California Regional Water Quality Control Board
San Diego Region

Total Maximum Daily Load (TMDL) for Chollas Creek Watershed Metals

Draft Source Analysis
September 15, 2000

INTRODUCTION

There are a variety of sources of copper, lead, and zinc found in urban runoff. Many studies have been done worldwide to identify the sources of heavy metals in urban runoff, including several studies in California (although there is minimal information available specifically for San Diego). One study performed in Santa Clara Valley, California in 1992 detailed the various sources of these metals in a local urban watershed (Woodward-Clyde 1992). The study found that significant sources of metals in urban runoff included air pollution/atmospheric emissions, automotive operation and maintenance, and potable water supply systems. In addition to the Santa Clara Valley study (Valley study), studies performed in other urban cities have also identified similar sources as well as sources not addressed in the Valley study. Since detailed studies of this nature have not been performed in San Diego, the data from these studies collectively can be used to identify potential sources of copper, lead, and zinc in the runoff to Chollas Creek, as well as assist in estimating their annual contributions to the watershed. The annual load estimates derived from these studies can be further supplemented by the data that is available specifically for Chollas Creek.

SANTA CLARA VALLEY AND OTHER URBAN STUDIES

Santa Clara Valley is located in the San Jose area near San Francisco, California. In 1992, a comprehensive study was performed by Woodward-Clyde Consultants for the Santa Clara Valley Nonpoint Source Pollution Control Program to identify major sources of heavy metals found in the Lower South San Francisco Bay. Local knowledge and site specific data were used to estimate total annual loads of metals whenever possible, supplemented by national data relevant to the study. Major sources of several metals, including copper, lead and zinc were identified, and a percentage of the total annual load for each metal was attributed to each major source.

Although a similar study of this detail has not been performed in the San Diego area, the similarities and differences between the two urban areas can be highlighted in order to extrapolate potential sources of copper, lead and zinc and their corresponding annual loads to the Chollas Creek watershed. This information, coupled with sampling data obtained for Chollas Creek, can be used to identify the major sources and estimate the total annual loads of these three metals.

The Valley study identified several major sources of heavy metals found in urban runoff. The sources were grouped into categories that include:

- Atmospheric emissions
- Automotive (other than emissions)
- Industrial
- Residential
- Water supply

Atmospheric emissions include both stationary point sources (e.g. industrial) and mobile sources including emissions from both diesel-fueled and unleaded-fueled vehicles; these emissions affect rainfall and also cause settling of particulates during dry weather. Automotive sources (other than emissions) included maintenance and operation activities for automobiles and trucks, such as wear and tear on tires and brake pads, and spills and leaks of fluids such as motor oil, coolants, etc. Industrial sources include industrial facilities that handle, process, or store metals that may be exposed to rainfall. Residential sources include application and disposal of household products, such as pesticides, fertilizers, paints, and maintenance and construction activities such as remodeling, building, and cleaning roofs and gutters. Water supply includes sources associated with potable water systems, including corrosion inhibitors, algae inhibitors, and corrosion of distribution infrastructure. All of these sources were evaluated for their significance in terms of their contribution to total annual loads. Industrial and residential sources were found to contribute less than 1% of the total annual loads for copper, lead and zinc, while atmospheric, automotive, and water supply sources were found to significantly contribute at least one of these three metals.

In addition to the Valley study, other studies in urban areas, although less extensive, have also identified many of these sources of metals in runoff. Sansalone, et. al. listed many of the sources identified in the Valley study as well as sources not addressed by the study (1997). Table 1 summarizes the following sources of copper, lead, and zinc in urban runoff according to Sansalone:

Table 1. Metal Sources in Urban Runoff (Sansalone 1997).

Metal	Urban Sources
Copper	Brakes, tires
Lead	Brakes, tires, fuels and oils, de-icing salts
Zinc	Brakes, tires, auto frame and body

Furthermore, a study performed in Germany in 1990 identified metal sources in urban runoff including automotive exhaust gases, tire abrasion particles, brake lining abrasion dust, lubricating oils and greases, and abrasion of roadways (Muschack 1990). Based on the existing data from these various studies, and particularly the Valley study since it is the most comprehensive, the total annual loads of copper, lead, and zinc to Chollas Creek can be estimated.

