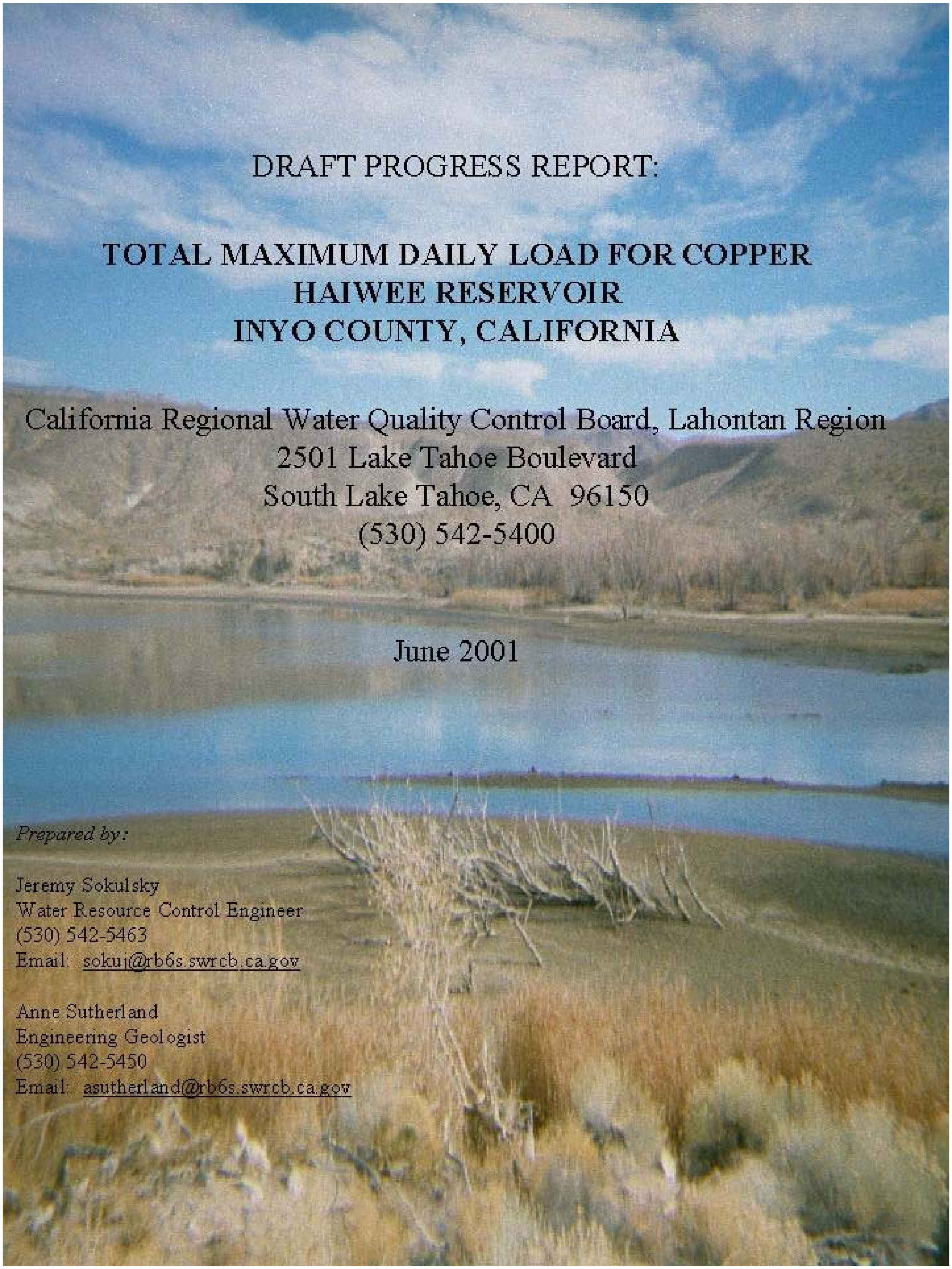

DRAFT PROGRESS REPORT:

TOTAL MAXIMUM DAILY LOAD FOR COPPER
HAIWEE RESERVOIR
INYO COUNTY, CALIFORNIA

California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Boulevard
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June 2001

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HAIWEE RESERVOIR
TOTAL MAXIMUM DAILY LOAD FOR COPPER
DRAFT PROGRESS REPORT

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Appendices

1. INTRODUCTION

The California Regional Water Quality Control Board, Lahontan Region (Regional Board) has developed this Progress Report to present the technical and scientific background for the forthcoming Total Maximum Daily Load (TMDL) for copper in Haiwee Reservoir, Inyo County. This Progress Report contains the draft TMDL technical support elements as recommended by United States Environmental Protection Agency (USEPA) Region IX staff to restore the water in Haiwee Reservoir to meet State water quality standards.

1.1 LEGAL AUTHORITY

The Water Quality Control Plan for the Lahontan Region, also known as the Basin Plan, sets standards for surface waters and ground waters in the region. These standards are comprised of designated beneficial uses for surface and ground water, numeric and narrative objectives necessary to support beneficial uses, and the State's antidegradation policy. Such standards are mandated for all waterbodies within the state under the Porter-Cologne Water Quality Act. In addition, the Basin Plan describes implementation programs to protect all waters in the region. The Basin Plan implements the Porter-Cologne Water Quality Act and serves as the State Water Quality Control Plan applicable to Haiwee Reservoir, as required pursuant to the federal Clean Water Act (CWA).

Section 305(b) of the CWA mandates biennial assessment of the nation's water resources, and these water quality assessments are used to identify and list impaired waters. The resulting list is referred to as the 303(d) list. The CWA also requires states to establish a priority ranking for impaired waters and to develop and implement TMDLs. A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and the TMDL allocates pollutant loadings to point and non-point sources such that those standards will be met.

The USEPA has oversight authority for the 303(d) program and must approve or disapprove the State's 303(d) lists and each specific TMDL. USEPA is ultimately responsible for issuing a TMDL if the state fails to do so in a timely manner.

As part of California's 1994 303(d) list submittals, the Regional Board identified Haiwee Reservoir as being impaired due to copper. The listing was based on elevated copper residuals in fish tissue levels found through the State Water Resources Control Board's Toxic Substances Monitoring Program (TSMP). It has continued to be listed because of two observed fish kills in 1991 and 1994 that were linked to copper sulfate applications to control algae in the reservoir.

1.2 REGULATORY CONTEXT

The CWA is administered by the Regional Board under its federally designated authority. This Regional Board is one of nine other regional boards in California, each generally separated by hydrologic boundaries. The State Water Resources Control Board (State Board) establishes statewide policies and serves as the review and appeal body for the decisions of the regional boards. The State Board is made up of five members appointed by the governor. Each Regional

Board consists of nine governor-appointed members who serve four year terms. Scientific information is gathered and policy is developed for the Regional Board by its civil service employees (staff).

The Regional Board has adopted a Basin Plan that specifies water quality standards for the Lahontan Region and implementation measures to enforce those standards. Some measures that go beyond the scope of the current Basin Plan, such as TMDLs, must first be adopted by the Regional Board in a Basin Plan amendment process before they are implemented. The process involves a public review and comment period on the proposed TMDL, followed by a Regional Board hearing to respond to comments and relevant revisions to the proposed amendment. The Regional Board then votes on its adoption, and if the amendment is adopted, it is sent to the State Board to undergo a parallel process. Next, it is sent to the Office of Administrative Law (OAL) to determine whether the amendment is consistent with the California Administrative Procedures Act (APA). State TMDL adoption is complete after OAL approval and state transmittal to the USEPA for final approval. The USPEA does not currently require states to include implementation plans as a part of the TMDL submittal. However, the State's position is that State law requires the Regional Boards to adopt implementation provisions concurrent with TMDLs.

The entire Basin Plan amendment process can take one to three years to proceed through all steps. The USEPA has authority to promulgate its own regulatory actions if they believe that the State process is not meeting the requirements of the Clean Water Act in a reasonable amount of time.

1.3 PROGRESS REPORT CONTEXT

This Progress Report is submitted to demonstrate progress on the Regional Board's commitment to the USEPA regarding TMDL development for fiscal year 2000/01. It was originally anticipated that a "technical" TMDL, which is a TMDL document that provides the technical and scientific basis of the analysis but does not include implementation measures, would be submitted to the USEPA by June 30, 2001. During the development of the Haiwee TMDL, it was determined that in order to establish a numeric target greater than zero for copper in Haiwee Reservoir, certain language in the Basin Plan relating to pesticide detections in the Region's waters must first be addressed through the potentially lengthy Basin Plan amendment process described in Section 1.2. Regional Board staff notified the USEPA of this impediment, and it was decided that a comprehensive "progress report" that outlined the technical and scientific basis of the TMDL would be submitted by June 30, 2001, with the understanding that Regional Board staff would continue progressing toward the completion of the formal TMDL with associated Basin Plan amendments and implementation measures by the Fall of 2002.

1.4 NUMERIC TARGET ISSUES

Section 303(d)(1)(C) states that TMDLs "shall be established at a level necessary to implement the applicable water quality standards…." Numeric targets help to interpret narrative water quality standards and establish the linkage between attainment of the standards and the TMDL. There are two applicable water quality objectives in the Basin Plan that apply to determine the

Numeric Target for copper in this Progress Report. The first can be summarized as “no toxics in toxic amounts,” which will be attained through California Toxics Rule (CTR) criteria for the protection of aquatic life, as well as through whole effluent toxicity testing to ensure that copper is not interacting with other physical or chemical factors in the reservoir to produce additive or synergistic toxicity.

The second water quality objective applicable to the Numeric Target for this TMDL progress report is a narrative standard which relates to pesticides in the Lahontan Region:

> “Pesticide concentrations, individually or collectively, shall not exceed the lowest detectable levels, using the most recent detection procedures available.”
>
> “There shall not be an increase in pesticide concentrations found in bottom sediments.”

As written, this water quality objective precludes the use of aquatic herbicides, including copper sulfate, in the Lahontan Region. Therefore, in order to meet this water quality objective, the numeric target for copper in Haiwee Reservoir must be equal to zero, or the Basin Plan must be amended to permit the use of copper sulfate under certain circumstances.

The potential need to maintain drinking water supplies was recently addressed in the CTR State Implementation Plan (SIP). Section 5.3 (Categorical Exceptions) states that RWQCBs may, after compliance with CEQA, allow short-term or seasonal exceptions from meeting the priority pollutant criteria objectives if determined to be necessary to implement control measures such as “resource or pest management . . . conducted by public entities to fulfill statutory requirements . . . or regarding drinking water. . .” The USEPA provides additional clarification to this section of the SIP in its May 1, 2001 letter to the State Board outlining its position and granting approval to several sections of the SIP. The USEPA approved the categorical exception provision as consistent with CWA requirements, subject to several enumerated understandings, one of which directly references copper sulfate use as a “covered activity” under the provision:

Covered Activities:

> 1.b. “The drinking water-related control measures refer to measures taken, such as the use of copper sulfate and zinc manganese, to control algae blooms or similar problems in drinking water supplies.”

Although this provision specifically pertains to CTR criteria exceedances, it highlights the need to carry out certain measures <u>in the absence of feasible alternatives</u> to balance important public interests and protect certain beneficial uses while minimizing the measure’s potential impacts on other beneficial uses. Regional Board staff plan to work with the Los Angeles Department of Water and Power (LADWP), USEPA, and the State Board to develop and initiate comprehensive studies at Haiwee Reservoir to determine if an amendment to the Basin Plan’s pesticide prohibition is indeed consistent with the best interests of the people of the state. If it is established that the use of aquatic herbicides to maintain drinking water quality can be balanced with the need to reasonably protect all beneficial uses assigned to Haiwee Reservoir, Regional

Board staff plan to propose a Basin Plan amendment to the pesticide prohibitions. Concurrently, staff will continue to refine the TMDL analysis presented in this report and develop implementation measures for attainment of water quality standards.

2. PROBLEM STATEMENT

2.1 BACKGROUND

Haiwee Reservoir is listed pursuant to the federal Clean Water Act, Section 303(d) for impairment due to copper. It first appeared on the 1994 303(d) list as a result of elevated copper residuals in fish tissue levels found through the State Water Resources Control Board's Toxic Substances Monitoring Program (TSMP). It has continued to be listed because of two observed fish kills in 1991 and 1994 that were linked to copper sulfate applications in the reservoir.

The Los Angeles Department of Water and Power (LADWP) owns and operates Haiwee Reservoir as part of the Los Angeles Aqueduct-Owens River system, which supplies drinking water to Los Angeles. LADWP has historically applied copper sulfate to the reservoir to control algae blooms that impart undesirable taste and odors to the water. LADWP was issued a Cleanup and Abatement Order in 1995 (CAO) by the Regional Board as a result of the fish kills. In response to the CAO, toxicity studies were conducted in North Haiwee and the copper sulfate application practices have been changed. No fish kills have been observed in the reservoir since 1994, though copper concentrations continue to be above water quality criteria levels.

Copper may be present in the environment due to a variety of manmade or natural sources. The implementation of this TMDL will focus on that portion of copper in the water column of Haiwee Reservoir that is attributed to controllable sources, such as the application of copper sulfate to the reservoir and the Los Angeles Aqueduct system. Further information or research may identify additional sources of copper to Haiwee Reservoir which can be quantified and potentially controlled. Currently identified copper sources, including those characterized as "undefined" and those attributed to copper sulfate applications, will be discussed in further detail in the Source Analysis (Section 4).

2.2 WATERSHED OVERVIEW

2.2.1 Reservoir Location

The Haiwee Reservoir complex is located in Inyo County, California, near the southern terminus of the Owens Valley. The area is bounded by the Sierra Nevada mountains to the west and the Coso Range to the east. The reservoir is just east of Highway 395, about 23 miles south of Lone Pine at an elevation of approximately 3,760 feet above mean sea level (amsl). See Figure 2-1 for the reservoir location.

2.2.2 Watershed Description

Haiwee Reservoir is located in the Lower Owens hydrologic area (hydrologic area No. 603.30). Numerous small streams flow into this watershed from the eastern flank of the Sierra Nevada mountains; however, these streams do not typically contribute water directly to the reservoir. The majority of inflow to the reservoir is from the Los Angeles Aqueduct (LAA), which diverts water from the Mono Basin and Owens Valley for use in Los Angeles. Therefore, the primary water supply for Haiwee Reservoir is derived from the 4,150 square mile Mono Basin and

Owens Valley (Mono-Owens) watershed (see Figure 2-2). The following overview discussions will encompass the larger Mono-Owens watershed as well as the immediate vicinity of Haiwee Reservoir. For clarity, paragraph subheadings or in-text comments will indicate the specific geographic location being described.

The Mono Basin and Owens Valley are characterized as high desert rangeland, with valley floor elevations ranging from 6,000 feet amsl near Mono Lake to about 3,500 feet amsl at the Owens (dry) Lake. The mountains that surround the watershed – the Sierra Nevada on the west and the Inyo and White Mountains on the east – rise more than 9,000 feet from the valley floor and include Mount Whitney at 14,494 feet amsl, the highest mountain in the conterminous United States (Danskin, 1998). The major river in the Mono-Owens watershed is the Owens River, which meanders southward through the valley. The headwaters of the Owens River are in the Long Valley area, in the northern portion of the Owens watershed.

2.2.3 Haiwee Reservoir Complex

The Haiwee Reservoir complex consists of North and South Haiwee Reservoirs, which are separated by an earthen berm known as the Merrit Cut. The reservoir complex was constructed in 1913 as part of the LAA system. The reservoir complex is long and narrow and characterized by meandering shorelines. Each reservoir is approximately 3.5 miles long and a quarter mile wide. The North Haiwee Reservoir has a maximum storage of 11,533 acre-feet and a water surface area of approximately 600 acres. Water from the North reservoir flows southward and can exit the reservoir through Merrit Cut to the South reservoir or through the Haiwee bypass channel to the second Los Angeles Aqueduct (LAA2).

South Haiwee Reservoir has a maximum storage of 46,600 acre-feet and, under normal operating conditions, a water surface area of approximately 800 acres. Water from the South reservoir flows to the first Los Angeles Aqueduct (LAA1) (LADWP, 1993). Just downstream of South Haiwee, water is occasionally diverted from LAA1 to LAA2 through a y-branch; however, this diversion is rare since most of the time the y-branch is closed. Retention times for the North reservoir vary from 4 to 23 days and for the South reservoir vary from 21 to 28 days, depending on the operation of the LAA. Figure 2-3 shows a schematic of the Haiwee Reservoir complex, showing potential pathways for water exchange between the reservoirs and the LAA.

2.2.4 Los Angeles Aqueduct-Owens River System

Given that most of the water for the reservoir complex is supplied by the LAA, a discussion of the sources of water and the transport mechanisms which convey water from the Mono Basin to Haiwee Reservoir is relevant. At the northernmost point of the LAA system in the Mono Basin, streams flowing out the Sierra Nevada are diverted to Grant Lake in the Mono Basin and eventually conveyed to the Owens River in the Long Valley through the 11.3-mile-long Mono Craters Tunnel. Following a 1990 decision by the California Court of Appeals, the State Water Resources Control Board amended the City of Los Angeles' water right licenses to require the city to release sufficient water into the diverted tributary streams to reestablish and maintain the fisheries that existed prior to the diversion of water (Mono Basin EIR, 1994). At the end of the Mono Craters Tunnel, water from the Mono Basin joins the upper reach of the Owens River and flows to Crowley Lake, also known as the Long Valley Reservoir (Danskin, 1998). The majority of the water from Crowley Lake flows through a penstock (pipeline) to the Pleasant Valley Reservoir in the Owens Valley, although some water is diverted to the natural channel of the Owens River to maintain fish habitat (R. Jackson, 2001, personal communication). Three hydroelectric plants located along the pipeline generate electricity as a result of a drop in altitude of about 1,600 feet from Long Valley to Owens Valley.

South of Pleasant Valley Reservoir, the Owens River, supplemented by the aqueduct's Mono Basin water, flows in its natural channel, discharging into Tinemaha Reservoir, south of the town of Big Pine. Below Tinemaha Reservoir, flow in the Owens River continues for approximately 5 miles before nearly all the water is diverted into the unlined channel of the LAA at the Aberdeen intake. South of the intake, partial flows are maintained in the natural channel of Owens River by groundwater contributions and intermittent operational releases from the LAA (R. Jackson, 2001, personal communication).

The LAA gains additional water from tributary streams flowing from the eastern flank of the Sierra Nevada and from production wells that discharge to the aqueduct. At the Alabama Gates, on the north side of the Alabama Hills near Lone Pine, the LAA becomes a concrete-lined channel, extending approximately 30 miles to North Haiwee Reservoir. Mean annual discharge of the LAA at North Haiwee Reservoir from 1970-1984 was 480,000 acre-feet per year (Danskin, 1998). The water is then conveyed southward to the Los Angeles area for distribution and use.

2.2.5 Geology/Soils

Mono Basin-Owens Valley Geology

Two principal topographic features represent the surface expression of the geologic setting of the Mono Basin-Owens Valley: the high, prominent mountains on the east and west sides of the valley and the long, narrow intermountain valley floor. The mountains are composed of sedimentary, metamorphic, and granitic rocks that are mantled in part by volcanic rocks and by glacial, talus, and fluvial deposits. The valley floor is underlain by fill that consists mostly of material eroded from the surrounding bedrock mountains, lacustrine and fluvial deposits. The valley fill also includes interlayered recent volcanic flows and pyroclastic rocks. The bedrock of the Coso Range forms the south end of the Owens Lake Basin. Regionally, there are many north to northeast trending normal faults on either side of the Mono Basin-Owens Valley watershed (Danskin, 1998).

Haiwee Reservoir Area Geology

The geology of the area near Haiwee primarily includes volcanic and sedimentary rocks with a variety of surficial deposits. Not adjacent to the reservoir, but within the immediate watershed, minor amounts of granitic rocks outcrop.

Volcanic rocks include silica-rich pyroclastic rocks located mainly in the southern portion of the reservoir, and cliff-forming basalt flows of Coso Peak. Minor amounts of andesitic lava flows, sills and plugs are within the boundary of the immediate watershed, but not adjacent to the reservoir.

The sedimentary rocks include alluvial fan-derived deposits consisting of well-cemented sandstones, mainly feldspar and limestone-dominated sands, some iron-bearing. The major portion of these sedimentary rocks occurs on the eastern side of Haiwee Reservoir (Stinson, 1977).

Haiwee Reservoir Area Soils

Soils surrounding the Haiwee Reservoir can be described by the similarities that occur within the western or eastern portions of the immediate watershed. The soils on the western slope are derived from metasedimentary, metavolcanic and pyroclastic rocks and alluvium from granitic rocks of the Sierra Nevada. The slopes range from 2 to 15 percent, with some slopes as steep as 75 percent closer to the Sierra rangefront. The soils are generally described as sandy loam, gravelly and or loamy sand, and cobbly sandy clay loam. Portions of the soils are classified as being very shallow to shallow in depth (5 to 20 inches), while the majority of the soil surrounding the western portion of the reservoir is classified as very deep (60 inches or greater). These very deep soils occur in the 2 to 15 percent slope areas and are considered well drained with moderately slow permeability and runoff with a slight hazard of erosion by water. The shallow soils occur in the steeper slopes and are classified as excessively drained with rapid runoff potential and therefore severe hazard of erosion by water.

Soils form alluvial fan terraces on the eastern side of the Haiwee Reservoir. The slopes range from 2 to 9 percent with 20 to 35 percent vegetative cover. The soils are classified as moderately deep to very deep, well drained soils that have slow to medium surface runoff potential and a slight hazard of erosion by water. Loamy sand, sand, and gravelly/cobbly loamy coarse sand are the general soil textural classifications that occur on the eastern flank of the reservoir. Localized portions of the soils on the eastern side are loamy coarse sands that occur on steeper slopes with rapid to very rapid surface runoff potential (NRCS, 2001).

2.2.6 Vegetation

The vegetation on the alluvial fans and slopes adjacent to Haiwee reservoir is a Mojave mixed scrub community. The dominant vegetative cover types are low-lying shrubs such as shadscale, spiny menodora, bud sagebrush, creosote bush and several varieties of perennial and annual forbs. Joshua trees are present in limited areas. Nearer the reservoir, stands of cottonwood, saltcedar and willow dominate (Singley, 1993). See Appendix C for a more complete list of plant species.

2.2.7 Climate

The climate in the Mono Basin and Owens Valley is greatly influenced by the Sierra Nevada mountains. Because of the orographic effect of the Sierra Nevada, a rain shadow is present east of the Sierran crest, and precipitation on the valley floor is appreciably less than that west of the crest. Consequently, climate is semi-arid to arid and is characterized by low precipitation, abundant sunshine, frequent winds, and moderate to low humidity. (Danskin, 1998)

According to data collected from 1948 through 2000 by the Western Regional Climate Center, the average annual maximum temperature at recorded at Haiwee Reservoir is about 73° F and the average annual minimum temperature is approximately 46° F. Daily temperatures in the Owens Valley area may be as low as –2° F in the winter or as high as 107° F in the summer.

