



CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Upper Sacramento River TMDL for Cadmium, Copper & Zinc

Final Report



April 2002

State of California

California Environmental Protection Agency

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REPORT PREPARED BY:
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EXECUTIVE SUMMARY

The Central Valley Regional Water Quality Control Board (Regional Board) has determined that the 25-mile segment of the upper Sacramento River between Keswick Dam and Cottonwood Creek near Balls Ferry in Shasta County is impaired because the water periodically contains levels of dissolved cadmium, copper, and zinc that exceed water quality standards developed to protect aquatic life. Historically, the elevated metals levels resulted in anadromous (chinook salmon and steelhead trout) fish mortality (“fish kills”). The elevated metal concentrations also contributed to progressive declines in anadromous fish populations in the Sacramento River. The impairment results primarily from discharges of acid mine drainage (AMD) – with elevated levels of cadmium, copper, and zinc – from inactive mines in the upper Sacramento River watershed, predominantly from the Iron Mountain Mines (IMM) site upstream of Keswick Dam and other mines upstream of Shasta Dam.

The Regional Board has developed a Total Maximum Daily Load (TMDL) program for dissolved cadmium, copper, and zinc loading into the upper Sacramento River because of these exceedances of water quality standards. A TMDL represents the maximum load of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL report describes the reductions needed to meet water quality standards and allocates those reductions among the sources in the watershed. Regional Board staff proposes implementing the water quality objectives listed in Table 1 as numeric targets for this TMDL.

Table 1. Proposed Numeric Targets for Dissolved Cadmium, Copper, and Zinc ^(a)

Metal	Acute Numeric Target (micrograms per liter [µg/l])	Chronic Numeric Target (µg/l)
Cadmium	0.22 ^(b)	0.22 ^(b)
Copper	5.6 ^(b)	4.1 ^(c)
Zinc	16 ^(b)	16 ^(b)

- (a) The proposed numeric targets are hardness dependent; the numbers in this table are based on a hardness of 40 milligrams per liter as calcium carbonate.
- (b) Central Valley Region Water Quality Control Plan trace element water quality objectives (maximum concentrations) for Sacramento River and its tributaries above State Highway 32 Bridge at Hamilton City (CVRWQCB, 1998a).
- (c) California Toxics Rule Criteria for Freshwater Aquatic Life Protection (4-day continuous concentration criteria, not to be exceeded more than once every three year period) for priority toxic pollutants in the State of California for inland surface waters (USEPA, 2000a).

According to recent water quality studies, the number of exceedances of the numeric targets has notably decreased during the past ten years. These decreases reflect the improvements made to water quality by remedial actions at the IMM site and other mines and improved coordination of Spring Creek Reservoir

(built to provide some limited control of releases from the IMM site) and Keswick Reservoir releases. However, metal loading at times remains high enough to cause periodic exceedances of the water quality objectives. Exceedances of the dissolved copper numeric targets have occurred during each of the past six years on the Sacramento River below Keswick Dam, and during three of the past six years on the Sacramento River below Shasta Dam. Exceedances of the dissolved cadmium and zinc numeric targets have occasionally occurred on the Sacramento River below Shasta and Keswick Dams. The exceedances typically corresponded to times of heavy rainfall runoff during the December-to-April period that cause the Spring Creek Reservoir to reach capacity and/or times that the Shasta Reservoir or Spring Creek Power Plant dilution releases are reduced for the purposes of storage and flood control. In addition, occasional exceedances below Keswick Dam are driven by Shasta Dam releases that have elevated concentrations of dissolved copper and/or zinc.

Regional Board staff expects that the proposed remediation activities scheduled for IMM and other mine sites during the next five years will address exceedances of the proposed numeric targets below Keswick Dam. Staff based this determination on the following:

1. The U.S. Environmental Protection Agency (USEPA) Superfund Program's water quality modeling indicated that the proposed remediation activities at the IMM site – in coordination with current site remediation activities – would control more than 95% of total IMM site releases and therefore result in significantly decreasing the frequency of numeric target exceedances below Keswick Dam.
2. Anticipated load reductions resulting from ongoing and proposed remediation activities at mines in the Shasta Lake area would improve the water quality of both the Shasta Dam and Keswick Dam releases.

For these reasons, staff proposes the following 5-year TMDL water management strategy in accordance with this TMDL report and other USEPA and Regional Board remediation plans:

- During the summer of 2001, the USEPA Superfund Program began implementation of proposed remediation activities that include the collection and treatment of AMD-contaminated surface water discharges from the area sources in the Slickrock Creek watershed at the IMM site; the activities will take approximately two years to complete.
- Responsible parties will conduct ongoing and proposed remediation activities at mines in the Shasta Lake area.
- Regional Board staff will increase monitoring in Shasta Lake to determine the sources and variability of dissolved metal concentrations in Shasta Dam releases during the past three years. Staff will develop mine remediation and other activities as needed to address Shasta Dam release concentrations that exceed 1.3 µg/l dissolved copper and 3.9 µg/l dissolved zinc.
- Regional Board staff will require NPDES-permitted dischargers to monitor dissolved cadmium, copper, and zinc, and flow to quantify their dissolved metal loads, and if

significant loads are detected, staff will establish effluent limits and continuous monitoring in renewed permits.

- U.S. Bureau of Reclamation (USBR), USEPA, Regional Board, and other regional agencies will continue monitoring water quality conditions in upper Sacramento River water.
- Regional Board staff will evaluate the ambient metal concentration data collected by its staff, other agencies, and dischargers to determine whether the remediations enable dissolved metal concentrations in Sacramento River water to comply with the proposed numeric targets. In addition, staff will evaluate dissolved metal loads contributed by NPDES dischargers downstream of Keswick Dam. Staff will coordinate TMDL reviews with USEPA's 5-Year Reviews for the IMM site scheduled for 2003 and 2008.
- After three years of monitoring data have been collected following the completion of remediation activities at Slickrock Creek, Regional Board staff will work with the USBR, USEPA, California Department of Fish and Game, and State Water Resources Control Board to modify the USBR dam operations Memorandum of Understanding established in 1980 (1980 MOU) to ensure maximum efficiency in managing releases from the Spring Creek Debris Dam (SCDD).

Regional Board staff bases this strategy on the following assumptions:

- Pending revision of the 1980 MOU, the USBR will continue to operate the SCDD and related facilities in a reasonable and prudent manner in compliance with operations criteria set forth in the 1980 MOU, 1992 Central Valley Project Operations Criteria and Plan, and 1993 Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project.
- The existing AMD collection and treatment facilities at IMM will be operated to provide maximum removal of metals in accordance with a court-approved consent decree.
- Regional Board staff will enforce existing permits on mines in the Shasta Lake areas to assure maximum removal or containment of heavy metals.
- Responsible parties will increase remediation efforts at mines in the Shasta Lake area as needed during the next five to ten years.

Based on the evaluation of the magnitude and frequency of exceedance (if any) during the three years following the completion of the USEPA's Slickrock Creek remediation activities, Regional Board staff will consider whether to recommend the removal of the upper Sacramento River from the CWA 303(d) List.

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LIST OF ACRONYMS

µg/l	micrograms per liter
1980 MOU	Memorandum of Understanding Among the State Water Resources Control Board, United States Water and Power Resources Service, and Department of Fish and Game to Implement Actions to Protect the Sacramento River System from Heavy Metal Pollution from Spring Creek and Adjacent Watersheds
ACIDD	Anderson-Cottonwood Irrigation District Dam
Basin Plan	Central Valley Region Water Quality Control Plan – Sacramento River and San Joaquin River Basins
C	carbon
Ca	calcium
CaCO ₃	calcium carbonate
Cd	cadmium
CDFG	California Department of Fish and Game
cfs	cubic feet per second
CO ₃	carbonate
CRA CERES	California Resources Agency, California Environmental Resources Evaluation System
CTR	California Toxics Rule
Cu	copper
CVO	USBR's Central Valley Operations Office
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Federal Clean Water Act
DWR	California Department of Water Resources, Northern District
Fe	iron
fish kills	fish mortality episodes
H	hydrogen
HDS	high density sludge (treatment plant)
in/yr	inches per year
kg/day	kilograms per day
MCLs	California/USEPA drinking water standards maximum contaminant levels
MDL	laboratory method detection limit
mg/l	milligrams per liter
msl	mean sea level
NOAA	National Oceanic and Atmospheric Administration
O	oxygen
OMR	California Department of Conservation, Office of Mine Reclamation, Abandoned Mine Lands Unit
pers. comm.	personal communication (either meeting or telephone)

PRPs	potentially responsible parties
RI/FS	Remedial Investigation/Feasibility Study
ROD	USEPA Record of Decision
S	sulfur
SCAKR	Spring Creek Arm of Keswick Reservoir
SCDD	Spring Creek Debris Dam
SCPP	Spring Creek Power Plant
SRCRD	Slickrock Creek Retention Dam
State Board	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TMDL Report	Upper Sacramento River TMDL for Cadmium, Copper, and Zinc Report
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
Zn	Zinc

1 INTRODUCTION

Section 303(d) of the Federal Clean Water Act (CWA) requires States to:

1. Identify those waters not attaining water quality standards (referred to as the “303(d) List”).
2. Set priorities for addressing the identified pollution problems.
3. Establish a “Total Maximum Daily Load” (TMDL) for each identified waterbody’s pollutant(s) to attain water quality standards.

The Central Valley Regional Water Quality Control Board (Regional Board) prepares the 303(d) List for the Central Valley with oversight and approval from the State Water Resources Control Board (State Board) and the U.S. Environmental Protection Agency (USEPA). The Regional Board includes waterbodies on the 303(d) List if the waterbodies are not expected to meet water quality standards even if dischargers of point sources comply with their current discharge permit requirements. A TMDL represents the maximum load (usually expressed as a rate, such as kilograms per day [kg/day]) of a pollutant that a waterbody can receive and still meet applicable water quality standards. A TMDL report describes the reductions needed to meet water quality standards and allocates those reductions among the sources in the watershed.

The Regional Board defines the upper Sacramento River as the segment between Shasta Dam and Red Bluff in Shasta and Tehama Counties (Figure 1-1). The current 303(d) List identifies this river segment as impaired by dissolved cadmium, copper and zinc and unknown toxicity; historical 303(d) Lists have also identified various portions of the upper Sacramento River as impaired by temperature, low flows, dioxin, and other organic constituents, which have since been addressed by other programs. The Regional Board first listed the upper Sacramento River as impaired by dissolved cadmium, copper, and zinc in the 1987-89 listing cycle, although metals impairments in this section of river were documented in numerous reports dating back to the 1950s and earlier. The Regional Board and other State and Federal agencies determined that dissolved cadmium, copper, and zinc impair the 25-mile segment of the upper Sacramento River between Keswick Dam and Cottonwood Creek (the first downstream tributary that acts as a significant source of dilution water) near Balls Ferry (Shasta County). This reach is particularly critical because it historically produced over half the total main-stem spawning run of fall-run chinook salmon (NOAA, 1989).

This report, the *Upper Sacramento River TMDL for Cadmium, Copper, and Zinc Report* (TMDL Report), provides the information needed to support the overall TMDL effort. It serves to

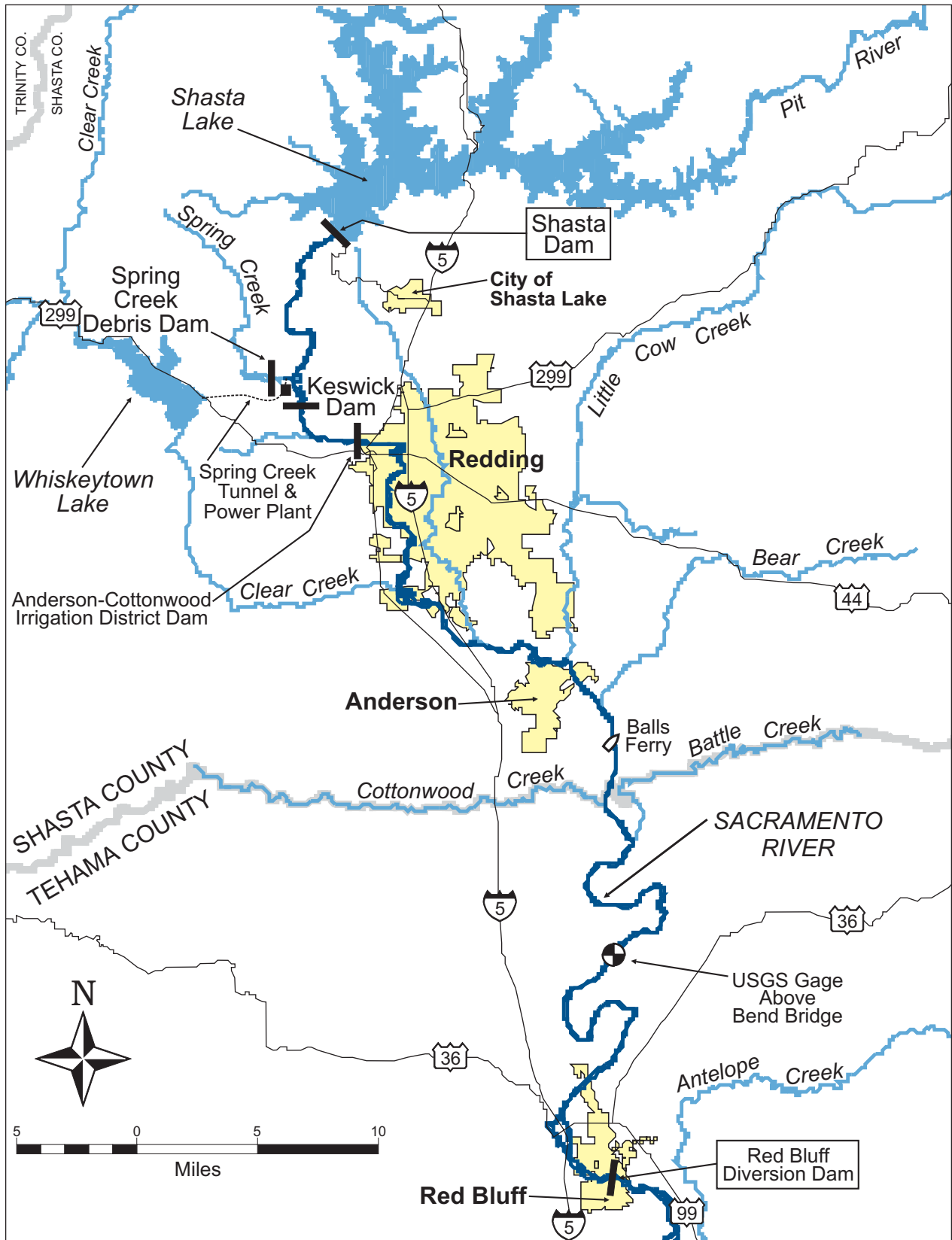


Figure 1-1. Upper Sacramento River Watershed
 This TMDL addresses the Sacramento River between Shasta Dam and Red Bluff Diversion Dam. Levels of dissolved cadmium, copper, and zinc in water impair the Sacramento River from Keswick Dam to the Cottonwood Creek confluence.

document the current conditions on the upper Sacramento River and the plans for implementation of remediation activities and monitoring. To meet State and Federal requirements, Regional Board staff prepared this report with the following elements:

- problem statement (Chapter 2);
- background information (Chapters 3 and 4);
- identification and quantification of sources and source loads (Chapter 5);
- numerical water quality targets (Chapter 6);
- determination of the maximum load of cadmium, copper, and zinc that will not adversely impact beneficial uses and the mathematical linkage between the water quality target and amount of contaminant (Chapter 7);
- allocation of portions of the necessary load reduction to the various sources (Chapter 8);
- margin of safety that takes into account uncertainties and consideration of seasonal variations (Chapter 9);
- implementation plans (Chapter 10), and
- public participation (Chapter 11).

Based on the available information presented in this report, Regional Board staff expects that remediation activities scheduled for the IMM site and other mine sites in the Shasta Lake watershed during the next five years will address the water quality impairments. As discussed in detail later in this report, the TMDL water management strategy includes remediation activities at the IMM site and other mine sites in the watershed, continued monitoring by regional and Federal agencies, increased Regional Board monitoring of Shasta Lake to identify causes of periodic increases in dissolved metals concentrations in Shasta Dam releases, and additional monitoring by NPDES dischargers during the next five years. If water quality standards are not exceeded during the three years following the completion of the proposed IMM site remediations, which will require approximately two years to complete, Regional Board staff would consider the removal of the upper Sacramento River from the CWA 303(d) List (i.e., “delist” the river).

Although Keswick Reservoir is part of the Shasta Dam to Red Bluff segment of the upper Sacramento River, this report does not address it because a separate TMDL will focus on that reach of the river. Keswick Reservoir encompasses almost the entire segment of the Sacramento River between Shasta Dam and Keswick Dam; therefore, this TMDL focuses on the river segment between Keswick Dam and Red Bluff Diversion Dam. In addition, another TMDL will address individual metal sources upstream of Shasta Dam.

2 PROBLEM STATEMENT

2.1 Definition of a Problem Statement

A problem statement identifies the context for TMDL development and describes the water quality standards issue(s) that prompted development of the TMDL. A problem statement includes the following elements:

- name(s) and location(s) of waterbody segments for which the TMDL is being developed,
- the pollutant(s) for which the TMDL is being developed and information about why the pollutant(s) are being addressed,
- the specific applicable water quality standard(s) for those pollutants,
- a description of the water quality impairment or threat which necessitated TMDL development, and
- adequate background information about the watershed setting for the TMDL to help the reader understand the key water quality, pollutant discharge, land use, and resource protection issues in the watershed.

The following sections in this chapter describe each of these elements, except the more detailed background information and associated citations. Chapter 3 provides background information about the watershed, including a description of historical mining activities and dams operations in the upper Sacramento River watershed. Chapter 4 provides information about the effects of cadmium, copper, and zinc on aquatic organisms, with a focus on their effects on anadromous fish.

2.2 The Problem

The Regional Board has determined that the 25-mile segment of the upper Sacramento River between Keswick Dam and Cottonwood Creek (the first downstream tributary that acts as a significant source of dilution water) near Balls Ferry in Shasta County is impaired by dissolved cadmium, copper, and zinc because the water has frequently contained levels of dissolved metals that exceed water quality standards developed to protect aquatic organisms. Historically, the elevated metal levels resulted in anadromous (chinook salmon and steelhead trout) fish mortality (“fish kills”) and contributed to progressive declines in anadromous fish populations in the Sacramento River. The metals impairment results primarily from discharges of acid mine drainage (AMD) – with elevated levels of cadmium, copper, and zinc – from inactive mines in the upper Sacramento River watershed, predominantly from the Iron Mountain Mines (IMM) site and other mines upstream of Shasta Dam.

Federal and State agencies have been monitoring the upper Sacramento River watershed since the early part of the 20th century. Documented deaths of fish were common in water below Keswick Dam during the mid-20th century (i.e., 1940 to 1986). Numerous salmon and steelhead trout fish kills took place in the upper Sacramento River between Keswick Dam and Balls Ferry, California. Since the late 1970s, major adult fish kills have ceased. However, metals concentrations still frequently exceed water quality standards developed to protect aquatic life.

2.3 Recent Water Quality Data and Water Quality Standards

Since the 1940s, Federal and State agencies have collected thousands of water samples from the upper Sacramento River and several of its tributaries for the analysis of total metals. Long-term data are available for the Sacramento River below Shasta Dam and Keswick Dam. Agencies began to analyze water samples for dissolved metals more frequently during the 1980s. Figure 2-1A illustrates dissolved copper concentrations in the Sacramento River below Keswick Dam for the period 1983 to 2001, and Figure 2-1B illustrates dissolved copper concentrations in the Sacramento River below Keswick Dam and Shasta Dam for the period 1995 to 2000. Appendix A provides plots of all available concentration data for dissolved cadmium, copper, and zinc in the Sacramento River below Shasta Dam and Keswick Dam, and above Bend Bridge near Red Bluff.

Regional Board staff derived the data displayed on Figure 2-1 and the plots in Appendix A from a variety of agency databases. Researchers used several methods to collect and analyze the water samples; therefore, there were varying quality control methods used in the field and several different analytical method detection limits. However, the abundance of data enables the illustration of several key characteristics of upper Sacramento River water quality. Chapters 3 and 4 provide the background information needed to put the following water quality characteristics in context.

2.3.1 Decrease in Frequency of Exceedances over Time

Historical levels of dissolved cadmium, copper, and zinc in the Sacramento River below Shasta and Keswick Dams frequently exceeded two sets of water quality standards developed for the protection of aquatic life:

1. Central Valley Region Water Quality Control Plan (Basin Plan) water quality objectives (maximum concentration criteria), and

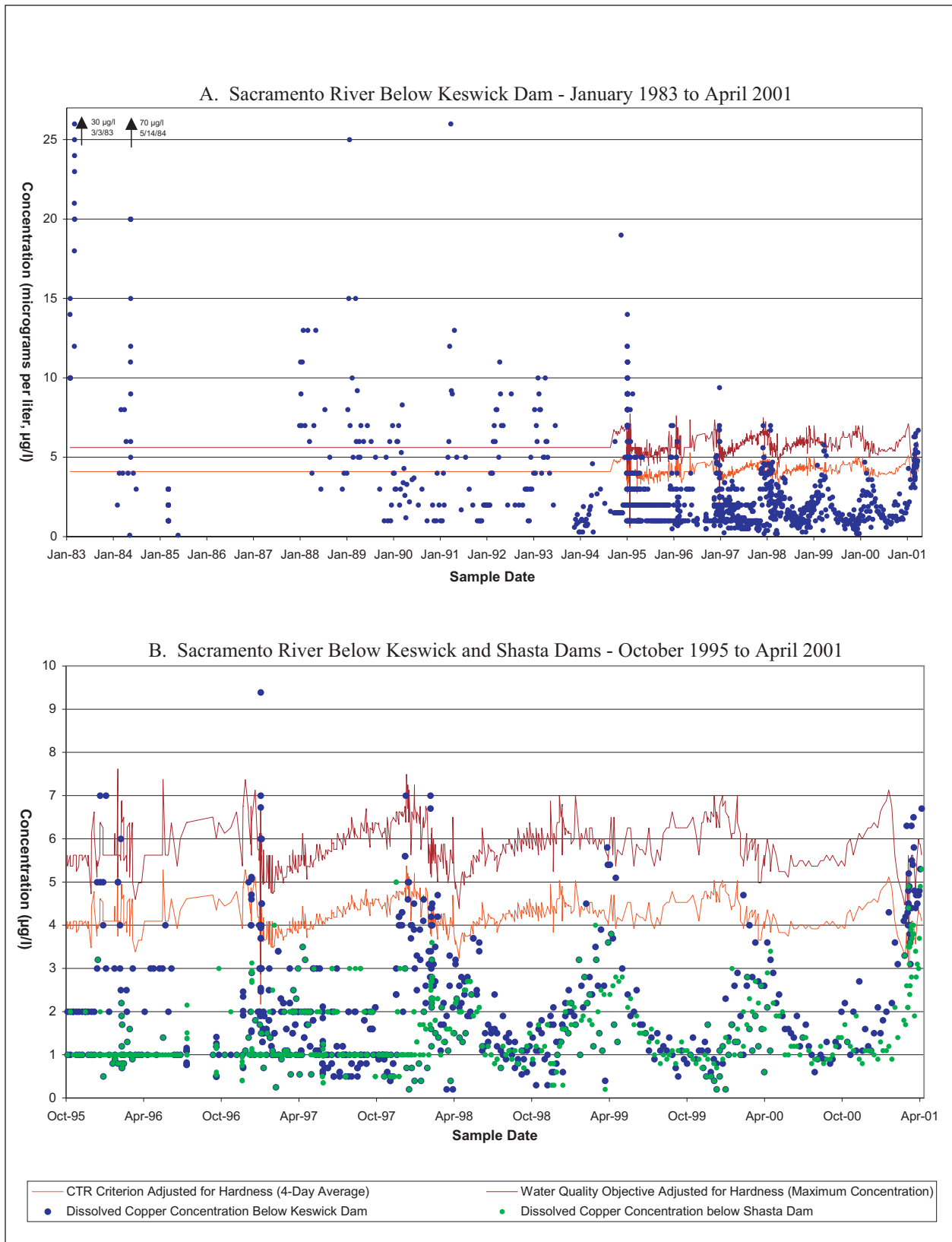


Figure 2-1. Dissolved Copper Concentrations in the Sacramento River Compared to the Basin Plan Water Quality Objective and the CTR Chronic Criterion
 [When hardness data were unavailable, a hardness of 40 mg/l was assumed for the calculation of the Basin Plan objective and CTR criterion.]

2. California Toxics Rule (CTR) Criteria for Freshwater Aquatic Life Protection (4-day continuous concentration criteria).

However, notable reductions in the frequency and magnitude of exceedances have occurred during the past ten years. The timing of these reductions corresponds to load reductions resulting from remediations completed at mine sites in the Shasta Lake region, especially at the IMM site (e.g., operation of a temporary lime neutralization plant during the high-flow seasons of 1989-1993, and continuous year-round treatment since 1994), and from changes in regional dam operations that improved coordination of AMD releases from the Spring Creek Debris Dam (SCDD) on Spring Creek downstream of the IMM site. (Refer to Chapter 3 for a description of remediation activities and dam operations.)

The Regional Board staff's review of tabular historical and recent total cadmium, copper, and zinc concentrations for the Sacramento River below Shasta Dam and Keswick Dam indicated that the concentrations of these metals rarely, if ever, exceeded the California/USEPA drinking water standards established for the protection of human health (maximum contaminant levels [MCLs]). Total cadmium concentrations exceeded the cadmium MCL of 5.0 micrograms per liter ($\mu\text{g/l}$) on three occasions in the early 1980s below Keswick Dam, and on one occasion in 1988 below Shasta Dam. Total copper concentrations exceeded the copper MCL of 1,300 $\mu\text{g/l}$ on several occasions during the 1940s. Total zinc concentrations apparently have yet to exceed the MCL of 5,000 $\mu\text{g/l}$ at either location. No MCL exceedances have occurred since 1988.

2.3.2 *Seasonal Variability*

Data collected during the 1990s indicate that dissolved copper and zinc concentrations¹ have considerable seasonal variability; higher concentrations often occurred during the wet season. Even though notable reductions in the frequency and magnitude of exceedances of Basin Plan objectives and CTR criteria have occurred during the past ten years, occasional exceedances still occur each year on the Sacramento River below Keswick Dam, most often during the December-to-April period. The exceedances typically correspond to times of heavy rainfall runoff that cause the Spring Creek Reservoir to reach capacity and/or times that the Shasta Reservoir or Spring Creek Power Plant dilution releases are reduced for the purposes of storage and flood control. Occasionally, the exceedances below Keswick Dam are driven by Shasta Dam releases that have unusually high concentrations of dissolved copper and/or zinc.

¹ Not enough dissolved cadmium concentration data were available to determine whether dissolved cadmium concentrations experience seasonal variability in the same manner as dissolved copper and zinc concentrations.

2.3.3 Water Quality Characteristics of Downstream Reach

Dissolved metal concentration data for the Sacramento River at Bend Bridge (see Figure 1-1) collected from the mid-1990s to 2001 indicate no exceedances of the Basin Plan objectives for dissolved copper, zinc, and cadmium, or the CTR criteria for dissolved zinc and cadmium. There was only one possible exceedance of the 4-day CTR criterion for dissolved copper of 4.1 µg/l (4.4 µg/l recorded on December 12, 1996). However, this apparent lack of exceedances may result primarily from the scarcity of data for downstream areas; few sampling dates for the Sacramento River at Bend Bridge corresponded to times of water quality standard exceedances at Keswick Dam during the mid-1990s to 2001 period. For example, of the 39 sampling dates at Bend Bridge, only four occurred within a day of exceedances of dissolved copper criteria at Keswick Dam; two of those dates had dissolved copper concentrations at Bend Bridge that approached (3.92 µg/l) or exceeded (4.4 µg/l) the CTR criterion. The one possible exceedance observed at Bend Bridge corresponded to an observed exceedance at Keswick Dam.

The USEPA's review of historical data indicated that when AMD spills occur from the SCDD, exceedances of water quality standards also can occur on the Sacramento River as far downstream as Bend Bridge (Michny, 2001; Sugarek, 2002). Available data indicate that when the SCDD is controlling releases of IMM AMD into the Sacramento River, metal concentrations downstream of Keswick Dam comply with water quality standards. In addition, the USEPA's review of historical data and the Regional Board's review of recent data indicate that the dilution effect of tributary inputs between Keswick Dam and Red Bluff can mitigate Keswick Dam releases with high metal concentrations; Cottonwood Creek is the first downstream tributary that acts as a significant source of dilution water.

3 BACKGROUND

3.1 Watershed Characteristics

3.1.1 *Physiography & Geology*

The upper Sacramento River is a perennial drainage in Shasta and Tehama Counties that has a length of approximately 61 miles from Shasta Dam to Red Bluff Diversion Dam (Figure 1-1). The upper Sacramento River basin includes portions of the Sacramento Valley, and all of the Klamath Mountains, the Coast Ranges, the Modoc Plateau, and the Cascade Mountains physiographic regions (Domagalski et al., 2000). These physiographic provinces are largely based on geologic factors, including rock types and tectonic setting. The Sacramento Valley is the low-lying part of the basin. The Sacramento Valley equates to the northern third of the Central Valley, which constitutes a structural downwarp and nearly flat alluvial plain extending more than 400 miles from Redding on the north to the Tehachapi Mountains on the south; it has an average width of 40 miles and spans 15,000 square miles (1/10th of the State) (Poland and Everson, 1966). Elevations of the alluvial plain are generally just a few hundred feet above sea level with extremes ranging from a few feet below sea level to about 1,000 feet above sea level (Hackel, 1966). Drainage from the Sacramento Valley is southward through the Sacramento River to its confluence with the San Joaquin River, near Suisun Bay, and then westward through San Francisco Bay to the Pacific Ocean.

The valley floor is divided into four geomorphic units: (1) dissected uplands, (2) low alluvial plains and fans, (3) river flood plains and channels, and (4) overflow lands and lake bottoms (Poland and Everson, 1966). The deposits containing fresh groundwater are principally unconsolidated continental deposits of Pliocene to Recent Age that extend to depths ranging from less than a 100 to more than 3,500 feet. The unconsolidated continental deposits consist chiefly of alluvium but in some areas include widespread lacustrine, marsh, and estuarine sediments. Consolidated rocks form the boundaries beneath and on the flanks of the productive groundwater reservoir in the unconsolidated deposits. Groundwater occurs under both confined (artesian) and unconfined (water table) conditions in the Central Valley. Recharge to the groundwater reservoir is by infiltration of rainfall, infiltration from streams, canals, and ditches, by infiltration of excess irrigation water, and by underflow entering the valley from tributary stream canyons. In the Sacramento Valley, water for irrigation, public supply, and industry is obtained primarily from surface water sources, but also in part from groundwater wells.

The predominant economic deposits in the upper Sacramento River basin include gold, silver, copper, zinc, iron, limestone, and aggregate deposits. Section 3.2 and Appendix B describe the history of mining activities associated with these mineral deposits.

3.1.2 Climate and Hydrology

The weather of the upper Sacramento River watershed is typical of Mediterranean climates; summers tend to be hot and dry, while winters are cool and rainy. The November-to-April period typically encompasses the months of highest rainfall. This TMDL report refers to these months as the winter-spring wet season (or rainy season). Figure 3-1, which charts daily and annual precipitation totals measured at Shasta Dam for the past ten years, clearly illustrates this rainfall pattern. Long-term annual averages indicate that the northern part of the watershed (Shasta Dam, 61 inches per year [in/yr]) receives more rainfall than the southern part (Redding, 33.5 in/yr) (Domagalski et al., 2000).

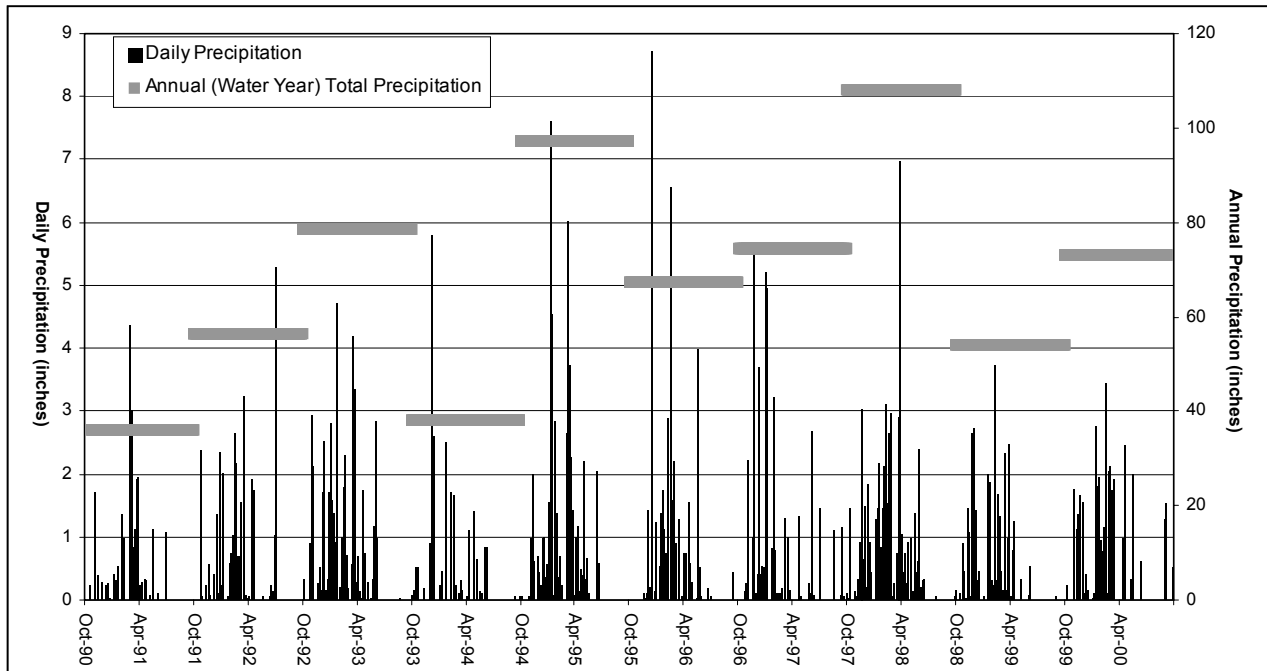


Figure 3-1. Daily and Annual (Water Year) Precipitation at Shasta Dam
 Water Year: October of the previous year through September of the current year.
 Source: California Department of Water Resources Data Exchange Center (<http://cdec.water.ca.gov>).

The annual runoff of the Sacramento River averages 16,960,000 acre-feet/year,² making it the largest river in California (Domagalski et al., 1997). Figure 3-2A illustrates Shasta Dam, Keswick Dam, and SCDD release flows, and Sacramento River flows above Bend Bridge. As Figure 3-2A indicates, the flows above Bend Bridge typically exceed flows below Keswick Dam. The higher flows above Bend Bridge result from the inputs of tributaries downstream of Keswick, such as Cottonwood Creek and Battle Creek. Exceptions to this pattern occur during the dry season when withdrawals from the Sacramento River downstream of Keswick Dam for agricultural use cause Bend Bridge flows to be nearly equal to, or even occasionally less than, Keswick Dam flows.

The comparison of Figure 3-2A to Figure 3-1 illustrates the typical flow/precipitation relationship: the annual flow regime in the Sacramento River is the opposite of the local precipitation patterns (and flow regimes of non-regulated rivers) in the region. The series of dams and diversions (Figure 1-1) that control the hydrology of the upper Sacramento basin cause this reversal. For example, Shasta Reservoir fills during the wet season (winter-spring) with the majority of releases occurring during the dry season (summer-fall). Figure 3-2B compares flows to precipitation for the winter season of water year 1999 to illustrate how Sacramento River flows above Bend Bridge tend to respond more immediately to local precipitation than do Shasta Dam release flows, probably as a result of inflows from unregulated tributaries downstream of Keswick Dam.

The dams and diversions coordinate surface water flows to provide irrigation water, hydroelectric power, flood control, recreation, and potable water, as well as maintenance of navigation flows, conservation of fish in the Sacramento River Sacramento-San Joaquin Delta from intrusion of saline ocean water, and compliance with instream fishery flow requirements (NOAA, 1989; USBR, 2001; Michny, 2001). The U.S. Bureau of Reclamation (USBR) and other agencies determine the amount of water allocated to irrigation, urban, environmental needs, and other uses in part by reservoir storage. The principal environmental needs involve controlling salinity in the Bay-Delta, meeting temperature requirements for migratory fishes, and controlling metal concentrations below Keswick Dam. Section 3.3 describes the characteristics of each of these features and their effects on the flow regime of the upper Sacramento River, the concentration and timing of contaminants from the mine sites on Iron Mountain and in the Shasta Lake region, and the spawning habitat of salmonid species.

² An acre-foot of water is the amount of water needed to cover one acre of land with one foot of water.

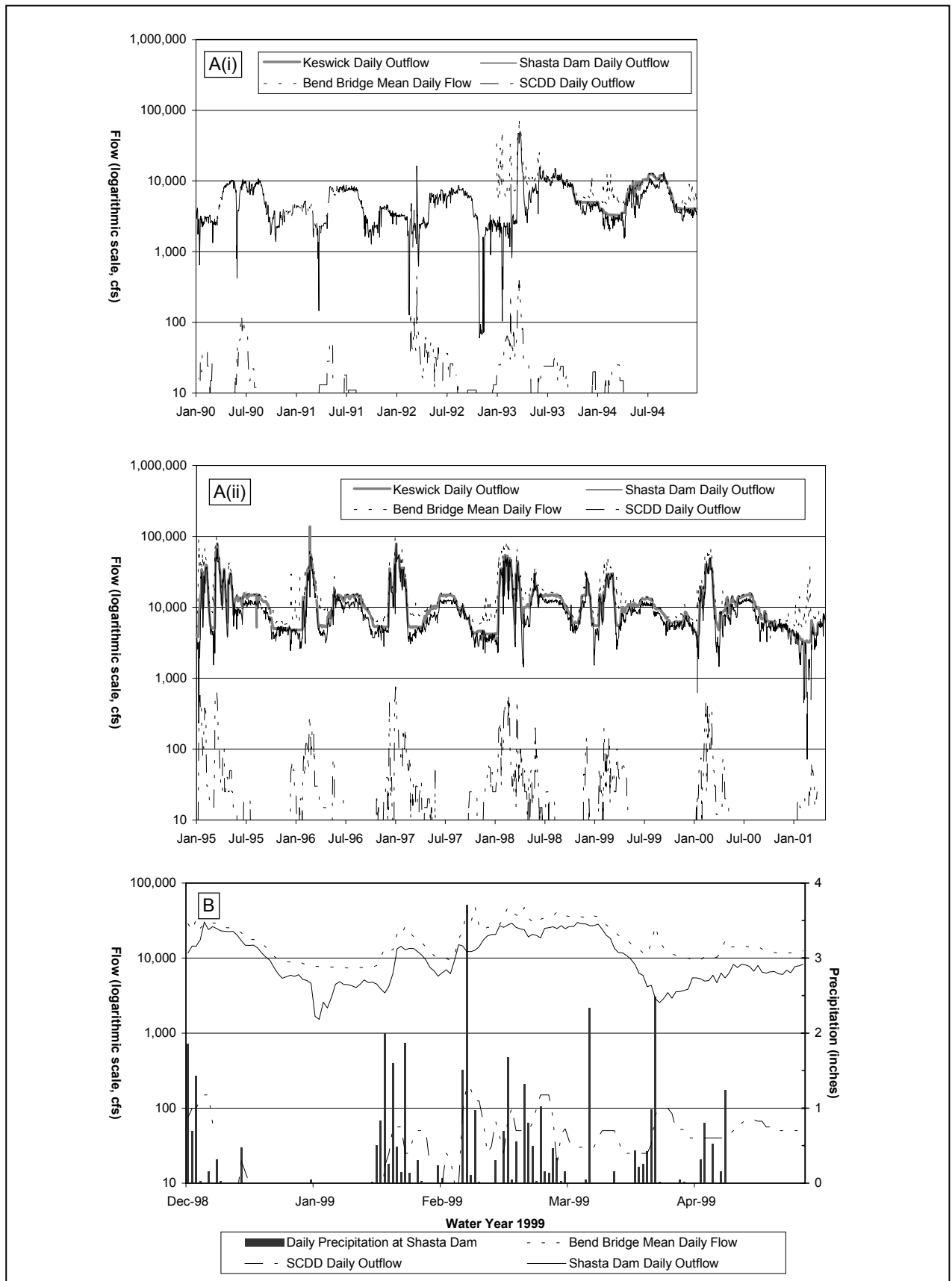


Figure 3-2. Hydrology of the Upper Sacramento River
 A. Shasta Dam, Keswick Dam, SCDD release flows and Sacramento River above Bend Bridge flows.
 B. Comparison of flows and precipitation for the winter season of water year 1999.

3.1.3 Land Use & Critical Habitat

Notable cities located adjacent to the upper Sacramento River include the City of Redding to the north and City of Red Bluff to the south. The major land uses in the upper Sacramento River basin are agriculture, forestry, urban development, and mining. In addition, the upper Sacramento River provides recreation opportunities, wildlife habitat, and aquatic habitat. The river supports a diversity of benthic invertebrates, aquatic flora, and fish species. As described in Chapter 4, elevated levels of dissolved metals have had measurable impacts on several aquatic species present in the Sacramento River, particularly the anadromous fish species.

Anadromous Fish Habitat

The river's substrate consists of gravel, cobble, and bedrock, which provide spawning and nursery habitat for anadromous³ chinook salmon and steelhead trout. The river is the largest and most important salmonid stream in California, providing more spawning habitat for chinook salmon than any other river in California (NOAA, 1989). Elevated levels of dissolved cadmium, copper, and zinc in the upper Sacramento River adversely affect fish habitat. Researchers have linked the elevated metals levels to AMD from mines in the Shasta Lake and Iron Mountain regions. The segment of the river most impacted is the 25-mile segment between Keswick Dam and Cottonwood Creek near Balls Ferry, a reach that historically produced over half the total main-stem spawning run of fall-run chinook salmon (NOAA, 1989). Impacts include numerous documented fish kills and effects on salmonids and other aquatic species populations (see Chapter 4).

There are four distinct spawning populations of chinook salmon in the Sacramento River, which are designated as the fall-run (the largest of the four runs), late fall-run, winter-run, and spring-run, according to the time of year when sexually mature adults begin to migrate from the Pacific Ocean through the Golden Gate into San Francisco Bay and then upstream in the Sacramento River to spawn (NOAA, 1989). Adult steelhead trout migrate into the upper Sacramento River primarily between July and the middle of the following March, and spawning occurs from late December to April. Fry and juvenile stages of the steelhead trout are present in the upper Sacramento River over the entire year, and juvenile steelhead may spend up to four years in the river before out-migration. Because of the overlapping reproductive cycles of the chinook salmon and steelhead trout runs, spawning adults, developing eggs, and early juvenile

³ Anadromous fish have a life history pattern in which the fish spawn in freshwater, then fry migrate to sea to mature.

stages may be found in the Sacramento River during all months of the year. Eggs and early developmental stages – the most sensitive life stages to trace metals contamination – of the four salmon runs and steelhead run are present during the wet season (November through April), the period during which the largest volumes of AMD are discharged from Iron Mountain (NOAA, 1989).

Recreational and Commercial Value of Fisheries

Recreational fisheries in the upper Sacramento River are present for fall-run and spring-run chinook salmon and steelhead trout; harvesting of winter-run fish is prohibited (NOAA, 1989). In addition, chinook salmon from the upper Sacramento River make a substantial contribution to the eastern Pacific Ocean commercial fishery (NOAA, 1989). The U.S. Fish and Wildlife Service (USFWS) and the USBR estimated the net economic value and associated benefits of the Sacramento River chinook salmon and steelhead trout originating above the Red Bluff Diversion Dam (including both wild and hatchery-reared stocks) and determined that the decline in the upper Sacramento River salmonid populations affects the commercial harvest by the ocean fishery (NOAA, 1989). Due to intermingling of different salmon stocks in the ocean, the commercial harvest rate in the ocean fishery is restricted to protect the weakest populations, which are the upper Sacramento River populations (NOAA, 1989). Therefore, if the upper Sacramento River stocks were stronger, the commercial fishery would have a larger allowable catch. Compliance with protective water quality standards, river flow regulation, temperature control, fish passage improvements, and the current restrictions on ocean fishing, are elements of ongoing fishery restoration efforts designed to re-establish the strength and numbers of the Sacramento River fishery (Michny, 2001).

3.2 Mining and Acid Mine Drainage in the Upper Sacramento River Watershed

3.2.1 Acid Mine Drainage

Historic mining activity in the upper Sacramento River watershed exposed minerals to surface water, percolating groundwater, rain, and oxygen. Acid mine drainage is produced primarily by the oxidation of pyrite, a common iron disulfide mineral; when pyrite is exposed to moisture and oxygen, sulfuric acid forms (Nordstrom and Alpers, 1999). The sulfuric acid runs through the metal-rich areas and leaches out copper, cadmium, zinc, and other heavy metals. This AMD flows out of mine seeps and portals. Mining has the overall effect of dramatically increasing sulfide oxidation rates and metals release orders of magnitude faster than natural rates by:

- providing greater accessibility of air through mine workings, waste rock, and tailings;

- creating greater surface area exposure through blasting, grinding and crushing; and
- concentrating sulfides in tailings.

Mine wastes and acid discharges from historic mining of the massive sulfide deposits have resulted in AMD that has caused extreme metal contamination in Boulder Creek, Slickrock Creek, Spring Creek, Little Backbone Creek, and West Squaw Creek (Alpers et al., 2000). Although cadmium, copper, and zinc in the upper Sacramento River derive from several sources, AMD from the IMM site (transported to the upper Sacramento River by Spring Creek) and from Shasta Lake outflow are the largest sources (see Chapter 5). The following section provides a brief history of mining activities in the Shasta Lake region, with particular attention to the IMM site.

3.2.2 Brief History of Mining in the Upper Sacramento River Watershed

Countless mines and prospects with a variety of extraction products are located in the upper Sacramento River watershed and Lake Shasta region. Metals have been mined from locations in the Klamath Mountains, the Sierra Nevada, and the Coast Ranges provinces (Alpers et al., 2000; OMR, 2000). Gold was mined in the Klamath Mountains, an area that is second only to the Sierra Nevada for gold production in California. Placer gold was recovered from ancient and modern stream deposits both in the Klamath Mountains and in the Sierra Nevada; “lode” gold (or hardrock) also was mined from both locations (Alpers et al., 2000; OMR, 2000). Lode gold was first mined in the 1860s from gossans overlying sulphide ores in the West Shasta Copper-Zinc District, which is located in the Klamath Mountains near Shasta Lake. Although this region is now better known for copper and zinc production, considerable quantities of gold and silver were produced (OMR, 2000). However, it became unprofitable to specifically mine for gold and silver in the West Shasta mining district because, beginning in the 1890s, large amounts of gold and silver were being produced as a by-product of the smelting of copper ore.

Copper was the principal commodity in the Shasta Lake region; copper mined from the West and East Shasta Districts accounted for more than half of the State’s total production (OMR, 2000). The mining districts contain several massive sulfide copper-zinc deposits with historic production. The massive sulfide deposits (as much as 200 feet thick) formed approximately 400 million years ago when sea-floor vents deposited sulfide minerals. The deposits consist of millions of tons of the minerals chalcopyrite (CuFeS_2), sphalerite [$(\text{Zn,Fe,Cd})\text{S}$], and pyrite (FeS_2) hosted by hydrothermally altered volcanic rocks with minimal capacity for neutralization of sulfuric acid (H_2SO_4) solutions formed during weathering

(OMR, 2000). The sulfide deposits contain up to 95% pyrite and average approximately 1% copper and 2% zinc (Nordstrom and Alpers, 1999).

Copper mining began in 1862 at Copper City, which was flooded when the Shasta Reservoir was filled. The construction of a smelter at Keswick by the owners of Iron Mountain Mines in 1896 enabled the expansion of copper mining within the Shasta Lake region (OMR, 2000). Large mines were developed in the West Shasta Copper-Zinc District, including the Mammoth and Balaklala mines. More than three million tons of copper ore were produced from the Mammoth complex before mining ceased in 1925 (OMR, 2000). Approximately one million tons of ore were mined at the Balaklala Mine between the 1890s and 1920s. Other large copper mines in the West Shasta Copper-Zinc District included the Keystone and Shasta King mines, which operated between the 1860s and the late 1920s. The Bully Hill and Rising Star complex was the largest operation in the East Shasta Copper District; more than one half million tons of ore were mined between 1900 and 1950.

At various times between 1896 and 1919, smelters were operated at Keswick, Kennett, Winthrop, and other locations. The emissions from copper smelting severely impacted air quality and caused massive environmental degradation and the loss of forests throughout the region. By 1919, most of the smelters had been shut down due to litigation resulting from the environmental damage caused by ore refining. Most mining of copper and zinc ores in the Shasta Lake region ceased by the 1920s because the cost of shipping the copper ore for refining elsewhere, combined with the high cost of grinding the ore to economical concentrations, made further mining unprofitable (OMR, 2000). The smelter at Kennett was inundated by Shasta Lake once Shasta Dam was completed.

There is currently no active copper, zinc, and cadmium mining in the Shasta Lake region. Several of the mines are undergoing remediation, but are otherwise inactive. Section 10.2 and Appendix B summarize past and proposed remediation activities for mines in the Shasta Lake region.

Iron Mountain Mines Site

The IMM site is in the southeastern foothills of the Klamath Mountains, approximately nine miles northwest of Redding (population ~70,000) in Shasta County (Figures 3-3 and 3-4). The IMM site is on a ridge drained by Boulder Creek to the north and Slickrock Creek to the south (USGS, 1979; Rae, 1998). These creeks drain into Spring Creek, which enters the Sacramento River approximately one mile upstream from Keswick Dam. The IMM site covers an area of approximately 4,400 acres (USEPA, 2001a) and has elevations that range from 1,600 feet above mean sea level (msl) near

Minnesota Flats, to 3,913 feet above msl at Sugarloaf Mountain (USGS, 1979). Land use in the area is predominantly recreational, with largely undeveloped wilderness property; two national forests border the site (USEPA, 2001a).

The Iron Mountain Mines complex is the largest of all mines in the upper Sacramento River watershed and Shasta Lake region (Montoya and Pan, 1992). The Iron Mountain ore body is estimated to have contained 37.5 million tons of sulfide ore prior to the onset of mining activity and related weathering; approximately 7.5 million tons of sulfide ore was mined at the IMM site (Nordstrom and Alpers, 1999). From the 1860s through 1963, the IMM site was mined periodically for iron, silver, gold, copper, zinc, and pyrite, although it was most heavily mined between 1896 and 1919 (Rae, 1998; USEPA, 2001). The mine has had multiple owners: Mountain Mining Company, Ltd., Mountain Copper Company, Stauffer Chemical Company, and, most recently, Rhone-Poulenc, Inc., Aventis CropSciences, and Iron Mountain Mines, Inc. Between 1896 and 1905, Mountain Copper Company, the owner of Iron Mountain Mines at that time, was the largest producer of copper in California (Rae, 1998).

Conditions at the IMM site are nearly optimal for the production of AMD, and its AMD is some of the most acidic and metal-rich reported anywhere in the world (Nordstrom and Alpers, 1999). The IMM site is historically the largest point source of toxic metals in the country (USEPA, 2000b). Both underground mining techniques (e.g., open stope mining) and surface mining techniques (open pit and sidehill mining) were used. The IMM ore bodies were heavily tunneled and stoped, and the ceilings of these stopes have since collapsed. The caved ceilings caused subsidence of the ground above, resulting in fractured chimneys (Rae, 1998). In addition, waste rock dumps, piles of mine tailings, and an open mine pit still remain at the site (USEPA, 2001). The exposure of the remaining ore to oxygen and water (rainfall and groundwater) has led to the formation of AMD with very high amounts of copper and zinc, as well as other metals such as cadmium.

Much of the AMD from the IMM site eventually discharges through mine adits and groundwater seepage, and is ultimately channeled into the Spring Creek Reservoir. The USBR releases the stored AMD into Keswick Reservoir (USEPA, 2001). The USBR coordinates releases to coincide with the Sacramento River flow below Keswick Dam. On occasion, uncontrolled spills and excessive waste releases have occurred when Spring Creek Reservoir reached capacity. Without sufficient dilution, this results in the release of quantities of heavy metals into the Sacramento River that are harmful to aquatic organisms (USEPA, 2001).

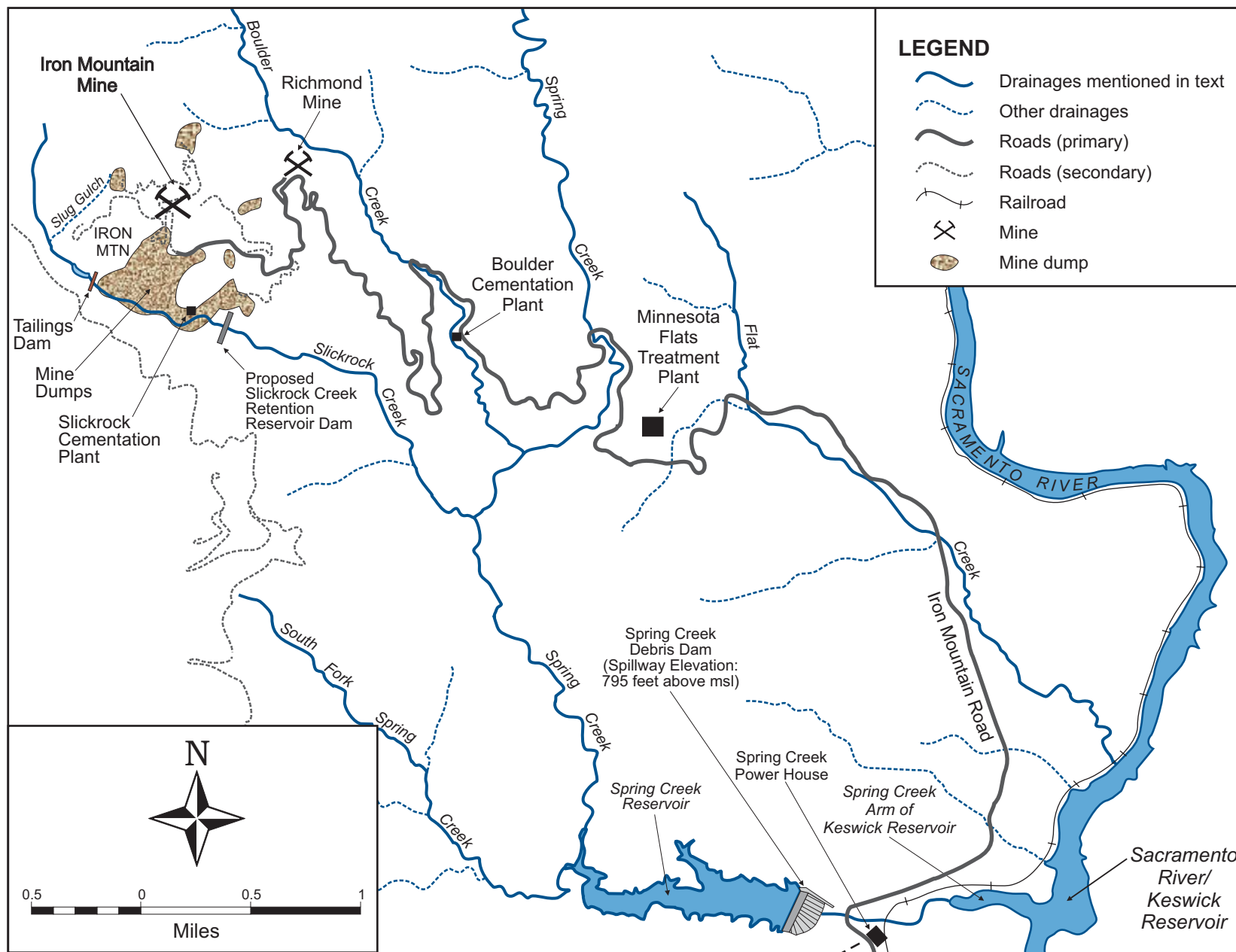


Figure 3-3. Geographic Features of the Iron Mountain Mine Region
(Sources: USGS, 1976 and 1979; Heiman, 1989; NOAA, 1989)

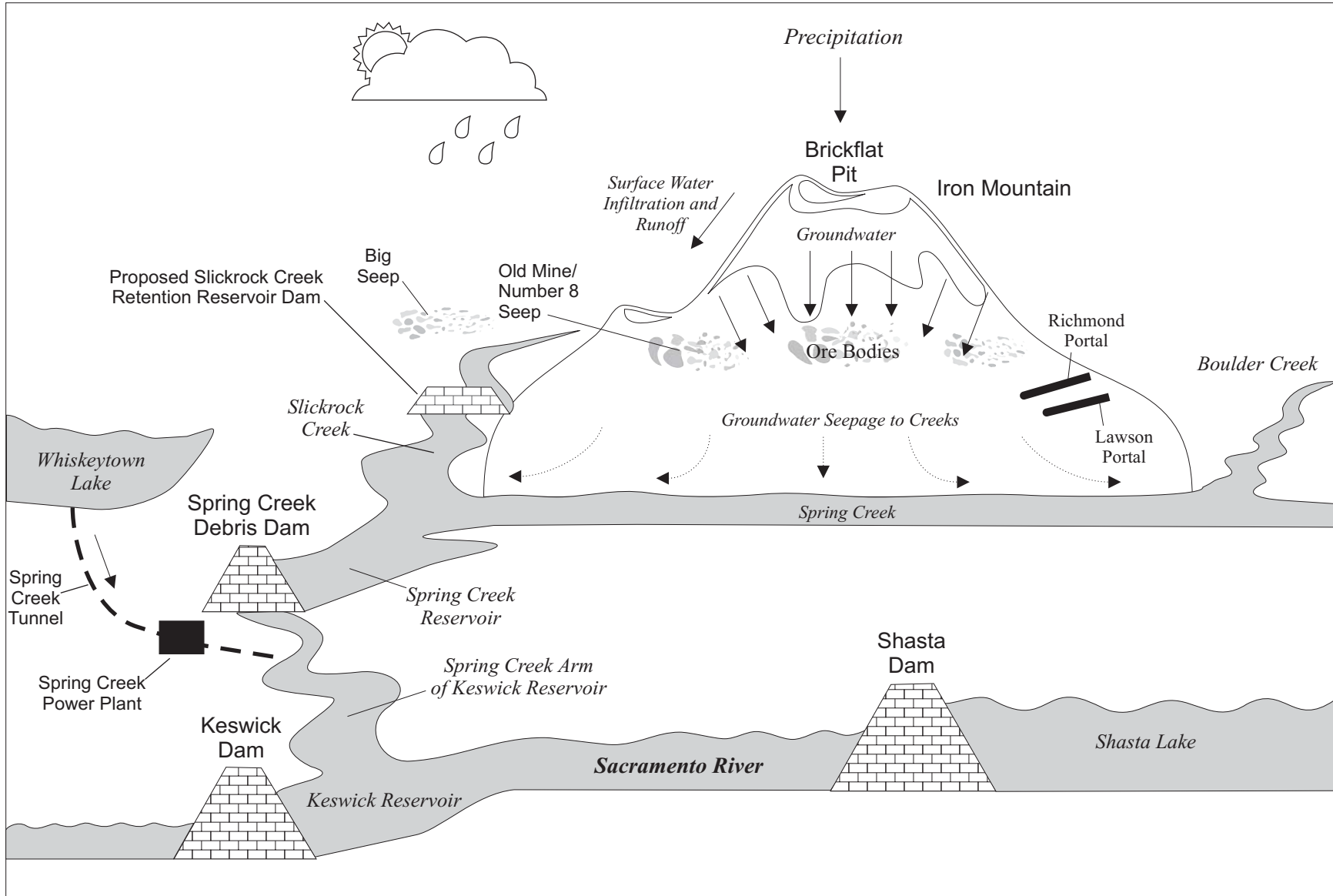


Figure 3-4. Hydrologic Features of the Iron Mountain Mine Region near Redding, California (Source: Adapted from NOAA, 1989)

In addition, AMD from the IMM site results in the deposition of contaminated sediments in Keswick Reservoir. When the acidic, metal-laden waters of Spring Creek enter the neutral Keswick Reservoir waters, the pH rises and causes metal precipitates to drop out of solution (Rae, 1998). Researchers have characterized three distinct sediment piles containing high levels of copper, zinc, and iron in the Spring Creek Arm of Keswick Reservoir (SCAKR), with total volume estimates currently as high as 230,000 cubic yards. A fourth pile exists in the main channel of Keswick Reservoir.

There have been several phases of remediation efforts at the IMM site, some of which are ongoing. Current remediation activities control on average 83% of total IMM site copper discharges and 89% of zinc discharges. However, even taking into account the response actions completed to date, IMM AMD is expected to cause regular annual exceedances of protective water quality standards in Keswick Reservoir, continued exceedances in the Sacramento River under certain storm conditions, and the continued release of 25,000 to 70,000 pounds per year of copper and 40,000 to 90,000 pounds of zinc to Keswick Reservoir and the main stem of the Sacramento River in normal to wet water years (USEPA, 1997b). Therefore, the remediation activities proposed for the next two years (see Chapters 7 and 10) are particularly relevant to this TMDL.

The USEPA developed a numerical water quality model to predict the effectiveness of various remedial alternatives for the IMM site with respect to limiting the frequency of SCDD spills and exceedances of the water quality standards below Keswick Reservoir (USEPA, 1997b). Based on the results of their modeling efforts and public review, the USEPA determined that the construction of the Slickrock Creek Retention Dam (SRCRD) would enable the treatment of Slickrock Creek drainage, which comprises approximately 60 to 70% of the remaining uncontrolled copper and 40 to 50% of the remaining uncontrolled zinc and cadmium site discharges. This action, when combined with the current remedies, would control more than 95% of total IMM site releases (USEPA, 2000b). Construction of the SRCRD began during the summer of 2001. Through a court ordered settlement, Aventis CropSciences (a former owner and operator), has arranged for a private contractor to operate and maintain the site remedies (USEPA's Record of Decision (RODs) 1-4) over the next 30 years, and to pay to the federal and State governments to fund future site costs (USEPA, 2000b). In addition, the USEPA continues to study potential remedial approaches for the area source (non-portal) AMD discharges from the Boulder Creek drainage (the remaining 5% of total site releases) and the removal of sediment that has accumulated in the SCAKR, Spring Creek Reservoir, and the main channel of Keswick Reservoir (Rae, 1998; USEPA, 2001; Sugarek, 2001).

