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SOURCES OF URBAN RUNOFF POLLUTION AND ITS EFFECTS ON AN URBAN CREEK

by

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components requires a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solving, and involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources; for the preservation and treatment of public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and is a vital communications link between the researcher and user community.

An evaluation of the receiving water effects of urban runoff is necessary before urban runoff control goals and practices can be established and selected. This report presents the results of an evaluation of the water quality and biological effects of urban runoff on Coyote Creek, near San Jose, California. Coyote Creek, upstream and in the study area, receives minimal pollutant discharges, except for urban runoff. The biological, water and sediment quality gradients observed illustrate significant degradation in the quality of the creek in the urban area.

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ABSTRACT

This report presents the final results and conclusions from an EPA-sponsored demonstration study of the water quality and biological effects of urban runoff on Coyote Creek, near San Jose, California. Various field procedures were used during the project to evaluate water, sediment, and biological changes in the creek as it passed through the urban area. The report describes the characteristics and sources of urban runoff pollutants which affect the creek, and the effects and potential controls for urban runoff.

The study sampled and analyzed runoff and dry particulate materials from many sources (e.g., street surfaces, parking lots, landscaped areas, vacant land, rooftops, rain). A major element of the project involved the use of various short- and long-term biological sampling techniques to evaluate the fish, benthic macroinvertebrates, and attached algae at many stations in the creek, above and within the urban area. It was concluded that the urbanized portion of the creek has been significantly degraded and that urban runoff is an important causative factor.

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SECTION 1

INTRODUCTION

This report describes a study which investigated the effects of urban runoff on a small stream—Coyote Creek, near San Jose, California (see Figure 1-1). To some extent the timing of this project overlapped with the last parts of a demonstration project* performed by Woodward-Clyde Consultants for the City of San Jose and the Environmental Protection Agency. Parts of the study areas of the two projects also overlapped.

The purpose of the study described herein was to investigate the kinds of water quality, sediment and biological changes that can occur in streams as they pass through urban areas. This report should help decision makers understand urban runoff problems and be useful when developing urban runoff control programs.

Coyote Creek and the San Jose area were selected for study for the following reasons:

- Coyote Creek originates in a wilderness area that is virtually free of pollutant sources. Its upper reaches pass through an undeveloped area, and it is not affected by urban runoff until the creek reaches San Jose.

- Coyote Creek's upstream waters pass through two man-made reservoirs. These reservoirs control the creek's flow during much of the year. Existing monitoring stations also provided a convenient means of accounting for flow rates.

- The creek is not affected by sanitary or industrial waste discharges, either above or within the study area.

- The recently completed, EPA-funded demonstration project in San Jose (1) provided detailed pollution, source and watershed characterization information for a portion of the study area, thus minimizing the effort needed to describe runoff conditions in the watershed.

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*The approach and findings of that project are presented in a report titled, "Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Practices" (1). Where appropriate, data developed during the previous project were used here to help characterize the urban runoff affecting Coyote Creek and to assess potential urban runoff control measures.

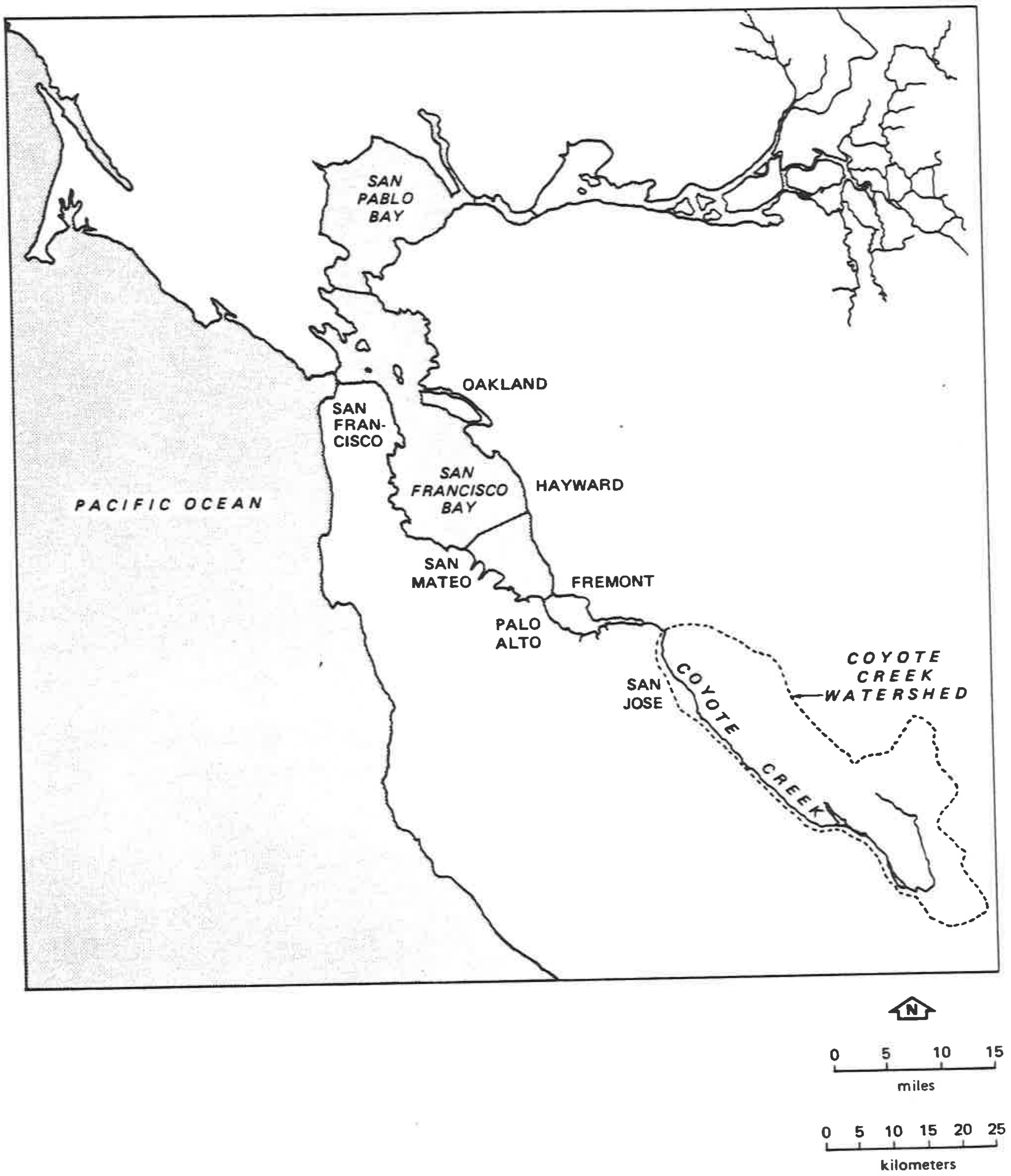

Figure 1-1. San Francisco Bay Area.

The three major elements of this study included:

- identifying and describing important sources of urban runoff pollutants
- describing the effects of these pollutants on water quality, sediment quality, aquatic organisms, and the creek's associated beneficial uses
- assessing potential measures for controlling the problem pollutants in urban runoff.

This project has developed data that demonstrate that water quality, sediment and biological conditions in Coyote Creek generally degrade as the creek passes through the urbanized area of San Jose. This information should be useful to those who need to estimate the degree and type of urban runoff control that may be required to protect or improve receiving waters. The project involved conducting field measurements, observations, sampling, and other studies of Coyote Creek from March 1977 through August 1980.