Average annual snowfall in the Owens Valley is 3.7 inches. Average precipitation ranges from more than 30 inches per year at the crest of the Sierra Nevada, to about 7 to 14 inches per year in the Inyo and White Mountains, to approximately 5 inches per year on the valley floor (Danskin 1998).

2.2.8 Threatened and Endangered Species

Bald eagles (*Haliaetus leucocephalus*), a federal- and state-listed endangered species, have been observed wintering at Haiwee Reservoir. The reservoir is located within the boundary of the northern edge of an area considered to be a potential habitat for the Mohave ground squirrel (*Spermophilus mohavensis*), a species designated as threatened by the State and a Category 2 candidate for Federal listing (Singley, 1993).

Two species, the loggerhead shrike (*Lanius ludovicianus*) and Merriam's kangaroo rat (*Dipodomys merriami*) have been noted in the immediate vicinity. The San Clemente loggerhead shrike (*Lanius ludovicianus mearnsi*) and the San Bernardino Merriam's kangaroo rat (*Dipodomys merriami parvus*) are both listed as federally endangered species. It is unclear if the observations were of the more common unlisted species, or if these may have been sightings of the listed subspecies.

2.2.9 Fish and Wildlife

Wildlife populations occurring in the Haiwee Reservoir area are diverse and include a variety of bird, mammal, rodent, reptile and fish species. See Appendix C for a more complete list of wildlife species. More than 20 species of water, marsh, and shorebirds have been observed at Haiwee Reservoir, with migrating waterfowl found in greatest numbers during the fall and winter months. Marsh and shorebirds found in riparian areas bordering the reservoir include American coot (*Fulica americana*), American avocet (*Recurvirostra americana*), great egret (*Casmerodius albus*), great blue heron (*Ardea Heroideas*), and black-crowned night heron (*Nycticorax nycticorax*). Many other bird species have been found in the wooded area and adjacent shrub habitat.

Major fish species in the reservoir include carp (*Cyprinus carpio*), largemouth bass (*Micropterus salmoides*), rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), bluegill (*Lepomis macrachirus*) and channel catfish (*Ictalurus punctatus*) (Singley, 1993).

2.2.10 Recreation

Because Haiwee Reservoir is a drinking water supply, recreation activities are limited. Historically, fishing and recreational use were not permitted at the reservoir, but have been allowed since the mid-1990's. Allowable recreational activities at Haiwee Reservoir include shore fishing and fishing with sealed waders or float tubes. Recreational boating, camping, flotation devices, except for float tubes and sealed waders, swimming, and any form of direct body contact with the water are prohibited (Singley, 1993).

2.2.11 Inyo County Population/Land and Water Use

Inyo County is the second largest county in California, with a total land area of approximately 10,140 square miles or about 6.5 million acres. The 1990 U.S. census indicates the population for Inyo County to be approximately 18,281, with an average density for the county of 1.7 persons per square mile. Local towns in the vicinity of Haiwee Reservoir include the small rural communities of Lone Pine, Olancha and Cartago.

Though the county contains a large land area, only 1.9 percent of the land is held in private ownership. Majority landowners include federal agencies (91.6 percent), the State of California (3.5 percent), the LADWP (2.7 percent), and other local agencies or Indian reservation lands (0.3 percent). (Jones & Stokes, 2000).

Besides the LADWP, most of the land adjacent to Haiwee Reservoir is managed by the Bureau of Land Management, with the exception of limited pockets of privately owned land. Agriculture and ranching are primary land uses near the reservoir.

In-valley uses of water include local municipal needs, Indian reservations, stockwater, irrigation of pastures, and cultivation of alfalfa. About 190,000 acres of the Owens Valley floor is leased by the LADWP to ranchers for grazing, and about 12,400 additional acres is leased for growing alfalfa. Several Owens Valley fish hatcheries (Fish Springs, Blackrock, and Mt. Whitney) also rely on ground and surface water for their needs. Since the early 1900's, water use in the Owens Valley has changed from meeting local needs to exporting a greater quantity of both ground and surface water (Danskin, 1998).

2.4 BENEFICIAL USES AND WATER QUALITY STANDARDS

Water quality standards consist of beneficial uses and water quality objectives. The 1995 Water Quality Control Plan for the Lahontan Region (Basin Plan) specifies water quality standards for all waters in the Lahontan Region, including Haiwee Reservoir. The water quality standards that are applicable to this TMDL are the narrative water quality objectives for pesticides and toxicity and the beneficial uses of Haiwee Reservoir that could be adversely affected by toxicity. There are no numerical water quality objectives in the Basin Plan for metals in Haiwee Reservoir; however, the California Toxics Rule (CTR) sets numeric standards for 126 priority pollutants, including copper, for all waters of the State.

The following beneficial uses are assigned to Haiwee Reservoir:

- Municipal and Domestic Supply

- Cold Freshwater Habitat
- Agricultural Supply
- Industrial Service Supply
- Groundwater Recharge
- Water Contact Recreation
- Non-contact Water Recreation
- Commercial and Sportfishing
- Wildlife Habitat
- Rare, Threatened, or Endangered Species
- Spawning, Reproduction and Development

The Basin Plan narrative water quality objective for pesticides is applicable to all inland surface waters of the Lahontan region. It states:

> "Pesticide concentrations, individually or collectively, shall not exceed the lowest detectable levels, using the most recent detection procedures available. There shall not be an increase in pesticide concentrations found in bottom sediments. There shall be no detectable increase in bioaccumulation of pesticides in aquatic life."

This objective precludes the continued use of copper sulfate to control algae in the reservoir and may require sediment remediation to reduce copper concentrations built up from past pesticide use. If studies show that the use of copper sulfate algicide does not negatively impact the overall reservoir ecosystem, an amendment to the above water quality objective may be pursued (see the Introduction and Appendix F for more details). The amendment would seek to create an exception to the pesticide objective if all of the following conditions are met:

- Without the use of aquatic pesticides, taste and odor problems will unreasonably affect municipal drinking water supplies.
- There are no reasonable alternatives to the use of pesticides.
- The use of pesticides is shown to be consistent with the maximum benefit to the people of the State.
- No individual pesticide or combination of pesticides and other chemical or physical factors shall be present in concentrations that adversely affect beneficial uses or are toxic to non-target species, outside of specified mixing zones.
- Pesticide concentrations in bottom sediments or aquatic life shall not adversely affect beneficial uses.

If the pesticide objective is amended, the narrative toxicity objective will be applicable to this TMDL. The following Basin Plan narrative water quality objective for toxicity is applicable to all inland surface waters of the Lahontan Region:

> "All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life".

> "The survival of aquatic life in surface waters subjected to a waste discharge or other controllable water quality factors, shall not be less than that for the same water body in areas unaffected by the waste discharge or, when necessary, for other control water that is consistent with requirements for "experimental water" as defined in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association, et al. 1992)."

In addition to Basin Plan objectives, the CTR establishes applicable numeric water quality criteria for priority pollutants including copper. These criteria are discussed further in the Numeric Target Section 3.2.

2.5 IMPAIRMENT OF BENEFICIAL USES

Of the eleven beneficial uses for Haiwee Reservoir, copper from natural and anthropogenic sources impacts may effect the following five beneficial uses:

- Cold Freshwater Habitat (COLD)
- Water Contact Recreation (REC-1)
- Commercial and Sportfishing (COMM)
- Wildlife Habitat (WILD)
- Spawning, Reproduction and Development (SPWN)

The preservation and enhancement of aquatic habitats and communities, including invertebrates, is a vital element of the COLD beneficial use. Copper sulfate applications may result in conditions toxic to benthic invertebrates and fish. Copper accumulation in the sediments and the food chain may result in negative impacts to the diversity and viability of aquatic life. Limited sediment toxicity testing at North Haiwee showed sediment pore water elutriates resulted in mortality and reduced reproduction to test organisms (Hansen et al, 1996). A benthic infaunal assessment was conducted at North Haiwee in 1998, and the subsequent report stated that the benthic community "as a whole appeared to be relatively low in abundance and diversity." (Mikel et al, 1999). These preliminary findings indicate that further study is needed to assess the extent of copper impacts to the Haiwee Reservoir ecosystem, and to determine if reductions of copper inputs are needed to mitigate these impacts.

2.4.1 History of Copper Sulfate Applications

Haiwee Reservoir has a history of nuisance algae blooms that can impart undesirable flavors and odors to drinking water. In 1957, a continuous feed system for applying copper sulfate to control algae growth was established at Merrit Cut and, in 1978, an additional continuous feed system was added at the inlet to North Haiwee Reservoir.

Traditionally, liquid copper sulfate was fed continuously at the inlet to North Haiwee Reservoir when water temperatures exceeded 63^{o} F. In 1992, the application method was modified by beginning the liquid copper sulfate feed when taste and odor conditions began to deteriorate, regardless of water temperature and by ramping up the copper dosage over a period of several days and pulsing the seasonal treatment with 10 days off between successive two-week feed periods (Yoshimura, 1993).

These changes in management practice resulted in reduced amounts of copper sulfate applied to the reservoir. For example, for the three years prior to 1992, an annual average of approximately 34 tons of copper sulfate were applied to the inlet of North Haiwee Reservoir; in 1992 and 1993, approximately 5.3 tons and 1.6 tons of copper sulfate were applied at this location, respectively (Yoshimura, 1993).

Since 1995, dry copper sulfate crystals have been applied aerially to the surface of the reservoir to eliminate plume effects and promote more thorough mixing . Only one-half of the reservoir is treated to allow for an “escape zone” for aquatic organisms. This technique has further reduced the amount of copper applied. From 1995 to 2000, a total of 3.7 tons of elemental copper have been applied to North Haiwee (Table 2-1) and 17.7 tons have been applied to South Haiwee (Table 2-2).

Table 2-1: North Haiwee Reservoir Copper Applications, 1995-2000

Year	Treatments per year	Tons Elemental Copper applied
1995	0	0
1996	2	1.03
1997	0	0
1998	3	1.36
1999	2	0.82
2000	1	0.48
Total	**8**	**3.7**

Table 2-2: South Haiwee Reservoir Copper Applications, 1995-2000

Year	Treatments per year	Tons Elemental Copper applied
1995	1	0.75
1996	7	5.04
1997	3	2.02
1998	4	2.76
1999	6	4.04
2000	5	3.04
Total	**26**	**17.7**

2.4.2 Water Column Copper Concentrations

Data from surface water copper monitoring at Merrit Cut and the South Haiwee outlet were available from 1995 to 2000. Typically, samples are collected several times a month, not necessarily in relation to copper sulfate treatments. Table 2-3 shows summary statistics for this dataset. Total recoverable copper measurements in both reservoirs generally show a decreasing trend, most likely reflecting the reduced amounts of copper sulfate applied since 1995.

Table 2-3: Total Recoverable Copper Statistics (µg/L)
North and South Haiwee Reservoir, 1995-2000

Merrit Cut	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Mean	34.4	21.3	15.9	12.4	10.6	10.0
Median	30.0	16.6	13.0	10.7	9.3	8.8
# of samples	13	45	47	46	34	29
S. Haiwee Outlet	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Mean	24.1	31.4	24.6	18.5	15.8	21.9
Median	22.0	27.0	22.4	16.0	15.1	17.2
# of samples	11	46	50	51	35	27

2.4.3 Sediment and Pore Water Copper Concentrations

California Department of Fish and Game (DFG) staff conducted a sediment sampling survey at North Haiwee in May 1992. Copper levels in the sediment were measured at up to 1,180 milligrams per kilogram (mg/kg) near the North Haiwee inlet channel. Background levels of copper based on the lowest results found in the survey were measured at 0.004 mg/kg (Rheiner, 1995). According to a study conducted at North Haiwee in 1996, dry weight copper in sediments ranged from 7 to 386 mg/kg (Hansen et al, 1996). As a comparison, toxicological benchmarks or criteria for copper in sediments range from 86 mg/kg dry weight (EC & MENVIQ 1992 toxics effect threshold) to 390 mg/kg dry weight (Long and Morgan 1991, effects range median).

Preliminary sediment toxicity studies were conducted at North Haiwee in March 1995. Sediment pore water concentrations of total copper were measured at up to 151 micrograms per liter (µg/L). Chronic toxicity tests on *Ceriodaphnia dubia* (water flea) showed mortality and reduced reproduction in 2 out of 2 pore water samples tested (Hansen et al, 1996).

More recent toxicity tests of North Haiwee Reservoir sediment pore water and elutriates have indicated no acute or chronic toxicity to very sensitive organisms (Mikel et al., 1999). These data also indicate that bioavailable copper was not present in significant concentrations in the interstitial water.

No toxicity studies or sediment surveys have been conducted on South Haiwee Reservoir. However, based on LADWP copper application records summarized in Tables 2-1 and 2-2, above, South Haiwee Reservoir is treated with copper sulfate 3.4 times more frequently than North Haiwee. For example, in the period from September 1995 through September 2000, South

Haiwee received 26 copper sulfate treatments for a total of 17.7 tons of elemental copper, compared to North Haiwee which was treated 8 times for a total of 3.7 tons of elemental copper. It may be surmised from these data that copper levels in the sediments of South Haiwee Reservoir would be proportionally elevated compared to North Haiwee Reservoir due to greater amounts and frequencies of copper sulfate applications.

2.4.4 Fish Kills and TSMP data

In 1991, LADWP applied copper sulfate at North Haiwee Reservoir from June 12 to September 21. On June 28, 1991, DFG staff investigated a telephone report of a suspected fish kill at the reservoir and discovered more that 100 dead carp and trout around the inlet to North Haiwee. Autopsies performed by DFG on fish collected from that incident indicated that the fish died from exposure to copper. (DFG, 1991). Water samples taken approximately 150 and 400 feet downstream of the treatment site indicated copper concentrations of 1,850 µg/L and 440 µg/L, respectively.

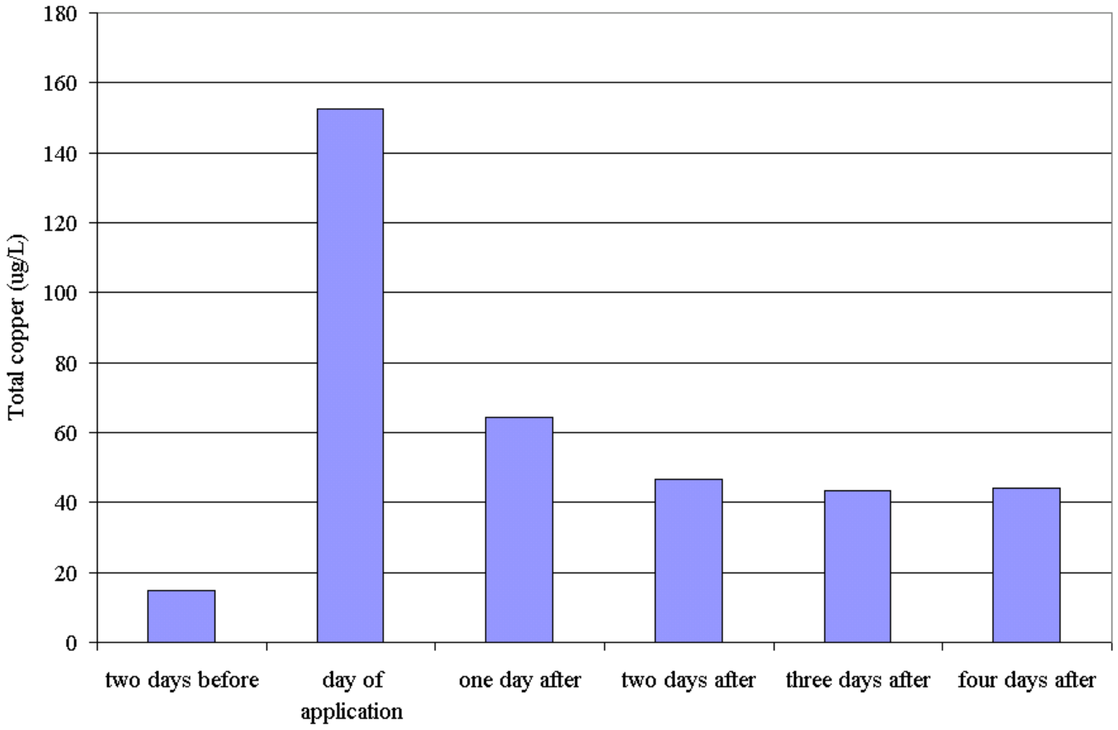
The State Water Resources Control Board’s Toxic Substances Monitoring Program (TSMP) is an annual monitoring program run in cooperation with the nine Regional Water Quality Control Boards (Regional Boards). The presence of toxic substances in fresh waters is determined by analyzing tissues from fish and other aquatic organisms. The results of the sampling are expressed in terms of Elevated Data Levels (EDLs). An EDL is that concentration of a toxic substance in a fish tissue that equals or exceeds a specified percentile (such as 85 percent) of all TSMP measurements of the toxic substance in the same fish and tissue type. The TSMP collected a smallmouth bass from North Haiwee in July 1991. Copper was detected at 84 mg/kg (wet weight) in the liver tissue of the bass (SWRCB, 1991), exceeding the 95th percentile EDL of 33 mg/kg, prompting the inclusion of the Reservoir on the 1994 303(d) list of impaired waters.

Another large fish kill was recorded in June 1994 involving nearly 700 specimens of carp, trout, bass, and bluegill and was also attributed to the addition of copper sulfate to the reservoir. A water sample collected approximately 200 yards downstream of the Los Angeles Aqueduct gate at North Haiwee Reservoir, where the dead fish washed up onshore, indicated a copper concentration of 100 µg/L (DFG, 1994). The acute and chronic values for the most sensitive fish species known to inhabit Haiwee Reservoir, rainbow trout, are 38.9 µg/L and 19.0 µg/L at 50 mg/L hardness. (Hill, 2001).

Following the June 1994 fish kill incident, the Lahontan Regional Board issued a Cleanup and Abatement Order (CAO) to LADWP, requiring them to determine the extent of copper contamination in sediments, evaluate the diversity of aquatic organisms, and identify potential impacts to the beneficial uses as described in the Basin Plan. The LADWP completed several studies on North Haiwee to fulfill the requirements of the CAO, including sediment pore water toxicity tests, benthic surveys, and sediment and water column copper measurements.

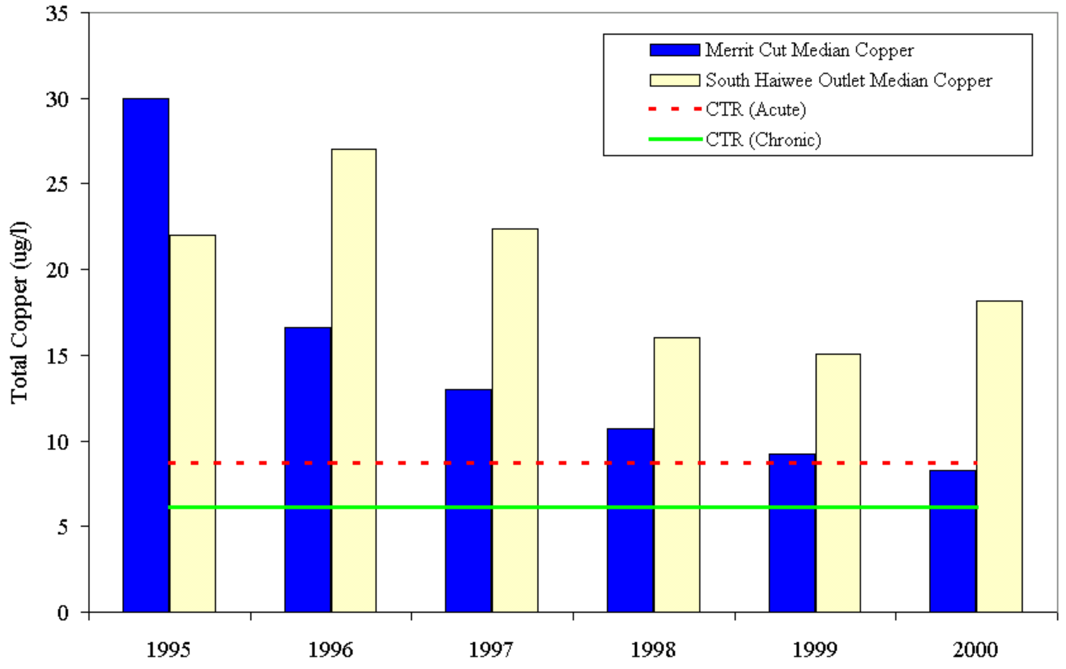
As a result of the CAO, LADWP revised application techniques and significantly reduced the amount of copper sulfate applied to Haiwee Reservoir, as discussed previously; however, total copper concentrations in the water column remain significantly above CTR criteria for several days following copper sulfate applications. Figure 2-4 shows the changes in mean total copper concentrations (averaged from a set of four samples per day taken from the treated and untreated halves of South Haiwee Reservoir) over a five-day period before, during, and after the application of copper sulfate.

Figure 2-4: Changes in Mean Total Copper Values Relative to Copper Sulfate Application South Haiwee Reservoir, September 1995



Copper concentrations measured during routine monitoring at Merrit Cut and South Haiwee Outlet are typically above the CTR copper criteria as well. Figure 2-5 shows annual median total copper concentrations for these locations for the period 1995 through 2000. CTR copper criteria adjusted for the 25th percentile hardness values at Haiwee Reservoir gives a numeric objective of 8.7 µg/L (acute) and 6.1 µg/L (chronic) total recoverable copper. The toxicity of copper may vary with site-specific water chemistry parameters such as hardness, organic matter and pH; therefore, the CTR criteria for copper may be adjusted to account for toxicological differences in site water. The CTR criteria cited here are based on the default toxicity adjustment factors, not site-specific factors that have yet to be determined.

Figure 2-5: Yearly median total copper concentrations at Merrit Cut and South Haiwee Outlet compared with CTR criteria.