COPPER

The Valley study found that approximately 90 percent of the estimated mean annual load of copper to the Lower South San Francisco Bay came from the following sources:

Automotive	50%
Atmospheric emissions	25%
Water supply	15%

Brake-pad wear was the only significant contributor from automotive sources. Atmospheric emissions included significant contributions from diesel-fueled vehicle exhaust and wet and dry deposition of the copper. Water supply sources included copper in the source water itself, and corrosion of plumbing.

Woodward-Clyde estimated the contributions from the automotive category by calculating the total annual load of copper from automobiles in the Santa Clara Valley due to break-pad wear. They calculated that the typical amount of copper released from a single car due to break-pad wear was 7.23 g/26,000 miles (Woodward-Clyde 1992). This amount was then multiplied by the estimated number of miles driven annually within the Santa Clara Valley watershed area to obtain the annual load of copper due to break-pad wear, which was approximately 7,360 lbs/year.

Assuming the copper release rate per car is the same in San Diego as determined in the Valley study, the total annual load of copper to the Chollas Creek watershed can be calculated by estimating the number of miles driven in the watershed (all calculations can be found in Appendix A). The California Department of Motor Vehicles (DMV) assessed that as of December 1999, there were a total of 1,998,988 autos and trucks in San Diego County (DMV 2000). Since the Chollas Creek watershed contains approximately 20% of the total population in San Diego County (SANDAG 1999), the number of cars and trucks in the watershed would be roughly 20% of the total amount in San Diego County, or 400,000 vehicles. It is also estimated that the US average number of miles driven per year per vehicle is 10,382 miles (MVMA 1991). Therefore, the total number of miles driven in the Chollas Creek watershed area annually is approximately 4.1×10^9 miles. Using the copper release rate determined in the Valley study, the annual load of copper to the Chollas Creek watershed due to brake-pad wear is approximately 2,500 lbs/year.

The Valley study also evaluated the total annual load of copper to the Lower South Bay due to atmospheric emissions and wet and dry deposition of copper particulates. The study found that atmospheric emissions of copper in Santa Clara Valley from vehicle exhaust was largely due to diesel-fueled vehicles (unleaded fuel exhaust contributed less than 1% of the total annual load) (Woodward-Clyde 1992). There were no identified point sources of copper emissions in Santa Clara County. Wet and dry deposition of copper that was in the atmosphere contributed to approximately 25% of the total annual copper load to the Lower South Bay. Emissions and wet and dry deposition data were obtained

from the California Air Resources Board (CARB) and the United States Environmental Protection Agency (USEPA), and studies performed for other US cities.

To accurately evaluate copper loads from wet and dry deposition to Chollas Creek, wet and dry deposition data for the watershed are needed. However, there are currently no completed deposition studies for copper, lead, and zinc in San Diego County. A workshop was held on February 9 and 10, 2000 in Los Angeles to specifically address the growing issue of atmospheric deposition impacts to the Pacific Coast. At the workshop, several deposition studies that are underway were discussed, including studies in San Francisco and Santa Monica, but these data are not yet available (UCLA 2000). Until sufficient data are available for San Diego, accurate calculations for loads from atmospheric deposition cannot be completed. Instead, the percentage of the total annual load contributed from air deposition estimated in the Valley study will be used to estimate contributions to Chollas Creek. The Valley study estimated copper load from air deposition to be 25% of the total load, so the estimated load to Chollas Creek would be approximately 1,430 lbs/year. This load would include wet and dry deposition due to stationary sources, mobile sources, and area sources.

Since the Valley study was performed in 1992, however, the USEPA has implemented a reformulated gasoline (RFG) program in 17 cities across the country, including San Diego, to reduce emissions such as toxic pollutants (including metals) and smog forming pollutants from automobiles. Phase I of the RFG program was implemented in 1995, and Phase II began January 1, 2000. The State of California implemented its own reformulated gasoline program effective in 1996 that met USEPA's Phase II requirements. It is expected, therefore, that metal emissions from automobiles may be less than that determined in the Valley study (i.e. 25%), but that emissions will not decrease further with the recent implementation of Phase II since California has been meeting the Phase II requirements since 1996. Although the RFG program does not impact diesel fuel, which contributes the largest amount of metals, the effects of the program may still be measurable.