The study focused on the urban reaches of Coyote Creek, extending from Lake Anderson to the confluence with Silver Creek (note that this includes the Keyes St. and Tropicana study areas that were investigated during the San Jose street cleaning demonstration project [1]). In this reach of Coyote Creek, there are few contributions (of either flow or pollutants) other than urban runoff. The sampling areas were selected such that each included a stretch of stream several hundred meters long, which met prescribed geographic criteria and criteria for physical/biological/chemical homogeneity. The urban sampling areas were all located between (rather than near) adjacent urban runoff outfalls to reduce the potential influences of individual outfalls on the samples.

The following were typically examined at sampling locations:

- basic hydrologic conditions
- water quality
- sediment properties
- general habitat characteristics
- fish
- benthic organisms (e.g., aquatic insects, crustaceans, mollusks)
- attached algae
- rooted aquatic vegetation (e.g., cattails)

The following sections of this report present the study's conclusions, a description of the study area, the study's overall methodology, urban runoff characteristics, and conditions in Coyote Creek.

SECTION 2

CONCLUSIONS

This section summarizes the conclusions presented in more detail later in this report. These conclusions pertain primarily to observations and data collected during the field program and subsequent sample analyses. However, some conclusions also cover information obtained during a comprehensive review of literature on related subjects. These conclusions are presented in terms of the following major subject areas:

- pollutant source areas, yields, and transport mechanisms
- runoff quality
- receiving water quality
- sediment quality
- bioaccumulation
- aquatic biology
- treatment goals.

It is important to stress that cause-and-effect relationships cannot be conclusively proven in a study such as this one, because there are many important factors which cannot be controlled or taken into account. Much care was taken to select monitoring locations which would minimize extraneous natural and man-made effects. Nonetheless, it is recognized that factors other than urban runoff may have contributed to the observed degradation in the creek's water quality, sediment quality, biological resources, and general aesthetic character as it passed through the urban area. Such factors may include changes in flow caused by natural infiltration, diversion of creek waters (e.g., for artificial ground water recharge), return of water from recharge basins into the creek, and temporary obstructions in the creek. Additional factors likely to have contributed to the observed impacts include changes in creek gradient and temperature (resulting from factors such as creek shading by vegetative overstory and releases from upstream impoundments). The observed decline in aquatic organism diversity and abundance may have been affected by these other factors. However, it is unlikely that the observed accumulation of pollutants in the sediment and the decrease in water quality in the creek in the downstream direction would be caused by these hydrologic influencing factors nearly as much as by the urban runoff discharges. Based upon information presented in other literature sources for other studies and test areas, the water and sediment characteristics observed in the creek showed the potential for being the principal cause of aquatic organism effects similar to those observed.

POLLUTANT SOURCE AREAS, YIELDS, AND TRANSPORT MECHANISMS

Many sources within the urban area are recognized as being potential contributors of urban runoff pollutants (1). Study results, however, do not indicate that any particular source contributes significant quantities of most of the pollutants. Nonetheless, some source areas do appear to be quite important. For example, street surfaces are believed to be responsible for significant contributions of several heavy metals, whereas oxygen-demanding materials and nutrients are believed to originate mostly from landscaped areas and areas of vacant land.

The following summarizes this study's conclusions regarding the relative contribution from various types of areas which are sources of urban runoff pollutants:

- Vacant and landscaped areas tend to be among the most permeable surfaces in an urban area and also tend to be located farthest from the storm sewerage system. Therefore, they typically contribute little flow during an urban runoff event. Although landscaped and vacant areas were found to make up almost half of the total San Jose urban area, only about 5 percent of the rain falling on these areas is expected to contribute to the outfall flow. Similarly, very little of the potential pollutant yields from these areas would be expected to reach storm sewer outfalls along Coyote Creek.

- Rooftops, which make up about 15 to 20 percent of the urban area, are also located at relatively long distances from the storm sewers. Most San Jose rooftops are not directly connected to the storm sewerage system, and their pollutant yield to storm sewer outfalls is expected to be about 30 percent.

- Sidewalks make up about 5 percent of the total urban area and are located closer to the storm drainage system, but some of their drainage flow is directed to adjacent landscaped or other relatively permeable areas. Therefore, only about one-half of the runoff yield from sidewalks reaches the outfalls and the receiving waters.

- Parking lots cover about 7 percent of the urban area and are mostly paved and impermeable. Again, some of the runoff in parking lots is directed towards adjacent permeable areas; only about one-half of the parking lot runoff is expected to reach the receiving waters.

- Street surfaces are located close to the storm drainage system and are almost totally impermeable. Street surfaces cover about 15 to 20 percent of the urban area, and most of the runoff that originates from street surfaces is expected to reach the outfall. Some of the street surface flow, however, does not reach the outfall because of infiltration into streets in poor condition and because of evaporation.

The amount of pollutants in urban runoff depends in part upon the size and frequency of rain events. Stated simply:

- larger events are capable of removing and transporting greater amounts of pollutants from their source areas to the receiving waters
- the less frequent the events, the more time available for pollutants to accumulate on the source areas.

Thus, during the winter rainy season (with its larger rainfall volumes and relatively short accumulation periods between storms) a typical storm gives relatively small contributions of street surface particulates compared to the total runoff yield (which contains particulates from many different sources). During such conditions, the street surfaces stay relatively clean (because of the frequent rains). Conversely, these large rains also result in greater erosion from the surrounding exposed land areas (especially if the soils are saturated and soft). For rains of moderate intensity and frequency (resulting in relatively dirty streets and dry antecedant soil conditions), a large proportion of the total urban runoff pollutants can be expected to originate on street surfaces.

Traffic has been found to be an important factor, especially during less intense storms. Large traffic volumes and relatively high speeds provide the energy needed at the street surface to loosen particulates. Heavy or fast traffic, combined with moderate to high storm intensities, have the potential for removing and transporting the maximum pollutant load. With lighter storms, traffic-induced turbulence becomes more important. However, storm intensity eventually becomes the limiting condition, because with very light storms, few particulates would be transported to the receiving waters, even if they were dislodged by traffic turbulence. Therefore, estimates of yields from different source areas within the watershed are very site dependent. Experience gained in this study highlights the importance of carefully considering a variety of factors (e.g., antecedent weather conditions, specific storm characteristics, and local traffic condition at the time of the storm).

It is estimated that if all of the total particulate pollutants deposited in the San Jose portion of the Coyote Creek watershed were added up, only about 30 percent would reach Coyote Creek via urban runoff. Similarly, it is estimated that only 10 percent of the nutrients and oxygen-demanding materials deposited in the contributing area would reach the creek. On the other hand, most of the heavy metals in the area would be expected to reach the creek. These differences are related to the fact that the remaining pollutants (i.e., those that are washed off the source areas but do not reach the outfalls) tend to be trapped or otherwise accumulate in other areas in the urban environment. The most significant areas of accumulation would probably be the soils, vegetation, and possibly groundwater.

URBAN RUNOFF QUALITY

When the quality of urban runoff affecting Coyote Creek was examined, many parameters were found to exceed the criteria for various beneficial uses. The runoff discharges to the creek in the non-urban (i.e., upstream) areas contained relatively small quantities of most pollutants, whereas the runoff discharges in the urban area contained increasing quantities of pollutants, in a downstream direction.

COYOTE CREEK WATER QUALITY

The water in Coyote Creek was found to be turbid, hard to very hard, and have high concentrations of both ammonia and bacteria. Nitrites, ammonia, turbidity, chlorides, and specific conductance were found to increase significantly as Coyote Creek passed through the urban area. Concentration increases were more pronounced during and immediately after runoff events.

During dry weather, many of the constituents (e.g., major ions, hardness, alkalinity, total solids, total dissolved solids, specific conductance, ammonia nitrogen, orthophosphate) were significantly greater in both the urban and non-urban reaches than they were during wet weather. Typically, the dry weather concentrations for these constituents were about 2 to 5 times the wet weather concentrations. Apparently, the runoff and rain-induced stream flow has the effect of diluting these constituents during wet weather.

