upstream of Lake Shasta.

MINE DRAINAGE CONTAMINANTS OF CONCERN

Most inactive mines do not have extensive drainage quality monitoring systems. Therefore, limited drainage quality data are available. Table 3 shows average mine drainage quality from four inactive mines. The most complete drainage quality data are from Iron Mountain Mine which has been studied more extensively than most other mines. Cadmium, copper, and zinc concentrations in drainage from Iron Mountain Mine and Afterthought Mine exceed drinking water standard. It appears, based on a few samples, that chromium, lead, and mercury concentrations in mine drainage also exceed drinking water standards. Arsenic concentrations are below the current maximum contaminant level but above the range that is currently being considered.

Table 3. Comparison of Metals Concentrations in Mine Drainage to Drinking Water Standards

Constituent, μg/l	Maximum contaminant level	Iron Mountain Mine	Afterthought Mine	Newton Mine	New Idria Mine
Arsenic	50[a]	--[b]	--	--	25 (3)[c]
Cadmium	5	88 (13)	303 (18)	--	17 (3)
Chromium	100	10 (1)	--	--	125 (2)
Copper	1,300	2,700 (36)	12,083 (16)	11,700 (2)	370 (3)
Lead	--	13 (2)	--	--	57 (3)
Mercury	2	--	--	0.2 (1)	4 (5)
Nickel	100	12 (2)	--	--	--
Zinc	5,000[d]	24,300 (36)	70,982 (18)	--	--

[a]The arsenic MCL will likely be reduced in the next few years. The range that is being considered is 0.5 to 20 μg/l.
[b]-- Not analyzed.
[c]Number of samples are in parentheses.
[d]Secondary standard.

Source of information: California Regional Water Quality Control Board, Central Valley Region. 1985. Mass Loading Assessment of Major Point and Nonpoint Sources Discharging to Surface Waters in the Central Valley.

Although the concentrations of several metals in mine drainage exceed drinking water standards, the concentrations in downstream drinking water supplies are consistently below drinking water standards. The City of Redding takes water from the Sacramento River downstream of Lake Shasta. There have been no problems meeting drinking water standards for metals in their water supply. Redding is notified by the Bureau of Reclamation when releases are made from the Spring Creek Diversion Dam at Iron Mountain Mine. As a general rule, Redding does not pump water from the river during the release periods due to customer concerns rather than water quality concerns (Personal Communication, Mike Robertson, City of Redding). Further downstream the City of Sacramento pumps water from the Sacramento River. As with Redding, metals concentrations are well below current drinking water standards. Arsenic concentrations in both the Redding and City of Sacramento water supplies will exceed the drinking water standard if it is set in the 0.5 to 20 μg/l range.

Of the contaminants of concern which are the focus of this Study of Drinking Water Quality in Delta Tributaries, the one contaminant for which mine drainage is a source, is arsenic. As shown in Table 1, the Regional Board estimates that mine drainage is the source of about 11 percent of the arsenic load in Central Valley streams. The primary source of the arsenic is from arsenopyrite rock associated with gold mines in the Yuba River watershed (Regional Board, 1992).

Recent work in the Yuba River watershed has shown that small feeder creeks downstream of inactive gold mines in that watershed have arsenic concentrations in the range of 1.2 to 21 μg/l. Fifty to ninety percent of this arsenic is in the dissolved form due to low iron content and near neutral pH in mine drainage from this particular area. Arsenic concentrations in the Yuba River downstream of the monitored feeder creeks are below 5.0 μg/l (Montoya et. al., 1992).

LOADS OF CONTAMINANTS

Of the total annual pounds of arsenic, cadmium, copper, lead, and zinc discharged from inactive mines to Central Valley receiving streams, the Regional Board estimates that over 99 percent are discharged to the Sacramento River Basin. The remaining less than one percent of these metals are discharged to the San Joaquin Basin or to the Delta (Regional Board Staff Report, 1993).

In 1985, the Regional Board estimated that loads from Iron Mountain Mine alone contributed approximately 76 percent of the cadmium, 80 percent of the zinc, and 67 percent of the copper to the Sacramento River below Keswick Dam (Montoya et. al., 1989).

The greatest loads of metals from most inactive mines are typically discharged between October and April when rainfall causes runoff from waste piles and tunnel complexes where water has risen and overflowed. Mine loads are strongly correlated with total annual precipitation. The seasonal loading pattern is different at Iron Mountain Mine due to the Spring Creek Diversion Dam release schedule stipulated in a 1980 Memorandum of Understanding with the Regional Board and several other agencies. Spring Creek Diversion Dam, which was constructed to control releases from the mine to prevent salmon kills, is operated to allow releases to coincide with high summer releases from Keswick Reservoir. Releases may also be made during periods of very heavy rainfall to avoid an uncontrolled spill. Total monthly loads from Iron Mountain Mine are therefore greatest during summer months and at times of heavy rainfall (Montoya, 1989).

MITIGATION OF MINE DRAINAGE EFFECTS

Mine drainage effects are mitigated in several ways. First, as the dissolved metals are transported away from the mine, the pH increases as the mine drainage is diluted from contact with other water. Some percent of the metals then precipitate out and metal concentrations in the receiving stream decrease. Much of the concern with acid mine drainage, therefore is with the threat to aquatic life immediately downstream of the discharge. Twenty one of thirty one mines surveyed by the Regional Board impacted receiving waters immediately downstream of the mine (Montoya et. al., 1992). Second, some unknown though probably significant percentage of contaminants are entrained in downstream reservoirs. Third, discharges from most mines occur during the rain season when river flows are higher and more dilution is generally available. Fourth, constructed abatement projects (described above) have reduced metals loadings at several of the key mines.

SIGNIFICANCE OF MINES TO THIS STUDY

Mine drainage is not important to drinking water quality in the downstream reaches of the Central Valley rivers. Metals concentrations were found to be below drinking water standards in both the Sacramento River at Freeport and the San Joaquin River at Vernalis in the 1990 Sanitary Survey of the State Water Project. As discussed previously, the City of Redding and the City of Sacramento have historically found all metals concentrations to be below drinking water standards in their raw and finished water. Unlike many contaminant sources, the effect of mines (located almost entirely in the upper reaches of the Central Valley watershed) is mitigated by downstream reservoirs and increased pH rather than aggravated by additional sources in the lower reaches of Central Valley Rivers. The primary concern of mine discharges remains to aquatic life or to river reaches immediately below the discharge with the possible exception of arsenic.

If the arsenic MCL is established at the lower end of the range that is being considered (0.5-20 μg/l), Sacramento River water suppliers may have difficulty meeting this standard. Arsenic concentrations in the Sacramento River are in the range of <1 to 6 μg/l. Eleven percent of the total arsenic discharged to Central Valley rivers is attributed to mine drainage. Some percent of this is likely entrained in reservoirs downstream of the mines so the total percent of the contribution of mines to arsenic loads in downstream reaches may be less than eleven percent. The significant sources of arsenic to the Central Valley Basin as a whole are considered to be urban runoff and agricultural drainage.

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