The Valley study also found that there are several pathways through which tap water can eventually reach surface and ground waters. The study estimated the amount of tap water that potentially reaches surface and ground waters (approximately 5% of the total water usage) and multiplied that amount by the estimated concentration of copper in tap water. These calculations indicated that the potable water supply was a significant source of copper loading in Santa Clara Valley. Copper in the water supply was attributed to both the amount found in the source water (largely influenced by algicide application) as well as the amount that leached into the potable water from corrosion of copper piping. Source water in Santa Clara Valley had a flow weighted average copper concentration of 18.8 µg/L (Woodward-Clyde 1992). The estimated average concentration of copper in tap water was 58.1 µg/L, indicating that corrosion of copper piping contributes approximately 39.3 µg/L. The total estimated loading for both source water and corrosion of piping was calculated to be 2,130 lbs/year.

In comparison, the Metropolitan Water District of Southern California (MWD), which supplies a large portion of drinking water in San Diego, indicated that their effluent that is delivered to the three San Diego plants (Miramar, Alvarado, and Otay) generally has copper concentrations below their detection limit of 10 µg/L (Wang pers. comm). In addition, the 1999 City of San Diego Annual Water Quality

Report indicated that copper was not detected above their detection limit for reporting (100 µg/L before February 2000 and 50 µg/L as of February 2000) in any of the three filtration plant effluents.

The algicide copper sulfate, another potential source of copper, is applied infrequently and in small, strategic amounts in MWD reservoirs (Wang pers. comm.), minimizing the amount of copper that would be found in the potable water supply from MWD. In San Diego, no copper sulfate has been added to any of the reservoirs in the past five years, except for the Miramar Reservoir, which is not located in the Chollas Creek watershed and does not supply the plant that services the watershed population. Since MWD effluent and the three San Diego plants' effluents have no detectable copper levels, and no algicide was added to reservoirs that service the Chollas Creek watershed in the past five years, it is concluded that algicide application in reservoirs is an insignificant contributor of copper in the Chollas Creek watershed.

Corrosion of copper piping in San Diego, however, is a significant source of copper. In 1999 the City of San Diego performed a lead and copper household monitoring study to measure copper and lead concentrations in household tap water. The first liter of water from the tap was collected after six to twelve hours of non-use of the household water prior to sampling. More than 50 homes were tested, and the average copper concentration for the homes was 180.7 µg/L while the average lead concentration was 2.6 µg/L. Since copper concentrations coming from the three plants are below 50 µg/L, and likely near 10 µg/L since MWD water is at that level, copper plumbing corrosion in residential homes adds 130 µg/L to 170 µg/L on average to the potable water supply. According to the City Water Department, approximately 60 million gallons per day (MGD) of potable water is used in the Chollas Creek watershed area (Carty pers.comm.). Woodward-Clyde (1992) estimated that 5% of the total potable water used will reach the storm drain system, so approximately 3 MGD of tap water reaches Chollas Creek. Since corrosion of copper piping contributes roughly 170 µg/L of copper to the water supply (the more conservative estimate), this source contributes approximately 1,550 lbs/year to the Chollas Creek watershed.

Other sources of copper that were identified in the Valley study, but determined to each contribute less than 1% of the total load, include unleaded-fueled vehicle exhaust; automotive coolant leaks, coolant dumping, oil leaks, and oil dumping; and residential paints. In San Diego, it is assumed that contributions from these sources would also be insignificant since the cities are similar in demographics.

In addition to copper sources identified by the Valley study, other potential sources of copper in urban runoff include tire wear (Sansalone 1997) and abrasion of roadways themselves (Muschack 1990). Based on calculations from the Valley study used to estimate the amount of zinc released by tire wear, copper loads due to tire wear were subsequently calculated. The amount of copper in rubber is 247 µg/g (Shaheen 1975). The Valley study calculated that tires wear at a rate of 1075 g/tire/40,000 miles (Woodward-Clyde 1992). Assuming four tires per vehicle, the copper emission rate would be 1.06 x 10^6 µg/40,000 miles, and total 239 lbs/yr.

Muschack (1990) determined emission rates of copper for different types of roads due to abrasion from traffic. The data from this study, however, have not yet been obtained. Once emission rates are determined, the total annual load of copper from roadway abrasion will be calculated.