Other stream parameters (e.g., temperature, pH, dissolved oxygen, nitrate nitrogen, arsenic) were found to be about the same for both wet and dry weather in both the urban and non-urban areas. Within the urban area, several constitutents were present in greater concentrations during wet weather than during dry weather. These included suspended solids, volatile suspended solids, and turbidity. This pattern is thought to be a result of erosion. Other constituents found in greater abundance in the urban area during wet weather were Chemical Oxygen Demand, organic nitrogen, and the heavy metals. For example, lead, zinc, copper, cadmium, iron, and nickel were found in greater abundance during wet weather by factors from 2 to more than 40 times. Similar differences between wet and dry weather were also noted for the non-urban area. However, the urban area wet weather concentrations were typically much higher than non-urban area concentrations.

The wet weather turbidity increases in the urban reach of Coyote Creek probably exceeded the water quality criteria for aquatic life. Wet weather lead concentrations in the urban reach substantially exceeded the water quality criteria for livestock (by about 20 times) and the criteria for aquatic life (by about 60 times). Wet weather lead concentrations in the non-urban reach also exceeded the livestock criteria by 2 times and the aquatic life criteria by about 6 times.

Although this study found and documented a significant decrease in the abundance and diversity of aquatic life in Coyote Creek as it passed through the urban area, it is not possible to assign responsibility to a particular pollutant or source. Short-term peak concentrations of several toxic pollutants were observed to be very high. Also, significant concentrations of these toxic pollutants were found in the sediments. However, with the present state of the art, it is not possible to relate such observations directly to water quality criteria or published test results on water quality effects.

COYOTE CREEK SEDIMENT QUALITY

Analysis of the sediment samples collected during the course of the study showed little overall difference between the urban and non-urban reaches. However, at various times, the differences between conditions at specific sampling locations were significant. This finding emphasized the need for caution in studying a system in which the inherent variability with respect to both time and location are so high.

This project was conducted over several seasons to minimize the degree to which a spot sampling approach might yield anomalous results which could be misleading. The time period covered is still not very long (relative to what would be needed to fully avoid errors caused by time variability), so it will be necessary to use considerable caution when applying the findings to other areas.

During the initial sediment survey, the gradation of quality with distance downstream was found to be significant. However, when all the survey results were combined, the differences were found to be much smaller. For example, during the initial survey, the urban area samples contained higher concentrations of sulfates (33 to 60 times greater), lead (about 10 times greater), and orthophosphates (up to about 4 times greater) than the samples from the non-urban area. Much more silt was found in the urban samples, and they had significantly greater concentrations of high molecular-weight hydrocarbon and oxygenated compounds. However, when all the sediment quality information was combined, only minor differences were found between the urban and non-urban sediments' Chemical Oxygen Demand, total phosphate, arsenic, and median particle sizes. Lead concentrations in the urban sediments were still greater than in the non-urban sediments, but only by a factor of 4 to 6 times (and this was the largest margin for any constituent monitored).

In analyzing the data from this study, it was found useful to consider the relative properties of sediments and the overlying water. This was done for selected constituents by computing the following ratio:

$$\text{S/W ratio}^{*} = \frac{\text{the measured concentration in the sediment sample}}{\text{the measured concentration in the water sample}}$$

For most readily-soluble constituents, the S/W ratio would be low. Conversely, it would be high for relatively insoluble constituents.

In this study, the S/W ratios were found to be very large for most of the constituents monitored. Furthermore, they tended to be similar for both the urban and non-urban areas. The largest difference between the urban and non-urban area S/W ratios was for lead (the S/W ratio for the urban area was more than 3,000 whereas it was about 400 for the non-urban area samples). The total Kjeldahl nitrogen S/W ratios for the urban area were more than

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*Note that some investigators refer to this S/W ratio as "enrichment", but that term is avoided here because of potential semantic problems.

20,000, whereas they were about 5,500 for the non-urban area samples. The differences in S/W ratios between the urban and non-urban reaches for the other constituents studied were much less pronounced.

It is important to consider that the concentration of pollutants in the interstitial films of water which surround the sediment grains may well be much higher than the concentration measured in the overlying water column. This is of particular importance when considering the potential effects on aquatic organisms that intimately contact the sediments and are thus exposed to such films on an ongoing basis. It is hypothesized that the interstitial waters in the sediments might well be polluted even in cases where the concentrations of urban runoff-derived pollutants in the water column are within acceptable limits.

BIOACCUMULATION

Some evidence of bioaccumulation of lead and zinc was found in many of the samples of algae, crayfish, and cattails. The measured concentrations of these metals in organisms exceeded concentrations in the sediments (up to a maximum factor of about 6). Concentrations of lead and zinc in the organisms exceeded water column concentrations by factors of 100 to 500 times, depending upon the organism. Lead concentrations in urban area samples of algae, crayfish, and cattails were found to be two to three times as high as in non-urban area samples, whereas zinc concentrations in urban area algae and cattail samples were about three times as high as the concentrations in the samples from the non-urban areas. Lead and zinc concentrations in fish tissue were not noticeably different between the urban and non-urban area samples.

AQUATIC BIOLOGY

The biological investigations in Coyote Creek have indicated distinct differences in the taxonomic composition and the relative abundance of the aquatic biota present in the various reaches of the stream. The non-urban reaches of the creek were found to support a fairly diverse assemblage of aquatic organisms including an abundance of native fish species and numerous benthic macroinvertebrate taxa (e.g., mayflies, caddisflies, crane flies, riffle beetles, midges, blackflies, amphipods, snails, and fingernail clams). Clean water taxa were abundant in the non-urban reach of the study area. In contrast, however, the urban portions of the creek were found to support an aquatic community that is generally lacking in diversity and is dominated by pollution-tolerant organisms (e.g., mosquito fish, and tubificid worms).

Though there was some degradation of physical habitat in the downstream reaches of the study area, it is believed that the detrimental effects of urban runoff are likely the primary reasons for the decline in biological conditions.

NEED FOR CONTROL MEASURES

Various beneficial use water quality criteria for Coyote Creek could conceivably be met in all reaches, but this would require the vigorous implementation of various measures to control the discharges of urban runoff. In this study, control levels for urban runoff were identified by comparing observed water quality concentrations with three targets:

- concentrations needed to support various beneficial uses
- concentrations typical of secondary wastewater effluent
- sediment and water quality concentrations typical of the non-urban control areas.

The degree of pollutant control required for urban runoff was found to be as follows: lead removal from urban runoff would have to be from 75 to about 98 percent; zinc removal from 35 to 50 percent; suspended and settleable solids removals would have to be 40 to 90 percent; and oxygen-demanding materials (e.g., Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Organic Carbon) and phosphate removals would have to be about 85 percent. Depending upon the location of acceptable biological conditions, total urban runoff control would have to be about 80 to 100 percent effective. These are all very high removal goals and would be difficult and costly to meet. A decision analysis procedure that considers partial fulfillment of goals, costs and acceptably degraded receiving water conditions is necessary before a control program could be designed for Coyote Creek.

SECTION 3

DESCRIPTION OF THE COYOTE CREEK WATERSHED

GENERAL DESCRIPTION

Figure 1-1 is a map of the San Francisco Bay Area showing the location of the Coyote Creek watershed. Figure 3-1 is a detailed map of the Coyote Creek watershed. The watershed itself is about 70 kilometers (45 miles) long, 15 kilometers (10 miles) wide, and contains about 80,000 hectares (200,000 acres). Nearly 15 percent of the watershed consists of developed urban areas. The urban area is part of the San Jose SMSA*, one of the largest and fastest growing metropolitan areas in the west. Most of the urban development is located in the northwest portion of the watershed.