Figures 2-1 and 2-2

Figure 2-1: Haiwee Reservoir Location Map

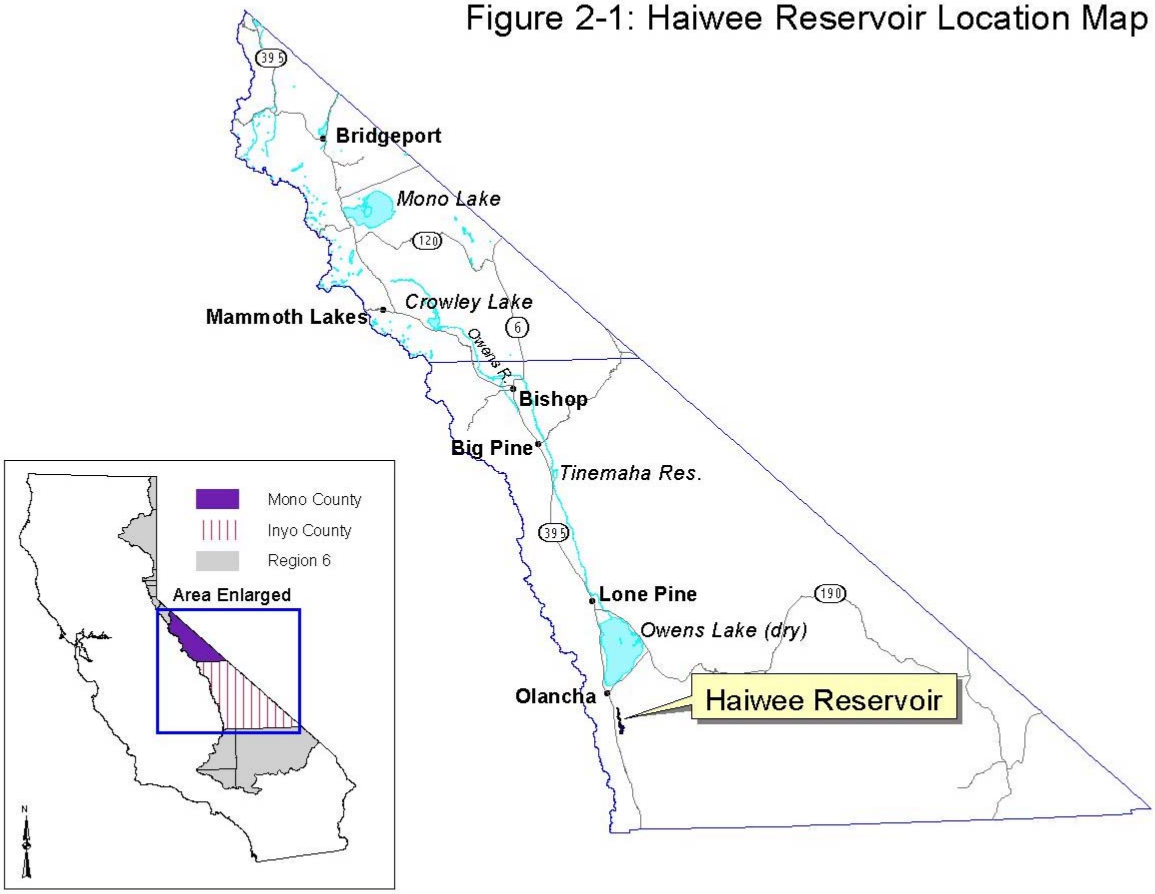
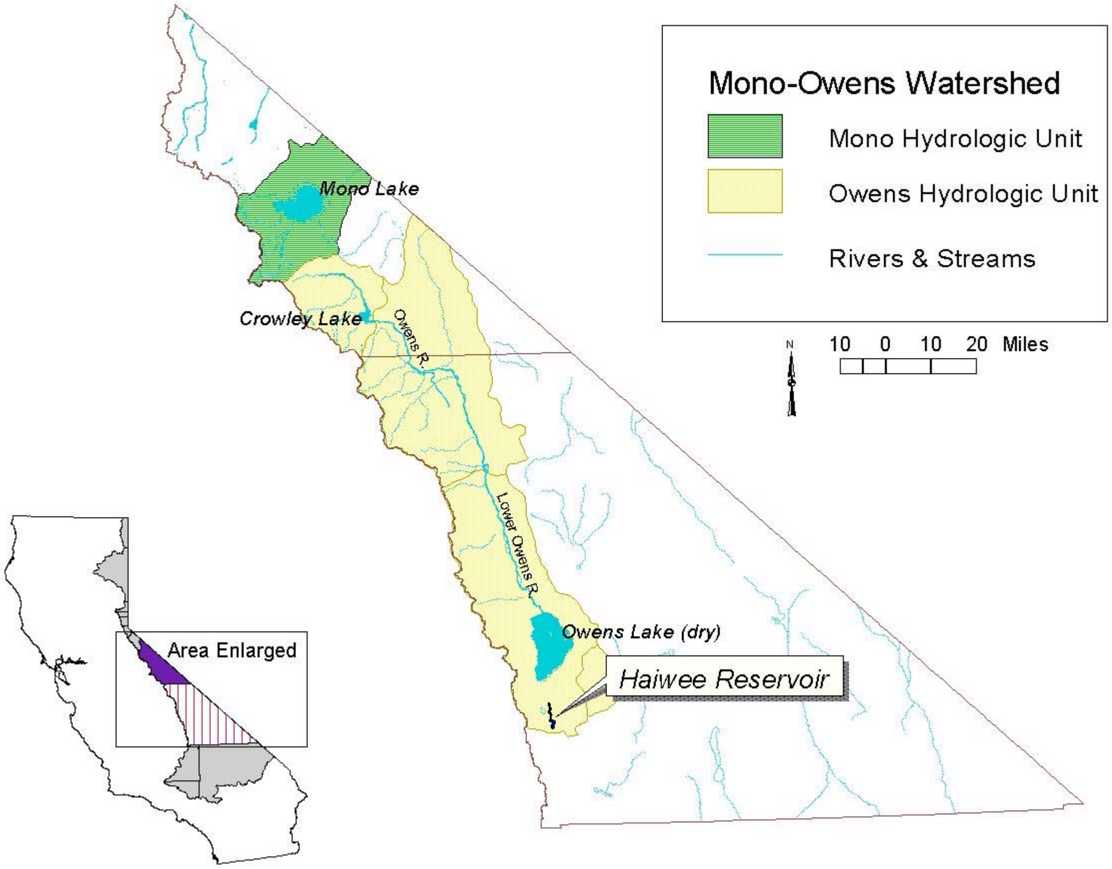


Figure 2-2: Watershed Overview Map



3. NUMERIC TARGET

NOTE: This Numeric Target is written assuming a Basin Plan Amendment will amend the current pesticide objective to allow for detectable pesticides under certain circumstances. This Numeric Target also requires completion of studies to determine mixing zone parameters.

3.1 INTRODUCTION

Section 303(d)(1)(C) states that TMDLs "shall be established at a level necessary to implement the applicable water quality standards…." Numeric targets help to interpret narrative water quality standards and establish the linkage between attainment of the standards and the TMDL. The narrative pesticide and toxicity water quality objectives in the Basin Plan are the most restrictive applicable narrative objective for this TMDL. The California Toxics Rule (CTR) establishes numeric criteria for copper. Each of these objectives is applicable to the habitat related beneficial uses described in the Problem Statement.

3.2 WATER COLUMN TOXICITY

The numeric target for the narrative toxicity objective will be zero observable copper toxicity. Copper toxicity includes both direct copper toxicity and toxicity from additive or synergistic effects with other compounds present in the reservoir. This numeric target applies at all times and in all areas within the reservoir except for a period following algicide discharges within the designated acute and chronic mixing zones.

3.3 CALIFORNIA TOXICS RULE CRITERIA

The numeric criteria for copper established in the CTR will be applied for the Haiwee Reservoir water column. The CTR can be found in Title 40, Part 131.38 of the Code of Federal Regulations (40 CFR 131.38) and is enforceable for all surface waters of the state.

The CTR's freshwater criteria for copper are expressed as a function of hardness in the water column. The Criteria Maximum Concentration (CMC) is the acute criterion that estimates the highest concentration of a material in a surface water to which an aquatic community can be briefly exposed without resulting in an unacceptable effect. The Criteria Continuous Concentration (CCC) is the chronic criterion that estimates the highest concentration of a material in a surface water to which an aquatic community can be indefinitely exposed without resulting in an unacceptable effect.

Following the USEPA recommendation for freshwater criteria for metals, the numeric target will be expressed in terms of the dissolved copper concentrations in the water column. The Conversion Factor (CF) converts the copper criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column. The CF is related to the CTR criteria, not the relationship between total recoverable and dissolved copper in site water. The CTR specifies a CF of 0.96 for copper. The Water Effects Ratio

(WER) is a multiplier that corrects for the bioavailability of copper under site-specific conditions. In the absence of site-specific WER values, the default value 1 will be used.

Criteria may be calculated from the following equations:

Eq. 3-1) $CMC = \exp\{0.9422\,[\ln(\text{hardness})] - 1.7\}\,(CF)\,(WER)$

Eq. 3-2) $CCC = \exp\{0.8545\,[\ln(\text{hardness})] - 1.702\}\,(CF)\,(WER)$

where the *CMC* and the *CCC* are both expressed as dissolved copper concentrations in micrograms per liter (μg/L), *exp* is the base e exponential function, *ln* is the natural logarithm function, and *hardness* is measured in milligrams per liter (mg/L) as calcium carbonate, $CaCO_3$.

These numeric targets hold at all times and in all areas within the reservoir except for the specified period following algicide applications within the designated acute and chronic mixing zones.

Data from the period of March 1995 to February 2001 show hardness in Haiwee Reservoir ranging from 43 to 100 mg/L with some seasonal variability. Table 3-1 contains CMC and CCC values for different hardness percentiles found in Haiwee Reservoir assuming the default WER of 1. The lowest monthly median hardness value of 55.4 mg/L occurs in June, corresponding to the 10th percentile hardness for the overall data set. The June median hardness value will be used to set the numeric targets of 7.7 μg/L and 5.4 μg/L of dissolved copper for the CMC and CCC, respectively. If site-specific studies are completed to determine WERs for Haiwee Reservoir, these concentrations will be modified accordingly. As will be discussed further in the Linkage Analysis, a hypothetical WER of 5 would increase these criteria concentrations by a factor of 5.

Table 3-1. Numeric Targets for Different Hardness Values*

Hardness		**Dissolved Copper (μg/L)**	
Percentile	**(mg/L)**	**CMC**	**CCC**
10th	55	7.7	5.4
25th	63	8.7	6.1
50th	73	10	6.9
90th	93	13	8.4

Assuming default WER of 1.
All concentrations rounded to two significant figures.

3.4 SEDIMENT TOXICITY

The numeric target for sediment toxicity will be zero observable sediment toxicity resulting from copper. Copper toxicity includes both direct copper toxicity and toxicity from additive or synergistic effects with other compounds present in the sediments. This numeric target is applicable at all times in all reservoir sediments.

4. SOURCE ANALYSIS

4.1 INTRODUCTION

This section identifies and evaluates the various sources of copper to the water column of Haiwee Reservoir. The copper sources to Haiwee Reservoir are categorized here as external and internal sources. External sources include copper from the discharge of copper sulfate to the reservoir itself and upstream in the Los Angeles Aqueduct-Owens River system. Internal sources are those that contribute to the copper load in Haiwee Reservoir by internal loading or recycling of copper residuals in reservoir sediments through processes of sediment resuspension, molecular diffusion, and groundwater seepage.

Both source categories include a percentage of “unspecified” copper, such as copper coming in from the Los Angeles Aqueduct (LAA) with no readily identifiable source from the available data and naturally occurring contributions of copper. Potential sources of this copper are historic mining activities, elevated copper in ground or surface waters due to copper-bearing minerals in soil or rock and undetermined water supply management practices in the watershed.

Copper sulfate is applied in the Owens Valley by two methods: hopper feed (for LAA treatments) and aerially (for reservoir treatments). These direct discharges of copper sulfate can be considered point sources. The term “point source” is defined very broadly in the Clean Water Act. It means any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container. It also includes vessels or other floating craft from which pollutants are or may be discharged (USEPA, 1996).

4.2 DATA AND METHODS USED

Data used in this TMDL analysis to assess sources of copper due to copper sulfate discharges were supplied by LADWP. Detailed information was available on timing, locations, and quantities of copper discharged since 1995. Haiwee Reservoir monitoring data were provided, including inflows, outflows, reservoir storage area/capacity data, and water quality information. Weekly monitoring on the LAA at Cottonwood Creek, approximately 15 miles north (upstream) of Haiwee Reservoir, offered additional information on amounts of copper coming into Haiwee Reservoir from the LAA.

The Haiwee Reservoir Copper Model was developed by Tetra Tech, Inc., under contract with the EPA, using Haiwee-specific hydrology, climate, water quality and copper discharge data. These data were integrated into a Microsoft Excel workbook of spreadsheets that performed a series of mass balance calculations to quantify sources of copper in Haiwee Reservoir. The model evaluated possible flow pathways for water in the reservoir system; fate and transport of sediment; copper from background sources and from copper sulfate discharge; copper binding to sediment in the water column; settling, burial, and resuspension of particulate copper; molecular diffusion of dissolved copper between the sediment layer and the water column; and groundwater seepage through a copper-influenced sediment layer. A detailed description of the data, assumptions, limitations and equations used in the model is provided in Appendix D and the supplemental document *Haiwee Reservoir Model User's Guide*.

Data from several sources were reviewed for information on potential sources of copper in the watershed. Jones & Stokes Associates collected water quality data on numerous streams in the Mono Basin and Owens Valley from May through August 1991. The Inyo County Water Department collected data, including copper measurements, on the Owens River between Tinemaha Reservoir and the Owens Lake in the winter and summer of 1999. The Inyo County Environmental Health Department and Crystal Geyser bottling plant's water quality laboratory, located about 10 miles north of Haiwee Reservoir, were consulted for information on copper in the water supply in the area. Geographic Information System (GIS) coverages such as PAMP (Principle Areas of Mine Pollution), MRDS (Mineral Resources Data System), and MAS_MILS (Minerals Availability System and Minerals Industry Location Systems), developed by the Department of Conservation and the USGS, were used to evaluate the potential sources of copper due to geologic processes and mining activities.

4.3 EXTERNAL COPPER SOURCES

4.3.1 Copper Sulfate Discharges to Haiwee Reservoir

Copper sulfate has been used by LADWP at Haiwee Reservoir since the 1950's. The data relied upon in this source analysis is from 1995 to 2000 and reflects current LADWP algae control techniques. A review of discharge data at North Haiwee Reservoir shows a total of 7,380 pounds of elemental copper discharged to North Haiwee Reservoir during this period, with an average of 1,230 pounds per year. The amounts of elemental copper discharged during this period ranges from zero pounds in 1995 and 1997 to 2,720 pounds in 1998 (Table 4-1).

Table 4-1: North Haiwee Reservoir Copper Sulfate Discharges 1995-2000

Year	# of Treatments	Tons Elemental Copper	Pounds Elemental Copper
1995	0	0	0
1996	2	1.03	2,060
1997	0	0	0
1998	3	1.36	2,720
1999	2	0.82	1,640
2000	1	0.48	960
Totals	**8**	**3.7**	**7,380**
Average (per year)	1.3	0.6	1,230

In South Haiwee Reservoir, copper sulfate is used more frequently, and the amounts of elemental copper discharged are greater, totaling 43,380 pounds, with an average of 6,197 pounds per year during the period of 1995-2000 (Table 4-2).

Table 4-2: South Haiwee Reservoir Copper Sulfate Discharges 1995-2000

Year	# of Treatments	Tons Elemental Copper	Pounds Elemental Copper
1995	1	0.75	1,500
1996	7	4.68	9,360
1997	3	2.02	4,040
1998	4	2.76	5,520
1999	6	4.04	8,080
2000	5	3.04	6,080
Totals	**32**	**21.7**	**43,380**
Average (per year)	4.6	3.1	6,197

4.3.2 Copper Sulfate Discharges in the LAA

Copper sulfate is discharged in the Los Angeles Aqueduct-Owens River system at various locations upstream (north) of Haiwee Reservoir. Dry copper sulfate is applied using an adjustable feed hopper to maintain a dosage rate of 0.1 to 0.2 pounds per hour per cubic foot per second of flow (this dosage rate yields a concentration of approximately 0.2 mg/L total copper in the LAA). Treatment duration generally ranges from seven to ten hours. Total recoverable copper concentrations are measured before, during and after discharge at Alabama Gates and Cottonwood Creek. Table 4-3 shows total copper concentrations in the LAA measured approximately 3 hours after copper sulfate discharge begins. Sampling locations are typically 200 yards downstream of the discharge point (LADWP, 1996).

Table 4-3: LAA Discharges - Total Recoverable Copper Concentrations (Measured approximately 3 hours after discharge begins)

Date	µg/L	Location of sample
3-Oct-95	207	Alabama Gates
27-Feb-96	249	Alabama Gates 250 Yards South
28-Feb-96	269	Alabama Gates 250 Yards South
19-May-98	215	Alabama Gates Metering Bridge
20-May-98	215	Alabama Gates Metering Bridge
23-Jun-98	255	Cottonwood 200 Yards South
24-Jun-98	263	Alabama Gates Metering Bridge
25-Jun-98	237	Alabama Gates Metering Bridge
18-May-00	24*	Cottonwood Bridge

*this datum is anomalously low; therefore, 2000 was excluded from calculations

4.3.4 Distinguishing Copper Sources in the LAA

Copper monitoring data are collected routinely at Cottonwood Creek on the LAA on approximately a weekly basis. Comparison of this routine monitoring data with the data collected before, during and after copper sulfate discharges indicates that an additional copper concentration exists in the LAA that does not correlate with any known copper sulfate discharges.

Since the Cottonwood Creek samples were collected approximately on a weekly basis, and fluctuations in the copper concentrations observed between LAA discharges were not large, a straight linear interpolation was used to fill the data gaps between the known weekly data and the modeled daily estimations. The copper concentrations collected during known LAA discharges were normalized to daily (24 hour) concentrations based on information about the duration of the discharges, which typically last about 7 to 10 hours. It was also assumed that the elevated concentrations due to LAA copper sulfate discharges would drop by half on the second day, and return to the "average" condition by the third day. This interpolated daily timeseries dataset was used to estimate the total copper load in the LAA.

The "average" condition is defined as the concentration that would exist in the aqueduct not considering LAA copper discharges. To estimate this concentration, monitoring data from the LAA at Cottonwood Creek were filtered to determine which measurements were taken when there were no aqueduct copper sulfate treatments. Copper loads were calculated by multiplying the observed data by the known average daily LAA water flows. The flow-weighted average copper concentration from 1995 to 2001 for the LAA (without the influence of copper sulfate treatments) was calculated as 12.7 µg/L total copper.

The estimated amount of copper coming in to Haiwee Reservoir from the LAA due to copper sulfate treatments in the LAA was distinguished from other upstream sources by performing a model run using the interpolated daily timeseries (including concentrations associated with LAA copper discharges) and another model run using the constant average concentration in LAA without copper discharges. The estimated load in the LAA attributed to copper sulfate discharges is the difference between the two model runs as expressed in equation 4-1:

Equation 4-1: $$\mathrm{LAA}_{\mathrm{CuSO4\ load}} = \mathrm{LAA}_{\mathrm{total\ Cu\ load}} - \mathrm{LAA}_{\mathrm{constant\ Cu\ (12.7\ \mu g/L)\ load}}$$

Table 4-4 shows the estimated amount of copper coming in to Haiwee Reservoir from the LAA due to copper sulfate treatments in the LAA and attributed to other upstream sources.

Table 4-4: Los Angeles Aqueduct Estimated Copper Sources to Haiwee Reservoir, pounds per year (rounded to nearest 100 lbs.)

Year	Total estimated load in LAA	Estimated load from upstream sources	Estimated load from copper sulfate discharges
1995	16,700	15,800	900
1996	22,800	15,400	7,400
1997	15,300	15,300	0
1998	20,100	16,600	3,500
1999	11,100	11,100	0
Totals	**86,000**	**74,200**	**11,800**
Average (per year)	17,200	14,800	2,300

Note: 2000 was excluded from calculations, as noted in text

4.4 INTERNAL COPPER SOURCES

Copper can enter the water column in Haiwee Reservoir through processes that can be described as internal loading or recycling. These processes include resuspension of copper in sediments to the overlaying water column, molecular diffusion from sediment pore waters into the water column, and copper attributed to groundwater seepage through a copper-influenced sediment layer. The copper loads due to these internal processes were analyzed using the Haiwee Reservoir Copper Model. A complete description of the assumptions and equations used to estimate sources from internal loading are found in Appendix D and the supplemental *Haiwee Reservoir Model User's Guide*.

For both North and South Haiwee Reservoirs, a mass balance of copper in the water column and a single sediment layer was performed using actual or calculated input parameters including the following:

- Water flow into North Haiwee and outflow from North and South Haiwee
- Calculated flow from North to South Haiwee
- Depth, surface area, and volume time-series for both reservoirs
- Mass and date of copper sulfate discharges

Data for which a reasonable approximation was derived by the model include the following:

- Dissolved and particulate fractions in the water column and sediment layer
- Molecular diffusion between sediment layer and water column
- Groundwater seepage through a copper-influenced sediment layer

Table 4-5 shows the modeled contributions of copper attributed to internal loading from 1995 to 2000.

Table 4-5: Estimated Internal Copper Loading from Sediments, pounds per year (rounded to nearest 5 lbs.)

	North Haiwee	***1995***	***1996***	***1997***	***1998***	***1999***	***2000***
Process	Groundwater	750	610	335	480	310	330
	Resuspension	90	65	20	10	5	30
	Molecular diffusion	835	815	395	460	260	355
	Total (North Haiwee)	**1,675**	**1,490**	**750**	**950**	**575**	**715**
	South Haiwee	***1995***	***1996***	***1997***	***1998***	***1999***	***2000***
Process	Groundwater	760	885	510	625	595	715
	Resuspension	60	110	70	50	60	140
	Molecular diffusion	710	870	575	470	505	830
	Total (South Haiwee)	**1,530**	**1,865**	**1,155**	**1,145**	**1,160**	**1,685**
	Totals (both reservoirs)	**3,205**	**3,355**	**1,905**	**2,095**	**1,735**	**2,400**

4.5 POTENTIAL SOURCES OF UPSTREAM COPPER

Copper is typically found in unpolluted lakes and rivers at concentrations of around 4 µg/L (Hill, 2001). Copper values detected in the LAA range from less than 3 µg/L up to 62 µg/L, with an flow-weighted average concentration of 12.7 µg/L, excluding concentrations measured at the time of copper sulfate treatments. Several potential sources were considered to quantify upstream copper sources, such as direct inputs to the LAA from production wells in the Owens Valley, and tributary streams, groundwater, springs or seeps affected by natural or anthropogenic copper sources. Undetermined water supply management practices in the watershed may also be a contributing source to LAA copper.

Research into these potential sources generally did not yield definitive information to account for the relatively high copper concentrations in the LAA. One complicating factor was that the copper test method detection limits for available sampling data were commonly higher than the range of background values seen in the LAA.

4.5.1 Production Well Inputs/Groundwater Sources

Eight wellfields in the Owens Valley contribute water directly to the LAA. Water from these wells could potentially contribute to copper in the LAA, either from naturally occurring copper in soil or rock, or copper leached from water supply components (such as corroding copper piping) into the groundwater. Production wells that contribute flows to the LAA are sampled periodically, but the copper detection limit is typically 1,000 µg/L, outside the range of values needed to compare with LAA background levels.

According to the Inyo County Department of Environmental Health (personal communication, 2001), tap water samples in the city of Bishop, where the detection limit for copper at the tap is 50 µg/L, typically contain copper at around 100 to 150 µg/L, occasionally as high as 300 to 600 µg/L. It is not known to what degree copper plumbing components contribute to the detected copper in tap water. The detection limit for copper at the drinking water supply wellheads (which would be more indicative of background copper concentrations in groundwater) is 1000 µg/L, again too high to provide a useful reference for background concentrations. It is relevant to note that copper is generally not detected at that limit in the Owens Valley.