Copper is also found naturally in water in background concentrations. Total copper concentrations were obtained from the City of San Diego Water Department for Miramar, Murray, Otay, San Vicente, and El Capitan Reservoirs between 1998 and 2000. Since data do not exist to determine actual background metal concentrations in Chollas Creek, local reservoir data were reviewed to use as guidance, since reservoirs should theoretically contain close to background concentrations of heavy metals. Copper concentrations throughout the reservoirs were frequently non-detect, but total concentrations that were detected ranged from approximately 1 µg/L to just over 60 µg/L (after adding algicide to Miramar in May 2000, copper concentrations reached 301 µg/L, but this value is excluded from background calculations). The average total copper concentration for all five reservoirs was 8.6 µg/L. Although background concentrations of copper are not considered a "source," this concentration will be used in determining the allocation of copper for background concentrations.

Table 2 summarizes the significant sources of copper to Chollas Creek based on the above calculations.

Table 2. Sources of Copper in Chollas Creek

Source	% of Total Load	Load in lbs/year
Brake-pad wear	44%	2,500 lbs/year
Potable water supply	27%	1,550 lbs/year
Air deposition	25%	1,430 lbs/year
Tire wear	4%	239 lbs/year
Total	**100%**	**5,700 lbs/year**

ZINC

The Valley study found that approximately 99 percent of the estimated mean annual load of zinc to the Lower South Bay came from the following sources:

Atmospheric emissions	13%
Automotive	66%
Water supply	20%

Approximately 60% of annual loading related to automotive activities is due to tire wear and 6% is due to illegal dumping of motor oil. 20% of the total zinc loading was attributed to corrosion inhibitors that contain zinc used in potable water supply systems. 13% of the total zinc load was attributed to diesel fuel emissions.

Woodward-Clyde (1992) estimated that the typical amount of zinc released per vehicle due to tire wear was 43.04 g/40,000 mi. Based on the estimated total number of miles driven annually in Santa Clara Valley, the study estimated a total load of 28,466 lbs/year of zinc to the Lower South Bay. By comparison, assuming the same typical release rate for zinc as determined in the Valley study and using the total miles driven in the Chollas Creek watershed (calculated for copper previously), the annual loading of zinc due to tire wear is approximately 9,700 lbs/year for Chollas Creek.

In addition to tire wear, another significant portion of loading due to automotive activities identified in the study included illegally dumped motor oil. Motor oil contains a zinc concentration of 1,060 µg/g (Shaheen 1975). Using Woodward-Clyde's estimates and assumptions (see attachment A), approximately 392,500 kg/year of motor oil that is illegally dumped reaches the storm water system in Chollas Creek watershed. Therefore, approximately 916 lbs/year of zinc reach the watershed due to illegally dumped motor oil.

The Santa Clara Valley Water District has used zinc orthophosphate as a corrosion inhibitor since 1983. Approximately 20% of the total zinc loading to the Santa Clara Valley watershed was attributed to the addition of zinc orthophosphate to potable water. The San Diego Water Department, by contrast, does not add any corrosion inhibitors that contain heavy metals to the water supply, only sodium hydroxide is added for pH control (Chaffin pers. comm). The pH is maintained at 8.2, which results in the water being slightly scale forming, thus reducing the amount of heavy metal corrosion in the piping. It is therefore assumed that the potable water supply in San Diego is not a significant source of zinc. In addition, the 1999 City of San Diego Water Quality Report indicates that zinc was not detected in amounts above the California Department of Health Services detection limit for reporting, which is 50 µg/L (San Diego 1999).

The Valley study also evaluated the total annual load of zinc to the Lower South Bay due to atmospheric emissions and wet and dry deposition of zinc particulates. The study found that atmospheric emissions of zinc in Santa Clara Valley from vehicle exhaust were largely due to both diesel fuel and unleaded fuel exhaust (Woodward-Clyde 1992). There were no identified point sources of zinc emissions in Santa Clara County. Wet and dry deposition of zinc that was in the atmosphere due to vehicle emissions contributed to approximately 13% of the total annual copper load to the Lower South Bay. Emissions and wet and dry deposition data were obtained from CARB and USEPA, and studies performed for other US cities.

To accurately evaluate zinc loads from wet and dry deposition in Chollas Creek, wet and dry deposition data for the watershed are needed. However, there are currently no completed deposition studies for zinc in San Diego County. A workshop was held on February 9 and 10, 2000 in Los Angeles to specifically address the growing issue of atmospheric deposition impacts to the Pacific Coast. At the workshop, several deposition studies that are underway were discussed, including studies in San Francisco and Santa Monica, but these data are not yet available (UCLA 2000). Until sufficient data are available for San Diego, accurate calculations for loads from atmospheric deposition cannot be completed. Instead, the percentage of the total annual load contributed from air deposition estimated in the Valley study will be used to estimate contributions to Chollas Creek. The Valley study estimated

zinc load from air deposition to be 13% of the total load, so the estimated load to Chollas Creek would be approximately 1,590 lbs/year. This load would include wet and dry deposition due to stationary sources, mobile sources, and area sources.