For much of its length, Coyote Creek flows northwesterly along the western edge of the watershed. Elevations in the watershed range from sea-level to nearly 920 meters (3,000 ft.). Near the San Jose urban area, the watershed can be characterized as a broad plain with rolling foothills to the east. A portion of the watershed (i.e., the narrow strip between Lake Anderson and the urban area) is used for light but productive agriculture. The upper reaches and the headwaters of Coyote Creek are in extremely rugged terrain, with slopes commonly exceeding 30 percent. These upper areas can be characterized as chapparal-covered hills and gullies in a fairly natural state; they receive little use by man. Much of this land is within the Henry Coe State Park; non-park land is used primarily for low-density cattle grazing.

The overall length of Coyote Creek is about 130 kilometers (80 miles) measured along the main channel and the middle fork. The creek's lower reaches drain generally in a northwesterly direction and empty into the extreme southern end of San Francisco Bay (see Figure 1-1) Several major facilities have been built on Coyote Creek to provide flood control and groundwater recharge. The largest are the dams which contain man-made reservoirs: Lake Anderson and Coyote Lake. Discharges from these lakes are controlled by the Santa Clara Valley Water District.

The major study area was located between the farthest downstream dam (Lake Anderson) and the first major confluence (where Coyote Creek meets Silver Creek, within the City of San Jose). Within this 39-kilometer (24-mile) study area, approximately 16 kilometers (10 miles) are urban and 23 kilometers (14 miles) are non-urban. The non-urban reach can be

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*Standard Metropolitan Statistical Area

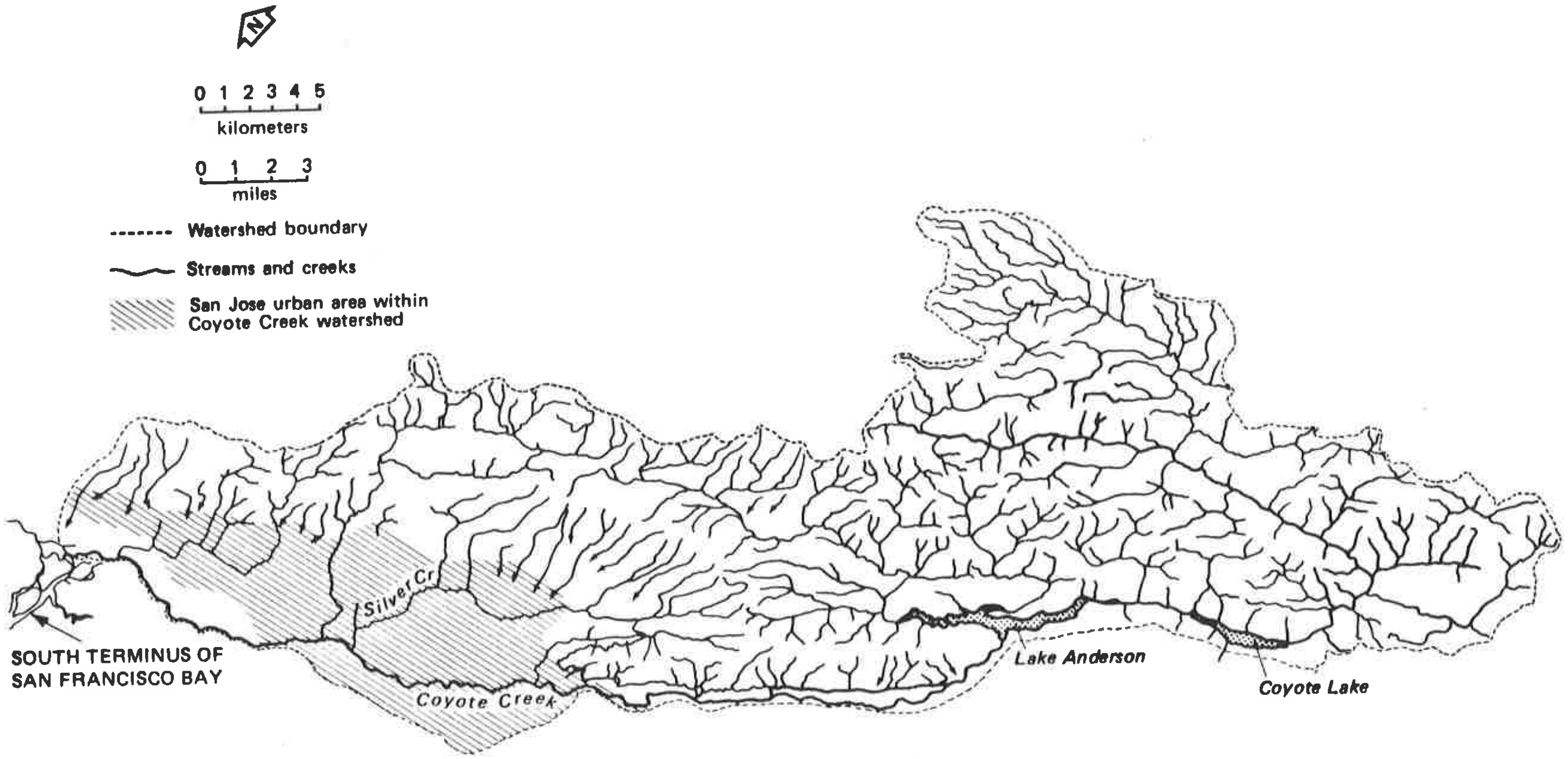

Figure 3-1. Coyote Creek Watershed.

characterized as having relatively low-intensity agricultural and open-space land uses. Sampling stations were located in both the urban and non-urban reaches of the stream for comparison.

HYDROLOGY

Average daily flows in the northern part of the creek are typically less than 1.5 cubic meters per second (50 cfs). Major storm flows, however, can approach 30 cubic meters per second (1,000 cfs). The flows in the northern part of the creek are controlled largely by the discharge from Lake Anderson and Coyote Lake.

Table 3-1 summarizes the water releases from Lake Anderson during the study period. Releases during February, March, and April of 1978 were quite irregular, varying from virtually zero to about one cubic meter per second (35 cfs). During May, the releases increased to about 2.3 cubic meters per second (80 cfs) and remained at about that level through August. During the winter of 1978-1979, reservoir releases were relatively low, because adequate natural flows entered the creek from storm runoff. From May through August of 1979, releases resumed at about 2.3 cubic meters per second (80 cfs) and dropped back to low levels again during the winter.

It should be understood that the beginning of the project followed two years of severe drought. The first major rains occurred the previous November, and seasonal rains that occurred during the study period were considered normal. Typical rainfall averages 33 centimeters (13 inches) per year in the area below Lake Anderson and 50 to 71 centimeters (20 to 28 inches) per year in the watershed above Lake Anderson. During the drought, which preceded this study, rainfall was only about one half these amounts.

Coyote Creek is an important element of the Santa Clara Valley Water District's groundwater recharge program. Several recharge basins have been established adjacent to the stream channel within the study area. Diversion channels withdraw water from Coyote Creek, route it into these large basins, and return it back into the creek, depending upon such factors as season, streamflow, and ground water level. Major diversions and additions to Coyote Creek within the study area are as follows:

- Diversions:
  - Main Avenue recharge area
  - Coyote Canal
  - Coyote recharge area

- Additions:
  - Coyote Canal Overflow #1
  - Fisher Creek
  - Metcalfe Creek
  - Coyote Canal Overflow #2

The water release data in Table 3-1 do not accurately represent the flow conditions at the sampling stations. Some of the stations were affected by factors such as recharge basin return flows (i.e., Coyote Creek water that

Table 3-1. COYOTE CREEK FLOWS DUE TO WATER RELEASES FROM ANDERSON DAM (m^3/sec.)