Chapter 7 (Linkage Analysis) provides a more detailed review of the USEPA's water quality modeling results and the linkages between metal loads from the IMM site. The USEPA's ROD4 issued on September 30, 1997, provides a detailed description of part IMM operations and past and ongoing remediation activities at the IMM site.

3.3 Effects of Dams and Diversions on Sacramento River Hydrology

A series of dams and diversions control the hydrology of the upper Sacramento River basin:

- Red Bluff Diversion Dam, Anderson-Cottonwood Irrigation District Dam, Keswick Dam, and Shasta Dam are on the upper Sacramento River;
- Spring Creek Tunnel directs water from Whiskeytown Lake to the Spring Creek Power Plant (SCPP) and Spring Creek; and
- Spring Creek Debris Dam is on Spring Creek.

Table 3-1 summarizes the characteristics of each of these features. Figure 1-1 illustrates the features' locations. These dams and diversions coordinate surface water flows to provide irrigation water, hydroelectric power, flood control, recreation, and potable water, as well as to maintain navigation flows, to protect fish in the Sacramento River Sacramento-San Joaquin Delta from intrusion of saline ocean water, to control temperature in the Sacramento River, to comply with instream fishery flow requirements, and to provide for other environmental needs (e.g., federal and State Endangered Species Acts) (NOAA, 1989; USBR, 2001; Michny, 2001). This flow coordination results in a complex water management system that greatly influences the concentration and timing of contaminants from the IMM site that enter the Sacramento River and dramatically affects the spawning habitat of salmonid species.

3.3.1 Dams and Diversions in the Iron Mountain Mines Region

Shasta Dam, completed in 1945, is the keystone of the Central Valley Project (CVP); it impounds Shasta Lake, which has a capacity of 4.5 million acre-feet (Rae, 1998; USBR, 2001). The penstock inlet is at the mid-level of the dam and normally releases colder, deeper waters, except for occasional periods when the reservoir is at low levels due to drought or reduced river inflow. A temperature control device enables reservoir withdrawals from various elevations. The elevation is determined by temperature operations for the chinook salmon in the Sacramento River; withdrawals are typically made from higher elevations during the spring season, and progressively lower elevations throughout the summer and fall seasons (Michny, 2001).

Table 3-1. Dams and Diversions in the Upper Sacramento River Basin ^(a)

Feature ^(b)	Location	Construction Date	Reservoir	Total Storage (acre-feet)	Spillway Elevation (feet ab. msl)	Hydraulic Height (feet)
Shasta Dam	Sacramento River, 12 miles northwest of Redding, CA	1938-1945, modified 1995-1996	Shasta Lake	4,552,000	1,065	522.5
Spring Creek Tunnel	Diverts water from Whiskeytown Lake to Spring Creek Power Plant (at foot of Spring Creek Dam)	~1964	Whiskeytown Lake on Clear Creek	-	-	-
Spring Creek Debris Dam	Spring Creek, Upstream of Power Plant Tailrace,	1961-1963	Spring Creek Reservoir	not available (na)	795	186
Keswick Dam	Sacramento River, 9 miles downstream of Shasta Dam and 4 miles northwest of Redding	1941-1950	Keswick Reservoir	23,800	587	118
Anderson-Cottonwood Irrigation District Dam	Sacramento River, ¼ mile upstream of Highway 273 Bridge, Redding	na	Lake Redding	na	~490	na
Red Bluff Diversion Dam	Sacramento River, south of Red Bluff (gates closed during summer)	1964	Lake Red Bluff	na	253 (pool elevation)	na

(a) Source: USBR, 2001; TopoZone, 2001.

(b) The U.S. Bureau of Reclamation operates all dams, diversions, and power plants except Anderson-Cottonwood Irrigation District Dam.

The reservoir fills during the wet season (winter-spring) with the majority of releases occurring during the dry season (summer-fall). This management strategy causes the annual flow regime in the Sacramento River to be the opposite of non-regulated rivers in the region. Highest flows in the upper Sacramento River typically occur during the dry season, and lowest flows typically occur during the wet season; the 1990-92 period shown in Figure 3-2A, which shows Shasta Dam release flows since 1990, best illustrates this characteristic. However, there are exceptions to this flow regime, such as during the high flow seasons of 1993-2000. These exceptions are discussed later in this section.

The construction of Shasta Dam has had a notable influence on the water quality of the Sacramento River below the Spring Creek confluence (NOAA, 1989; USEPA, 1997b; Michny, 2001). Once construction of Shasta Dam was completed, water that was formerly available to dilute the AMD entering the Sacramento River from Spring Creek was no longer as readily and regularly available. Major fish kills in the upper Sacramento River were documented soon after the dam was constructed (NOAA, 1989). However, toxicity problems were documented both before and after the completion of Shasta Dam in 1945. Only

limited water quality information is available from the pre-Shasta Dam period; however, water quality modeling and the limited available data indicate that, prior to the construction of the Shasta Dam, the IMM discharges caused metal levels in the Sacramento River to exceed levels that are safe for aquatic life for more than 330 days each year on average, even after the discharges became fully mixed with Sacramento River waters downstream of the confluence of Spring Creek and the Sacramento River (USEPA, 1997b).

Keswick Dam, completed in 1950, is the regulating dam located on the Sacramento River approximately nine miles downstream of Shasta Dam (Rae, 1998). The USBR constructed the dam to buffer fluctuations in discharges from Shasta Dam and SCPP and to control runoff from the 45 square miles of drainage area between Shasta Dam and Keswick Dam, while also producing electricity (NOAA, 1989; Michny, 2001). Once USBR completed the Shasta and Keswick Dams, salmon and steelhead were restricted to spawning grounds in areas downstream of Keswick Dam, and were unable to migrate past the area impacted by AMD discharges from Iron Mountain and other mines in the Shasta Lake region (Rae, 1998; Michny, 2001).

Spring Creek tunnel diverts water from Whiskeytown Lake to the SCPP, which is on the south bank of Spring Creek between the SCDD and the SCAKR (see Figure 1-1).⁴ The USBR completed the SCDD in 1963 to control sedimentation to protect the SCPP tailrace channel, and to control IMM AMD to protect Sacramento River fisheries. The SCDD is located on Spring Creek just above its confluence with the SCAKR. Construction of the SCDD reduced the frequency and massiveness of fish kills. However, during extreme storm events, the SCDD has filled beyond capacity, spilling toxic levels of AMD into the Sacramento River on an average of every two to three years, causing episodes when emerging fry were killed (Rae, 1998; Michny, 2001).

AMD from the IMM site is presently controlled, to some extent, by coordinated dilution in the Sacramento River (NOAA, 1989). Optimally, the USBR releases contaminated water from the SCDD when the discharge from Shasta Dam is high, thereby allowing maximum dilution of the contaminated

⁴ From 1896 until 1907, the Keswick smelter operated in the vicinity of the present Spring Creek Reservoir, and caused much of the surrounding area to be denuded of vegetation as a result of toxic smelter fumes. The deforestation caused by the smelter resulted in extremely high sedimentation rates in the Spring Creek basin, and within nine years after the completion of Keswick Dam, a delta had formed in the Spring Creek Arm of Keswick Reservoir containing an estimated 750,000 cubic yards of material. As SCPP neared construction, the USBR evaluated alternatives for sediment control for the tailrace channel. The USBR and officials from other agencies recognized an opportunity to also achieve some protection for the Sacramento River fisheries with the construction of a debris dam that would retain water contaminated by AMD. This resulted in the approval for the construction of SCDD in 1960 (Rae, 1998; NOAA, 1989).

water. However, AMD amounts are highly variable from season to season and year to year. In addition, the water levels in the Whiskeytown and Shasta reservoirs, which are a function in part of the rain pattern of prior years, impacts the ability of the system to operate in a manner that assures that the metal concentrations remain below levels that pose a risk to aquatic organisms (Smith and Sugarek, 2001). Shasta Lake cannot always provide an adequate volume of dilution water because Shasta Dam does not typically release large volumes of water during the wet season when the greatest runoff from the IMM site occurs (NOAA, 1989). In particular, the flows in the Sacramento River available at the onset of major early season storm events cannot generally provide adequate dilution of the IMM contaminants at current levels of metals discharges (USEPA, 1997b). Storm inflows into the Spring Creek Reservoir frequently occur at several hundred to 2,000 cubic feet per second (cfs); Sacramento River flows are frequently near minimum legal flows during the first storm of the season, and are not generally more than 10,000 cfs. In addition, large uncontrolled releases of water from SCDD have occurred when heavy rains cause the Spring Creek Reservoir to fill and overflow; these overflows have occurred during the wet season when regulated flows in the Sacramento River were low (NOAA, 1989; Pedri, 2001).

1980 Memorandum of Understanding & Dam Operations

Prior to 1980, the California Department of Fish and Game (CDFG) and Regional Board staff periodically provided information to the USBR on toxicity criteria and dilution ratios or equations, for the USBR's use in determining SCDD releases. In 1980, the USBR entered into a memorandum of understanding with CDFG and the State Water Resources Control Board, acting on behalf of the Regional Board (1980 MOU) (SWRCB et al., 1980).⁵ In the 1980 MOU, the parties agreed on, among other things: 1) new interim toxicity criteria for copper and zinc to be met below Keswick Reservoir, and 2) new interim dilution ratios or equations for USBR's use in operating SCDD. The USBR still manages SCDD operations according to the 1980 MOU (and two other documents, see below). The authoring agencies designed the 1980 MOU to be an interim document, describing protective operations until alternative solutions to the Spring Creek toxicity problem could be achieved. The 1980 MOU provides for reservoir and Sacramento River monitoring at a frequency based upon reservoir elevation, so that as the reservoir rises, USBR staff conducts operational monitoring more frequently. USBR staff uses the monitoring data to calculate allowable SCDD releases based on Keswick Reservoir release volumes, the concentration of copper and zinc in Spring Creek, and a presumed precipitation factor. The staff calculates the SCDD

⁵ The 1980 MOU is entitled "Memorandum of Understanding Among the State Water Resources Control Board [on behalf of the Regional Board], United States Water and Power Resources Service [former name of the USBR], and Department of Fish and Game to Implement Actions to Protect the Sacramento River System from Heavy Metal Pollution from Spring Creek and Adjacent Watersheds" (SWRCB et al. 1980).

releases so as not to exceed the USBR’s operations criteria for copper and zinc in the Sacramento River prescribed in the 1980 MOU, which also provides emergency criteria for instances when the reservoir is approaching spill conditions. In recent years, staff in USBR’s Central Valley Operations Office (CVO) has attempted to target the more stringent Basin Plan water quality objectives for dissolved metal concentrations for the upper Sacramento River as well as the 1980 MOU objectives, since they have access to dissolved metals data as well as total concentrations. Table 3-2 summarizes the 1980 MOU objectives and the water quality objectives. Chapter 6 provides a more detailed description of the Basin Plan water quality objectives.

Table 3-2. 1980 USBR-SWRCB-CDFG MOU and Basin Plan Objectives ^(a)

Objective ^(a)		Dissolved Concentration Measured on the Sacramento River below Keswick Dam [Total Concentration Values] (µg/l)		
		Cadmium	Copper	Zinc
1980 USBR-SWRCB-CDFG MOU Objectives ^(b, c)	Spring Creek Reservoir is less than 5,000 acre feet (~86% capacity)	-	9.6 [10]	70 [72]
	Spring Creek Reservoir is => than 5,000 acre feet (emergency situation)	-	14.4 [15]	106 [108]
Basin Plan Objectives		0.22	5.6	16

(a) Sources: SWRCB et al., 1980; CVRWQCB, 1998a.

(b) The 1980 MOU lists objectives as total copper and zinc values rather than as dissolved values. Regional Board staff converted the MOU total copper and zinc values to dissolved values using acute conversion factors (copper [0.96], zinc [0.978]) presented in the Code of Federal Regulations, Title 40, Part 131, Section 36(b)(1) and (2). Brackets indicate the total concentration values cited in the MOU.

(c) According to the 1980 MOU, when Spring Creek Reservoir storage is less than 5,000 acre feet, concentrations of total copper and zinc in the Sacramento River should not exceed 10 and 72 µg/l, respectively; when Spring Creek Reservoir storage is equal to or greater than 5,000 acre feet, concentrations of total copper and zinc in the Sacramento River will not exceed 15 and 108 µg/l, respectively. The USBR would adjust SCDD releases according to equations provided in the 1980 MOU for emergency and non-emergency conditions. The USBR considered Spring Creek Reservoir storages equal to or greater than 5,000 acre feet to be emergency situations and would make additional short-term water releases from Shasta and Whiskeytown Reservoirs to meet the emergency criteria. The USBR’s rationale for having higher emergency criteria is that accepting more risk in a controlled situation is more desirable than complete loss of control, which occurs when Spring Creek Reservoir fills and spills. The USBR has since updated the release schedule listed in the 1980 MOU (USEPA, 1997b).

In addition to the 1980 MOU, the USBR’s dam operations are governed by the 1992 Long-Term Central Valley Project Operations Criteria and Plan (1992 CVP-OCAP) (USBR, 1992) and 1993 Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project (1993 Biological Opinion) (NMFS, 1993). The 1992 CVP-OCAP summarizes the 1980 MOU in the context of the other criteria that govern CVP reservoir storage and dam releases. The 1993 Biological Opinion provided additional criteria for SCDD and Shasta Dam operations to minimize chronic exposure of metal concentrations on adult and juvenile winter-run chinook salmon and eliminate potential scouring

of toxic metal-laden sediments in Keswick Reservoir (NMFS, 1993). The 1993 Biological Opinion directs the USBR to:

1. Utilize a real-time flow-monitoring device at the weir below the SCDD to provide an accurate measurement of outflow.
2. Utilize analytical instruments capable of detecting copper and zinc at concentrations equal to that specified by the Basin Plan and methods consistent with USEPA quality assurances and quality control guidelines.
3. Increase the sampling frequency of copper and zinc concentrations in the SCDD outflow and Keswick Dam outflow during and immediately following all major storm events, or when malfunctions at the AMD treatment facilities upstream of SCDD cause metal concentrations to change, and provide the water quality data to the National Marine Fisheries Service (NMFS).
4. During the dry season, utilize the results of the real-time flow monitoring device and analytical tests to reduce metal concentrations in the Sacramento River to levels as low as the SCDD evacuation period will allow and target the Basin Plan water quality objectives (except during critical water years when Keswick Dam releases are too low under this schedule to accommodate full evacuation of SCDD).
5. Maintain Keswick Reservoir at or above the normal operating level during all operation of the SCPP to prevent the scouring of toxic metal-laden sediments in Keswick Reservoir.

CVO staff continues to cooperate with CDFG and Regional Board staff members, who periodically call with requests for additional releases from Shasta and Keswick Dams. USBR has been as responsive as possible to these requests although USBR always evaluates project needs and downstream flooding before considering such requests. Although Shasta Dam releases periodically contain a notable amount of heavy metals (refer to Chapter 5, Source Assessment), flows released by the Shasta Dam and/or Spring Creek Power Plant plus accretion flows directly into Keswick Reservoir typically serve to dilute metal-laden Spring Creek waters to reduce toxicity downstream of Keswick Reservoir (Cooke and Connor, 1998). In addition, there have been numerous instances in past years when the USBR has released water from Shasta Dam to dilute uncontrollable AMD spills or to allow large releases from SCDD in anticipation of large inflows to Spring Creek Reservoir. Figure 3-2B, which illustrates Shasta Dam and SCDD release flows for the winter season of water year 1999, clearly illustrates examples of such instances. Such coincident releases are not mandated, but have become accepted practice per the 1980 MOU. If flooding is occurring downstream, however, the USBR does not release water from Shasta Lake (Cooke and Connor, 1998; Michny, 2001).

The USBR also manages SCPP operations to minimize mobilization of contaminated sediments and metal precipitates (Rae, 1998; NMFS, 1993). As noted in the previous section, when the acidic, metal-laden waters of Spring Creek enter the neutral Keswick Reservoir waters, the pH rises and causes metal

precipitates to drop out of solution. The USBR based the 1980 MOU on the assumption that 50% of the dissolved metals will form precipitates in the SCAKR and Keswick Reservoir; more recent USEPA studies indicate that the precipitation rate is approximately 35% under most conditions (USEPA, 1997b). The SCDD releases some contaminated water into the SCAKR on a continuous basis.⁶ Because flows in the Sacramento River poorly flush the SCAKR, contaminants can accumulate to high concentrations in the SCAKR. Intermittent discharges from the SCPP can then rapidly flush these accumulations of contaminated water and precipitates into the main stem of the river (NOAA, 1989). When the USBR makes releases from the SCDD, the USBR maintains a minimum flow of 250 cfs (“Speed No Load”) from SCPP to minimize mobilization of contaminated sediments and metal precipitates in the SCAKR. If USBR makes SCDD releases but SCPP has not operated recently and power generation is scheduled, the USBR typically runs the SCPP units at “Speed No Load” for several hours before beginning power generation. Maintenance of the minimum flow from SCPP provides a “gentle flushing” flow that reduces the risk of AMD collecting in the SCAKR and flowing out as an unregulated pulse (“slugging”) when the SCPP comes online to generate power (NOAA, 1989; Michny, 2001). In addition, the 1993 Biological Opinion directs the USBR to maintain Keswick Reservoir at or above the normal operating level during all SCPP operations to help prevent the mobilization of the SCAKR contaminated sediments and metal precipitates (NMFS, 1993; Michny, 2001).

3.3.2 Red Bluff Diversion Dam and Anderson-Cottonwood Irrigation District Dam

Red Bluff Diversion Dam and Anderson-Cottonwood Irrigation District Dam (ACIDD) are located on the Sacramento River downstream of Keswick Dam. These dams have more of an effect on fish passage than water quality. Lake Red Bluff is a seasonal lake (May 16 through September 14) formed on the Sacramento River by the closure of the gates at Red Bluff Diversion Dam (USBR, 2001). The dam is a feature of the Central Valley Project. Lake Red Bluff is approximately 3 miles long with approximately 200 surface acres. The lake provides a coldwater fishery for trout, steelhead, and salmon. However, the Red Bluff Diversion Dam inhibits passage of adult chinook salmon and steelhead trout. There is an agreement between the USBR and the CDFG to keep the dam open during salmonid spawning runs, except during emergency situations (NOAA, 1989).

⁶ In general, the SCDD releases contaminated water into the SCAKR on a continuous basis. The SCDD typically releases only when SCPP is operating, but the SCPP may not be generating at all times while the SCDD is releasing water. When there is water in Spring Creek Reservoir, the gates of the SCDD can be closed, but there is minor leakage. When the reservoir is empty or near empty, there is essentially no release (Michny, 2001).

The ACIDD is less than ¼ mile upstream of the Highway 273 Bridge in Redding. The ACIDD is a component of the Anderson-Cottonwood Irrigation District's diversion works used to acquire, transport, and distribute irrigation water to its customers, generally beginning in the spring season and concluding in the fall season, since the early 1920s (CRA CERES, 2001). The Anderson-Cottonwood Irrigation District Dam has fish passage facilities.

4 EFFECTS OF CADMIUM, COPPER, AND ZINC ON AQUATIC LIFE

4.1 Physical Characteristics of Cadmium, Copper, and Zinc

The following is a brief description of the physical characteristics of cadmium, copper, and zinc.⁷

4.1.1 Cadmium

Cadmium is a soft, white, easily fusible metal similar to and commonly associated with zinc and lead. It is readily soluble in acid and is highly toxic. Compared to other metals, cadmium is relatively mobile in aquatic environments and may be transported in solution either as hydrated cations or as organic or inorganic complexes. Cadmium ion precipitates from solution as a carbonate, hydroxide, or sulfide, and forms soluble complexes with other anions.

Cadmium is strongly adsorbed to clays, mud, humic and organic materials, and some hydrous oxides, all of which tend to remove it from the water column by precipitation. In polluted waters, complexing with organic materials is the most important factor in determining the aquatic fate and transport of cadmium. Sorption processes account for removal of dissolved cadmium to bed sediments and are increasingly effective as pH increases. Increased hardness and/or alkalinity have been demonstrated to decrease the toxicity of cadmium.

4.1.2 Copper

Copper is a reddish, malleable metal that occurs in nature in its native form and as sulfides, oxides, and carbonates. Copper is an essential trace element in plants and animals. Because copper forms chemical complexes with the anions present, the toxicity of copper to aquatic life depends on the level of alkalinity. At lower alkalinity, copper is generally more toxic to wildlife.

4.1.3 Zinc

Zinc is usually found in nature as sulfide associated with sulfides of other metals. Because compounds of zinc are generally soluble in neutral and acidic solution, zinc is readily transported in most natural waters

⁷ The text for this summary was obtained from a California Department of Water Resources report prepared for the Regional Board (DWR, 1985). The report derived its descriptions from two USEPA documents (USEPA, 1976 and 1980).

and is one of the most mobile of the heavy metals. Hardness, dissolved oxygen, temperature, and synergistic effects with other compounds all affect the toxicity of zinc to aquatic life.

4.2 General Effects on Biota

The following sections provide a general description of the effects of cadmium, copper, and zinc on aquatic organisms. This TMDL report focuses on aquatic organisms for the following reasons:

- Concentrations of cadmium, copper, and zinc in upper Sacramento River water have frequently exceeded water quality standards developed to protect aquatic organisms.
- There is historical evidence of acute heavy metals toxicity to aquatic organisms in the upper Sacramento River (e.g., fish kills).
- Concentrations of cadmium, copper, and zinc have not exceeded water quality criteria designed for the protection of humans during the 1990s.
- There is no current evidence of acute or chronic heavy metals toxicity to humans due to consumption of water or fish from the upper Sacramento River.

4.2.1 Accumulation in Aquatic Organisms

Dietary and waterborne routes expose aquatic organisms to cadmium, copper, and zinc and other metals. Waterborne routes include uptake of metals released from sediments into the water column, metals in solution, and metals in sediments. Low trophic level⁸ species such as phytoplankton obtain most heavy metals directly from the water. *Bioconcentration* describes the net accumulation of metals directly from water. The *bioconcentration factor* is the ratio of metal concentration in an organism to metal concentration in water. A *bioaccumulation factor* describes the degree to which metals accumulate from water and prey, relative to metal concentration in the water. Compounds *bioaccumulate* when rates of uptake are greater than rates of elimination. Because rates of uptake are generally much greater than rates of elimination, heavy metals may concentrate within organisms. Repeated consumption and accumulation of metals from contaminated food sources results in tissue concentrations of metals that are higher in each successive level of the food chain. This process is termed *biomagnification*. Studies

⁸ Trophic levels are the hierarchical strata of a food web characterized by organisms that are the same number of steps removed from the primary producers. The USEPA's 1997 Mercury Study Report to Congress (USEPA, 1997a) used the following criteria to designate trophic levels based on an organism's feeding habits:

Trophic level 1: Phytoplankton.

Trophic level 2: Zooplankton and benthic invertebrates.

Trophic level 3: Organisms that consume zooplankton, benthic invertebrates and phytoplankton.

Trophic level 4: Organisms that consume trophic level 3 organisms.

(e.g., Seiti et al., 1995) have found that aquatic food chains exposed to AMD in the upper Sacramento River have accumulated cadmium, copper, and zinc without evidence of biomagnification.

4.2.2 Toxicity of Heavy Metals to Aquatic Organisms

Aquatic organisms exhibit several types of detrimental effects from chronic and acute exposures to cadmium, copper, and zinc. Cadmium is of concern because it is known to be toxic to aquatic organisms and it readily bioaccumulates in aquatic organisms. Among fish, salmonids appear to be the most vulnerable to cadmium toxicity (NOAA, 1989). A cadmium concentration of 1.1 µg/l can be acutely toxic to juvenile chinook salmon, depending on water hardness (Reyes, 1994). Copper and zinc are essential trace elements that can be toxic at high concentrations. Copper and zinc concentrations of less than 7.4 µg/l and 84 µg/l, respectively, can be acutely toxic to chinook salmon, depending on water hardness (Reyes, 1994). Chronic effects of these heavy metals include:

- reproductive impairment and developmental abnormalities (fish, invertebrates, and algae);
- reduction in growth (fish, invertebrates, and algae);
- behavioral effects, such as avoidance of areas with elevated copper and zinc, lethargy, decreased food consumption, and changes in foraging behavior (fish);
- increased susceptibility to infection (fish);
- decreased abundance and diversity (invertebrates) and changes in community (algae);
- reduction in photosynthesis and effects on morphology (algae); and
- varying effects on hematology and physiology (fish).

Section 4.3 provides a summary of effects observed in aquatic organisms in the upper Sacramento River.

4.2.3 Bioavailability and Mixture Interactions

Cadmium, copper, and zinc (heavy metals) are bioavailable if they are present in forms organisms can ingest and metabolize (Reyes, 1994). Most water quality criteria for the heavy metals relate to total recoverable concentrations; however, the USEPA now recommends the use of dissolved metal concentrations to set and measure compliance with aquatic life water quality standards because dissolved metal concentrations more closely approximate the bioavailable fraction of the metal in the water column than do total recoverable metal concentrations (USEPA, 2000a).

Water hardness has been the only physical/chemical water quality parameter incorporated in deriving the criteria (Reyes, 1994⁹). Chronic and acute zinc and cadmium toxicity decrease with increased hardness; acute toxicity of copper appears to decrease with increased hardness. Researchers have found that other factors such as metal speciation and pH also modify metal toxicity and affect bioavailability. In general, the toxicity of cadmium and zinc increases with increases in pH, while copper toxicity increases with decreases in pH. When bound to an organic compound, copper does not contribute toxicity. In contrast, researchers have reported that inorganic copper compounds (e.g., hydroxide copper species, CuOH^+ and $[\text{Cu}(\text{OH})_2]^{2+}$) are toxic. However, carbonate species (e.g., CuCO_3) do not make a significant contribution to copper toxicity. The same principles may be applied to other cationic metals, including zinc and cadmium. Biological and physical factors – such quantity of organisms, water temperature, and environmental variability – might also affect bioavailability of heavy metals.

Water quality criteria for cadmium, copper, and zinc relate to individual metals and do not address mixture interactions. However, toxicants generally occur as mixtures in ambient water. Metal mixture interactions are described as additive, more than additive (“synergistic”, more toxic than the sum of the individual components), or less than additive (“antagonistic”, less toxic than the components). Table C-1 in Appendix C summarizes the variety of effects of metal mixture interactions.

4.3 Effects on Biota in the Upper Sacramento River

The continuous release of metals from the IMM site and other mine sites has resulted in historical fish kills and has contributed to a progressive decline in the fisheries population in the Sacramento River (USEPA, 2001b; Rae, 1998; Schwarzbach, 1993; CH2M Hill, 1992; NOAA, 1989). Toxicity to fish is of particular concern because, as noted earlier, the most important salmon habitat in California lies directly downstream of Keswick Dam. Because of the winter-run chinook salmon decline, in May 1989 the NMFS took emergency action to list the winter run chinook salmon as “threatened” under the Federal Endangered Species Act and to designate the Sacramento River from Red Bluff Diversion Dam to Keswick Dam as a critical habitat (USEPA, 2001a). The State of California then classified the winter-run chinook salmon as “endangered” (NOAA, 1989). In January 1994, the NMFS issued its final rule reclassifying the winter-run chinook salmon as an endangered species. The following sections provide a

⁹ In late 1994, Regional Board staff conducted an extensive literature review of cadmium, copper, and zinc toxicity in freshwater aquatic organisms and compiled a report that summarized the literature and tabulated available data in appendices (Reyes, 1994). The reader should refer to the 1994 staff report for original citations.

more detailed description of the documented fish kills, salmonid population decline, and effects on other species.

4.3.1 Documented Fish Kills

Deaths of fish were common in water below Keswick Dam during the mid-20th century (NOAA, 1989; Cooke and Connor, 1998; CH2M Hill, 1992; Michny, 2001). According to actual observations and bioassay-based calculations, more than twenty reported and estimated salmon and steelhead trout fish kills took place in the upper Sacramento River between Keswick Dam and Balls Ferry, California between 1940 (shortly after the construction of the Shasta Dam) and 1986 (CH2M Hill, 1992; NOAA, 1989¹⁰). In addition, river toxicity testing in the late 1930s indicated near lethal concentrations of copper in the Sacramento River upstream of the IMM sites and lethal concentrations of copper downstream of the IMM site (Michny, 2001). The fish kills and river toxicity were associated with acid mine drainage – loaded with cadmium, copper, and zinc – from the Iron Mountain Mines site (NOAA, 1989). There have also been indications that, following an uncontrolled spillage of contaminated water into the Sacramento River, there is a corresponding reduction in the number of adult salmon returning to spawn three to four years after the spillage.

Construction of the SCDD in 1963 reduced the frequency of fish kills, but during extreme storm events, the SCDD can fill beyond capacity, spilling toxic levels of AMD into the Sacramento River (Rae, 1998). Since the late 1970s, major adult fish kills have ceased. However, metals concentrations may be high enough to have sublethal effects on adult fish and to kill eggs and larvae¹¹ (Cooke and Connor, 1998).

4.3.2 Salmonid Population Decline

Historically, metal contamination from the Iron Mountain Mines sites contributed to the progressive decline of spawning populations of chinook salmon and steelhead trout in the upper Sacramento River from the late 1960s to mid-1980s. Other factors have also contributed to the decline of salmonid populations: poor fish passage over the Red Bluff Diversion Dam and high water temperatures in the river

¹⁰ On July 28, 1989, the National Oceanic and Atmospheric Administration (NOAA) released a Findings of Fact for Iron Mountain Mine that reviewed the literature and available data that described the effects of cadmium, copper, and zinc toxicity in freshwater aquatic organisms in the upper Sacramento River below Spring Creek (NOAA, 1989). In addition, the USEPA updated the documentation of fish kills near Redding (1899 to 1986) in their 1992 Endangerment Assessment for IMM (CH2M Hill, 1992). The reader should refer to these documents for the citations for the fish kill data.

are the primary factors; difficult fish passage over the Anderson-Cottonwood Irrigation District Dam, loss of gravel for spawning habitat below Keswick Dam, and predation by hatchery-released steelhead trout and warm water squawfish are probably minor factors.

The fall-run chinook population declined 11.6% between the late 1960s and mid-1980s, and the winter-run population declined 96.8% over the same period; steelhead trout runs have declined by 84.3% during the same period (NOAA, 1989). The greatest decline in salmon spawning populations between 1959 and 1982 occurred in the reach below the Keswick Dam, between the Anderson-Cottonwood Irrigation District Dam in Redding and Balls Ferry (NOAA, 1989). In contrast, spawning from Balls Ferry to the Red Bluff Diversion Dam remained relatively stable during this period and spawning below the diversion dam increased.

The winter-run chinook salmon experienced the most precipitous decline of all salmon populations in the upper Sacramento River (NOAA, 1989). Unlike most salmon that spawn when they reach the spawning ground, the winter-run chinook salmon hold over for several months before they begin spawning (Schwarzbach, 1993). The combination of the several month hold-over and coincidence of any spring-time AMD releases potentially exposes the adults of winter-run salmon to greater metal contamination while on the spawning grounds in the Sacramento River than other salmon runs. Winter-run salmon spawning further downstream at Red Bluff may be at less risk because of the dilution effect of large tributary streams (Schwarzbach, 1993).

4.3.3 *Effects on Other Species*

Researchers have attributed decreased abundance and diversity of benthic invertebrates and aquatic flora in the Sacramento River downstream from the mouth of Spring Creek and changes in benthic invertebrate and changes in benthic invertebrate communities in the Sacramento River near Redding to elevated levels of trace metals in the system (NOAA, 1989). There is no current evidence of acute or chronic heavy metals toxicity to humans due to consumption of water or fish from the upper Sacramento River.

¹¹ Direct evidence is difficult to find in fast-flowing waters (Cooke and Connor, 1998). Cooke and Connor's review of water quality data and toxicity tests in laboratory settings indicates that metals concentrations in the upper Sacramento River are high enough to kill eggs and larvae.

5 SOURCE ANALYSIS

5.1 Introduction

The source analysis evaluates pollutant sources and documents estimates of the various pollutant loads to the impaired waterbody. The Regional Board staff's source analysis has the following components:

- Identification of dissolved cadmium, copper, and zinc sources in the upper Sacramento River watershed.
- Identification of available flow and dissolved metal concentration data.
- Development of methods used to estimate the source contributions.
- Quantification of dissolved metal source contributions to the upper Sacramento River.

This chapter addresses the daily dissolved copper, cadmium, and zinc loads each source contributes to the upper Sacramento River. Chapter 7 describes the relationship between the sources' daily dissolved metal loads, dissolved metal concentrations in the upper Sacramento River, and the exceedance of water quality objectives.

5.2 Sources of Cadmium, Copper, and Zinc in the Upper Sacramento River Watershed

Regional Board staff conducted a search of available project and permit files, published literature, and USGS topographic maps to identify the potential sources of cadmium, copper, and zinc to the upper Sacramento River. Staff identified several types of potential cadmium, copper, and zinc sources in the watershed:

Point sources:

- Metal mine sites with AMD such as portals and tailings.
- Treated effluent from municipal wastewater treatment plants.
- Industrial dischargers within municipal service areas.
- Other National Pollutant Discharge Elimination System (NPDES) dischargers.

Nonpoint sources:

- Acid seeps from abandoned mines and other diffuse sources.
- Municipal stormwater runoff.
- Erosion of naturally occurring metals-enriched soils.

Table 5-1 lists potential metal dischargers and their receiving waters and Figure 5-1 illustrates the locations of potential sources. Regional Board staff included on Table 5-1 only those mines known to

Locator # on Figure 5-1	Site	Receiving Waterbody	Receiving Waterbody Discharges to the Sacramento River:		
			Upstream of Shasta Dam	Between Shasta Dam and Keswick Dam	Downstream of Keswick Dam
Mines					
1	Afterthought Mine	Little Cow Creek			X
2	Balaklala Mine	West Squaw Creek	X		
3	Bully Hill Mine	Town Creek	X		
4	Early Bird Mine	West Squaw Creek	X		
5	Golinski Mine	Little Backbone Creek	X		
6	Gossen Mine	Little Backbone Creek	X		
7	Greenhorn Mine	Willow Creek ^(a)		X	X
8	Iron Mountain Mines	Boulder, Slickrock, & Spring Creeks		X	
9	Keystone Mine	West Squaw Creek	X		
10	Mammoth Mine	Little Backbone Creek	X		
11	Rising Star Mine	Horse Creek	X		
12	Shasta King Mine	West Squaw Creek	X		
13	Stowell Mine	Spring Creek/Flat Creek		X	
14	Sutro Mine	Little Backbone Creek	X		
Wastewater Treatment Plants					
15	City of Anderson Water Pollution Control Plant	Sacramento River			X
16	City of Redding Clear Creek Wastewater Treatment Plant	Sacramento River			X
17	City of Redding Stillwater Wastewater Treatment Plant	Sacramento River			X
18	City of Red Bluff Wastewater Reclamation Plant	Sacramento River			X
19	City of Shasta Lake Wastewater Treatment Facility	Churn Creek			X
20	Rio Alto Water District – Lake California Wastewater Treatment Plant	Sacramento River			X
21	Shasta County Cottonwood Wastewater Treatment Plant	Cottonwood Creek			X
Water Treatment Plants					
22	Bella Vista Water District – Water Treatment Plant	Churn Creek			X
23	City of Shasta Lake Water Treatment Plant	Churn Creek			X

Table 5-1. Potential Metal Dischargers in the Upper Sacramento River Watershed					
Locator # on Figure 5-1	Site	Receiving Waterbody	Receiving Waterbody Discharges to the Sacramento River:		
			Upstream of Shasta Dam	Between Shasta Dam and Keswick Dam	Downstream of Keswick Dam
24	Clear Creek Community Services District – Water Treatment Plant	Clear Creek			X
Industrial Facilities & Municipalities					
25	Calaveras Cement Company	Stillwater Creek			X
26	Crystal Creek Aggregate, Inc.	Rock Creek			X
27	Mountain Gate Limestone Quarry	Stillwater Creek			X
28	Northstate Asphalt, Inc.	Clear Creek			X
29	Pactiv Corporation –Pulp Mill	Sacramento River			X
30	Shasta Paper Company, Inc. – Shasta Pulp Mill	Sacramento River			X
31	J.F. Shea Company, Inc. – Fawndale Rock and Asphalt	Stillwater Creek			X
32	Sierra Pacific Industries – Anderson Division Facility	Sacramento River			X
33	Sierra Pacific Industries – Shasta Lake Division Facility	Churn Creek			X
34	Siller Brothers, Inc. – Sawmill Facility	Small unnamed tributary to the Sacramento River			X
35	Wheelabrator Shasta Energy Company – Cogeneration Facility	ACID canal tributary to Cottonwood Creek			X
36	Wisconsin-California Forest Products, Inc. – Latona Road Sawmill	Small unnamed tributary to the Sacramento River			X
Fish Hatcheries					
37	USFWS Coleman National Fish Hatchery	Battle Creek			X
38	Mt. Lassen Trout Farms: six hatcheries in the Battle Creek watershed and two hatcheries in the Paynes Creek watershed.	Battle Creek/Paynes Creek			X
39	USFWS/USBR Winter Run Fish Rearing Facility	Sacramento River		X	
40	CDFG Darrah Springs Hatchery	Battle Creek			X

(a) Greenhorn Mine discharges to Willow Creek, a tributary to Whiskeytown Lake, which ultimately drains to either Spring Creek via Spring Creek Tunnel, or to Sacramento River downstream of Keswick Dam via Clear Creek.

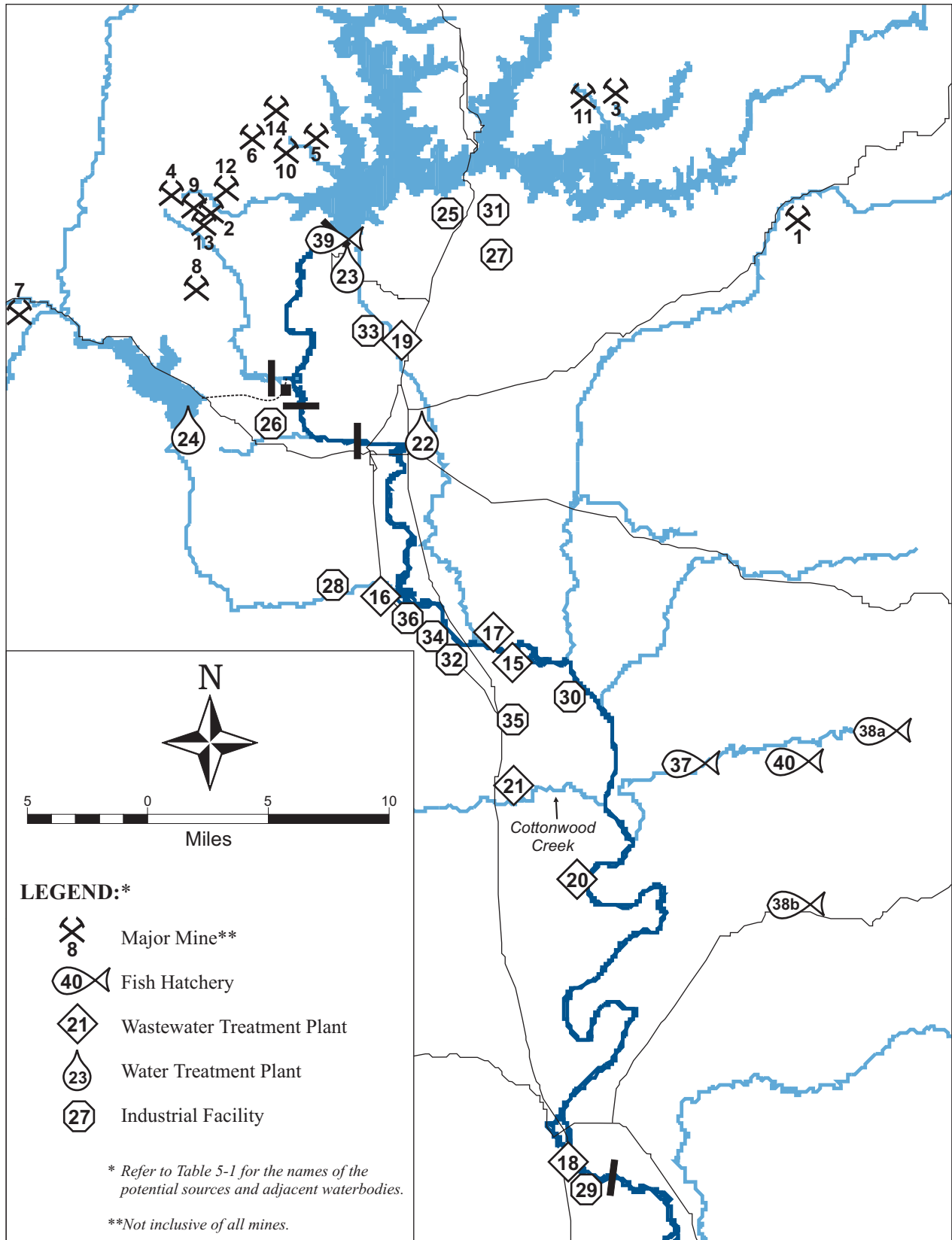


Figure 5-1. Approximate Locations of Potential Metal Sources within the Upper Sacramento River Watershed

produce notable quantities of AMD. However, there are countless named and unnamed mine sites, tailings, prospects, and other mine features throughout the upper Sacramento River watershed, including the Cottonwood Creek watershed, for which no concentration or load data are available. (Refer to Chapter 3 for a description of AMD production and a brief history of mining in the upper Sacramento River watershed.)

5.3 Available Data

Regional Board staff calculated source load values using the available dissolved metals concentration data and flow data from gauging stations near the source locations. Since the 1940s, Federal and State agencies have collected thousands of water samples from the upper Sacramento River and several of its tributaries for the analysis of total metals. Agencies began to analyze water samples for dissolved metals more frequently during the 1980s. Regional Board staff used dissolved metal concentration data to calculate source loads because dissolved metal concentrations more closely approximate the bioavailable fraction of the metal in the water column than do total recoverable metal concentrations.

Staff analyzed data collected and compiled by the Regional Board, USGS, USBR, City of Redding, CDFG, and CH2M Hill (a contractor for the USEPA). As noted in Chapter 2, the data were generated using several methods to collect and analyze the water samples; therefore, there were varying quality control methods used in the field and several different analytical method detection limits. Many of the dissolved metal concentrations (especially the dissolved cadmium concentrations) are reported at levels approaching the laboratory method detection limits and reporting accuracy varies. The following sections describe how Regional Board staff addressed the limitation of the available data. Appendix A provides plots of all available dissolved concentration data.

Staff calculated source loads using the dissolved concentration data for the October 1995 to September 2000 period, as defined by water year, because water year 1996 was the first year for which the IMM on-site lime neutralization plant was operational the entire year (refer to USEPA ROD4 for a comprehensive description of IMM site remediation activities). As noted in Chapters 2 and 3, notable reductions in the frequency and magnitude of exceedances of water quality standards on the Sacramento River have occurred during the past ten years. The timing of these reductions corresponds to load reductions resulting from remediations completed at mine sites in the Shasta Lake region, especially at the IMM site (e.g., operation of a temporary lime neutralization plant during the high-flow seasons of 1989

through 1993, and continuous year-round treatment since 1994), and from USBR's dilution of IMM AMD with Shasta Dam releases (when feasible).

Table 5-2 identifies the locations for which dissolved concentration data are available. As the comparison of Tables 5-1 and 5-2 indicates, dissolved metal concentration data are not available for the majority of potential metal sources identified in the upper Sacramento River watershed, nor for the countless named and unnamed mine features located throughout the watershed. Regional Board staff compensated for this lack of source data by using data available from Sacramento River gages below Keswick Dam (Keswick Reservoir outflow) and above Bend Bridge. These gages act as "monitoring points" because they provide information about the cumulative loads from all point and nonpoint sources upstream of Keswick Dam and Bend Bridge, respectively. Section 5.6 describes the use of monitoring point data to calculate dissolved metal mass balances and water balances in order to evaluate metal transport processes and to indirectly assess whether unmonitored metal sources (e.g., erosion of naturally occurring metals-enriched soils) made measurable contributions to the Sacramento River. Data sets for the Shasta Dam outflow and Keswick Dam outflow are the most comprehensive of all the location-specific data sets. Data collected at other sites are more sporadic and provide only periodic glimpses of load fluctuations. Of the three metals, dissolved cadmium concentration data sets had the least amount of information.

Table 5-3 identifies the available flow data for the upper Sacramento River watershed. Typically, the availability of dissolved metal concentration data was the limiting factor for developing source load calculations. The flow record for Cottonwood Creek was the exception; concentration data were sometimes available on dates for which no flow data were available. As noted in Chapter 2, the data were generated using several methods to collect and analyze the water samples; therefore, there were varying quality control methods used in the field and several different analytical method detection limits. Many of the dissolved metal concentrations (especially the dissolved cadmium concentrations) are reported at levels approaching the laboratory method detection limits and reporting accuracy varies. The following sections describe how Regional Board staff addressed the limitation of the available data.

Table 5-2. Dissolved Metal Concentration Data Coverage for the Upper Sacramento River

Sampling Location (upstream to downstream)	Data Source ^(a)	Sources Addressed by This Monitoring Location
Sacramento River below Shasta Dam (Shasta Dam outflow)	CVRWQCB, CH2M Hill, USGS-SRTMS, USBR, City of Redding, CDFG	Point and nonpoint sources upstream of Shasta Dam, including AMD from mines.
Spring Creek below Spring Creek Debris Dam	CH2M Hill, USGS-SRTMS, USBR ^(b)	AMD from the Iron Mountain Mine complex.
Spring Creek Power Plant outflow (a portion of Whiskeytown Lake water)	CVRWQCB, CH2M Hill, USGS-SRTMS	Mines and other point and nonpoint sources in the Whiskeytown Lake watershed. ^(c)
Sacramento River below Keswick Dam (Keswick Dam outflow)	USBR, CVRWQCB, CH2M Hill, USGS-SRTMS, CDFG	All point and nonpoint sources upstream of Keswick Dam.
Stillwater Wastewater Treatment Plant (WWTP) Outflow	City of Redding	WWTP discharge.
Clear Creek WWTP Outflow	City of Redding	WWTP discharge.
Little Cow Creek	DWR	Afterthought Mine
Cottonwood Creek	CH2M Hill	Cottonwood Creek and its tributaries
Sacramento River above Bend Bridge	USGS-SRTMS & NAWQA	All sources upstream of Bend Bridge.

- (a) Data sources: CDFG (CH2M Hill, 2001), CH2M Hill (CH2M Hill, 2001), City of Redding (Ames, 2001; Craig and Elliott, 1999), CVRWQCB (CH2M Hill, 2001; Heiman, 2001), DWR (DWR, 1985, USBR (CH2M Hill, 2001; Wisniewski, 2001), USGS-NAWQA (USGS National Water-Quality Assessment: CH2M Hill, 2001; Domagalski et al., 2000), USGS-SRTMS (USGS Sacramento River Trace Metals Study: CH2M Hill, 2001; Domagalski et al., 2000).
- (b) Because of the scarcity of dissolved metal concentration data and the relative abundance of total metal concentration data for SCDD releases, Regional Board staff converted the available total metal concentrations to dissolved values using the acute conversion factors presented in the Code of Federal Regulations, Title 40, Part 131, Section 36(b)(1) and (2). The conversion factors for copper and zinc are 0.96 and 0.978, respectively. The conversion factor for cadmium is a hardness-dependent equation: $[1.136672 * (\ln \text{hardness})^{0.041838}]$. Published studies, as well as the staff's review of available data, indicate that dissolved and total concentrations are approximately equal in SCDD releases; therefore, Regional Board staff considers the conversion factors to be appropriate for SCDD releases.
- (c) Whiskeytown Lake drains to either Spring Creek via Spring Creek Tunnel or to the Sacramento River downstream of Keswick Dam via Clear Creek.

Table 5-3. Flow Data Coverage for the Upper Sacramento River

Sampling Location (Upstream to Downstream)	Data Source	Type of Data	Data Availability
Sacramento River below Shasta Dam	CDEC ^(a)	Daily	1996-2001 (continuous)
Spring Creek below Spring Creek Debris Dam	CH2M Hill	Daily	1963-2001 (continuous)
Spring Creek Power Plant outflow	CH2M Hill	Daily	1964-2001 (continuous)
Sacramento River below Keswick Dam	CDEC	Daily	1993-2001
Stillwater and Clear Creek WWTPs Outflow	City of Redding	Monthly	Dec 1992-May 1993, Jan 1998-Dec 1998
Little Cow Creek	DWR	3 Sampling Events	1984 ^(b) (periodic)
Cottonwood Creek	CDEC	Hourly ^(c)	1984-2001 (continuous)
Sacramento River above Bend Bridge	CDEC	Daily	1993-2001 (continuous)

- (a) CDEC: California Department of Water Resources California Data Exchange Center (<http://cdec.water.ca.gov>)
- (b) See Appendix D for description of available data.
- (c) Because few concentration data sets were available for Cottonwood Creek, Regional Board staff used the highest hourly flow on a given day with concentration data to calculate conservative metal load estimates.

5.4 Source Load Calculation Methods

The calculation of a mass of a constituent in a given volume of water is:

$$M_x = C_x \times V$$

Where: M_x = Mass of constituent, X
 C_x = Concentration of constituent, X, in mass per volume
 V = Volume of water

Regional Board staff used two methods to calculate daily source loads for flowing systems. If both dissolved metal concentration and flow data were available for a given source or monitoring location, staff used the following equation, a variation of the above equation developed for flowing systems, to calculate the mass of a particular metal (CVRWQCB, 1998b):

$$m_x = C_x \times Q$$

Where: m_x = Mass of metal, X, per unit time
 C_x = Dissolved concentration of metal, X, in mass per volume
 Q = Volumetric flow rate.

If more than one concentration value was available for a given day, staff chose the maximum (conservative) value to calculate the load for that day. If the only available metal concentration value for a given day was lower than the associated laboratory method detection limit (MDL), and the MDL was lower than the Basin Plan water quality objective, staff used ½ the MDL to estimate loads for that day. An “x” symbol represents all such estimated load values on the plots in this chapter and in Appendix E. However, if the MDL was higher than the Basin Plan water quality objective for that metal, staff did not calculate a load for that day because such a calculation would almost certainly over-estimate the daily load. Figure 5-2 provides an example of how Regional Board staff calculated loads using data provided in different units of measure. In addition, Appendix D describes how Regional Board staff calculated loads for Afterthought Mine, a metal source for which very little dissolved metal concentration information was available.

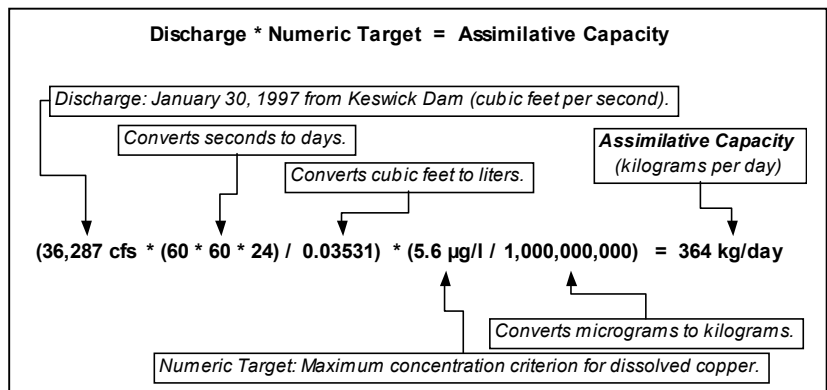


Figure 5-2. Load Calculation Example

Regional Board staff used a different method to estimate stormwater metal loads for the municipalities of Redding, Lake Shasta City, and Anderson because no concentration or runoff information was available for calculating loads using the above equation. Staff instead had to estimate stormwater runoff and metal loads using the following equations:

$$Q_e = Rf \times A \times RC$$

- Where:
- Q_e = Estimated volumetric runoff rate
 - Rf = Daily rainfall amount typically associated with intense (but not worst-case) storms in the watershed.
 - A = Municipal area
 - RC = Runoff coefficient

$$m_e = C_{Sac} \times Q_e$$

- Where:
- m_{e-x} = Estimated mass of constituent, X, per unit time
 - C_{Sac-x} = Maximum dissolved concentration of constituent, X, in mass per volume (as measured by the Sacramento Stormwater Program for the Sacramento region)
 - Q_e = Estimated volumetric runoff rate

Appendix D provides a more detailed description of the stormwater load calculations and includes the staff's assumptions inherent in the calculations.

5.5 Evaluation of Source Loads

As noted earlier, dissolved metal concentration data were not available for the majority of metal sources identified in the upper Sacramento River. Regional Board staff had dissolved metal concentration and flow data for the following sources:

- Shasta Dam reservoir;
- IMM site via SCDD;
- Whiskeytown Lake releases via Spring Creek Tunnel/Power Plant (SCPP);
- City of Redding Stillwater and Clear Creek Wastewater Treatment Plants;
- Afterthought Mine; and
- Cottonwood Creek.

In addition, staff estimated load values for City of Redding, Lake Shasta City, and Anderson stormwater discharges. The following text describes the source load values that Regional Board staff calculated and

identifies which of the monitored sources appear to contribute the most dissolved copper, cadmium, and zinc to the upper Sacramento River. Figure 5-3 compares the dissolved copper load calculations for Shasta Dam and SCDD releases to their corresponding release flows to demonstrate seasonality and relationship with flow. Figures E-1, E-2, and E-3 in Appendix E illustrate the dissolved copper, zinc, and cadmium load calculations for all the sources upstream of Keswick Dam (i.e., the Shasta Dam, SCDD, SCPP release loads). Figures 5-4 through 5-12 illustrate the dissolved copper, zinc, and cadmium load calculations for the monitored sources downstream of Keswick Dam.

Although concentration data were not available for the other potential sources (e.g., other NPDES-permitted sources), Regional Board staff was able to indirectly assess whether these unmonitored sources made measurable contributions to the Sacramento River by calculating dissolved metal mass balances and water balances for (1) Keswick Reservoir and (2) Sacramento River from Keswick Dam to Bend Bridge. Section 5.6 describes the evaluation of these balances and reviews the results of the mass balance calculations.

5.5.1 Dissolved Copper Source Loads

Figure E-1 in Appendix E illustrates the daily loads of dissolved copper from sources upstream of Keswick Dam, i.e., the IMM site (via SCDD), Shasta Dam releases, and SCPP releases. The figure illustrates several key characteristics of the dissolved copper loads:

- Spring Creek Power Plant releases contributed much less dissolved copper compared to the loads contributed by the IMM site and Shasta Lake. Both the general loading trends and the maximum daily loads measured for each of the sources during the 5-year study period highlight this characteristic. SCDD annual maximum daily loads ranged from 125 to 1,121 kg/day, Shasta Dam annual maximum daily loads ranged from approximately 164 to 466 kg/day, and SCPP annual maximum daily loads ranged from 7 to 21 kg/day, with one anomalously high value of 200 kg/day in February 1996 (a time period when SCDD and Shasta Dam releases did not have unusually high load values).
- SCDD annual maximum daily loads exceeded the other source loads for four out of five of the study years. As indicated by Figure F-1, Shasta Dam releases appeared to contribute more dissolved copper load than the SCDD releases during the wet season of water year 1999. In addition, Shasta daily loads were often comparable to SCDD loads during non-peak periods during the wet season.
- Shasta Dam loads typically exceed SCDD loads during the dry season. Figure 5-3 shows that Shasta Dam discharges continue throughout the dry season, while SCDD often has periods of low-to-no flow, which explain the difference in load patterns.
- Dissolved copper loads from the IMM site and Shasta Reservoir have considerable seasonal variability. Higher loads most often occurred during the December-to-April period.

Figure 5-3 illustrates the correlation between high flows and loads below Shasta Dam and SCDD.

Figure 5-4 illustrates the daily loads of dissolved copper calculated using available concentration data for the City of Redding Stillwater and Clear Creek Wastewater Treatment Plants effluent, Cottonwood Creek, and Keswick Dam releases. Figure 5-5 illustrates the maximum daily loads estimated for Afterthought Mine AMD and City of Redding, Lake Shasta City, and Anderson stormwater runoff.

Figures 5-4 and 5-5 illustrate several key characteristics of the dissolved copper loads:

- Dissolved copper loads from the Stillwater and Clear Creek Wastewater Treatment Plants did not exceed 0.1 and 0.3 kg/day, respectively, and had very low variability during the two periods (December 1992 through May 1993 and January through December 1998) data were available.
- Regional Board staff estimated that City of Redding stormwater runoff contributes a maximum daily dissolved copper load of approximately 3.0 kg/day during moderately intense storms. This estimate indicates that the City of Redding stormwater runoff contributes more dissolved copper than the wastewater treatment plants. However, stormwater runoff is not continuous throughout the year because storms are intermittent and typically occur only during the wet season. Lake Shasta City and Anderson stormwater runoff contribute a maximum daily dissolved copper load of approximately 0.3 kg/day each.
- Regional Board staff estimated that Afterthought Mine contributes a maximum daily dissolved copper load of approximately 2.2 kg/day to the Sacramento River. Staff based the estimate on concentration data available for multiple locations downstream of the mine during April, June, and August 1984; more recent data adequate for the source analysis were unavailable. Staff considers this a conservative estimate for two main reasons. First, staff selected concentration data for the sampling site nearest the mine (i.e., 0.05 miles downstream of the mine) on the day with the highest flow. In addition, staff assumed that no deposition occurs along the twenty-three mile reach of Little Cow Creek between the mine and the Little Cow Creek-Sacramento River confluence. Staff has identified no other metal sources between Afterthought Mine and the upper Sacramento River.
- Because few concentration data sets were available for Cottonwood Creek, Regional Board staff used the highest hourly flow on a given day with concentration data to calculate conservative metal load estimates. Seventeen of the nineteen available sample dates had dissolved copper loads ranging between approximately 0.02 and 9.5 kg/day, and three dates had loads ranging between 24.4 and 48.8 kg/day. Previous researchers have observed that Cottonwood Creek is a relatively significant source of metals during periods of extensive rainfall runoff; however, elevated loads of total recoverable metals were associated with the colloidal forms rather than dissolved metals (CVRWQCB, 1998c; Alpers et al., 2000). This analysis indicates that Cottonwood Creek may be the biggest contributor of dissolved and/or colloidal copper to the Sacramento River downstream of Keswick Dam (not including Keswick Dam releases).