Since the Valley study was performed in 1992, however, the USEPA has implemented a reformulated gasoline (RFG) program in 17 cities across the country, including San Diego, to reduce emissions such as toxic pollutants (including metals) and smog forming pollutants from automobiles. Phase I of the RFG program was implemented in 1995, and Phase II began January 1, 2000. The State of California implemented its own reformulated gasoline program effective in 1996 that met USEPA's Phase II requirements. It is expected, therefore, that metal emissions from automobiles may be less than that determined in the Valley study (i.e. 25%), but that emissions will not decrease further with the recent implementation of Phase II since California has been meeting the Phase II requirements since 1996. Although the RFG program does not impact diesel fuel, which contributes the largest amount of metals, the effects of the program may still be measurable.

Other sources of zinc that were identified in the Valley study, but determined to each contribute less than 1% of the total load, include automotive coolant leaks, coolant dumping, and oil leaks; residential paints; corrosion of plumbing; and source water. In San Diego, it is assumed that contributions from automotive coolant leaks, coolant dumping, and oil leaks; and residential paints would also be insignificant since the cities are similar in demographics. Corrosion of plumbing and source water have been shown to be insignificant in Chollas Creek as previously discussed.

In addition to the sources identified in the Valley study, brake-pad wear and auto bodies/frames may also be a significant source of zinc in urban runoff (Sansalone 1997). A report completed by Sustainable Conservation in San Francisco identified auto wrecking/dismantling facilities and scrap metal recycling facilities as two of the most significant industries that contribute metals to storm water runoff (O'Brien 2000). A review of auto wrecking/dismantling shops and scrap metal recycling facilities (Standard Industrial Classification (SIC) 5015 and 5093) in the Chollas Creek watershed was conducted. There were 21 facilities identified with these SICs in the watershed, although most of them were clustered near the mouth of Chollas Creek along San Diego Bay, and would not impact upstream reaches of the creek. Of these facilities, 12 storm water annual reports were reviewed. Only 3 of the facilities tested for copper, lead, and zinc in their storm water runoff. Notably, all three facilities had fairly high concentrations of the three metals in their discharge. Among the three facilities, copper ranged from 72 to 500 µg/L, zinc ranged from 260 to 1,000 µg/L, and lead ranged from 42 to 690 µg/L. Since most of these facilities would impact the mouth of Chollas Creek more significantly than Chollas Creek itself, the potential impact of these facilities was not quantified. However, 13267 letters will be drafted for industries located upstream along Chollas Creek that likely have metals in their stormwater. The facilities will be directed to sample for copper, lead, and zinc by the next wet season; once sufficient data are collected, estimated loads from these facilities will be calculated.

Moreover, the new Municipal Storm Water Permit requires municipalities, including the City of San Diego, to identify industries such as auto dismantlers and metal recyclers that threaten water quality, and to require these facilities to test for and manage pollutants that are likely to reach stormwater. It is

anticipated that these types of industries that may discharge metals in their stormwater will be required to test for metals as part of their required monitoring program. These data will also be used to monitor metal contributions from dismantling and recycling facilities in the future.

Beyond zinc contributions from auto body/frames located at auto dismantling facilities, autos that are still being driven may contribute to zinc loads as well. However, there are no known studies that have estimated the amount of zinc that is released from the bodies/frames of autos that are still in use. Zinc loads from this potential source would be estimated if relevant data becomes available at a later date.

Galvanized chain-link fences may also contribute zinc to urban runoff. There are long stretches of chain-link fencing along roadways in the Chollas Creek watershed. However, there are no known studies on the amount of zinc contributed by fencing. Zinc loads from this potential source would be estimated if relevant data becomes available at a later date.

Zinc is also released through the abrasion of roadways (Muschack 1990). However, the emission rates are currently not available from this study. Once the data are obtained, the total annual load of zinc from the abrasion of roadways will be determined.