Month	Year	Mean daily flow	Minimum daily flow	Maximum daily flow
February	1978	0.63	0.01	0.98
March	1978	0.66	0.00	1.14
April	1978	0.55	0.32	0.70
May	1978	2.02	0.41	2.36
June	1978	2.28	2.19	2.38
July	1978	2.15	1.70	2.26
August	1978	2.15	2.13	2.17
September	1978	1.85	1.80	2.13
October	1978	1.78	1.52	2.03
November	1978	1.35	0.75	1.55
December	1978	0.46	0.35	0.73
January	1979	0.18	0.01	0.36
February	1979	0.22	0.01	0.49
March	1979	0.34	0.27	0.44
April	1979	0.57	0.17	1.39
May	1979	2.12	1.40	2.59
June	1979	2.39	2.15	2.53
July	1979	2.20	2.10	2.39
August	1979	2.09	1.97	2.24
September	1979	1.93	1.58	2.11
October	1979	1.23	0.62	1.62
November	1979	0.37	0.29	0.54
December	1979	0.34	0.33	0.37
January	1980	0.30	0.08	0.39
February	1980	0.23	0.08	0.69
March	1980	0.12	0.10	0.13
April	1980	0.33	0.03	0.90
May	1980	1.80	0.90	2.29
June	1980	1.95	1.22	2.06
Total		1.19	0.00	2.59

Source: Santa Clara Water District (personal communication -Mr. Larry Wilson).

was previously diverted), direct groundwater influx through the creek banks and bed, and dry weather flows from storm drain outfalls. In the urban reaches of the creek, these dry weather flows were thought to consist mostly of leakage from domestic water lines, landscape irrigation, and car washing water. Some of the sampling stations were also affected by direct groundwater infiltration and dammed pools in the creeks. For example, certain stretches of creek were dry for short periods of time, while downstream reaches had flowing water (from these and other sources). For this reason, it would be inaccurate to conclude that a streamflow value of zero implies an absence of water or aquatic life. The sampling stations were carefully selected so that running water was present throughout the period of study.

OUTFALL LOCATIONS

Table 3-2 and Figure 3-2 describe the stormwater outfalls and drainage areas along the 25 kilometer (16 mile) reach of Coyote Creek that extends from the town of Coyote (on the south) to the Silver Creek confluence (on the north). Figure 3-2 also shows the locations of two areas studied during a previous street cleaning demonstration project (1).

There are an average of 0.6 to 3 storm drain outfalls per kilometer (1 to 5 per mile) along this reach of Coyote Creek. Other storm drain outfalls are located downstream from the Silver Creek confluence, but they are not included in this table or figure, because they are outside of the main study area. There may be a few additional storm drain outfalls upstream from those identified here, but they were not located during the study. The identified outfalls range from 20 to 180 centimeters (8 to 71 inches) in diameter, but most are about 76 centimeters (30 inches) in diameter. The drainage area per outfall ranges from 2 to 320 hectares (5 to 800 acres), but most of the outfalls drain areas smaller than 40 hectares (100 acres).

SAMPLING STATIONS

The urban area sampling stations located within a 25 kilometer (16 miles) reach of the creek are shown in Figure 3-2. The non-urban area stations were located upstream of this reach (i.e., above the outfalls), but downstream of Lake Anderson.

Figure 3-3 is a profile diagram of Coyote Creek that shows the elevation of the streambed and locations of the sampling stations. Stations above the 39 kilometer (24 mile) point (as measured from a reference point at the creek mouth) were considered upstream of the urban area (the upper boundary was considered to be at the Coyote Road gaging station). Table 3-3 describes the drainage areas which cumulatively contribute to selected stations. The urban area stations were found to have about 3 to 4 percent (1,700 to 2,500 hectares or 4,000 to 6,000 acres) of their total drainage urbanized, whereas the non-urban area stations have less than 0.1 percent of their drainage area urbanized. The three stations designated as Hellyer, Sylvandale, and Senter can be considered transition stations (about 0.6 to 1.5 percent of their drainage areas are urbanized).

Table 3-2. MAJOR DRAINAGE AREAS AND STORMWATER OUTFALLS WHICH CONTRIBUTE TO COYOTE CREEK

Outfall Number	Approximate Location of Outfall* (meters)	Outfall Diameter (cm)	Approximate Drainage Area (hectares)
1	240 m N of Julian Street	46	10
2	at Julian Street	46	15
3	60 m S of Julian Street	69	80
4	240 m S of Julian Street	140	40
5	60 m S of Santa Clara Street	46	10
6	360 m S of Santa Clara Street	53	10
7	60 m N of San Carlos Street	53	30
8	at E. Williams Street	20	5
9	60 m S of E. Williams Street	76	35
10	150 m S of I-280	110	10
11	at Martha Street**	69	35
12	at Story Road	76	10+
13	at W. Alma Avenue	150	80
14	180 m S of W. Alma Avenue	69	40
15	at Phelan Avenue	170	100
16	300 m S of Phelan Avenue	69	5
17	790 m N of Tully Road	180	80
18	450 m N of Tully Road	91	10
19	at Tully Road	140	300
20	at Tully Road	91	60
21	60 m S of Tully Road	91	30
22	670 m S of Tully Road	84	20
23	970 m N of Capital Expwy.	170	200
24	at Capital Expwy.	110	30
25	at Capital Expwy.	61	10
26	420 m S of Capital Expwy.	91	40
27	670 m S of Capital Expwy.	46	10
28	1300 m S of Capital Expwy.	84	60
29	1500 m S of Capital Expwy.	61	15
30	1500 m W of U.S. 101	30	2
31	1200 m W of U.S. 101	30	2
32	670 m W of U.S. 101	91	60
33	300 m W of U.S. 101	30	15
34	240 m W of U.S. 101	30	5
35	1200 m S of U.S. 101	140	200
36	1800 m S of U.S. 101	120	20
37	near Piercy Road	110	25

*This list pertains to the reach of Coyote Creek which extends from the town of Coyote to the confluence with Silver Creek (see Figure 3-2).