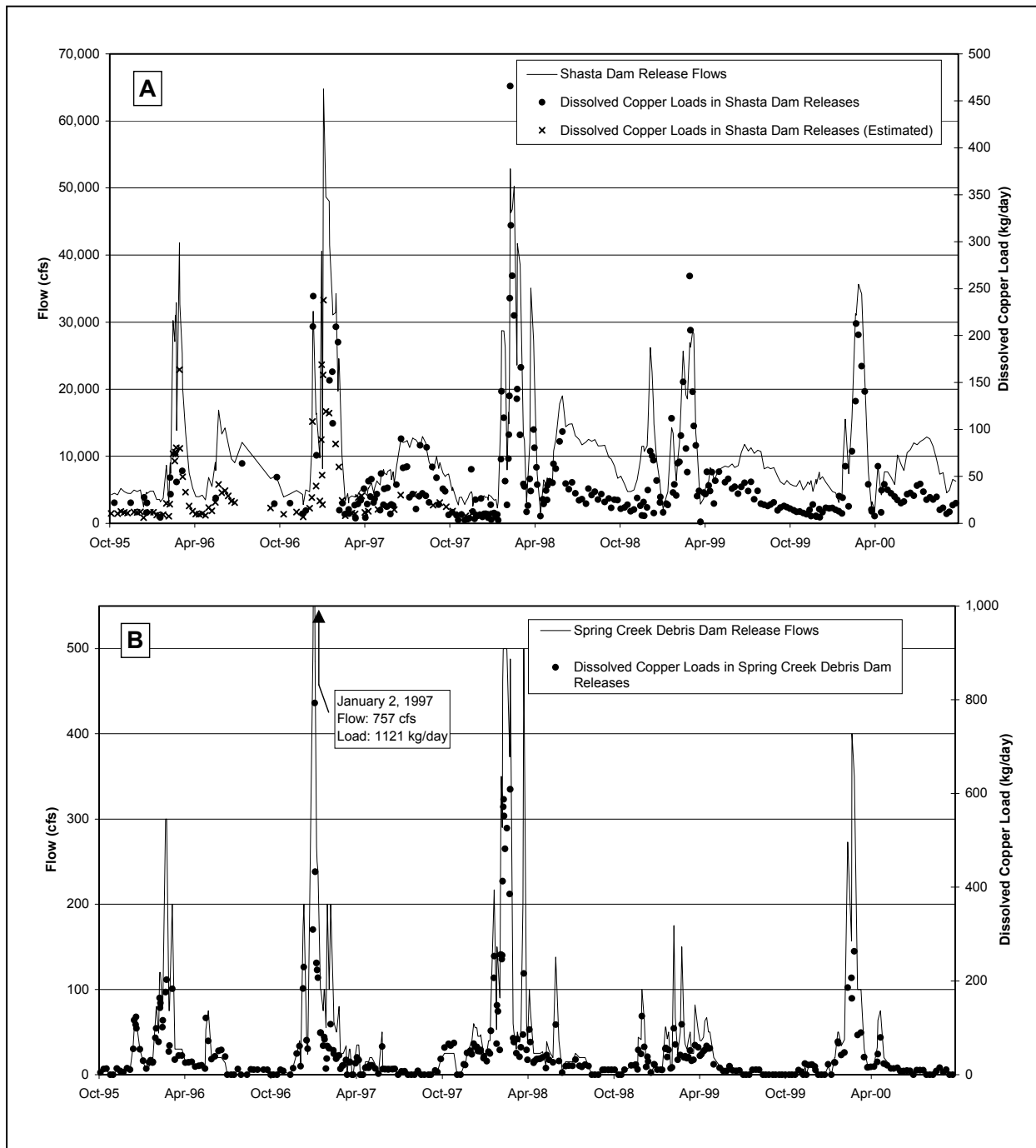


Figure 5-3. Comparison of Flows and Loads
 A. Shasta Dam Releases
 B. Spring Creek Debris Dam Releases

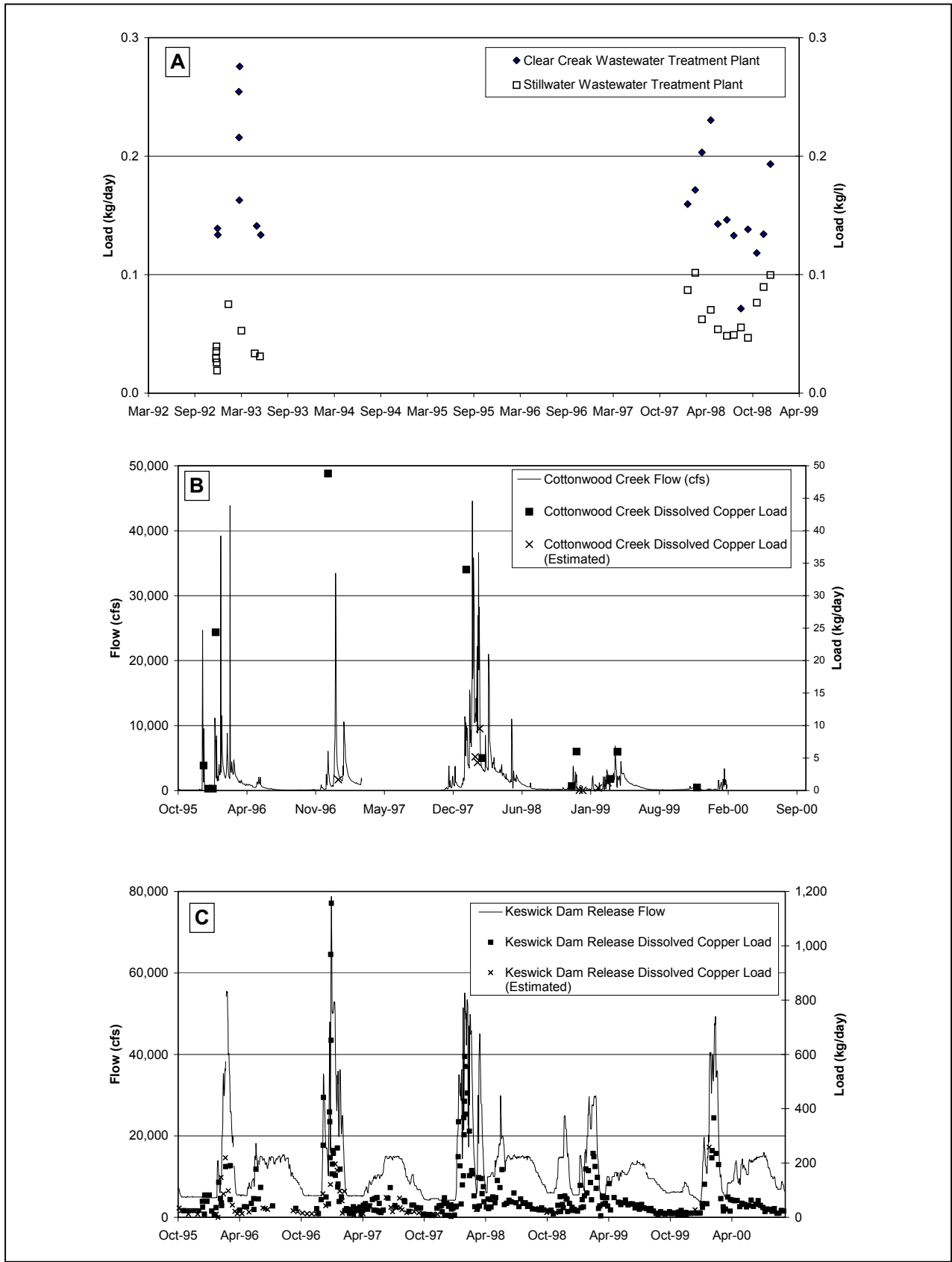


Figure 5-4. Dissolved Copper Loads for Sources Downstream of Keswick Dam
 A. Clear Creek and Stillwater Wastewater Treatment Plants, B. Cottonwood Creek,
 & C. Keswick Dam Releases.

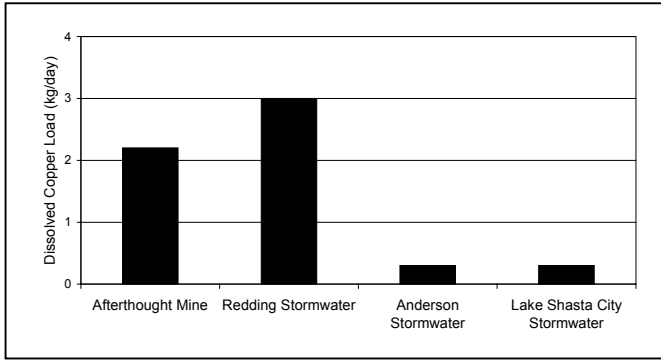


Figure 5-5. Estimated Maximum Dissolved Copper Loads for Afterthought Mine AMD and City of Redding, Lake Shasta City, and Anderson Stormwater Runoff

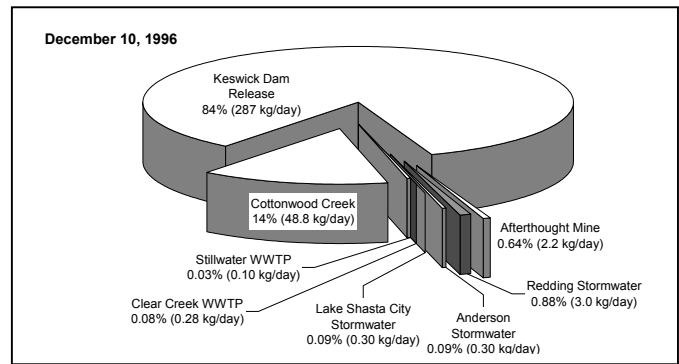


Figure 5-6. Dissolved Copper Loading Pattern for Sources Downstream of Keswick Dam

Regional Board staff chose two dates that had dissolved copper data for both Cottonwood Creek and Keswick Dam to compare to the maximum daily loads of the other sources in order to illustrate the differences in loading patterns. Figure 5-6 shows the maximum daily loads estimated or recorded during the 1995-2000 study period for sources other than Cottonwood Creek and Keswick Dam.¹² Figure 5-6 shows the typical scenario: Keswick Dam releases of dissolved copper loads exceed the sum of the loads from the wastewater treatment plants, municipal stormwater runoff, Afterthought Mine, and Cottonwood Creek. (Note, the highest recorded Cottonwood Creek load of 48 kg/day was measured on the day illustrated by Figure 5-6, and is based on the highest hourly flow recorded that day.) However, occasionally Cottonwood Creek dissolved copper loads are greater than loads released by Keswick Dam (e.g., January 18, 1996). This alternate scenario seems to occur when a storm passes over both the Cottonwood Creek watershed and the watershed upstream of Keswick Dam, but the USBR does not increase Keswick Dam release flows.

5.5.2 Dissolved Zinc Loads

Figure E-2 in Appendix E illustrates the daily loads of dissolved zinc in SCDD, Shasta Dam, and SCPP releases. The figure illustrates that dissolved zinc loads have the same key characteristics as the dissolved copper loads from these sources:

- Spring Creek Power Plant releases contributed small amounts of dissolved zinc compared to the loads contributed by SCDD and Shasta Dam releases.

¹² Because of the limited data for the Stillwater and Clear Water treatment plants, staff selected the maximum load values for the entire period of record rather than the 1995-2000 period.

- Dissolved zinc loads in SCDD and Shasta Dam releases had considerable seasonal variability, with higher loads most often occurring during the December-to-April wet season.
- Shasta Dam releases of dissolved zinc exceeded SCDD releases during the four of the five wet seasons included in the study period. Estimates of Shasta Dam loads during the dry seasons indicated that Shasta Dam loads may have exceeded SCDD loads during the dry season as well.

Figure 5-7 illustrates the daily loads of dissolved zinc calculated using available concentration data for the City of Redding Stillwater and Clear Creek Wastewater Treatment Plants effluent, Cottonwood Creek, and Keswick Dam releases. Figure 5-8 illustrates the maximum daily loads estimated for Afterthought Mine AMD and City of Redding, Lake Shasta City, and Anderson stormwater runoff. These figures indicate that dissolved zinc loads have the same key characteristics as the dissolved copper loads:

- Dissolved zinc loads from the Stillwater and Clear Creek Wastewater Treatment Plants did not exceed 0.6 and 1.4 kg/day, respectively, and had very little variability.
- Regional Board staff's calculations indicate that City of Redding stormwater runoff contributes a maximum daily dissolved zinc load of approximately 43 kg/day, which is greater than dissolved zinc loads contributed by the wastewater treatment plants. Lake Shasta City and Anderson stormwater runoff each contribute a maximum daily dissolved zinc load of approximately 4.8 kg/day. Afterthought Mine contributes a maximum daily dissolved zinc load of approximately 9.3 kg/day to the Sacramento River. (Appendix D describes the Afterthought Mine and stormwater load calculations and assumptions.)
- Regional Board staff's calculations indicated that Cottonwood Creek dissolved zinc concentrations and loads increased with increases in flow. The nineteen sample dates had dissolved zinc loads approximately ranging between less than 1 kg/day and 329 kg/day. Of the sources downstream of Keswick Dam, Cottonwood Creek appears to be the biggest contributor of dissolved zinc to the Sacramento River downstream of Keswick Dam.

Figure 5-9 shows the typical scenario: Keswick Dam releases of dissolved zinc loads exceed the sum of the loads from the wastewater treatment plants, municipal stormwater runoff, Afterthought Mine, and Cottonwood Creek. Even on a day on which Cottonwood Creek had an unusually high daily dissolved zinc load (329 kg/day on February 24, 1998), Keswick Dam releases of dissolved zinc greatly exceeded Cottonwood Creek loads.

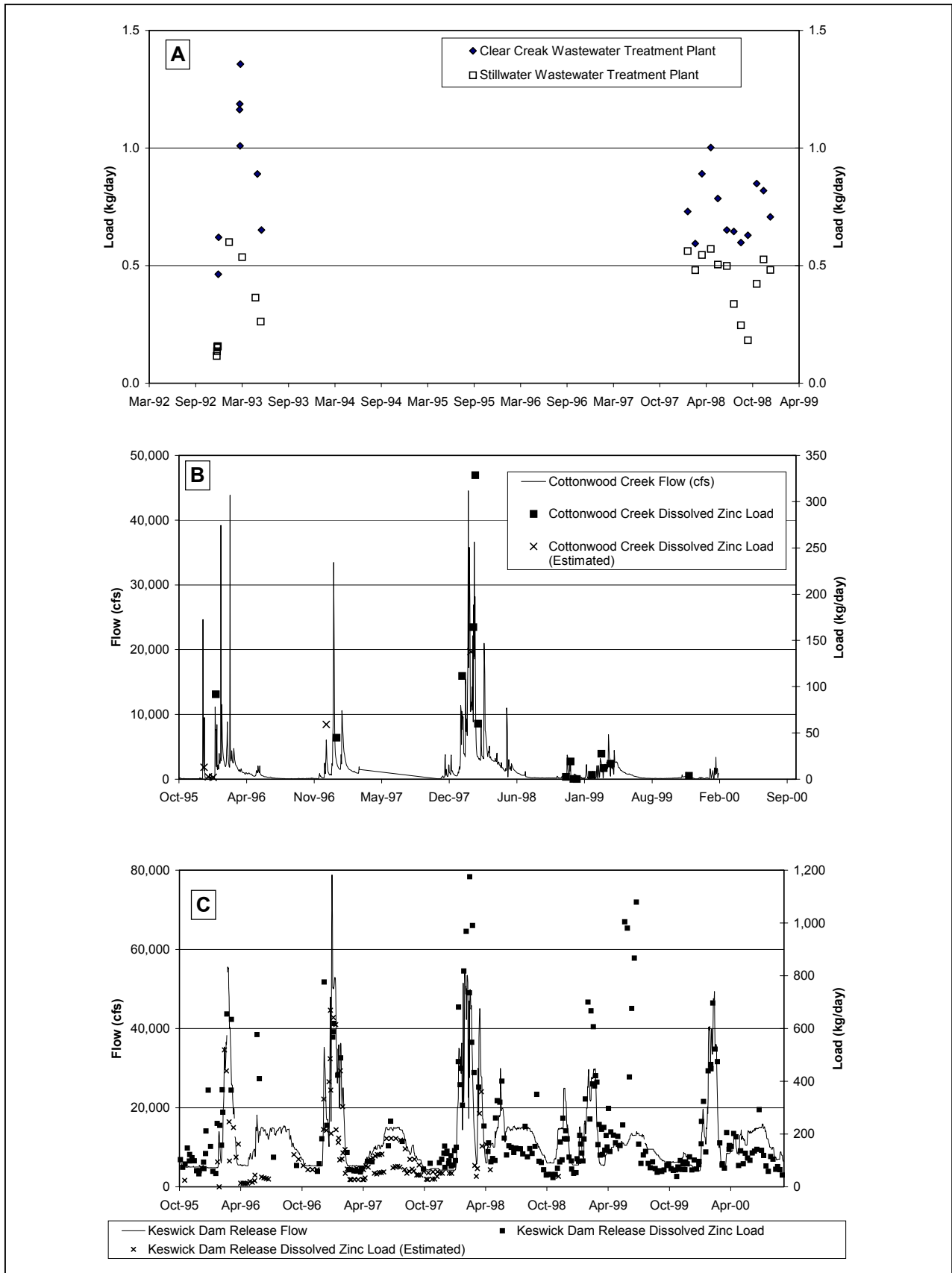


Figure 5-7. Dissolved Zinc Loads for Sources Downstream of Keswick Dam
 A. Clear Creek and Stillwater Wastewater Treatment Plants, B. Cottonwood Creek,
 & C. Keswick Dam Releases.

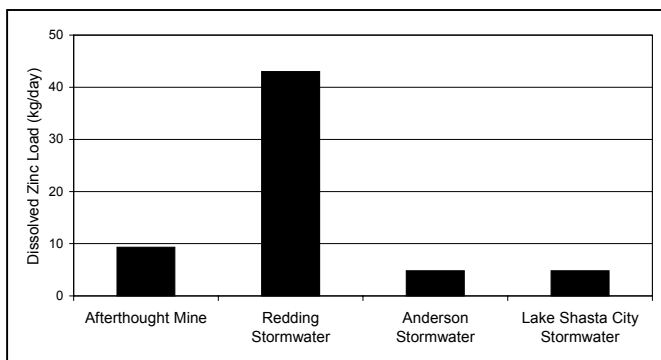


Figure 5-8. Estimated Maximum Dissolved Zinc Loads for Afterthought Mine AMD and City of Redding, Lake Shasta City, and Anderson Stormwater Runoff

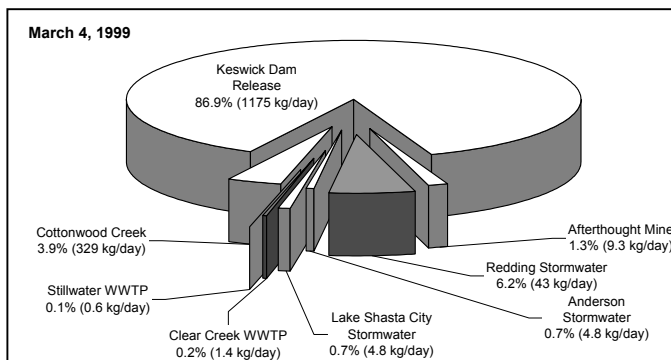


Figure 5-9. Dissolved Zinc Loading Pattern for Sources Downstream of Keswick Dam

5.5.3 Dissolved Cadmium Loads

Very little dissolved cadmium data were available compared to the relative abundance of the copper and zinc data. Regional Board staff's analysis of dissolved cadmium loads had the following constraints:

- SCPP Releases.** Eleven water samples collected between December 1995 and February 1998 had concentration data adequate for calculating dissolved cadmium loads (i.e., the laboratory MDLs were lower than the Basin Plan water quality objective of 0.22 µg/l). Of those samples, nine had dissolved cadmium levels below the MDL of 0.1 µg/l. Regional Board staff used ½ the MDL to estimate loads for these dates. The USGS analyzed the two samples with dissolved cadmium levels (0.013 µg/l and 0.011 µg/l on December 11, 1996 and May 9, 1997, respectively) detected above their MDL using a method with a much lower MDL than the methods used to analyze the other samples. This may imply that very minor quantities of dissolved cadmium are present in SCPP releases, and that the loads estimated using ½ the MDL may over-estimate the actual loads.
- Shasta Dam Releases.** Thirteen water samples collected between December 1995 and February 1998 had concentration data adequate for calculating dissolved cadmium loads. Of those samples, eight had dissolved cadmium levels below the MDL of 0.1 µg/l. Regional Board staff used ½ the MDL to estimate loads for these dates. A comparison of the load values calculated for these dates to other load values indicate that, except for the estimates calculated for February 1998 dates, the estimated loads are comparable to the other load values. As noted on Figure A-3 in Appendix A, several samples taken during that period had detection limits greater than the Basin Plan water quality objective; these data values were not included in the source analysis.
- SCDD Releases.** Twenty-six water samples collected between October 1995 and January 1999 had concentration data adequate for calculating loads. All of these water samples had dissolved cadmium concentrations above their MDLs.

Figure E-3 in Appendix E illustrates the daily loads of dissolved cadmium from SCDD, Shasta Dam, and SCPP releases, calculated using the available dissolved cadmium data. Given the data limitations, the available dissolved cadmium data indicate that dissolved cadmium loads have the following general characteristics:

- SCPP releases contributed less dissolved cadmium than SCDD and Shasta Dam releases.
- SCDD peak load values were typically higher than Shasta Dam load values. However, Shasta Dam and SCDD releases appear to discharge comparable amounts of dissolved cadmium to Keswick Reservoir during non-peak times.

As with the sources upstream of Keswick Dam, a very small quantity of dissolved cadmium data was available for downstream sources. Only three water samples from Cottonwood Creek were analyzed for dissolved cadmium. CH2M Hill collected the water samples from Cottonwood Creek during the 1995-1996 water year. All three samples had cadmium levels below laboratory MDLs, which were well below the Basin Plan water quality objective (0.22 µg/l). Regional Board staff used ½ the detection limit to estimate loads for the three sample dates.

Figure 5-10 illustrates the daily loads of dissolved cadmium calculated using available concentration data for the City of Redding Stillwater and Clear Creek Wastewater Treatment Plants effluent, and Keswick Dam releases. Figure 5-11 illustrates the maximum daily loads estimated for Afterthought Mine AMD and City of Redding, Lake Shasta City, and Anderson stormwater runoff, and Cottonwood Creek.

Figure 5-12 compares the downstream source loads to Keswick Dam release loads. The figures indicate the following characteristics:

- Maximum daily dissolved cadmium loads calculated for the Stillwater and Clear Creek Wastewater Treatment Plants were approximately 0.025 and 0.009 kg/day, respectively. In January 1998, the City of Redding began using “clean” sampling techniques (Ames, 2001; Craig and Elliott, 1999), which, as illustrated on Figure 5-10A, appeared to cause a decrease in the variability and magnitude of dissolved cadmium loads. The maximum daily load measured during the more recent sampling efforts for both treatment plants was 0.002 kg/day.
- Regional Board staff’s calculations indicate that City of Redding stormwater runoff contributes a maximum daily dissolved cadmium load of approximately 0.097 kg/day, which is greater than dissolved cadmium loads contributed by the wastewater treatment plants. Lake Shasta City and Anderson stormwater runoff each contribute a maximum daily dissolved cadmium load of approximately 0.011 kg/day. Afterthought Mine contributes a maximum daily dissolved cadmium load of approximately 0.08 kg/day to the Sacramento River. (Appendix D describes the Afterthought Mine and stormwater load calculations and assumptions.)
- The maximum daily load estimated for Cottonwood Creek was 0.16 kg/day, indicating that it may be the biggest contributor of dissolved cadmium downstream of Keswick Dam. However, because Regional Board staff used ½ the detection limit to estimate dissolved cadmium loads, the estimates for dissolved cadmium loads in Cottonwood Creek may be skewed high by the creek’s high discharges. Regional Board staff estimated the following loads (with corresponding dates and flows) for Cottonwood Creek for the three days that had dissolved cadmium concentration data:
 - 0.160 kg/day (12/14/1995, 1311 cfs);

- 0.030 kg/day (12/27/1995, 243 cfs); and
- 0.023 kg/day (1/10/1996, 187 cfs).
- Keswick Dam dissolved cadmium loads apparently far exceed the loads from the wastewater treatment plants, municipal stormwater runoff, Afterthought Mine, and Cottonwood Creek.

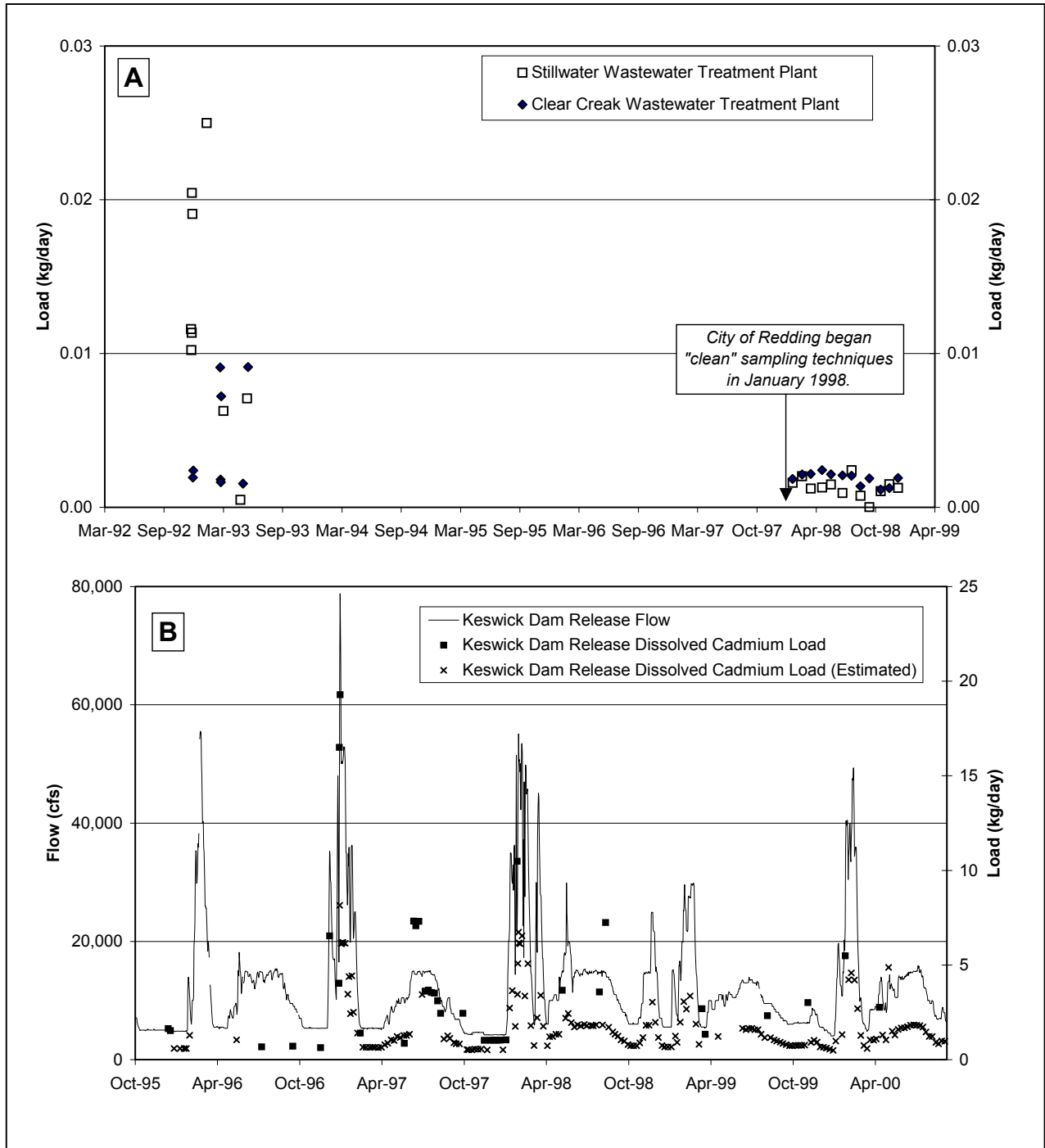


Figure 5-10. Dissolved Cadmium Loads for Sources Downstream of Keswick Dam
 A. Clear Creek and Stillwater Wastewater Treatment Plants B. Keswick Dam Releases.

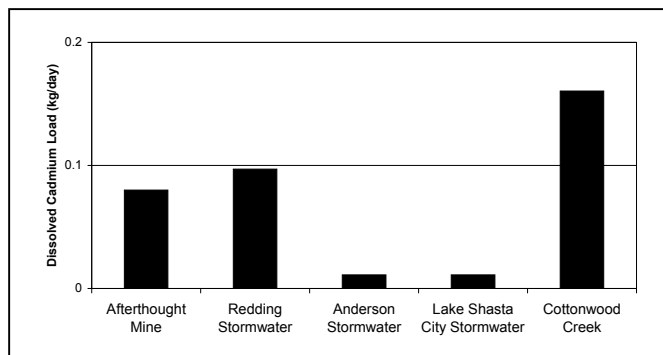


Figure 5-11. Estimated Maximum Dissolved Cadmium Loads for Afterthought Mine AMD, City of Redding, Lake Shasta City, and Anderson Stormwater Runoff, and Cottonwood Creek

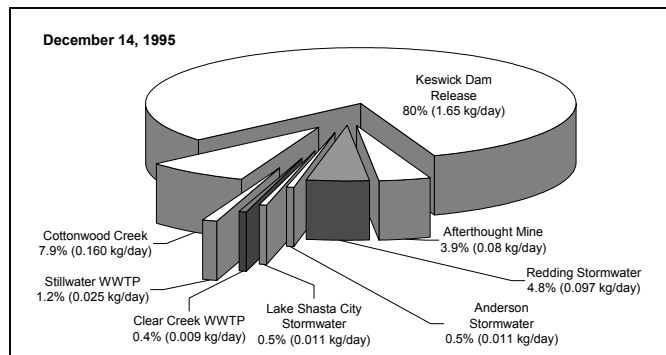


Figure 5-12. Dissolved Cadmium Loading Pattern for Sources Downstream of Keswick Dam

5.6 Evaluation of Dissolved Metal Mass Balances and Water Balances

Regional Board staff calculated dissolved metal mass balances and water balances for the Keswick Reservoir and for the Sacramento River from Keswick Dam to Bend Bridge. Staff made these calculations in order to evaluate metal transport processes and to indirectly assess whether unmonitored metal sources (e.g., erosion of naturally occurring metals-enriched soils) made measurable contributions to the Sacramento River. These “instantaneous” balances compared the dissolved metal loads and water flows for the monitored sources (“inputs”) to the loads and water flows measured at two *monitoring points* (“outputs”) on days that load values were available for both the sources and their corresponding monitoring points.^{13,14} The figures and tables in Appendix F show the Keswick Reservoir and the Sacramento River dissolved metal mass balance values and water balance values.

¹³ Regional Board staff used the same mass balance method as that used by the authors of a USGS study that evaluated copper loads derived from concentrations in dissolved, colloid, and whole water samples collected during six sampling periods in 1996 and 1997 (Alpers et al., 2000). The USGS authors noted that their mass balance results indicated the difficulty and uncertainty in computing mass balances from single instantaneous measurements of concentration and discharge. They wrote that a more sound approach would be to integrate samples over longer time intervals, such as the duration of a storm event or on a monthly basis. Regional Board staff did not have access to such data, and, in addition, had to make use of concentration data collected by multiple agencies using multiple methods for purposes other than calculating mass balances. However, staff had enough “instantaneous” mass balance values to successfully discern broad patterns.

¹⁴ The sampling location below Keswick Dam acts as a monitoring point for all point and nonpoint sources upstream of Keswick Dam because metal loads in Keswick Dam releases represent the accumulated loads from the IMM site, SCPP, Shasta Lake, and other sources upstream of Keswick Dam. The sampling location on the Sacramento River above Bend Bridge acts as a monitoring point for the cumulative effect of all point and nonpoint sources located between Keswick Dam and Red Bluff, combined with loads from Keswick Reservoir. Keswick Reservoir releases act as both (1) an indication of the accumulated loads from upstream sources, and (2) a source of metal to the downstream segment of the Sacramento River. Regional Board staff did not evaluate monitoring points within Keswick Reservoir and Shasta Lake because separate TMDL efforts will evaluate these waterbodies.

Staff used the following equations to calculate the balance values:

Keswick Reservoir Balances

$$\text{Water Balance}_{(\text{Day X})} = (\text{Keswick Dam Flow}_{(\text{Day X})}) \div (\text{Shasta Dam Flow}_{(\text{Day X})} + \text{SCPP Flow}_{(\text{Day X})} + \text{SCDD Flow}_{(\text{Day X})})$$

$$\text{Load Balance}_{(\text{Day X})} = (\text{Keswick Dam Load}_{(\text{Day X})}) \div (\text{Shasta Dam Load}_{(\text{Day X})} + \text{SCPP Flow}_{(\text{Day X})} + \text{SCDD Load}_{(\text{Day X})})$$

Sacramento River between Keswick Dam and Bend Bridge¹⁵

$$\text{Water Balance}_{(\text{Day X})} = (\text{Bend Bridge Flow}_{(\text{Day X})}) \div (\text{Keswick Dam Flow}_{(\text{Day X})})$$

$$\text{Load Balance}_{(\text{Day X})} = (\text{Bend Bridge Load}_{(\text{Day X})}) \div (\text{Keswick Dam Load}_{(\text{Day X})})$$

The figures and tables in Appendix F illustrate the balance values as percentages for the ease of interpretation. In general, dissolved metal balances consistently greater than 100% indicate *more* output than input, which could imply that there are additional, unmonitored source inputs contributing a notable amount. Dissolved metal balances consistently less than 100% indicate that dissolved metals may experience “net attenuation” (e.g., dissolved metals may adsorb to fine-grained sediments) in the waterbody; that is, dissolved metals loads *drop out* at a rate faster than any unmonitored sources *add* metal loads. Dissolved metal balances that approximate 100% imply either that the identified sources are the main contributors, or that metals are lost through attenuation at a rate nearly equal to the input of any unmonitored sources.

5.6.1 Mass Balances for Keswick Reservoir

Figures F-1A, F-2A, and F-3A and Tables F-1A, F-2A, and F-3A in Appendix F illustrate the dissolved metal mass balances and water balances for Keswick Reservoir for copper, zinc, and cadmium sampling periods, respectively. Table F-4 lists the mass balance summary statistics cited in the following sections.

Keswick Reservoir Water Balances

The sampling periods for the dissolved copper and zinc balance calculations were nearly identical. There were fewer sampling periods for the dissolved cadmium balance calculations than for the dissolved copper and zinc balance calculations, but the dates used for the cadmium mass balance calculations were included in the copper and zinc data sets. Therefore, the water balance values are almost identical for the dissolved copper, zinc, and cadmium analyses.

¹⁵ Staff did not incorporate the other monitored dissolved metal sources downstream of Keswick Dam in the Sacramento River balance calculations because of the relative scarcity of data for these sources. Instead, staff compared load estimates for these
(Footnote continued on next page.)

The water balance values for the dissolved copper, zinc and cadmium sampling periods closely approximated 100%. This indicates that the Shasta Dam, SCDD, and SCPP releases were the primary source of water to Keswick Reservoir. That is, there were no additional water sources that consistently added substantial quantities of water to the reservoir.

Keswick Reservoir Dissolved Metal Balances

The dissolved metal mass balances indicated that dissolved copper, zinc, and cadmium experience *net attenuation* in Keswick Reservoir. That is, apparently dissolved metals loads typically *drop out* in the reservoir at a rate faster than any unmonitored sources *add* metal loads to the reservoir.

The dissolved copper balances span a range of values both above and below 100%. However, 86 of the 99 sampling periods (87% of the sampling periods) had balance values less than 100%, indicating that net attenuation typically occurs. A USGS study that evaluated copper loads derived from concentrations in dissolved, colloid, and whole water samples collected during six sampling periods in 1996 and 1997 had similar mass balance calculations for Keswick Reservoir (Alpers et al., 2000). The authors of the USGS study hypothesized that increased sorption of copper during transport through Keswick Reservoir could cause the apparent copper attenuation.

The dissolved zinc and cadmium mass balance values are similar to, but not exactly the same as, the copper balance values, probably as a result of differing copper:zinc:cadmium ratios of source contributions, different chemical properties, and the use of estimated load values in the balance calculations.¹⁶ Seventy-one of the 100 dissolved zinc sampling periods (71% of the sampling periods) had balance values less than 100%, which indicates an apparent *net attenuation* of dissolved zinc in the reservoir, although not so attenuated as dissolved copper. The USGS study that evaluated 1996 and 1997 metal loads noted that dissolved zinc was less attenuated than dissolved copper in Keswick reservoir (Alpers et al., 2000).

All seven of the dissolved cadmium sampling periods had balance values less than 100%. Six of the seven sampling periods used for calculating the dissolved cadmium balances had corresponding dissolved

monitored source loads to the resulting differences between the loads calculated for the Keswick Dam and Bend Bridge sampling locations, as discussed later in the text.

¹⁶ A comparison of estimated dissolved zinc load values plotted on Figure f-2 in Appendix F to the other load values calculated for adjacent days indicates that the estimates are comparable, or even less than, the other values. This indicates that the estimates may underestimate the load values.

copper balance values less than 100%, and four of the seven sampling periods had dissolved zinc balance values less than 100%. This indicates that dissolved cadmium may attenuate more than dissolved copper and zinc in Keswick Reservoir. The USGS study that evaluated 1996 and 1997 metal loads indicated that three of the five dissolved cadmium sampling periods for the USGS study (which were different from the sampling periods used in this source analysis) had dissolved cadmium balance values less than 100% (Alpers et al., 2000).

Approximately 13% and 29% of the sampling periods had dissolved copper and zinc balance values, respectively, greater than 100%. This could indicate that during these sampling periods, unmonitored sources of copper and zinc may be making contributions to Keswick Reservoir that are greater than the amount that typically drops out. The USGS study considered the remobilization of accumulated precipitates in the SCAKR to be the most likely source of additional dissolved copper (Alpers et al., 2000). Regional Board staff reviewed the small amount of published load data for Flat Creek, which receives water from upper Spring Creek via a diversion and discharges to Keswick Reservoir upstream of the SCAKR. Flat Creek apparently contributes amounts too small (e.g., in the range of 0.0016 to 0.081 kg/day of dissolved copper (Alpers et al., 2000)) to explain the balance values greater than 100%.

5.6.2 Mass Balances for the Sacramento River (Keswick Dam to Bend Bridge)

Figures F-1B, F-2B, and F-3B and Tables F-1B, F-2B, and F-3B in Appendix F illustrate the dissolved metal mass balances and water balances for the Sacramento River between Keswick Dam and Bend Bridge for copper, zinc, and cadmium sampling periods, respectively. Table F-4 lists the mass balance summary statistics cited in the following sections.

Sacramento River Water Balances

The water balance values for the 26 sampling periods for dissolved copper and zinc, and the 12 sampling periods for dissolved cadmium, all exceeded 100%. This indicates that there are additional water sources that consistently *add* to water released from Keswick Reservoir.

Sacramento River Dissolved Metal Balances

The dissolved metal mass balances indicate that dissolved zinc and cadmium loads typically experience *net attenuation*, while dissolved copper loads typically experience a *net increase*, in the Sacramento River between Keswick Dam and Bend Bridge. That is, apparently dissolved zinc and cadmium loads *drop out*

(e.g., by adsorption to fine-grained sediments) at a rate faster than the downstream monitored and unmonitored sources add dissolved zinc and cadmium. In contrast, downstream monitored and unmonitored sources typically *add* dissolved copper at a rate faster than dissolved copper loads drop out. Monitored sources may account for the majority of the net increase in dissolved copper loads in the Sacramento River downstream of Keswick Dam.

The dissolved copper balances span a range of values both above and below 100%. However, 18 of the 26 sampling periods (69%) had balances that exceeded 100%, which indicates an apparent *net increase* in dissolved copper loads in the Sacramento River between Keswick Dam and Bend Bridge.¹⁷ A review of Table F-4 indicates that the differences between Keswick Dam loads and Bend Bridge loads were less than 42 kg/day for 16 of the 18 sampling periods with a mass balance greater than 100%. As noted earlier, the sum of the estimated maximum daily dissolved copper loads for the monitored sources may be as high as 50.1 kg/day, indicating that the monitored sources may account for the majority of the net increase in dissolved copper loads in the Sacramento River downstream of Keswick Dam. Approximately 31% of the sampling periods had dissolved copper balances less than 100%, which indicates that a *net attenuation* of dissolved copper occurs during some periods, even though the corresponding water balances for these periods were greater than 100%.

The dissolved zinc balances span a range of values both above and below 100%. However, in contrast to the dissolved copper balance values, 20 of the 26 sampling periods (77%) had balances less than 100%, which indicates an apparent *net attenuation* in dissolved zinc loads in the Sacramento River between Keswick Dam and Bend Bridge. The USGS study that evaluated metal loads during six sampling periods in 1996 and 1997 also observed a net attenuation in dissolved zinc loads between Keswick Dam and Bend Bridge (Alpers et al., 2000).

Eleven of the 12 dissolved cadmium sampling periods (92%) had balance values less than 100%, which indicates an apparent *net attenuation* in dissolved cadmium loads in the Sacramento River between Keswick Dam and Bend Bridge. In comparison, 9 of those same 12 sampling periods had dissolved zinc balances less than 100%, while only two of those 12 periods had dissolved copper balance values less than 100%. This indicates that dissolved cadmium loads may attenuate more than zinc, and that both dissolved

¹⁷ The USGS study that evaluated metal loads during six sampling periods in 1996 and 1997 determined that dissolved copper loads measured for Keswick Dam releases were sometimes slightly greater than, and other times slightly less than, loads at Bend Bridge; in comparison, the USGS study determined that total copper loads typically increased between Keswick Dam and Bend Bridge (Alpers et al., 2000).

cadmium and zinc loads attenuate more than dissolved copper loads in the Sacramento River between Keswick Dam and Bend Bridge. The USGS study that evaluated metal loads during six sampling periods in 1996 and 1997 also observed a net attenuation in dissolved cadmium loads between Keswick Dam and Bend Bridge (Alpers et al., 2000).

6 NUMERIC TARGETS

6.1 Definition of a Numeric Target

Numeric targets are the specific instream goals for the TMDL that will enable the full protection of the upper Sacramento River's beneficial uses. The development of numeric targets involves the following elements:

- Identification of the target media and the basis for using the selected target media to interpret or apply applicable water quality standards.
- Identification of target levels for the selected target media and the technical basis for the target levels.
- Comparison of historical or existing conditions and desired future conditions for the target media selected for the TMDL.

6.2 Identification of the Target Media

The target media should address as directly as possible whether remediation actions are enabling the attainment of beneficial uses. Figure II-1 and Table II-1 of the Basin Plan identify the designated existing and potential beneficial uses of surface waters in the Sacramento and San Joaquin Basins (CVRWQCB, 1998a). The upper Sacramento River provides water for fisheries, wildlife habitat, domestic, municipal, and agricultural uses within its watershed. Table 6-1 lists additional beneficial uses identified in the Basin Plan. The beneficial uses most impacted by copper, cadmium, and zinc in the upper Sacramento River (Shasta Dam to Red Bluff) are warm and cold freshwater habitat.¹⁸

Other characteristics to be considered for the target media include:

- whether variability in the target media can be modeled and causes of variability are understood; and
- whether measurements of the target media would reflect mass load reductions in a timely manner.

¹⁸ As noted earlier, Spring Creek enters the Sacramento River system in the Spring Creek arm of Keswick Reservoir, approximately two miles upstream of Keswick Dam. The City of Redding is approximately four miles downstream of Keswick Dam. Although the City of Redding obtains its drinking water from the Sacramento River, the metals from Iron Mountain and from sources in the Shasta Lake region do not pose a significant threat to this water supply because of dilution effects and the effectiveness of the City's water-treatment plant (Jorgenson, 2000). In the event of an uncontrolled release of metal-rich drainage from the IMM site, the City of Redding has a contingency plan to switch to alternate groundwater sources.

Table 6-1. Existing and Potential Beneficial Uses of the Sacramento River, Shasta Dam to Colusa Basin Drain (CVRWQCB, 1998 (a))

Beneficial Use	Status
Municipal & domestic water supply (MUN)	Existing
Agriculture – irrigation & stock watering (AGR)	Existing
Industry – service supply (IND) & power (POW)	Existing
Recreation – contact, canoeing & rafting (REC-1) & other noncontact (REC-2)	Existing
Freshwater Habitat – warm (WARM) & cold (COLD)	Existing (a)
Migration – warm (WARM) & cold (COLD)	Existing
Spawning– warm (WARM) & cold (COLD)	Existing
Wildlife habitat (WILD)	Existing
Navigation (NAV)	Existing

(a) Beneficial uses most impaired by copper, cadmium and zinc in the upper Sacramento River.

Target media could include biota, water or sediment. Regional Board staff selected water as the primary target media for this TMDL for the following reasons:

- Numerous studies have linked detrimental effects in aquatic organisms to chronic and acute exposures to cadmium, copper, and zinc in water (see Chapter 4); therefore, monitoring metals levels in water provides a direct measure of aquatic habitat conditions and improvement.
- The USEPA has developed a numerical water quality model to predict the effectiveness of various remedial alternatives for the IMM site with respect to limiting the frequency of SCDD spills and exceedances of the water quality standards below Keswick Reservoir (USEPA, 1997b) (see Chapter 7).
- Long-term water quality data that provide a good baseline from which to evaluate the success of past and future load reductions in a timely manner is available (see Chapters 2 and 10).
- Several agencies (e.g., USEPA, USBR, and City of Redding) will continue to regularly collect water quality data and make the data available to the Regional Board for review.

6.3 Target Levels

Regulatory agencies identify numerical aquatic life criteria as short-term (acute) and long-term (chronic) averages, rather than as one number, so that the criteria more accurately reflect toxicological and practical realities (Stephan et al., 1985; USEPA, 2000a). The combination of a maximum concentration criterion (e.g., a maximum concentration limit) and a continuous concentration criterion (e.g., a four-day average concentration limit) for each metal provides protection of aquatic life from acute and chronic toxicity to animals and plants and from bioaccumulation by aquatic organisms, without being as restrictive as a one-number criterion would have to be.

The USEPA document, *Guidance for Developing TMDLs in California*, noted that it is appropriate to set TMDL numeric targets equal to existing numeric water quality standards (Smith, 2000). Federal and State agencies have developed narrative and numeric criteria for metals in water for both human health and wildlife protection. As noted in Chapter 2, two sets of water quality standards developed for the protection of aquatic life are relevant for this TMDL. The Regional Board's Basin Plan water quality objectives for dissolved cadmium, copper, and zinc provide *maximum concentration criteria* (acute criteria) for the Sacramento River above Highway 32 Bridge at Hamilton City. The USEPA's CTR provides *continuous concentration criteria* (chronic criteria) for all waterbodies in California including the upper Sacramento River.

Because aquatic organisms such as fish are much more sensitive than humans to trace metals such as copper, zinc, and cadmium, the water-quality criteria for aquatic life protection that are enforced by the Regional Board and the USEPA are much more stringent than criteria established for human health protection. Dissolved metal concentrations in the upper Sacramento River are less than the California/USEPA drinking water standards established for the protection of human health (MCLs). The following sections provide a more detailed review of the Regional Board's Basin Plan objectives and the USEPA's CTR criteria.

6.3.1 Basin Plan Water Quality Objectives

In 1985, the State Board, with approval from the USEPA, adopted site-specific maximum concentration (acute) criteria for cadmium, copper and zinc in the Sacramento River (and tributaries) upstream of Hamilton City (CVRWQCB, 1998a; USEPA, 2000a). The water quality objectives cited in the Basin Plan are 0.22 µg/l, 5.6 µg/l and 16 µg/l, for cadmium, copper, and zinc, respectively, all in the dissolved form using a hardness of 40 milligrams per liter (mg/l) as calcium carbonate (CaCO₃). The allowable metal concentrations change in relation to the hardness, or alkalinity, of the water. If deviations in hardness occur, the objectives are determined using the following formulas:

$$\begin{aligned} \text{Copper objective } (\mu\text{g/l}) &= e^{(0.905)(\ln \text{ hardness [mg/l]} - 1.612)} \\ \text{Zinc objective } (\mu\text{g/l}) &= e^{(0.830)(\ln \text{ hardness [mg/l]} - 0.289)} \\ \text{Cadmium objective } (\mu\text{g/l}) &= e^{(1.160)(\ln \text{ hardness [mg/l]} - 5.777)} \end{aligned}$$

Where: ln = natural logarithm
 e = exponent

Components of alkalinity, such as carbonate and bicarbonate, will combine with some toxic heavy metals and reduce their toxicity. Therefore, in general: the harder the water, the higher the allowable concentration of metals.

The Basin Plan water quality objectives are based on continual-flow toxicity tests conducted on juvenile¹⁹ chinook salmon in a laboratory setting by the CDFG (Finlayson and Wilson, 1989). CDFG determined median lethal concentrations during 4 days (96-hour LC₅₀ values²⁰) and recommended “safe” concentrations of metals as one tenth of the 96-hour LC₅₀ values (Finlayson and Verrue, 1982). Onsite toxicity tests that exposed juvenile chinook salmon and steelhead trout to Spring Creek acid-mine waste for 96 hours and 240 hours resulted in 96-hour LC₅₀ values similar to those from the laboratory tests that used metal sulfate mixtures with similar ratios, indicating that the effects of Spring Creek AMD on salmonids are reproducible and comparable to the laboratory results and confirming that these metals are the major toxic components of the waste (Finlayson and Wilson, 1989). Copper toxicity studies conducted for the California Office of the Attorney General observed comparable copper toxicity values for swim-up steelhead trout and chinook salmon fry in surface waters in the vicinity of IMM (Hagler and Bailey Consulting, 1996 & 1998). The 1989 CDFG study also determined that there were no significant differences between the mean 96-hour and mean 240-hour LC₅₀ values for either the salmon or trout, indicating that acutely lethal effects of waste occur within 96 hours. In addition, the study determined that there were no significant differences between the mean LC₅₀ values for salmon and steelhead trout.

CDFG’s tests indicated antagonistic toxicity for the three-metal mixtures; therefore, results for the metals tested individually were used as the basis for the Basin Plan water quality objectives. USEPA equations for average allowable dissolved metal concentrations were adjusted to equal one tenth of the 96-hour LC₅₀ values for juvenile chinook salmon at a hardness of 20 mg/l CaCO₃, and then adjusted upward for the 40 mg/l CaCO₃ hardness of the Sacramento River below Keswick Dam (Finlayson and Wilson, 1989).

In recognition of the need for site-specific protective criteria, the USEPA allows for the development of criteria for the protection of fish and aquatic life using either one species or a group of aquatic organisms when it has been demonstrated that they are important (e.g., recreationally or commercially) and are more sensitive to the toxicant. The Basin Plan water quality objectives are based on metals toxicity to chinook

¹⁹ Eggs and fry are the most sensitive life stage of the salmonid species.

²⁰ LC₅₀: median lethal concentration., the lethal concentration calculated for 50% of the organisms tested.

salmon and steelhead trout because these fish appear to meet these specifications for the upper Sacramento River (Finlayson and Wilson, 1989; Hagler Bailey, 1996 & 1998).

6.3.2 California Toxics Rule Criteria

As noted earlier, the USEPA approved the maximum concentration criteria that were included in the Basin Plan as water quality objectives. However, the USEPA Administrator made a finding that it was still necessary to develop separate chronic criteria for copper, cadmium, and zinc for the Sacramento River (and tributaries) above Hamilton City, as part of the statewide criteria promulgated in the CTR (USEPA, 2000a).

The CTR Criteria for Freshwater Aquatic Life Protection include 4-day continuous concentration criteria of 1.1 µg/l, 4.1 µg/l and 54 µg/l, for cadmium, copper, and zinc, respectively, all in the dissolved form using a hardness of 40 mg/l as CaCO₃. The USEPA selected the 4-day averaging period based on the shortest duration in which chronic test effects are sometimes observed for certain species and toxicants. Freshwater aquatic species are not expected to be affected unacceptably if the 4-day average concentration of an individual metal does not exceed its CTR continuous concentration criterion more than once every three-year period (USEPA, 1996b & 2000a). If deviations in hardness occur, the criteria are determined using the following formulas:

$$\text{Copper criterion } (\mu\text{g/l}) = (e^{(0.8545)(\ln \text{ hardness [mg/l]} - 1.702)}) \times (0.960)$$

$$\text{Zinc criterion } (\mu\text{g/l}) = (e^{(0.8473)(\ln \text{ hardness [mg/l]} + 0.884)}) \times (0.986)$$

$$\text{Cadmium criterion } (\mu\text{g/l}) = (e^{(0.7852)(\ln \text{ hardness [mg/l]} - 2.715)}) \times (1.101672 - \{[\ln \text{ hardness}] \times 0.041838\})$$

Where: e = exponent
ln = natural logarithm

The continuous concentration criterion for cadmium is based on the results of flow-through chronic toxicity tests conducted on a wide variety of aquatic species (USEPA, 1996b). Because insufficient chronic copper and zinc toxicity data were available, the continuous concentration criteria for copper and zinc were adapted from the CTR maximum concentration criteria using acute-chronic ratios developed for selected fish and invertebrate species.^{21, 22}

²¹ The CTR maximum concentration criteria for cadmium, copper, and zinc are 1.6 µg/l, 5.7 µg/l, and 54 µg/l, respectively, with a hardness of 40 mg/l. The CTR maximum and continuous criteria for metals were originally calculated using the *Water Quality Criteria Documents; Availability – Appendix B-Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses* (45 Federal Register 79341, November 28, 1980), as amended by the *Guidelines for Deriving Numerical national Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (Stephan et al., 1985).
(Footnote continued on next page.)

6.3.3 Proposed Numeric Targets

Table 6-2 illustrates which Basin Plan objectives and CTR criteria Regional Board staff propose as numeric targets for this TMDL. The acute Basin Plan objectives for cadmium and zinc are more stringent than the chronic CTR criteria for cadmium and zinc. Therefore, because the acute Basin Plan objectives for cadmium and zinc are more protective of aquatic organisms in the waterbody, the Basin Plan objectives should apply as both the acute and chronic numeric targets (Mitchell, 2001).²³ Upon completion of all remedial activities at IMM and evaluations of mine sites upstream of Shasta Dam (see Chapter 10), the Regional Board may consider amending the Basin Plan to make the Basin Plan objectives consistent with the CTR criteria.

Table 6-2. Proposed Numeric Targets

Metal (dissolved form)	Acute Numeric Target (µg/l) (maximum concentration)	Chronic Numeric Target (µg/l) (4-day continuous concentration, not to be exceeded more than once in any three-year period)
Cadmium	0.22 ^(a)	0.22 ^(a)
Copper	5.6 ^(a)	4.1 ^(b)
Zinc	16 ^(a)	16 ^(a)

- (a) Central Valley Region Water Quality Control Plan trace element water quality objectives (maximum concentrations) for Sacramento River and its tributaries above State Highway 32 Bridge at Hamilton City (CVRWQCB, 1998a).
- (b) California Toxics Rule Criteria for Freshwater Aquatic Life Protection (4-day continuous concentration criteria) for priority toxic pollutants in the State of California for inland surface waters (USEPA, 2000a).

The criteria were recalculated pursuant to the *Water Quality Criteria Documents for the Protection of Aquatic life in Ambient Water, 1995 Updates* (USEPA, 1996b) and converted to dissolved values using conversion factors presented in the Code of Federal Regulations, Title 40, Part 131, Section 36(b)(1) and (2) (USEPA, 2000b). *Note:* The maximum concentration criteria for cadmium, copper, and zinc listed in the CTR do not apply to the Sacramento River (and tributaries) above Hamilton City because the USEPA approved the site-specific maximum concentration criteria adopted in the Basin Plan.

- ²² The USEPA calculated the maximum and chronic hardness-dependent copper criteria using the following method, which incorporates a margin of safety at multiple points:
- The USEPA evaluated and ranked the copper mean acute values for 56 species and 43 genera of fish and invertebrates. The USEPA calculated a final acute value (FAV) using the four lowest genus mean acute values, which were all lower than the species mean acute values for the *Oncorhynchus* species (salmon and trout) evaluated.
 - The USEPA calculated the maximum criterion by dividing the FAV by 2 and converting the resulting total copper criterion to a dissolved copper criterion.
 - Because insufficient chronic copper toxicity data were available, the USEPA adapted the CTR maximum concentration criterion by dividing the FAV by the geometric mean of the species mean acute-chronic ratios (SMACRs) for the two most sensitive species for which ratios were determined. SMACRs were available for nine species; because the *Oncorhynchus* species did not have the lowest SMACRs, the USEPA did not select its SMACR for the calculation. The resulting CTR chronic criterion for copper is therefore protective of both the *Oncorhynchus* species and other even more sensitive aquatic species.
- ²³ According to the *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California*, "If a water quality objective and a CTR criterion are in effect for the same priority pollutant, the more stringent of the two applies." (Page 1, Footnote 4). Therefore, even if the chronic CTR criteria for cadmium and zinc were chosen to be the chronic numeric targets for this TMDL, the acute Basin Plan objectives would drive any effort to measure compliance because ambient concentrations would not be allowed to spike higher than the acute objectives. That is, the higher four-day chronic average would never come into play.

6.4 Comparison of Numeric Targets to Historical Conditions

The long-term water quality data sets for Sacramento River below Shasta Dam and Keswick Dam indicate that, historically, dissolved concentrations of cadmium, copper, and zinc frequently exceeded both the chronic CTR criteria and acute Basin Plan water quality objectives (see Chapter 2 and Appendix A). A notable decrease in the frequency of exceedances is evident during the 1980s and 1990s, which correlates to (1) load reductions resulting from remediations completed at mine sites in the Shasta Lake region and at the Iron Mountain Mines site, and (2) improved coordination of releases from Spring Creek Debris Dam, Spring Creek Power Plant, Shasta Dam, and Keswick Dam. However, exceedances still can occur during the high flow season (November to April). Additional reductions in loads resulting from proposed remediation activities at the IMM site and other mine sites in the Shasta Lake area should enable the consistent attainment of water quality objectives and the full protection of the upper Sacramento River's beneficial uses. Refer to Chapters 7, 8, and 10 for more detailed descriptions of anticipated reductions in metals loads.

6.5 Compliance with Federal and State Antidegradation Policy

Any proposed numeric targets must comply with Federal and State antidegradation policies. The USEPA's antidegradation regulations (Code of Federal Regulations, Title 40, Part 131, Section 12) require States to adopt antidegradation policies that establish three levels of protection (Grubbs, 2000):

- Tier 1: Water quality necessary to support existing uses is maintained.
- Tier 2: Where water quality is better than the minimum level necessary to support protection and propagation of fish, shellfish and wildlife, and recreation in and on the water ("fishable/swimmable"), that water quality is also maintained and protected unless, through a public process, some lowering water quality is deemed necessary to accommodate important economic or social development.
- Tier 3: Where waterbodies are of exceptional recreational or ecological significance, water quality is maintained and protected.

The State of California antidegradation policy, adopted in 1968, requires the maintenance of existing high quality water to the maximum extent possible, except under specific circumstances documented by the policy (SWRCB, 1968). The antidegradation policy requires that, "wherever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present

and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.”

At the time of the State’s policy adoption, levels of cadmium, copper and zinc in the upper Sacramento River frequently exceeded levels required to enable attainment of designated beneficial uses because the most effective remediation activities had not yet taken place. Since then, the frequency of exceedances of such levels has decreased as a result of load reductions resulting from remediations completed at mine sites in the Shasta Lake region and at Iron Mountain Mines and improved coordination of releases from Spring Creek Debris Dam, Spring Creek Power Plant, Shasta Dam, and Keswick Dam. Compliance with the numeric targets proposed in Table 6-2 will comply with the antidegradation policy because metals concentrations will be lower than concentrations in the upper Sacramento River have been since 1968. Therefore, compliance with the proposed numeric targets will also enable compliance with the State of California antidegradation policy.

7 LINKAGE ANALYSIS

7.1 Introduction

The linkage analysis defines the cause-and-effect relationship between numeric targets, selected target media, and identified sources. Understanding this relationship enables the estimation of load reductions so that Federal and State agencies can design remediation activities that effectively decrease dissolved metal concentrations to levels below the desired numeric targets and thereby protect beneficial uses. This chapter first expresses the linkage relationship qualitatively in the form of conceptual models. Quantitative tools complete the linkage. This TMDL relies on USEPA's numeric model of the IMM discharges to quantify load reductions at IMM that are required to meet numeric targets.

7.2 Conceptual Relationships

The beneficial uses most impacted by cadmium, copper, and zinc in the upper Sacramento River are warm and cold freshwater habitats. Chinook salmon and steelhead trout fisheries downstream of Keswick Dam have been particularly impacted. Figure 7-1 provides a conceptual model of the relationship between beneficial uses and sources. Continual-flow toxicity tests conducted on juvenile chinook salmon and other aquatic species have established the link between dissolved cadmium, copper, and zinc concentrations in water and acute and chronic health effects on aquatic species (see Chapter 4 (Effects of Cadmium, Copper, and Zinc on Aquatic Life) and Chapter 6 (Numeric Targets)). The numeric targets indicated in Chapter 6 identify levels of dissolved cadmium, copper, and zinc in water that are non-toxic to aquatic life.

Exceedances of numeric targets occur when the metal loads exceed the loading capacity of a waterbody. A waterbody's loading capacity, also called its assimilative capacity, represents the maximum rate of loading of a pollutant that the waterbody can assimilate without violating water quality standards (Code of Federal Regulations, Title 40, Part 130, Section 2(f)). Figure 7-2 illustrates the equation used to calculate the assimilative capacity. By definition, numeric target exceedances occur when metal loads exceed the assimilative capacity because the numeric target is a component of the assimilated capacity calculation. When metal loads are much less than the assimilative capacity, there is an availability of excess assimilative capacity (i.e., more metal can be added without causing an exceedance of a numeric target). Figures G-1A through G-2C in Appendix G compare assimilative capacity to maximum daily loads of dissolved copper, cadmium, and zinc in Shasta Dam and Keswick Dam releases and in the

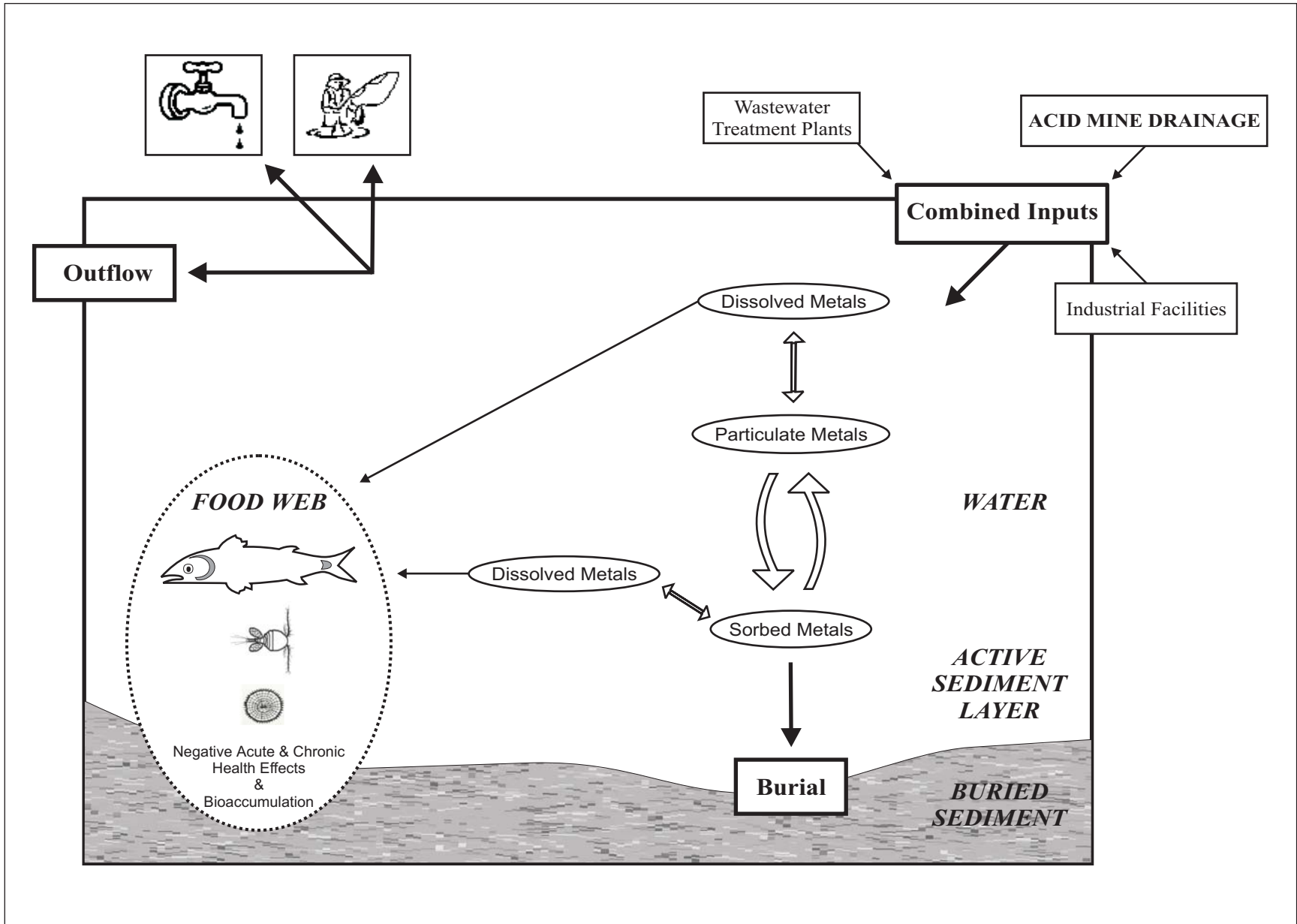


Figure 7-1. Metals Cycling in Freshwater Habitats

Sacramento River below Bend Bridge. The figures indicate when metal loads exceeded their corresponding assimilative capacities, resulting in exceedances of one or more numeric targets.