In addition to the numerous anthropogenic zinc sources that have been identified, zinc is also found in waters in background concentrations. Total zinc concentrations were obtained from the City of San Diego Water Department for Miramar, Murray, Otay, San Vicente, and El Capitan Reservoirs between 1998 and 2000. Zinc concentrations throughout the reservoirs were frequently non-detect, but total concentrations that were detected ranged from approximately 1 µg/L to more than 90 µg/L. The average total zinc concentration for all five reservoirs was 6.8 µg/L. Although background concentrations of zinc are not considered a "source," this average background concentration will be used in determining the allocation of zinc for background concentrations.

Table 3 summarizes the significant sources of zinc to Chollas Creek based on the above calculations.

Table 3. Sources of Zinc in Chollas Creek

Source	% of Total Load	Load in lbs/year
Tire wear	79%	9,700 lbs/year
Air deposition	13%	1,590 lbs/year
Illegal disposal of motor oil	8%	916 lbs/year
Total	**100%**	**12,200 lbs/year**

LEAD

The Valley study found that the most significant sources of lead are atmospheric deposition of diesel-fueled vehicle exhaust, and to a lesser extent, unleaded-fueled vehicle exhaust. It is also anticipated that

roughly 100% of the total annual lead load to Chollas Creek comes from atmospheric deposition of diesel-fueled and unleaded-fueled vehicle exhaust, since no other significant sources of lead have been identified for Chollas Creek. Therefore, wet and dry deposition data for the Chollas Creek watershed are needed to estimate annual lead loads. However, there are currently no completed deposition studies for lead in San Diego County. A workshop was held on February 9 and 10, 2000 in Los Angeles to specifically address the growing issue of atmospheric deposition impacts to the Pacific Coast. At the workshop, several deposition studies that are underway were discussed, including studies in San Francisco and Santa Monica, but these data are not yet available (UCLA 2000). Until sufficient data are available for San Diego, accurate calculations for loads from atmospheric deposition cannot be completed.

Furthermore, it is not possible to estimate lead loads based on a percentage of the total loads, as was done for copper and zinc, since no other significant source of lead has been identified. Therefore, in order to roughly estimate lead loads to Chollas Creek, the deposition rates determined for Fresno, California will be used. Although Fresno and San Diego differ in climate, populations, etc., Fresno is the closest city to San Diego that has deposition data for lead. The lead deposition rate for Fresno was obtained from National Urban Runoff Program (NURP) studies (Brown and Caldwell 1984). The deposition rate for lead was determined to be 2.22 mg/m^2/month for Fresno in 1984. Since the Chollas Creek watershed is approximately 6.59×10^7 m^2, roughly 1.74×10^9 mg/year of lead would be deposited, or 3,800 lbs/year.

Since the Fresno data are from 1984, however, it is likely that annual lead loads from diesel fuel would currently be less than the estimate, due to both the RFG program and the Clean Air Act as amended in 1990, which prohibits the introduction of gasoline containing lead or lead additives into commerce for use as a motor vehicle fuel after December 31, 1995. However, for TMDL purposes, the conservative data from Fresno will be used.

Other sources of lead that were identified in the Valley study, but determined to each contribute less than 1% of the total load, include automotive coolant leaks, coolant dumping, oil dumping, and oil leaks; corrosion of plumbing; and source water. In San Diego, it is assumed that contributions from automotive coolant leaks, coolant dumping, oil dumping, and oil leaks would also be insignificant since the cities are similar in demographics.

Corrosion of plumbing and source water are also not significant sources of lead in Chollas Creek. The City of San Diego 1999 Annual Report indicated that lead was not detected above the detection limit of 5 µg/L in any of the effluents from the three San Diego plants (although reservoir lead concentrations may occasionally be higher than 5 µg/L, lead concentrations are reduced during the plants' filtration process). The 1999 City of San Diego lead and copper household monitoring study indicated further that the average lead concentration from household taps was 2.6 µg/L. These low concentrations indicate that corrosion of plumbing and source water are not significant contributors of lead in the Chollas Creek watershed.

In addition to lead sources identified by the Valley study, other potential sources of lead may include brake-pad wear, tire wear, and de-icing salts (Sansalone 1997). Since de-icing does not occur in San Diego, this activity would not be a source of lead for the Chollas Creek watershed. Currently, data regarding tire wear emissions and brake-pad wear emissions of lead are not available, but the Rubber Manufacturer's Association is currently assisting in the data search for tire-wear emissions. If these data are obtained at a later date, total annual loads from tires and brake pads will be determined.