**This is the Keyes St. study area described in the previous demonstration study (1).

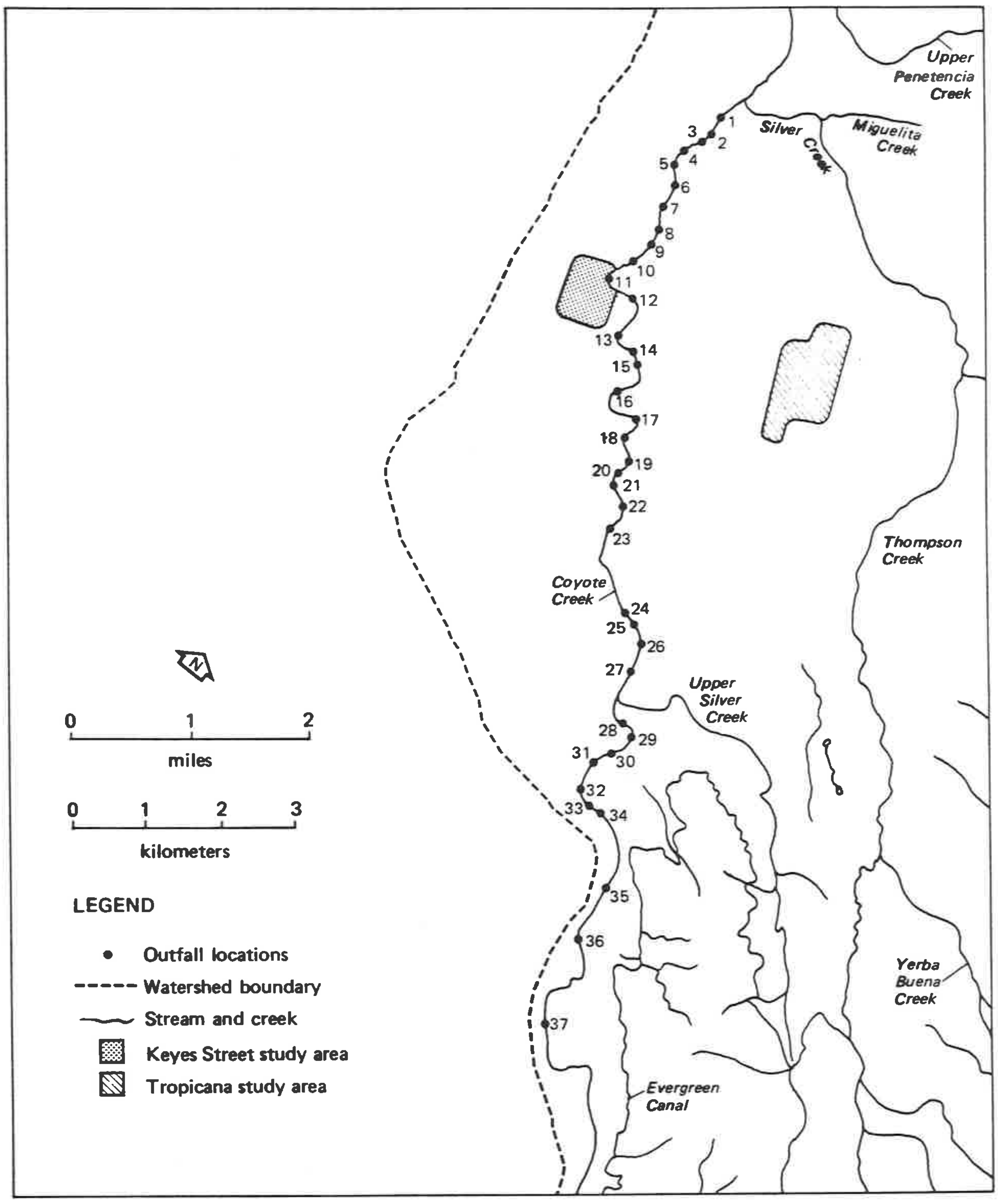

Figure 3-2. Locations of stormwater outfalls within the study area.

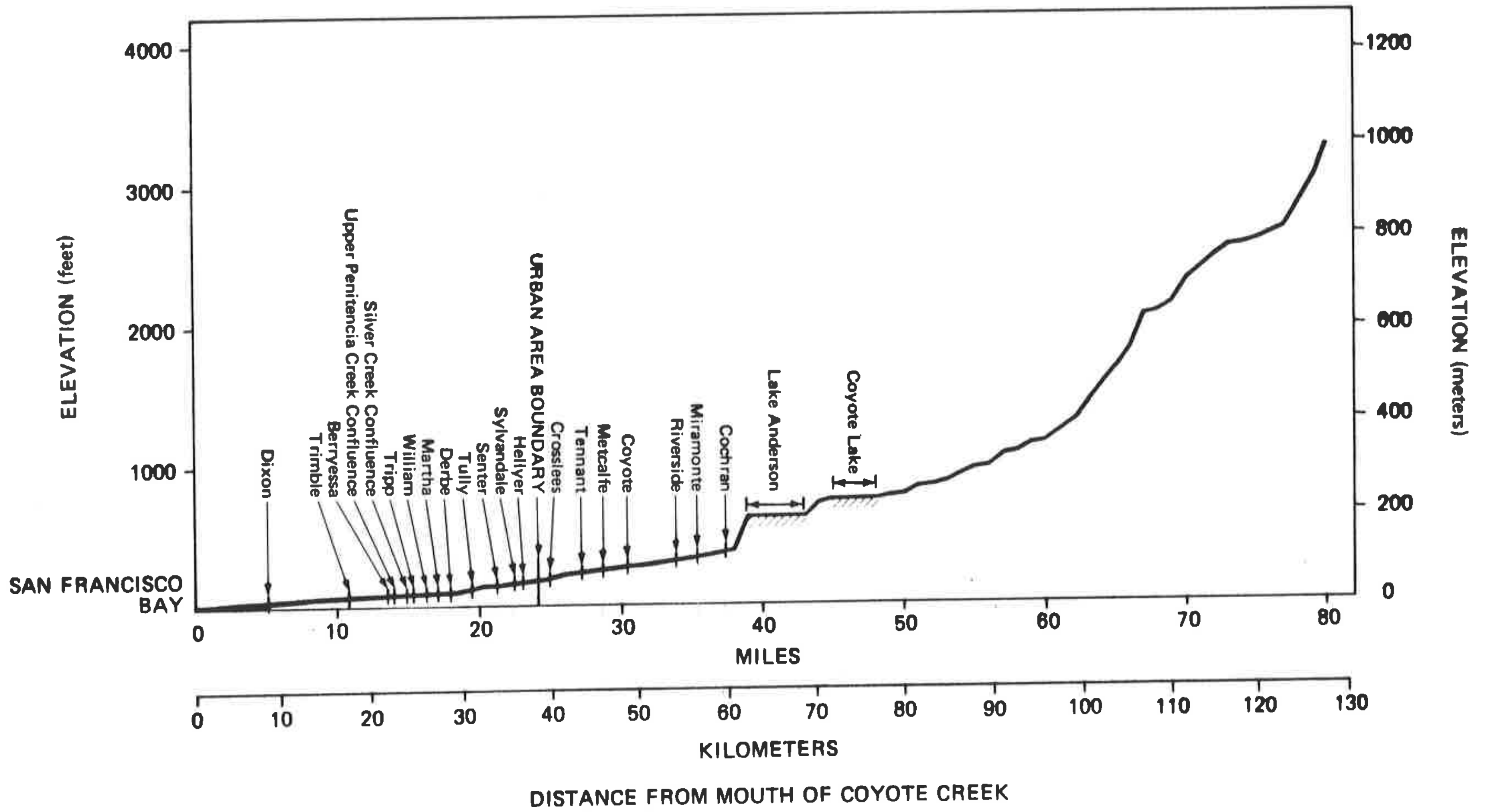

Figure 3-3. Elevation and location of sampling stations.

Table 3-3. WATERSHED AREA CONTRIBUTING TO COYOTE CREEK, UPSTREAM OF SEVERAL SELECTED SAMPLING STATIONS

Sampling Station	Total Area (hectares)	Urban Area (hectares)	Non-urban Area (hectares)	Percent Urban
Cochran	49,510	<5	49,510	<0.01
Miramonte	50,260	<5	50,260	<0.01
Metcalfe	52,360	<50	54,360	<0.1
Crosslees	54,030	50	53,980	0.1
Hellyer	54,400	350	54,050	0.6
Sylvandale	54,720	450	54,320	0.7
Senter	55,300	800	50,500	1.5
Derbe	56,300	1740	54,560	3.2
William	56,920	2150	54,770	3.9
Tripp	57,260	2460	54,800	4.5

The following paragraphs describe pertinent conditions at selected sampling stations, going from the non-urban to the most urban stations.

- Cochran: The creek habitat consisted primarily of riffles and flowing pools. The bottom consisted of cobbles and gravel, with some sand. The water temperature was depressed by water released from Lake Anderson. The creek was about one meter (3 ft.) deep, 5 to 10 m (15 to 30 ft.) wide, and flowed at a velocity less than about 0.5 m/sec (1.5 ft/ sec.).