A potential pathway for copper in tap water to reach groundwater recharge areas or surface water is from septic system leachfields or sewer discharges. The majority of publicly-owned treatment works in Mono and Inyo Counties employ clay-lined evaporation ponds to treat waste water that limit the amount of effluent that may reach ground or surface water. Many unincorporated rural areas and small towns are on septic systems, which present the possibility of tap water leaching into groundwater (D. Feay, personal communication, 2001). However, due to the rural, low-density population of Mono and Inyo Counties, it is unlikely that tap water is a significant source of copper and is considered “de minimis” for the purposes of this sources analysis.

4.5.2 Tributary Stream Inputs

Water quality data, including copper measurements, were available from several sources on numerous tributary streams to the LAA and on the Owens River in Mono and Inyo Counties. Jones & Stokes Associates collected water quality data in the Owens Valley in the spring and summer of 1991. Data were collected on Crooked, Mammoth, Convict, Hilton, McGee and Rock Creeks (all are located in Mono County and drain into the Mono Basin from the eastern Sierra Nevada), and from the Owens River at East Portal and the Crowley Lake outlet, also in Mono County. These data indicate that copper is not typically measured at a detection limit of 20 µg/L. Regional Board monitoring data on Pine Creek in the eastern Sierra Nevada (the site of a tungsten mine in Inyo County near Bishop) shows that copper is not detected at 10 µg/L (M. Ochs, personal communication, 2001).

4.5.3 Lower Owens River Data

The lower Owens River terminates at Owens Lake and does not flow into Haiwee Reservoir; however, it is relevant to review copper data on this reach of the river as it represents potential background conditions (particularly for groundwater) between Tinemaha Reservoir and Owens Lake.

The Inyo County Water Department collected surface water samples along the lower Owens River from Tinemaha Reservoir to Owens Lake in March and August 1999. Analytical results indicate copper was generally not detected at a detection limit of 10 µg/L. One sample (out of eighteen total) collected in the summer 1999 at the pumpback facilities near Owens Lake showed copper at 20 µg/L. Water can be released from the LAA to the lower Owens River or pumped from the river back to the LAA at this point. This detection may be attributed to copper in the LAA water. The flow in the lower Owens River is supplied mainly by groundwater (particularly in the winter months); however, LADWP augments the flow of the lower Owens River with operational releases from the LAA, chiefly in the summer months. Because groundwater is an important source of water to this reach of the Owens River, the lack of copper detections in this limited dataset may indicate that groundwater copper concentrations in the area are comparably low as well.

4.5.4 Mining Activity/Geologic Processes

Numerous mines are present in the mountains surrounding the Mono Basin-Owens Valley area. Principal ores include gold, silver, lead, zinc, tungsten, industrial minerals such as evaporite deposits from the Owens Lake area, and sand/gravel/cinder deposits. Copper mining has historically occurred in the area, particularly on the east side of the Owens Valley in the White and Inyo mountains. South and east of Haiwee Reservoir there is documented historical mining of lead-silver-zinc and some minor tungsten and copper mining (USGS, 1996; DOC, 2000). Copper minerals such as chalcopyrite, azurite, chrysocolla, and malachite are associated with nearly all of the lead-silver-zinc deposits and some of the tungsten deposits in the area immediately east of Haiwee Reservoir. Approximately 1,000 tons of copper have been directly mined from the area (Hall, 1962).

This area east of Haiwee Reservoir does not typically contribute any tributary streams into the reservoir or the LAA, but copper-bearing minerals could have an effect on springs, seeps, or other groundwater contributions to the system. Information is limited on occurrences of copper in the Sierra Nevada mountains, where most of the tributary streams come into the LAA, and it appears the southeastern Sierra Nevada was not historically an important copper mining region. This does not rule out the possibility that copper-bearing minerals are associated with the geology in the Sierra Nevada; however, based on currently available data, no definitive statements can be made regarding the contributions due to this potential source.

4.5.6 Potential Minor Sources of Background Copper

Other possible sources of copper loading to the water column of Haiwee Reservoir were investigated and judged to be insignificant. They include the following:

<u>Copper residuals in sediments in the LAA.</u> According to LADWP, sediments are typically flushed out of the LAA, either as part of a maintenance regime or by high flow rates in the aqueduct; therefore, this potential source was disregarded.

<u>Copper from atmospheric deposition/rainfall</u>. No data was available to estimate the potential contribution of copper from this source; however, rainfall in the area has a minimal influence on the water budget of Haiwee Reservoir, and it is expected that concentrations of copper in rainfall will be relatively low.

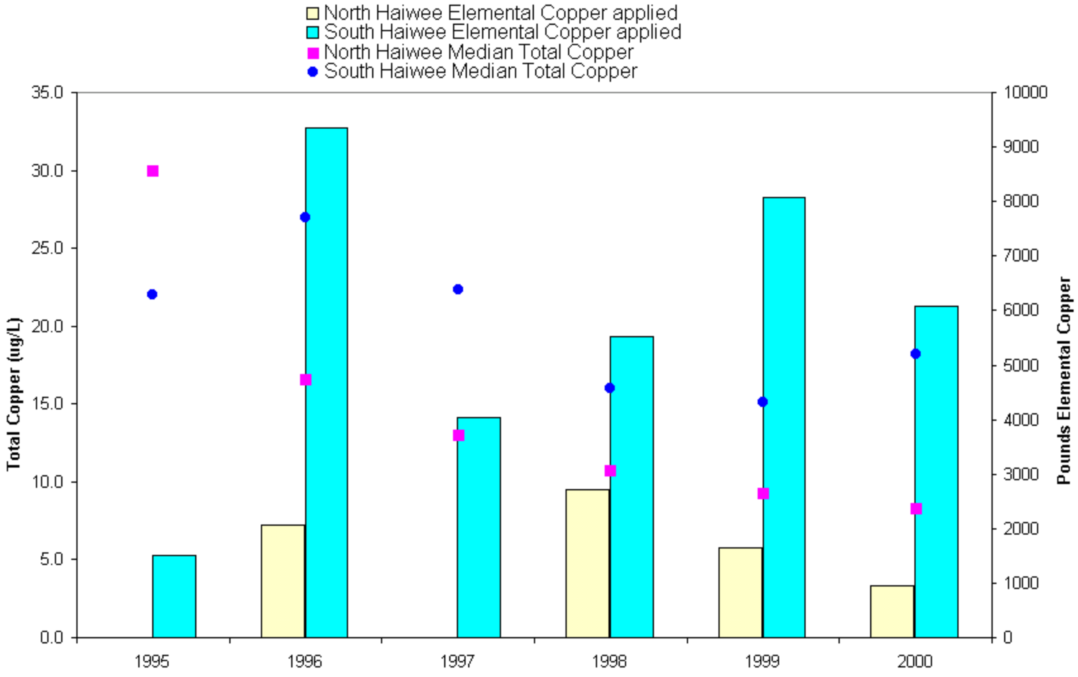
<u>Copper in stormwater runoff.</u> This source may be significant in urban areas where copper from brake and tire wear may accumulate on paved surfaces and be entrained in stormwater runoff (for example, see the Chollas Creek Copper TMDL for urban San Diego). Given the low-density, rural nature of the Mono-Owens watershed, with associated low traffic volumes and low

percentages of impervious surfaces contributing to runoff, it is unlikely this potential source is significant.

4.6 TOTAL YEARLY SOURCES OF COPPER TO HAIWEE RESERVOIR

Quantities of copper algicide discharged directly to Haiwee Reservoir complex vary considerably, both year-to-year and reservoir-to-reservoir. To determine which year most closely characterizes a "representative" year for copper discharges and residuals in the reservoir, summary statistics were performed on weekly monitoring data for North and South Haiwee for the period 1995 to 2000. The median total copper concentrations and pounds of elemental copper applied for each reservoir per year were plotted (Figure 4-1). From 1996 to 2000, median copper concentrations generally show a declining trend. This decline probably reflects the reduced amounts of copper sulfate applied to the reservoir compared to pre-1995 amounts, and may indicate that historically higher amounts of copper applied to the reservoir are "flushing through" the system. The latter portion (1998-2000) of the Haiwee Reservoir monitoring dataset is thought to be most representative of current conditions.

Figure 4-1: Median total copper concentrations in North and South Haiwee Reservoir and amounts of copper sulfate applied, 1995-2000.



Copper discharges in the LAA also vary, from no discharges in 1997 and 1999, to five discharges in 1998 (see Table 4-4). In 1998, an estimated 3,500 pounds of elemental copper were applied in the LAA. The amount of elemental copper applied to the LAA in 1998 represents the only estimate of copper in the aqueduct for the period from 1998-2000 (no copper was applied in the LAA in 1999, and 2000 was excluded from calculations because of anomalous data); therefore, 1998 was chosen as the representative year for this source analysis.

Based on the calculations and data presented in the previous sections, the estimated yearly load of elemental copper to the water column of Haiwee Reservoir is 30,435 pounds. Table 4-5 shows the total contributions of the various sources.

Table 4-5: Water Column Copper Source Analysis Summary
(based on 1998 data)
pounds per year

	Source	**Total**	**% of Total**
External	Copper Sulfate Applications in Reservoir	8,240	27.1%
	Copper Sulfate Applications in LAA	3,500	11.5%
	Upstream Sources of Copper in LAA	16,600	54.5%
Internal	Groundwater	1,105	3.6%
	Resuspension	60	0.2%
	Molecular Diffusion	930	3.1%
	Total Yearly Copper Load*	**30,435**	**100%**

4.7 MASS BALANCE SUMMARY

As outlined in this source analysis, copper enters and exits the water column of Haiwee Reservoir through several different pathways. Copper comes in from copper sulfate discharges, from the LAA, and from internal loading processes. Copper settles out of the water column to the sediment layer, or is entrained in the water column and exits the reservoir system through the LAA1 (for south Haiwee), the LAA2 (for North Haiwee), or from North to South Haiwee through the Merrit cut. As shown in Table 4-6, the modeled net annual mass balance of copper in the water column is zero (copper is continuously present in the Haiwee Reservoir water column; however, it is not *accumulating* on an annual basis). Copper does accumulate in the sediments, however; modeling data from 1998 indicate that approximately 40 to 50 percent of the copper load accumulates in the sediments (see the mass balance discussion and Table D-1 in Appendix D).

Table 4-6: Haiwee Reservoir Water Column Mass Balance Summary (based on 1998 data)

	North Haiwee Reservoir	lbs/year
Sources	Copper Sulfate Discharges in Reservoir	2,720
	Copper Sulfate Discharges in LAA	3,500
	Upstream Copper in LAA	16,600
	Internal Loading	950
Sinks	Out to Sediment Layer	2,440
	Out to LAA2	7,995
	Out to South Haiwee	13,090
	Out to Groundwater	75
	Yearly Copper Load in Water Column	**23,770**
	Yearly Copper Load Leaving Water Column	23,600
	Yearly Mass Balance Copper in Water Column	0%
	South Haiwee Reservoir	
Sources	Copper Sulfate Discharges in Reservoir	5,520
	Incoming Copper from North Haiwee	13,090
	Internal Loading	1,145
Sinks	Out to Sediment Layer	3,100
	Out to LAA1	16,885
	Out to Groundwater	130
	Yearly Copper Load in Water Column	**19,755**
	Yearly Copper Load Leaving Water Column	20,115
	Yearly Mass Balance Copper in Water Column	0%

5. LINKAGE ANALYSIS & LOADING CAPACITY

5.1 INTRODUCTION

The linkage analysis establishes the methods and data that form the quantitative link between of the numeric targets and the associated loading capacities. A loading capacity is the maximum amount of a pollutant that a water body can assimilate and still meet its water quality standards.

The California Toxics Rule (CTR) establishes numeric copper concentration criteria. The linkage analysis applies these criteria to the reservoir system under different loading conditions to determine appropriate loading capacities. The most restrictive of the loading capacities calculated determines the allowable additional loading capacity or the required load reductions. The potential for increases or decreases to the loading capacities due to site-specific conditions will also be discussed.

5.2 STEADY-STATE LOADING CAPACITY

The steady-state loading capacity will be the governing loading capacity under all conditions except when copper is discharged either directly to a reservoir or into the LAA. For this loading capacity copper concentrations are assumed to be uniform throughout the entire volume of the reservoirs. Though this assumption is not practical considering plug flow conditions and fluctuating incoming copper concentrations, it is necessary to establish the maximum loading capacity for the reservoir. Making the conservative assumption that internal loading and losses will not change copper concentrations over short periods of time, the maximum allowable concentration is equal to the CTR chronic criteria, or CCC, of 5.7 μg/L.

The corresponding dissolved copper loading capacity will be calculated by multiplying the CCC by the volume of water in the reservoir (Equation 5-1).

Eq. 5-1 Instantaneous

Steady-State Loading Capacity (dissolved) = CCC (dissolved) * Volume (entire reservoir)

The instantaneous loading capacities represent the maximum allowable load in the specified volume of water, independent of time. The instantaneous steady-state loading capacity for North Haiwee is 193 pounds of copper. The instantaneous steady-state loading capacities for South Haiwee are 309 pounds of copper for the median volume and 205 pounds for the lowest volume treated between 1995 and 2000.

The instantaneous loading capacity is translated to an annual loading capacity by multiplying by the appropriate number of annual water exchanges to determine the overall annual loading capacity. It is important to note that on an annual basis cumulative losses of copper from the water column to the sediment are significant. This results in an effective increase in loading capacity. The changes in internal losses under different loading scenarios are discussed in Appendix E. The effective increase in the annual steady-state loading capacities as a result of internal losses will be 350 and 360 pounds for North and South Haiwee, respectively. The effective annual steady-state loading capacities, for the median volumes in North and South Haiwee are 7,060 and 5,390 pounds per year, respectively.

5.3 POST COPPER DISCHARGE LOADING CAPACITY

Following a copper discharge, copper is not evenly distributed throughout the reservoir and the post-discharge and upstream loading capacities must be analyzed to determine which will be most restrictive under the current conditions. Immediately following the discharge of copper, a volume of water in the treated portion of the reservoir will contain an increased concentration of copper. Free-swimming organisms must be able to escape and the zone of water that would cause acute toxicity. Figure 5-1 shows a plan view, time series for the days following a copper application, consistent with the lateral and axial mixing assumptions presented in Appendix E.

An acute post-discharge loading capacity will set the allowable load in the treated portion of the reservoir. A separate chronic post copper discharge loading capacities will set the allowable load for the appropriate volume after vertical and lateral mixing occurs. Because these loading capacities only apply for a limited time following copper discharge, calculating annual post-discharge loading capacities would be inappropriate. Copper discharge methods and mixing zones are discussed in Appendix E. Figure 5-2 shows the appropriate mixing zones used to determine these loading capacities.

5.3.1 Acute Post-discharge Loading Capacity

Immediately following a discharge of copper, a vertical concentration gradient will exist within the water column. Concentrations below the first few feet will decrease with depth until sufficient time passes to mix the copper throughout the epilimnion. The acute post-discharge loading capacity will set the allowable copper loads in the portion of the reservoir effected by the discharged copper.

Without site-specific mixing data or modeling it is not possible to determine the rate of vertical mixing and diffusion or to determine the properties of this concentration gradient. Therefore, it is assumed that the average concentration within the zone of initial dilution (ZID) will be equal to the CMC. This assumption should assure that at the boundary of the ZID the concentration will be below the actual CMC, while zones higher in the water column are at greater concentrations. Because the concentration in the zone of acute dilution (ZAD) may be above the CCC, but must be below the CMC, the average concentration in the ZAD will be assumed equal to the average of the two. The Implementation Plan will specify the time allowed for concentrations to persist above the CCC level in the ZID and the ZAD. The acute post-discharge loading capacity will be calculated using Equation 5-2.

Eq. 5-2 Post-discharge Loading Capacity = CMC * ZID Volume + (CCC + CMC)/2 * ZAD Volume

Table 5-1 shows the allowable concentrations for each of the zones, the volumes of water in these zones, the resulting loading capacities within each zone and the total instantaneous loading capacity for the treated half of the reservoir. North Haiwee results are for the median volume, while the two sets of results for South Haiwee are for the median and lowest treated volumes.

Table 5-1: Mixing zone concentrations, volumes and loads for the acute loading capacity.

Reservoir	Zone of Initial Dilution			Zone of Acute Dilution			Total
	Volume (acre-ft)	Conc. (μg/L)	Load (pounds)	Volume (acre-ft)	Conc. (μg/L)	Load (pounds)	Loading Capacity (pounds)
North Haiwee	3,670	7.7	77	921	6.6	16	**93**
South Haiwee (median volume)	5,161	7.7	108	1,395	6.6	25	**133**
South Haiwee (low volume)	4,253	7.7	89	741	6.6	13	**102**

5.3.2 Chronic Post-discharge Loading Capacity

For the chronic post-discharge loading capacity, the following conservative assumptions were made:

- the reservoir is stratified at a depth of 20 feet; and
- no significant dilution is expected to occur in the four-day period following a copper discharge.

Therefore, the post-discharge loading capacity of copper in the epilimnion may be calculated using equation 5-3.

Eq. 5-3 Post-discharge loading capacity = CCC * Volume of epilimnion

The volume in the top 20 feet of the water column in North Haiwee under the median operating volume is 9,180 acre-feet. The loading capacity associated with this volume is 142 pounds. In South Haiwee the volumes in the top 20 feet of the water column are 13,111 and 9,987 acre-feet for the median and lowest volume dosed, respectively. The loading capacities associated with these volumes are 203 and 155 pounds.

Table 5-2 summarizes the loading capacities, concentrations and associated volumes of water for each of the loading capacities described above. In practice, the pre-discharge concentration of copper in the reservoir will reduce the available load.

Table 5-2: Steady-state and post-discharge loading capacities with associated volumes and concentrations. Annual loading capacity is calculated by multiplying the steady-state instantaneous loading capacity by the number of annual water exchanges and adding the effective loading capacity from internal losses.

	Critical Volume	Volume (acre-ft)	Critical Concentration (ug/L)	Instantaneous Loading Capacity (lbs)	Annual Loading Capacity (lbs/year)
North Haiwee					
Steady State	Whole Reservoir	12476	5.7	193	**7,062**
Post Discharge Chronic	Epilimnion	9180	5.7	142	
Post Discharge Acute	ZID / ZAD	3670 / 921	7.7 / 6.6	93	
South Haiwee Median Volume					
Steady State	Whole Reservoir	19903	5.7	309	**5,390**
Post Discharge Chronic	Epilimnion	13111	5.7	203	
Post Discharge Acute	ZID / ZAD	5161 / 1395	7.7 / 6.6	133	
South Haiwee Low Volume					
Steady State	Whole Reservoir	13230	5.7	205	**3,703**
Post Discharge Chronic	Epilimnion	9987	5.7	155	
Post Discharge Acute	ZID / ZAD	4253 / 741	7.7 / 6.6	102	

5.4 UPSTREAM DISCHARGE LOADING CAPACITY

The upstream discharge loading capacity accounts for upstream loading to downstream water bodies. This situation occurs following a copper discharge to either to the LAA, which flows into North Haiwee, or a discharge to North Haiwee, which flows into South Haiwee.

Discharges of waters with elevated copper concentrations from North to South Haiwee should consider that one of the most productive locations for fishing in the Haiwee Reservoir system is at the inlet to South Haiwee below Merritt Divide. Therefore, all copper applications in North Haiwee should assure that the rolling one-hour average of water entering South Haiwee not exceed the CMC. Further, the rolling four-day average must not exceed the CCC. The loading capacities associated with these time intervals are shown in Equations 5-4 and 5-5. Note that the rolling averages assume a relatively constant flow, and should not be flow-weighted to protect against a burst of low concentration water masking a longer duration of high concentration water.

Eq. 5-4 Acute Loading Capacity = flow (for any one hour) * CMC

Eq. 5-5 Chronic Loading Capacity = flow (for any four-days) * CCC

To assure protection of aquatic life in North Haiwee, mixing zones should be applied as they would for any point source discharge to a lentic water body. The associated loading capacities must be calculated assuming high LAA flow and low reservoir volumes using a mixing zone model or other mixing zone procedures as appropriate. This information will be required from the discharger.

The second of these methods may be appropriate for determining the upstream discharge parameters for North Haiwee flowing to South, as well.

5.5 WATER COLUMN TOXICITY

The water column toxicity target accounts for additive and synergistic effects between copper and other chemical and physical factors present in Haiwee Reservoir waters, and allows for no observable toxicity except in the mixing zones period following pesticide discharges. If copper related water column toxicity is observed at concentrations below the CTR-based CMC and CCC criteria, these criteria concentration must be set at lower levels. If the CMC or CCC are lowered as a result of this numeric target the loading capacities calculated above will change accordingly.

Because the currently available literature does not provide a basis for predicting additive and synergistic effects in natural systems, arriving at a unique load for this numeric target is not possible without site-specific data. One method for setting revised criteria concentrations is outlined in the USEPA Technical Support Document for Water Quality-based Effluent Control. If chronic or acute toxicity units (TUc and TUa, respectively) are developed the concentration limit may be found using the relationships CCC = 1.0 TUc and CMC = 0.3 TUa.

5.6 SEDIMENT TOXICITY

Similar to the water column toxicity discussion above, observed sediment toxicity will require reactive loading reductions to the point necessary to prevent copper related toxicity.

5.7 CTR MODIFIERS AND HYPOTHETICAL LOADING CAPACITIES

Two site-specific factors may increase the allowable copper concentrations in Haiwee Reservoir. These factors are the water effect ratio (WER) and the translator.

5.7.1 Water Effect Ratios

While the water column and sediment toxicity numeric targets account for additive and synergistic effects that may increase toxicity in site-water, the water effect ratio (WER) accounts for chemical and physical factors that may reduce the toxicity of copper in site water. The WER is a multiplier that corrects for the bioavailability of copper under site-specific conditions. To determine a site-specific WER, side-by-side toxicity tests using laboratory and site water are

compared to determine the relative toxicity of copper in each setting. If a site-specific WER is determined for Haiwee Reservoir, the CCC and CMC will change accordingly.
A hypothetical WER of 5 will result in a CCC and CMC of 28.5 and 38.5 □g/L of dissolved copper, respectively. The loading capacities calculated in the previous sections will correspondingly increase by a factor of 5. WERs of this magnitude have been found for other water bodies, however, it must be understood that there is no indication that this hypothetical value has any applicability to Haiwee Reservoir. The hypothetical WER is simply used to facilitate technical discussion.

5.7.2 Translators

The numeric target and future monitoring will focus on the dissolved copper criteria, which is more closely associated with bioavailability then total recoverable copper. Factors influencing the proportion of dissolved to total recoverable copper are discussed in Appendix E. A translator is a multiplier that converts the dissolved copper criteria to total recoverable limits. The total recoverable copper loading capacities can be derived from the dissolved copper loading capacities using the translator in the following relationship.

Eq. 5-6

$$\text{Loading Capacity (total recoverable)} = \frac{\text{Loading Capacity (dissolved)}}{\text{Translator}}$$

The only available data for Haiwee Reservoir that relates dissolved to total recoverable copper are from six samples collected from North Haiwee on March 21, 1996, set shown in Table 5-2. This data does not present enough evidence to establish a site-specific translator, but it does indicate that less than one half of the total recoverable copper was dissolved in the water column in these samples. The highest observed fraction of dissolved to total recoverable copper from this small data set is 0.31.