Muschack (1990) determined emission rates of lead for different types of roads due to abrasion from traffic. However, the emission rates are currently not available from this study. Once these data are obtained, the total annual load of lead from the abrasion of roadways will be determined.

In addition to the numerous anthropogenic lead sources that have been identified, lead is also found in waters in background concentrations. Total lead concentrations were obtained from the City of San Diego Water Department for Miramar, Murray, Otay, San Vicente, and El Capitan Reservoirs between 1998 and 2000. Lead concentrations throughout the reservoirs were frequently non-detect, but total concentrations that were detected ranged from approximately 0.5 µg/L to just over 60 µg/L. The average total lead concentration for all five reservoirs was 7.0 µg/L. Although background concentrations of copper are not considered a "source," this concentration will be used in determining the allocation of copper for background concentrations.

Based on the above calculations, the significant sources of lead are vehicle emissions, and the approximate total annual loading of lead to the Chollas Creek watershed is 3,800 lbs/yr. This annual load would include wet and dry deposition due to stationary sources, mobile sources, and area sources.

STORM WATER MONITORING

Annual loads of copper, lead and zinc have been estimated for Chollas Creek in the NPDES monitoring reports for the City of San Diego and co-permittees municipal stormwater permit. Table 4 presents the summarized data of the estimated loads for each metal for each storm event measured between 1994 and 1995 (data after 1995 does not include storm volumes and/or total metal results, so loads could not be determined). Data for individual storm events were calculated based on the metal concentrations measured for each storm multiplied by the total storm volume.

Table 4. Total Pounds of Contaminant per Storm Event

Date of Storm	2/17/94	3/24/94	4/24/94	11/10/94	1/11/95	2/14/95	4/16/95
Lead (lbs)	145	114	95	3.4	54.9	301	100
Copper (lbs)	44	24	60	3.5	21.2	109.5	60.5
Zinc (lbs)	343	195	436	17.6	187	985	398.5

Total annual loads to Chollas Creek were then calculated by finding the average load per storm event for each metal (data from 11/10/94 was not included since it appears to be an outlier), and multiplying

the average by 18, which is the typical number of storms per year for Chollas Creek (Woodward-Clyde 1999). Table 5 below compares these results to the total annual loads calculated based on the Santa Clara Valley study data.

Table 5. Total Annual Loads (Storm Water Monitoring) vs. Total Annual Loads (Calculated)

	Total Annual Load (lbs/year) Based on Storm Water Monitoring	**Total Annual Load (lbs/year) Calculated Based on Studies**
Lead	2,430	3,800
Copper	960	5,700
Zinc	7,600	12,200

The estimated loads based on storm data are consistently less than the estimated loads based on calculations. This observation is likely due to the fact that less than 100% of metals released into the watershed ultimately reaches Chollas Creek (some of it will leach into pervious surfaces, etc.). Further, storm data do not account for dry weather flows. Currently, there are no data for dry weather flows in Chollas Creek. However, dry weather flow samples were taken in September 2000; as soon as the sampling results are available, an additional discussion on dry weather flow contributions will be included.

ADDITIONAL STORMWATER SAMPLING

During February 2000, the City of San Diego organized additional sampling of two storm events in Chollas Creek. Results from the sampling of these two storms provided additional information on the distribution of copper, lead and zinc in Chollas Creek (Figure 1). Samples were also tested for cadmium, but no total or dissolved cadmium was detected in any sample for either storm, further justifying the elimination of this metal from the TMDL. Zinc was detected at every location in both total and dissolved samples for both storm events. Total copper and lead were found at almost all locations, although only a few locations had detectable dissolved copper levels. Tables 6 and 7 provide the sampling results.

Table 6. First Storm Event (February 12, 2000)

Location	**Total Hardness (mg/L)**	**Contaminant**	**Total Result (mg/L)**	**Dissolved Result (mg/L)**
Delevan	58	Copper	68	37
		Lead	34	-
		Zinc	160	45

Federal @ Home	54	Copper	68	-
		Lead	52	-
		Zinc	300	20
Federal @ 94	100	Copper	43	-
		Lead	76	-
		Zinc	370	45
69th	120	Copper	23	-
		Lead	16	-
		Zinc	100	20

Table 7. Second Storm Event (February 21, 2000)