- Miramonte: The creek habitat consisted of riffles and flowing pools. The bottom consisted of cobbles and gravel, with some sand. Some trees were present, but the area was generally open. The water temperature was still depressed due to water releases. The creek was about 0.5 m (1.5 ft.) deep, 3 to 5 m (9 to 15 ft.) wide, and flowed at about 1 m/sec (3 ft/sec).

- Riverside: At this location, most of the creek runs through a diversion channel (Coyote Canal) adjacent to agricultural lands and a golf course. The creek was mud-bottomed, with some cobbles along the shoreline. Bankside vegetation was limited to grasses, giving the creek little shading. The channel was about one meter (3 ft.) deep, 2 to 3 m (6 to 9 ft.) wide, and flowed at about 0.5 m/sec (1.5 ft/sec).

- Coyote: Water overflows from the Coyote Canal were redirected to the natural channel above this location. The creek was bordered by agricultural land. The bottom consisted of sand and cobbles overlain with silt. The stream banks were lined with shrubs and trees, providing the creek with partial shade. The creek was generally less than 0.5 m (1.5 ft.) deep, 5 to 8 m (15 to 25 ft) wide, and flowed at about 0.3 m/sec (1 ft/sec).

- Metcalfe: The bottom consisted of cobbles and gravel, with some sand. The sample site was generally unshaded and had riffle and flowing pool habitats. The creek was about 0.5 m (1.5 ft.) deep, 3 to 8 m (9 to 25 ft.) wide, and flowed at about 0.5 m/sec (1.5 ft/sec).

- Tennant: The creek habitat consisted of pools, long runs, and riffles. The bottom consisted primarily of gravel and cobbles, with an accumulation of silt in the pools. The banks were bordered by grasses and trees which provided partial shade. The creek was 0.2 to over 1 m (0.5 to over 3 ft.) deep, 2 to 15 m (6 to 45 ft.) wide, and flowed at up to about 1 m/sec (3 ft/sec). Some pool areas may have been more than one meter (3 ft.) deep.

- Hellyer: The creek habitat consisted of riffles and slowly flowing pools. The bottom varied from gravel to silt and mud. Portions of the banks were tree-lined and shaded. The creek was about 0.2 to 1 m (0.5 to 3 ft) deep and varied in width from about 2 m (6 ft.) in riffles to about 12 m (36 ft.) in pools.

- Sylvandale: Habitat consisted mostly of slowly flowing pools heavily shaded with some undercut banks. Substrate varied from gravel and sand in the short riffles to silt and detritus in the pools. The creek was 0.2 to 1.2 m (0.5 to 4 ft) deep and varied in width from about 1 m (3 ft) in riffles to about 7 m (20 ft) in pools.

- Senter: Slowly flowing pools dominated this reach of the creek. The pools were as deep as 1.3 m (4.5 ft) and as wide as 16 m (50 feet). The area was well shaded. Substrate in the pools consisted of silt and mud. Substrate in several short riffles consisted of silt, sand, and gravel. Riffles were 1 to 2 m (3 to 6 ft) wide and 0.2 m (0.5 ft) deep.

- Tully: This reach consisted entirely of pool habitat, because accumulations of debris and downfall had virtually dammed the creek at the upstream side of the Tully Road bridge. Very little flow was observed downstream of the bridge. The banks were tree-lined, and the creek well shaded. The pools were mud-bottomed, 8 to 10 m (24 to 30 ft.) wide, and appeared to be 1 to 2 m (3 to 6 ft.) deep.

- Derbe: This habitat consisted primarily of slowly-flowing pools, with some short riffles. Much debris was in the water, and the creek was well shaded. The bottom consisted of gravel and sand, with some silt. The creek was about 0.8 (2.5 ft.) deep and 1 to 3 m (3 to 9 ft.) wide.

- William: The creek habitat consisted primarily of slowly flowing pools, with some short riffles in upstream areas. The bottom consisted of silt, mud, and detritus, but the water in this area was markedly clearer than at upstream stations. The creek was about 0.5 m (1.5 ft.) deep, 2 to 3 m (6 to 9 ft.) wide, and flowed at about 0.3 m/sec (1 ft/sec).

- Tripp: The banks were tree-lined and the creek well shaded. The creek habitat was mostly flowing pools, with some short riffles. The bottom consisted of sand and silt, with some gravel. The creek was 0.5 to 1 m (1.5 to 3 ft.) deep and 2 to 4 m (6 to 12 ft.) wide.

- Berryessa: Pool habitat was dominant upstream of Berryessa Road; riffle habitat predominated downstream. The banks were tree-lined. The bottom consisted primarily of gravel and sand, overlain with silt. The creek varied from 0.2 to about 1 m (0.5 to about 3 ft.) deep, was 3 to 5 m (9 to 15 ft.) wide, and flowed at about 0.3 m/sec (1 ft/sec).

- Trimble: The creek habitat was primarily pools upstream of Trimble Road, with riffles downstream. The bottom consisted of sand, gravel, and some cobbles, all overlain with varying amounts of silt. Although some trees were present, the stream banks were generally bordered by herbaceous vegetation. The creek was about

0.1 to 0.3 m (0.3 to 1 ft.) deep, about 3 m (9 ft.) wide, and flowed at about 0.5 m/sec (1.5 ft./sec).

- Dixon: This station is located in a tidal channel, just upstream from the mouth of the creek. Habitat consisted entirely of a flowing pool, the depth and flow of which is influenced by the tidal action of San Francisco Bay. The tidal water is frequently contaminated by effluent from the San Jose-Santa Clara Water Pollution Control Plant, an advanced secondary sewage treatment facility which has a capacity of about 1.5 billion liters per day (400 MGD). The creek was about 1.5 m (4.5 ft.) deep at low tide, mud-bottomed, and about 10 m (30 ft.) wide.

SECTION 4

PROJECT METHODOLOGY

Lake Anderson discharge values were obtained from the Santa Clara Valley Water District. Creek flow rates at the sampling stations were measured by the field personnel using a digital current meter or estimated on the basis of drogue movement. All stream sampling on this project was conducted manually using submerged plastic wide-mouth bottles. The samples were preserved and analyzed according to EPA requirements, using commercial analytical laboratories.

Sediment samples were obtained by scooping bottom material into glass jars and sealing the containers underwater. The samples were then frozen and delivered to a commercial analytical laboratory for EPA-approved analysis. Sediment core samples (for examining stratification) were obtained using a liquid carbon dioxide freezing core sampler. The schedule for water quality and sediment sampling is presented in Table 4-1.

Biological samples (e.g. mosquito fish, filamentous algae, crayfish, cattail plant segments) were obtained at selected sampling stations. These were chemically digested and analyzed for total lead and zinc concentrations.

Fish were collected by seining and electroshocking representative pool and riffle habitats at 40 locations within the Coyote Creek system. Most of the collection efforts were focused on the portion of Coyote Creek between Lake Anderson and the confluence of Silver Creek. However, to further define the species composition and distribution of fishes, additional samples were obtained from both the upper and lower reaches of Coyote Creek, as well as from several locations within major tributaries. Captured fishes were identified and counted. The total length and weight were recorded for each specimen. Where numerous individuals of a particular species were encountered, only length range and aggregate weight were recorded.

Quantitative collections of benthic macroinvertebrates were made at nine locations in Coyote Creek. Replicate benthic macroinvertebrate samples were collected from natural substrates (e.g., cobbles, gravel, sand) in both pool and riffle habitats by means of an Ekman dredge (sample area = $0.023m^2$) or a Surber sampler (sample area = $0.093m^2$), as appropriate. Additionally, artificial substrates were used at six sampling locations. These consisted of replicate pairs of Hester-Dendy multiplate samplers constructed of multiple, parallel plates of Masonite (sample area = $0.120m^2$). The Hester-Dendy samplers were left in the stream for 8 weeks and then removed and examined in the laboratory.