Table 5-3: Total recoverable verses dissolved copper concentrations for samples collected from North Haiwee Reservoir.

Water Column Copper Data from North Haiwee Reservoir, March 21, 1996 (Jenkins et al.. 1996)

Sample ID	Dissolved Cu (ug/L)	Total Cu (ug/L)	Dissolved/Total %
2-Top	1.11	4.45	24.94%
2-Bottom	0.97	4.71	20.59%
5-Top	0.41	1.34	30.60%
5-Bottom	0.94	11.07	8.49%
17-Top	0.75	2.99	25.08%
17-Bottom	1.49	5.89	25.30%

A hypothetical site-specific translator of 0.33 applied to the steady state and chronic post discharge loading capacities would result in total copper loading capacities 3 times greater than the dissolved copper loading capacities. A more conservative hypothetical translator of 0.66 may be more appropriate for calculating the total copper acute post-discharge loading capacity. This more conservative translator may account for increases in the fraction of dissolved copper immediately following a copper discharge. These hypothetical translators do not presume to be applicable to Haiwee Reservoir. They are presented here simply to facilitate technical discussion.

5.7.3 Hypothetical Loading Capacities

Using the hypothetical WER and translator dramatically changes the allowable loading capacities as shown in Table 5-4. The resulting annual steady-state total copper loading capacities are 15 times greater than the corresponding annual dissolved copper loading capacities shown in Table 5-2, above.

Table 5-4: Steady state and post-discharge loading capacities with associated volumes and concentrations using a WER of 5 and translators of 0.33 for steady state and chronic post-discharge loading capacities, and a translator of 0.66 for acute post-discharge loading capacities. Annual loading capacity is calculated by multiplying the steady-state instantaneous loading capacity by the number of annual water exchanges and adding the effective loading capacity from internal losses.

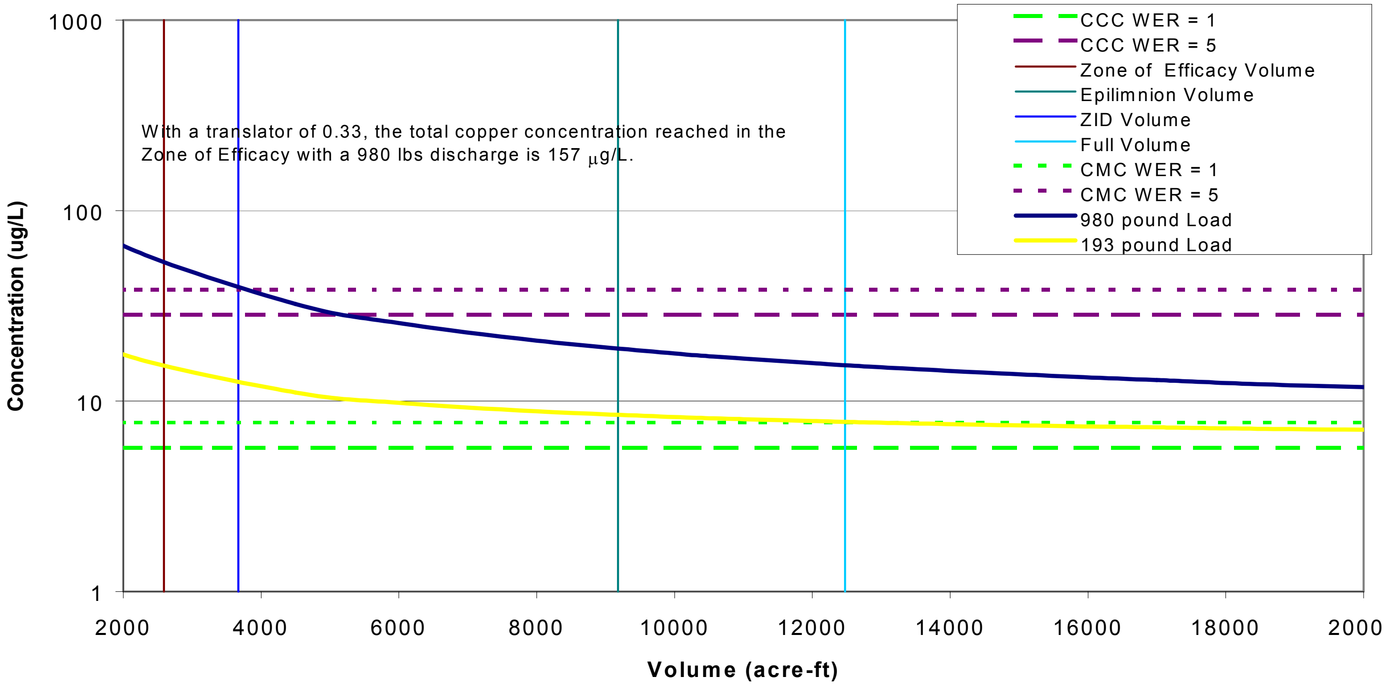
	Critical Volume	Volume (acre-ft)	Critical ~~Dissolved~~ Concentration (ug/L)	Instantaneous ~~Total~~ Loading Capacity (lbs)	Annual ~~Total~~ Loading Capacity (lbs/year)
North Haiwee					
Steady-state	Whole Reservoir	12476	28.5	2,931	**102,046**
Post-discharge Chronic	Epilimnion	9180	28.5	2,156	
Post-discharge Acute	ZID / ZAD	3670 / 921	38.5 / 33.0	707	
South Haiwee Median Volume					
Steady-state	Whole Reservoir	19903	28.5	4,675	**76,569**
Post-discharge Chronic	Epilimnion	13111	28.5	3,080	
Post-discharge Acute	ZID / ZAD	5161 / 1395	38.5 / 33.0	1,007	
South Haiwee Low Volume					
Steady-state	Whole Reservoir	13230	28.5	3,108	**51,018**
Post-discharge Chronic	Epilimnion	9987	28.5	2,346	
Post-discharge Acute	ZID / ZAD	4253 / 741	38.5 / 33.0	775	

Figures 5-3 and 4 show the resulting dissolved copper concentration for applied loads to North and South Haiwee using the translator of 0.33, including a pre-discharge copper concentration equal to the 75th percentile total recoverable copper concentration found from samples collected at the outlet of each reservoir. Under these hypothetical conditions, effective concentrations may be achieved in the zone of efficacy without exceeding the allowable concentrations in the epilimnion or whole reservoir. It should be noted that these figures do not use the translator of 0.66 that would be appropriate in the initial hours of dilution in the smaller volumes of water.

Figure 5-3

North Haiwee Dissolved Concentration Volume Relationships

for Various Added Copper Loads Including a 17.9 μg/L Background Total Copper Concentration and a Translator of 0.33

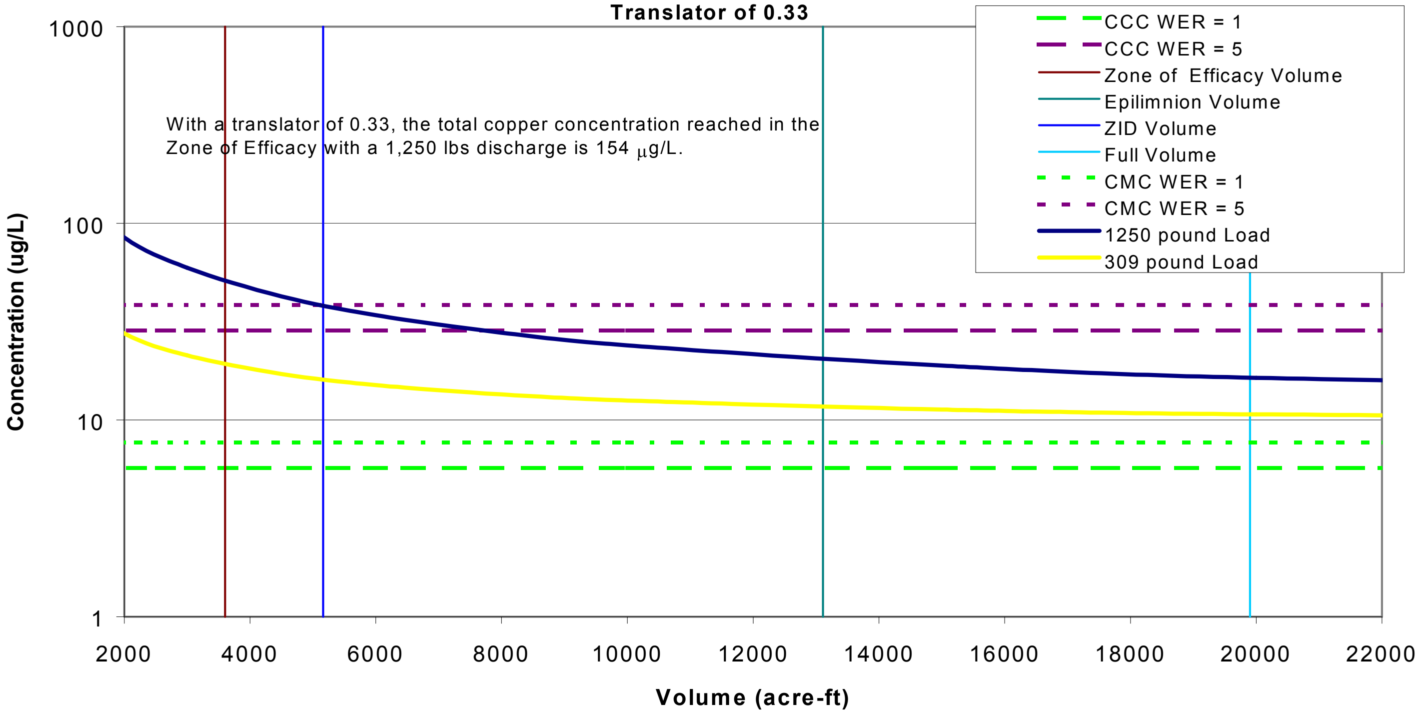


With a translator of 0.33, the total copper concentration reached in the Zone of Efficacy with a 980 lbs discharge is 157 μg/L.

Figure 5-4

South Haiwee Dissolved Concentration Volume Relationships

for Various Added Copper Loads Including a 26.7 μg/L Background Total Copper Concentration and a Translator of 0.33



With a translator of 0.33, the total copper concentration reached in the Zone of Efficacy with a 1,250 lbs discharge is 154 μg/L.

5.7.4 Potential for Algae Control

To effectively reduce algae populations, target copper concentrations must be achieved in the portion of the water column where their populations are greatest. Figures 5-3 and 4 show that total copper concentrations in the zone of efficacy are at levels targeted by LADWP in the past for algae control.

Other means of achieving efficacious copper concentration levels could include discharging copper to a smaller portion of the reservoir than one-half. There are many discharge scenarios that may make this possible. Any discharge scenario must respect the plug flow assumption for water moving through Haiwee Reservoir and understand that organisms must not be expected to travel a distance greater than half of the width of the reservoir to escape zones of high copper concentration. For example, discharging copper to one quarter of the reservoir, by dividing the reservoir down the long and short axes would not allow for a greater concentration to be achieved in the zone of efficacy. The lack of axial mixing will limit dilution to the portion of the reservoir receiving copper. It may be possible, however, to achieve greater concentrations in the zone of efficacy if copper were discharged to a strip down the middle of the reservoir which only covers one-quarter of the surface of the reservoir.

5.7.5 Current Calculations Do Not Employ Site-Specific Factors

It is not possible to determine site-specific WERs and translators for the Haiwee Reservoir system with currently available data. Therefore, for this initial TMDL analysis, loading capacities used to determine the load allocations will be calculated using default values of 1 for both the WER and translator.

6. LOAD ALLOCATION

6.1 INTRODUCTION

Loading capacities are the sum of wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and an explicit or implicit margin of safety (MOS). The loading capacity is loosely referred to as the "Total Maximum Daily Load" or TMDL even though it is frequently not expressed as a daily load.

TMDL = WLA + LA + MOS

This section will discuss potential LAs and WLAs in relation to the loading capacities presented in the Linkage Analysis and Loading Capacity. Site-specific WERs and translators must be determined before definitive load allocations can be made. Because the margin of safety is implicit, it does not require a specific allocation.

6.2 LOAD ALLOCATIONS

6.2.1 Steady-state Load Allocations

The annual steady-state loading capacities found in the Linkage Analysis, using default WER and translator values of 1, were 7,060 and 5,390 pounds per year for North and South Haiwee, respectively. The external sources discussed in the Source Analysis are summarized in Table 6-1, showing that a total of 23,000 and 19,000 pounds of copper enter North and South Haiwee, respectively. To meet the annual steady-state loading capacity using the default WER and translator, nearly 70 percent load reductions will be required in each reservoir.

Table 6-1: External Sources to the Water Column (pounds per year)*

Source	Load
North Haiwee	
Copper Sulfate Discharges to Reservoir	2,720
Copper Sulfate Discharges to LAA	3,500
Undefined Copper from LAA	16,600
Total	**22,820**
South Haiwee	
Copper Sulfate Discharges to Reservoir	5,520
Copper from North Haiwee	13,090
Total	**18,610**

*Data is from 1998 and uses the Haiwee Reservoir Model.

Using the hypothetical WER of 5 and translators of 0.33 and 0.66, as described in the Linkage Analysis, the steady-state loading capacity is 102,000 and 76,600 pounds per year for North and

South Haiwee, respectively. Under these conditions, the steady-state loading capacity would not require a load reduction because the annual loads to the reservoirs are less than these loading capacities.

6.1.1 Post-Discharge Load Allocations

Both the acute and chronic post-discharge loading capacities must be found to determine the most restrictive loading capacity and the available load for copper discharges. The pre-discharge reservoir concentrations will be required to determine the load of copper in the reservoir before additional copper loads are added. The methods for designating the pre-discharge concentrations must be determined. If no discharges have occurred in the proceeding weeks, one possible method could be to use the 75th percentile observed outlet copper concentration.

Using the default WER and translator value of 1, load reductions would be required before copper may be discharged to either reservoir.

Table 6-2 summarizes the post-discharge load allocations using the hypothetical WER and translators described in the Linkage Analysis and the 75th percentile observed outlet concentrations as the pre-discharge concentrations. The acute post-discharge loading capacity is the most restrictive for these pre-discharge concentrations and sets the copper discharge WLA.

Table 6-2: Load allocations using a WER of 5 and translators of 0.33 and 0.66 to calculate the chronic and acute post-discharge loading capacities, respectively. The 75th percentile observed outlet total recoverable copper concentration is used for pre-discharge copper concentrations for North and South haiwee, 17.9 μg/L and 26.7 μg/L, respectively.

	Critical Volume	Volume (acre-ft)	Instantaneous ~~Total~~ Loading Capacity (pounds)	~~Total~~ Load from Pre-discharge Concentration (lbs)	Load Allocations (lbs)
North Haiwee Median Volume					
Chronic Post Discharge	Epilimnion	9180	2,156	447	1,709
Acute Post Discharge	ZID / ZAD	3670 / 921	707	223	**484**
South Haiwee Median Volume					
Chronic Post Discharge	Epilimnion	13111	3,080	952	2,128
Acute Post Discharge	ZID / ZAD	5161 / 1395	1,007	476	**531**
South Haiwee Low Volume					
Chronic Post Discharge	Epilimnion	9987	2,346	725	1,621
Acute Post Discharge	ZID / ZAD	4253 / 741	775	363	**412**

6.3 LOAD REDUCTIONS AND LIMITATIONS

If site-specific WERs and translators result in loading capacities less than current annual load, load reductions will be required. Load reductions may be achieved by decreasing the copper discharged to the reservoirs as pesticides, by decreasing the copper entering from the Los Angeles Aqueduct (LAA), or both. Setting a stringent WLA for copper discharged as pesticides has the advantage of being completely controllable, but the loss of copper as a mechanism for algae control may have negative repercussions. Further investigation into the sources of copper to the LAA may show that it is feasible to set a LA for copper entering the reservoir system that may allow for continued use of copper based pesticides.

Default WERs and Translators

Load reductions could be prioritized by the expected ability to control the load. Table 6-3 summarizes the required load reductions to meet the annual steady-state loading capacity if the default value of 1 were used for WERs and translators. Because copper discharges can be easily and completely controlled, they would be eliminated. The additional load reduction would be taken from the unidentified LAA category, requiring a 57 percent reduction. If the unidentified load from LAA could be reduced below 7,060 pounds, however, further copper discharges may be possible.

Table 6-3: Loading reductions to meet the steady-state loading capacity using the default WER and translator values of 1.

Source	Current Load (pounds/year)	Allowable Load (pounds/year)	Percent Reduction
North Haiwee			
Copper Sulfate Discharges to Reservoir	2,720	0	100
Copper Sulfate Discharges to LAA	3,500	0	100
Undefined Copper from LAA	16,600	7,060	57
Total	**22,820**	**7,060**	**69**
South Haiwee			
Copper Sulfate Discharges to Reservoir	5,520	1,320	76
Copper from North Haiwee	13,090	4,070	69
Total	**18,610**	**5,390**	**71**

*Loading data is from 1998 and uses the Haiwee Reservoir Model as described in the Source Analaysis.

The load reductions in North Haiwee will result in water with lower copper concentrations entering South Haiwee through Merritt Divide. If loading to North Haiwee were reduced by the amount specified in Table 6-3, the Haiwee Copper Model predicts that the load entering South Haiwee will be 4,070 pounds per year. Because this load is less than the loading capacity for South Haiwee no additional load reduction would be required and an additional 1,320 pounds of copper could be added to the South Haiwee as a discharge. All discharges would be required to meet the post-discharge load allocations.

7. MARGIN OF SAFETY, SEASONAL VARIATION AND CRITICAL CONDITIONS

7.1 INTRODUCTION

TMDLs must include an explicit or implicit margin of safety (MOS) to account for uncertainty in the TMDL analysis. An explicit MOS can be provided by reserving (not allocating) part of the total loading capacity and requiring greater load reductions from existing and/or future source categories. An implicit MOS can be provided by conservative assumptions in the TMDL analysis. The Haiwee Reservoir TMDL includes an implicit margin of safety.

The TMDL analysis must also take into account seasonal variations and critical conditions to assure that the load allocations will support water quality standards at all times. This section will evaluate sources of uncertainty in the TMDL analysis, the conservative assumptions that will comprise the implicit MOS, and conclude with a discussion of seasonal variations and critical conditions.

7.2 SOURCES OF UNCERTAINTY

Considerable quantities of data were available on hydrologic conditions, including inflow, outflow, and reservoir volume information. This information limited the element of uncertainty related to the water balance of the reservoir, which was a crucial component of the linkage and loading capacity calculations. A detailed dataset of copper monitoring information exists, which aided in estimating copper sources to the reservoir.

Although these data provided information to evaluate several key components of the TMDL, limited or incomplete data introduced uncertainty in other areas of the analysis, as described below.

1. Very little data were available regarding sediment copper concentrations and partitioning between particulate and dissolved copper in the sediment layer; further, no sediment data for South Haiwee were available.

2. No data were available on the flow volume between North and South Haiwee Reservoirs.

3. Limited dissolved copper data required assumptions to be made regarding the relationship between total recoverable and dissolved copper concentrations.

4. The effects of increased particulate matter resulting from algae blooms and die-off on copper partitioning and sedimentation in the reservoir are difficult to predict.

5. No data were available regarding groundwater copper concentrations or flows.

6. No data were available on copper entering the reservoirs from bank erosion or direct surface runoff.

7. Detection limits for copper monitoring data in the watershed were generally too high to indicate whether creeks or streams were significant sources of copper to the LAA or the reservoir.

8. Data on the amount of copper sulfate discharged in the LAA were not available; therefore, the contribution from this source was estimated using copper monitoring data and the Haiwee Reservoir Copper Model.

9. Total recoverable copper concentration data may be inaccurate due to the lack of stringent quality assurance/quality control procedures in sampling and analysis.

10. No information was available regarding the applications of polymer and ferric chloride to the LAA. These applications may effect copper partitioning, sedimentation patterns, or result in additive or synergistic toxicity effects in combination with copper.

11. Volume-to-elevation relationships for South Haiwee Reservoir have not been updated since 1972; North Haiwee Reservoir has not been updated since 1984. Some filling due to sedimentation may have occurred that will change these relationships in the reservoirs.

12. The Haiwee Reservoir Copper Model uses turbidity values as a TSS indicator in its calculations; however, the correlation is not well supported by literature or limited data from Haiwee Reservoir.

13. The Haiwee Reservoir Copper Model assumes one representative sediment size (sandy-silt) with one dry bulk density, porosity, and average settling rate derived from literature values.

14. The model assumes that the Y-gate connecting LAA1 and LAA2 is always closed; therefore, flow through the Y-branch is assumed to be zero. The flow balance will be inaccurate during times when the Y-branch is open (this is assumed to be a rare occurrence).

7.3 CONSERVATIVE ASSUMPTIONS

7.3.1 California Toxics Rule Conservative Assumptions

CTR is protective of the more sensitive species (*Ceriodaphnia dubia*) that may inhabit Haiwee Reservoir. The CTR default WER of 1 is conservative because it assumes that the toxicity of natural (site) water and laboratory water are the same; however, natural waters typically contain more organic matter or other metal binding sites that result in the formation of reduced-toxicity copper complexes. The translator of 1 is conservative because it maximizes the potential dissolved portion of the copper in the system to a much greater degree than is expected in a natural system. Further, the numeric target is set at the level corresponding to the median of June hardness values (the month with the lowest hardness measurements in the dataset).

If site-specific WERs and translators are found for Haiwee Reservoir, they will be protective because:

- The WER and translator protocols minimize uncertainty by using site water under various critical conditions.
- The WER protocol bases the final WER upon statistically conservative results to arrive at protective values.

7.3.2 Mixing Zone Conservative Assumptions

The assumptions that the Zone of Initial Dilution (ZID) is a completely mixed, isolated volume in the top 10 feet of the water column in one half of the reservoir are conservative. Because copper sulfate is highly soluble in water, it is expected that applied copper sulfate will dissolve in the top few feet of the water column and slowly mix and diffuse downward in the water column. This will likely result in a concentration gradient with higher concentrations near the top of the water column and lower concentrations towards the bottom of the water column.

Monitoring for compliance with the designated mixing zones will allow a buffer to be included in the ZID to allow for short term lateral mixing. The volumes associated with these buffers have not been included in the calculations of dilution, resulting in a reduced volume and thus higher calculated concentrations than will be expected. Setting the stratification layer at 20 feet and not accounting for any mixing between the waters above and below the stratification layer are similarly conservative assumptions.

Copper applications and mixing zones are restricted to a confined area allowing for ample locations for mobile species to escape to safe areas both vertically and laterally in the water column. Mixing zone calculations assume that copper applications occur at one moment, which maximizes the initial concentration of copper in the water column at any one time. In practice, mobile organisms will have the opportunity to migrate out of the zone of high copper concentrations as the copper is successively discharged in passes over a period of two to four hours.

A margin of safety for the water column or sediment toxicity targets is unnecessary. The numeric target of zero copper-associated toxicity outside of the designated mixing zones following copper discharges is protective for all water column and sediment related water quality standards.