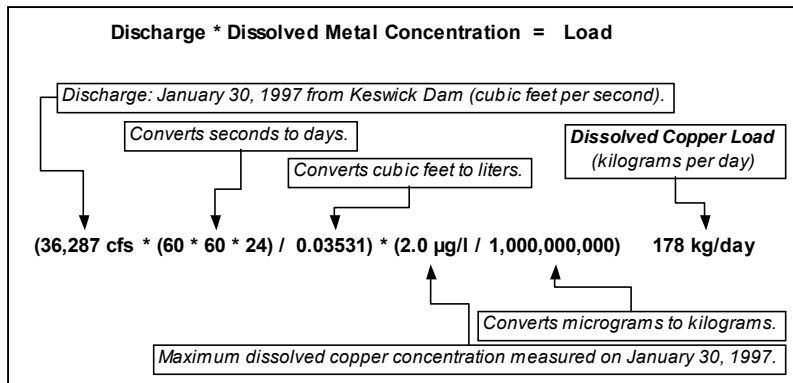


Figure 7-2. Example of Assimilative Capacity Calculation

7.2.1 Assimilative Capacity of the Sacramento River Upstream of Keswick Dam

Ongoing loads of metal-laden water from the IMM site and mines in the Shasta Lake region drive the exceedances of the numeric targets on the Sacramento River below Keswick Dam. Figure 7-3 illustrates the discharge events in January 1995, which provide a good example of one of the scenarios that cause exceedances and present acute risks to the aquatic organisms downstream of Keswick Dam. During the January 1995 storms, the IMM site metal discharges were the source of greater than 90% of the Keswick Reservoir metal loads (USEPA, 1997b). Even though the onsite treatment plant removed the majority of metals from the AMD during that time (see the green portion of the IMM site's bar graph on Figure 7-3), the SCDD still released a large volume of untreated AMD from the IMM site into the Sacramento River for a period of several weeks.

This continuous release of untreated AMD from the IMM site caused the Sacramento River below Keswick Dam to exceed the acute Basin Plan objectives for dissolved copper and zinc and chronic CTR criteria for dissolved copper almost continuously from January 9 through January 27, 1995 (dissolved cadmium data were unavailable for this period). At times during the storm events, Sacramento River dissolved copper concentrations were more than twice the levels of the Basin Plan and CTR criteria (Figure 7-3).

Figure 7-3 highlights the relationship between concentration, load, and assimilative capacity – a relationship that is made very complicated in this region by the effects of dam flow manipulations²⁴ and

²⁴ As noted in Chapter 3, the USBR manipulates releases from Shasta Dam, Keswick Dam, SCDD, and the SCPP to provide dilution for SCDD discharges and to address other beneficial uses, which may have requirements that conflict with the need for dilution flows.

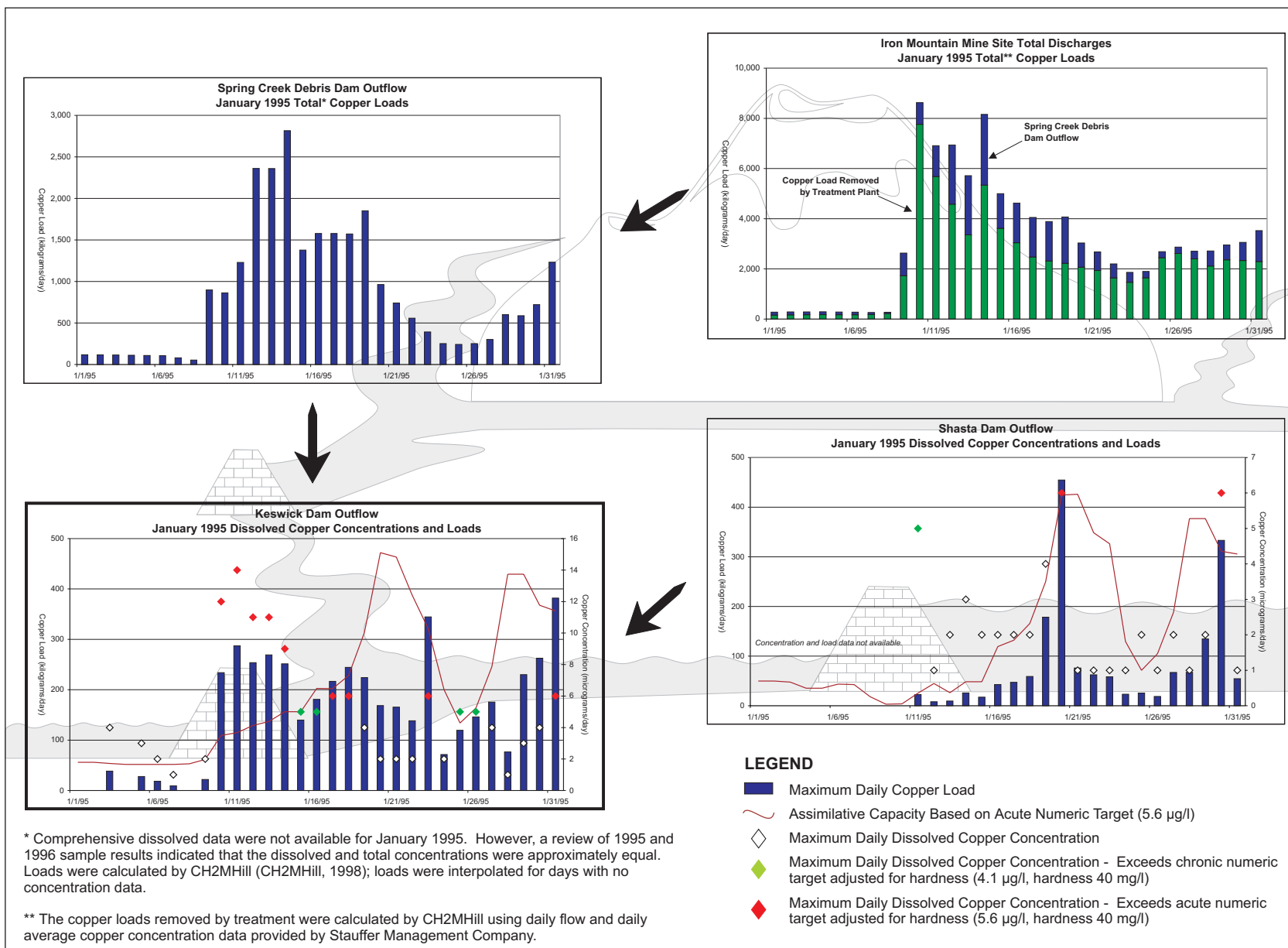


Figure 7-3. Copper Loads, Concentrations, and Assimilative Capacity Upstream of Keswick Dam in January 1995.

depositional processes in Keswick Reservoir.²⁵ In January 1995, metal loads from the IMM site via SCDD drove the exceedances that occurred on the Sacramento River below Keswick Dam, especially during the January 10-15 period when Shasta Dam releases were low (see Figure 3-2A) and had little assimilative capacity (see Figure 7-3) to dilute the IMM site metal loads.

As noted in Chapter 5, Shasta Dam releases sometimes act as a significant source of metal loads in the upper Sacramento River, although the metal concentrations rarely exceed the numeric targets. For example, during the period October 1995 to September 2000 (the period analyzed by the source assessment), dissolved copper concentrations in Shasta Dam releases did not exceed the acute numeric target level for copper (5.6 µg/l), and only exceeded the chronic numeric target level for brief periods (i.e., less than four days). However, exceptions to this normal situation can occur, as illustrated by Figures 2-1B and 7-3, and Figures G-1A through G-1C, which show data for Shasta Dam for early 1995 and 2001. Available data indicate that Shasta Dam releases had dissolved copper and zinc concentrations that exceeded the proposed acute and chronic numeric targets on three days in January 1995. In March and April 2001, Shasta Dam releases had dissolved copper concentrations that exceeded the chronic numeric target of 4.1 µg/l and approached the acute numeric target of 5.6 µg/l; dissolved copper concentrations in Keswick Dam releases exceeded the numeric targets almost continuously during this time period.²⁶ Figures G-1 and G-2 illustrate how these exceedances relate to the daily loads and assimilative capacity of Shasta Dam and Keswick Dam releases.

7.2.2 Assimilative Capacity of the Sacramento River Downstream of Keswick Dam

The dissolved metal assimilative capacity and load calculations for Keswick Dam releases and for the Sacramento River above Bend Bridge reflect the water and dissolved metal transport processes described in Chapter 5. Figure 7-4 compares the Keswick Dam and Bend Bridge dissolved copper assimilative

²⁵ As described in Chapter 3, studies indicate that approximately 35 to 50% of dissolved metals form precipitates in the SCAKR and Keswick Reservoir; i.e., Keswick Dam does not typically immediately release the entire metal load that comes into the Keswick Reservoir. However, intermittent discharges from the SCPP can flush accumulations of contaminated water and precipitates from the SCAKR into the main stem of the river; therefore, there are times that Keswick Dam may release more metal load than the amount recently received from upstream sources.

²⁶ The unusually high dissolved copper concentrations measured in Shasta Dam releases in early 2001 probably resulted from the combination of two factors. First, a controlled release from a mine in the Shasta Lake area occurred during the summer of 2000; the effects of the release would not be observed in Shasta Dam releases for several months (Pedri, 2001). In addition, Shasta Dam flows were exceptionally low during March and April 2001 (see Figure 3-2A), which could have affected the metal concentrations below Shasta and Keswick Dams by drawing water from Shasta Lake's thermocline, a level of Shasta Lake's water column that experiences higher metal concentrations (Bruns, pers. comm.), and decreasing the assimilative capacity of downstream waters by decreasing the amount of available dilution flow.

capacities based on the acute numeric target.²⁷ Figures G-2A through G-3C show data for Keswick Dam releases and the Sacramento River above Bend Bridge dissolved metal assimilative capacities, daily loads, and concentrations that exceeded numeric targets.

As Figure 7-4 indicates, the dissolved copper assimilative capacity of the Sacramento River above Bend Bridge typically exceeded the assimilative capacity of Keswick Dam releases; the assimilative capacity at

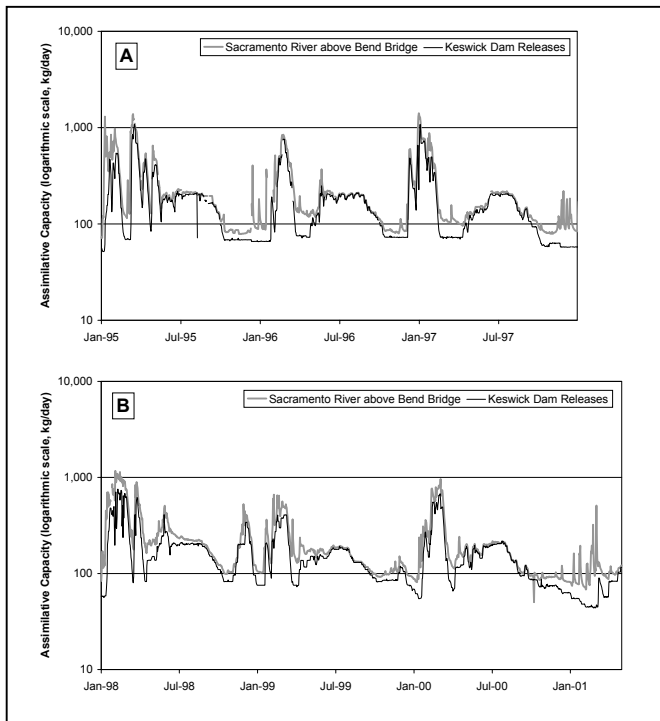


Figure 7-4. Assimilative Capacity of the Sacramento River below Keswick Dam and above Bend Bridge

Bridge and Keswick Dam ranged between -36 kg/day and 1,240 kg/day, with more than 90% of the differences being less than 150 kg/day.

Bend Bridge exceeded Keswick Dam's assimilative capacity on 2266 of the 2316 days (98%) with data for both locations. These assimilative capacity calculations are in agreement with the water balance calculations described in Chapter 5, which indicated that additional water sources (i.e., tributary flow and surface runoff inputs) consistently *add* to water released from Keswick Reservoir. The few days that the assimilative capacity of Keswick Dam releases was greater than that of the Sacramento River at Bend Bridge occurred for only brief periods during the dry season, a time that water is typically withdrawn from the Sacramento River for agricultural uses. The assimilative capacity differences between Bend

Figures G-3A through G-3C indicate that daily dissolved metal loads exceeded the assimilative capacity at Bend Bridge on only one day during the period of record.^{28, 29} This indicates that, although there are

²⁷ By definition, the assimilative capacity calculations for dissolved zinc and cadmium mirror the pattern of the calculations for dissolved copper because the same flow values are used; only the numeric target value changes in the calculations made for each metal.

²⁸ On December 12, 1996, the daily dissolved copper load exceeded its assimilative capacity at Bend Bridge based on the chronic numeric target; the corresponding dissolved copper concentration was 4.4 µg/l. Keswick Dam releases exceeded the chronic numeric target the previous day.

²⁹ However, as noted in Section 2.3.3, this apparent lack of exceedances may occur primarily because few sampling dates for the Sacramento River at Bend Bridge corresponded to times of observed exceedances at Keswick Dam.

downstream sources of dissolved metals, there is enough dilution tributary flow and surface runoff inputs, and/or attenuation of dissolved metals from the Sacramento River, between Keswick Dam and Bend Bridge to counter the additional metal inputs. As noted in Chapter 5, the mass values for the 26 sampling periods in water years 1996 through 2000 for dissolved copper and zinc, and the 12 sampling periods for dissolved cadmium indicated that dissolved zinc and cadmium loads typically experienced *net attenuation* in the Sacramento River between Keswick Dam and Bend Bridge. That is, apparently dissolved zinc and cadmium loads *decreased* (probably by adsorption to fine-grained sediments) at a rate faster than the downstream monitored and unmonitored sources added dissolved zinc and cadmium. The attenuation of dissolved zinc and cadmium, combined with tributary flow and surface runoff water inputs, caused dissolved zinc and cadmium concentrations above Bend Bridge to be lower than the numeric targets. In contrast, dissolved copper loads typically experienced a *net increase* in the Sacramento River between Keswick Dam and Bend Bridge. However, tributary flow and surface runoff inputs still *diluted* the dissolved copper loads in the river to an extent that, but for the one day in December 1996, the dissolved copper concentrations above Bend Bridge did not exceed numeric targets.

7.3 Numeric Modeling

The source and linkage analyses indicated that:

- Dissolved metal loads from the IMM site released by SCDD typically cause exceedances of numeric targets (especially for dissolved copper) in Keswick Dam releases. Shasta Dam releases typically (but not always) act as sources of dilution for SCDD releases.
- Keswick Dam releases are the dominant source of dissolved metal loads to the Sacramento River between Keswick Dam and Bend Bridge.

Because the IMM site is the dominant contributor of dissolved metals to the Sacramento River, the USEPA developed a numerical water quality model to predict the effectiveness of various remedial alternatives with respect to limiting the frequency of SCDD spills and exceedances of the numeric targets in the Sacramento River below Keswick Dam. The USEPA developed its model as part of its 1994 Water Management Feasibility Study³⁰ and 1996 Water Management Feasibility Study Addendum³¹ (USEPA, 1997b). The model used a mass balance approach to account for heavy metals as they are carried in the streams (Boulder Creek, Slickrock Creek, and Spring Creek) through Spring Creek Reservoir into Keswick Reservoir and mixed with Sacramento River water released from Shasta Lake. The model takes

³⁰ USEPA's *Water Management Feasibility Study*. June 1994.

³¹ USEPA's *Water Management Feasibility Study Addendum*. April 9, 1996. See also: *Iron Mountain Mine Water Quality Model Version 2 – Documentation with Diskette*. May 1996.

into account all the remedial actions implemented to date and calculates (1) the frequency at which the Basin Plan objectives and the CTR criteria would be exceeded in the main stem of the Sacramento River below Keswick Dam over the 31-year study period (1965 to 1995), and (2) the Sacramento River flow required to ensure the dilution of IMM-contaminated SCR waters to meet water quality standards. The USEPA determined that the model is capable of taking into account the uncertainties inherent in real-time operation of Central Valley Project facilities.

For the modeling conducted in 1996, the USEPA generally assumed that uncertainties could be addressed by targeting SCDD operations to meet a value equal to 75% of the Basin Plan objectives and CTR criteria. Comments submitted by the USBR indicate that this assumption might be overly optimistic, which would cause the model to understate the frequency and duration of exceedances. In response to this comment, comments from the responsible parties regarding other specific model assumptions, and other information obtained since May 1996, in 1997 the USEPA conducted an additional modeling analysis of the difficulties inherent in trying to predict metal concentrations below the SCDD in real-time under highly variable conditions. As part of the most recent analysis, USEPA conducted new model runs using:

- water quality and flow data obtained since the 1996 modeling effort;
- new flow projections from the USBR;
- CTR chronic criteria;³²
- additional information regarding the operational efficiency of the SCDD.

In particular, the model relied on the assumption that Shasta Dam releases have an average dissolved copper concentration of 1.3 µg/l and dissolved zinc concentration of 3.9 µg/l (Sugarek, 2002; CH2M Hill, 1997). The model incorporated dissolved metals concentration data for 54 samples collected between 1994 and 1997. To calculate average concentrations, the USEPA used ½ the detection limit for the samples with metal concentrations below the MDL and the actual concentrations for the remaining samples.³³

The USEPA determined that the additional analysis confirmed the reliability and reasonableness of the 1996 IMM water quality model to predict, with reasonable accuracy, the types of conditions that would

³² At the time of the USEPA's modeling efforts, the CTR criteria were considered to be "proposed" criteria, not final criteria.

³³ Regional Board staff collected samples in 1993 that had an average concentration of 1.9 µg/l dissolved copper and 3.9 µg/l dissolved zinc, indicating some variability in the copper concentrations over time (CH2M Hill, 1997; Sugarek, 2001).

cause SCDD spills and exceedances of the numeric targets (USEPA, 1997b).³⁴ The analysis indicated that, even if significant resources are expended to perform an intensive monitoring program and make frequent operational adjustments, achieving a 75% SCDD operational efficiency under all conditions could be an overly optimistic assumption. The USEPA therefore considered a range of operational efficiencies in evaluating the probability of future SCDD spills under variable hydrologic conditions, including a straight 75% assumption and a split operational efficiency that varies the assumed efficiency from 50 to 75% depending on the Spring Creek Reservoir inflows (75% was used for Spring Creek Reservoir inflows less than 50 cfs and 50% was used for Spring Creek Reservoir inflows greater than 50 cfs).

7.3.1 Modeling of Current Conditions

Under current conditions (i.e., with treatment of the three major IMM sources and in the absence of further response actions), the USEPA's modeling analysis indicated the following:

- The model consistently indicated that exceedances of the numeric targets in the winter would continue to occur on a regular and frequent basis below Keswick Dam, even assuming that the USBR would always be able to precisely define the appropriate releases during highly variable storm conditions (USEPA, 1997b). Using a more realistic estimate of SCDD operations would increase the frequency of the predicted exceedances. Uncontrolled spills of IMM contaminants would continue to occur every 3 to 4 years if the SCDD were operated to target the Basin Plan objectives below Keswick Dam and every 2 to 3 years if the SCDD were operated to target the CTR criteria below Keswick Dam. IMM site releases also would continue to affect natural resources below the SCDD by discharging large loads of heavy metals that form precipitates that contaminate downstream sediments.
- The two most important factors that currently make it impossible for SCDD to permit dilution of IMM AMD in a manner that maintains the numeric targets below Keswick Dam in the Sacramento River are: (1) the storm inflows to the Spring Creek Reservoir are highly contaminated, and (2) storms that cause these contaminated waters to fill the reservoir within a few days will likely occur every 5 to 10 years. More frequent SCDD spills (on the order of one spill every 3 to 4 years) would occur because of other factors such as preceding drought conditions that will limit the flow in the Sacramento River.
- Significant further remediation of the IMM area source discharges, such as reducing dissolved copper concentrations in Spring Creek Reservoir to 100 µg/l or less, is required to ensure that continued operations of SCDD would be able to safely release any continuing uncontrolled IMM discharges to protect the Sacramento River below Keswick Dam. Reducing metal loads to the Spring Creek Reservoir would permit the IMM AMD to be evacuated from the SCDD at a faster rate, which in turn would decrease the frequency of SCDD spills and exceedances of numeric targets.

³⁴ See also: USEPA's *Response to Comments on Water Management Feasibility Study and Addendum* (September 30, 1997) and *(Footnote continued on next page.)*

7.3.2 Modeling of Anticipated Conditions

This TMDL strategy involves the USEPA's construction of the Slickrock Creek Retention Dam to enable the treatment of contaminated Slickrock Creek flow. This action would remove essentially all Slickrock Creek area AMD discharges (USEPA, 1997b).³⁵ The Slickrock Creek area sources comprise approximately 60 to 70% of the remaining uncontrolled copper and 40 to 50% of the remaining uncontrolled zinc and cadmium site discharges. This action, when combined with the current remedies, would control more than 95% of total site releases (USEPA, 2000b). Figure 7-5 illustrates the nature of (1) current reductions in copper loads from the SCDD accomplished by the lime-neutralization high-density-sludge treatment plant, and (2) anticipated reductions as a result of diverting contaminated Slickrock Creek flow from the proposed retention reservoir to the treatment plant. Chapter 10 provides a more detailed description of the proposed SRCRD construction.

Water quality modeling based on conservative estimates of anticipated load reductions from the SCDD indicates that the proposed construction of the SRCRD and associated treatment of Slickrock Creek flow would provide significant protection to the environment by reducing the frequency, duration, and degree of numeric target level exceedances. In particular, the proposed remediation actions would:

- Reduce the expected SCDD spill frequency to once every 8 to 10 years if the USBR operates the SCDD to target the Basin Plan objectives below Keswick Dam (as compared to the current frequency of every 3 to 4 years) and every 4 to 8 years (as compared to 2 to 3 years) if the USBR operates the SCDD to target the CTR criteria below Keswick Dam. (Treatment of Slickrock Creek flows would cause the SCDD releases to be less toxic and therefore permit releases at a faster rate, thereby preventing the SCDD from overflowing as often or as long.)
- Reduce the toxicity of the spills that do occur because the Spring Creek Reservoir would contain lower concentrations of metals.
- Decrease the days that the Sacramento River below Keswick Dam experiences a violation of a numeric target by approximately 80%.
- Significantly reduce the mass loads of copper, cadmium, and zinc through removal of approximately 60% to 70% of the remaining uncontrolled copper and 40% to 50% of the remaining uncontrolled zinc and cadmium IMM site discharges.

Water Quality Model Output in Support of Response to Comments (September 30, 1997).

³⁵ The USEPA generally relied upon an efficiency of 90% as a conservative estimate for the analysis using the water quality model; however, the USEPA anticipates that the remedy will be more effective than that estimate (USEPA, 1997b).

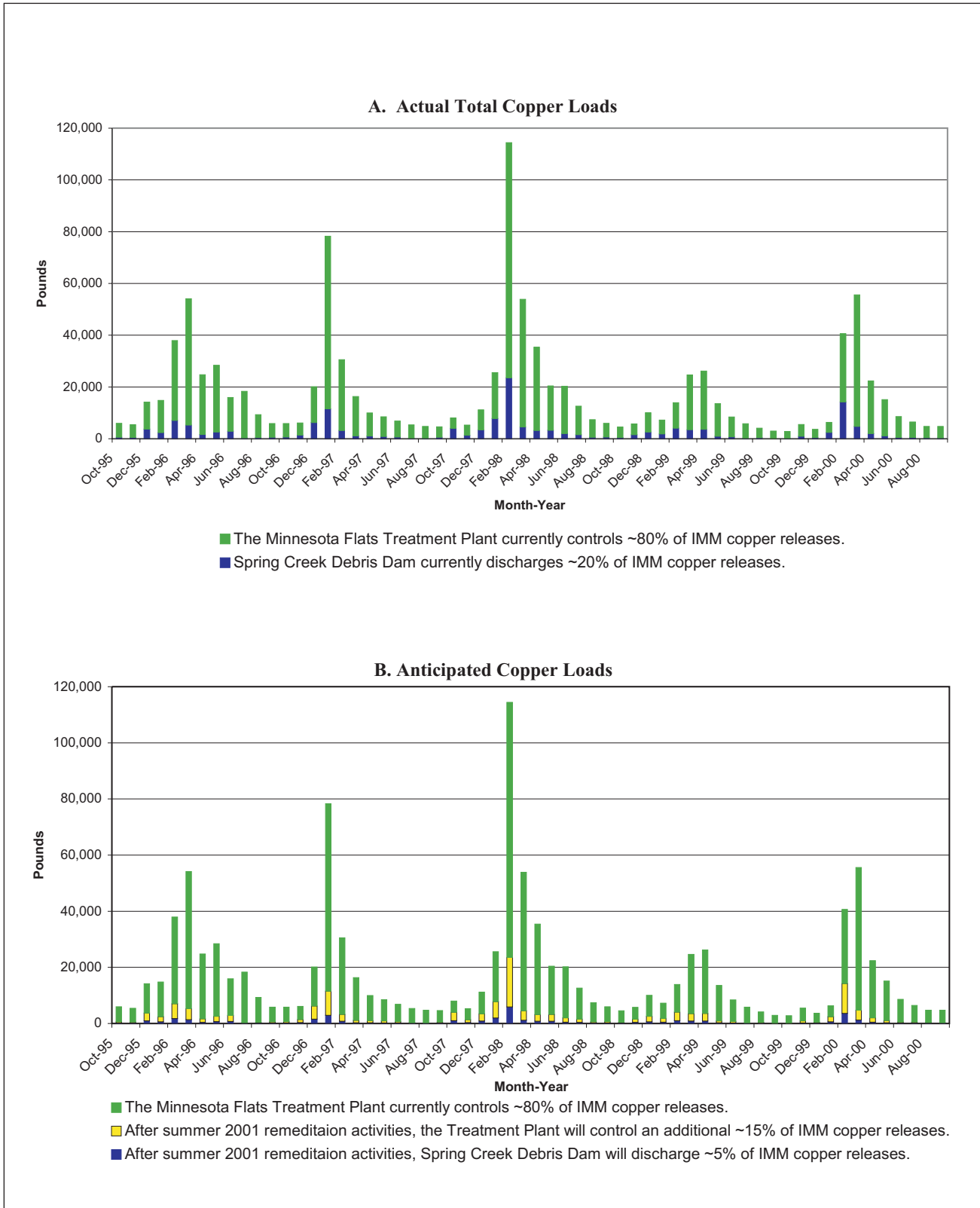


Figure 7-5. Total Copper Loads from Iron Mountain Mines Site
 A. Actual loads for past five years. B. Hypothetical loads showing anticipated Spring Creek Debris Dam load reductions resulting from proposed construction of Slickrock Creek Retention Dam.

Reducing metal loads from the IMM site via the SCDD also produces ancillary environmental benefits by reducing the need for special dilution releases (USEPA, 1997b). For example, if special releases of water are required for dilution of IMM AMD, those releases reduce the amounts of water in storage that would otherwise be available for temperature control in the Sacramento River or other environmental needs. An additional ancillary benefit can be realized with reduced reliance on the current use of the Spring Creek Power Plant discharges to ensure regular flushing of the heavy metals from SCAKR. Demand for water from the Trinity River and upper Clear Creek would be reduced, increasing its availability for beneficial uses in those watersheds.

8 LOAD REDUCTION ALLOCATIONS

8.1 Definition of Allocations

A TMDL typically represents the sum of all individual allocations of the waterbody's assimilative capacity. The TMDL must be less than or equal to the assimilative capacity; it is equal to the assimilative capacity only if the entire assimilative capacity is allocated. Allocations can be made to point sources (wasteload allocations) or nonpoint sources (load allocations). Federal regulations define a load allocation as:

“The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which may range from reasonably accurate estimates or to gross allotments, depending on the availability of data and appropriate techniques for predicting loading. Wherever possible, natural and nonpoint source loads should be distinguished.” (*Code of Federal Regulations, Title 40, Part 130, Section 2(g)*)

This TMDL presents allocations in terms of the existing assimilative capacity of the Sacramento River below Keswick Dam and above Bend Bridge (the two monitoring points for this TMDL), as described below. Load reductions are assigned to IMM and Shasta Dam releases.

8.2 Load Reduction Allocation for Sources above Keswick Dam

Figures G-2A through G-2C in Appendix G illustrate the daily loads, assimilative capacity, and dissolved concentrations for copper, zinc, and cadmium³⁶ in Keswick Dam releases. Keswick Dam releases represent the accumulated discharges from the IMM site, SCPP, Shasta Lake, and other point and nonpoint sources. As noted in Chapter 5 (Source Assessment), the IMM site and Shasta Lake dissolved metal discharges during the wet season account for the majority of metal loads discharged from Keswick Dam, as well as the exceedances of numeric targets below Keswick Dam.

8.2.1 Load Reduction for Iron Mountain Mines Site

As noted in Chapter 7 (Linkage Analysis), the USEPA developed a numerical water quality model to predict the effectiveness of various remedial alternatives with respect to reducing loads from IMM site to limit the frequency of SCDD spills and exceedances of the numeric targets below Keswick Dam. The USEPA's method involved determining (1) the reduction in metals loads (which occur almost entirely in

³⁶ See Chapter 7 (Linkage Analysis) for a discussion of the relationship between assimilative capacity, concentration, and load.

the dissolved form) from the IMM site *combined with* (2) the Sacramento River flow required to ensure the dilution of IMM-contaminated SCDD release waters to meet water quality standards below Keswick Dam. Current remediation activities have resulted in an average reduction in copper discharges of 83% and an average reduction in zinc and cadmium discharges of 89%. The USEPA's water quality modeling (based on conservative estimates of anticipated load reductions from the SCDD) indicated that construction of the SRCRD and treatment of Slickrock Creek flow would reduce approximately 60 to 70% of the remaining uncontrolled copper and 40 to 50% of the remaining uncontrolled zinc and cadmium site discharges. This action, when combined with the current remedies, would control more than 95% of total IMM site releases. Table 8-1 and Figure 8-1 illustrate the effects of these reductions using SCDD release loads and flow data for the past five years as an example.

Table 8-1. Metal Loads Before and Anticipated Loads After Proposed IMM Site Remediation Activities

Metal	Daily Loads Calculated for Water Years 1996 Through 2000 ^(a)	Anticipated Post-Remediation Loads ^(b)
Copper	2 – 1121	0.9 - 448
Zinc	4 – 2517	2.5 - 1510
Cadmium	0.06 – 16.8	0.04 – 10.8

(a) The daily load calculations correspond to SCDD releases flows ranging from 2 to 757 cfs.

(b) Estimated post-remediation load values are based on an anticipated 60% reduction of past copper loads, and 40% reduction of past zinc and cadmium loads.

Such load reductions would result in a decrease of the expected SCDD spill frequency from once every three to four years to once every eight to ten years if the SCDD is operated to target the Basin Plan objectives below Keswick Dam, and from once every two to three years to once every four to eight years if the SCDD is operated to target the CTR criteria below Keswick Dam. The decrease in uncontrolled spills from SCDD would decrease the number of days that the Sacramento River below Keswick Dam experiences a violation of a numeric target by approximately 80%. As explained in Chapters 6 and 9, the CTR chronic criteria include a margin of safety that should be adequate to protect freshwater aquatic organisms so long as dissolved cadmium, copper, and zinc concentrations do not exceed the criteria more than once every three years for a 96-hour period. USEPA modeling indicates that uncontrolled spills – and associated exceedances of numeric targets – will still probably occur after the completion of the proposed SRCRD. However, by significantly decreasing the frequency of uncontrolled spills from SCDD, the proposed remediations at the IMM site should enable Keswick Dam releases to comply with the proposed chronic dissolved copper numeric target (which is based on the CTR chronic criterion for

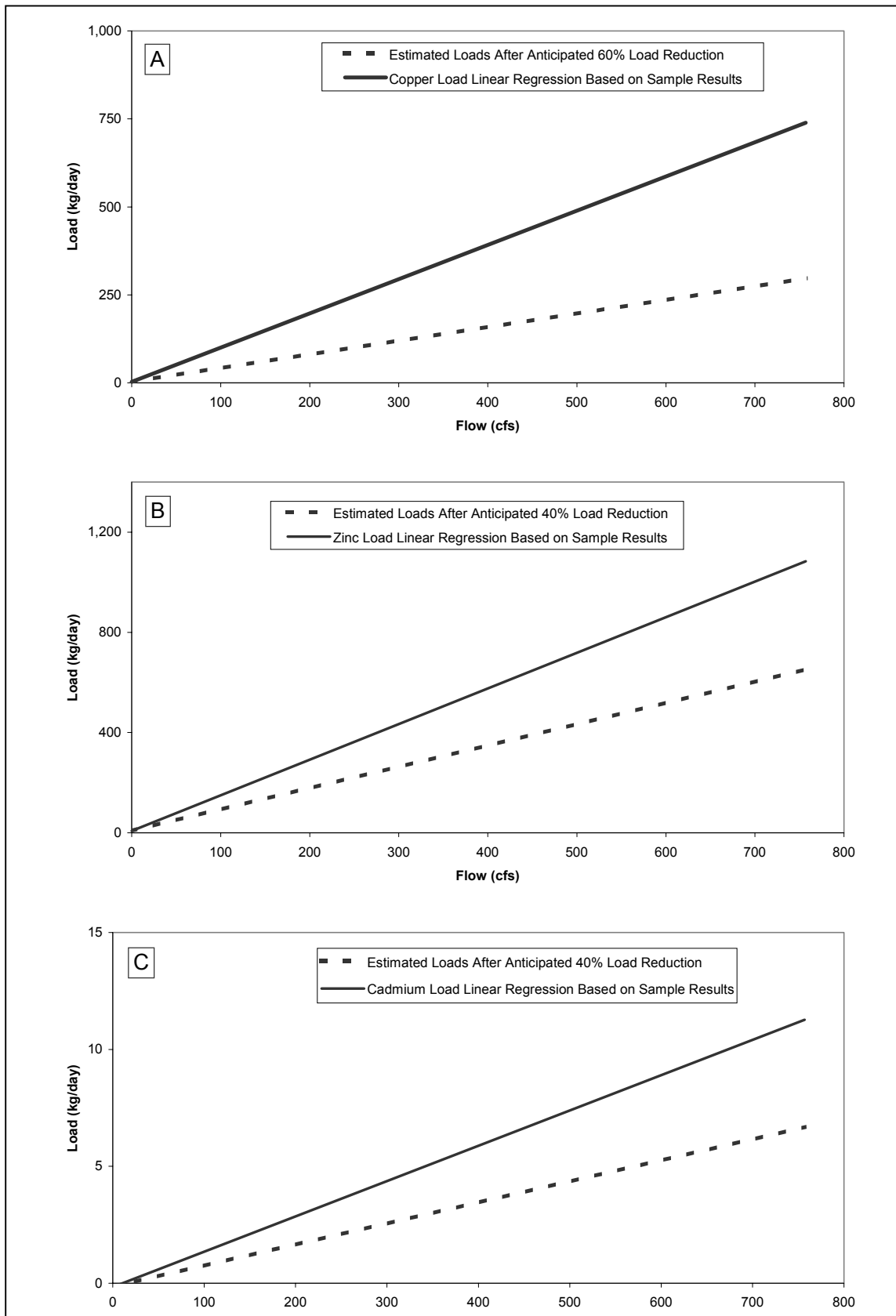


Figure 8-1. Metal Loads Before and Anticipated Loads After Proposed Iron Mountain Mines Site Remediation Activities

dissolved copper), as well as significantly decrease the frequency of exceedances of the acute dissolved copper target and the acute/chronic dissolved cadmium and zinc targets (which are based on the acute Basin Plan objectives).

As a result, for this TMDL Regional Board Staff allocates to the IMM site the load reductions prescribed by the USEPA model (60 to 70% of the remaining uncontrolled copper and 40 to 50% of the remaining uncontrolled zinc and cadmium site discharges) to enable Keswick Dam releases to comply with the proposed numeric targets. Regional Board staff bases this allocation on the following assumptions:

- Shasta Dam releases will have 4-day average dissolved copper concentrations less than 1.3 µg/l, as assumed by the USEPA IMM numeric water quality model.
- The USBR will continue to operate the SCDD and related facilities in a reasonable and prudent manner in compliance with operations criteria set forth in the 1980 MOU, 1992 CVP-OCAP, and 1993 Biological Opinion, until such time the 1980 MOU is revised.

The following section discusses typical dissolved metal concentrations in Shasta Dam releases and the Shasta Dam load reduction allocation.

8.2.2 Load Reduction for Mine Sites Upstream of Shasta Dam

Given the recent significant decreases in metal loads from the IMM site, other sources in the area now make up a more significant share of the total metals load from sources upstream of Keswick Dam. As described in Chapter 3 and Appendix B, past remediation activities at mines discharging above Shasta Dam have reduced the metals loads to Shasta Lake. However, additional remediation efforts are needed because:

- Metal concentrations in Shasta Dam releases occasionally exceed the proposed numeric targets, and
- During the January 1998 to April 2001 period, dissolved copper concentrations in Shasta Dam releases have frequently exceeded the 1.3 µg/l average concentration assumed by the USEPA's IMM numeric water quality model (Figures 8-2 and A-2). In addition, dissolved zinc concentrations have occasionally exceeded the 3.9 µg/l average concentration assumed by the model during that time period (Figure A-3B).

As illustrated by Figure 8-2, dissolved copper concentrations above 1.3 µg/l in Shasta Dam releases correspond to a wide range of discharge values. As a result, for this TMDL Regional Board Staff allocates to the Shasta Dam releases the average dissolved copper and zinc concentrations assumed by the USEPA model (1.3 µg/l dissolved copper and 3.9 µg/l dissolved zinc) to enable Keswick Dam releases to comply with the proposed numeric targets for dissolved copper, zinc and cadmium (rather than assign a

load-based allocation). Regional Board staff bases this allocation on the assumption that the USBR will continue to operate the SCDD and related facilities in a reasonable and prudent manner in compliance with operations criteria set forth in the 1980 MOU, 1992 CVP-OCAP, and 1993 Biological Opinion, until such time the 1980 MOU is revised.

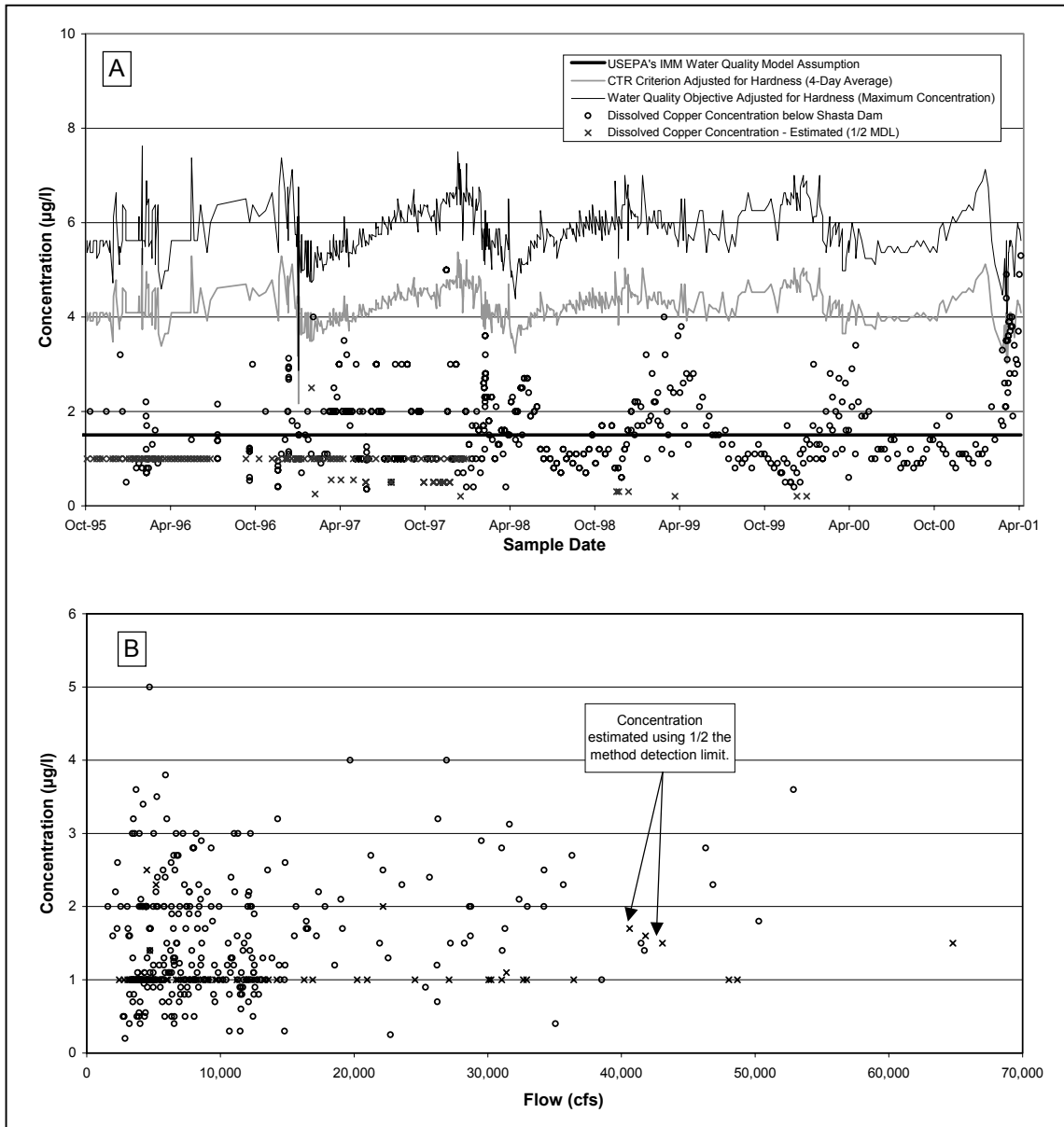


Figure 8-2. Shasta Dam Releases – Dissolved Copper Concentration and Flow Data for 1995-2001
 A. All Available Dissolved Copper Concentration Data for Shasta Dam Releases.
 B. Dissolved Copper Concentration Versus Flow.

Sources of dissolved cadmium, copper, and zinc to Shasta Lake may include both surface mines and inundated smelter sites. As noted earlier, another TMDL will address individual sources of dissolved

cadmium, copper, and zinc to Shasta Lake. Because the assignment of load reductions to individual mines sites upstream of Shasta Dam will be part of this separate TMDL, Regional Board staff assigns the metals allocation to Shasta Dam releases; Shasta Dam acts as a monitoring point for the accumulated loads from all point and nonpoint sources upstream of the dam. Chapter 10 (Implementation Plan) describes the activities planned for determining the causes of seasonal variations in metals concentrations in Shasta Dam releases and remediation activities planned for the mines in the Shasta Lake watershed.

8.3 Allocation for Sources between Keswick Dam and Red Bluff

At this time, Regional Board staff does not assign allocations for point and nonpoint sources downstream of Keswick Dam for this TMDL for three reasons:

1. As described in Chapter 5 (Source Assessment), discharges from Keswick Dam account for the majority of dissolved cadmium, copper, and zinc loads measured in the upper Sacramento River above Bend Bridge. Reductions in metals loads in Keswick Dam releases resulting from remediations at the IMM site, in combination with remediation activities at mines in the Shasta Lake area, are expected to reduce dissolved metal loads and concentrations measured in the Sacramento River between Keswick Dam and Bend Bridge.
2. As demonstrated by Figure 7-4, the Sacramento River below the confluence with Cottonwood and Battle Creeks has a higher assimilative capacity than the river immediately below Keswick Dam because of the addition of dilution water from tributaries downstream of Keswick Dam, and the apparent attenuation of dissolved metals. Figure 7-4 also demonstrates that there is an availability of excess assimilative capacity in the Sacramento River below Cottonwood and Battle Creeks.
3. NPDES Permits, Waste Discharge Requirements, Cleanup and Abatement Orders, and other regulations require the point and nonpoint source dischargers to operate using best management practices. The dischargers are expected to meet effluent limits in these requirements.

As described in Chapter 10, Regional Board staff will require NPDES-permitted dischargers to monitor for dissolved metals. Staff will evaluate the monitoring results and assign wasteload allocations as needed to ensure that the Sacramento River between Keswick Dam and Red Bluff complies with the proposed numeric targets.

9 MARGIN OF SAFETY, SEASONAL VARIATION, & CRITICAL CONDITIONS

9.1 Margin of Safety

The TMDL process involves the establishment of a margin of safety (MOS) to account for data uncertainty, growth, and critical conditions. The MOS can be derived implicitly, through conservative assumptions about numeric targets, or explicitly, through reservation of unallocated load. This technical TMDL incorporates two types of implicit MOSs.

The first set of implicit MOSs is incorporated in the numeric targets:

- The proposed acute and chronic cadmium and zinc numeric targets, and acute copper numeric target, are equivalent to the Basin Plan water quality objectives, which are based on 4-day toxicity tests conducted on aquatic species by CDFG. These targets have two types of implicit MOS. First, the objectives are based on 4-day (chronic) toxicity tests, rather than instantaneous (acute) toxicity tests. Second, the objectives are equal to *one tenth* of the median lethal concentrations during 4 days (96-hour LC₅₀ values). CDFG determined that such objectives would safely reflect maximum (instantaneous) metal concentrations tolerated for unimpaired aquatic life (Finlayson and Verrue, 1982; Finlayson and Wilson, 1989).
- The proposed chronic copper numeric target is equivalent to the CTR chronic criterion for copper, which the USEPA adapted from the CTR maximum concentration criteria using an acute-chronic ratio developed for sensitive fish and invertebrate species (USEPA, 1996b). The USEPA incorporated a MOS in both the calculation of the maximum concentration criteria and the acute-chronic ratio (refer to Footnote #23 in Section 6.3.2). The USEPA determined that the chronic CTR copper criterion would provide a MOS adequate to protect freshwater aquatic organisms so long as the four-day average concentration of copper does not exceed the chronic copper criterion more than once every three-year period (USEPA, 2000a).
- As noted in Chapter 6, the chronic cadmium and zinc numeric targets for this TMDL are equivalent to the acute Basin Plan water quality objectives for cadmium and zinc because the Basin Plan objectives are lower (i.e., more protective of aquatic species) than the chronic CTR criteria for cadmium and zinc. As with the chronic copper criterion, the USEPA determined that chronic CTR cadmium and zinc criteria would provide a MOS adequate to protect freshwater aquatic organisms so long as the four-day average concentrations of cadmium and zinc do not exceed the chronic cadmium and zinc criterion more than once every three years (USEPA, 2000a). Presumably, the Basin Plan objectives would be equally protective.

The second implicit MOS is incorporated in the USEPA's numerical water quality model designed to predict the effectiveness of various remedial alternatives at the IMM site with respect to limiting the frequency of SCDD spills and exceedances of the numeric targets below Keswick Reservoir:

- The USEPA generally assumed that uncertainties inherent in real-time operation of Central Valley Project facilities could be addressed by targeting SCDD operations to meet a split

operational efficiency that varies the assumed efficiency from 50 to 75% depending on the Spring Creek Reservoir inflows of the Basin Plan objectives and CTR criteria.

- The USEPA anticipates that the collection and treatment of baseflow from Slickrock Creek would remove essentially all Slickrock Creek area source AMD discharge load. However, the USEPA's water quality model generally relied upon an efficiency of 90% as a conservative estimate; the USEPA anticipates that the remedy will be more effective than that estimate.

9.2 Seasonal Variation & Critical Conditions

Data collected in the 1990s indicate that dissolved copper and zinc concentrations have considerable seasonal variability. Occasional exceedances of water quality standards occur each year on the Sacramento River below Shasta and Keswick Dams, most often during the December-to-April period. The exceedances typically corresponded to the concurrent occurrence of three critical short-term conditions:

1. Times of heavy rainfall runoff that causes the Spring Creek Reservoir to reach capacity and SCDD to have an uncontrolled spill.
2. Times that Shasta Dam releases higher than normal concentrations of dissolved cadmium, copper, and zinc. For example, in March and April 2001, Shasta Dam releases had dissolved copper concentrations that exceeded the CTR criterion of 4.1 µg/l and approached the Basin Plan objective of 5.6 µg/l. In addition, Shasta Dam releases that have metal concentrations exceeding the levels assumed by the USEPA's IMM numeric water quality model may lead to exceedances of the proposed numeric targets downstream of Keswick Dam.
3. Times that the Shasta Dam or Spring Creek Power Plant dilution releases are reduced for the purposes of storage and flood control.

Chapters 8 (Load Reductions Allocations) and 10 (Implementation Plan) describe how the frequency of these critical conditions can be decreased, and how, when the conditions do occur, they can be mediated to prevent an exceedance of the numeric targets. The proposed construction of the SRCRD and treatment of Slickrock Creek baseflow at the IMM site would significantly reduce the likelihood of the first critical condition (uncontrolled spills) occurring in the future. Chapter 10 provides a description of the USEPA's construction schedule for the SRCRD and related remediation components. Chapter 10 also describes the activities planned for determining the causes of seasonal variations in metals concentrations in Shasta Dam releases and remediation activities planned for mines upstream of Shasta Dam. These activities will significantly reduce the likelihood of the second critical condition (higher than normal metal concentrations in Shasta Dam releases) occurring in the future. The second critical condition possibly may be avoided by selecting Shasta Dam withdrawals at different levels.

Other potential critical conditions include interruptions in AMD treatment (particularly at the IMM site), accidents, natural catastrophes (e.g., earthquakes), and willful malicious acts (e.g., acts of terrorism and illegal dumping). The 1980 MOU, which outlines dam operations necessary to minimize Spring Creek toxicity problems, addresses these other critical conditions. On several occasions, the USBR has been able to coordinate releases from Shasta Dam and SCPP to prevent exceedances of the Basin Plan objectives during the past few years when there have been uncontrolled spills from SCDD. Chapter 10 evaluates the 1980 MOU measures that may need to be updated, depending upon the effectiveness of the proposed remediation activities during the next five years.

10 IMPLEMENTATION

Regional Board staff expects that the proposed remediation activities scheduled for IMM and other mine sites during the next five years will address exceedances of the proposed numeric targets on the Sacramento River below Keswick Dam. Staff based this determination on the following:

1. The U.S. Environmental Protection Agency (USEPA) Superfund Program's water quality modeling indicated that the proposed remediation activities at the IMM site – in coordination with current site remediation activities – would control more than 95% of total IMM site releases and therefore result in significantly decreasing the frequency of numeric target exceedances below Keswick Dam.
2. Anticipated load reductions resulting from ongoing and proposed remediation activities at mines in the Shasta Lake area would improve the water quality of both the Shasta Dam and Keswick Dam releases.

For these reasons, staff proposes the following 5-year TMDL water management strategy in accordance with this TMDL report and other USEPA and Regional Board remediation plans:

- During the summer of 2001, the USEPA Superfund Program began implementation of proposed remediation activities that include the collection and treatment of AMD-contaminated surface water discharges from the area sources in the Slickrock Creek watershed at the IMM site; the activities will take approximately two years to complete (Sugarek, 2001; Pedri, 2001; USEPA, 1997b).
- Responsible parties will conduct ongoing and proposed remediation activities at mines in the Shasta Lake area.
- Regional Board staff will increase monitoring in Shasta Lake to determine the sources and variability of dissolved metal concentrations in Shasta Dam releases during the past three years. Staff will develop mine remediation and other activities as needed to address Shasta Dam release concentrations that exceed 1.3 µg/l dissolved copper and 3.9 µg/l dissolved zinc.
- Regional Board staff will require NPDES-permitted dischargers to monitor dissolved cadmium, copper, and zinc, and flow to quantify their dissolved metal loads, and if significant loads are detected, staff will establish effluent limits and continuous monitoring in renewed permits.
- USBR, USEPA, Regional Board, and other regional agencies will continue monitoring water quality conditions in upper Sacramento River water.
- Regional Board staff will evaluate the ambient metal concentration data collected by its staff, other agencies, and dischargers to determine whether the remediations enable dissolved metal concentrations in Sacramento River water to comply with the proposed numeric targets. In addition, staff will evaluate dissolved metal loads contributed by NPDES dischargers downstream of Keswick Dam. Staff will coordinate TMDL reviews with USEPA's 5-Year Reviews for the IMM site scheduled for 2003 and 2008.
- After three years of monitoring data have been collected following the completion of remediation activities at Slickrock Creek, Regional Board staff will work with the USBR,

USEPA, California Department of Fish and Game, and State Water Resources Control Board to revise the 1980 MOU to ensure maximum efficiency in managing releases from the SCDD.

Regional Board staff bases this strategy on the following assumptions:

- The USBR will continue to operate the SCDD and related facilities in a reasonable and prudent manner in compliance with operations criteria set forth in the 1980 MOU, 1992 CVP-OCP, and 1993 Biological Opinion, until such time the 1980 MOU is revised.
- The existing AMD collection and treatment facilities at IMM will be operated to provide maximum removal of metals in accordance with a court-approved consent decree.
- Regional Board staff will enforce existing permits on mines in the Shasta Lake areas to assure maximum removal or containment of heavy metals.
- Responsible parties will increase remediation efforts at mines in the Shasta Lake areas as needed during the next five to ten years.

Based on the evaluation of the magnitude and frequency of exceedance (if any) during the three years following the completion of the USEPA's Slickrock Creek remediation activities, Regional Board staff will consider whether to recommend the removal of the upper Sacramento River from the CWA 303(d) List (i.e., "delist" the river).

There are several components for implementing and monitoring the control measures required by the watershed management strategy proposed in this TMDL. The following sections describe these components in more detail.

10.1 USEPA Superfund Remediation Activities at the IMM Site

The remediation activities described in USEPA's ROD4 began at the IMM site in the summer of 2001; the activities will take approximately two years to complete (Sugarek, 2001; Pedri, 2001). The estimated cost of the remediation is \$21.2 million (USEPA, 1997b). Through a court ordered settlement, Aventis CropSciences (a former owner and operator), has arranged for a private contractor to operate and maintain the site remedies (RODs 1-4) over the next 30 years, and to pay to the federal and state governments \$514 million in 2030 to fund future site costs (USEPA, 2000b). Currently, Iron Mountain Mines, Inc., is the site owner; the USEPA is the lead oversight agency, and the State is the support agency, for remediation activities (Sugarek, 2001).

The selected remedy relies on the collection and treatment of additional AMD-contaminated surface water discharges from the area sources in the Slickrock Creek watershed (USEPA, 1997b). The proposed

remediation should enable treatment of essentially all IMM AMD from the Slickrock Creek area sources, which comprise approximately 60 to 70% of the remaining uncontrolled copper and 40 to 50% of the remaining uncontrolled zinc and cadmium releases from the IMM site. Treatment of the Slickrock Creek AMD should neutralize the acidity of the water and remove more than 99% of the metals. The concentrations of Slickrock Creek discharges are expected to decrease proportionately under all hydrologic conditions. The USEPA considers the proposed remediation to be an interim remedy; the USEPA does not expect that this remediation will address all of the remaining sources of metal releases from the IMM site.

The proposed remediation has the following components (USEPA, 1997b):

- Construct the Slickrock Creek Retention Dam (SRCRD) and necessary surface water diversion facilities to ensure the collection and storage of contaminated surface runoff and groundwater in the Slickrock Creek watershed.
- Construct facilities to provide controlled releases of contaminated waters from the SRCRD to the AMD conveyance pipeline to the Minnesota Flats treatment plant.
- Construct facilities to divert relatively uncontaminated surface water from the area upstream from the highly disturbed mining area of the Slickrock Creek basin and convey that water around the Slickrock Creek Retention Reservoir. The diversion would also divert stormwater around the retention reservoir and the water from the unmined side of the Slickrock Creek watershed.
- Integrate the collection and conveyance of the Old/No. 8 Mine Seep AMD to the treatment plant into the operation of the reservoir, including consideration of emergency failure scenarios.
- Construct an erosion control structure for the hematite piles³⁷ consistent with California mining waste requirements.
- Construct one or more sedimentation basin(s) or other USEPA approved control structures in the Slickrock Creek watershed to minimize sedimentation of the Slickrock Creek Retention Reservoir and to ensure proper functioning of the controlled release facilities.
- Upgrade the hydraulic capacity of the existing pipeline (or if necessary construct a new pipeline) from Slickrock Creek to the Boulder Creek crossing as required to ensure adequate reliable capacity to convey Slickrock Creek and Old/No. 8 Mine Seep AMD.
- Construct an additional pipeline to reliably convey Slickrock Creek and Old/No. 8 Mine Seep AMD from the Boulder Creek Crossing to the treatment plant.

³⁷ Significant portions of the gossan cap on Iron Mountain were mined to recover gold and silver in a heap leaching operation. The finely crushed wastes from the heap leaching operations were dumped into Hogtown Gulch (a tributary to Slickrock Creek), forming the enormous waste piles that are commonly called “the hematite piles”. The hematite piles are actively eroding into Slickrock Creek and contribute approximately 1% of the metals in Slickrock Creek (USEPA, 1997b)

- Modify the Minnesota Flats treatment plant to ensure proper treatment, of the Slickrock Creek area AMD discharges in conjunction with AMD flows collected from other IMM areas.
- Construct a tunnel to provide for gravity discharge of the high volumes of effluent from the Minnesota Flats treatment plant to Spring Creek below the upper Spring Creek diversion to Flat Creek.
- Construct facilities to assure collection of significant identified sources (including but not limited to seeps from Brick Flat Pit and the hematite piles) and convey those releases to the Slickrock Creek Retention Reservoir.
- Perform long-term operations and maintenance of all components.

The SRCRD and reservoir would be within the Slickrock Creek drainage on Iron Mountain, directly downstream of the most heavily disturbed mining area in the watershed (USEPA, 1997b). Inflows include:

- surface-water runoff from the highly disturbed mining areas,
- flows from the former open pit mine and current sludge disposal site,
- flows from Slickrock Creek,
- flows from the Old No. 8 Mine Seep, and
- flows from the hematite pile area.

The SRCRD would be located approximately 200 feet upstream of the hematite piles. A dam at this location would collect drainage from an area of approximately 546 acres; however, 387 acres of this drainage area would be intercepted by a clean-water diversion (modified as necessary) and discharged into Slickrock Creek below the proposed SRCRD. An additional 44 acres of drainage above Brick Flat Pit (an open pit to be filled with dewatered sludge and tailings to prevent accumulation of water) is also currently collected and diverted into Slickrock Creek below the proposed SRCRD. The potential AMD-generating area of the Slickrock Creek drainage is therefore approximately 115 acres. The reservoir developed behind the SRCRD will temporarily store AMD before it is conveyed by pipeline to the Minnesota Flats treatment plant. The SRCRD will be sized to contain 100-year storms, which would require a reservoir capacity of at least 170 acre-feet. Preliminary information indicates that the SRCRD would be approximately 105 feet high (75 feet above the existing streambed).

The USEPA will continue to evaluate the need for, and technical feasibility of, additional remediation activities to address area source AMD discharges from the Boulder Creek drainage (the remaining 5% of total site releases). In addition, the USEPA has begun preliminary work in support of what is anticipated to be the next Remedial Investigation/Feasibility Study for the site, which is to evaluate the removal of

sediment that has accumulated in the SCAKR, the Spring Creek Reservoir, and the main channel of Keswick Reservoir (Rae, 1998; USEPA, 2001a; Sugarek, 2001).

10.2 Remediation Activities at Mines in the Shasta Lake Watershed

Table 10-1 summarizes the status of remediation activities at Shasta Lake area mines. Appendix B provides more information about past and proposed future remediation activities for these mines. In addition, Regional Board staff will increase monitoring in Shasta Lake (e.g., at multiple depths and location throughout the lake pool) to determine any additional metal sources and to better define metal transport in the lake. Regional Board staff will develop additional mine remediation and other activities as needed to address metal concentrations in Shasta Dam releases that exceed 1.3 µg/l dissolved copper and 3.9 µg/l dissolved zinc.

10.3 Pollution Control Activities for Sources between Keswick Dam and Red Bluff

Afterthought Mine discharges to Little Cow Creek approximately 23 miles upstream of the Little Cow Creek – upper Sacramento River confluence, which is approximately 2.5 miles east of Anderson. Greenhorn Mine discharges to Willow Creek, a tributary to Whiskeytown Lake, which ultimately drains to either Spring Creek via Spring Creek Tunnel, or to Sacramento River downstream of Keswick Dam via Clear Creek. The Regional Board has issued NPDES Permits and Cease and Desist Orders to these mines. Because of the responsible parties' inaction, the Regional Board will pursue enforcement actions to achieve some level of remediation (Woodward, 2001).

Regional Board staff will continue to review monitoring data collected by the City of Redding for its municipal treatment plants. As noted in Chapter 5, little-to-no monitoring information was available for other NPDES-permitted dischargers. Regional Board staff will require selected NPDES-permitted dischargers to monitor dissolved cadmium, copper, and zinc, and flow to better quantify loads.

Table 10-1. Permit Types and Proposed Future Remediation Activities for Shasta Lake Area Mines

Mine	Permit Type	Proposed Remediation Schedule (Schedule)
West Squaw Creek Watershed ^(a)		
Balaklala Mine	NPDES / Cease and Desist Order	Evaluate alternative technologies necessary to reduce metal discharges. Implement Best Management Practices (BMPs) to reduce metal discharges. Develop Use Attainability Analysis (UAA) for removal off selected beneficial uses of watercourse. (2002-2008)
Early Bird Mine	NPDES / Cease and Desist Order	All planned remediation activities have been completed.
Keystone Mine	NPDES / Cease and Desist Order	Evaluate effectiveness of constructed wetlands; develop additional mitigations as necessary to achieve 99% reduction in metals. Implement BMPs to reduce metal discharges. Develop UAA for removal off selected beneficial uses of watercourse. (2002-2008)
Shasta King Mine	NPDES / Cease and Desist Order	Evaluate impacts and access to waste rock piles poised above West Squaw Creek. Implement BMPs to reduce metal discharges. Develop UAA for removal off selected beneficial uses of watercourse. (2002-2008)
Little Backbone Creek Watershed		
Golinski Mine	Cleanup and Abatement Order	Evaluate effectiveness of bulkhead seals installed in 2001. Institute additional mitigations as necessary. (2003-2008)
Gossen Mine	NPDES / Cease and Desist Order	Evaluate contribution of waste rock dumps and mitigate discharges from dumps as appropriate. (2002-2008)
Mammoth Mine	NPDES / Cease and Desist Order	Evaluate potential remedies for large seep into stream. Evaluate contribution of waste rock dumps. Institute remedial activities. (2002-2008)
Sutro Mine	NPDES / Cease and Desist Order	Evaluate contribution of waste rock dumps and mitigate discharges from dumps as appropriate. (2002-2005)
Horse Creek		
Rising Star Mine	NPDES / Cease and Desist Order	Evaluate remedial alternatives to portal discharge and waste rock dumps. Devise interim remedial measures; develop and implement appropriate final remedial activities. (2002-2008)
Town Creek		
Bully Hill Mine	NPDES / Cease and Desist Order	Evaluate remedial alternatives to portal discharge and waste rock dumps. Devise interim remedial measures; develop and implement appropriate final remedial activities. (2002-2008)

10.4 USBR Dam Operations

The 1980 MOU between the USBR, SWRCB, and CDFG may not be adequate for the following reasons:

- The 1980 MOU operations objectives are higher (i.e., less protective of aquatic life) than the numeric targets proposed in this TMDL, which are based on the Basin Plan water quality objectives for copper and zinc, and the chronic CTR criterion for copper.
- The 1980 MOU does not include operations objectives for cadmium.
- The 1980 MOU is based on the assumption that 50% of the dissolved metals will form precipitates in the SCAKR and Keswick Reservoir; recent USEPA studies indicate that the precipitation rate is approximately 35% under most conditions.