Location	Total Hardness (mg/L)	Contaminant	Total Result (µg/L)	Dissolved Result (µg/L)
Delevan	47	Copper	23	11
		Lead	23	-
		Zinc	180	67
Federal @ Home	36	Copper	19	-
		Lead	19	-
		Zinc	160	57
Federal @ 94	63	Copper	27	-
		Lead	35	-
		Zinc	220	32
69th	100	Copper	-	-
		Lead	-	-
		Zinc	54	30

COPPER

Dissolved copper was only detected at the Delevan sampling location. Based on the calculations used to determine acute and chronic criteria for dissolved metals (identified in Numeric Targets), copper exceeded both acute and chronic criteria at Delevan for both storm events. The chronic and acute criteria are found in Table 8:

Table 8. Dissolved Exceedances for Copper at Delevan

	CMC (µg/L)	CCC (µg/L)	Dissolved Result (µg/L)
Storm Event 1	8.0	5.6	**37**
Storm Event 2	6.6	4.9	**11**

ZINC

Dissolved zinc exceeded both acute and chronic criteria during the second storm event at both the Delevan and the Federal @ Home locations. There were no exceedances of dissolved zinc at any location for the first storm event. Interestingly, these results do not indicate a first-flush phenomenon. Table 9 provides the exceedance data for dissolved zinc.

Table 9. Dissolved Exceedances for Dissolved Zinc During the Second Storm

Location	CMC (µg/L)	CCC (µg/L)	Dissolved Results (µg/L)
Delevan	62	62	**67**
Federal @ Home	49	50	**57**

LEAD

Lead had no detectable dissolved concentrations in any of the samples collected.

DISCUSSION OF SAMPLING RESULTS

Based on the sampling results, in general, the sampling location at 69th had the lowest metals concentrations, followed by the two locations at Federal. The Delevan sampling site had the most exceedances, two CMC and two CCC for copper and one CMC and one CCC for zinc. Results of the sampling are consistent with the expected loadings from vehicle use. The locations at Delevan and Federal @ Home had the highest dissolved copper and zinc concentrations. These two locations have the heaviest traffic volume of the four sampling sites since they are both located near the intersection of two highways, Highway 94 and Highway 805. In addition to the higher traffic volume, cars would also be breaking more frequently in this general vicinity as well, as cars transition onto exit and entrance ramps for the two highways, and as the traffic pattern slows during more congested hours. This pattern of metal concentrations is consistent with results found by Muschack in 1990; results measured at a road location with a traffic light had higher values for almost all parameters than measurements taken at thoroughfare roads. Muschack explained that the higher values may be due to the fact that the road is a "main road leading out of town and that a traffic light is situated within the segment of the road covered by the measurements. This leads to a much higher number of brake and acceleration activities: Connected to this is an increased abrasion of the tires, higher use of brake linings; [and] higher automotive exhaust gas emissions…" (Muschack 1990).

The sampling location at 69th, by contrast, had no exceedances for dissolved metals in either of the storm events sampled. These results are also consistent with predicted results, since 69th street is located in a more residential area with the least traffic volume out of the four locations sampled.

CHOLLAS CREEK WET WEATHER TOXICITY STUDY

A two-year project funded by the US EPA (205j Non-point Source Grant) is in progress that is aimed at evaluating the extent and magnitude of potential impairments in San Diego Bay resulting from Chollas Creek discharges. Although this study is primarily geared toward determining effects in San Diego Bay, it should also provide additional information for Chollas Creek as well. The project represents an ongoing collaboration with the City of San Diego, the San Diego Unified Port District, the San Diego Regional Water Quality Control Board, and the Southern California Coastal Water Research Project (SCCWRP). There were five tasks outlined in the proposal including:

1) Determining the extent of the wet weather plume,
2) Assessing how much of the wet weather discharge plume is toxic to marine aquatic life,
3) Measuring the magnitude of toxicity within the wet weather discharge plume,
4) Measuring how long the wet weather toxicity persists, and
5) Determining the constituent(s) responsible for the observed toxicity in the wet weather plume.

SCCWRP's preliminary measurements from three sampled storm events showed that all samples taken from the channel and from within the plume from San Diego Bay were toxic. The samples collected outside of the plume, however, were not toxic. SCCWRP will also assess if the magnitude of toxicity is proportional to the amount of runoff, as well as conduct TIEs on creek and selected plume samples. As the study progresses and more data are available, pertinent information to the TMDL will be included in the Source Analysis.