7.3.3 Source Analysis Conservative Assumptions

Source analysis calculations were based on a “representative” year of copper discharges, rather than an average or median year. The year depicted in the source analysis, 1998, represents the largest amount of copper discharged to North Haiwee Reservoir (2,270 pounds) for the period 1995 to 2000. The estimated amount of copper discharged to the LAA in 1998 also represents the high value for the available data. These high values of copper discharges provide a conservative assumption in the source analysis calculations. For South Haiwee Reservoir, the amount of copper discharged in 1998 (5,520 pounds) corresponds closely to the average value of 6,197 pounds of copper for the period 1995 to 2000.

7.3.4 Modeling Conservative Assumptions

Copper partitioning in the water column is assumed to be shifted strongly toward the dissolved phase, which results in an estimate of greater concentrations of biologically available copper in the water column.

7.4 SEASONAL VARIATION AND CRITICAL CONDITIONS

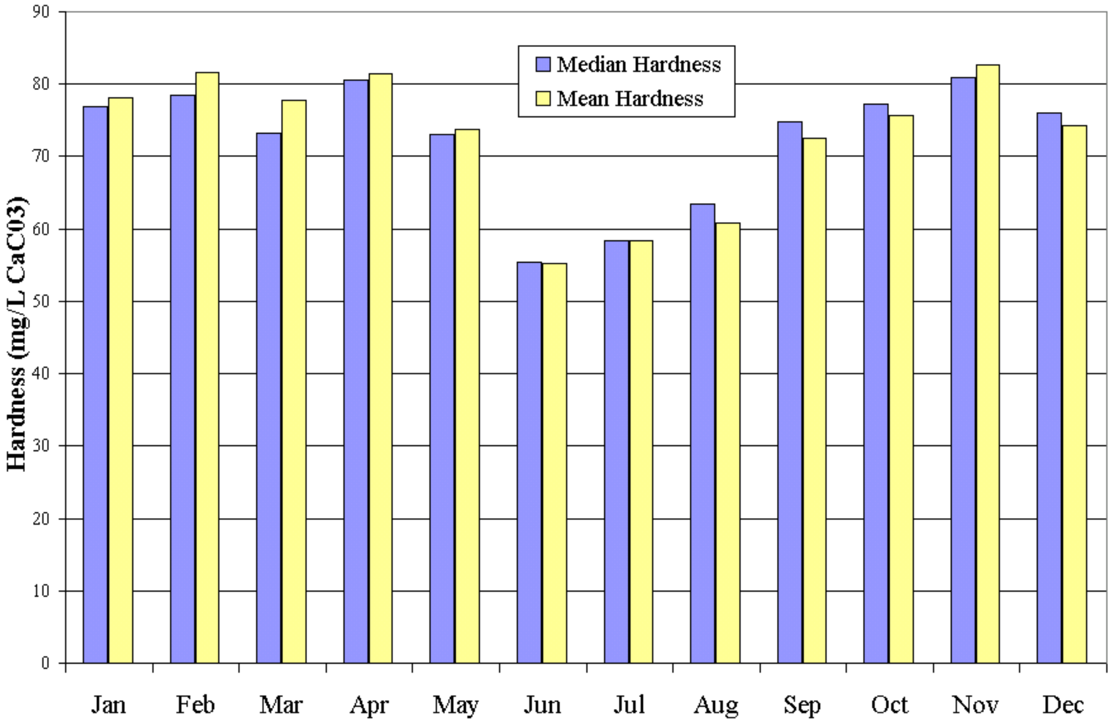
The TMDL must include consideration of seasonal and interannual variations and critical conditions. The USEPA defines critical conditions as “the combination of environmental factors (e.g., flow, temperature, etc.) that result in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence” (USEPA, 1999).

The major continuous sources of copper entering the reservoir system from the LAA do not exhibit a predictable seasonal variation. Though some elevated copper concentrations found in the water exiting North or South Haiwee can be correlated to copper applications, generally, copper concentrations measured in the reservoir are variable with a decreasing trend observed from 1995 to 1998. Using the 75th percentile copper concentrations detected during routine monitoring at each reservoir outlet accounts for most expected variability in copper concentrations.

The copper sulfate applications to the LAA, North Haiwee and South Haiwee vary seasonally. Copper sulfate discharges are the primary critical condition present in the reservoir system due to the resulting dramatic increase in copper concentrations. Copper sulfate applications are triggered by observation of undesirable taste and odors, which correspond to seasonal periods (typically summer and early fall) of high algae production. Cumulative increases of copper from multiple treatments within one reservoir residence time will be protected against in the Implementation Plan.

Critical conditions for copper toxicity occur when water hardness is low, thus reducing the CCC and CMC. Hardness observed at North Haiwee Reservoir from 1995 to 2001 appears to have a minor seasonal variation. Figure 7-1 shows mean and median hardness values grouped by month for the period 1995 through 2001. The lowest values occur during the months of June, July and August.

Figure 7-1: Mean and Median Hardness Values Grouped by Month (data collected at Merrit Cut from 1995-2001)



The numeric target is set at the level corresponding to the median hardness value for the month of June, 55.4 µg/L. Using this value is protective because it gives lower CCC and CMC values, 5.4 µg/L and 7.7 µg/L, respectively, than would be expected during any other month. This assumption is reasonable because the majority of copper sulfate discharges occur in the summer and early fall months.

The speciation of copper compounds and complexes present in the water column and sediments vary seasonally and depend on factors such as pH, temperature, alkalinity, salinity, and concentrations of bicarbonate, sulfide, and organic ligands. Both biologic availability and toxicity are significantly reduced by increased loadings of suspended solids, natural organic chelators and increased water hardness. Changes in these variables may result in fluctuations in the availability of metal binding sites in the water column and sediment, or a shift in the oxidation-reduction potential of the system (Brownlow, 1996). Copper tends to form reduced-toxicity complexes by binding with organic matter, humic acids and acid volatile sulfides (AVS) in anoxic sediment. Under oxygenated conditions, copper may also be sorbed onto oxide or clay minerals. Seasonal water column and sediment toxicity monitoring will verify that conditions in Haiwee Reservoir remain conducive to copper complexation with inorganic and organic compounds, resulting in reduced bioavailability and toxicity.

REFERENCES

Brownlow, A.R. 1996. *Geochemistry*, 2nd ed. New Jersey: Simon and Schuster.

California Department of Fish and Game (DFG). 1991. Pesticide Laboratory Report.
-----1994. *Initial Report of Fish and Wildlife Loss; Request for Laboratory Analysis*.

California Natural Resources Conservation Service (NRCS), United States Department of Agriculture. 2001. *Benton-Owens Valley Soils Survey for Haiwee Reservoir, Inyo County, California.*

California Regional Water Quality Control Board (CRWQCB). 1995. *Cleanup and Abatement Order No. 6-95-45*. California Regional Water Quality Control Board - Lahontan Region.

California State Water Resources Control Board (SWRCB). 1991. *Toxic Substances Monitoring Program Report*. Division of Water Quality, Monitoring and Assessment Unit.
-----1994. Decision 1631: *Decision And Order Amending Water Right Licenses To Establish Fishery Protection Flows In Streams Tributary To Mono Lake And To Protect Public Trust Resources At Mono Lake And In The Mono Lake Basin.* (available at http://www.monobasinresearch.org/images/legal/d1631text.htm).

Danskin, W. 1998. *Evaluation of the Hydrologic System and Selected Water-Management Alternatives in the Owens Valley, California*. USGS Survey Water-Supply Paper 2370, in cooperation with Inyo County and the Los Angeles Department of Water and Power (available at http://ca.water.usgs.gov/rep/wsp2370/).

Department of Conservation, Office of Mine Reclamation. 2000. *PAMP (Principle Areas of Mine Pollution)*. Tabular Digital Data

Eisler, Ronald. 1998. *Copper Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Contaminant Hazard Reviews Report 33.* U.S. Geological Survey. USGS/BRD/BSR--1997-002.

Hall, Wayne E. and E.M. MacKevett, Jr. 1962. *Geology and Ore Deposits of the Darwin Quadrangle, Inyo County, California*: U.S. Geological Survey Prof. Paper 368.

Hill, C. 2001. *Haiwee Reservoir – Effects of Copper on Biota*. Tetra Tech, Inc.

Ingersoll, C.G., et al. 2000. *Prediction of Sediment Toxicity Using Consensus-based Freshwater Sediment Quality Guidelines*. USEPA 905/R-00/007.

Jenkins, K.D., et al. 1996. *The Bioavailability and Potential Chronic Toxicity of Copper in Sediments and Surface Waters of North Haiwee Reservoir, Inyo County, CA*. Prepared for Los Angeles Department of Water and Power, Water Quality and Distribution Division.

Jones & Stokes, Associates. 2000. *Inyo County General Plan Update* (available at http://www.jonesandstokes.com/plan/inyogp/).

Kneebone, P.A., et al. 2000. *Rapid Evolution of Arsenic Speciation in Arsenic- and Iron-Enriched Reservoir Sediments*. Submitted to Environmental Science and Technology, May 2001.

Mikel, T., et al. 1999. *North Haiwee Reservoir Chronic Toxicity and Benthic Infaunal Assessment Report*. Prepared for Los Angeles Department of Water and Power, Water Quality and Distribution Division.

Rheiner, T. 1995. *Staff Report – Copper Sulfate Application to Tinemaha Reservoir and the Haiwee Reservoir Complex and Water Quality, Inyo County*. California Regional Water Quality Control Board Lahontan Region.

Singely, G.C., et al. 1993. *Mitigated Negative Declaration – Limited Fishing Permit Request Haiwee Reservoir Inyo County*. Los Angeles Department of Water and Power.

Stinson, M.C. 1977. *Geologic Map and Sections of the Haiwee Reservoir 15-Minute Quadrangle*. Map Sheet 37. California Division of Mines and Geology.

Stinson, M.C. and Robert Streitz. 1974. *Geologic Map of California - Death Valley Sheet.* California Division of Mines and Geology.

Stolarik, G.F, and J. Don Christie. 1999. *Interim Arsenic Management Plan for Los Angeles.* Proceeding of the 1999 American Water Works Association Annual Conference, Chicago. Los Angeles Department of Water and Power.

Thomann, R. V. and Mueller, J. A. 1987. *Principles of Surface Water Quality Modeling and Control*. Harper International Edition.

U.S. Environmental Protection Agency. 1991. *Technical Support Document for Water-Quality Based Toxics Control*. EPA/505/2-90-001. Office of Water.
-----1994. *Short Term Methods for Estimating the Chronic Toxicity of Effluents to Freshwater Organisms*. Third Edition. Eds: Lewis PA, Klemm, Lazorchak JM, Norberg-King TJ, Peltier WH, Heber MA. EPA/600/4-91/002. Office of Research and Development.
-----1994. *Interim Guidance on Determination and Use of Water Effect Ratios for Metals*. EPA/823/B-94-001. Office of Water, Washington, DC.

U.S. Geological Survey. 1996. *MAS_MILS (Minerals Industry Location Systems_ Minerals Availability System): Active-, inactive-, and abandoned-mine information and selected geochemical data for the State of California.* Open-File Report 96-004.

Western Regional Climate Center. 2001. *Haiwee, California - Period of Record (1948-2000). General Climate Summary – Temperature* (available at http://www.wrcc.dri.edu/).

Yoshimura, R. 1993. *Copper Sulfate Use in Owens Valley, 1992*. LADWP Water Quality Division Internal Memorandum, January 7, 1993.

UNPUBLISHED ELECTRONIC DATA SUPPLIED BY LADWP

DWP Haiwee Elemental Copper.xls
South Haiwee Copper.xls
South Haiwee Outlet Copper.xls
North Haiwee Copper.xls
Merrit Cut Copper.xls
Merrit Cut TSS.xls
Aqueduct Copper.xls
OV Treatment times.xls
Merrit Cut Alkalinity.xls

GLOSSARY

Additive toxicity. A characteristic property of a mixture of toxicants that exhibits a total toxic effect equal to the arithmetic sum of the effects of the individual toxicants.

Axial mixing. Mixing along the long axis (length) of a waterbody.

Benthic. Material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.

Criterion Continuous Concentration (CCC). Highest concentration of a toxicant or an effluent to which organisms can be exposed for a long duration without causing an unacceptable effect (synonymous with chronic criteria).

Criterion Maximum Concentration (CMC). Highest concentration of a toxicant or an effluent to which organisms can be exposed to for a brief period without causing an acute effect (synonymous with acute criteria).

Dissolved metal (copper). That portion of metal in an aqueous sample that passes through a 0.45 micron membrane filter.

Epilimnion. See "Stratification".

Hypolimnion. See "Stratification".

Lateral mixing. Mixing along the short axis (width) of a waterbody.

Mixing zone. A limited area or volume of water where initial dilution of a discharge takes place and where numeric water quality criteria can be exceeded by acutely toxic conditions are prevented.

Residence time. The average amount of time a parcel of water will reside in a defined area (such as a reservoir**).**

Stratification (of waterbody). Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter, warmer water overlying heavier, cooler and denser water. The upper layer is called the "**epilimnion"**; the lower layer is the **"hypolimnion".**

Synergistic toxicity. Characteristic property of a mixture of toxicants that exhibits a greater-than-additive total toxic effect

Total recoverable metal (copper). Metal that is in aqueous solution after the sample is appropriately acidified and digested. A measure of both dissolved and particulate metal in an aqueous sample.

Toxic unit acute (Tu_a). A measure of toxicity determined by the reciprocal of the effluent concentration that causes 50 percent of the organisms to die by the end of the acute exposure period.

Toxic unit chronic (Tu_c). A measure of toxicity determined by the reciprocal of the effluent concentration that causes no observable effect on the test organisms by the end of the chronic exposure period.

Water Effects Ratio. A USEPA-approved method to adjust aquatic life criteria for metals to reflect site-specific conditions. A measure of the toxicity of a material in site water divided by the measure of toxicity of the same material obtained in laboratory dilution water.

Unstratified. Indicates a vertically uniform or well-mixed condition in a waterbody. See also "Stratified."

Zone of Acute Dilution (ZAD). In a mixing zone, that area where effluent concentrations must be less than the acute water quality criteria but may exceed the chronic water quality criteria.

Zone of Initial Dilution (ZID). In a mixing zone, the area nearest the discharge point. Effluent concentrations may exceed both acute and chronic water quality criteria.

APPENDIX A
PUBLIC PARTICIPATION

A.1 PUBLIC PARTICIPATION REQUIREMENTS

Federal TMDL regulations require that the public be allowed to review and comment on TMDLs. For TMDLs adopted as Basin Plan amendments in California, opportunities for public participation are provided through the procedures summarized in the USEPA Region IX *Guidance for Developing TMDLs in California* (2000), and through the California Environmental Quality Act (CEQA) review process.

The Lahontan Regional Board maintains mailing lists for parties interested in receiving draft Basin Plan amendments and/or hearing notices, and a separate mailing list for its agenda announcements. The Basin Plan amendment and CEQA review processes include opportunities for written public comments and for testimony at a noticed public hearing. Written responses are required for written public comments received during the noticed public review period, and staff respond orally to late written comments and hearing testimony before Board action is taken.

The Lahontan Regional Board's Basin Plan amendments (including draft TMDLs) are now made available on the Internet and publicized through press releases. Further opportunities for public participation are also provided in connection with review and approval of Regional Board-adopted Basin Plan amendments by the SWRCB and the USEPA. Documentation of public participation, including copies of hearing notices, press releases, written public comments and written responses, and tapes or minutes of hearing testimony will be included in the administrative record of the Basin Plan amendments for USEPA review.

A.2 HAIWEE RESERVOIR TMDL PUBLIC PARTICIPATION

The Haiwee Reservoir TMDL Progress Report is not a formal TMDL document and, as such, will not be adopted as a Basin Plan Amendment or be subject to CEQA review. The progress report will serve as the technical basis for the Haiwee Reservoir Copper TMDL and its implementation plan; therefore, stakeholder participation was considered an integral part of the development of the progress report. As the complete TMDL is developed and refined, opportunities for stakeholder involvement will be expanded upon during the CEQA review and Basin Plan Amendment processes. Below is a summary of the primary opportunities for stakeholder participation provided thus far in the TMDL process for Haiwee Reservoir.

- January 10, 2001:

  Regional Board staff met with LADWP staff in Los Angeles to give a presentation on the upcoming TMDL for Haiwee Reservoir. The goals of the meeting were to establish a good working relationship with LADWP, facilitate information exchange, and provide a common understanding of the TMDL process and the Haiwee Reservoir TMDL.

- February 1, 2001:

Regional Board staff held a public meeting to provide general information on the TMDL process, notify the public of the initiation of the proposed TMDL for Haiwee Reservoir, and to solicit input and involvement in the development of current and future TMDLs. The meeting was held in Bishop, and was publicized through press releases in the Inyo Register (Inyo County) and the Los Angeles Times. Meeting "flyers" were mailed to local and regional public, government and resources agencies, academic/research organizations, recreation/outdoor groups, and potentially affected water suppliers.

- April 5, 2001:

  An informational meeting was held in South Lake Tahoe to demonstrate the Excel spreadsheet-based Haiwee Reservoir Copper Model and discuss critical policy issues. Representatives from Tetra Tech, Inc., under contract by the USEPA for this project, were on hand to present the model and answer questions related to its use. Attendees included staff from LADWP, Department of Pesticide Regulation, the Regional Board and the USEPA. Prior to the meeting, the model was provided electronically to interested stakeholders for their review and comment.

- April 23, 2001:

  Regional Board staff arranged a teleconference call to discuss future site-specific studies at Haiwee Reservoir related to copper toxicity. Members of LADWP's management and technical staff and their consultants participated, as well as staff of the USEPA and the Regional Board.

- June 13, 2001:

  The Haiwee Reservoir TMDL Progress Report was presented as an informational item at a public meeting of the Lahontan Regional Board. The public meeting was held in Bishop (Inyo County) and was noticed in local and regional newspapers.

A.3 FUTURE PUBLIC PARTICIPATION

Prior to the final submittal of the Haiwee Reservoir Copper TMDL to the Lahontan Regional Board and the USEPA, the public will be given the opportunity to review and comment on the TMDL to fulfill CEQA requirements as discussed above. Regional Board staff anticipates working closely with interested stakeholders during the development of the implementation plan and associated Basin Plan amendments. This section will be updated to reflect that level of involvement.

APPENDIX B
PLAN AND TIMELINE FOR COMPLETING THE FINAL TMDL

B.1 INTRODUCTION

This appendix outlines the steps necessary to incorporate the final Haiwee Reservoir Copper TMDL into the Basin Plan. Figure B-1 shows the general schedule for the individual steps described below.

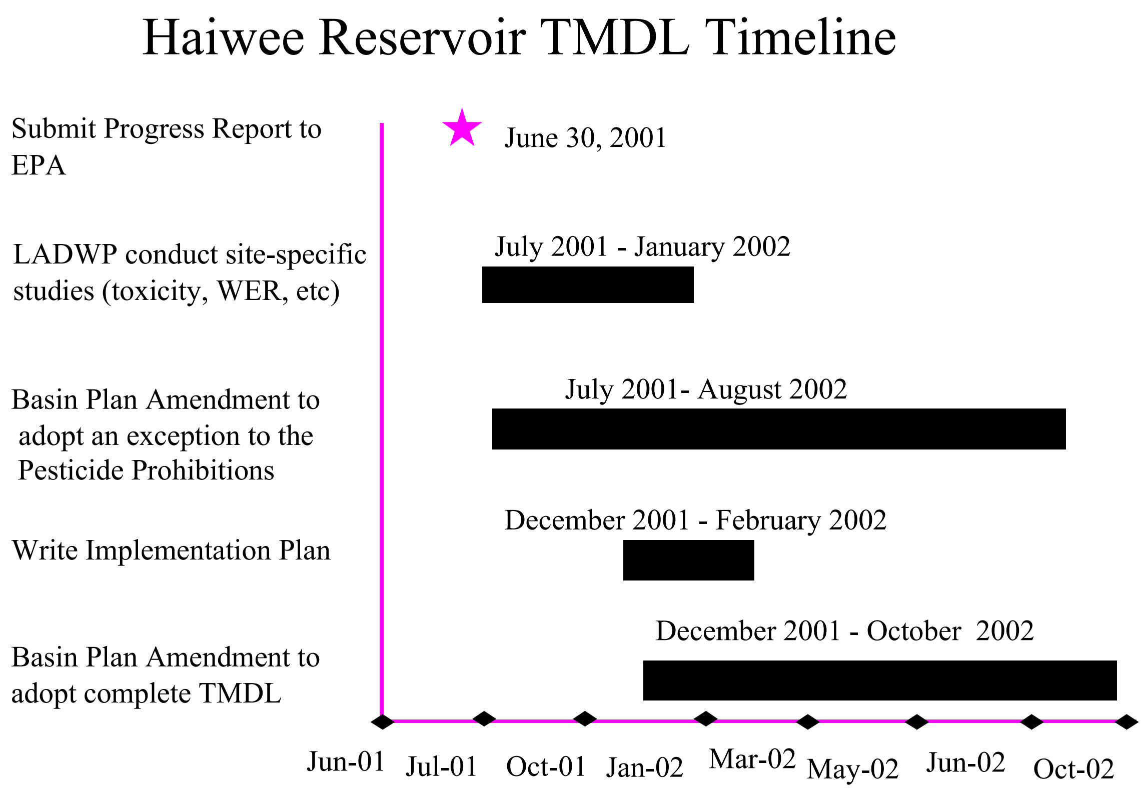


Figure B-1: Haiwee Reservoir TMDL Timeline outlining the final steps needed to complete the TMDL and associated Basin Plan amendments.

B.2 RESERVOIR STUDIES

In April of 2001, discussions began between the Regional Board, the USEPA and LADWP regarding site-specific studies to address the following:

- Water column toxicity
- Sediment toxicity
- Reservoir mixing characteristics
- Site-specific water effect ratio
- Site-specific translator

- Basic reservoir properties such as oxygen profiles and stratification

Additional data may be gathered to address data gaps identified in this progress report and to facilitate the use of the Biotic Ligand Model to determine potential copper toxicity in Haiwee Reservoir.

During the course of discussions, an informal study plan guidance was outlined to aid LADWP and their consultants in developing a proposal for these site-specific studies. Formalizing the work to be accomplished and setting a definitive schedule will be the Regional Board's first priority starting in July. The goal is to initiate fieldwork beginning in the summer of 2001 with initial results available in January of 2002 and continued studies through 2002.

B.3 PESTICIDE PROHIBITION BASIN PLAN AMENDMENT

The TMDL must support all water quality standards. Therefore, the current Basin Plan water quality objective for pesticides must be amended to allow pesticides under certain conditions, which are expected to apply to Haiwee Reservoir. The amendment process will begin in July with the preparation of draft language and CEQA documentation. The public review process is slated to begin in December of 2001 and staff plan to bring the amendment before the Regional Board in the spring of 2002. However, due to the numerous steps involved in the Basin Planning process, delays may prevent Regional Board action on the amendment before the summer of 2002.

Following action by the Regional Board, the amendment must be acted upon by the State Water Resources Control Board, the Office of Administrative Law and USEPA before the amendment will be accepted as part of the Basin Plan.