However, in recent years, USBR staff has voluntarily targeted the more stringent Basin Plan water quality objectives for dissolved metal concentrations for the upper Sacramento River in addition to the 1980 MOU objectives. USBR staff also has consulted with other federal and state agencies in order to improve SCDD operations and target the Basin Plan objectives when CVP operations allow. In addition, the USBR has developed an operations strategy for the SCPP to minimize mobilization of contaminated sediments and metal precipitates. The USBR continues to operate the SCDD, Shasta Dam, and SCPP to maximize the dilution of SCDD releases to the extent feasible, in compliance with operations criteria set forth in the 1980 MOU, 1992 CVP-OCAP, and 1993 Biological Opinion.

Nevertheless, the USBR will continue to have water management goals (e.g., flood control and other CVP requirements) for Shasta Lake and Whiskeytown Lake releases that could conflict with the requirement of diluting AMD in the upper Sacramento River in an effort to comply with the Basin Plan water quality objectives and CTR criteria for dissolved metal concentrations below Keswick Dam and downstream reaches. After three years of monitoring data have been collected following the completion of remediation activities at Slickrock Creek, the USBR will work with the Regional Board staff, USEPA, CDFG, and the State Water Resources Control Board to revise the 1980 MOU to take into account the performance of the USEPA remedies in RODs 1-4, new technology, and new information (e.g., the Regional Board staff evaluation of the variability of dissolved metal concentrations in Shasta Dam releases; see below). The purpose of revisions to the 1980 MOU would be to ensure maximum efficiency in managing releases from the SCDD.

10.5 Monitoring

Regional Board staff will review the monitoring data collected by the USBR, City of Redding, USEPA, and Regional Board staff on an annual basis to ensure dissolved metals concentrations in the upper

Sacramento River comply with this TMDL. Regional Board staff will also increase sampling in Shasta Lake to identify within the lake the extent of increased dissolved metal concentrations. In addition, staff will (1) evaluate dissolved metal loads contributed by NPDES dischargers downstream of Keswick Dam and (2) continue to assess discharges from mine sites throughout the watershed (e.g., under NPDES Permits and Cease and Desist Orders). Staff expects that the remediation activities described in this chapter will enable dissolved metal concentrations in the upper Sacramento River between Keswick Dam and Red Bluff Diversion Dam to comply with the proposed numeric targets. If dissolved metal concentrations still exceed the criteria after the implementation of this five-year water management strategy, staff will work with the USEPA, USBR, and responsible parties to develop additional remediation activities.

11 PUBLIC PARTICIPATION

Regional Board staff received data and background information from the USEPA, USGS, USBR, and the City of Redding. In addition, staff solicited public participation during public comment periods by:

- Notifying interested parties (e.g., State, federal and local agencies, mine owners, NPDES-permitted dischargers, and other interested persons) and distributing copies of the draft TMDL.
- Posting the draft report to the Regional Board website.
- Responding to the public's written and verbal comments.

Staff incorporated relevant comments and additional data received during the public comment periods in this final TMDL report. Appendix H presents responses to comments and copies of the written comments.

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CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Upper Sacramento River TMDL for Cadmium, Copper & Zinc

*Final Report
Appendices*



April 2002

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**APPENDIX A.
PLOTS OF DISSOLVED METAL CONCENTRATIONS IN THE
UPPER SACRAMENTO RIVER WATERSHED**

Dissolved Metal Concentrations below Shasta Dam

Figure A-1. Sacramento River below Shasta Dam – Dissolved Cadmium Concentrations

Figure A-2. Sacramento River below Shasta Dam – Dissolved Copper Concentrations

Figure A-3. Sacramento River below Shasta Dam – Dissolved Zinc Concentrations

a. All Available Data

b. Water Years 1996-2000

Dissolved Metal Concentrations below Keswick Dam

Figure A-4. Sacramento River below Keswick Dam – Dissolved Cadmium Concentrations

Figure A-5. Sacramento River below Keswick Dam – Dissolved Copper Concentrations

a. All Available Data

b. Water Years 1996-2000

Figure A-6. Sacramento River below Keswick Dam – Dissolved Zinc Concentrations

a. All Available Data

b. Water Years 1996-2000

Dissolved Metal Concentrations above Bend Bridge

Figure A-7. Sacramento River above Bend Bridge – Dissolved Cadmium Concentrations

Figure A-8. Sacramento River above Bend Bridge – Dissolved Copper Concentrations

Figure A-9. Sacramento River above Bend Bridge – Dissolved Zinc Concentrations

Figure A-2. Sacramento River below Shasta Dam - Dissolved Copper Concentrations

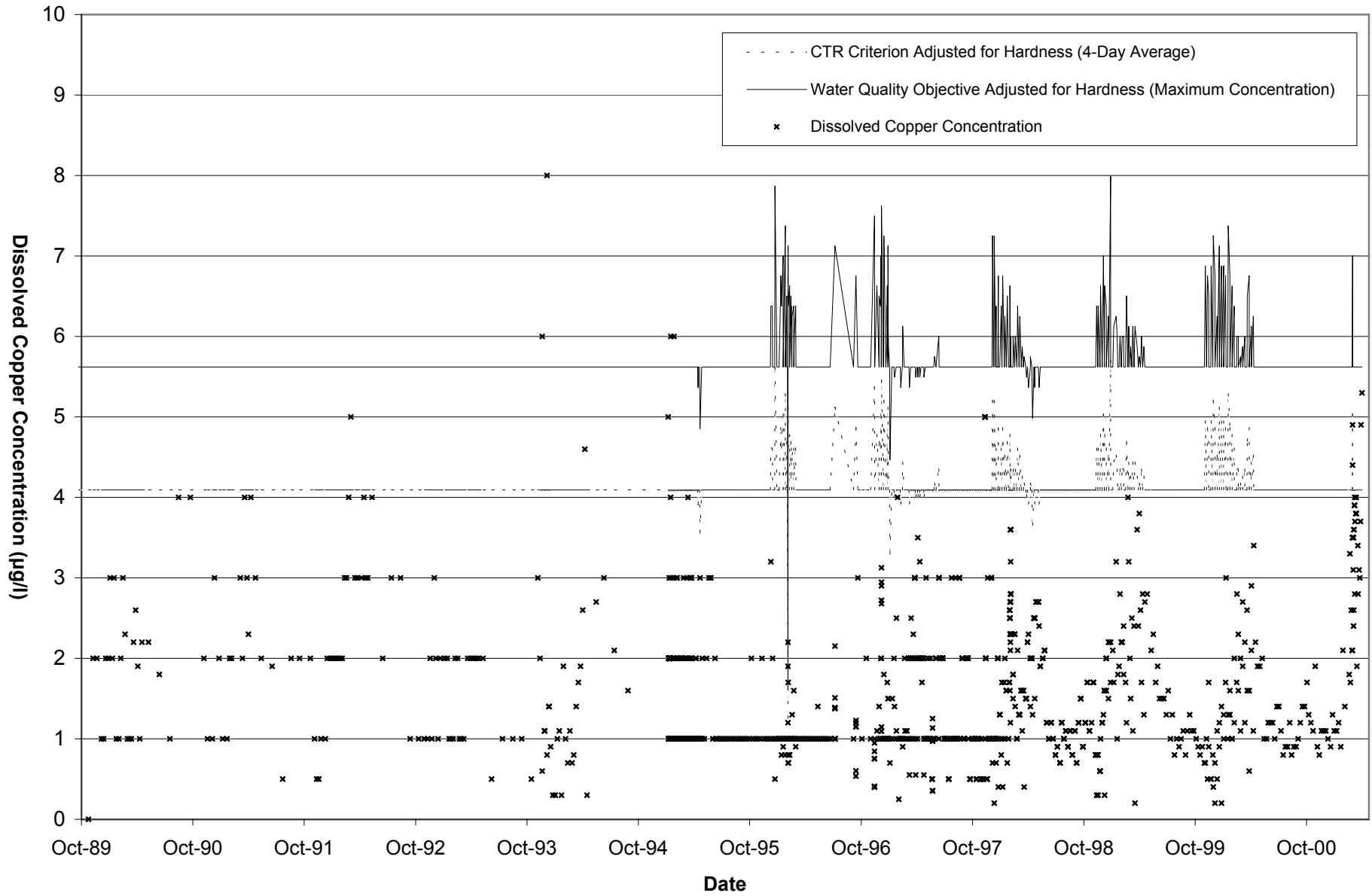


Figure A-3. Sacramento River Below Shasta Dam - Dissolved Zinc Concentrations
A. All Available Data

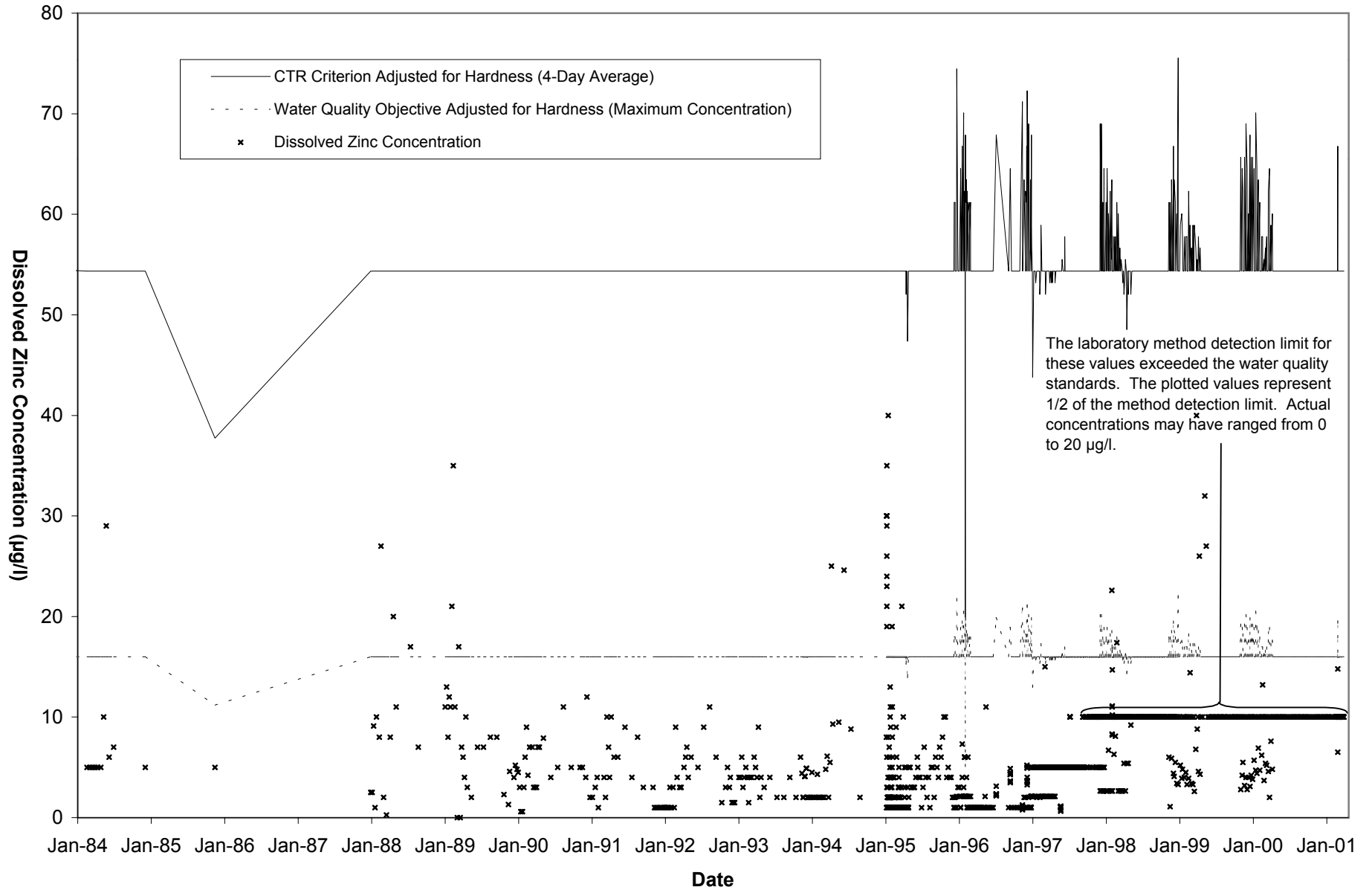


Figure A-3. Sacramento River Below Shasta Dam - Dissolved Zinc Concentrations
B. Water Years 1996-2000

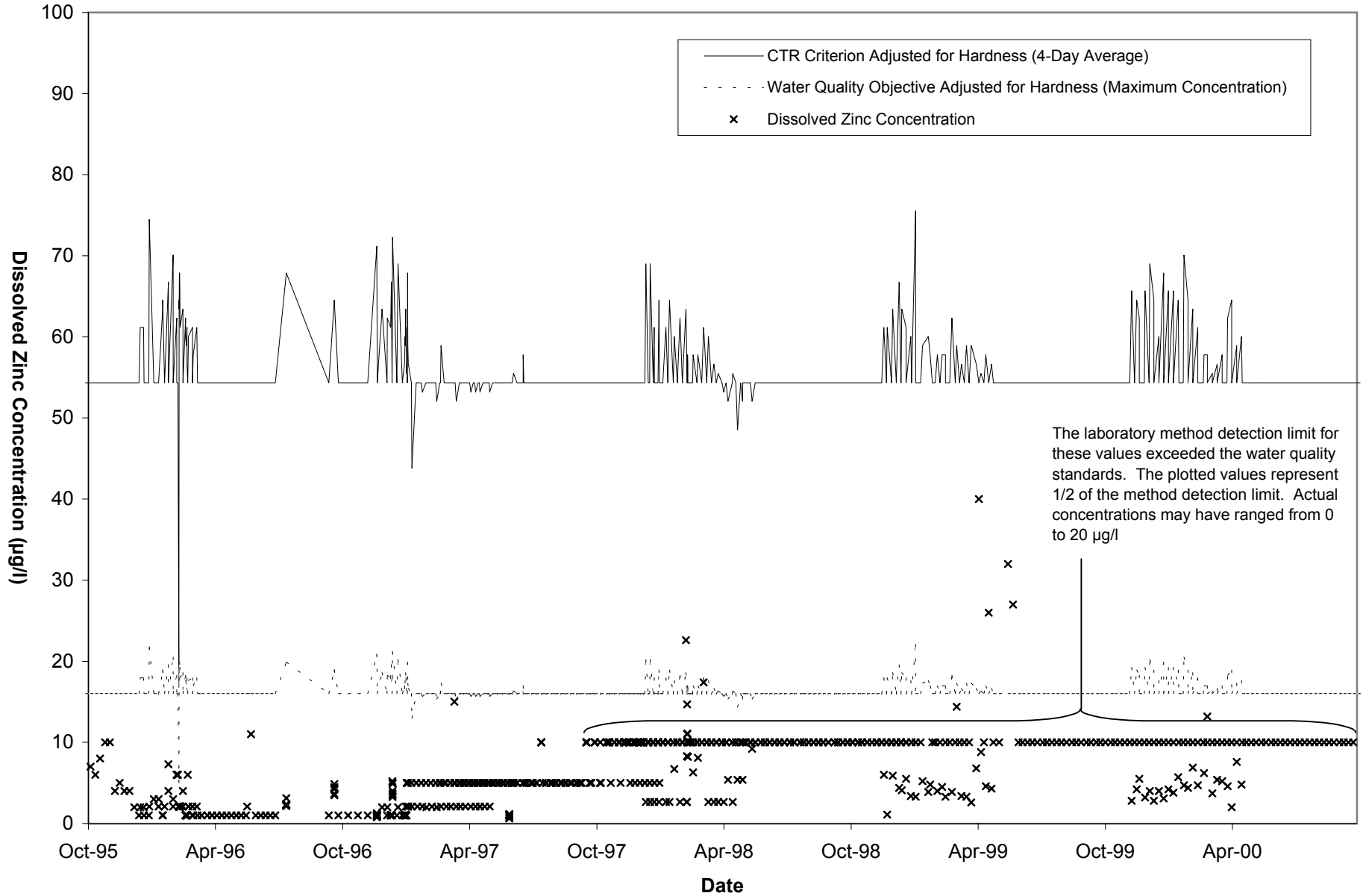


Figure A-4. Sacramento River below Keswick Dam - Dissolved Cadmium Concentrations

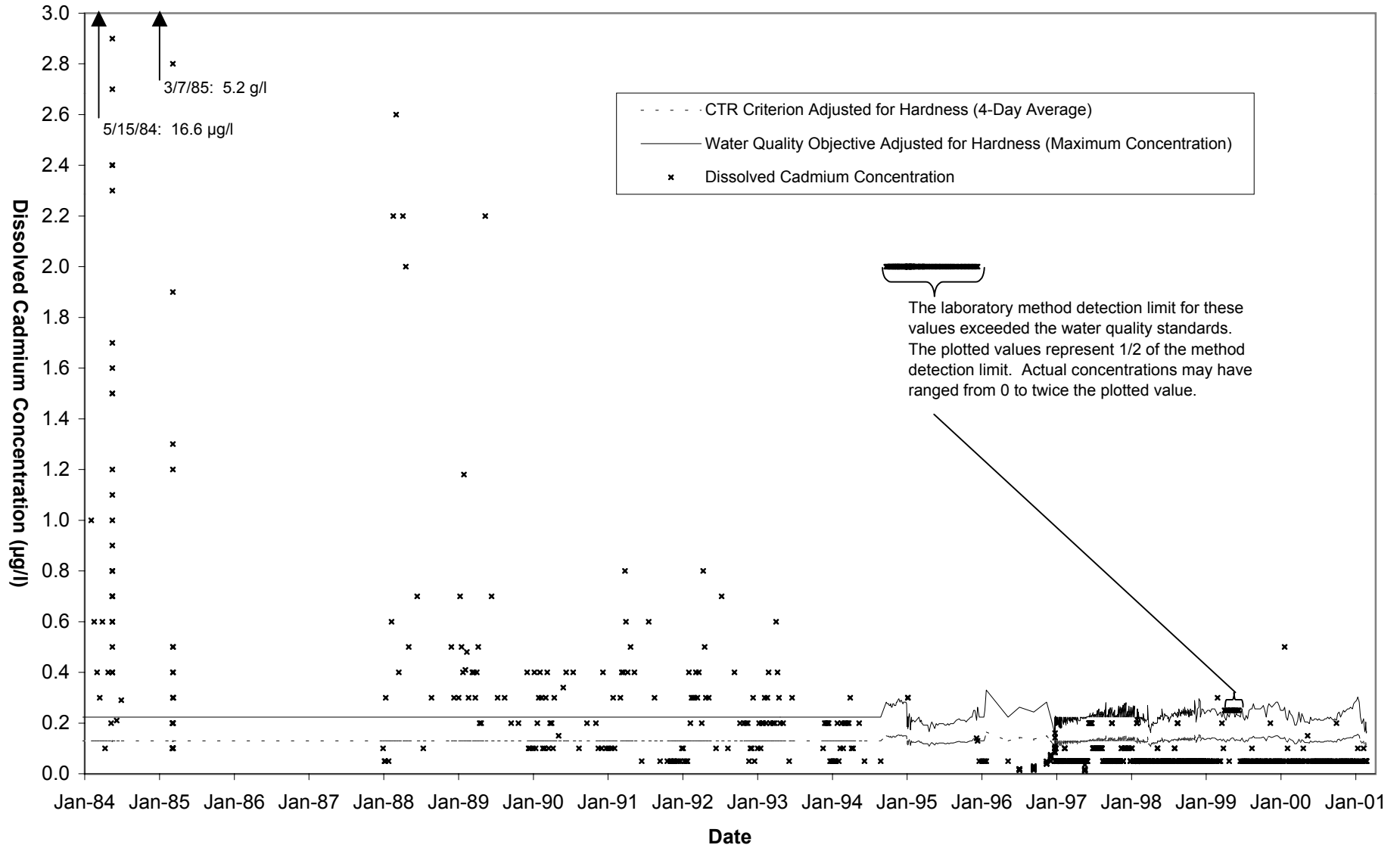


Figure A-5. Sacramento River below Keswick Dam - Dissolved Copper Concentrations
A. All Available Data

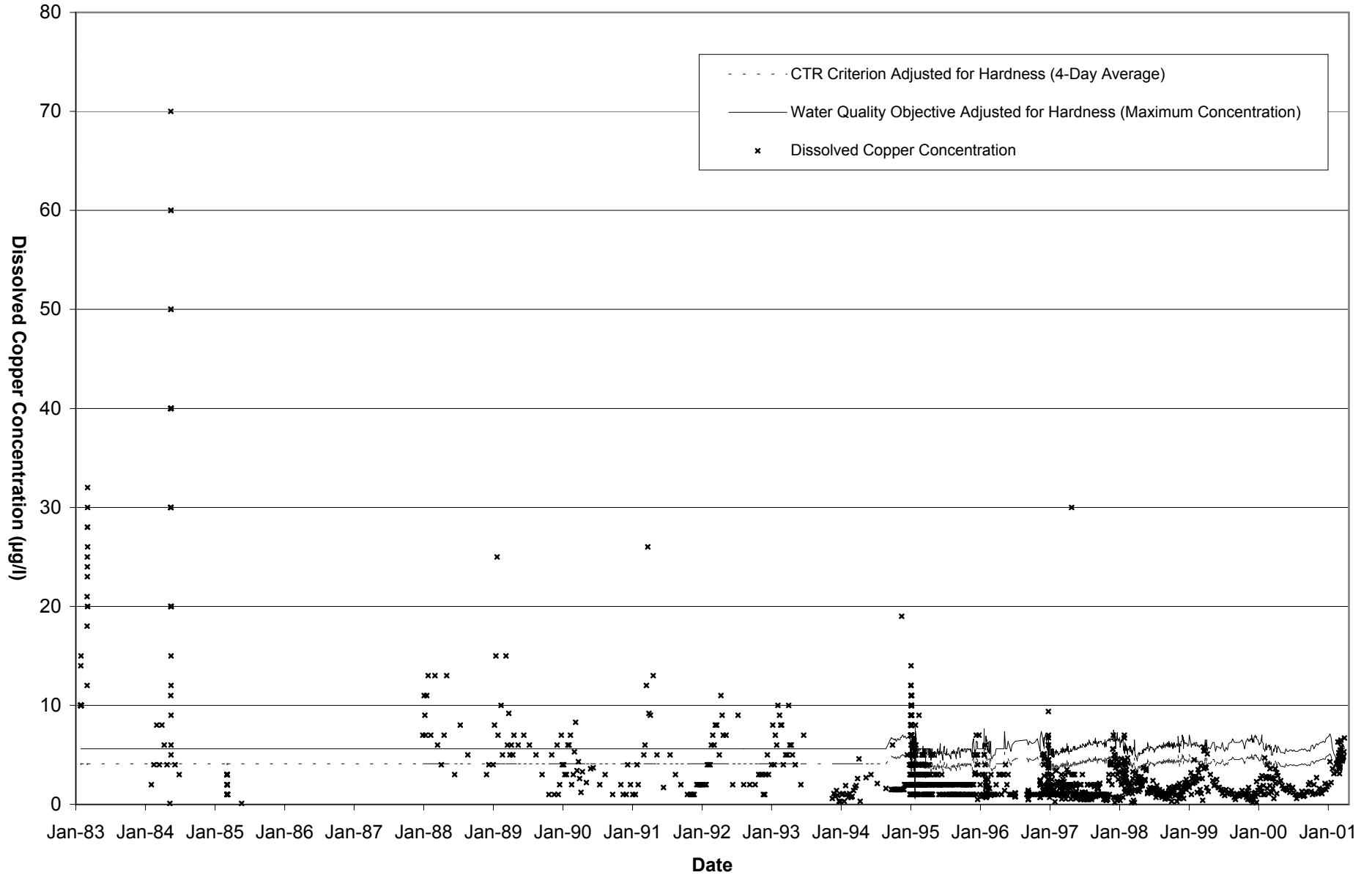


Figure A-5. Sacramento River below Keswick Dam - Dissolved Copper Concentrations
B. Water Years 1996-2000

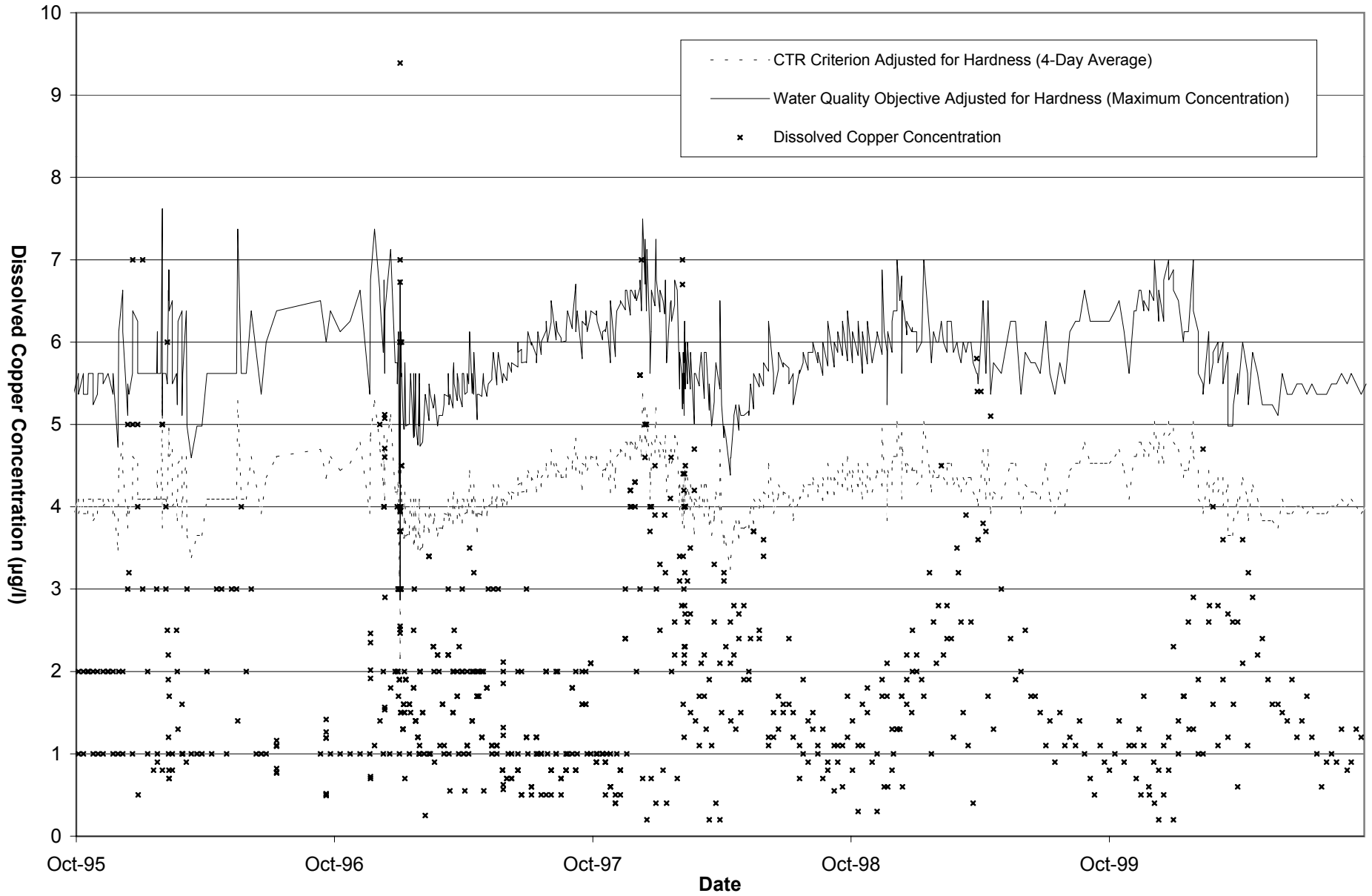


Figure A-6. Sacramento River below Keswick Dam - Dissolved Zinc Concentrations
A. All Available Data

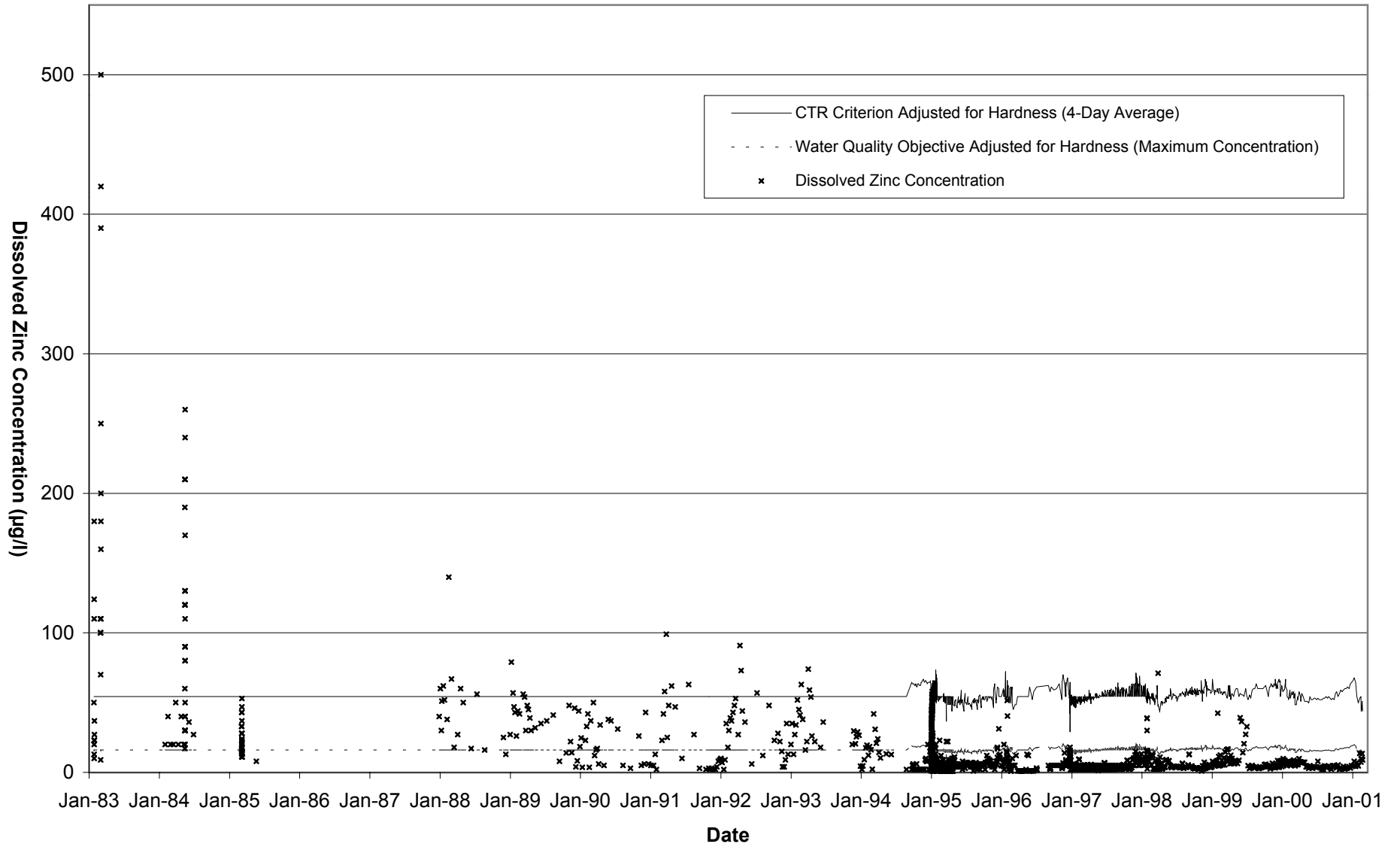


Figure A-6. Sacramento River below Keswick Dam - Dissolved Zinc Concentrations
B. Water Years 1996-2000

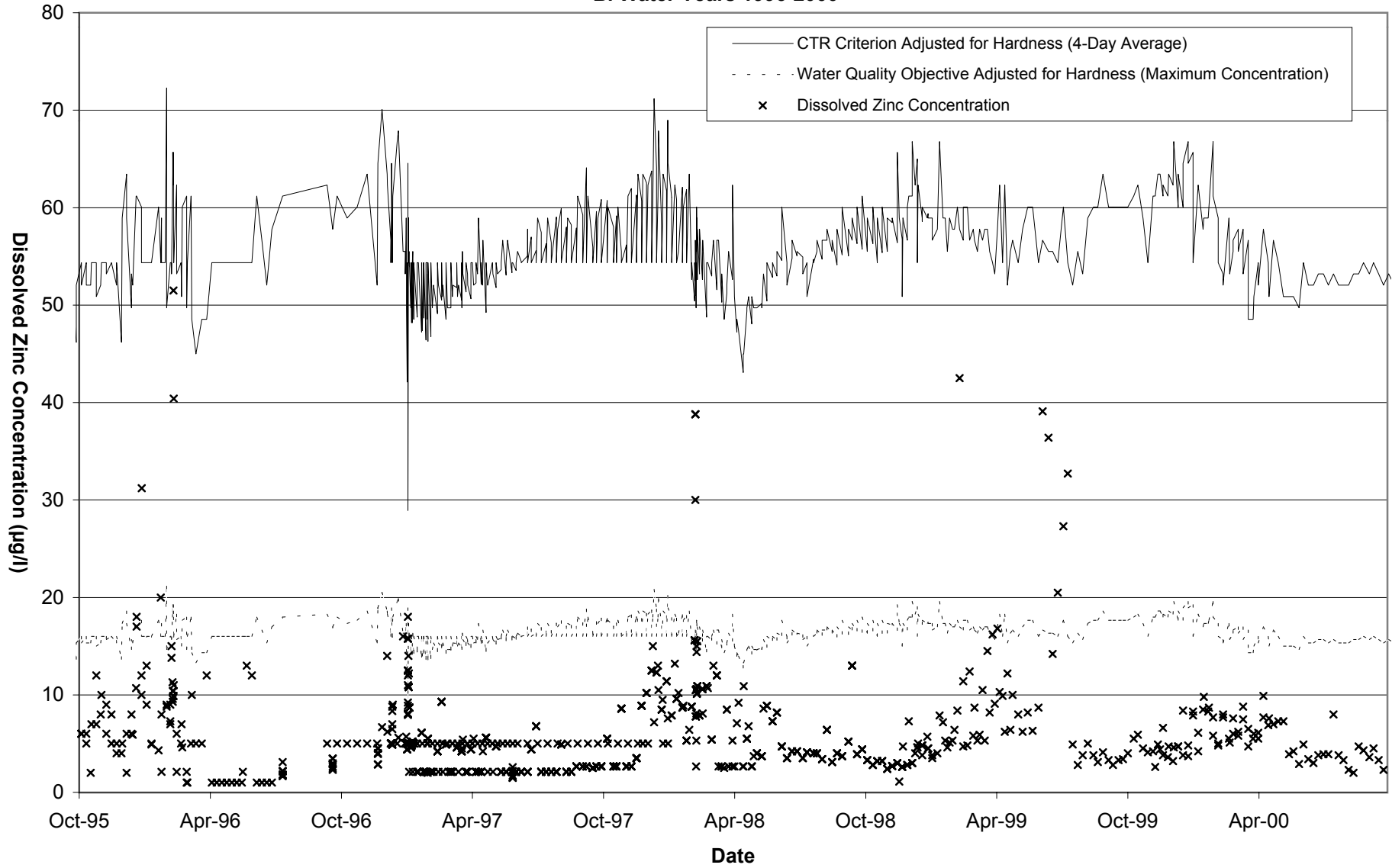


Figure A-7. Sacramento River above Bend Bridge - Dissolved Cadmium Concentrations

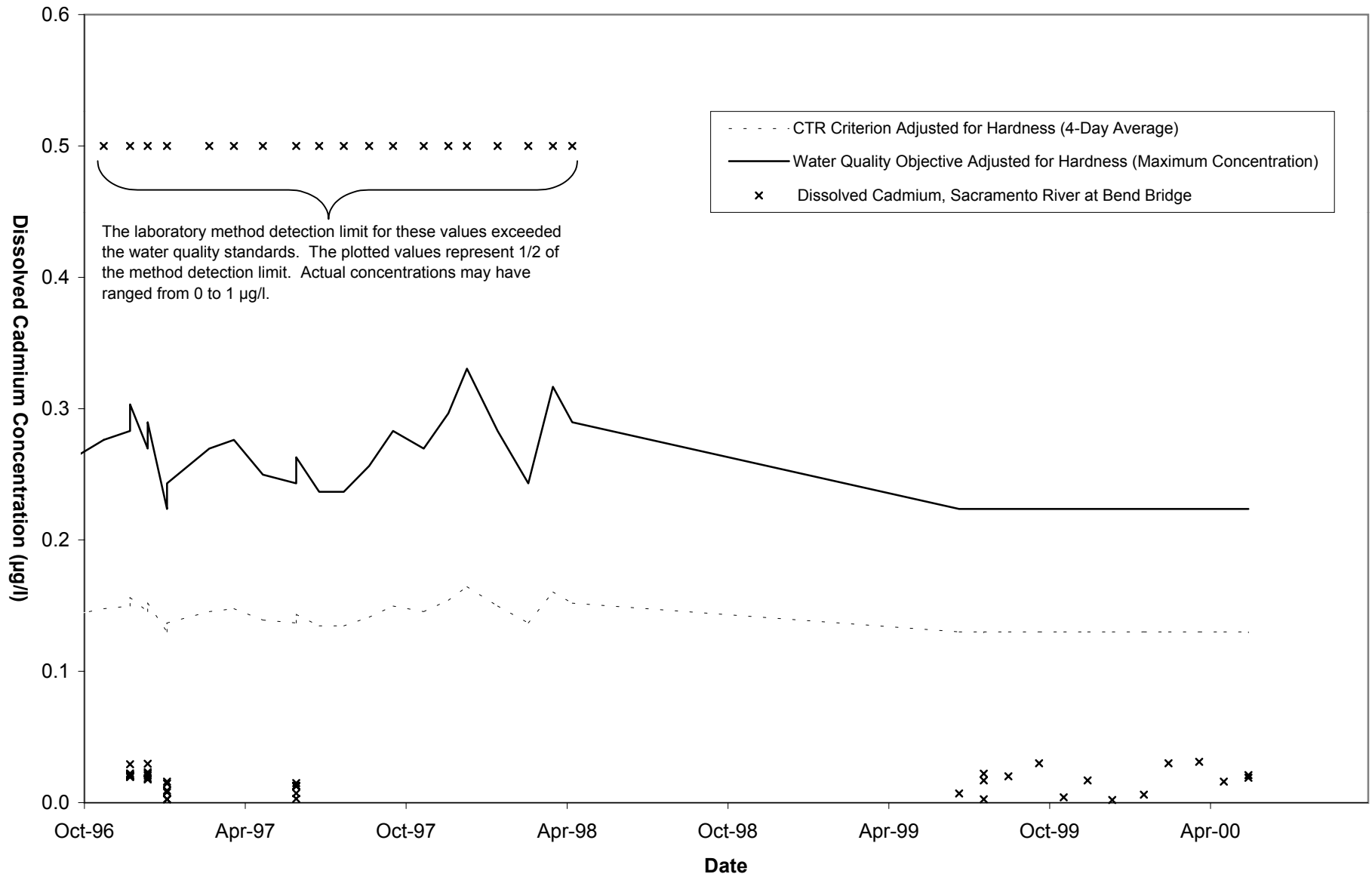


Figure A-8. Sacramento River above Bend Bridge - Dissolved Copper Concentrations

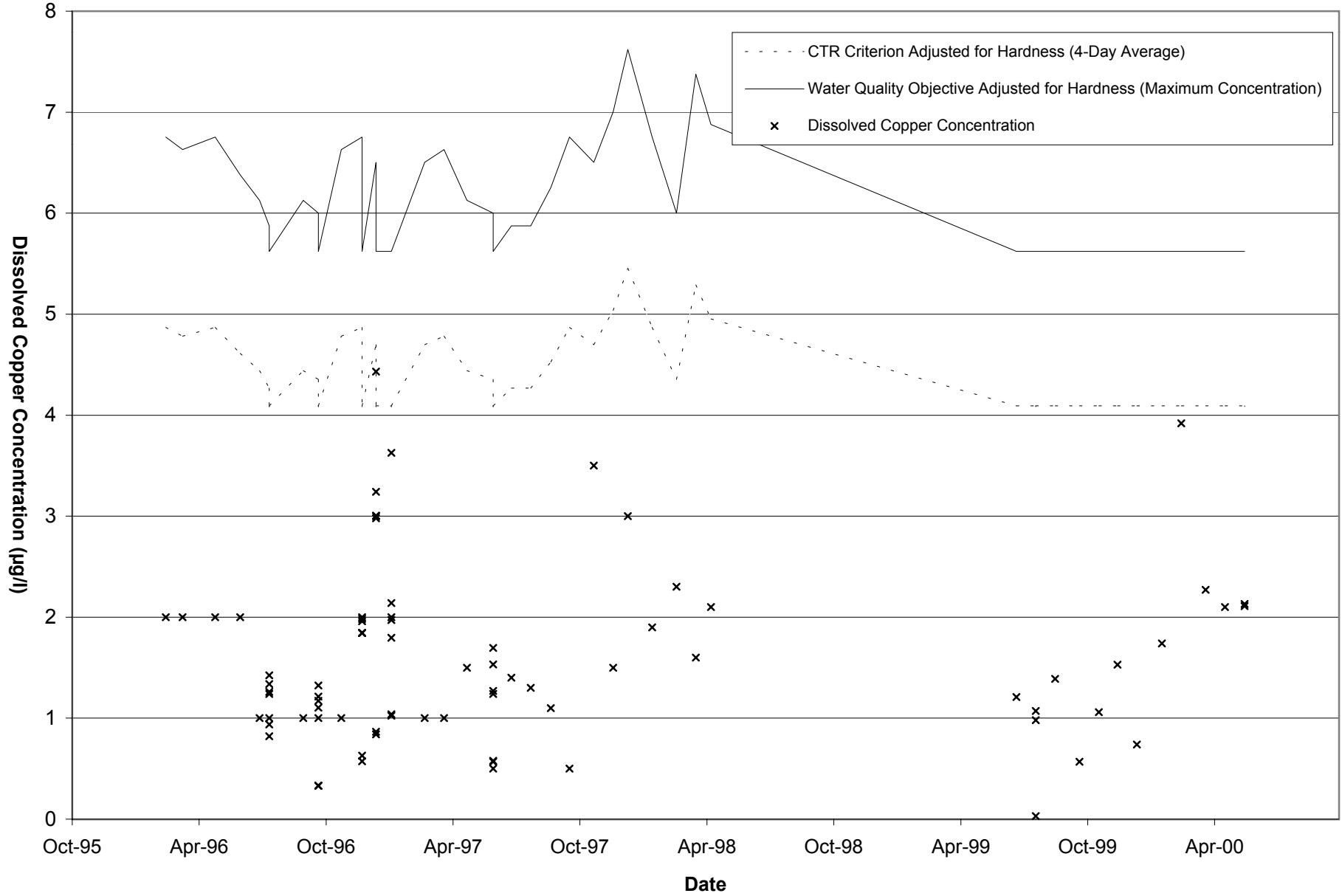
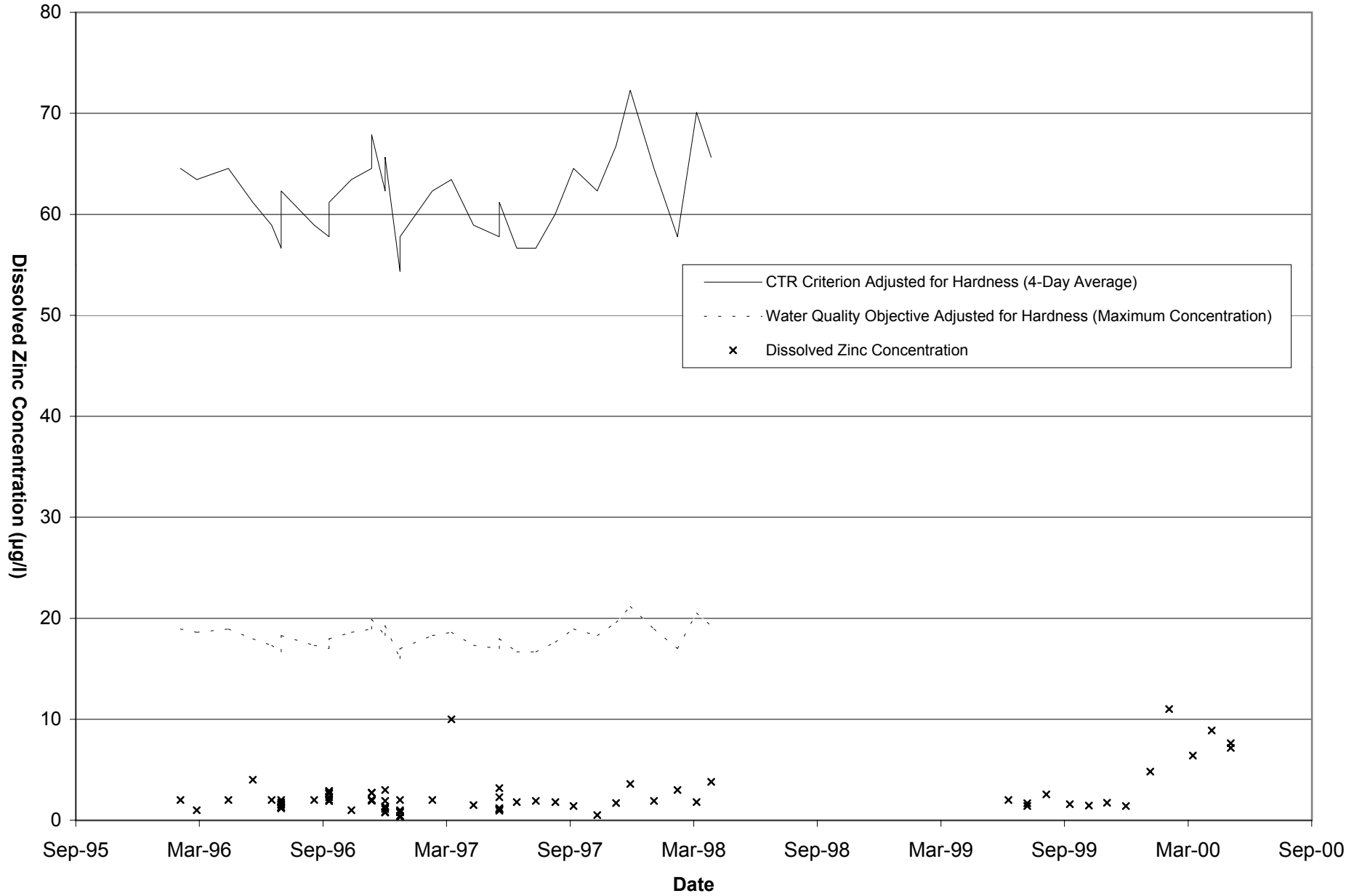


Figure A-9. Sacramento River above Bend Bridge - Dissolved Zinc Concentrations



**APPENDIX B.
HISTORY OF SHASTA LAKE WATERSHED MINES**

West Squaw Creek Watershed

Historic mining areas that have contributed metal loads to West Squaw Creek in the past include the Early Bird Mine, the Shasta King Mine, the Weil portal of the Balaklala Mine, the Upper and Lower Windy Camp portals of the Balaklala Mine and the Keystone Mine. Mining of these properties ceased in 1928. As a result of reclamation activities, only the Windy Camp area of the Balaklala Mine and the Keystone Mine currently contribute significant metal loads to West Squaw Creek (SMI, 1996).

Recent remediation activities for mines in the West Squaw Creek drainage have included installation of portal seals, diversion of surface water around historic mining areas, a feasibility study for additional treatment options, pilot studies (including in-situ treatment of mine water), wetlands treatment and waste rock pile management (SHN, 2001).

Past reclamation activities in place in the West Squaw Creek watershed include the plugging of several portals including the Weil, Early Bird, Lower Shasta King, Upper Windy Camp and Lower Windy Camp. Sealing or plugging of portals and mine workings has been accomplished by placing bulkheads in mine tunnels to prevent the escape of water, thus eventually flooding the mine workings and preventing oxygen from reaching the mineralized rock. This method of sealing requires that the mine and surrounding area be geologically sound and able to withstand the hydraulic pressure caused by the water that backs up in the mine (SMI, 1996). The portal and seep discharges are contributing metals and acidity to water flowing in the watershed drainages. Implementation by Mining Remedial Recovery Company (MRRC) of best management practices has been successful (SHN, 2001). To date, six portals with year-round discharges have been sealed. The sealing has resulted in reduction in copper loading in West Squaw Creek at the mouth of Shasta Lake by greater than 85%. The remaining portals are not yet sealed due to inaccessibility or lack of flow data (SHN, 2001).

Other reclamation activities include the recently completed Keystone diversion channel that diverts surface water runoff from the Keystone area around the Balaklala – Windy Camp area (SMI, 1996).

In addition, several sites have surface water diversion structures. Diversion of surface waters around mine openings and waste rock piles reduces the amount of water in contact with mineralized rock and hence lowers metals loading to the streams (SMI, 1996).

Some accessible portions of waste dumps have also been capped, or moved and capped. Additional control of waste rock dumps is limited by physical steepness of the terrain and inability to safely operate equipment or the lack of terrain that is amenable to location of disposal areas.

Remediation of the MRRC mines in the West Squaw Creek watershed has resulted in significant improvements to the water quality of the creek and of Shasta Lake in the vicinity of the West Squaw Creek inflow (SHN, 2001). The pH of water in West Squaw Creek has improved from about 3 to 4 prior to remediation to a range of 5 to 7 in recent years. As a result of the water quality improvements, CVRWQCB data indicate that the severity and frequency of reported fish kills in Shasta Lake has declined steadily and significantly during the past 5 to 10 years (SHN, 2001). Since MRRC assumed control of the mines in 1991, they have expended approximately \$7 million for remedial activities.

Early Bird Mine. The Early Bird Mine is on the south side of West Squaw Creek. The tributary from the Early Bird Mine area enters West Squaw Creek upstream of the tributaries from the Keystone, Balaklala and Shasta King Mines. Plugging of the Early Bird Portal and subsequent grouting of leaks from the plug resulted in a 99% reduction in metals loads from the mine. The upstream and downstream concentrations of metals are below detection levels, and currently fish are living in the stream above and below the location where the drainage from the Early Bird Mine enters West Squaw Creek. No additional reclamation activities are planned for the Early Bird Mine area.

Keystone Mine. The Keystone Mine is upgradient of the Balaklala Mine in the Windy Creek drainage. Windy Creek is a tributary to West Squaw Creek (SHN, 2001). In 1993, bulkheads were installed on the main Keystone portal and two higher level portals. After emplacement, the hydraulic head created by the seals caused surface seeps of AMD to rupture through weak rock behind the bulkhead, with flows up to 100 gpm to the stream. Currently, the pressure behind the main portal averages 50 pounds per square inch (psi) indicating that the inner workings remain at least partially flooded. As a result, copper and zinc concentrations in the water within the mine voids have been reduced from historic levels based on the quality of water samples taken from the portal and mine seeps.

In 1999, an in-situ limestone treatment system was initiated to improve the water quality of the water inside the mine. This treatment was successful in raising the pH level, and copper and zinc concentrations were reduced in the water within the mine. A second bulkhead was installed temporarily to further limit the amount of water reaching the surface. MRRC recently completed a wetland treatment cell (vertical flow pond) to further treat the discharge, reducing the metal loading and acidity from the Keystone Mine. Residual flows from the existing areas that have received extensive remediation efforts have demonstrated that the remedies in place are not completely effective in eliminating fish mortality in the reach of Squaw Creek below Windy Creek. The site is currently regulated by a NPDES Permit and a Cease and Desist Order.

Balaklala Mine. The Balaklala Mine contains two large ore bodies, the Windy Camp and the Weil. Operations at the Balaklala Mine ceased in 1928. The Upper and Lower Windy Camp portals are located in the Windy Camp area. Windy Creek flows directly through the site (SHN, 2001). Reclamation activities in the Balaklala-Windy Camp area include the plugging of the Upper and Lower Windy Camp portals and diversion of surface water runoff from the Keystone Mine around the Windy Camp area (SMI, 1996). A collapsed stope in the Windy Camp Mine created openings to the surface that were upgradient of the Upper and Lower Windy Camp portals (SHN, 2001). Water would infiltrate into the mine from the ground surface above the mine from Windy Camp Creek (through surface cracks and by fracture flow), as well as from the creek bed to the west, which receives water-containing AMD from the Keystone Mine diversion outlet. The result was generation of AMD within the mine from all of these water sources, then discharges of high volume and poor quality. The Lower Windy Camp portal also produces AMD from within the workings. The Upper Windy Camp portal emerges from the east side of Windy Camp, some 300 feet from the lower portal. AMD is also produced from the upper portal. The Upper and Lower Windy Camp portals were sealed in 1984 resulting in an 80% reduction of the metal loading to the West Squaw Creek (Woodward, 2001).

The Balaklala waste rock pile, comprising approximately 40,000 cubic yards of sulfide containing rock was located in the valley where Windy Creek historically flowed. Surface water, water from above the pile, and water from within the mines, flowed over and through the pile, generating AMD and resulting in a significant additional metal load to the stream. In 1996/97, the pile was consolidated into the open pit excavated in the upper reaches of the drainage and the stream was channeled over the mining area. The waste rock was then capped and vegetated. The creek flow was conducted over, rather than into, the pile through the use of an HDPE-lined channel constructed of gabion baskets arranged in a manner to retard flow, thereby reducing erosion. During the remediation of the waste rock at this site, a previously

unknown small AMD flow was discovered, collected, and directed via pipe to an anoxic drain. Discharge from the anoxic drain is currently routed to the lower reaches of Windy Creek. MRRC installed some experimental passive limestone treatment “drains” below the Windy Camp portal; however, high stream flows destroyed the drains.

The Windy Camp and Keystone areas comprised the largest source of metal loading to West Squaw Creek as of 1996 (SMI, 1996). Plugging of the Lower Windy Camp portal was only partially successful in decreasing the metal load from the area. The Balaklala Mine (WC Portal) is currently regulated by a NPDES Permit and a Cease and Desist Order.

The Weil Portal provided access to the Weil ore body. Two additional portals that accessed the Weil ore body are also adjacent to the main road to the Balaklala Mine. The Weil portal was sealed in 1982. There is no significant increase in metals loads observed as the Weil tributary crosses the Weil waste rock piles. Plugging the Weil Portal was an effective remediation, with 99.9% reduction of metal loads, meeting NPDES permit requirements. No additional reclamation activities are planned for the Weil portal (SMI, 1986).

Shasta King Mine. The Shasta King Mine workings lie northeast of the Balaklala Mine, across West Squaw Creek (SHN, 2001). The mine has eight adits, one just above West Squaw Creek and the other seven located a few hundred feet above West Squaw Creek. Waste dumps from the adits generally extend from the portals and into the creek. Access to this mine is extremely limited. Reclamation activities at the Shasta King Mine included plugging of the Lower Shasta King portal in July 1989, with subsequent grouting of leaks from the plug (SMI, 1996). The principal metal loads from the Shasta King Mine seem to be generated from the waste rock, which extends to the stream (SHN, 2001). Access to the waste rock piles is also extremely limited. The Shasta King Mine is currently regulated by a NPDES Permit and a Cease and Desist Order.

Little Backbone Creek

NPDES permits and a Cease and Desist Order are regulating the Mammoth, Gossen and Sutro Mines. Remedial work is underway at most sites. Mammoth, Gossen, and Sutro Mines had bulkhead seals placed in portals to reduce metals discharge. The Golinski Mine, which is located on U.S. Forest Service property, is regulated by a CVRWQCB Cleanup and Abatement Order. Site evaluation and remediation for the Golinski Mine were conducted in the summer of 2001; two bulkhead seals were installed in the Golinski Mine and their effectiveness is being evaluated (Woodward, 2001).

Horse Creek and Town Creek

The non-operating Bully Hill and Rising Star Mines discharge (AMD) from several portals, seeps, and waste rock dumps. The discharge from the Bully Hill Mine enters Town Creek, which flows into Shasta Lake. Discharges from the Rising Star Mine enter an unnamed tributary to Horse Creek, which also flows, into Shasta Lake. The discharge from the main portals of the Bully Hill Mine and the Rising Star Mine are regulated under a NPDES Permit (CVRWQCB, 1997).

Remediation work was conducted at these two mines in 2000, including construction of a road to the mines, a surface water diversion of Town Creek around the Bully Hill Mine waste rock pile, and a pilot-scale vertical upflow treatment pond at the discharge of the Rising Star Mine (Woodward, 2001).

**APPENDIX C.
CADMIUM-COPPER-ZINC MIXTURE INTERACTIONS**

Table C-1. Cadmium, Copper, and Zinc Mixture Interactions (a)

Mixture	Effects on:		
	Algae	Invertebrates	Fish
Copper + Zinc	Additive, synergistic, or antagonistic toxicity, depending on the concentration of each of the metals and the pH; most mixtures behaved either additively or synergistically at pH 4.5, and antagonistically at higher pHs.	Antagonistic toxicity. (b)	Antagonistic (juvenile chinook salmon); the lower Cu:Zn ratio (1:12) was more antagonistic than the higher (1:3). Steelhead trout alevins and fry tend to be more sensitive than eggs to solutions of copper and zinc. (c)
Copper + Cadmium	Antagonistic toxicity; cadmium may inhibit copper toxicity.	Synergistic toxicity. (b)	Additive toxicity (juvenile chinook salmon); the higher Cu:Cd ratio (1:0.028) was more additive than the lower (1:0.083). (c)
Cadmium + Zinc	Additive toxicity.	Additive toxicity. (b)	Additive toxicity (juvenile chinook salmon) with Zn:Cd ratio of 1:0.083. (c)
Cadmium + Copper + Zinc	Toxicity may result when exposed to mixtures with individual metal components present in concentrations below water quality objectives.	Additive toxicity. (b)	Antagonism increased with decrease in Cu:Zn:Cd mixture ratio from 1:3:0.02 to 1:12:0.08 (juvenile chinook salmon). (d)

- (a) Source: Literature reviews provided in the 1994 and 1998 Regional Board staff report [Reyes, 1994; Cooke and Connor, 1998]; Finlayson and Verrue, 1982; and Finlayson and Wilson, 1989.
- (b) Toxic effects were observed although all individual toxicants were present below water quality objectives.
- (c) One study indicated that mixture toxicity on fathead minnow could not be predicted based on the additivity of individual metal concentrations.
- (d) The 96-hour LC₅₀ values for Cu:Zn:Cd with a mixture ratio of 1:3:0.02 were 37 µg/l Cu, 121 µg/l Zn, and 1.1 µg/l Cd. The 96-hour LC₅₀ values for Cu:Zn:Cd with a mixture ratio of 1:12:0.08 were 18 µg/l Cu, 218 µg/l Zn, and 1.8 µg/l Cd. An LC₅₀ value is the median lethal concentration; i.e., the lethal concentration calculated for 50% of the organisms tested.

**APPENDIX D.
LOAD CALCULATIONS FOR AFTERTHOUGHT MINE
& MUNICIPAL STORMWATER DISCHARGES**

D.1 Load Calculations for Afterthought Mine

Very little metals concentration information exists for runoff from the Afterthought Mine. Afterthought Mine discharges to Little Cow Creek approximately 23 miles upstream of the Little Cow Creek – upper Sacramento River confluence, which is approximately 2.5 miles east of Anderson. Seasonal changes in precipitation result in cyclic changes in the amount of AMD from Afterthought Mine. From late spring to early fall, little mine water is available to create AMD. However, early rains during fall and winter provide a flushing action that produces highly concentrated AMD; the distribution of rainfall can cause a large discharge of AMD during a period of low stream flow (DWR, 1985). Another issue is that the AMD and Little Cow Creek flows do not mix well, causing the AMD to remain as a plume for a considerable distance ($\frac{1}{4}$ to $\frac{1}{2}$ mile downstream) (DWR, 1985).

Regional Board staff collected samples from Little Cow Creek at Dersch Road (approximately one mile upstream of the Little Cow Creek – upper Sacramento River confluence) in April and June 1996 (Alpers et al., 2000). The samples had total metal concentrations of 5.2 and 6 $\mu\text{g/l}$ copper, and 16 and ~ 170 $\mu\text{g/l}$ zinc, respectively. During the 1970s and 1980s, the California Department of Water Resources (DWR) compiled a larger data set that included dissolved metal concentrations. DWR collected water samples from Little Cow Creek 0.05, 0.5, 1.1 and 1.8 miles downstream of the Afterthought Mine (DWR, 1985). DWR collected the samples during multiple sampling events in 1978, 1982, and 1984. DWR collected Little Cow Creek flow data only during the April, June, and August 1984 sampling events, and therefore calculated load values for Little Cow Creek flows only for those sampling events. The April sampling event had the highest flow (56,610 gallons per minute [gpm]) of the different sampling events, while the August sampling event had the lowest flow (4,598 gpm, a magnitude lower than the April flow). Table D-1 shows the maximum and minimum daily dissolved metal loads calculated for Little Cow Creek. To provide a conservative estimate of Afterthought Mine's metal contribution to the upper Sacramento River, Regional Board staff used in the source assessment only the maximum values that DWR calculated. In addition, staff assumed that no dilution or deposition occurs along the twenty-three mile reach of Little Cow Creek between the mine and the Little Cow Creek-Sacramento River confluence.

Table D-1. Maximum and Minimum Daily Dissolved Metal Loads Calculated for Little Cow Creek Downstream of Afterthought Mine (DWR, 1985)

	Daily Load (kg/day)	Concentration (µg/l)	Little Creek Flow (gpm)	Sampling Period	Sampling Location
Copper					
Maximum:	2.2	7	56,610	April 1984	0.05 miles downstream of mine
Minimum:	< 0.1 ^(a)	< 2	11,860	June 1984	1.8 miles downstream of mine
Zinc					
Maximum:	9.3	30	56,610	April 1984	0.5 miles downstream of mine
Minimum:	1.0	40	4,695	August 1984	1.8 miles downstream of mine
Cadmium ^(b)					
Maximum:	0.08	170	4,695	August 1984	0.5 miles downstream of mine
Minimum:	< 0.01	< 28	11,860	June 1984	1.8 miles downstream of mine

(a) A "<" indicates that the dissolved metal concentration was less than the laboratory method detection limit. DWR calculated the load using the method detection limit as the concentration value. (Note: Regional Board staff typically uses ½ the detection limit to estimate loads for this scenario.)

(b) Dissolved cadmium loads in general did not appear to correlate to Little Cow Creek flows as well as copper and zinc loads did. However, six of the nine samples collected in 1984 had dissolved cadmium concentrations less than the laboratory method detection limit, which makes it harder to determine accurate load amounts. (Note, dissolved metal concentrations often were higher in August than in April because there was less dilution flow in Little Cow Creek; however, because the flow was decreased, there was less load.)

D.2 Load Calculations for Municipal Stormwater Discharges

No stormwater runoff data or dissolved metal concentration data were available for calculating stormwater metal loads for the municipalities of Redding, Lake Shasta City, and Anderson. Therefore, Regional Board staff developed estimates for use in the source assessment. The following sections describe how Regional Board staff derived the estimates. Tables D-3 and D-4 at the end of this appendix summarizes the data used for calculating the stormwater loads for each municipality.

D.2.1 Stormwater Runoff Calculation

Regional Board staff estimated stormwater runoff using the following equation:

$$Q_e = R_f \times A \times C_r$$

Where: Q_e = Estimated volumetric runoff rate

R_f = Rainfall amount for one day

A = Municipal area

C_r = Runoff coefficient

Rainfall. Regional Board staff used two inches per day as the rainfall amount for one day. Staff’s review of daily rainfall data collected at Shasta Dam and Redding indicated that this amount is typically associated with intense (but not worst-case) storms in this region.

Municipal Areas. Staff used the following approximate areas:

- Redding: 33,459 acres
- Anderson: 4,012 acres
- Lake Shasta City: 4,841 acres.

Runoff Coefficients. Runoff coefficient values vary from 0.05 for flat sandy areas to 0.95 for impervious urban surfaces (Shaw, 1988). Staff estimated runoff coefficients for Redding based on the percentage of each type of land surface within the municipality area. Table D-2 lists the runoff coefficient values that staff used to calculate the overall runoff coefficient for Redding. Staff assumed that Anderson and Lake Shasta City had similar land surface types and areas, and therefore used the same runoff coefficient for all three municipal stormwater runoff calculations.

Table D-2. City of Redding Land Surface Types and Associated Runoff Coefficients
(Source of land surface type percentages: Manuel, 2001)

Land Surface Type	Estimated Percent of Total Municipal Area per Land Surface Type (expressed in decimal format)	Runoff Coefficient for Each Surface Type	Coefficient x Area Percentage
Low density residential:	0.16	0.4	0.064
Commercial and Offices:	0.02	0.7	0.014
Industrial Intensive:	0.02	0.9	0.018
Public and quasi public:	0.05	0.25	0.0125
Medium density residential:	0	0	0
Agricultural – recreational preserve:	0.04	0.15	0.006
Undeveloped/Vacant:	0.49	0.2	0.098
Greenway:	0.22	0.2	0.044
Estimated Municipal Runoff Coefficient: (sum of “adjusted” coefficients)			0.2565

D.2.2 Stormwater Loads Calculation

Regional Board staff estimated stormwater loads using the following equation:

$$m_e = C_{Sac} \times Q_e$$

Where: m_{e-x} = Estimated mass of constituent, X, per unit time

C_{Sac-x} = Maximum dissolved concentration of constituent, X, in mass per volume

Q_e = Estimated volumetric runoff rate

Maximum Dissolved Concentration. Because stormwater metal concentration data were not available for the municipal areas in this study, staff used dissolved copper, zinc, and cadmium data collected by the Sacramento Stormwater Program for the Sacramento region in 1995 and 1996. The program collected water samples from discharge sites at Strong Ranch Slough, Sump #104, and Sump #111. The dissolved copper concentrations ranged from 2.5 to 6.7 $\mu\text{g/l}$, the dissolved zinc concentrations ranged from 16 to 98 $\mu\text{g/l}$, and the dissolved cadmium concentrations ranged from less than 0.1 to 0.22 $\mu\text{g/l}$ (Cooke and Connor, 1998). Staff selected the highest concentration value measured for each metal for use in the stormwater load calculations. Staff then adjusted the concentrations using population density ratios that compared the density of a given upper Sacramento municipal area to the population density of Sump #104's watershed (see Table D-3). Staff made the following assumptions when using the data:

- The sources and quantities of metal releases in the Sacramento region in 1995 and 1996 are similar sources and quantities of metal releases in the Redding, Anderson, and Lake Shasta City municipal areas, and are most strongly influenced by population density.
- Similar rainfall rates (and therefore dilution rates) occur in Sacramento as in the municipalities in the upper Sacramento River watershed.
- The peak concentrations measured in Sacramento in 1995 and 1996 provide an estimate of the concentration that would result from an intense storm.³⁸

Estimated Volumetric Runoff Rate. Staff used the stormwater runoff estimates described in the previous section.

³⁸ The Regional Board has previously determined that the Sump #104 watershed exhibits a strong seasonal first flush of pollutants as a result of the long dry period typically extending from May to September (CVRWQCB, 1989). Pollutants contributed by vehicle exhaust, vehicle and tire wear, spills, and atmospheric fallout accumulate within the watershed during this dry period. The 1989 Regional Board study noted that many urban studies have documented the occurrence of an event first flush effect. The first flush effect typically weakens or becomes non-existent after a certain amount of seasonal rainfall.

Table D-3. Summary of Supporting Data Regional Board Staff Used to Calculate Stormwater Metal Loads for Redding, Lake Shasta City, and Anderson.

Municipality	Population (Year 2000)	Area (acres)	Population Density	Population Density Factor ^(a)	Available Concentration Data (µg/l)		
					Copper	Cadmium	Zinc
Redding	80,865	33,459	2.42	0.25	<i>None available.</i>		
Anderson	9,022	4,012	2.25	0.23			
Lake Shasta City	9,008	4841	1.86	0.19			
Sacramento Sump #104 watershed	21,487	2,200	9.68	<i>Not applicable.</i>	6.7	98	0.22

(a) Population density factor = (municipal area X) / (Sump #104 watershed area).

Table D-4. Summary of Data Regional Board Staff Used to Calculate Stormwater Metal Loads for Redding, Lake Shasta City, and Anderson.

Municipality	Estimated Stormwater Runoff	Estimated Metal Concentrations (µg/l) Adjusted for Population Density ^(a)			Estimated Metal Loads (kg/day)		
		Copper	Zinc	Cadmium	Copper	Zinc	Cadmium
Redding:	1,764,348,258 l/day [721 cfs]	1.7	24	0.05	3.0	43	0.097
Anderson:	211,559,377 l/day [87 cfs]	1.6	23	0.05	0.3	5	0.011
Lake Shasta City:	255,273,915 l/day [104 cfs]	1.3	19	0.04	0.3	5	0.011

(a) Estimated concentration = (Sump #104 metal concentration data) x (Population density ratio for municipal X).

**APPENDIX E.
PLOTS OF DISSOLVED METALS LOADS IN THE
UPPER SACRAMENTO RIVER WATERSHED**

Figure E-1. Dissolved Copper Loads for Sources Upstream of Keswick Dam

Figure E-2. Dissolved Zinc Loads for Sources Upstream of Keswick Dam

Figure E-3. Dissolved Cadmium Loads for Sources Upstream of Keswick Dam

Figure E-1. Dissolved Copper Loads for Sources Upstream of Keswick Dam

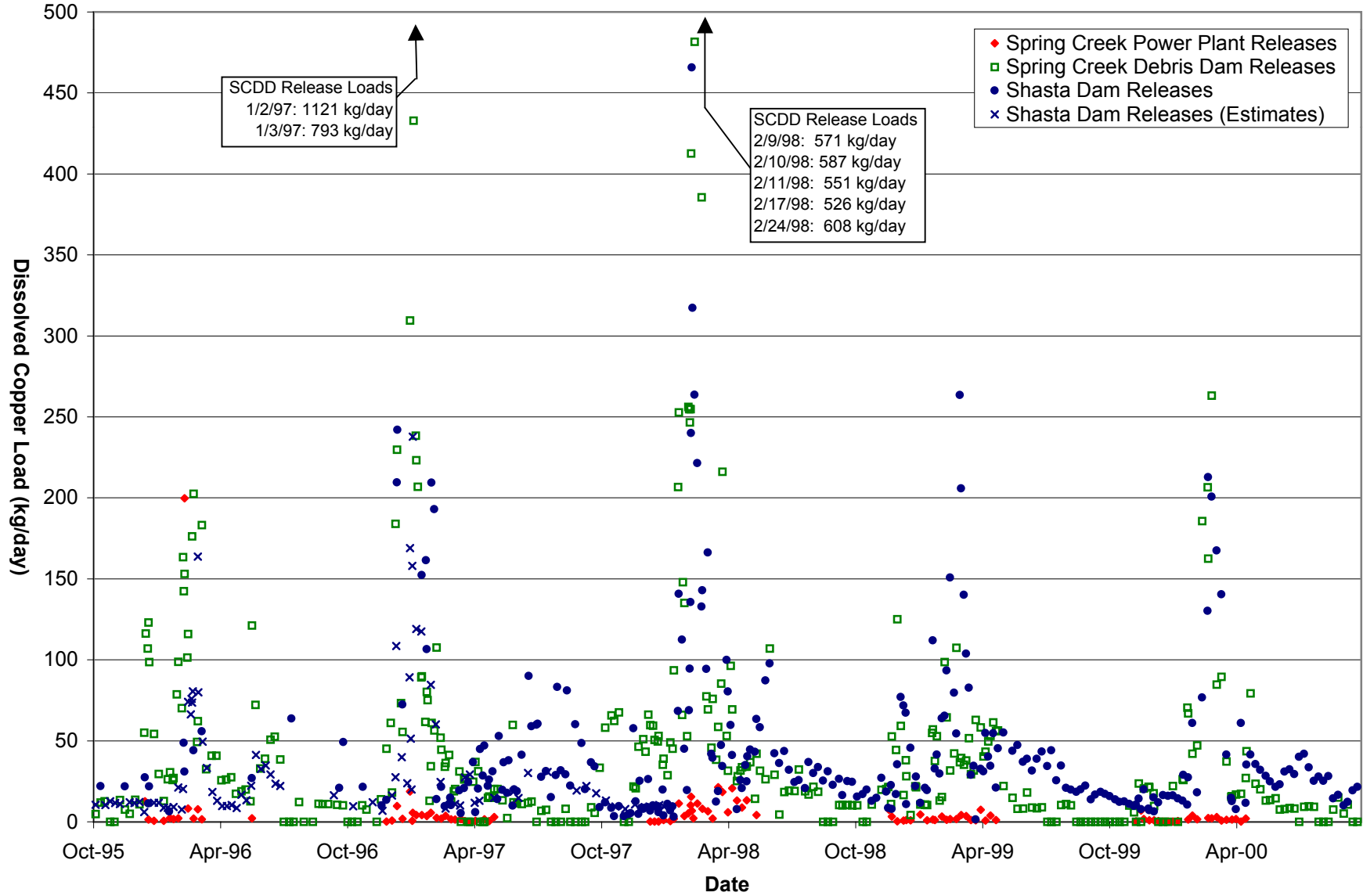


Figure E-2. Dissolved Zinc Loads for Sources Upstream of Keswick Dam

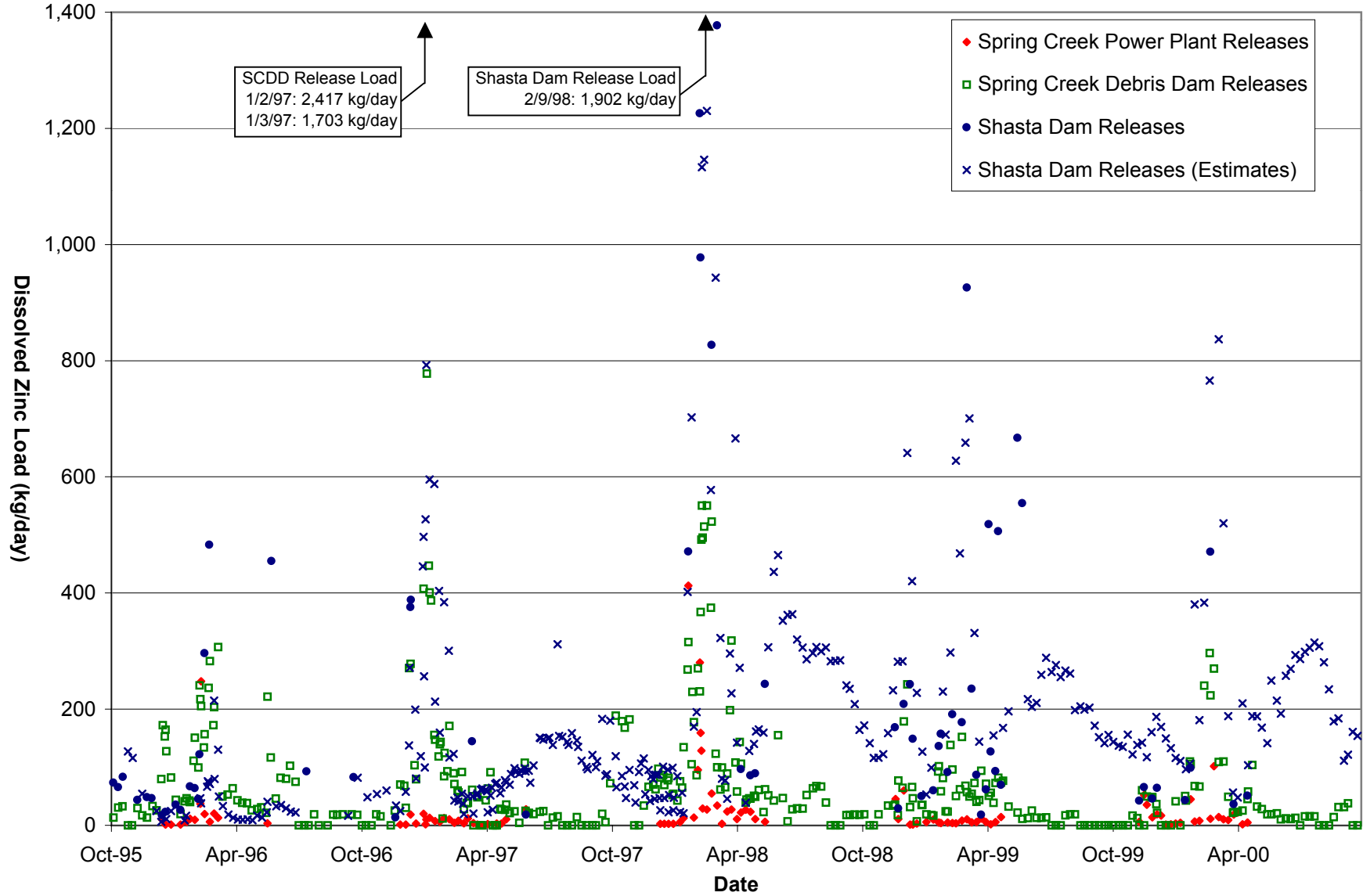
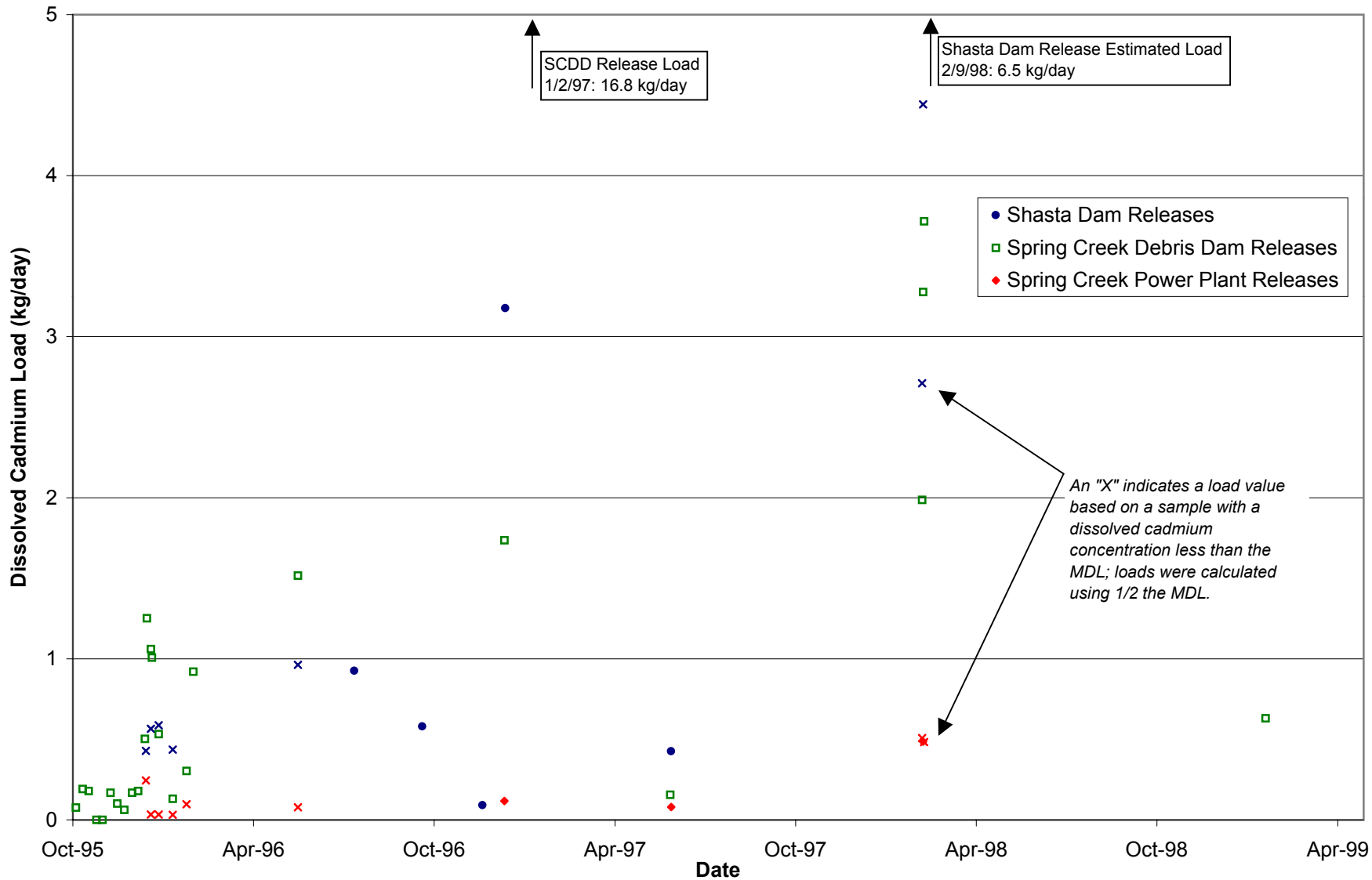


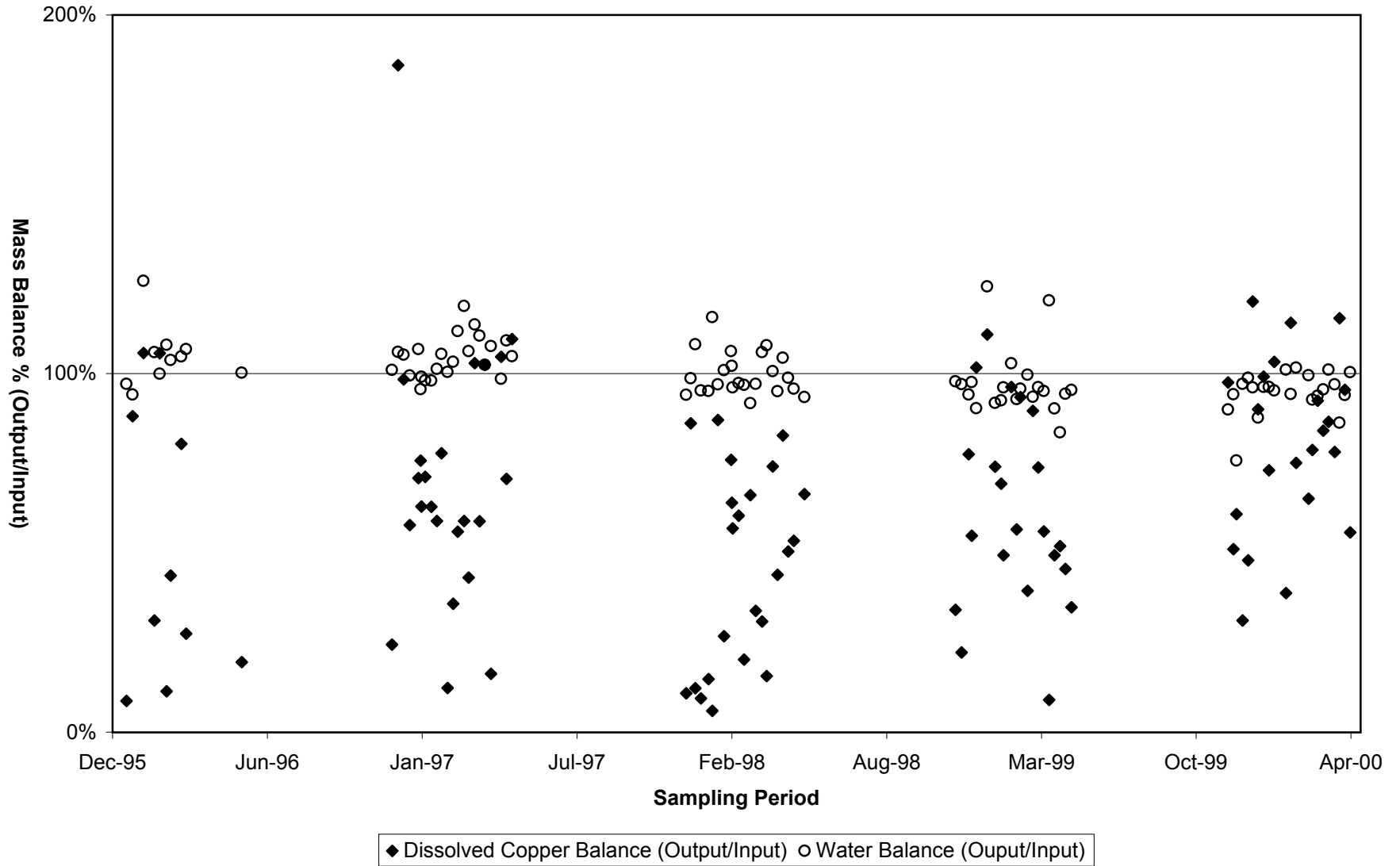
Figure E-3. Dissolved Cadmium Loads for Sources Upstream of Keswick Dam



APPENDIX F.
DISSOLVED METAL BALANCES AND WATER BALANCES
FOR KESWICK RESERVOIR &
SACRAMENTO RIVER BETWEEN KESWICK DAM AND BEND BRIDGE

Figure F-1A.	Dissolved Copper & Water Balances for Keswick Reservoir
Figure F-1B.	Dissolved Copper & Water Balances for Sacramento River (below Keswick Dam to above Bend Bridge)
Figure F-2A.	Dissolved Zinc & Water Balances for Keswick Reservoir
Figure F-2B.	Dissolved Zinc & Water Balances for Sacramento River (below Keswick Dam to above Bend Bridge)
Figure F-3A.	Dissolved Cadmium & Water Balances for Keswick Reservoir
Figure F-3B.	Dissolved Cadmium & Water Balances for Sacramento River (below Keswick Dam to above Bend Bridge)
Table F-1A.	Dissolved Copper Mass Balance Calculations for Keswick Reservoir
Table F-1B.	Dissolved Copper Mass Balance Calculations for Sacramento River (below Keswick Dam to above Bend Bridge)
Table F-2A.	Dissolved Copper Mass Balance Calculations for Keswick Reservoir
Table F-2B.	Dissolved Copper Mass Balance Calculations for Sacramento River (below Keswick Dam to above Bend Bridge)
Table F-3A.	Dissolved Copper Mass Balance Calculations for Keswick Reservoir
Table F-3B.	Dissolved Copper Mass Balance Calculations for Sacramento River (below Keswick Dam to above Bend Bridge)
Table F-4.	Dissolved Metal Balances and Water Balances Summary Statistics

Figure F-1A. Dissolved Copper & Water Balances for Keswick Reservoir



**Figure F-1B. Dissolved Copper & Water Balances for Sacramento River
(below Keswick Dam to above Bend Bridge)**

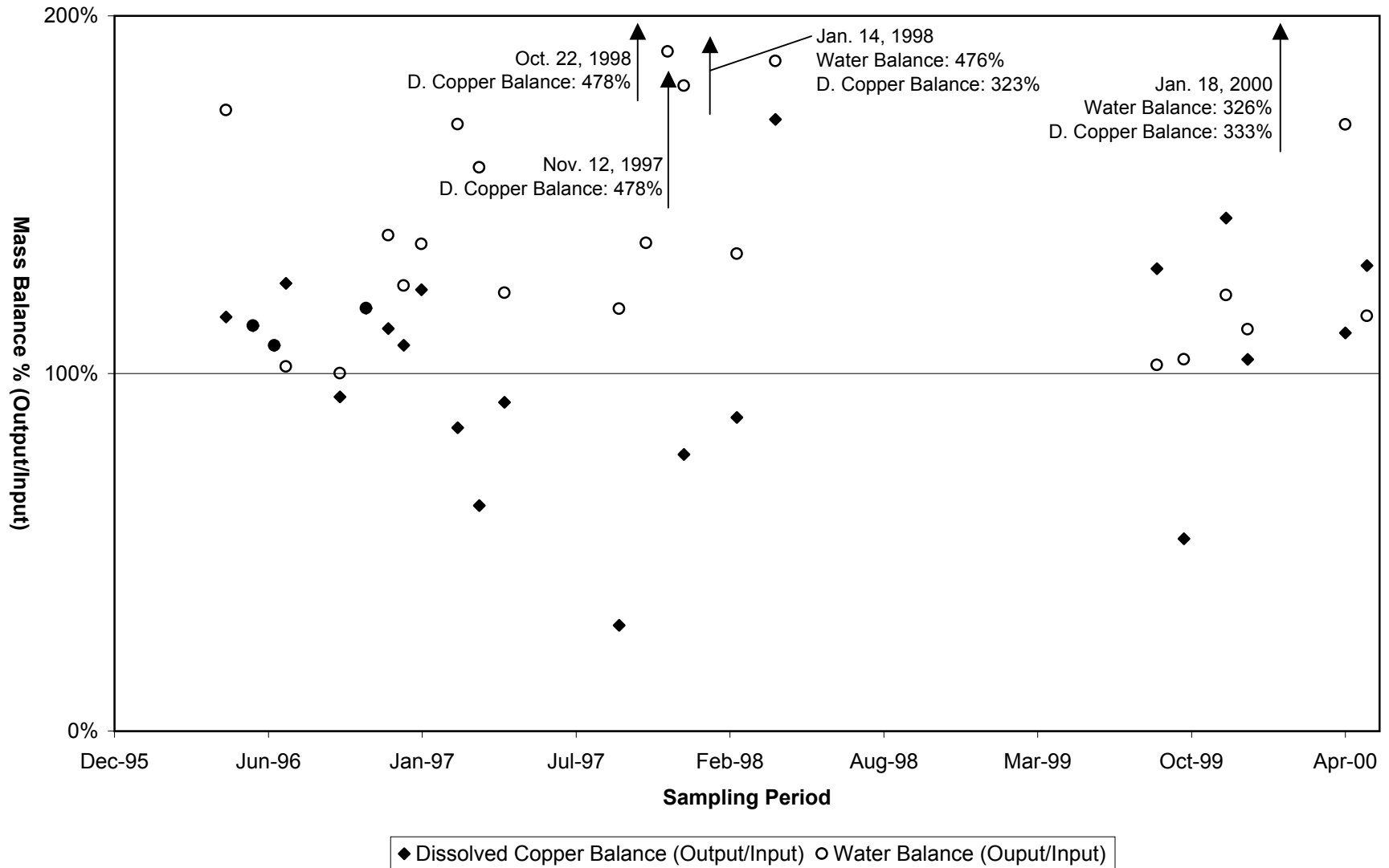
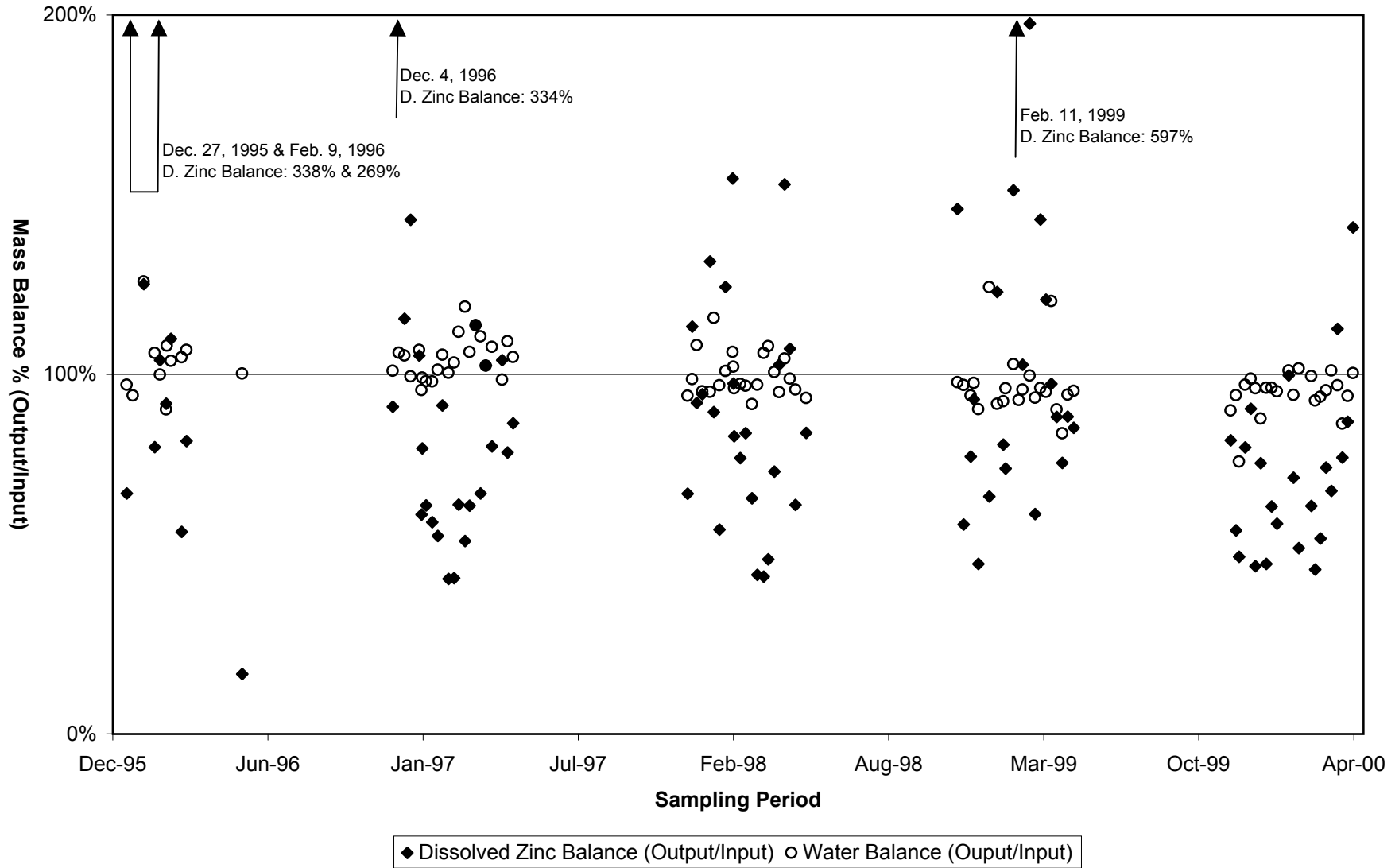


Figure F-2A. Dissolved Zinc & Water Balances for Keswick Reservoir



**Figure F-2B. Dissolved Zinc & Water Balances for Sacramento River
(below Keswick Dam to above Bend Bridge)**

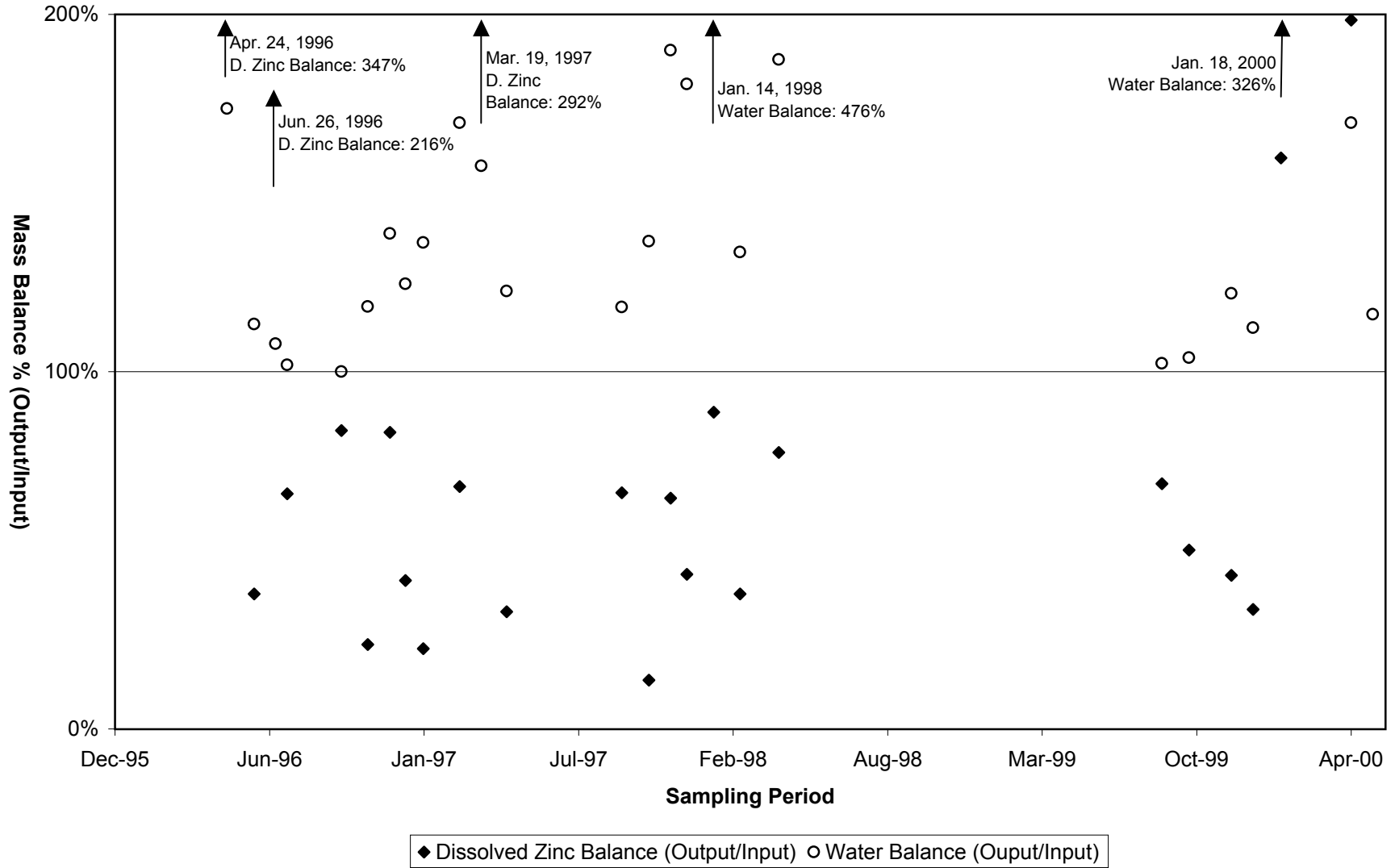


Figure F-3A. Dissolved Cadmium & Water Balances for Keswick Reservoir

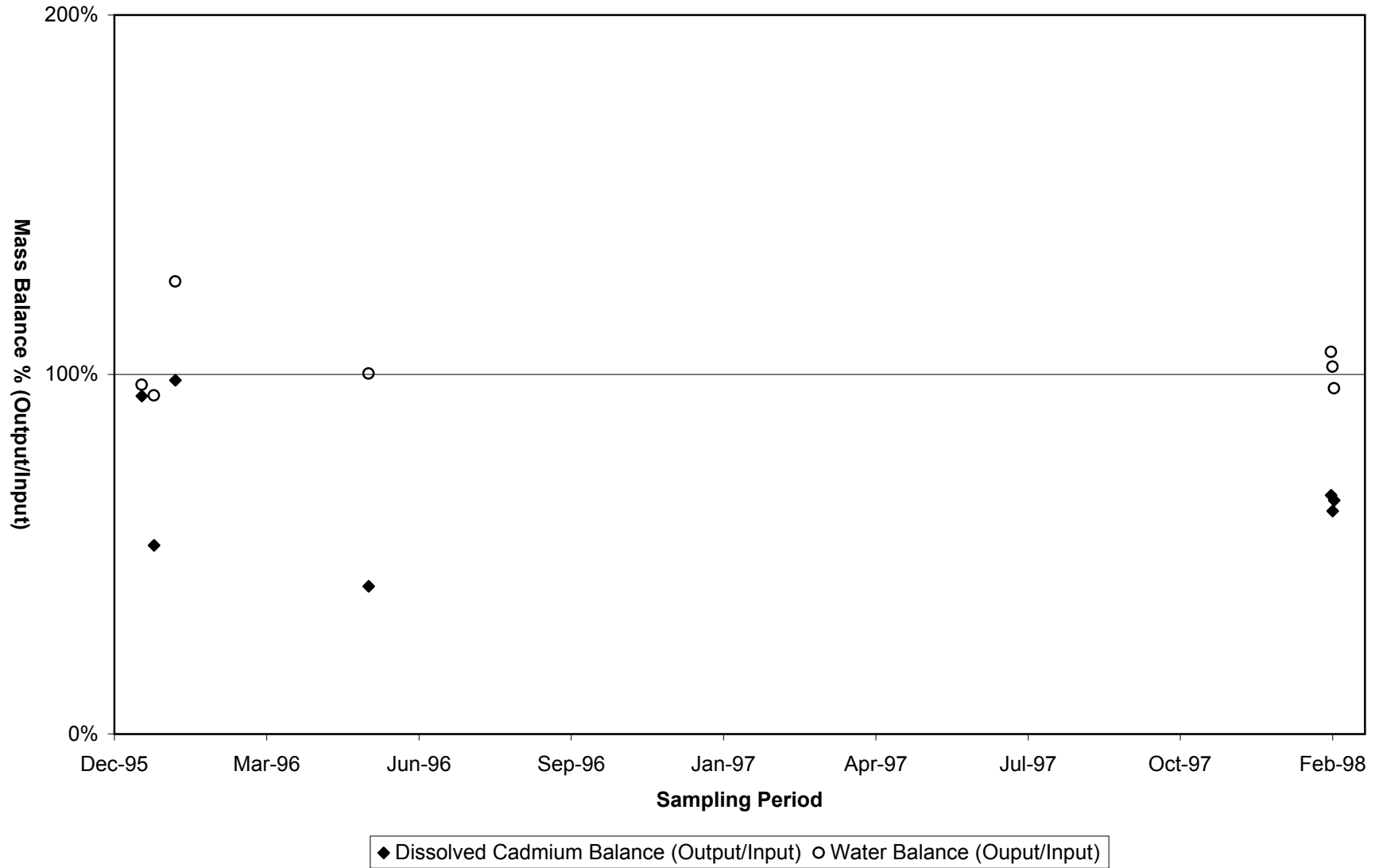


Figure F-3B. Dissolved Cadmium & Water Balances for for Sacramento River
(below Keswick Dam to above Bend Bridge)

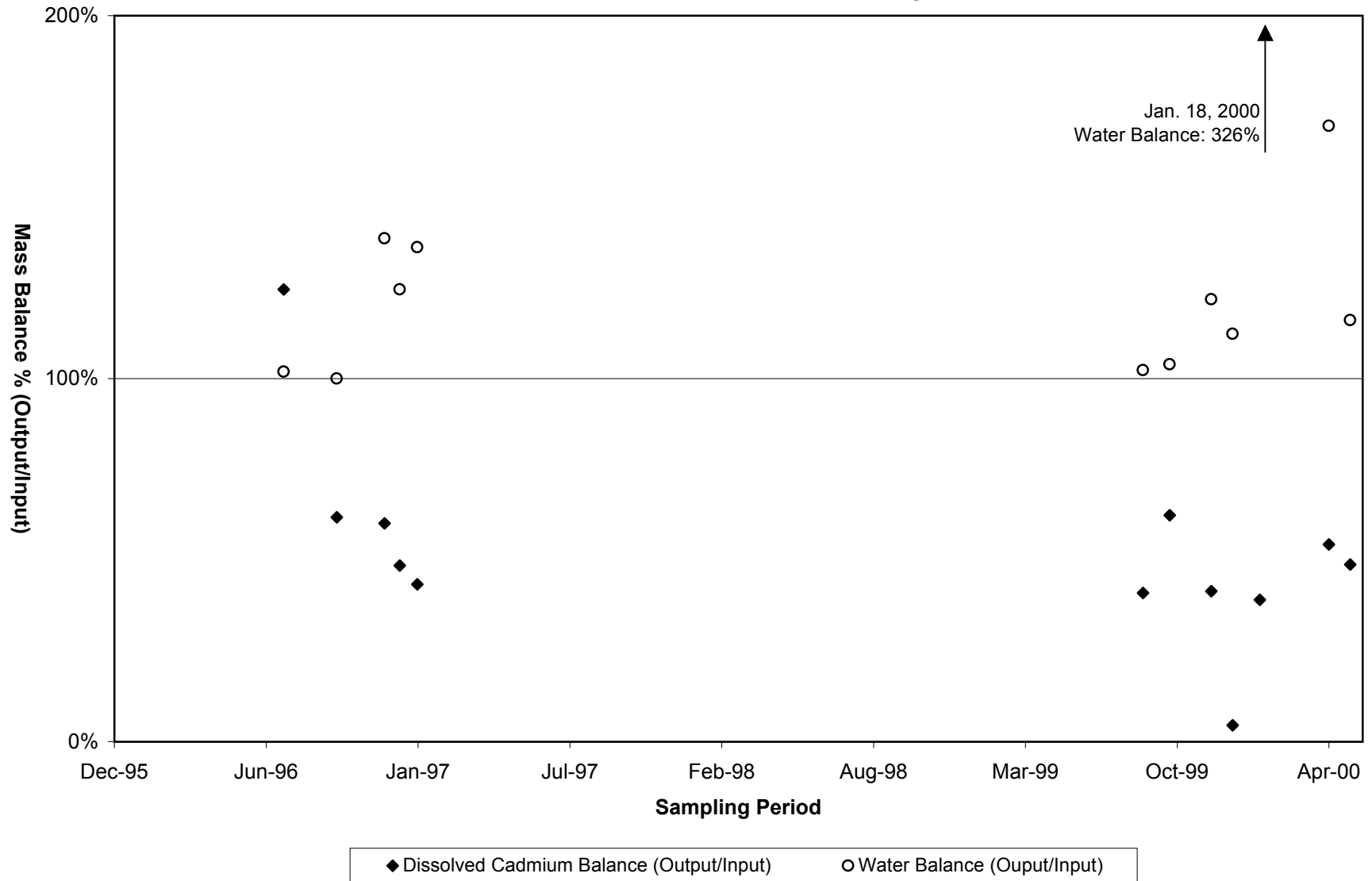


Table F-1A. Dissolved Copper Mass Balance Calculations for Keswick Reservoir

DATE	DISSOLVED COPPER BALANCE						WATER BALANCE					
	Dissolved Copper Inputs to Keswick Reservoir (kg/day)			Total Inputs to Keswick Reservoir (kg/day)	Output from Keswick Reservoir (kg/day)	Dissolved Copper Output / Input (in percent)	Water Inputs to Keswick Reservoir (cfs)			Total Inputs to Keswick Reservoir	Output from Keswick Reservoir	Water Output / Input (in percent)
	Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases				Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases			
19-Dec-95	11.3	123.1	1.4	135.8	11.8	9%	4,626	68	264	4,958	4,815	97%
27-Dec-95	11.7	54.2	0.7	66.6	58.7	88%	4,796	30	272	5,098	4,799	94%
10-Jan-96	8.7	12.8	0.7	22.2	23.5	106%	3,558	5	258	3,821	4,808	126%
24-Jan-96	9.2	27.0	1.7	37.9	11.8	31%	3,747	20	785	4,552	4,821	106%
31-Jan-96	21.2	98.9	2.2	122.3	129.2	106%	8,670	80	1,825	10,575	10,564	100%
09-Feb-96	30.9	153.1	199.7	383.7	43.7	11%	7,417	120	2,182	9,719	10,498	108%
14-Feb-96	74.0	115.9	8.2	198.1	86.5	44%	30,243	80	3,734	34,057	35,338	104%
28-Feb-96	163.7	62.2	7.7	233.6	187.8	80%	41,807	75	3,919	45,801	47,972	105%
05-Mar-96	55.8	183.2	1.5	240.6	66.0	27%	25,343	200	2,526	28,069	29,971	107%
16-May-96	27.0	121.3	2.2	150.4	29.4	20%	7,868	53	639	8,560	8,580	100%
26-Nov-96	13.4	45.1	0.2	58.7	14.4	24%	4,988	25	268	5,281	5,335	101%
04-Dec-96	16.2	18.1	0.7	35.0	65.2	186%	4,724	10	291	5,025	5,326	106%
11-Dec-96	209.5	229.8	9.7	449.1	441.6	98%	29,530	200	3,781	33,511	35,269	105%
19-Dec-96	72.4	55.4	1.8	129.7	74.8	58%	16,438	24	626	17,088	16,994	99%
30-Dec-96	168.9	309.5	18.7	497.2	352.2	71%	40,606	500	3,827	44,933	47,982	107%
02-Jan-97	158.0	1,120.6	0.6	1,279.3	968.7	76%	43,060	757	294	44,111	42,162	96%
03-Jan-97	237.8	793.0	5.6	1,036.4	652.3	63%	64,779	585	1,904	67,268	66,644	99%
08-Jan-97	119.1	223.3	4.2	346.6	246.7	71%	48,673	250	2,481	51,404	50,418	98%
16-Jan-97	152.2	89.8	4.2	246.2	154.7	63%	41,475	100	1,435	43,010	42,152	98%
23-Jan-97	106.5	80.3	3.6	190.4	112.2	59%	31,086	100	1,139	32,325	32,739	101%
29-Jan-97	84.5	34.3	5.6	124.4	96.8	78%	31,398	150	2,555	34,103	35,954	105%
06-Feb-97	13.9	107.7	2.4	124.0	15.3	12%	22,717	200	1,988	24,905	25,019	100%
13-Feb-97	21.4	44.6	2.0	68.1	24.4	36%	8,754	62	831	9,647	9,961	103%
19-Feb-97	8.2	36.3	3.7	48.3	27.0	56%	3,354	50	1,531	4,935	5,517	112%
27-Feb-97	10.3	12.5	1.6	24.3	14.3	59%	3,816	20	639	4,475	5,316	119%
05-Mar-97	11.0	20.2	1.4	32.5	14.0	43%	4,083	25	799	4,907	5,214	106%
13-Mar-97	5.3	0.0	1.7	7.0	7.2	103%	3,919	0	770	4,689	5,330	114%
19-Mar-97	27.4	27.0	0.5	55.0	32.3	59%	4,485	30	262	4,777	5,282	111%
26-Mar-97	29.2	0.0	0.0	29.2	29.9	102%	5,188	0	5	5,193	5,319	102%
03-Apr-97	5.9	36.9	0.5	43.4	7.1	16%	4,394	35	446	4,875	5,248	108%
16-Apr-97	47.0	0.0	1.6	48.6	50.9	105%	6,007	0	590	6,597	6,501	99%
23-Apr-97	26.0	15.6	0.5	42.0	29.7	71%	5,304	15	241	5,560	6,070	109%
30-Apr-97	14.9	20.2	3.0	38.1	41.7	110%	6,069	20	2,044	8,133	8,526	105%
11-Dec-97	6.9	59.6	0.2	66.7	7.2	11%	4,004	55	412	4,471	4,205	94%
17-Dec-97	9.4	50.5	0.2	60.1	51.8	86%	3,836	45	412	4,293	4,234	99%
23-Dec-97	5.9	53.0	0.2	59.1	7.3	12%	3,458	47	411	3,916	4,234	108%
30-Dec-97	3.9	38.9	1.0	43.8	4.1	9%	3,992	25	414	4,431	4,221	95%
09-Jan-98	6.9	49.0	0.4	56.4	8.3	15%	3,538	40	897	4,475	4,257	95%
14-Jan-98	3.1	93.6	1.9	98.6	5.9	6%	3,198	85	1,913	5,196	6,014	116%
21-Jan-98	140.7	252.7	11.3	404.7	352.2	87%	28,742	217	3,306	32,265	31,293	97%
29-Jan-98	44.9	135.2	3.5	183.6	49.1	27%	26,225	130	2,058	28,413	28,673	101%

DATE	DISSOLVED COPPER BALANCE						WATER BALANCE					
	Dissolved Copper Inputs to Keswick Reservoir (kg/day)			Total Inputs to Keswick Reservoir (kg/day)	Output from Keswick Reservoir (kg/day)	Dissolved Copper Output / Input (in percent)	Water Inputs to Keswick Reservoir (cfs)			Total Inputs to Keswick Reservoir	Output from Keswick Reservoir	Water Output / Input (in percent)
	Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases				Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases			
07-Feb-98	135.6	254.7	10.2	400.5	304.2	76%	22,164	290	4,150	26,604	28,257	106%
08-Feb-98	239.9	412.6	15.5	668.0	427.6	64%	36,312	462	3,965	40,739	41,603	102%
09-Feb-98	465.7	571.4	6.8	1,043.8	593.0	57%	52,867	500	3,946	57,313	55,079	96%
17-Feb-98	221.4	526.1	11.2	758.7	457.9	60%	50,275	500	4,172	54,947	53,463	97%
24-Feb-98	142.9	609.0	8.1	760.0	153.8	20%	41,718	488	4,142	46,348	44,883	97%
04-Mar-98	166.2	69.5	6.5	242.2	160.1	66%	32,346	50	1,563	33,959	31,148	92%
11-Mar-98	39.4	76.0	2.0	117.3	39.7	34%	12,375	50	422	12,847	12,470	97%
19-Mar-98	18.9	58.6	21.3	98.8	30.5	31%	7,031	50	3,625	10,706	11,339	106%
25-Mar-98	34.3	216.1	18.4	268.9	42.0	16%	35,071	500	4,185	39,756	42,886	108%
02-Apr-98	80.4	31.6	5.8	117.8	87.3	74%	21,913	38	1,694	23,645	23,795	101%
08-Apr-98	41.2	69.4	20.7	131.3	57.6	44%	7,314	75	3,390	10,779	10,242	95%
15-Apr-98	7.8	25.3	13.2	46.2	38.3	83%	1,594	25	4,143	5,762	6,015	104%
22-Apr-98	20.7	33.6	8.8	63.1	31.8	50%	6,504	25	3,597	10,126	10,004	99%
29-Apr-98	24.8	34.1	13.3	72.3	38.6	53%	6,766	25	4,191	10,982	10,512	96%
13-May-98	63.4	42.0	4.1	109.6	72.8	66%	10,802	39	2,419	13,260	12,391	93%
24-Nov-98	7.8	52.6	3.2	63.7	21.7	34%	10,685	44	4,401	15,130	14,793	98%
02-Dec-98	35.4	125.0	0.3	160.8	35.7	22%	14,463	100	476	15,039	14,595	97%
11-Dec-98	71.8	16.6	0.7	89.0	69.0	78%	22,558	10	480	23,048	21,696	94%
15-Dec-98	10.9	28.1	1.0	40.0	21.9	55%	14,810	14	473	15,297	14,931	98%
21-Dec-98	45.6	4.2	0.9	50.7	51.6	102%	9,317	2	1,288	10,607	9,578	90%
04-Jan-99	11.6	10.7	4.4	26.7	29.6	111%	2,159	5	2,268	4,432	5,507	124%
14-Jan-99	19.5	10.4	0.9	30.9	22.9	74%	4,698	5	1,288	5,991	5,500	92%
22-Jan-99	111.9	57.0	1.4	170.3	118.0	69%	14,286	56	1,955	16,297	15,073	92%
25-Jan-99	32.8	37.6	1.1	71.6	35.3	49%	13,407	42	1,550	14,999	14,419	96%
04-Feb-99	63.9	15.2	3.3	82.4	79.3	96%	9,324	10	1,928	11,262	11,577	103%
11-Feb-99	93.4	64.4	1.3	159.1	89.9	57%	17,346	67	576	17,989	16,706	93%
16-Feb-99	150.7	31.7	1.7	184.1	172.0	93%	25,656	25	529	26,210	25,100	96%
25-Feb-99	54.5	107.5	1.6	163.6	64.5	39%	18,558	150	3,351	22,059	21,976	100%
04-Mar-99	205.8	39.4	4.1	249.2	223.4	90%	26,277	36	4,199	30,512	28,529	94%
11-Mar-99	103.7	37.9	3.5	145.1	107.1	74%	28,247	40	2,053	30,340	29,177	96%
18-Mar-99	28.9	29.4	1.1	59.4	33.3	56%	10,751	25	2,223	12,999	12,361	95%
25-Mar-99	1.4	63.0	1.0	65.4	5.9	9%	2,866	82	2,038	4,986	6,003	120%
01-Apr-99	32.6	58.3	7.5	98.4	48.5	49%	3,701	52	2,354	6,107	5,510	90%
08-Apr-99	54.8	43.4	0.8	99.0	51.4	52%	5,891	40	676	6,607	5,523	84%
15-Apr-99	34.5	53.0	3.8	91.3	41.5	45%	8,282	63	2,238	10,583	9,981	94%
23-Apr-99	21.0	55.9	1.1	78.0	27.2	35%	6,604	50	2,297	8,951	8,537	95%
11-Nov-99	10.6	0.0	0.4	10.9	10.7	98%	6,166	0	747	6,913	6,220	90%
18-Nov-99	7.8	0.0	7.0	14.8	7.6	51%	6,363	0	201	6,564	6,182	94%
22-Nov-99	19.9	20.6	1.6	42.2	25.6	61%	4,792	10	3,341	8,143	6,165	76%
30-Nov-99	7.2	21.3	0.9	29.4	9.2	31%	5,857	10	1,835	7,702	7,481	97%
07-Dec-99	6.4	9.8	1.0	17.2	8.2	48%	6,542	5	1,960	8,507	8,406	99%
13-Dec-99	11.9	0.0	0.5	12.3	14.8	120%	6,928	0	942	7,870	7,562	96%
20-Dec-99	16.4	0.0	0.1	16.5	14.9	90%	6,109	0	202	6,311	5,532	88%

DATE	DISSOLVED COPPER BALANCE						WATER BALANCE					
	Dissolved Copper Inputs to Keswick Reservoir (kg/day)			Total Inputs to Keswick Reservoir (kg/day)	Output from Keswick Reservoir (kg/day)	Dissolved Copper Output / Input (in percent)	Water Inputs to Keswick Reservoir (cfs)			Total Inputs to Keswick Reservoir	Output from Keswick Reservoir	Water Output / Input (in percent)
	Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases				Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases			
27-Dec-99	15.9	0.0	0.1	16.0	15.9	99%	5,431	0	200	5,631	5,419	96%
03-Jan-00	16.2	22.1	0.2	38.5	28.1	73%	4,743	10	440	5,193	5,000	96%
10-Jan-00	14.4	0.0	0.5	14.9	15.4	103%	4,524	0	200	4,724	4,500	95%
25-Jan-00	27.3	66.9	1.4	95.7	37.1	39%	8,585	50	2,911	11,546	11,667	101%
31-Jan-00	60.8	42.0	3.9	106.8	121.9	114%	15,542	34	2,654	18,230	17,179	94%
07-Feb-00	18.1	47.2	1.6	66.8	50.2	75%	7,395	41	3,184	10,620	10,796	102%
23-Feb-00	212.7	162.6	2.2	377.5	245.8	65%	31,046	400	4,597	36,043	35,870	100%
28-Feb-00	200.6	263.1	2.2	465.9	366.7	79%	35,651	350	4,418	40,419	37,465	93%
06-Mar-00	167.4	84.7	2.9	255.0	235.7	92%	34,209	100	2,393	36,702	34,405	94%
13-Mar-00	140.4	89.6	0.8	230.8	194.1	84%	21,248	100	1,712	23,060	22,035	96%
20-Mar-00	41.4	37.3	1.3	79.9	69.2	87%	7,685	30	2,652	10,367	10,474	101%
28-Mar-00	12.6	15.8	1.4	29.9	23.3	78%	3,220	12	2,920	6,152	5,964	97%
03-Apr-00	7.7	16.9	1.7	26.3	30.4	115%	1,955	12	3,568	5,535	4,774	86%
10-Apr-00	60.8	17.4	0.2	78.4	74.9	95%	8,575	12	460	9,047	8,500	94%
17-Apr-00	11.6	27.1	2.0	40.7	22.7	56%	4,323	32	4,035	8,390	8,421	100%

**Table F-1B. Dissolved Copper Mass Balance Calculations for Sacramento River
(Keswick Dam to Bend Bridge)**

DISSOLVED COPPER BALANCE					WATER BALANCE		
Date of Load & Discharge Measurements Below Keswick Dam	Loads Measured Below Keswick Dam (kg/day)	Date of Load & Discharge Measurements Above Bend Bridge (a)	Loads Measured Above Bend Bridge (kg/day)	Dissolved Copper Output / Input (in percent)	Discharge Below Keswick Dam (Input)	Discharge Above Bend Bridge (Output)	Water Output / Input (in percent)
24-Apr-96	39.0	24-Apr-96	45.1	116%	5,313	9,224	174%
29-May-96	68.3	30-May-96	77.4	113%	13956	15,815	113%
26-Jun-96	29.3	27-Jun-96	31.6	108%	11982	12,913	108%
11-Jul-96	42.0	11-Jul-96	52.6	125%	14,815	15,096	102%
19-Sep-96	32.9	20-Sep-96	30.8	93%	9,503	9,504	100%
23-Oct-96	13.0	23-Oct-96	15.4	118%	5,316	6,283	118%
21-Nov-96	31.9	22-Nov-96	35.9	113%	5,295	7,340	139%
11-Dec-96	441.6	12-Dec-96	476.3	108%	35,269	43,935	125%
03-Jan-97	652.3	03-Jan-97	805.1	123%	66,644	90,739	136%
19-Feb-97	27.0	20-Feb-97	22.9	85%	5,517	9,359	170%
19-Mar-97	32.3	20-Mar-97	20.4	63%	5,282	8,325	158%
21-Apr-97	34.6	22-Apr-97	31.8	92%	7,060	8,653	123%
17-Sep-97	35.8	17-Sep-97	10.6	30%	7,306	8,626	118%
22-Oct-97	10.6	22-Oct-97	50.4	478%	4312	5,886	137%
19-Nov-97	11.3	19-Nov-97	32.3	285%	4,631	8,798	190%
10-Dec-97	72.0	10-Dec-97	55.6	77%	4,201	7,581	180%
14-Jan-98	41.2	14-Jan-98	133.1	323%	6,014	28,619	476%
17-Feb-98	457.9	18-Feb-98	401.4	88%	53,463	71,332	133%
08-Apr-98	57.6	09-Apr-98	98.6	171%	10,242	19,189	187%
17-Aug-99	25.6	18-Aug-99	33.1	129%	9,511	9,733	102%
21-Sep-99	20.3	22-Sep-99	10.9	54%	7,554	7,849	104%
15-Nov-99	19.9	16-Nov-99	28.5	143%	6,243	7,608	122%
13-Dec-99	14.8	14-Dec-99	15.4	104%	7,562	8,493	112%
18-Jan-00	16.7	19-Jan-00	55.8	333%	4,021	13,096	326%
18-Apr-00	66.0	19-Apr-00	73.4	111%	8,425	14,291	170%
16-May-00	39.5	17-May-00	51.4	130%	8,504	9,870	116%

(a) Regional Board staff compiled available Bend Bridge measurements for either the same day as, or the day following, the date of Keswick Dam measurements; no Keswick Dam measurement date is repeated.