B.4 IMPLEMENTATION PLAN

After the reservoir studies and Basin Plan Amendment for pesticide use are underway, TMDL Implementation Planning will begin in the winter of 2001. Initial study results will indicate the potential magnitude of the loading reductions required, considering site-specific factors. Once the final study results are received in January of 2002, a more definitive Implementation Plan will be drafted. The plan will be draft until the all studies confirming initial findings regarding site-specific conditions are completed.

B.5 FINAL TMDL BASIN PLAN AMENDMENT

The final TMDL Basin Plan amendment will benefit from the site-specific studies conducted and will follow the amendment for the pesticide water quality objective. The goal will be to have all TMDL Basin Plan amendment materials nearly completed when the Regional Board acts upon the pesticide Basin Plan amendment. Within weeks of the Regional Board action, the TMDL Basin Plan amendment materials will be released for 45-day public review and the final TMDL will come before the Regional Board for approval in the late summer or fall of 2002.

APPENDIX C
PLANT SPECIES AND OBSERVED WILDLIFE AT HAIWEE RESERVOIR

Plant Species
Shadscale (*Atriplex confertfiloia*);
Spiny menodora (*Mendora spinsecens*);
Bud sagebrush (*Artemisia spinescens*);
Creosote bush (*Larrea divaricata*);
Joshua tree (*Yucca brevifolia*);
Spiny hopsage (*Grayia spinosa*);
Allscale (*Atriplex polucarpa*);
Desert needlegrass (*Stipa speciosa*);
Bottlebrush squirreltail (*Sitanion hystric*); and
Cottonwood (*Populus fremontii*)
Willow (*Salix sp*.).
Rubber rabbitbrush (*Chrysothamnus nauseosus*);
Saltgrass (*Distichlis spicata* var. stricta);
Wiregrass (*Juncus balticus*);
Saltcedar (*Tamarix ramosissima*).

Observed Wildlife
Birds of Prey
Golden eagle (*Aquila chrysaetos*)
Bald eagle (*Haliaetus leucocephalus*) (a federal- and state-listed threatened species)
Red-tailed hawk (*Buteo jamaicensis*)
Northern harrier (*Circus cyaneus*)

Mammals:
Mule deer (*Odocoileus hemionus*)
Bobcat (*Lynx rufus*); coyote (*Canis latrans*)
Jackrabbit (*Lepus californicus*)
White-tailed antelope squirrel (*Ammospermophilus leucurus*)
Desert kangaroo rat (*Dipodomys deserti*)
Merriam's kangaroo rat (*Dipodymus merriami*)
Deer mouse (*Peromyscus maniculatus*)
Canyon mouse (*Peromyscus crinitus*)
Desert woodrat (*Neotoma lepida*)
California myotis (*Myotis californicus*)
Western pipistrel (*Pipistrellis Hesperus*)
Pallid bat (*Antrozous pallidus*)

Reference: (Singley, 1993)

APPENDIX D
PARAMETERS USED TO ESTIMATE INTERNAL COPPER SOURCES

D.1 MODEL INPUT PARAMETERS

Table D-1 shows the input parameter values used to derive the modeled estimates of copper sources to Haiwee Reservoir water column.

Table D-1: Haiwee Reservoir Copper Model Control Sheet - Parameter Values

Parameter	Description	Value
Year	Model Year	1998
Inflow Data Type	LAA interpolated timeseries (w/ upstream dosing)	2
LAA Cu	“Average” copper concentration in LAA (w/o dosing)	12.7 µg/L
LAA Multiplier	Flocculent removal of Cu (1 = no Cu removed)	1
Groundwater Cu	Copper in aquifer	2 µg/L
Rain Cu	Copper in rainfall	0 µg/L
NH Water Column Cu	North Haiwee initial copper conc in water column	5.5 µg/L
SH Water Column Cu	South Haiwee initial copper conc in water column	8.7 µg/L
NH Sediment Layer Cu	North Haiwee initial copper conc in sediment layer	0.2 mg/L
SH Sediment Layer Cu	South Haiwee initial copper conc in sediment layer	0.6 mg/L
NH SED depth	Active sediment layer depth	1 inch
SH SED depth	Active sediment layer depth	1 inch
K_{d1}	Water column partition coefficient	0.01 m3/g
K_{d2}	Sediment layer partition coefficient	0.0001 m3/g

D.2 WATER COLUMN COPPER-WATER PARTITION COEFFICIENTS

The equilibrium of dissolved to particulate copper is calculated using a partition coefficient (K_{d1}). Studies have shown that metals like copper have K_{d1} values that typically range from 0.01 m^3/g to 0.1 m^3/g (Thomann and Mueller, 1987). The fractions of dissolved and particulate copper are found through Equations D-1 and D-2, respectively.

Eq. D-1 $$F_{d1} = \frac{1}{K_{d1} m_1 + 1}$$

Eq. D-2 $$F_{p1} = 1 - F_{d1}$$

F_{d1} and F_{p1} are the fractions of dissolved and particulate copper in the water column, respectively, and m_1 is the concentration of copper in the water column. This section describes the effect of selecting different K_{d1} values.

As the sediment concentration increases, the dissolved fraction of copper in the water column decreases because there are more surfaces available for copper to bind. Inversely, as sediment concentration decreases, there are fewer binding sites and more copper in the water column; therefore, the dissolved fraction will increase. The partition coefficient describes how strongly this transition takes place. Mathematically, the value of K_{d1} is proportional to the particulate fraction of copper in the water column; in other words, increasing K_{d1} causes the dissolved-particulate copper equilibrium to shift more strongly to the particulate phase.

Changing K_{d1} changes the mode of transport for copper throughout the reservoir system, but preserves the total mass of copper in the reservoir. For example, if sediment concentrations are equal an increase in K_{d1} will result in more particulate copper, which then becomes available for settling, resuspension, or burial. Both particulate and dissolved copper are available for transport with flow. Table D-2 shows the copper mass balance results from the Haiwee Reservoir Copper Model in the Haiwee Reservoir corresponding to the high and low range values of K_{d1}. The sediment layer mass balance is included in the table for completeness; however, the sediment layer is only considered in this source analysis for its effect on the water column copper load.

Table D-2: Total Copper Mass Balance Comparison
Using low and high range K_{d1} values
(Data from 1998)

K_{d1}=0.01		**K_{d1}=0.1**	
Water Column Cu (lb/yr)		*Water Column Cu (lb/yr)*	
In	43,525	In	48,185
Out	43,715	Out	47,450
net % out (loss)	**100**	**net % out (loss)**	**98**
• ***Sediment Layer Cu (lb/yr)***		*Sediment Layer Cu (lb/yr)*	
In	5,875	In	24,450
Out	2,457	Out	11,530
net % in (remaining)	**42**	**net % in (remaining)**	**47**

Note that the net percent of copper accumulation in the water column and sediment layer stay virtually the same for the different K_{d1} values. On a *yearly* basis, there is no net copper accumulation in the water column of Haiwee Reservoir, and around a 40 to 50 percent accumulation of copper in the sediment layer based on an assumed 1 inch depth for the active sediment layer and the specified initial copper levels in sediment.

As discussed above, K_{d1} values typically range from 0.01 m^3/g to 0.1 m^3/g. Table D-3 compares the modeled internal copper loading contributions from the sediment layer in response to changing K_{d1} values (low, middle and high range K_{d1} values were used).

Table D-3: Model Response of Internal Copper Loading to Changes in Water Column Partition Coefficient (K_{d1})

(Based on 1998 data)

		K_{d1}	**0.01**	**0.05**	**0.1**
		Dissolved Cu %	*97%*	*87%*	*78%*
	North Haiwee				
Process	groundwater		480	1,445	2,080
	resuspension		10	30	40
	diffusion		460	2,165	3,300
		Total internal load (lbs elemental copper/year)	**950**	**3,640**	**5,420**
		K_{d1}	**0.01**	**0.05**	**0.1**
		Dissolved Cu %	*97%*	*87%*	*78%*
	South Haiwee				
Process	groundwater		625	1,505	1,890
	resuspension		50	125	155
	diffusion		470	2,315	2,990
		Total internal load (lbs elemental copper/year)	**1,145**	**3,945**	**5,035**

For this analysis, a K_{d1} of 0.01 m^3/g was used. This represents the low range of values found in literature (Thomann and Mueller, 1987), and is conservative maximizing the dissolved copper and the amount of copper in the water column verses the sediments.

The sediment partition coefficient, K_{d2}, used was 0.0001 m^3/g, yielding a dissolved copper percentage in the sediment pore water of 4 percent. Changes in K_{d2} have a minimal influence on copper concentrations in the water column.

APPENDIX E
PHYSICAL AND CHEMICAL PROPERTIES SUPPORTING THE LINKAGE ANALYSIS

E.1 INTRODUCTIONS

This appendix explores Haiwee Reservoir physical and chemical properties and reservoir dynamics related to the Linkage Analysis and Loading Capacity.

E.2 PHYSICAL AND CHEMICAL ASSUMPTIONS

To calculate loads from the CTR copper criteria equations for the CCC and CMC, hardness and volume must be determined. In the reservoirs, these parameters are not constant, and the Implementation Plan may be written to account for monitored fluctuations. To determine loading capacities, reasonable and conservative assumptions will be employed. These conservative assumptions make up the implicit margin of safety, further discussed in the Margin of Safety.

E.2.1 CTR Criteria Concentrations

The CCC and CMC will be calculated using the hardness value of 55.4 mg/L. This hardness corresponds to the monthly median from June, which is the lowest monthly median value from samples collected at Merrit Cut between 1995 and 2000.

E.2.2 Volume Relationships

The operating volume in North Haiwee is held in a very narrow range, as seen from Table E-1 and Figure E-1. Table E-1 shows that from 1995 to 2000 there was only a 7 percent difference between the highest treated volume and the 10th percentile operating volume. Therefore, loading capacities for North Haiwee will be calculated using the median volume of 12,476 acre-ft.

For South Haiwee Reservoir, however, volumes vary greatly (Table E-1 and Figure E-2). Table E-1 shows that there was nearly a 50 percent difference in volume between the highest and lowest volumes treated. Therefore, loading capacities will be determined according to the lowest reservoir volume when copper sulfate was applied, 13,230 acre-ft. To demonstrate the difference in loading capacity for different volumes in South Haiwee, loading capacities will also be calculated for the median reservoir operating volume, 19,903 acre-feet, which was determined by using the median of reported reservoir elevations. The median volume will also be used for calculating annual loading capacities

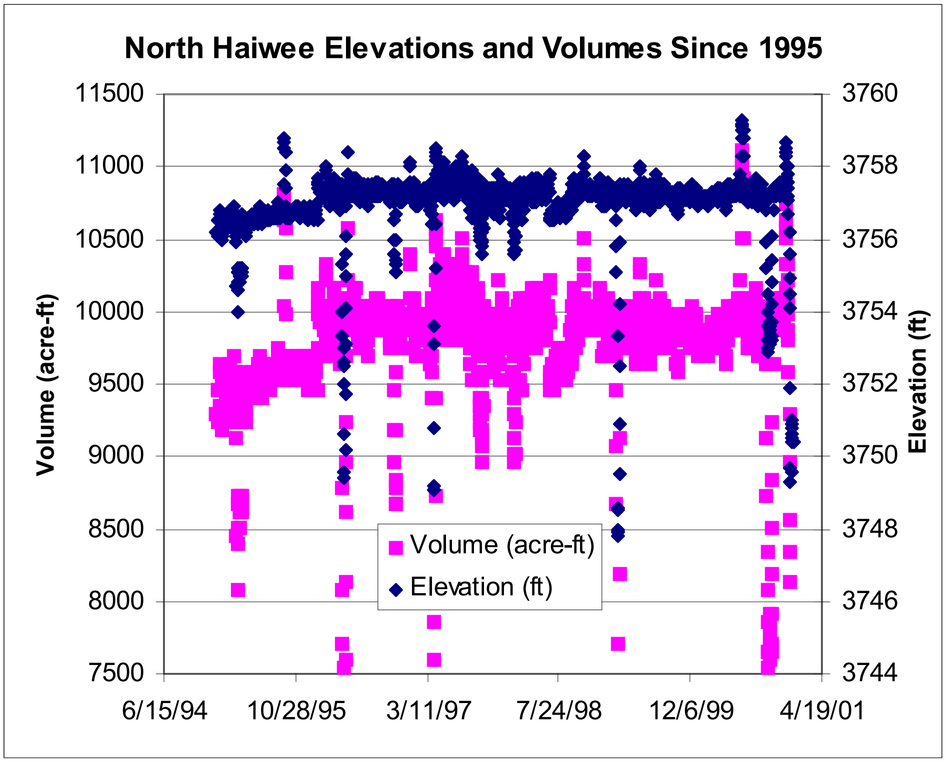


Figure E-1: North Haiwee volumes and elevations.

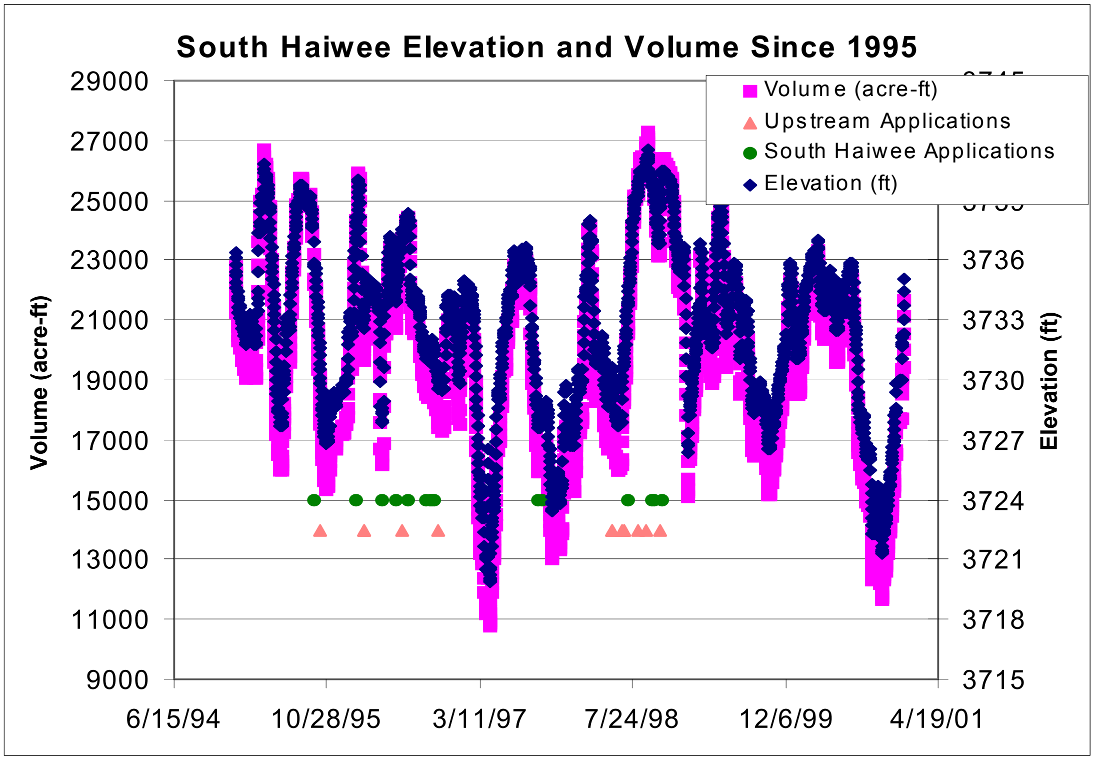


Figure E-2: South Haiwee volumes and elevations.

Table E-1: North and South Haiwee volumes including the highest and lowest volumes treated with copper sulfate between 1995 and 2000.

Percentile	Volume (Acre-ft) North Haiwee	Volume (Acre-ft) South Haiwee
90th	12650	24423
50th	12476	19903
10th	12074	15355
Lowest Treated	12103	13230
Highest Treated	12825	25941
Greatest Difference	**6%**	**49%**

E.2.3 Residence Times and Water Exchanges

The residence time for each reservoir was calculated by dividing the median daily volume by the median daily flow rate. The resulting residence times were 10.5 and 28.5 days for North and South Haiwee, respectively. To determine the number of volumes of water that move through the reservoir annually, or number of annual water exchanges, the number of days in a year was divided by the residence time. The corresponding number of annual water exchanges for North and South Haiwee were 34.7 and 16.3, respectively.

E.2.4 Reservoir Mixing

The mixing characteristics of the water in the reservoir will influence copper movement in the reservoir and will determine appropriate mixing zones.

Lateral Mixing

Lateral mixing distributes copper discharged to one portion of the reservoir across the width of the reservoir. Surface water samples collected the day before, day of, and day after copper sulfate discharges give information about the rate of lateral mixing. Samples are collected from each of four quadrants, two quadrants in the treated portion and two in the untreated portion. Figure E-3 (at end of section) shows a map from the July 3, 1996 copper sulfate discharge to North Haiwee, indicating the discharge area with sampling locations. Figures E-4 and E-5 show plots of the mean copper concentrations from samples collected in the treated and untreated portions of the reservoir. Figure E-4 shows that in North Haiwee, one day after a discharge, copper concentrations in the treated and untreated portions of the reservoir converge and are nearly equal. Figure E-5 shows that in South Haiwee the treated portion of the reservoir still contains somewhat elevated copper concentrations as compared to the untreated portion, but that the two portions have largely converged.

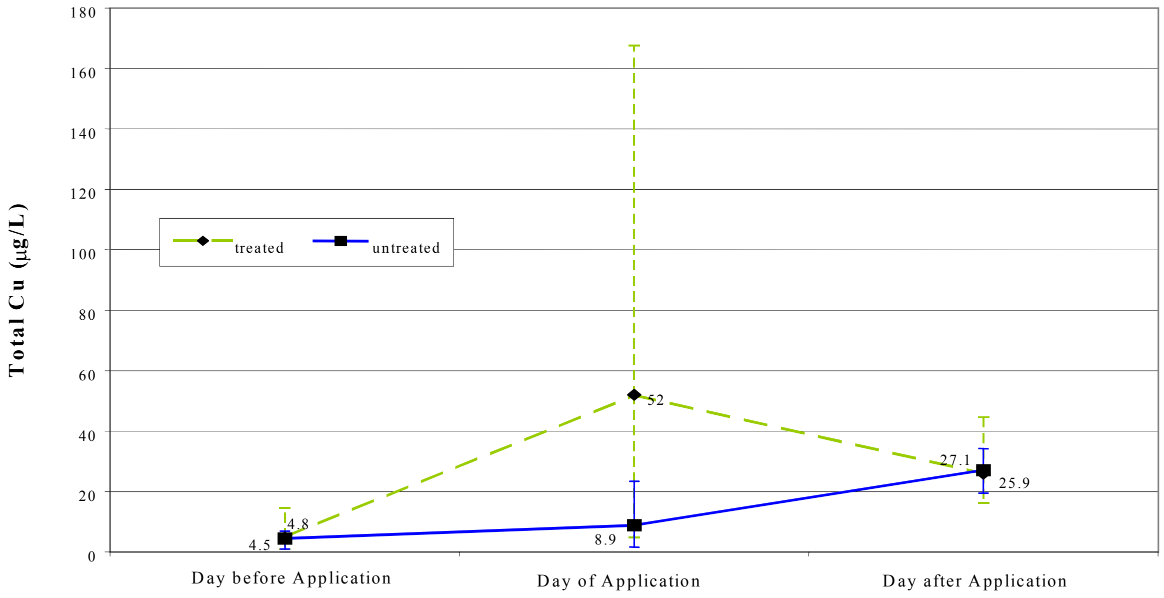


Figure E-4: Plots of the mean total copper concentrations in the treated and untreated portions of North Haiwee reservoir the day before, day of and day following the treatment. Data represent the means and range of daily means from 7 copper sulfate treatments, betw een 1996 and 2000.

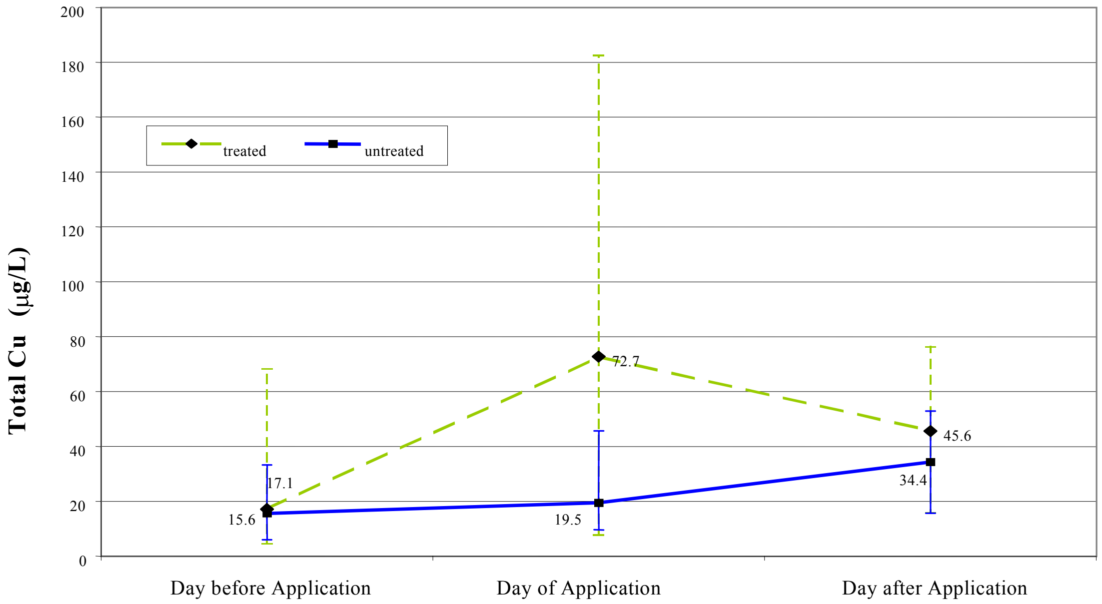


Figure E-5: Plots of the mean total copper concentrations in the treated and untreated portions of South Haiwee reservoir the day before, day of and day following the treatment. Data represent the means and range of daily means from 24 copper sulfate treatments, between 1996 and 2000.

Any interpretation of these data must consider that the samples were collected from the surface of the water column and from the main channel of the reservoir, not near the shore. Winds blowing across the width of the reservoir will mix surface water more rapidly than mixing will occur at depth. The local topography will focus winds along the length of the reservoirs, however, minimizing this effect. Because the samples are collected in the main channel of the reservoirs, data indicating mixing may not be applicable for areas near the shoreline and in coves in the untreated portion of the reservoir.

Despite the factors discussed above, the data showing that significant lateral mixing does occur over a one day period has lead to the simplifying assumption that complete lateral mixing occurs within one day. This assumption is conservative for free-swimming organisms, because any portion of the reservoir where mixing has not yet occurred will provide a zone for escape to avoid high copper concentrations. This assumption is not conservative, however, for immobile organisms in the untreated half of the reservoir. Because dilution may not occur completely across the water column, organisms may be subjected to increased copper concentrations for a period longer than one day. Even with mortality of immobile organisms in the main body of the channel greater than expected by this simplifying assumption, the remaining organisms populating the near shores zones will be sufficient to repopulate the entire reservoir in a reasonable amount of time.