Table F-2A. Dissolved Zinc Mass Balance Calculations for Keswick Reservoir

DATE	DISSOLVED ZINC BALANCE						WATER BALANCE					
	Dissolved Zinc Inputs to Keswick Reservoir (kg/day)			Total Inputs to Keswick Reservoir (kg/day)	Output from Keswick Reservoir (kg/day)	Dissolved Zinc Output / Input (in percent)	Water Inputs to Keswick Reservoir (cfs)			Total Inputs to Keswick Reservoir	Output from Keswick Reservoir	Water Output / Input (in percent)
	Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases				Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases			
19-Dec-95	22.6	164.6	1.3	188.5	126.1	67%	4,626	68	264	4,958	4,815	97%
27-Dec-95	24.6	82.2	1.4	108.3	366.4	338%	4,796	30	272	5,098	4,799	94%
10-Jan-96	26.1	19.6	1.3	47.0	58.8	125%	3,558	5	258	3,821	4,808	126%
24-Jan-96	66.9	40.3	11.1	118.3	94.4	80%	3,747	20	785	4,552	4,821	106%
31-Jan-96	63.6	150.7	9.4	223.8	232.6	104%	8,670	80	1,825	10,575	10,564	100%
08-Feb-96	46.4	217.1	37.0	300.6	276.2	92%	9,034	120	1,916	11,070	9,988	90%
09-Feb-96	38.1	205.0	247.7 (a)	490.9	1,322.9	270%	7,417	120	2,182	9,719	10,498	108%
14-Feb-96	296.0	156.8	19.2	472.0	518.8	110%	30,243	80	3,734	34,057	35,338	104%
28-Feb-96	214.8	203.7	20.1	438.7	246.5	56%	41,807	75	3,919	45,801	47,972	105%
05-Mar-96	130.2	306.8	13.0	450.0	366.7	81%	25,343	200	2,526	28,069	29,971	107%
16-May-96	40.4	221.8	3.3	265.5	44.1	17%	7,868	53	639	8,560	8,580	100%
26-Nov-96	24.4	70.3	1.3	96.1	87.5	91%	4,988	25	268	5,281	5,335	101%
04-Dec-96	23.1	30.2	1.4	54.7	182.5	334%	4,724	10	291	5,025	5,326	106%
11-Dec-96	375.7	278.1	18.5	672.3	776.7	116%	29,530	200	3,781	33,511	35,269	105%
19-Dec-96	80.4	79.3	3.1	162.8	232.9	143%	16,438	24	626	17,088	16,994	99%
30-Dec-96	208.7	407.4	19.7	635.7	669.2	105%	40,606	500	3,827	44,933	47,982	107%
02-Jan-97	526.8	2,517.1	1.5	3,045.5	1,857.0	61%	43,060	757	294	44,111	42,162	96%
03-Jan-97	792.5	1,703.4	9.8	2,505.7	1,989.5	79%	64,779	585	1,904	67,268	66,644	99%
08-Jan-97	595.5	400.8	12.7	1,009.1	641.5	64%	48,673	250	2,481	51,404	50,418	98%
16-Jan-97	213.1	147.5	7.4	368.0	216.6	59%	41,475	100	1,435	43,010	42,152	98%
23-Jan-97	159.7	139.7	6.2	305.6	168.2	55%	31,086	100	1,139	32,325	32,739	101%
29-Jan-97	384.1	84.7	12.5	481.4	439.9	91%	31,398	150	2,555	34,103	35,954	105%
06-Feb-97	116.7	171.3	10.2	298.3	128.6	43%	22,717	200	1,988	24,905	25,019	100%
13-Feb-97	42.8	71.0	4.3	118.1	51.2	43%	8,754	62	831	9,647	9,961	103%
19-Feb-97	41.0	57.0	7.9	105.9	67.5	64%	3,354	50	1,531	4,935	5,517	112%
27-Feb-97	19.6	28.0	3.3	50.9	27.3	54%	3,816	20	639	4,475	5,316	119%
05-Mar-97	50.0	38.6	11.9	100.5	63.8	63%	4,083	25	799	4,907	5,214	106%
13-Mar-97	20.1	0.0	4.0	24.1	27.4	114%	3,919	0	770	4,689	5,330	114%
19-Mar-97	54.9	48.2	1.3	104.4	69.8	67%	4,485	30	262	4,777	5,282	111%
26-Mar-97	63.5	0.0	0.0	63.5	65.1	102%	5,188	0	5	5,193	5,319	102%
03-Apr-97	22.6	63.5	2.3	88.3	70.6	80%	4,394	35	446	4,875	5,248	108%
16-Apr-97	73.5	0.0	3.0	76.5	79.5	104%	6,007	0	590	6,597	6,501	99%
23-Apr-97	64.9	27.0	2.9	94.9	74.3	78%	5,304	15	241	5,560	6,070	109%
30-Apr-97	74.3	35.9	10.5	120.7	104.3	86%	6,069	20	2,044	8,133	8,526	105%
11-Dec-97	26.0	82.2	2.7	110.9	74.1	67%	4,004	55	412	4,471	4,205	94%
17-Dec-97	46.9	69.3	2.7	118.9	134.7	113%	3,836	45	412	4,293	4,234	99%
23-Dec-97	22.4	81.8	2.7	106.9	98.4	92%	3,458	47	411	3,916	4,234	108%
30-Dec-97	25.9	54.5	2.7	83.1	78.5	94%	3,992	25	414	4,431	4,221	95%
09-Jan-98	22.9	75.9	5.8	104.6	137.5	131%	3,538	40	897	4,475	4,257	95%
14-Jan-98	20.7	134.6	12.4	167.7	150.1	90%	3,198	85	1,913	5,196	6,014	116%
21-Jan-98	471.2	315.4	412.6	1,199.2	681.5	57%	28,742	217	3,306	32,265	31,293	97%

DATE	DISSOLVED ZINC BALANCE						WATER BALANCE					
	Dissolved Zinc Inputs to Keswick Reservoir (kg/day)			Total Inputs to Keswick Reservoir (kg/day)	Output from Keswick Reservoir (kg/day)	Dissolved Zinc Output / Input (in percent)	Water Inputs to Keswick Reservoir (cfs)			Total Inputs to Keswick Reservoir	Output from Keswick Reservoir	Water Output / Input (in percent)
	Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases				Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases			
29-Jan-98	170.1	177.8	13.3	361.2	449.0	124%	26,225	130	2,058	28,413	28,673	101%
07-Feb-98	1,225.7	230.6	280.3	1,736.6	2,682.7	154%	22,164	290	4,150	26,604	28,257	106%
08-Feb-98	977.4	367.4	159.1	1,503.9	1,465.9	97%	36,312	462	3,965	40,739	41,603	102%
09-Feb-98	1,901.6	491.8	128.4	2,521.8	2,089.0	83%	52,867	500	3,946	57,313	55,079	96%
17-Feb-98	1,230.2	550.4	27.1	1,807.6	1,386.7	77%	50,275	500	4,172	54,947	53,463	97%
24-Feb-98	826.8	523.0	54.7	1,404.6	1,175.1	84%	41,718	488	4,142	46,348	44,883	97%
04-Mar-98	1,377.2	100.1	34.0	1,511.3	990.8	66%	32,346	50	1,563	33,959	31,148	92%
11-Mar-98	80.2	99.7	2.7	182.7	80.9	44%	12,375	50	422	12,847	12,470	97%
19-Mar-98	45.6	89.4	23.5	158.5	69.4	44%	7,031	50	3,625	10,706	11,339	106%
25-Mar-98	227.4	318.1	27.1	572.6	278.1	49%	35,071	500	4,185	39,756	42,886	108%
02-Apr-98	142.1	58.3	11.0	211.4	154.3	73%	21,913	38	1,694	23,645	23,795	101%
08-Apr-98	96.6	105.9	22.0	224.5	230.6	103%	7,314	75	3,390	10,779	10,242	95%
15-Apr-98	39.0	39.1	26.9	105.0	160.4	153%	1,594	25	4,143	5,762	6,015	104%
22-Apr-98	85.9	46.1	23.3	155.4	166.5	107%	6,504	25	3,597	10,126	10,004	99%
29-Apr-98	89.4	49.2	10.8	149.4	95.2	64%	6,766	25	4,191	10,982	10,512	96%
13-May-98	243.2	61.9	6.2	311.3	260.7	84%	10,802	39	2,419	13,260	12,391	93%
24-Nov-98	28.8	77.0	10.8	116.5	170.1	146%	10,685	44	4,401	15,130	14,793	98%
02-Dec-98	208.8	178.9	59.8	447.4	260.7	58%	14,463	100	476	15,039	14,595	97%
11-Dec-98	242.9	31.3	1.2	275.4	212.4	77%	22,558	10	480	23,048	21,696	94%
15-Dec-98	148.6	46.6	1.2	196.3	182.7	93%	14,810	14	473	15,297	14,931	98%
21-Dec-98	228.0	7.0	3.2	238.1	112.5	47%	9,317	2	1,288	10,607	9,578	90%
04-Jan-99	52.8	19.1	5.5	77.5	51.2	66%	2,159	5	2,268	4,432	5,507	124%
14-Jan-99	59.8	16.6	10.1	86.5	106.3	123%	4,698	5	1,288	5,991	5,500	92%
22-Jan-99	136.3	101.8	4.8	243.0	195.5	80%	14,286	56	1,955	16,297	15,073	92%
25-Jan-99	157.5	58.7	3.8	219.9	162.3	74%	13,407	42	1,550	14,999	14,419	96%
04-Feb-99	91.3	23.9	4.7	119.9	181.3	151%	9,324	10	1,928	11,262	11,577	103%
11-Feb-99	191.0	96.2	3.8	291.0	1,737.3	597%	17,346	67	576	17,989	16,706	93%
16-Feb-99	627.8	50.6	3.4	681.7	700.2	103%	25,656	25	529	26,210	25,100	96%
25-Feb-99	177.1	152.2	8.2	337.5	666.8	198%	18,558	150	3,351	22,059	21,976	100%
04-Mar-99	925.9	57.4	10.3	993.6	607.3	61%	26,277	36	4,199	30,512	28,529	94%
11-Mar-99	235.0	54.3	5.0	294.3	421.2	143%	28,247	40	2,053	30,340	29,177	96%
18-Mar-99	86.8	40.4	5.4	132.7	160.3	121%	10,751	25	2,223	12,999	12,361	95%
25-Mar-99	18.2	94.0	11.5	123.7	120.4	97%	2,866	82	2,038	4,986	6,003	120%
01-Apr-99	61.6	71.8	5.8	139.1	122.7	88%	3,701	52	2,354	6,107	5,510	90%
08-Apr-99	126.8	56.2	1.7	184.7	139.2	75%	5,891	40	676	6,607	5,523	84%
15-Apr-99	93.2	72.8	5.5	171.5	151.4	88%	8,282	63	2,238	10,583	9,981	94%
23-Apr-99	69.5	73.5	14.1	157.1	133.7	85%	6,604	50	2,297	8,951	8,537	95%
11-Nov-99	42.2	0.0	6.2	48.5	39.6	82%	6,166	0	747	6,913	6,220	90%
18-Nov-99	65.4	0.0	52.1	117.5	66.6	57%	6,363	0	201	6,564	6,182	94%
22-Nov-99	117.3	49.8	35.2	202.2	99.6	49%	4,792	10	3,341	8,143	6,165	76%
30-Nov-99	45.9	48.2	13.9	108.0	86.0	80%	5,857	10	1,835	7,702	7,481	97%
07-Dec-99	64.0	21.4	19.2	104.6	94.6	90%	6,542	5	1,960	8,507	8,406	99%
13-Dec-99	169.5	0.0	16.8	186.3	87.0	47%	6,928	0	942	7,870	7,562	96%

DATE	DISSOLVED ZINC BALANCE						WATER BALANCE					
	Dissolved Zinc Inputs to Keswick Reservoir (kg/day)			Total Inputs to Keswick Reservoir (kg/day)	Output from Keswick Reservoir (kg/day)	Dissolved Zinc Output / Input (in percent)	Water Inputs to Keswick Reservoir (cfs)			Total Inputs to Keswick Reservoir	Output from Keswick Reservoir	Water Output / Input (in percent)
	Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases				Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases			
20-Dec-99	149.5	0.0	1.5	151.0	113.7	75%	6,109	0	202	6,311	5,532	88%
27-Dec-99	132.9	0.0	1.7	134.6	63.6	47%	5,431	0	200	5,631	5,419	96%
03-Jan-00	116.1	41.4	3.0	160.5	101.5	63%	4,743	10	440	5,193	5,000	96%
10-Jan-00	110.7	0.0	4.2	114.9	67.2	58%	4,524	0	200	4,724	4,500	95%
25-Jan-00	98.7	105.5	44.9	249.1	248.4	100%	8,585	50	2,911	11,546	11,667	101%
31-Jan-00	380.3	67.5	6.5	454.3	323.7	71%	15,542	34	2,654	18,230	17,179	94%
07-Feb-00	180.9	66.9	7.8	255.7	132.1	52%	7,395	41	3,184	10,620	10,796	102%
23-Feb-00	471.0	224.0	11.2	706.2	447.6	63%	31,046	400	4,597	36,043	35,870	100%
28-Feb-00	1,151.5	269.7	101.6	1,522.8	696.7	46%	35,651	350	4,418	40,419	37,465	93%
06-Mar-00	837.1	109.1	14.1	960.2	522.0	54%	34,209	100	2,393	36,702	34,405	94%
13-Mar-00	519.9	110.1	10.5	640.5	474.5	74%	21,248	100	1,712	23,060	22,035	96%
20-Mar-00	188.0	49.3	9.1	246.5	166.6	68%	7,685	30	2,652	10,367	10,474	101%
28-Mar-00	36.2	22.9	18.6	77.7	87.6	113%	3,220	12	2,920	6,152	5,964	97%
03-Apr-00	47.8	23.1	21.8	92.8	71.3	77%	1,955	12	3,568	5,535	4,774	86%
10-Apr-00	209.8	25.6	1.7	237.1	205.9	87%	8,575	12	460	9,047	8,500	94%
17-Apr-00	50.8	45.2	4.9	100.9	142.2	141%	4,323	32	4,035	8,390	8,421	100%

(a) CH2MHill measured a dissolved copper concentration of 46.4 µg/l for the SCPP sample on February 9, 1996, which caused the Regional Board staff's load calculation to be anomalously high. However, the SCPP concentration data set had enough other "unusually" high values that staff could not determine whether the values were "bad data" or whether SCPP occasionally discharges loads that occasionally exceed SCDD and Shasta Dam loads.

**Table F-2B. Dissolved Zinc Mass Balance Calculations for Sacramento River
(Keswick Dam to Bend Bridge)**

DISSOLVED ZINC BALANCE					WATER BALANCE		
Date of Load & Discharge Measurements Below Keswick Dam	Loads Measured Below Keswick Dam (kg/day)	Date of Load & Discharge Measurements Above Bend Bridge (a)	Loads Measured Above Bend Bridge (kg/day)	Dissolved Zinc Output / Input (in percent)	Discharge Below Keswick Dam (Input)	Discharge Above Bend Bridge (Output)	Water Output / Input (in percent)
24-Apr-96	13.0	24-Apr-96	45.1	347%	5,313	9,224	174%
29-May-96	409.8	30-May-96	154.8	38%	13,956	15,815	113%
26-Jun-96	29.3	27-Jun-96	63.2	216%	11,982	12,913	108%
11-Jul-96	112.3	11-Jul-96	73.9	66%	14,815	15,096	102%
19-Sep-96	80.8	20-Sep-96	67.5	84%	9,503	9,504	100%
23-Oct-96	65.0	23-Oct-96	15.4	24%	5,316	6,283	118%
21-Nov-96	58.7	22-Nov-96	48.7	83%	5,295	7,340	139%
11-Dec-96	776.7	12-Dec-96	322.5	42%	35,269	43,935	125%
03-Jan-97	1,989.5	03-Jan-97	447.4	22%	66,644	90,739	136%
19-Feb-97	67.5	20-Feb-97	45.8	68%	5,517	9,359	170%
19-Mar-97	69.8	20-Mar-97	203.7	292%	5,282	8,325	158%
21-Apr-97	96.7	22-Apr-97	31.8	33%	7,060	8,653	123%
17-Sep-97	44.7	17-Sep-97	29.5	66%	7,306	8,626	118%
22-Oct-97	52.8	22-Oct-97	7.2	14%	4,312	5,886	137%
19-Nov-97	56.7	19-Nov-97	36.6	65%	4,631	8,798	190%
10-Dec-97	154.2	10-Dec-97	66.8	43%	4,201	7,581	180%
14-Jan-98	150.1	14-Jan-98	133.1	89%	6,014	28,619	476%
17-Feb-98	1,386.7	18-Feb-98	523.6	38%	53,463	71,332	133%
08-Apr-98	230.6	09-Apr-98	178.4	77%	10,242	19,189	187%
17-Aug-99	88.4	18-Aug-99	60.7	69%	9,511	9,733	102%
21-Sep-99	61.0	22-Sep-99	30.5	50%	7,554	7,849	104%
15-Nov-99	74.9	16-Nov-99	32.2	43%	6,243	7,608	122%
13-Dec-99	87.0	14-Dec-99	29.1	33%	7,562	8,493	112%
18-Jan-00	96.4	19-Jan-00	154.1	160%	4,021	13,096	326%
18-Apr-00	156.7	19-Apr-00	310.9	198%	8,425	14,291	170%
16-May-00	81.2	17-May-00	184.0	227%	8,504	9,870	116%

(a) Regional Board staff compiled available Bend Bridge measurements for either the same day as, or the day following, the date of Keswick Dam measurements; no Keswick Dam measurement date is repeated.

Table F-3A. Dissolved Cadmium Mass Balance Calculations for Keswick Reservoir

DATE	DISSOLVED CADMIUM BALANCE						WATER BALANCE					
	Dissolved Cadmium Inputs to Keswick Reservoir (kg/day)			Total Inputs to Keswick Reservoir (kg/day)	Output from Keswick Reservoir (kg/day)	Dissolved Cadmium Output / Input (in percent)	Water Inputs to Keswick Reservoir (cfs)			Total Inputs to Keswick Reservoir	Output from Keswick Reservoir	Water Output / Input (in percent)
	Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases				Shasta Dam Releases	Spring Creek Debris Dam Releases	Spring Creek Power Plant Releases			
19-Dec-95	0.6	1.0	0.0	1.6	1.5	94%	4,626	68	264	4,958	4,815	97%
27-Dec-95	0.6	0.5	0.0	1.1	0.6	52%	4,796	30	272	5,098	4,799	94%
10-Jan-96	0.4	0.1	0.0	0.6	0.6	98%	3,558	5	258	3,821	4,808	126%
16-May-96	1.0	1.5	0.1	2.6	1.0	41%	7,868	53	639	8,560	8,580	100%
07-Feb-98	2.7	2.0	0.5	5.2	3.5	66%	22,164	290	4,150	26,604	28,257	106%
08-Feb-98	4.4	3.3	0.5	8.2	5.1	62%	36,312	462	3,965	40,739	41,603	102%
09-Feb-98	6.5	3.4	0.5	10.4	6.7	65%	52,867	500	3,946	57,313	55,079	96%

**Table F-3B. Dissolved Cadmium Mass Balance Calculations for Sacramento River
(Keswick Dam to Bend Bridge)**

DISSOLVED CADMIUM BALANCE					WATER BALANCE		
Date of Load & Discharge Measurements Below Keswick Dam	Loads Measured Below Keswick Dam (kg/day)	Date of Load & Discharge Measurements Above Bend Bridge (a)	Loads Measured Above Bend Bridge (kg/day)	Dissolved Cadmium Output / Input (in percent)	Discharge Below Keswick Dam (Input)	Discharge Above Bend Bridge (Output)	Water Output / Input (in percent)
11-Jul-96	0.68	11-Jul-96	0.85	125%	14,815	15,096	102%
19-Sep-96	0.71	20-Sep-96	0.44	62%	9,503	9,504	100%
21-Nov-96	0.63	22-Nov-96	0.38	60%	5,295	7,340	139%
11-Dec-96	6.55	12-Dec-96	3.17	48%	35,269	43,935	125%
03-Jan-97	8.15	03-Jan-97	3.53	43%	66,644	90,739	136%
17-Aug-99	1.16	18-Aug-99	0.48	41%	9,511	9,733	102%
21-Sep-99	0.92	22-Sep-99	0.58	62%	7,554	7,849	104%
15-Nov-99	0.76	16-Nov-99	0.32	41%	6,243	7,608	122%
13-Dec-99	0.93	14-Dec-99	0.04	4%	7,562	8,493	112%
18-Jan-00	0.49	19-Jan-00	0.19	39%	4,021	13,096	326%
18-Apr-00	1.03	19-Apr-00	0.56	54%	8,425	14,291	170%
16-May-00	1.04	17-May-00	0.51	49%	8,504	9,870	116%

(a) Regional Board staff compiled available Bend Bridge measurements for either the same day as, or the day following, the date of Keswick Dam measurements; no Keswick Dam measurement date is repeated.

Table F-4. Dissolved Metals and Water Balances Summary Statistics

Percentage of Sampling Periods that Metal Balance Was:	Keswick Reservoir			Sacramento River - Keswick Dam to Bend Bridge		
	Copper	Zinc	Cadmium	Copper	Zinc	Cadmium
<50%:	33%	11%	14%	4%	38%	58%
<100%:	87%	71%	100%	31%	77%	92%
>=100%:	13%	29%	0%	69%	23%	8%
>150%:	1%	8%	0%	19%	23%	0%
# of Sampling Periods:	99	100	7	26	26	12
# of Sampling Periods with Balances less than 100%:	86	71	7	8	20	11
# of Sampling Periods with Balances greater than 100%:	13	29	0	18	6	1

Percentage of Sampling Periods* that Water Balance Was:	Keswick Reservoir			Sacramento River - Keswick Dam to Bend Bridge		
	Copper	Zinc	Cadmium	Copper	Zinc	Cadmium
<50%:	0%	0%	0%	0%	0%	0%
<100%:	60%	60%	43%	0%	0%	0%
>=100%:	40%	40%	57%	100%	100%	100%
>150%:	0%	0%	0%	0%	35%	17%
# of Sampling Periods:	99	100	7	26	26	12

* The water balance percentages for dissolved copper and zinc in the Sacramento River between Keswick Dam and Bend Bridge are identical because the same dates were sampled for both metals; all but one of the dates were identical for copper and zinc measurements for Keswick Reservoir.

Output - Input	Sacramento River - Keswick		
	Copper	Zinc	Cadmium
Lower Limit:	-56.4	-1,542.1	-4.62
Upper Limit:	152.8	154.2	0.17
Median Difference*:	6.8	-29.1	-0.40

* Nineteen of 26 sampling periods had copper load differences between -25.2 and 21.0 kg/day; 19 of 26 sampling periods had zinc load differences between -87.4 and 57.7 kg/day; and 10 of 12 sampling periods had cadmium load differences between -0.88 and 0.17 kg/day.

APPENDIX G.
PLOTS OF DISSOLVED METAL ASSIMILATIVE CAPACITY & LOADS FOR THE
SACRAMENTO RIVER BELOW SHASTA DAM AND KESWICK DAM
& ABOVE BEND BRIDGE

In addition to plotting dissolved metal load and assimilative capacity values, these figures indicate when dissolved metal concentrations exceed the numeric targets to help illustrate when dissolved metal loads exceed their assimilative capacities. Figures G-1A, G-2A, and G-3A indicate when dissolved copper concentrations exceeded the chronic numeric target level for even brief periods (i.e., less than four days), although, by definition, this target applies to four-day averages.

Figure G-1. Sacramento River below Shasta Dam – Assimilative Capacity and Loads

- a. Dissolved Copper
- b. Dissolved Zinc
- c. Dissolved Cadmium

Figure G-2. Sacramento River below Keswick Dam – Assimilative Capacity and Loads

- a. Dissolved Copper
- b. Dissolved Zinc
- c. Dissolved Cadmium

Figure G-3. Sacramento River above Bend Bridge – Assimilative Capacity and Loads

- a. Dissolved Copper
- b. Dissolved Zinc
- c. Dissolved Cadmium

Figure G-1. Sacramento River below Shasta Dam – Assimilative Capacity, Concentrations, and Loads
A. Dissolved Copper

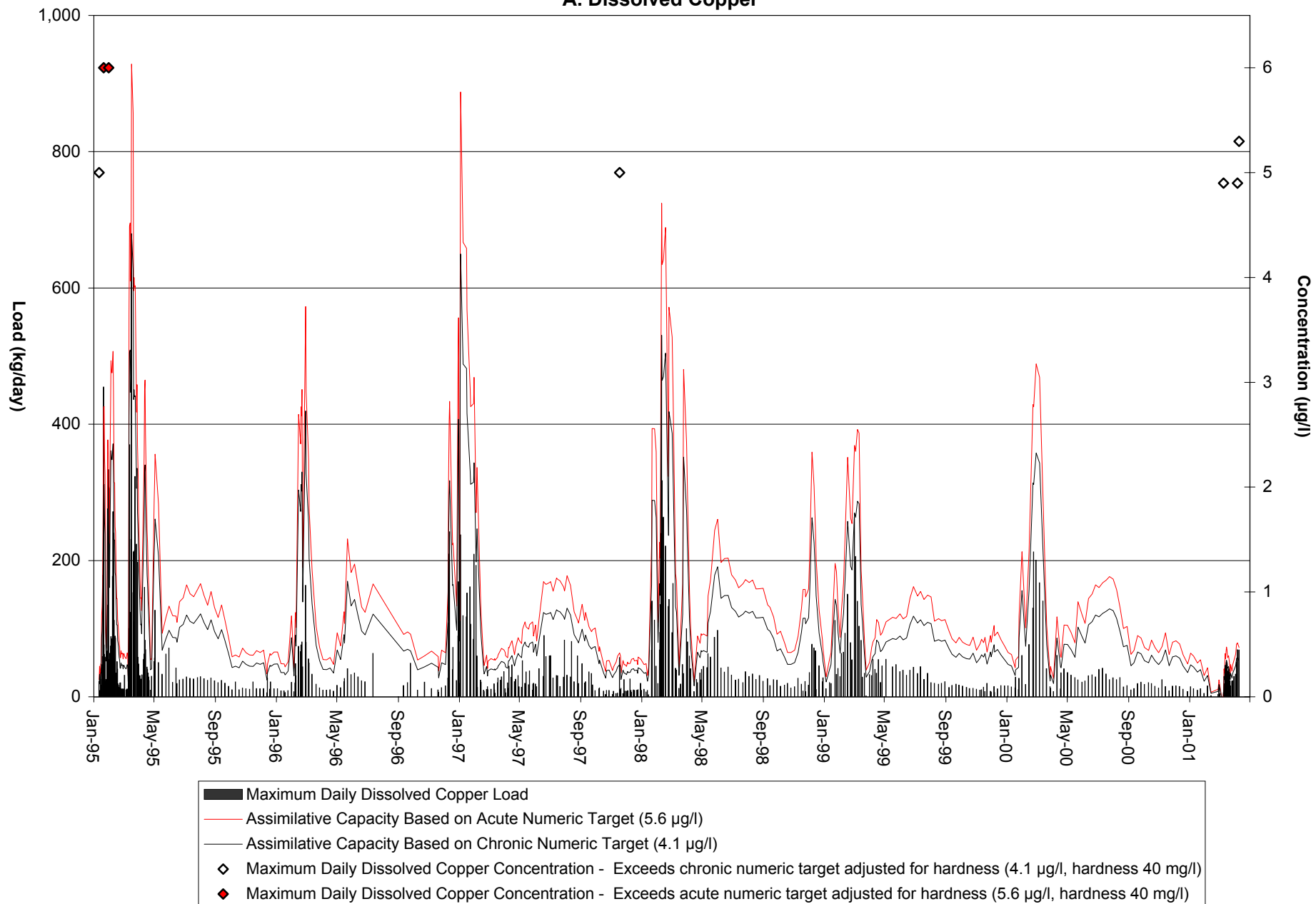
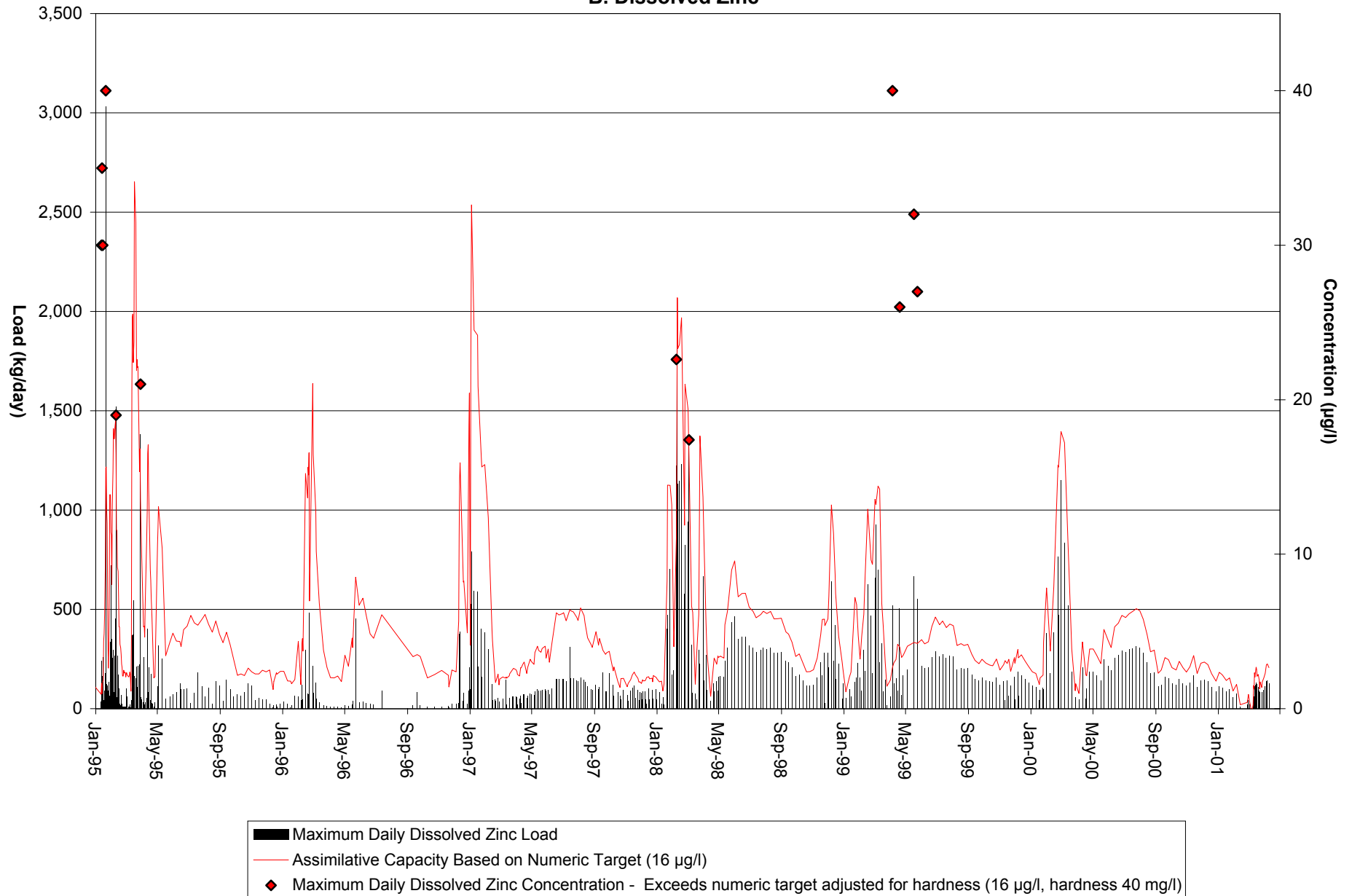


Figure G-1. Sacramento River below Shasta Dam – Assimilative Capacity, Concentrations, and Loads
B. Dissolved Zinc



**Figure G-1. Sacramento River below Shasta Dam – Assimilative Capacity, Concentrations, and Loads
C. Dissolved Cadmium**

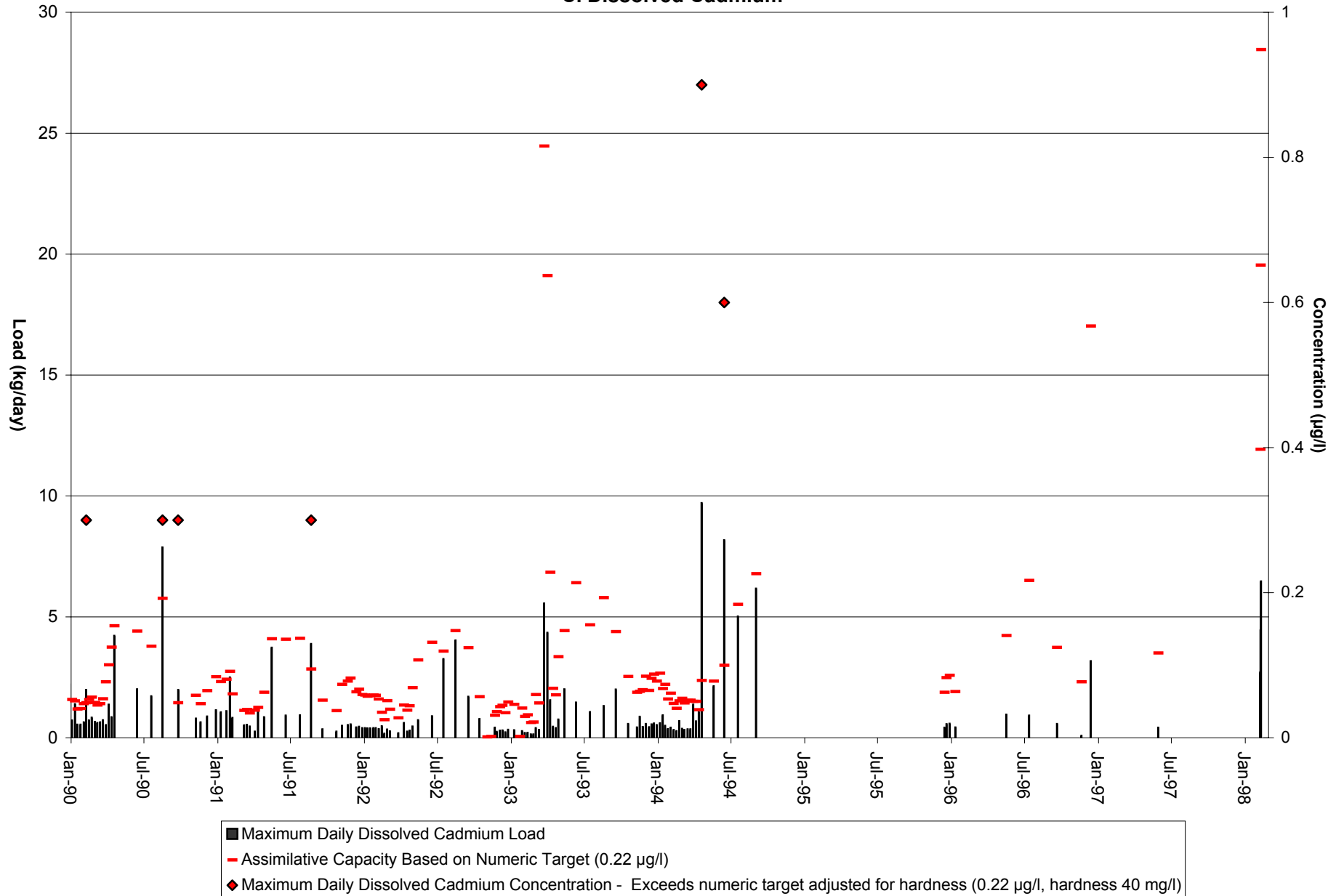


Figure G-2. Sacramento River below Keswick Dam – Assimilative Capacity, Concentrations, and Loads
A. Dissolved Copper

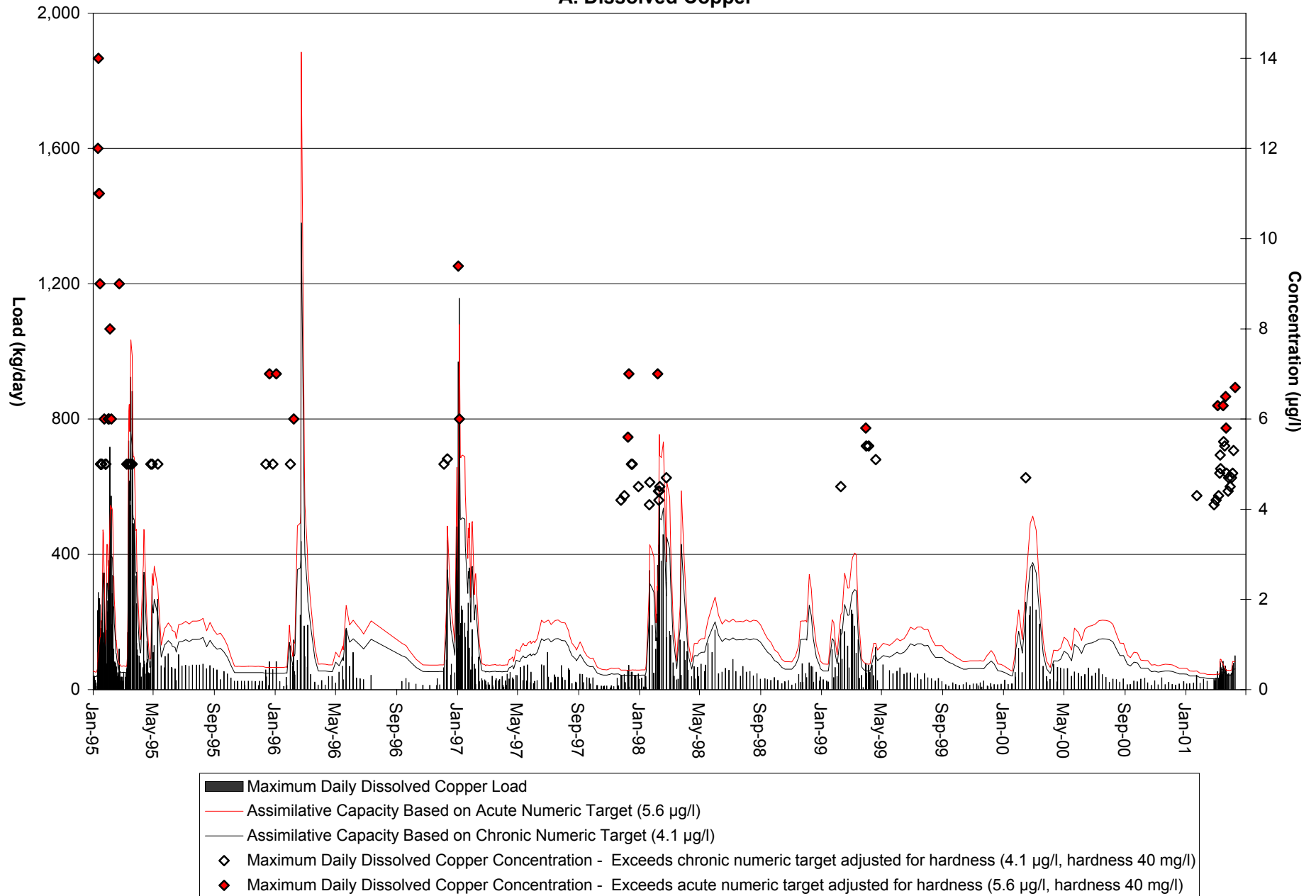
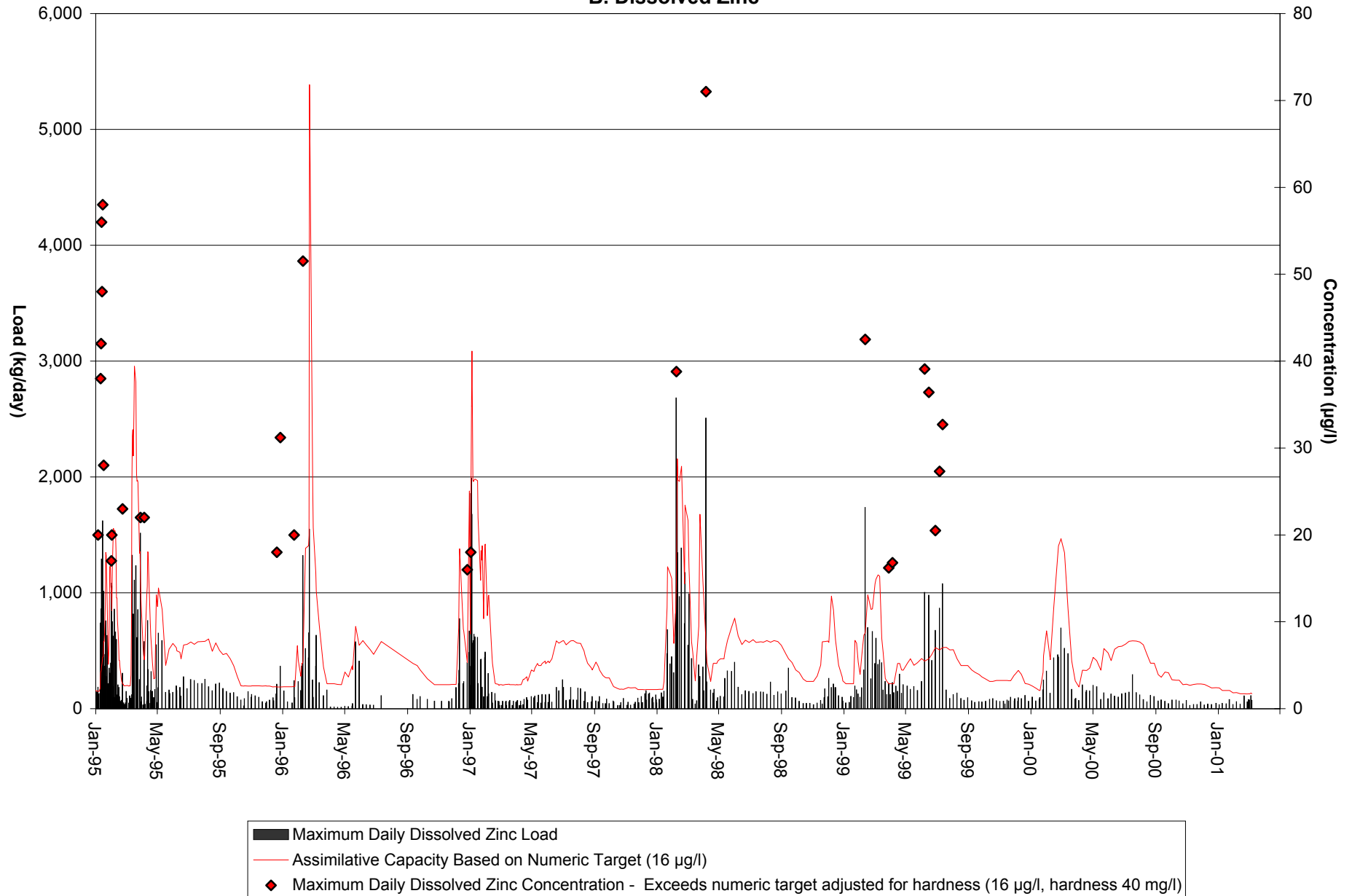


Figure G-2. Sacramento River below Keswick Dam – Assimilative Capacity, Concentrations, and Loads
B. Dissolved Zinc



**Figure G-2. Sacramento River below Keswick Dam – Assimilative Capacity, Concentrations, and Loads
C. Dissolved Cadmium**

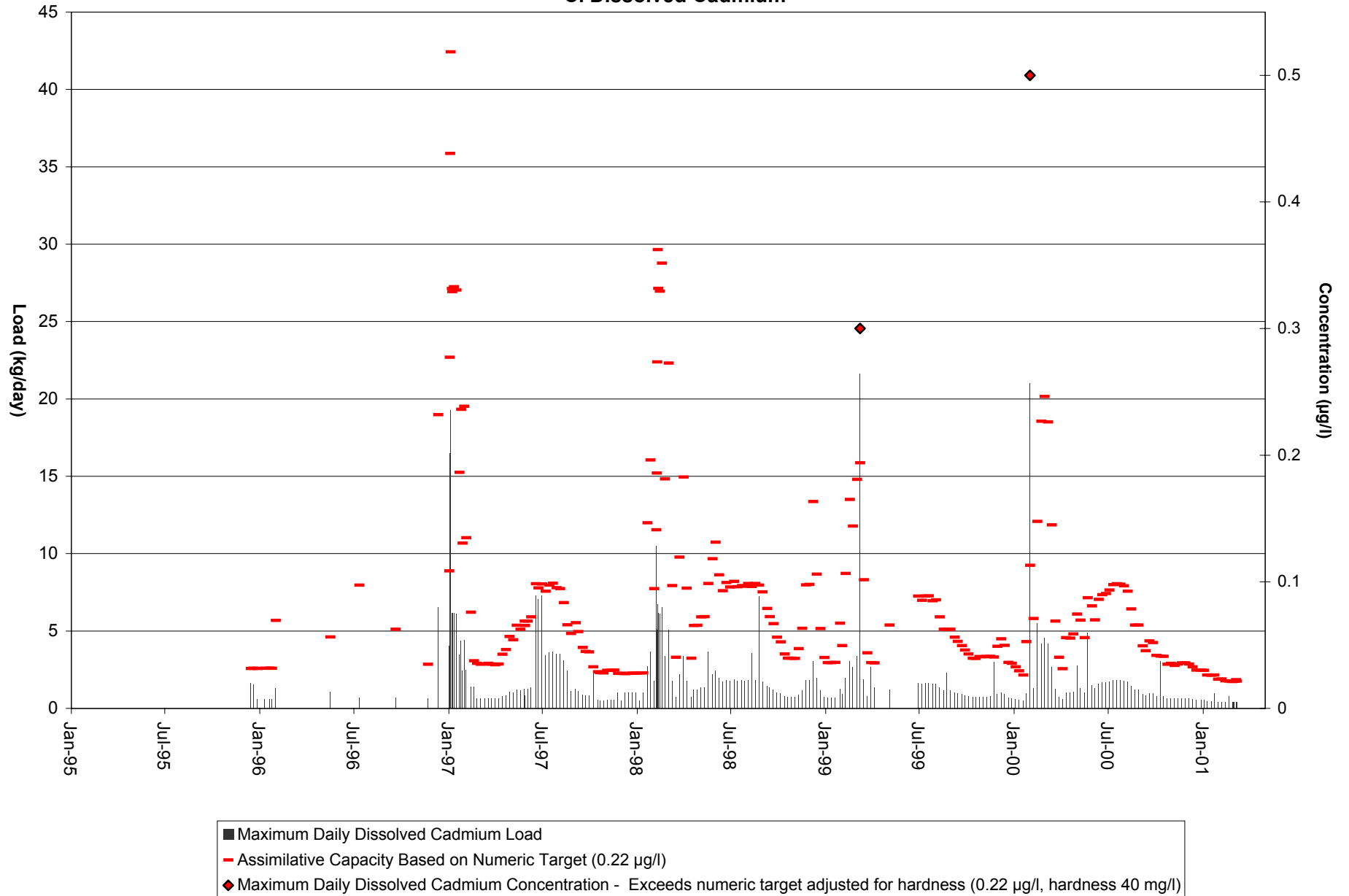


Figure G-3. Sacramento River above Bend Bridge – Assimilative Capacity, Concentrations, and Loads
A. Dissolved Copper

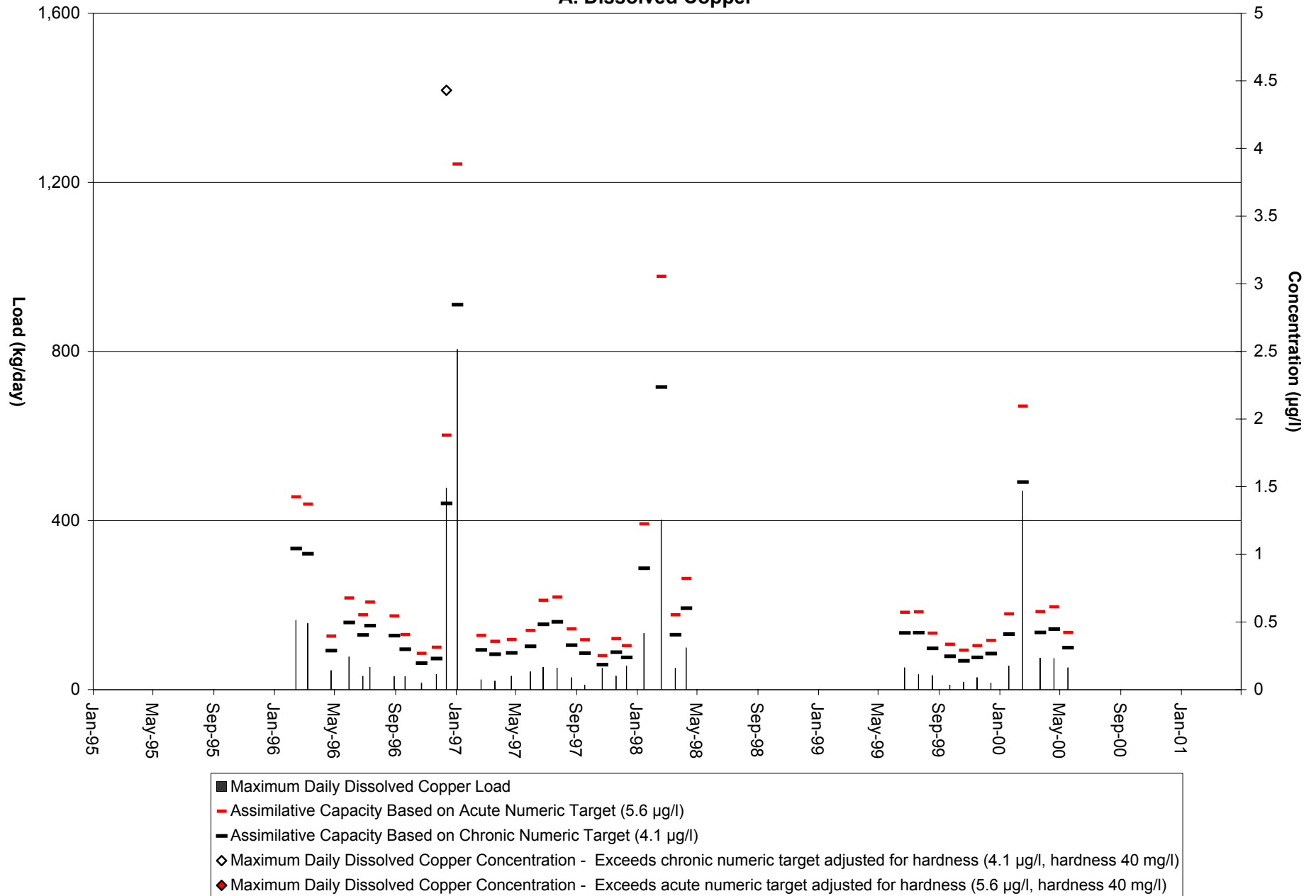


Figure G-3. Sacramento River above Bend Bridge – Assimilative Capacity and Loads
B. Dissolved Zinc

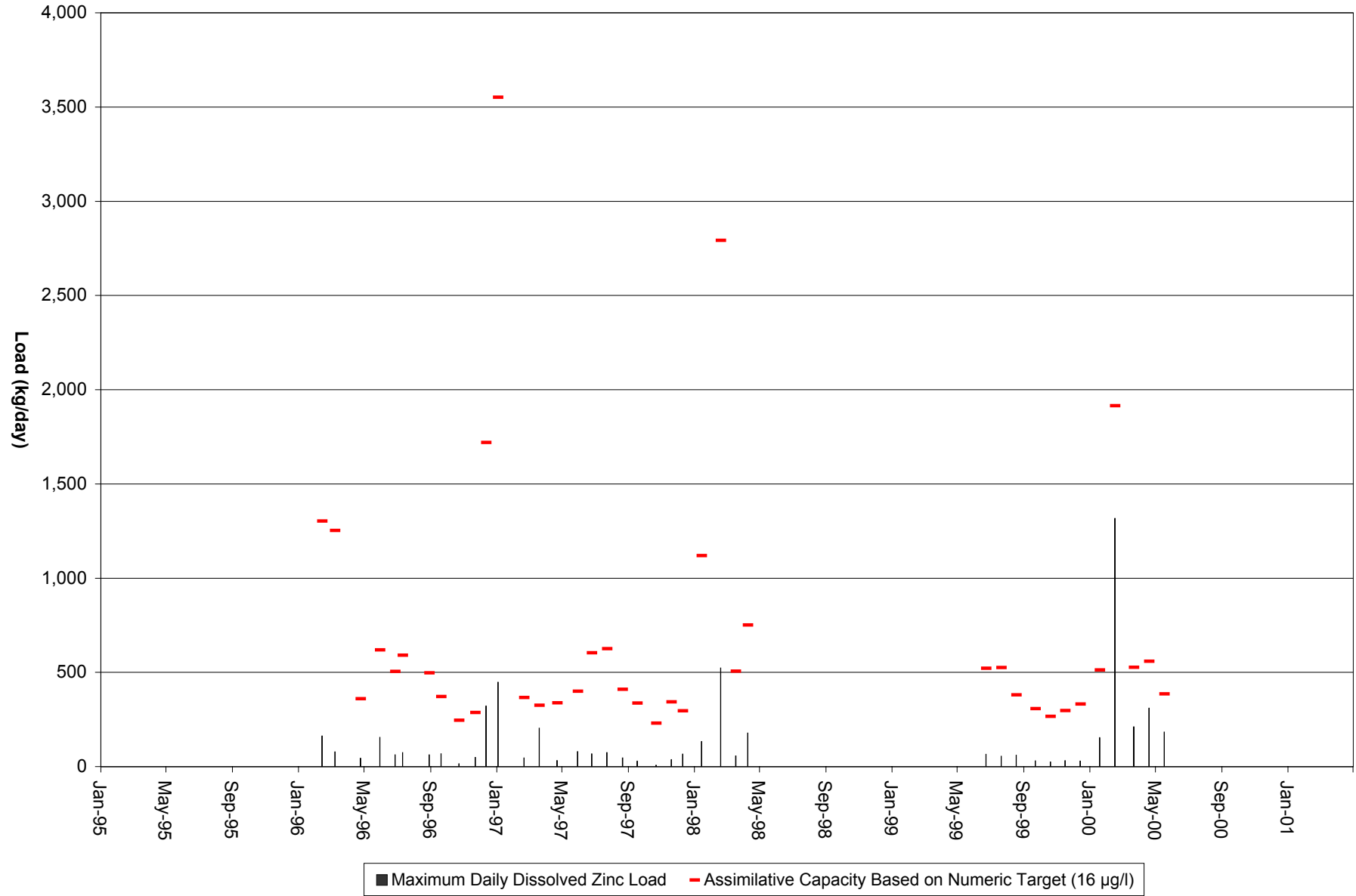
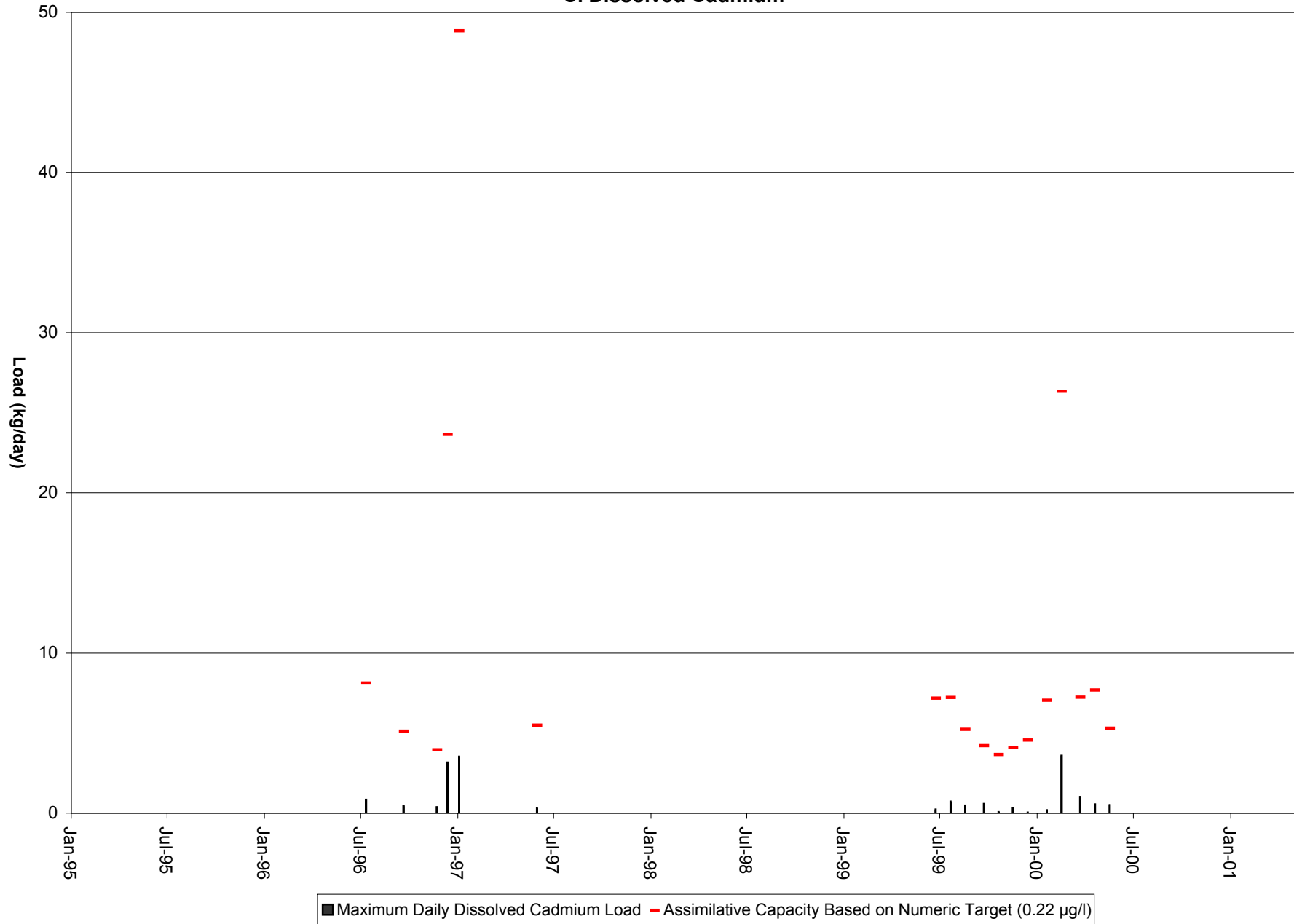


Figure G-3. Sacramento River above Bend Bridge – Assimilative Capacity, Concentrations, and Loads
C. Dissolved Cadmium



**APPENDIX H.
RESPONSES TO COMMENTS RECEIVED ON
THE UPPER SACRAMENTO RIVER TMDL FOR CADMIUM, COPPER & ZINC
DRAFT REPORT**

The following are Regional Board staff responses to comments received on the *Upper Sacramento River TMDL for Cadmium, Copper and Zinc Draft Report*, which was released in September 2001 and re-released in March 2002. Regional Board staff assigned a number to each comment provided in the written letters and electronic notes submitted by the individual reviewers (see attached) and cited that number in the responses below. Where indicated in the responses, Regional Board staff made corresponding changes to the text of the report. The staff appreciates the efforts and thoughts of all who submitted comments.

U.S. Environmental Protection Agency (USEPA).

Letter from David Smith (TMDL Team Leader, USEPA Region 9 Water Division) and Richard Sugarek (Remedial Project Manager, USEPA Region 9 Superfund Division) to Patrick Morris (Senior WRC Engineer, Regional Board Sacramento River Mercury TMDL Unit), dated December 18, 2001.

Comments #1, 4, 7, 8, 9a, 12-16: Delineation of Allocations and Assumptions.

Regional Board staff agrees with the USEPA's comment that the TMDL should more clearly identify the individual load allocations for the three source categories upstream of Keswick Dam. Staff has made changes to the text to indicate the assignment of load allocations to the mine sites upstream of Shasta Dam – with Shasta Dam acting as the point of compliance – in addition to the allocation to the IMM site. Staff also defined more of the assumptions made about metal loads from Shasta Lake and included in the Implementation Plan increased monitoring of Shasta Dam releases and other Shasta Lake locations to determine the sources and variability of dissolved metal concentrations in Shasta Dam (particularly those that exceed 1.3 µg/l dissolved copper and 3.9 µg/l dissolved zinc). Because of its minor metals input, staff did not assign allocation to the sources of dissolved metals in Spring Creek Power Plant discharges.

Comments #2, 5, 6 & 7: Iron Mountain Mines Allocation. Regional Board staff agrees with the USEPA's comment that the Iron Mountain Mines (IMM) load reduction allocation should be clearly assigned to the mine itself, and not to the USEPA. Pursuant to the recent settlement between Aventis CropSciences (a

former owner and operator of IMM), USEPA and the State, staff has made changes throughout the report text to indicate that:

1. IMM is responsible for the load reduction allocation.
2. Aventis CropSciences arranged for, among other things, a private contractor to operate and maintain the current IMM remedial actions pursuant to CERCLA (RODs 1-4) over the next 30 years and for payment at year 2030 to fund the clean-up after year 2030.
3. Iron Mountain Mines, Inc. is the current owner.
4. USEPA is the lead oversight agency and the State is the support agency with respect to these clean-up efforts.

Comments #3, 10 & 11: Future Implementation Changes

Regional Board staff updated the “TMDL water management strategy” text throughout the report based on the revised load reduction allocation for mines upstream of Shasta Dam and USEPA’s comments about the need for, and technical feasibility of, additional remediation activities to address Boulder Creek AMD discharges and Keswick Reservoir sediment removal.

Comment #9b: TMDL Review Schedule

Regional Board staff agrees with the USEPA’s comment that it would be appropriate to coordinate the Regional Board’s periodic TMDL reviews with the USEPA’s 5-Year Reviews for the IMM site. Staff updated the text to reflect the proposed timing of future TMDL reviews.

U.S. Bureau of Reclamation (USBR).

Letter from Frank Michny (Regional Environmental Officer, Mid-Pacific Regional Office) to Patricia Vellines (Engineering Geologist, Regional Board Sacramento River Mercury TMDL Unit), dated November 20, 2001.

Comments #i, iii, vii, 29-30, 32, 40 & 45: Delineation of Allocations and Assumptions

Based on the USBR and USEPA comments, Regional Board staff edited the report text to clearly indicate that load reduction allocations are assigned to the metal sources (e.g., the mine sites located upstream of Keswick and Shasta Dams), and not to the USBR and USEPA. Staff has made changes to the text to indicate the assignment of load allocations to the mine sites upstream of Shasta Dam – with Shasta Dam acting as the point of compliance – in addition to the allocation to the IMM site. Because the assignment of load reductions to individual mine sites upstream of Shasta Dam will be part of a separate TMDL, Regional Board staff assigns the load reduction allocation to Shasta Dam releases; Shasta Dam acts as a monitoring point for the accumulated loads from all point and nonpoint sources upstream of the dam.

Although this TMDL assigns the load reduction allocation to Shasta Dam releases, the metals sources (e.g., mine owners with USEPA and Regional Board oversight) upstream of the dam are responsible for the remedial actions required to decrease the loads released from Shasta Dam. In addition, staff revised the TMDL report so that the Implementation Plan addresses the load reduction allocation for Shasta Dam releases as part of the remediation activities scheduled during the next five years, rather than incorporate the load reduction in the margin of safety to be addressed during the next five to ten years. Staff also defined more of the assumptions made about metal loads from Shasta Lake and included in the Implementation Plan increased monitoring of Shasta Dam releases and other Shasta Lake locations to determine the sources and variability of dissolved metal concentrations in Shasta Dam (particularly those that exceed 1.3 µg/l dissolved copper and 3.9 µg/l dissolved zinc). Because of their minor metals input, staff did not assign load reduction allocations to the Spring Creek Power Plant discharge and the NPDES-permitted dischargers downstream of Keswick Dam; however, staff will review new monitoring data and assign load reductions to NPDES-permitted dischargers as warranted in the years ahead.

Comments #ii, 1-3, 5, 23-24, 26-28, 31, 35-39, 42-44: “Improved” Dam Operations

Regional Board staff edited the text throughout the report to clarify the meaning of the previously used phrase “improved dam manipulations”. The text now explains that the USBR’s dam operations are governed by the 1980 MOU, the 1992 Long-Term Central Valley Project Operations Criteria and Plan (CVP-OCAP), and the 1993 Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project; the phrase “improved dam manipulations” is no longer used in the text. Staff also updated the text to indicate that after three years of monitoring data have been collected following the completion of remediation activities at Slickrock Creek, Regional Board staff will work with the USBR, USEPA, California Department of Fish and Game, and State Water Resources Control Board to revise the 1980 MOU as needed to ensure maximum efficiency in managing releases from the SCDD (see next response). In addition, staff edited the text throughout the report to indicate that the USBR voluntarily targets the Basin Plan objectives.

Comments #iv, vi, 16, 25, 34, 41: TMDL and 1980 MOU Review Schedule

Regional Board staff agrees with the USEPA’s comment that it would be appropriate to coordinate the Regional Board’s periodic TMDL reviews with the USEPA’s 5-Year Reviews for the IMM site. Staff updated the text to reflect the proposed timing of future TMDL reviews. In addition, staff updated the text throughout the report to indicate that after three years of monitoring data have been collected following the completion of remediation activities at Slickrock Creek, Regional Board staff will work with the USBR, USEPA, California Department of Fish and Game, and State Water Resources Control

Board to (1) determine whether additional remediation activities are required for the Sacramento River downstream of Keswick Dam to be in compliance with the proposed numeric targets, and (2) revise the 1980 MOU to ensure maximum efficiency in managing releases from the SCDD.

Comment #v: Meeting Basin Plan objectives in the Sacramento River below Keswick Dam.

Regional Board staff updated the text to reflect comments from the USBR. The revised text indicates that, pending revision of the 1980 MOU, the USBR will continue to operate the SCDD and related facilities in a reasonable and prudent manner in compliance with operations criteria set forth in the 1980 MOU, 1992 Central Valley Project Operations Criteria and Plan, and 1993 Biological Opinion for the Operation of the Federal Central Valley Project. After three years of monitoring data have been collected following the completion of remediation activities at Slickrock Creek, the Regional Board staff will work with the USBR, USEPA, California Department of Fish and Game, and State Water Resources Control Board to revise as needed the 1980 MOU to take into account the performance of the USEPA remedies in RODs 1-4, new technology, and new information (e.g., the Regional Board staff evaluation of potential sources and variability of dissolved metal concentrations in Shasta Dam releases). The purpose of any revisions to the 1980 MOU would be to ensure maximum efficiency in managing releases from the SCDD.

Comments #6, 21: Improvements in fish population declines.

Regional Board staff updated the text to reflect USBR's comments and clarify the description of the multiple causes of fish population declines.

Comment #7: Improvements in fish population declines.

Regional Board staff updated the text to clarify the meaning of "changes in regional dam operations".

Comment #8: Water Quality of the Sacramento River at Bend Bridge.

Regional Board staff updated Section 2.3.3 to include additional information provided by the USBR and USEPA.

Comments #9 and 11: Instream fishery flow requirements and Endangered Species Act

Regional Board staff updated the text in multiple sections of the report to include instream fishery flow requirements and the federal and State Endangered Species Acts as factors in USBR water management strategies.

Comments #10: CTR compliance and the strengthening of the Sacramento River fisheries.

Regional Board staff updated the text to indicate that multiple factors – not just compliance with the CTR and Basin Plan objectives – are required to restore Sacramento River fisheries.

Comments #12: Temperature control device at Shasta Dam.

Regional Board staff updated the text to include a description of the temperature control device.

Comments #13, 20 & 22: Fish kills before and after Shasta Dam construction.

Regional Board staff updated the text in Section 3.3.1 to indicate the multiple effects Shasta and Keswick Dams have had on downstream water quality and fisheries.

Comments #14: Purposes of Keswick Dam.

Regional Board staff updated the text in Section 3.3.1 to indicate the multiple purposes of Keswick Dam.

Comments #15, 17, 18 & 19: Former name of USBR, Operation of SCPP at Speed No Load, and SCDD releases.

Regional Board staff updated the text in Section 3.3.1 to indicate that “U.S. Water and Power Resources Service” is the former name of the USBR and to clarify the descriptions of the “Speed No Load” operation of SCPP and SCDD releases during non-storm periods.

Comment #22: Coincidence of springtime AMD releases and timing of spawning chinook.

Regional Board staff updated the text to reflect USBR’s comments and clarify the description of the coincident timing of springtime AMD releases and spawning chinook.

Comment #33: Clarification of “...willful malicious acts”.

Regional Board staff updated the text to indicate that willful malicious acts include acts of terrorism and illegal dumping.

Comment #46: Clarification of IMM responsible parties.

Regional Board staff updated the main text to refer the reader to existing USEPA documents that provide comprehensive descriptions of IMM responsible parties, site history, and remediation activities, rather than attempt to provide a comprehensive review in this report.

California Department of Fish & Game (CDFG).

Letter from Donald B. Koch (Regional Manager, CDFG Northern California-North Coast Region) to Gary M. Carleton (Executive Officer, Regional Board – Central Valley Region, Sacramento), dated October 31, 2001.

Comment #1: Table 5-1 corrections and additions.

Regional Board staff updated Table 5-1 to reflect CDFG's corrections for the Bella Vista Water District water treatment plant and the Coleman National Fish Hatchery regarding the location of their receiving waterbody confluences with the Sacramento River. Staff also added the Darrah Springs Hatchery.

Comment #2: Consideration of the availability of dilution water (in addition to pollution control at IMM).

Regional Board staff appreciates the CDFG's recommendation to examine the impacts of water storage projects proposed by CALFED when the TMDL is re-evaluated in five years. Staff revised the text throughout the report to better define the USBR's criteria for operations and providing dilution water (i.e., 1980 MOU, the 1992 CVP-OCAP, and the 1993 Biological Opinion). Such an examination will be conducted in 5 years when Regional Board staff will work with the USBR, USEPA, California Department of Fish and Game, and State Water Resources Control Board to evaluate and revise the 1980 MOU as needed to ensure maximum efficiency in managing releases from the SCDD.

Sierra Pacific Industries (SPI).

Letter from Scott Leiby (Safety & Environmental Director, Sierra Pacific Industries) to Patricia Vellines (Engineering Geologist, Regional Board Sacramento River Mercury TMDL Unit), dated October 26, 2001.

Comment #1: Additional allocation of loads to industrial dischargers.

Regional Board staff appreciates SPI's concern that the Regional Board may allocate loads to industrial dischargers to achieve the proposed numeric targets if the activities scheduled during the first five years of the TMDL water management strategy do not achieve the targets. In response to this and other similar comments, Regional Board staff revised the Implementation Plan so that the load reduction allocation for Shasta Dam releases is addressed by the Implementation Plan for remediation activities scheduled during the next five years, rather than included in the TMDL as a component of the margin of safety to be addressed during the next five to ten years. Staff also defined more of the assumptions made about metal loads from Shasta Lake and included in the Implementation Plan increased monitoring of Shasta Dam releases and other Shasta Lake locations to determine the sources and variability of dissolved metal

concentrations in Shasta Dam. Under the Clean Water Act, the USEPA requires that a TMDL create a technically feasible and reasonably fair division of the allowable load among sources. In the years ahead, Regional Board staff will review new data that evaluate the effectiveness of the IMM remedies, and better define metal loads from Shasta Lake area sources and downstream dischargers. Staff will make every effort to develop allocate load reductions that are both technically feasible and fair, if additional load reductions are needed after the IMM and Shasta mines remedies are complete.

City of Redding.

E-mail from Marci Ames (Industrial Waste Analyst, City of Redding Public Works, Field Operations Division) to Patricia Vellines (Engineering Geologist, Regional Board Sacramento River Mercury TMDL Unit), dated November 16, 2001.

Regional Board staff appreciates the City of Redding's recommendations for NPDES discharger sampling and analytical methods. This TMDL report does not include the level of detail outlined in the City's comments. Staff will incorporate the City's comments in future monitoring plans as they are developed.



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

December 18, 2001

Mr. Patrick Morris
Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, CA 95827

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SACRAMENTO
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DEC 20 PM 12

SUBJECT: Comments on the Draft TMDL for Cadmium, Copper and Zinc for the Upper Sacramento River

Thank you for the opportunity to comment on the September 25, 2001 draft report, Upper Sacramento River TMDL for Cadmium, Copper and Zinc, prepared by the Regional Water Quality Control Board (RWQCB), Central Valley Region. We believe that in many respects the draft report is well written, and we support the basic conclusion of the TMDL analysis that currently planned controls at Iron Mountain Mine and mines upstream of Shasta Lake are reasonably likely to result in attainment of applicable water quality standards and the TMDL below Keswick Dam. However, we recommend some revisions in the TMDL to more accurately identify source allocations and control actions. Specifically, the TMDL should be revised to address three key issues:

#1 1. Delineation of Allocations The TMDL should more clearly identify the individual load allocations that together comprise the TMDL. Individual load allocations should be expressed for three source categories - Iron Mountain Mine (IMM), sources above Shasta Dam, and sources that contribute to the Spring Creek Power House metal discharges. It would be appropriate to express these allocations as concentrations at the appropriate points of compliance.

#2 2. Iron Mountain Mine Allocation The Iron Mountain Mine load allocation should be clearly assigned to the mine itself, and not to EPA. EPA does not own and is not legally responsible for discharges from this facility; instead, EPA, in conjunction with the State, has been carrying out and otherwise overseeing remedial actions pursuant to CERCLA.

#3 3. Future Implementation Chances The TMDL implementation provisions should not establish requirements for implementation actions at IMM beyond the 1997 ROD, and the document should not assume EPA will implement additional controls at IMM beyond the scope of the 1997 ROD. We agree with the basic assumption of the TMDL, namely that actions that are planned for the next several years should be sufficient to meet water quality standards below Keswick Dam. We believe it is premature to reach conclusions about the need for, and technical feasibility of, additional

#3
controls at IMM to achieve protective water quality standards below Keswick Dam. First; the actions currently underway at IMM need to be implemented and monitored. Second, the RWQCB should develop more information about the effectiveness of the controls on the sources discharging into Lake Shasta under various conditions and the effect that additional controls on those sources will have on loads throughout the Upper Sacramento River system. This information can then be used to allocate loads among sources in this area if additional load reductions are found to be necessary to achieve water quality standards below Keswick Dam.

I. Background

The Upper Sacramento River is a managed water system that, among other things, serves critical water supply and environmental needs for the State of California. This highly complex system is controlled largely through the Central Valley Project (CVP), which consists of a series of reservoirs and other facilities that are operated by the United States Bureau of Reclamation (USBR) to meet a wide range of important public needs, including flood control, environmental protection, power production and water supply project requirements.

A large number of abandoned and inactive mines in the Shasta Mining District discharge significant loads of heavy metals into Lake Shasta and the Sacramento River. There are also background concentrations of heavy metals that occur naturally in these waters. Historically, the presence of the heavy metals from active and inactive mines have posed unacceptable risks to the ecological resources in this area, including several threatened and endangered species. The presence of these metals also complicates and restricts the operation of the CVP facilities, at times limiting the ability of the CVP to meet its other purposes.

Over the past several decades, the state and federal governments (including EPA, USBR, the California Department of Toxic Substances Control and the Regional Water Quality Control Board, among others) have taken significant steps to address and lessen the impact of the releases from the mines in the Shasta Mining District. The governments have conducted extensive studies of the nature of the discharges to the Sacramento River. These studies indicate that the discharges are highly variable from season to season and year to year. In addition, the water levels in the reservoirs, which are a function in part of the rain pattern of prior years, impacts the ability of the system to operate in a manner that assures that the metal concentrations remain below levels that pose a risk to aquatic receptors. Extensive efforts by the United States and the State have resulted in the development and refinement of a water quality model (the IMM Water Quality Model) that can be used to predict how these complex patterns will respond to various conditions. The IMM Water Quality model is currently the best tool available for evaluating the potential effectiveness of remedial actions to maintain water concentrations below Keswick Dam at protective

levels. The TMDL Report relies on the IMM Water Quality Model and we support that approach.

In general, the sources of heavy metal loads in the area can be grouped as follows:

- A. Iron Mountain Mine (IMM)
- B. Sources that contribute to the metal loads in Lake Shasta that ultimately flow into Keswick Reservoir, and
- C. Sources that contribute to the Spring Creek Power House (SCPH) releases.

Historically, IMM was the largest point source discharger of heavy metals in the area and indeed the country. IMM is currently owned by Iron Mountain Mines, Inc. Pursuant to the Superfund program, EPA has implemented several response actions at IMM that have reduced metal concentrations from IMM by more than 80%. Steps currently underway at IMM by EPA are expected to decrease historical releases by 95%. With the significant decrease in load from IMM, other sources in the area now make up a more significant share of the total metals load. The RWQCB is currently overseeing response actions that are intended to reduce the metal loads from other mines in the Shasta Mining District.

Studies performed by EPA and the State indicate that it is unlikely that the metal discharges from the mines in the Shasta Mining District could be completely controlled. Therefore, any successful strategy for achieving compliance with protective water quality standards in the Sacramento River must consider most the effective means of reducing metal discharges from those sources (both IMM and other sources) and managing the metal discharges that do occur. Given the degree to which all discharges combine to contribute to the metal load in the river, we strongly recommend against overly segmenting the TMDL analysis; rather, the TMDL should ensure that assumptions about various sources (such as the metal loads from lake Shasta) are formally incorporated into the TMDL for the area below Lake Shasta.

II. Allocation Holder

Several mines in the Shasta Mining District are currently under clean-up and abatement orders (CAOs) or other orders from the EPA or the RWQCB. EPA is currently the lead agency at IMM' and the RWQCB is currently taking the lead with respect to other sources under the Porter-Cologne Water Quality Control Act and related statutes. We believe that in general it is not appropriate to consider the regulatory agency overseeing the clean-up to be the "allocation holder". Rather, the person who is liable for the clean-up (such as the owner or operator of the mine) or the source should be considered the allocation holder in the TMDL. Therefore, the TMDL should be revised to identify specific allocations for the specific sources of concern (e.g., Iron Mountain Mine and mine sites located in watersheds tributary to Shasta Lake). These allocations should be made for discharge

#4

#5

locations and not to the agencies that are working to remediate these discharges.

To clarify the current situation at IMM, EPA and the State recently entered into a settlement with Aventis CropSciences, the former owner and operator of IMM. Pursuant to that settlement, Aventis CropSciences arranged for, among other things, The IT Corporation to operate and maintain the current IMM remedy (RODs 1-4) over the next thirty years and for a payment at year 2030 to fund the clean-up after year 2030. Currently, EPA is the lead oversight agency and the State is the support agency with respect to these clean-up efforts.

The owner of the mine is Iron Mountain Mines, Inc. (IMMI) and its President, Mr. T. W. Arman. The United States and the State are still in litigation with IMMI and Mr. Arman.

#6 | The current draft of the TMDL report could be misinterpreted to assign to "the USEPA ... responsibility for load reductions and maintenance of metal concentrations in the Sacramento River below Keswick Dam to levels below the numeric targets..." (Page 71). The language in the TMDL should be clarified to avoid confusion. While EPA, with support from the State, is currently implementing actions to further reduce the metal loads from IMM, legal responsibility for reducing the heavy metal releases from IMM rests with the liable parties, not the regulatory agencies implementing or overseeing response actions. For similar reasons, we believe that neither the RWQCB nor the USBR should be designated as an allocation holder in the TMDL.

III. **Allocation Strategy,**

The RWQCB does not allocate specific loads to specific sources in the draft TMDL report; rather, the report evaluates actions that are anticipated to be implemented over the next several years and concludes that those measures should be sufficient to achieve water quality standards below Keswick Dam. In large part, the analysis relies upon the IMM Water Quality Model, including the assumption that metal loads from Lake Shasta will be at or below 1.5 ppb copper.

#7 | We support the RWQCB reliance on the IMM Water Quality Model to express the TMDL allocation for IMM as an integrated set of control practices for each of the sources of heavy metals in the context of the expected operation of the CVP. Among other things, the CVP operations in the Upper Sacramento River system are too complex and too dynamic to allow the RWQCB to be able to set simple load allocations or even seasonal load allocations. The allocation for IMM should be clearly explained in the TMDL document to comprise the expected metals loading levels associated with implementation of the ROD 4 (1997) for IMM, along with references to the supporting modeling analysis that shows why this range of loading levels is expected to result in attainment of the TMDL below Keswick Dam.

In addition, while there is extensive data on certain aspects of the water system, such as the load characteristic's in and around IMM and directly below Shasta Dam and Keswick Dam, there is significantly less data on the loads from individual sources discharging into Lake Shasta under various conditions. Once additional data is developed, it may be useful to present that data in a manner that allows for a meaningful comparison of the relative load from the various sources. For example and as pointed out in the TMDL report, under some conditions sources discharging to Lake Shasta are the dominant source of metals below Keswick Dam. Given the reliance on the IMM Water Quality Model (and the assumptions of that model), we recommend that this group of sources receive a specific load allocation in the TMDL for each metal equal to the metals concentration discharge levels from Lake Shasta as described in the EPA/State modeling analysis and draft TMDL.

#8

We also support a focus on meeting water quality standards rather than a simple load allocation because the relationship between total load and dissolved metals is highly complex and variable in this reach of the river. The acute water quality standard for the Upper Sacramento River is stated in terms of dissolved metals as a function of hardness. Significant sitespecific studies support these site-specific water quality standards. For this reason, we believe it is appropriate to focus on meeting water quality standards at various locations, which in turn allows some flexibility in CVP operations as loads shift from source to source over time and under varying flow and hydrologic conditions.

IV. **Need for Future Action**

We agree with the RWQCB's portrayal of current EPA and State efforts (those described as Phase 1 in the draft report) to control heavy metal pollution in the Upper Sacramento River, and concur with RWQCB's expectation that these efforts may be sufficient to fully meet protective water quality standards in the Upper Sacramento River.

We believe that the TMDL report should state that the existing remedial efforts are a first phase of actions that may achieve the TMDL. The TMDL report should characterize the associated uncertainty that those steps will be adequate, the efforts that will be undertaken to monitor the effectiveness of these remedial actions, and that if necessary the TMDL will be revised. We believe that it would be appropriate to coordinate RWQCB's periodic TMDL Reviews with EPA's 5-Year Reviews for the IMM site.

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#9b

The TMDL report goes on to characterize steps that may be taken in Phase 2. Phase 2 activities are those actions that, according to the TMDL report, will be taken if, the Phase 1 activities are not adequate to meet the TMDL. In some places, the document properly describes the future EPA activities at IMM by stating that EPA is currently investigating the sediments in

Keswick Reservoir and the remaining 5% of acid mine drainage at IMM and that those sources may be addressed in the future. However, in other places the document seems to suggest that EPA will in fact remediate the sediments in Keswick Reservoir and the remaining 5% discharges at IMM.

#10 EPA is committed to performing an effective and protective cleanup at IMM, consistent with CERCLA requirements. However, it is too early in the CERCLA process to determine whether it is necessary or technically practicable to remediate the remaining 5 percent of the historic IMM heavy metal discharges. Consistent with the requirements of CERCLA, EPA will continue to study the feasibility of taking additional actions at the site that could further reduce the IMM heavy metal discharges and to remediate other problem areas at the site. The report should therefore not state that specific additional actions will unequivocally be taken by EPA; rather the document should state the EPA is investigating whether to take actions to address these sources and that actions may be taken in the future depending on the outcome of those studies and other factors.

#11 Similarly, we do not believe it is necessary or appropriate to speculate at this time about what actions will be taken by others in the future if the Phase 1 activities are not sufficient.

V. Need to consider Other Sources

#12 We agree that the heavy metal discharges from the Iron Mountain Mine (IMM) Superfund site are a significant metal load and should be one focus of the TMDL for the Upper Sacramento River. However, we believe that it is important to consider the other significant discharges into the Upper Sacramento River, including the discharges from the sources above Shasta Dam and the sources that contribute to the Spring Creek Power House (SCPH) releases.

#13 The IMM Water Quality Model, which models metal sources and takes into consideration the manner in which the USBR is expected to operate CVP facilities in the future, assumes that sources of heavy metal pollution above Shasta Dam would not result in discharges that exceed 1.5 ppb copper. This is in essence, a load allocation, not a margin of safety, that should be incorporated into the TMDL. The TMDL document appears to treat these upstream metals sites either as background sources or as other nonpoint sources. Federal regulations require inclusion of load allocations for nonpoint sources and background loading sources in TMDLs (see 40 CFR 130.2 and 130.7). As discussed above, because these sources appear to be significant metals loading sources in some circumstances, we strongly recommend inclusion of, a specific load allocation for this group of sources in the TMDL. By addressing this group of sources as a load allocation, the TMDL decision will help facilitate identification of effective controls to address ongoing discharges from these upstream sites. The load allocation for the group of sources

#14

#15 | above Shasta Dam could be expressed as the assumed concentration
level for each metal , measured below Shasta Dam in Keswick
Reservoir. The TMDL should include a monitoring program to
#16 | evaluate the performance of controls at these sources. If
monitoring indicates that the 1.5 ppb copper or other assumptions
are not appropriate, then additional remedial actions or controls
may be warranted at the metal sources above Shasta Dam.

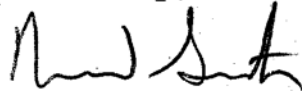
VI. **Other Issues**

#17 | The TMDL report in some instances suggests that abandoned mines
are not point sources. While the facts of a given case may indicate
that portions of an inactive or abandoned mine may be an area source,
in general our experience is that inactive or abandoned mines are a
collection of point sources.

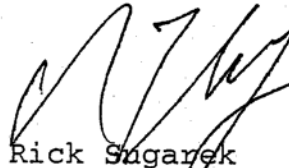
* * * *

Thank you for your consideration of these comments. Please do
not hesitate to contact Debra Denton at (916) 341-5520 or Rick Sugarek
at (415) 972-3151 if you have any questions or comments on these
issues.

Sincerely,



David Smith
TMDL Team Leader



Rick Sugarek
Remedial Project Manager



United States Department of the Interior

BUREAU OF RECLAMATION

Mid-Pacific Regional Office

2800 Cottage Way

Sacramento, California 95825-1898

IN REPLY

REFER TO:

MP-150

ENV-5.00

NOV 20 2001

Ms. Patricia Vellines
Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, CA 95827

Subject:

Comments on the Upper Sacramento River, Total Maximum Daily Load (TMDL) for Cadmium, Copper and Zinc

Dear Ms. Vellines:

Thank you for the opportunity to comment on the Regional Water Quality Control Board, Central Valley Region, (Regional Board) draft staff report *Upper Sacramento River TMDL for Cadmium, Copper and Zinc* (Draft Report). The Bureau of Reclamation (Reclamation) makes these comments based on this document and on many years participation in the Iron Mountain Mines (IMM) remediation process.

General Comments

i The Draft Report places the burden for meeting the Upper Sacramento River TMDL for cadmium, copper and zinc squarely on the shoulders of Reclamation and the Environmental Protection Agency (EPA)., Reclamation believes this is an arbitrary and inequitable allocation of responsibility for meeting the TMDL. Moreover; this allocation of responsibility is inconsistent with the agreement reached as part of the IMM Superfund Site remedial process and settlement. Finally, Reclamation believes that the Margin of Safety included in the Draft Report is inaccurate and inconsistent with the TMDL process.

ii The Draft Report states that the Regional Board's strategy for implementing the TMDL will be to require "improved" dam operations by Reclamation and to require EPA and responsible parties to undertake proposed remediation activities. Additionally, the Regional Board will impose monitoring responsibilities on the National Pollutant Discharge Elimination System (NPDES) dischargers. Essentially, it appears that the entire strategy is to acknowledge remediation activities ongoing and/or proposed by EPA and responsible parties, and then to place the burden to meet the TMDL entirely on Reclamation through dam operations.

iii This is clearly an inequitable and arbitrary allocation of the burden to meet the TMDL. Reclamation is not a responsible party., nor is it a discharger. Reclamation has always

iii | assisted with control of the acid mine drainage from IMM and other sources. However, Reclamation has no legal responsibility for the acid mine drainage.

In the preamble to EPA's Final Rule revising the regulatory requirements for TMDLs under the Clean Water Act, EPA has articulated that allowable load should be divided among sources in a reasonably fair manner. "EPA believes the allocation methodology should create a technically feasible and reasonably fair division of the allowable load among sources." *Revisions to the Water Quality Planning and Management Regulation and Revisions to the National Pollutant Program in Support Of Revision tot the Water Quality Planning and Management Regulation*, 65 Fed. Reg. 43586, 43620, July 13, 2000. While this rule has not yet been implemented, the preamble provides guidance for implementing the program. This guidance indicates that EPA believes States should consider fairness in allocating loads among sources. To allow responsible parties and point sources to continue to contribute an unregulated amount of load to the system while holding Reclamation responsible for meeting the TMDL does not comport with considerations of fairness.

iv | Moreover, Reclamation, along with the other parties to the 1980 Memorandum of Understanding (1980 MOU), agreed to not address the issue of altering Reclamation's operations until two years after the remediation activities at Slickrock Creek are completed. The purposed this agreement is to allow. time to evaluate how the remedial activities improve pollutant levels before trying to adjust Reclamation's operations. Reclamation held a firm position during the IMM settlement negotiations that Reclamation was not at any time, now or in the future, to be held legally responsible for meeting Basin Plan or other standards for copper, cadmium or zinc in the Sacramento River below Keswick Dam. This position was stated in draft letters provided to both State and EPA settlement attorneys.

In response, Reclamation received from Keith Takata, Director of EPA's Superfund Division, a letter dated May 3, 2000, which states:

v | "I also wanted to take this opportunity to reaffirm some points of common understanding with respect to this site. As we have discussed on numerous occasions, EPA has never identified the USBR as a liable party under CERCLA in connection with the Iron Mountain site. Without intending to suggest that such liability exists in the first instance, we believe the USBR's operation of the Spring Creek Debris Dam and related facilities in a reasonable and prudent manner appears to satisfy all obligations, if any existed in the first instance, of USBR under CERCLA. I also want to reaffirm our position that, based on available information, it is not our intent to look to the USBR to perform additional response actions under CERCLA, in the event that the CERCLA response action fails to achieve water quality standards at all times. For example, EPA understands that, despite prudent operation and maintenance of the Spring Creek Debris Dam and related facilities, exceedances of the State Basin Plan Standards (SBPS) below Keswick Dam may occur on an infrequent basis, for example due to unusual hydrologic conditions or remedy failure, and that USBR will not be considered to be responsible for those exceedances."

#vi

During a February 4, 1998, meeting among Reclamation, Regional Board, California Department of Fish and Game (DFG), and EPA agency representatives and counsel, held to discuss revising the 1980 MOU, it was agreed that rushing in to such a discussion of Reclamation's operations would not allow for the evaluation of EPA's ongoing and future remedial activities and the impact on water quality. Meeting attendees recognized that Reclamation is not responsible for exceedances of Basin Plan Standards, and that revising the 1980 MOU should wait until the IMM remedy is complete and can be evaluated. Similarly, it is premature to rush to establish TMDLs in the upper Sacramento River at this time.

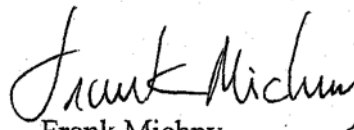
#vii

The TMDL process allows the State to determine maximum loads for impaired waters and then allocate that load among the sources. The Draft Report instead seems to set the maximum load and then use Reclamation's operations as the tool to reach the load target (along with remediation activities). If that isn't successful, then the Regional Board will use Part 2 of the process to figure out which dischargers and responsible parties are actually responsible for exceeding the TMDL. Until that time, the loads attributable to dischargers and responsible parties are to be considered as part of the margin of safety for implementation of the TMDL. The only clear reason for including these loads in the margin of safety is because the Regional Board lacks the data to attribute loads to these sources. The Regional Board should make some attempt to collect data from all sources of cadmium, copper and zinc before establishing a TMDL rather than attributing the maximum load to Reclamation operations.

Please see the attached for specific comments pertaining to your Draft Report.

Thank you again for the opportunity to comment on the Draft Report. If you would like to discuss these comments, please contact Michelle Prowse at (916) 978-5036.

Sincerely,



Frank Michny

Regional Environmental Officer

Enclosure

cc: Mr. Rick Sugarek
U.S. Environmental Protection Agency, Region 9
75 Hawthorne Street
San Francisco, CA 94105

Specific Comments

1. Page ii under 1 "...improved U.S. Bureau of Reclamation manipulation of dam flows..."

The word 'continued' should replace 'improved' and 'coordination' should replace 'manipulation.'

Reclamation strenuously objects to a TMDL program based on improved operations of Reclamation facilities. Reclamation has operated under the 1980 MOU, but also notes that in recent years Reclamation has operated to meet the more stringent Basin Plan standards. It is not clearly defined what the expectations are for the "improved dam operations" for the next five years. If this constitutes a continuation of current practices and level of effort, that would generally be acceptable to Reclamation. However, if this TMDL strategy contemplates modifying the way Reclamation operates, Reclamation would have to participate in the operational review. Any change in operation will have an impact on Reclamation's ability to meet authorized project purposes and would require further evaluation. Reclamation operates in accordance with an Operations Criteria and Plan and to a Biological Opinion based on that Plan, as well as to flood control requirements, water rights permits, and other project purposes. Revised operations could have impacts on endangered species, on flood control operations, and on water deliveries.

The effects of the "improved operations". are documented in the Draft Report. One of the goals as stated in the Draft Report is to incorporate the "improved operations" into an updated MOU. Reclamation's concern is that the incorporation of the "improved operations" in an MOU would limit the operational flexibility that has allowed "improved operations." If an updated MOU contains additional operational definitions, constraints and requirements, the operational flexibility that is the basis for improvements made to date may be lost, defeating the purpose of incorporating it into an MOU.

EPA's IMM water quality model, which analyzes the expected effectiveness of the IMM remedy on meeting water quality objectives and thus protecting the Sacramento River ecosystem, relies on Reclamation projections of future Central Valley Project (CVP) operations (through the PROSIM model) to meet environmental/societal needs and an analysis of the historic CVP operational performance. EPA's remedy and modeling analysis did not rely on "improvement" of Reclamation CVP operations. Reclamation will continue to coordinate actions with EPA's IMM remedy. Reclamation has agreed to renegotiate the 1980 MOU, that describes Reclamation's voluntary operational commitments with respect to the continuing IMM discharges, once the Slickrock Creek remedy has been implemented and its effectiveness evaluated. Reclamation will continue to make voluntary improvements to CVP operations when feasible within the overall constraints and commitments of CVP operations in the Upper Sacramento River, and within the capabilities of Reclamation's resources.

2. Page ii, Part 1 b "...improve dam operations..."

See comment #1.

2. Page iii Part 1 f "...in combination with USBR dam operations..."

See comment #1.

4. Page 1 "The Regional Board first listed the upper Sacramento River as impaired by cadmium, copper, and zinc in -the 1987-89 listing cycle, although impairments in this section of river were documented in numerous reports dating back to the 1950s."

The report appears to imply that Cd, Cu, and Zn are the limiting factors for the river not being fully utilized as a warm and cold-water habitat. If this is the intent, these statements neglect other impacts on the Sacramento River fishery, including development in the area, river temperature problems, fish passage, agricultural drainage; Delta export impacts, and ocean harvest.

5. Page 2, paragraph under bullets "...improved dam operations..."

See comment #1.

6. Page 4 Part 2.2 "...elevated levels of cadmium, copper, and zinc have contributed to a steady decline in the fisheries population in the Sacramento River."

Reclamation agrees that elevated concentrations of copper, cadmium and zinc have dramatically contributed to a decline in the Sacramento River fishery populations. But, several other factors, such as loss of spawning gravels, elevated river temperatures, diversions, and commercial and sport fishing practices, among others, also contributed to the decline and perhaps should be mentioned here. With implementation of EPA's IMM remedial actions, and Reclamation's implementation of several major programs such as installing the temperature control device on Shasta Dam and several measures undertaken pursuant to the ESA Biological Opinion, the declining fish populations have significantly improved.

7. Page 5 Part 2.3.1 2nd to last paragraph "...and from changes in regional dam operations that improved dilution of AMD."

It is unclear what this document considers to be "changes in dam operations" during this period. Specific improvement should be noted in the Draft Report. Reclamation actions over the past ten years primarily reflect ongoing implementation of the 1980 MOU. Releases of water from Shasta Dam to dilute acid mine drainage (AMD) were made when possible, consistent with the 1980 MOU, due to the ongoing drought from 1987 through 1993. Additional requirements were imposed on CVP operations by the ESA Biological Opinion to minimize slugging of sediments from the Spring Creek Arm of Keswick Reservoir (SCAKR.). Many other requirements of the Biological Opinion benefited the fishery, most notably management of the CVP to control river temperatures.

8. Page 6 Part 2.3.3 "This lack of exceedances results primarily from the dilution effect of tributary inputs between Keswick Dam and Red Bluff... °"

Historic/recent data in EPA's data base indicate that when AMD spills occur from the Spring Creek Debris Dam (SCDD), exceedances of the protective water quality standards can occur near Keswick Dam and downstream, even as far as the Bend Bridge. In general, data collection efforts have not focused on the downstream areas and only limited data are therefore available. At some point downstream, diluting inflows become sufficient to result in compliance with the protective water quality criteria.

In general, available data indicate that when the SCDD is controlling the release of IMM AMD into the Sacramento River, California Toxics Rule (CTR) requirements are complied with at Keswick Dam and downstream.

9. Page 9 (last paragraph) "The dams and diversions manipulate surface water flows to provide irrigation water, hydroelectric power, flood control, recreation, and potable water, as well as maintenance of navigation flows and conservation of fish in the Sacramento River Sacramento-San Joaquin Delta from intrusion of saline ocean water (NOAA, 1989; USBR, 2001). The U.S. Bureau of Reclamation (USBR) and other agencies determine the amount of water allocated to irrigation, urban, environmental needs, and other uses in part by reservoir storage."

When discussing Reclamation's use of the Sacramento River flow, the report should note the instream fishery flow requirements.

10. Page 12 Part 3.1.3 "Therefore, if the upper Sacramento River stocks were stronger, the commercial fishery would have a larger allowable catch."

There are many factors that could cause a decline, one of which being a natural ebb in the flow of life. There are many factors between Red Bluff and the ocean also that could cause the decline. One example: aquatic pests and control (one being copper-based herbicides) - taken from <http://www.dbw.ca.gov/>

"Effects of Control Methods on the *Egeria densa* "Community" Key Findings/Recommendations:

Data on treatment efficacy, collected at three trial locations, suggest that the chemical Sonar was the least effective in reducing *Egeria densa* biomass. At two sites, Owl Harbor and Sandmound Slough, the copper-based herbicide, Komeen was the most effective control method. At one site within White Slough, mechanical harvesting produced the best results while at another site within White Slough, Reward was most effective.

Compliance with protective water quality standards is only one element of a fishery restoration plan meant to re-establish the strength and numbers of the Sacramento River fishery. Many other elements of the plan are also currently being implemented, including river flow regulation, temperature control, fish passage improvements and the current restrictions on ocean fishing that are mentioned. CTR compliance alone would not allow the governments to remove current restrictions on ocean fishing.

11. Page 16 Part 3.3 "...and to provide for other environmental needs..."

The Endangered Species Act (ESA) is an example of this.

12. Page 17 (1 st paragraph) "...the powerhouse outlet is at the mid-level of the dam..."

This does not include the operation of the temperature control device. It should be noted that although the penstock inlet is at the mid-level of the dam, actual withdrawals from the reservoir could be from various elevations from the temperature control device. The elevation is determined by temperature operations for the Chinook salmon in the Sacramento River; typically higher elevations in the spring, moving lower through the summer into the fall.

13. Page 18 Part 3.3.1 "Major fish kills in the upper Sacramento River were documented soon after the dam was constructed (NOAA, 1989)."

The Sacramento River fishery was clearly impacted prior to the construction of the dams on the Sacramento River. The construction of Shasta Dam effectively served to improve the water quality of the Sacramento River above IMM from near lethal concentrations of 15 ppb copper to concentrations of less than 2 ppb. The dams also improved the general year round conditions in the Sacramento River and the fishery increased several fold.

However, the fishery was no longer able to migrate/escape past copper and zinc pollution discharging from IMM, but was confined below Keswick Dam after 1950. As a result, the earlier smaller fish kills and sublethal events became more massive when IMM pollution discharged uncontrolled into a controlled Sacramento River system and on top of a fishery confined below Keswick Dam. The construction of the SCDD mitigated the massive fish kills, but the SCDD spilled on an average of every two to three years causing numerous events where emerging fry were killed.

14. Page 18 Part 3.3.1 "The USBR constructed the dam to act as a buffer for extreme fluctuations in discharges from Shasta Dam, while also producing electricity (NOAA, 1989)."

In addition, Keswick Dam controls the runoff from an additional 45 square miles of drainage area below Shasta Dam and acts as a buffer for fluctuations in discharges from Spring Creek Power Plant (SCPP). Also note that flood protection is only one of several project purposes of the CVP.

15. Page 19 1980 MOU section "...United States Water and Power Resources Service [a division of USBR]_"

[a Division of USBR] should be replaced with [former agency name of USBR] - this was Reclamation's name for a few years in the 1980's.

16. Page 20 Table 3-2 (c) "...but has not updated the MOU itself."

Reclamation has agreed to work with the State agencies and the EPA to appropriately revise the 1980 MOU after EPA's Slickrock Creek remedial actions are completed and in place brig

enough to allow for data collection and an evaluation of the effectiveness of the remedy and measurement of the improvement to the waters discharging from this watershed. In the interim, Reclamation is informally working with the State and the EPA to operate CVP facilities to meet the protective Basin Plan standards in a manner consistent with Reclamation's operational responsibilities, constraints and commitments.

17. Page 20 1st sentence, last paragraph "The USBR also manages SCPP operations to minimize mobilization of contaminated sediments and metal precipitates (Rae, 1998)."

When Reclamation makes a release from SCDD, a minimum flow of 250 cfs is maintained from SCPP to minimize mobilization of contaminated sediments and metal precipitates in the SCAKR. A release of only 250 cfs from SCPP does provide power generation, but is very inefficient and equates to a loss of peak power production. Under normal operating conditions, Reclamation does not run SCPP at "Speed No Load" while SCDD releases are made. If releases are made from SCDD but SCPP has not operated recently and power generation is scheduled, the units at the SCPP generally will be run at Speed No Load for several hours before they begin generating.

Reclamation also curtails authorized operations of the Keswick Reservoir elevations, at a loss of peak power production; to prevent mobilizing the SCAKR sediments.

18. Page 21 top paragraph "The SCDD releases some contaminated water into the SCAKR on a continuous basis."

In general, the SCDD releases contaminated water into the SCAKR on a continuous basis. It is primarily "conjunctively operated" with the SCPP, i.e. releasing only when the SCPP is on, but SCPP may not be generating at all times while the SCDD is releasing water. When there is water in Spring Creek reservoir, the gates of the SCDD can be closed, but there is minor leakage. When the reservoir is empty or near empty, there is essentially no release.

19. Page 21 top paragraph "Because flows in the Sacramento River poorly flush the SCAKR, contaminants tend to accumulate to high concentrations in the SCAKR. Intermittent discharges from the SCPP can then rapidly flush these accumulations of contaminated water and precipitates into the main stem of the river (NOAA, 1989). If SCDD is releasing flows when the USBR has not scheduled the SCPP for operation, the USBR may operate the SCPP at "Speed No Load" during the releases or for several hours before generation begins. Running at Speed No Load requires that small amounts of water be run through the SCPP, which provides some flushing of the SCAKR so that a buildup of precipitates does not occur. This helps to minimize any "slugging" of sediments into the Sacramento River when the SCPP does come online."

When Reclamation makes a release from SCDD, a minimum flow of 250 cfs is maintained from SCPP to minimize mobilization of contaminated sediments and metal precipitates in SCAKR. A release of only 250 cfs from SCPP does provide power generation, but is very inefficient and equates to a loss of peak power production. Under normal operating conditions, Reclamation does not run SCPP at "Speed No Load" while SCDD releases are made. If releases are made

from SCDD but SCPP has not operated recently and power generation is scheduled, the units at the SCPP generally will be run at Speed No Load for several hours before they begin generating. The 250 cfs gentle "flushing" flow reduces the risk for the AMD to collect in the SCAKR and potentially flow out as an unregulated pulse.

20. Page 26 Part 4.3.1 "Deaths of fish were common in water below Keswick Dam during the mid-20th century (NOAA, 1989; Cooke and Corner, 1998)."

There were also fish kills prior to the mid-20th century. DFG performed river toxicity testing in the late 1930's: Prior to the construction of Shasta Dam, the Sacramento River was a muddy, polluted river that had near lethal concentrations of copper above IMM and lethal concentrations of copper below IMM. There are no data, however; the dead fish were washed down the river.

21. Page 26 Part 4.3.2 "The spawning population of Chinook salmon and steelhead trout in the upper Sacramento River has declined steadily since the 1960s, apparently because of metal contamination from the Iron Mountain Mines sites. 11"

The footnote 11 should be incorporated into this paragraph to show the larger picture. Again, there are many factors between Red Bluff and the ocean that have likely contributed to declines. As noted earlier, the use of copper-based herbicides in the delta is an example. There are a number of factors that lead to the decline of the Sacramento River fishery. IMM is an important factor, but it is one of several factors.

22. Page 27 Part 4.3.2 "In addition, springtime releases of AMD coincide with spawning."

Most AMD releases would occur in the early winter and fall and any spring releases would be more likely to be diluted with the higher springtime release from Keswick.

23. Page 32 top of page Part 5.3 "...and from changes in regional dam operations that improved dilution of AMD." .

This could read "...and from Reclamation's dilution of AMD with Shasta Dam flows, when feasible." Sometimes Shasta water is too high in metals to use as dilution, or cannot be released due to downstream flooding or other operational constraints.

See comment #1.

24. Page 58 Part 6.4 "...combined with improved USBR dam operations..."

See comment #1.

25. Page 58 Part 6.4 "...and an updated agreement between USBR and State Board..."

Reclamation has agreed to work with the State agencies and the EPA to appropriately revise the 1980 MOU after EPA's Slickrock Creels remedial actions are completed and in place long

enough to allow for data collection and an evaluation of the effectiveness of the remedy and measurement of the improvement to the waters discharging from this watershed. In the interim, Reclamation is informally working with the State and EPA to operate CVP facilities to meet the protective Basin Plan standards in a manner consistent with Reclamation's operational responsibilities, constraints and commitments.

26. Page 68 part 8.2 "If the upper Sacramento River behaved as a natural watershed system, Regional Board staff would assign individual load or wasteload allocations to each of the dissolved metal sources. However, the USBR's manipulation of releases from Shasta Dam, SCDD, and SCPP typically control dissolved metal concentrations measured below Keswick Dam. To prevent future exceedances of numeric targets below Keswick Dam, any load reduction allocation has to address the complicated relationship between the timing of discharges from the different metal sources (e.g., discharges resulting from intense storm runoff) and the USBR's control of Shasta Dam, SCDD, and SCPP releases."

Suggest replacing "manipulation of releases from" to "operation of." Reclamation agrees that the TMDL must consider the complex operations of CVP facilities in setting load allocations to sources of the pollution, in the same manner that EPA considered them in assessing the effectiveness of the proposed IMM remedies. However, Reclamation is not responsible for the sources of the pollution addressed in this TMDL.

27. Page 71 1 st paragraph "...in combination with improved dam manipulations..."

See comment #1.

28. Page 71 2nd paragraph "...with improved USBR dam operations..."

See comment #1.

29. Page 71 3rd paragraph "As a result, Regional Board staff assigns the USEPA and USBR joint responsibility for load reductions and maintenance of metal concentrations in the Sacramento River below Keswick Dam to levels below the numeric targets."

Reclamation strenuously objects to this inappropriate assignment of responsibility. Reclamation is not responsible for the metal load reductions. Reclamation has voluntarily operated CVP facilities to minimize the impacts of AMD on the Sacramento River, and has agreed to work with the State and EPA to revise the 1980 MOU when it is appropriate to do so. However, Reclamation took an adamant position during IMM settlement negotiations that Reclamation was hopeful of lessening the burden of IMM-related operations at SCDD and Keswick Dam, and did not anticipate making onerous efforts to improve operations. The parties involved in that settlement, including the EPA and the Regional Board, understand that settlement of the IMM litigation meant accepting the risk of future exceedances of the Basin Plan standards.

30. Page 72 Part 8.3 "At this time, Regional Board staff does not assign allocations for point (e.g., treatment plants and other permitted dischargers) and nonpoint sources (e.g., Afterthought

Mine) downstream of Keswick Dam for this TMDL for three reasons:

1. As described in Chapter 5 (Source Assessment), discharges from Keswick Dam account for the majority of dissolved cadmium, copper, and zinc loads measured in the upper Sacramento River above Bend Bridge. Reductions in metals loads in Keswick Dam releases resulting from remediations at the IMM site, in combination with improved USBR dam release manipulations and remediation activities at mines in the Shasta Lake area, are expected to reduce dissolved metal loads and concentrations measured in the Sacramento River between Keswick Dam and Bend Bridge."

It is Reclamation's position that downstream dischargers should be issued allocations as well as sources in the Shasta Lake watershed. Reclamation is not a source of the pollution.

Reclamation believes that the sources of the pollution above Shasta Dam must be considered in setting the TMDL for the river below Keswick Dam. The Draft Report itself indicates that at times these sources provide a dominant load to the river. EPA's remedy assumed that the Shasta Dam releases would provide a base load of 2 ppb copper or less. If the TMDL assignment allows releases from these mines that result in 4 ppb copper, for example, the IMM remedy would be seriously impaired.

31. Page 72 Part 8.3 "...improved USBR dam release manipulations..."

See comment #1.

32. Page- 72 Part 8.3 (bottom paragraph) "As described in Chapter 10, Regional Board staff will require dischargers to monitor for dissolved metals."

Does this mean that dischargers are required to sample for metals, but at the same time have no load allocations to meet?

33. Page 74 Part 9.2 "...willful malicious acts."

Unclear as to what is meant by this. Does this refer to acts of terrorism or illegal dumping? Examples would be helpful.

34. Page 75 (last paragraph) "However, the 1980 MOU is out of date."

Reclamation has agreed to work with the State agencies and the EPA to appropriately revise the 1980 MOU after EPA's Slickrock Creek remedial actions are completed and in place long enough to allow for data collection and an evaluation of the effectiveness of the remedy and measurement of the improvement to the waters discharging from this watershed. In the interim, Reclamation is informally working with the State and EPA to operate CVP facilities to meet the protective Basin Plan standards in a manner consistent with Reclamation's operational responsibilities, constraints and commitments.

35. Page 76 #1 "...improved U.S. Bureau of Reclamation (USBR) manipulation of dam flows..."

See comment #1.

36. Page 76 #1 "The USEPA Superfund Program's water quality modeling indicated that the proposed remediation activities at the IMM site -in coordination with current site remediation activities and improved U.S. Bureau of Reclamation (USBR) manipulation of dam flows - would control more than 95% of total IMM site releases and substantially decrease the frequency of numeric target exceedances below Keswick Dam."

See comment #1.

37. EPA's modeling analysis relied on Reclamation's projected flows (through the PROSIM model) and not on special releases of dilution water. PROSIM is a monthly planning model and may not be an appropriate tool to determine operational flexibility. SCDD can fill and spill in a few days and a monthly time-step model cannot capture the capability of the CVP to operate to such events. It also does not accurately model current CVP operational requirements. PROSIM is no longer the appropriate tool for use in analyzing Reclamation operations, improved or otherwise.

38. Page 76 Part 1(b) "Within the next five years, the USBR will improve dam operations to help eliminate the frequency of numeric target exceedances below Keswick Dam. In addition, Regional Board staff will work with the USBR, California Department of Fish and Game, and State Water Resources Control Board to update the USBR dam operations memorandum of understanding established in 198Q."

See comment #1.

It is unclear what improvements to dam operations are expected. Reclamation has agreed to work with the State agencies and the EPA to appropriately revise the 1980 MOU after EPA's Slickrock Creek remedial actions are completed and in place long enough to allow for data collection and an evaluation of the effectiveness of the remedy and measurement of the improvement to the waters discharging from this watershed.

Reclamation will to the extent possible continue its current operations strategy for targeting the Basin Plan standards and minimizing the mobilization of SCAKR sediments. However, Reclamation has stated, and as noted in the General Comment section of this letter, has received agreement from the other parties to the IMM settlements including the EPA and State agencies, that Reclamation is not now or at any time in the future to be held legally responsible for meeting Basin Plan or other standards for copper, cadmium or zinc in the Sacramento River. Reclamation made it abundantly clear during settlement negotiations that remedial activities at IMM should ultimately allow Reclamation to reduce its voluntary burden of meeting Basin Plan standards below Keswick.

39. Page 76 Part 1(f) "...in combination with USBR dam operations..."

See comment #1 .

Three years following EPA's completion of Slickrock Creek remedial actions is an appropriate time to review the 1980 MOU. Reclamation notes that (f) appropriately does not say "improved dam operations." It would be even more appropriate to say "in combination with Reclamation's current level of dam operations."

40. Page 76 Part 1(f) "...staff will evaluate dissolved metal loads contributed by NPDES dischargers downstream of Keswick Dam."

Please clarify the above, with reference to Page 72 Part 8.3: "At this time, Regional Board staff does not assign allocations for point (e.g., treatment plants and other permitted dischargers) and nonpoint sources (e.g., Afterthought Mine) downstream of Keswick Dam..."

Does this mean they must collect samples but are not required to meet loads? What if they exceed toxic limits?

41. Page 80 Part 10.2 "As noted in previous chapters, the 1980 MOU between the USBR, SWRCB, and CDFG is no longer adequate for the following reasons:"

As stated in Section 10.2, Reclamation has, in recent years, voluntarily targeted the more stringent Basin Plan standards, and does also voluntarily coordinate operations of the SCPP and SCDD to minimize mobilization of the SCAKR sediments. Reclamation agrees that the 1980 MOU should be revised, but as discussed during IMM settlement negotiations and as agreed to among Reclamation, the Regional Board and DFG, the appropriate time to revise the 1980 MOU is after EPA's Slickrock Creek remedial actions are completed and in place long enough to allow for data collection and an evaluation of the effectiveness of the remedy and measurement of the improvement to the waters discharging from this watershed.

In the interim, Reclamation continues to informally, and voluntarily, work with the State and the EPA to operate the CVP facilities to meet the protective Basin Plan standards in a manner consistent with Reclamation's other operational responsibilities and commitments.

Reclamation has targeted the 5.6 ppb (assuming 40 mg/1 hardness) level for copper below Keswick, and Reclamation has met this objective but for a few instances. Figure 2-1 shows the copper concentrations compiled from all data received from various sources. (Printed in color, it is much easier to see.) The upper red line is the Basin Plan objective. There are relatively few times that this was exceeded except during spring 2001. See footnote 27 from page 62.

Reclamation has stated, and as noted in the General Comment section of this letter, has received agreement from the other parties to the IMM settlement, including the EPA and State agencies, that Reclamation is not now or at any time in the future to be held legally responsible for meeting Basin Plan or other standards for copper, cadmium or zinc in the Sacramento River. Therefore,

Reclamation strenuously objects to the notion that the 1980 MOU be updated "to ensure compliance with this TMDL." Reclamation will resist any such language (such as "compliance" that suggests Reclamation's operations, as they relate to reducing mining pollution, are anything but voluntary in nature.

42. Page 80 Part 10.2 "However, in recent years, USBR staff has attempted to target the more stringent Basin Plan water quality objectives for dissolved concentrations for the upper Sacramento River in addition to the 1980 MOU objectives, and consulted with other federal and state agencies to improve dam operations to meet the requirements of various agencies."

This should be reworded: However, in recent years, USBR staff has targeted the more stringent Basin Plan...1980 MOU objectives.

43. Page 80 Part 10.2 "...and consulted with other federal and state agencies to improve dam operations to meet the requirements of various agencies."

USBR staff consult with other federal and state agencies in order to improve SCDD operations and target the Basin Plan standards when CVP operations allow.

See comment #1.

44. Page 80 Part 10.2 "In addition, the USBR has developed an operations strategy for the SCPP to minimize mobilization of contaminated sediments and metal precipitates, and will improve SCDD, Shasta dam, and SCPP operations based on past experience, the USEPA's water quality modeling results, and the effectiveness of USEPA's remediation activities at the IMM site."

Reclamation will to the extent possible continue its current operations strategy for targeting the Basin Plan standards and minimizing the mobilization of SCAKR sediments. However, Reclamation has stated, and as noted in the General Comment section of this letter, has received agreement from the other parties to the IMM settlement, including the EPA and State agencies, that Reclamation is not now or at any time in the future to be held legally responsible-for meeting Basin Plan or other standards for copper, cadmium or zinc in the Sacramento River. Reclamation made it abundantly clear during settlement negotiations that remedial activities at IMM should ultimately allow Reclamation to reduce its voluntary burden of meeting Basin Plan standards below Keswick.

45. Page 81 Part 10.5 "Regional Board staff will review the monitoring data collected by the USBR, City of Redding, USEPA, and the CVRWQCB (under NPDES/Cease and Desist Orders)..."

Reclamation does not monitor the Sacramento River under any permit or order, but rather under voluntary agreement with the 1980 MOU. Reclamation expects that the frequency of monitoring may be reduced in the future due to ongoing remedial actions at IMM. Reclamation agrees that ongoing remediation activities may allow the proposed numeric targets to be met. However, if dissolved metal concentrations still exceed criteria at the end of Part 2 of the TMDL effort, Reclamation will support Regional Board staff in their effort to work with the EPA to develop additional remediation activities, but these activities will not be Reclamation's responsibility.

46. Page B-7 "...and the PRPs are currently designing the Slickrock..."

Stouffer Management Company (SMC) designed the Slickrock Creek Retention Reservoir on behalf of Rhone-Poulenc. CH2M Hill is constructing the Slickrock Creek Retention Reservoir pursuant to that design for EPA. .

Memorandum

To: Mr. Gary M. Carlton, Executive Officer
Central Valley Regional Water
Quality Control Board
3443 Routier Road, Suite A
Sacramento, California 95827-3098

Date: October 31, 2001

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From: **Donald B. Koch, Regional Manager**
for
Northern California-North Coast Region
Department of Fish and Game
601 Locust Street, California 96001

Subject: Upper Sacramento River Total Maximum Daily Load (T MDL) for Cadmium, Copper, and Zinc

The Department of Fish and Game has reviewed the subject draft TMDL report and has the following comments.

We found the report to be generally complete and well documents the historic and present conditions in the Upper Sacramento River.

1

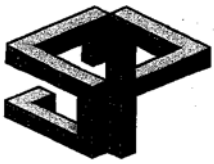
In Table 5-1, pages 29 and 30, there are two mistakes and one omission. The first mistake is regarding "Locator #22 Bella Vista Water District-Water Treatment Plant, Receiving Waterbody, Churn Creek." The chart states: "The receiving waterbody discharges to the Sacramento River between Shasta Dam and Keswick Dam." Churn Creek actually discharges downstream of Keswick Dam. The second mistake is regarding "Locator #39, USFWS/USBR Winter Run Fish Rearing Facility, Receiving Waterbody, Sacramento River." The chart indicates this facility discharges downstream from Keswick Dam. The discharge is actually between Shasta Dam and Keswick Dam. The chart omits Darrah Springs Hatchery. This Department fish rearing facility discharges to Battle Creek which enters the Sacramento River below Keswick Dam.

2

"Section Seven, Linkage analysis, page 66, Section 7.3.2, Modeling of Anticipated Conditions," discusses anticipated conditions resulting from future remediation activities at Iron Mountain Mines (IMM). In addition to pollution control, consideration will also have to be given to availability of dilution water. The CALFED Record of Decision identifies future water storage projects. Depending on the size; location, and operation of these storage projects, the performance of the IMM remediaton could change. When the TMDL is revisited in five years, it should examine the impacts of water storage projects proposed by CALFED.

Thank you for the opportunity to comment on the TMDL document. If you have any questions or comments regarding this matter, please contact Environmental Scientist Jane Vorpapel at (530) 225-2124.

cc: Ms. Jane Vorpapel
Department of Fish and Game
601 Locust Street
Redding, California 96001



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Sierra Pacific Industries

Human Resources • P.O. Box 496011 • Redding, CA 96049-6011 • (530) 378-8200

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26 October
2001

Ms. Patricia Vellines
Engineering Geologist
Sacramento TMDL Unit
California Regional Water Quality Control Board, Central Valley Region
3443 Routier Road, Suite A
Sacramento, California 95827-3003

Subject: Comments on the Upper Sacramento River Total Maximum Daily Load
(TMDL) for Cadmium, Copper, and Zinc

Dear Ms.
Vellines:

Sierra Pacific Industries (SPI) has reviewed the draft staff report, *Upper Sacramento River TMDL for Cadmium, Copper and Zinc* (Draft Report), issued by the Central Valley Regional Water Quality Control Board (Regional Board), and is responding to your request for comments dated 3 October 2001. SPI currently discharges storm water to the upper Sacramento River, downstream of the Keswick Dam, under a general storm water permit. In general, SPI agrees with the Draft Report, but has some concerns regarding the Implementation Plan.

SPI agrees that impairment of the upper Sacramento River between Keswick Dam and Cottonwood Creek is primarily the result of discharges of acid mine drainage (AMD) above the Keswick Dam. The Draft Report indicates that releases from the Keswick Dam contribute 80 percent or more of the dissolved cadmium, copper, and zinc in the upper Sacramento River. Because remediation activities are scheduled for the Iron Mountain Mine and other mine sites that are anticipated to significantly decrease AMD-contaminated discharges, SPI agrees that a two-part TMDL Implementation Plan is appropriate.

1

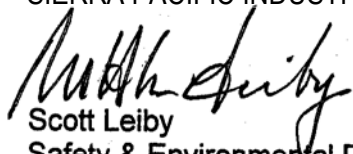
However, SPI is concerned that the Implementation Plan does not address whether additional activities may be required, if the activities scheduled during the first part of the TMDL strategy do not result in compliance with the proposed numeric targets for the upper Sacramento River. Specifically, SPI is concerned that the Regional Board may allocate inappropriate loads to industrial dischargers to achieve the proposed numeric targets, even though the industrial dischargers do not contribute significantly to the concentrations of dissolved cadmium, copper, and zinc in the upper Sacramento River.

We appreciate the opportunity to comment on the Draft Report. Please contact Scott Leiby at (530) 378-8282 if you have any questions or wish to discuss SPI's comments.

Ms. Patricia Vellines
California Regional Water Quality Control Board, Central Valley Region
26 October 2001
Page 2

Very truly yours,

SIERRA PACIFIC INDUSTRIES


Scott Leiby
Safety & Environmental Director

cc: Paul Emmen, SPI

From: "Marcia Ames" <mames@ci.redding.ca.us>
To: "Patricia Vellines" <VeIlinP@rb5s.swrcb.ca.gov>
Date: 11/16/01 2:34PM
Subject: Fw: TMDL comments ,

P
a
t

Thanks for letting us comment on the TMDL document. What a project! Thanks for using our data, too. We've put a lot of thought, time and money getting low level metals data for the Sacramento River and it's nice to see it used.

I have a few comments on Section 10.3 (pg 81), 2nd paragraph with regard to NPDES discharger sampling:

- #1
- 1) A sample location needs to be specified. Effluent would make the most sense as it would most accurately determine metal load addition to the river. Sampling downstream of the effluent imparts too many variables to accurately determine added metals loads. Such variables include adequate mixing and upstream characteristics river characteristics. It's also more reasonable to get a 24 hour composite of a effluent since automatic samplers can usually be secured in a building or behind a fence on the wastewater treatment plant property.
 - 2) A minimum monitoring frequency and the duration of monitoring (how many years) would be helpful in determining the impact to our monitoring programs.
 - 3) "Dissolved metals" should be changed to "total recoverable metals and hardness" since the equilibrium of the effluent (hardness •70 mg/I) will change when mixed with river water (hardness •45 mg/I). This would allow for application of a translator to give dissolved metals in the effluent to compute a dissolved load added to the river.
 - 4) Cadmium, copper and zinc should be sampled using EPA 1669 "clean techniques" and samples should be tested using EPA 1638 ICP/MS. Conventional techniques do not deliver low enough detection or reporting, limits to determine compliance with water quality criteria. Typical RL's for ICP for Cd, Cu and Zn are 1.0, 2.0 and 20 ug/I respectively. Water qualify criteria for these are 0.22, 5.6 and 16 respectively.

Relative to the last comment, Section 10, Part 1(d) and (f) (pg 77), should include a statement requiring the use of EPA 1669/1638 techniques when monitoring effluents, tributary and ambient metals concentrations where conventional (ICP, FAA or GFAA) techniques do not give results sufficiently above the reporting limit to accurately quantify conditions in those streams. This is particularly necessary when determining ambient conditions and, therefore, the effectiveness of upstream treatment activities. The duration and frequency of monitoring events should be addressed as well. Also, if ambient monitoring events need to be coordinated with various agencies (i.e. sampling on the same day or on successive days at downstream sites), a statement should be made to that effect.

CC: "Nolan Randall" <randaln@rb5r.swrcb.ca.gov>, "Steve Craig" <scraig@ci.redding.ca.us>; "Rich Elliott" <relliot@ci.redding.ca.us>