Axial Mixing

Because each of the reservoirs is long and narrow with the inlet and the outlet streams positioned at opposite ends of the reservoirs, axial flows through the length of a reservoir are expected to be somewhat cohesive. With limited axial mixing, water movement within a reservoir will be estimated as a plug flow. Thus, water entering the reservoir will be assumed to migrate down the length of the reservoir with negligible mixing with upstream or downstream water.

Figure 5-2 shows a representation of post-discharge lateral and axial mixing based on the lateral and axial mixing assumption described above.

Vertical Mixing and Stratification

Without depth profile data, it is not possible to describe the vertical mixing within the reservoir system from direct observation. In general, thermal stratification varies according to many factors, including temperature and shear stress. There are many valid arguments against long-term vertical stratification in both North and South Haiwee. Both reservoirs are relatively shallow, 30 to 35 feet deep, and have long longitudinal fetches. Further, the uniform geometry of North Haiwee Reservoir combined with the low residence time of only 10.5 days may limit the conditions under which it would be expected to stratified.

Because stratification would result in limiting the mixing of copper in the water column under certain conditions, the post application loading capacities will be developed under the conservative assumption that vertical stratification exists. This assumption may be reasonable during the period when copper-based pesticides may be applied. Thermal stratification would occur during periods of low wind and high temperatures, conditions that would be expected during the summer and early fall when algae productivity is high and copper sulfate has historically been discharged. Further, aerial treatments are not allowed during windy conditions to minimize drift.

E.2.5 Dissolved Oxygen Considerations

Available habitat is a consideration in determining the protection of aquatic life. If a reservoir does stratify for any significant period of time, dissolved oxygen (DO) concentrations can be expected to sag in the hypolimnion from algae decay and respiration. Under these conditions, habitat for organisms that require high DO concentrations, such as trout, would be limited to the epilimnion where oxygen levels are expected to be higher due to contact with the atmosphere.

E.2.6 Copper Losses

Factors discussed in the Source Analysis, such as precipitation, aerial deposition, groundwater inputs, still-water diffusion and sediment settling and resuspension, could influence the concentration of copper in the water column. The Source Analysis indicates that aerial deposition and direct precipitation do not significantly influence water column copper concentrations. Groundwater inputs and still-water diffusion contribute an estimated six percent to the overall copper inputs to the reservoir system. Both of these inputs are expected to enter the reservoir throughout the year and the groundwater inputs are largely balanced by similar outputs. Therefore, during the critical periods of up to four days following copper discharges, these sources and sinks are not expected to significantly influence water column copper concentrations. Also, during the critical condition of a stratified water column, the influence of both groundwater inputs and still-water diffusion will be limited to the hypolimnion.

Sediment settling and resuspension are expected to result in a net loss of copper from the water column. Depending on the partitioning between particulate and dissolved copper in the water column and sediments, the net losses to settling could be as great as 10 percent of the total copper mass per year. Further, following aerial copper discharges, it is possible to have increased settling of dead algae and increased concentration of copper sorbed to the particulate matter. This could cause particulate copper to settle out of the water column at a rate greater than the average, thereby reducing the total recoverable copper concentrations in the water column.

Short-term Copper Losses

Using the conservative assumption that only 4 percent of the copper in the water column is in the particulate form, the overall influence of copper losses as a result of settling will be minimal over the four-day period following copper applications. The influence of settling may be worthy of further investigation once site specific suspended sediment and dissolved to total copper partitioning data have been found.

Annual Copper Losses

On an annual basis, cumulative losses of copper from the water column to the sediment are significant. The amount of internal copper losses is related to the concentration of copper in the water column. Therefore, reducing incoming copper loads will reduced the amount of cumulative losses of copper.

Both losses to sediments and inputs from still-water diffusion will change with varying concentrations of copper in the water column. Less copper in the water column will result in less copper sorbed to particles and, therefore, less mass of copper settling into the sediment layer. Likewise, a greater copper concentration gradient between the high concentration sediments and low concentration water column will result in increased diffusion into the water column. The still-water diffusion increase may be temporary, however, due to an accumulation over time of sediments with lower copper concentrations.

As expected, the Haiwee Reservoir Model predicts that the internal copper losses will decrease as incoming copper loads are decreased. Because copper losses effectively increase the annual steady-state loading capacity, the conservative loading capacity will be found at low copper concentrations. Table E-2 shows the results of running the model with incoming copper concentrations from LAA reduced to 4 μg/L and no direct discharges of copper to the reservoir. The resulting annual losses to internal loading are 350 and 360 pounds per year for North and South Haiwee, respectively. These loads will be added to the annual steady-state loading capacities.

Table E-2: Summary of internal loading if copper inputs from LAA are reduced to 4 μg/L and there are no direct discharges of copper. Results are found using the Haiwee Reservoir Copper Model with 1998 hydrologic and sedimentation data as inputs. All values are in pounds per year.

Process	Sources	Sinks	Net Gain or (Loss)
North Haiwee			
Groundwater	134	25	109
Sediment - resuspension & settling	2	573	(571)
Still-water Diffusion	113	0	113
Total	**249**	**598**	**(349)**
South Haiwee			
Groundwater	164	40	124
Sediment - resuspension & settling	12	617	(605)
Still-water Diffusion	126	0	126
Total	**302**	**657**	**(355)**

E.2.7 Copper Speciation and Toxicity

Bioavailability of copper is linked to the speciation of copper. Free ionic copper (Cu^{+2}) is the most toxic species of copper. Dissolved copper readily interacts with organic and inorganic chemicals in water to form complexes that reduce copper toxicity. Hardness, dissolved organic carbon content, pH and cation and anion concentrations all influence the toxicity of dissolved copper. Copper sorbed to particulate matter is believed to be minimally toxic (Eisler, 1998). The CTR criteria concentrations are based on dissolved copper and do not differentiate between the free ionic and dissolved states. The CTR equations are adjusted for changes in hardness but do not take into account differences resulting from other factors. The water effect ratio (WER) accounts for the site-specific factors influencing toxicity through direct observation of toxicity of site water in the laboratory.

The proportion of dissolved to particulate copper is related to the amount of particulate matter and the partitioning of copper in the site water. Partitioning can be influenced by many chemical and physical factors. The translator accounts for site-specific factors influencing copper partitioning by analyzing site water directly.

E.3 DISCHARGE PROCEDURES

Copper sulfate is discharged directly to Haiwee Reservoir by aerial application. In practice, applications occur over a two to four hour period. The aircraft must land and reload crystalline copper sulfate at least once each application. Historically, copper sulfate has been applied to one-half of the reservoir at a time, though other application schemes may be possible. The treated reservoir is divided along the long axis and only one half of one reservoir is treated on any given day. The aerial application is reportedly very accurate, and copper sulfate is applied in the coves as well as the main body of the reservoirs. A gap is left between each pass of the aircraft to assure there is no overlap between passes.

Copper sulfate crystals hit the surface of the water and rapidly disassociate into free ionic copper and sulfate (Eisler, 1998) in the top few feet of the water column. The free ionic copper binds to organic and inorganic matter, as well as humic acids and other soluble compounds. Once solubilized, copper will spread through molecular diffusion and physical mixing. The size of the copper sulfate crystals will determine at what depth copper concentrations will be maximized. Because the desired zone of efficacy is in the top of the water column the crystals are presumed to be small and very high concentrations are expected at the top of the water column with decreasing concentrations below the first few feet. The rate of vertical mixing in the epilimnion will vary depending on temperature, wind, stratification and a number of other factors.

Reportedly, the quantity of copper sulfate applied is chosen to meet a certain concentration in the top ten feet of the water column in the half of the reservoir treated. The desired concentration to kill algae ranges from below 150 µg/L to 200 µg/L, depending on the target algae species (B. White, verbal communication, 2001). In their calculations, LADWP does not account for concentrations of copper existing in the reservoir before copper is discharged. Table E-3 shows the representative concentrations achieved in the target volume from past applications, both including and excluding pre-discharge copper concentrations.

Table E-3: Copper concentrations in the treated portion of the reservoir (one half of the reservoir in the top 10 feet of the water column).

Date of Application	Elemental Cu Discharged (tons)	Pre-discharge* Copper Conc. (ug/L)	Treatment Volume (acre-feet)	Target* Copper Conc. (ug/L)	Copper Conc. With Pre-discharge (ug/L)
North Haiwee Treatments					
7/3/96	0.500	10.8	2593	142	**153**
10/23/96	0.525	5.2	2592.5	149	**154**
8/11/98	0.425	5.3	2575	121	**127**
9/9/98	0.425	2.6	2586.5	121	**123**
10/24/98	0.500	4.5	2628.5	140	**144**
7/27/99	0.488	3.1	2598.5	138	**141**
8/3/99	0.325	6.6	2592.5	92	**99**
9/3/00	0.481	19.9	2586.5	137	**157**
South Haiwee Treatments					
2/3/96	0.600	26.8	3990.5	111	**137**
4/23/96	0.625	21.7	3322.5	138	**160**
6/11/96	0.688	7.5	3705	136	**144**
7/17/96	0.725	18.2	3990.5	134	**152**
9/18/96	0.663	26.4	3483	140	**166**
10/2/96	0.875	20.7	3502	184	**204**
10/16/96	0.863	42.5	3457	183	**226**
9/17/97	0.619	23.1	3271.5	139	**162**
10/1/97	0.625	14.5	3265.5	141	**155**
10/29/97	0.775	12.0	3104	184	**196**
7/8/98	0.688	12.3	3993.5	127	**139**
9/23/98	0.788	9.5	4284	135	**145**
9/30/98	0.788	19.7	4108.5	141	**161**
10/27/98	0.500	10.2	4085	90	**100**

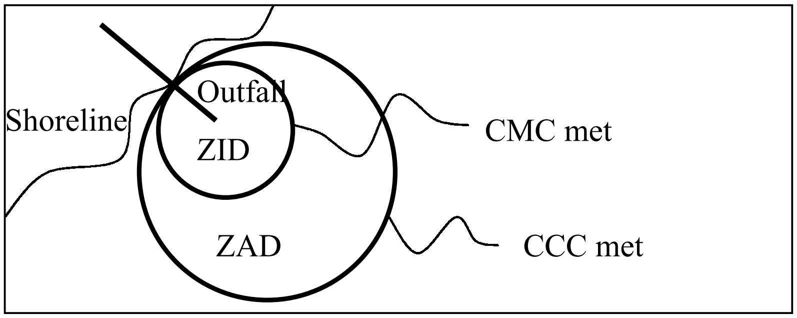
*Target concentrations do not account for pre-discharge copper concentrations. Pre-discharge concentrations are the average of the samples collected before the copper discharge (usually the day before the discharge).

Table E-3 shows that though the desired concentrations in South Haiwee were never greater than 184 μg/L, accounting for pre-discharge concentrations, levels as high as 226 μg/L were reached. On many occasions successive copper sulfate applications to South Haiwee follow only a week apart, resulting in accumulations of copper in the reservoir water column. Table E-3 also shows that the target copper concentration was frequently the 150 μg/L concentration, indicating some algae control is believed to occur at concentrations in the 120 μg/L range.

E.4 MIXING ZONES

To determine the post-discharge loading capacities, mixing zones must be designated to define where elevated copper concentrations will be allowed. For discharges from a single point, a mixing zone defines three different zones of dilution, as can be seen in Figure E-6. At the boundary of each zone of dilution the lower concentration must be met. Figure E-6 shows that the Zone of Initial Dilution (ZID) is nearest the discharge point. Within the ZID, concentrations may be greater than both the CCC and CMC. In the Zone of Acute Dilution (ZAD), concentrations must be less than the CMC, but may be greater than the CCC. All waters outside of these two zones must have copper concentrations below the CCC concentration.

Figure E-6: Mixing zones from a hypothetical point source discharge.



E.4.1 Mixing Zones for a Pesticide Discharge

In the case of a pesticide discharge to water, there must be an exception to the standard assumption that immobile organisms will not be effected. The mixing zones will necessarily sacrifice some immobile organisms in the affected area for a period of time following pesticide discharges. However, a large population of these immobile organisms will still be present outside the dilution zones. Because these immobile organisms reproduce rapidly and have short lifecycles, their populations will increase to appropriate levels within an acceptable period of time. For these reasons and because toxic concentrations of copper will not persist more than a few days following a copper discharge, these mixing zones are protective of the overall reservoir ecosystem.

Free-swimming organisms, such as fish, must have the opportunity to escape the zones of acute and chronic toxicity. The degree and duration of exposure determines the ability of an organism to survive high copper concentrations. It is not practical for a free-swimming organism to travel long distances to escape high copper concentrations. Therefore, discharging copper across the width of the reservoir, thereby forcing organisms to swim between thousands of feet and many miles, is not acceptable. The geometry of both North and South Haiwee will allow for mixing zone boundaries parallel to the length of the reservoir. Thus, the width of the reservoir will be the maximum distance an organism must travel to escape zones of high copper concentrations.

E.4.2 Critical Mixing Zone Conditions

The critical mixing zone conditions will occur when the reservoir is stratified and the hypolimnion has low DO concentrations, limiting both the vertical mixing available for dilution and the habitat free-swimming organisms may use to avoid elevated copper concentrations (see Figure 5-2). Because this copper discharge is over a surface rather than from a pipe, the mixing zones must be modified accordingly. Figure 5-2 shows a schematic of the proposed mixing zones. Also shown is a Zone of Efficacy, which is the zone where copper concentrations are targeted to meet levels great enough to be toxic to target algae species.

To allow free-swimming organisms to avoid the ZID, the boundary with the ZAD will be set 5 feet above the hypolimnion. For this discussion, stratification will be assumed to occur at a depth of 20 feet. Therefore, the boundary of the ZID will be at a depth of 15 feet in the treated half of the reservoir. In the zone between 15 and 20 feet of depth in the treated half of the reservoir, concentrations may be greater than the CCC, but must be less than the CMC. If stratification occurs at a depth lower than 20 feet, the lower limit of the ZID may fluctuate at 5 feet above the stratification depth, or, in the absence of stratification, at 5 feet above the bottom of the reservoir.

Under the condition that stratification occurs at a depth less than 20 feet, the loading capacity associated with the 20 foot stratification layer should still be protective. This assumes that DO concentrations will not drop below acceptable levels if the hypolimnion is large. The only organisms potentially negatively impacted would be immobile organisms that reside in the upper water column. A sufficient population of these organisms, however, is expected to survive to repopulate the reservoir to appropriate levels following the copper discharge.

Below the stratification layer, mixing will be assumed to be negligible. In the half of the reservoir not treated, the concentrations must be below the CCC concentrations to allow for suitable habitat. In practice, lateral mixing will occur after the copper discharge. The lateral distances for the mixing zones will be set in the Implementation Plan following more detailed investigations into Haiwee Reservoir mixing properties. The concentrations and associated loads in the hypolimnion will be assumed to be uninfluenced by copper discharges; therefore, the loading capacity associated with the hypolimnion will not be included in the post-discharge loading capacities.

E.5 WATER COLUMN AND SEDIMENT TOXICITY

E.5.1 Water Column Toxicity

The water column toxicity target accounts for additive and synergistic effects between copper and other chemical and physical factors present in Haiwee Reservoir waters. In the natural environment, many factors influence the toxicity of copper to organisms. Some factors, such as the presence of naturally occurring arsenic or the controlled release of polymer or ferric chloride from the Cottonwood Creek flocculent plant along the LAA, may cause copper related toxicity to be observed at concentrations below those allowed by the CTR criteria.

Because the currently available literature does not provide a basis for predicting additive and synergistic effects in natural systems, arriving at an allowable concentration is not possible without site-specific data. Setting a loading capacity based on this target will be reactive and will require modifications in the loading capacity set according to results from toxicity testing using site water. If chronic or acute toxicity units (TUc and TUa, respectively) are determined, the concentration criteria may be found using the relationships given in the USEPA Technical Support Document for Water Quality-based Effluent Control, as CCC = 1.0 TUc and CMC = 0.3

TUa. Once determined, these CCC and CMC concentrations may be employed to determine loading capacities.

E.5.2 Sediment Toxicity

Complex interactions determine the bioavailability and fate and transport of copper in natural sediments. Additive and synergistic effects of copper in sediments are difficult to understand other than through direct observation. The loading capacity associated with the sediment toxicity numeric target must be reactive to observations of copper associated sediment toxicity.

APPENDIX F
ADDITIONAL DATA NEEDS

F.1 INTRODUCTION

To establish and implement a Copper Total Maximum Daily Load for Haiwee Reservoir that employs the California Toxic Rule and toxicity water quality objectives, additional site-specific data are needed. The intent of this appendix is to outline those data needs and provide a basic framework to develop a site-specific study plan for Haiwee Reservoir. Generally, the study plan should be designed to address the following issues:

- Water column toxicity
- Sediment toxicity
- Water effect ratio for copper (WER)
- Haiwee Reservoir water chemistry, mixing, and copper fate and transport properties
- Relationship between dissolved and total recoverable copper (translator)
- Source analysis refinement
- Effects of polymer and ferric chloride additions in the LAA

It is important to note that this appendix is provided to give a general outline of the additional data needed; it should not be construed as a Regional Board directive or formal request for information. Studies may be conducted that incorporate all, part or none of the suggested methods of data collection and analyses. Alternate site-specific methodologies, such as the Biotic Ligand Model, may also be considered.

F.2 WATER COLUMN TOXICITY

Prior to performing WER and mixing zone studies, it is important to demonstrate that the site water itself is not toxic to aquatic life. Therefore, samples of reservoir water should be collected for chronic toxicity tests using three species: *Ceriodaphnia dubia*, *Pimephales promelas*, and *Selenastrum capricornutum* with a minimum of three different testing periods. Furthermore, as these reservoirs are treated with ferric chloride and polymer, in addition to copper sulfate, it is important that water column toxicity is evaluated both when these substances are added and when they are not, to be sure that reservoir samples are amenable to WER testing.

At a minimum, it is advisable that three separate depth-integrated samples of reservoir water be subjected to toxicity tests as mentioned above from each of three different testing periods not associated with copper sulfate applications. Suggested sampling locations are near the inlet of the Los Angeles Aqueduct to North Haiwee, in the middle/south portion of North Haiwee and in South Haiwee.

If toxicity is observed in any of these samples a toxicity identification evaluation (TIE) should be conducted to determine the causative toxicant(s). Samples must be of sufficient volume for TIE analysis and the Study Plan must include provisions for such analysis.

F.3 SEDIMENT TOXICITY

Similarly, it is important to demonstrate that Haiwee Reservoir sediments are not toxic to aquatic life. Because sediment toxicity may vary in different areas of the reservoir complex, twelve (12) separate samples should be collected from different locations in each of both North and South Haiwee. Sampling sites should be at representative areas along both the length and width of each reservoir. The effects of polymer and ferric chloride additions in the LAA on reservoir sedimentation dynamics should be considered when selecting sampling sites.

Conduct EPA *Hyalella* and *Chironomus* 10-day whole sediment toxicity tests using each sediment sample collected. Analyze each sample for acid volatile sulfides, simultaneously extracted metals, total organic carbon, dissolved oxygen, and particle size. Analyze statistical relationships between toxicity and chemistry and particle size of all samples collected. If toxicity is observed, a TIE to determine the causative toxicant(s) may be appropriate.

F.4 WATER EFFECT RATIO (WER) STUDY FOR HAIWEE RESERVOIR

The USEPA gives states the discretion to adjust aquatic life criteria for metals to reflect site-specific conditions through the use of the WER. In general, WER development consists of the following:

- Preliminary Analysis
    - Site definition and study plan development
- Sampling Design
    - Discharge and receiving water considerations; seasonal and critical conditions
- Laboratory Procedures
    - Testing organisms
    - Analytical procedures
    - WER calculation
- Implementation
    - Site-specific criteria approval by USEPA
    - Permit limits
    - Monitoring requirements

Several guidance documents on developing site-specific WERs are available– the *Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals* (USEPA, 1994) and the *Streamlined Water-Effect Ratio Procedure for Discharges of Copper* (USEPA, 2001). Regional Board staff intend to work closely with USEPA Region IX staff and LADWP to develop a WER study plan for Haiwee Reservoir.

F.5 PHYSICAL AND CHEMICAL PROPERTIES

It is important to understand the physical and chemical processes in Haiwee Reservoir including:

- lateral and vertical mixing of copper after copper sulfate application,
- relationship between total recoverable, dissolved and free ionic copper,
- vertical stratification in the water column, and

- variations of physical and chemical parameters such as temperature, conductivity, suspended-sediment concentration (SSC), turbidity, pH, alkalinity and DO after copper sulfate application and in different seasons.

A suggested method for addressing these points follows:

1. Collect and analyze water samples for total recoverable, dissolved, and free ionic copper, SSC, total and dissolved organic carbon, and hardness at eight to 12 representative locations around the reservoirs and at various depths (e.g., surface, 1 meter, mid-water column and 1 meter from bottom).
2. Perform field measurements for temperature, conductivity, DO, turbidity and pH at each location at one meter depth intervals.

This sampling should be conducted prior to, immediately following and at 24 hour intervals after copper sulfate application for 96 hours. Reduced intensity sampling should also be conducted on a seasonal basis not associated with copper sulfate applications.

F.6 TRANSLATORS

Compliance with the CTR will be measured in dissolved copper; however, copper loads are expressed as total copper. The translator can be used to convert from dissolved to total recoverable copper. It is possible that between the reservoir properties and WER studies described above all of the data required to calculate a translator will be collected. Consult appropriate guidance documents to determine if further analysis will be required.

F.7 SOURCE ANALYSIS REFINEMENT

Additional data are needed to refine the copper source analysis. Potential areas of investigation include groundwater production well and surface water sampling. All samples should be analyzed using a method detection limit for copper of 2 µg/L if possible; at a maximum no greater than 10 µg/L. Investigation into water supply management practices in the Mono-Owens watershed may be warranted as well.

F.8 EFFECTS OF POLYMER/FERRIC CHLORIDE ADDITIONS

LADWP began the *Interim Arsenic Management Plan* in March 1996 to control arsenic concentrations in the LAA. Most of the arsenic found in the LAA comes from geothermal springs feeding into Hot Creek in the Long Valley area of the Owens Valley. Ferric chloride and cationic polymer are added to the LAA near Cottonwood Creek to enhance arsenic removal by sedimentation in North Haiwee Reservoir. The long-term average arsenic concentration in the LAA is 22 µg/L. LADWP's ferric chloride dose, averaging 5.7 mg/L as $FeCl_3$, is selected to meet a goal of approximately 10 µg/L at Merrit Cut. LADWP estimates that an average of 67 percent of the influent arsenic is removed through sedimentation in North Haiwee Reservoir (LADWP, 1999). Based on average flow and removal rates, some 40 metric tons of arsenic has been deposited in Haiwee sediments since March 1996 (Kneebone et al, 2001).

It is currently unknown how the implementation of the *Interim Arsenic Control Plan* effects copper partitioning and removal, sedimentation dynamics, and related toxicity in the reservoir.

Further studies may be warranted to determine the long-term implications of the arsenic control strategy.