Table 4-1. SAMPLING SCHEDULE FOR WATER QUALITY AND SEDIMENT SAMPLING EFFORT

	Approximate Distance Upstream from Mouth (km)	Sediment Quality Studies			Major Water Quality Monitoring			In-Situ Water Quality Studies								
		Jun '78	July '79	Nov '79	March '77	July '79	Nov '79	March 3, '77	May 8, '79	May 9&10, '79	June 16&25, '79	July 2&3, '79	Sept 20, '79	Sept 24, '79	Sept 25&27, '79	Oct 3, '79
Non-Urban Area Stations[1]																
Below Dam	62.4										X				X	
Cochran	61.4	X			X			X	X		X				X	
Burnett	59.2										X				X	
Miramonte	55.8	X	X	X		X	X		X	X	X	X	X	X	X	
Riverside	53.0				X						X				X	
Coyote	48.4				X			X			X					
Metcalfe	46.6	X	X	X		X	X		X	X	X	X	X	X	X	
Tennant	43.4				X			X	X		X				X	
Crosslees	39.7										X				X	
Upper Urban Area Stations[2]																
Coyote Road gage	38.8										X					
Bayshore	37.5										X				X	
Hellyer	36.8				X			X	X	X	X			X	X	
Sylvandale	35.6		X	X		X	X				X	X	X			
Capitol	33.8								X		X					
Senter	32.9		X	X		X	X			X	X	X	X	X	X	
Tully	31.2				X			X	X		X					
Derbe	28.7	X	X	X		X	X		X	X	X	X	X	X	X	
Story	27.5										X					
Martha	26.9			X											X	
William	25.8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Tripp	23.7	X	X	X		X	X		X	X	X	X	X	X	X	X
Lower Urban Area Stations[3]																
Maybury	22.6										X				X	
Berryessa	21.8		X		X	X		X			X	X				X
Oakland	20.0										X					
Trimble	17.2				X			X			X				X	
SR 237	13.5										X				X	
Dixon	9.2				X			X				X			X	X

[1] These sampling stations were in the non-urban area and are located below Anderson Dam, and above the confluence with Silver Creek.

[2] These sampling stations were in the urban area and are located above Silver Creek.

[3] These sampling stations were in the urban area but were located below Silver Creek.

Qualitative benthic collections were also made with the use of a D-frame sweep net. The benthic samples were washed through a sieve having a mesh size of 500mm. Organisms retained on the screen were removed and preserved in 10 percent formalin, transferred to 70 percent ethanol, identified to the lowest practicable taxon, and enumerated.

Attached algae samples were obtained from both natural and artificial substrates throughout the various reaches of Coyote Creek. Qualitative samples of attached algae were collected by scraping uniform areas of natural substrates such as logs and rocks. Quantitative collections of attached algae were made with the use of artificial substrates consisting of diatometers equipped with glass slides. These were suspended in the water column at six locations within the study area for eight weeks, then removed and examined in the laboratory. The qualitative samples were preserved in 5 percent formalin and identified. The quantitative samples were air-dried, scraped, cleaned with 30 percent hydrogen peroxide and potassium permanganate, mounted in Hyrax, identified, and enumerated using the proportional count method.

Rooted aquatic plants were sampled qualitatively whenever they were encountered in the study area. Plant specimens were collected, pressed or preserved, and identified.

A summary of the data and locations of aquatic biological sampling is presented in Table 4-2.

TABLE 4-2. SCHEDULE FOR BIOLOGICAL SAMPLING EFFORT

	Approximate Distance Upstream from Mouth (km)	Date and Type of Sampling[4]						
		Oct '77	Nov '77	June '77	June '78	Sept '79	April '80	July '80
Non-Urban Area Stations[1]								
Gilroy Hot Springs	87.2			F				F
(14.4 km above Coyote Dam)								
Canada	81.1							F
(8.3 km above Coyote Dam)								
Dunne	67.6	F						
(Inflow to Anderson Lake)								
Below Anderson Dam	62.4	F			F	F		
Cochran	61.4	F		FBA	F	F		
Burnett	59.2				F	F		
Miramonte	55.8			FBA	FB	FB		
Riverside	53.0				F	F		
Sycamore	51.2				F	F		
Coyote	48.4				F			
Metcalfe	46.6			FBA	FB	FB		
Bernal	45.3				F	F		
Tennant	43.4				F	F		
Crosslees	39.7				F			
Upper Urban Area Stations[2]								
Coyote Road gage (Urban Area Boundary)	38.8				F			
Bayshore	37.5				F			
Hellyer	36.8	F			F	F		
Sylvandale	35.6				FB	FB		
Capitol	33.8				F			
Senter	32.9				F	FB		
Tully	31.2		F		F			
Derbe	28.7			FBA	F	FB		
Story	27.5		F		F			
Martha	26.9					B		
William	25.8		F					
Santa Clara	24.9		F					
Tripp	23.7			FBA	FB	FB		
Lower Urban Area Stations[3]								
Silver Creek at Silver Creek Road	40.0					F		
Silver Creek at Cunningham	30.8					F		
Silver Creek at mouth	23.4				F	F		
Mabury	22.6				F			
Upper Penitencia Creek below falls	32.6					F		
Upper Penitencia Creek at Mineral Springs	32.0					F		
Upper Penitencia Creek at Alum Rock	30.4					F		
Upper Penitencia Creek at Viceroy	26.1				F	F		F
Upper Penitencia Creek at gage	22.5							F
Upper Penitencia Creek at mouth	21.8				F	F	F	F
Oakland	20.0				F			
Nimitz	19.4					F		
Trimble	17.2				F			
SR237	13.5				F			

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[1] These sampling stations were in the non-urban area and most were located below Anderson Dam, and above the confluence with Silver Creek.

[2] These sampling stations were located in the urban area above Silver Creek.

[3] These sampling stations were located in the urban area below Silver Creek.

[4] Legend:
F = Fish Collections
B = Benthic macroinvertebrate collections
A = Attached algae collections

SECTION 5

URBAN RUNOFF CHARACTERISTICS

GENERAL CHARACTERISTICS

Information obtained during the previous San Jose street cleaning demonstration study (1) was reviewed and used as the basis for estimating the quantities and characteristics of urban runoff likely to drain into Coyote Creek. The data are summarized in Table 5-1. They were then analyzed using an equilibrium water chemistry computer program to estimate the specific inorganic chemical compounds probably present and to forecast which pollutants would remain soluble and which would go out of solution (and become part of the sediments). The estimates are shown in Tables 5-2 and 5-3.

Most of the urban runoff pollutants were predicted to be in soluble forms and would, therefore, be carried in the water column. However, this was not the case for some types of pollutants. For example, 95 percent of the inorganic lead was predicted to be insoluble particulates. Depending upon the size of these precipitate particles (or the particles to which they may become attached), the lead could remain in suspension or could settle out in the storm sewerage system and/or the receiving waters. Two other contaminants may settle out: chromium and phosphate. The precipitation of lead particles was substantiated in the field studies as relatively high concentrations of lead were found in the sample of creek sediments collected in the urban area. The soluble fractions of other inorganic constituents monitored here were primarily in ionic form.

The information presented in Tables 5-2 and 5-3 and data obtained from the Santa Clara County area-wide wastewater management plan (2) were used to estimate the urban area unit pollutant contributions (i.e., yields) for the study area. Table 5-4 presents these estimated runoff yields on a kilogram per hectare per year basis; it also presents the estimated annual yields that affect representative sampling stations. Appendix D contains a more detailed discussion of the relative yields of point and non-point sources of pollutants entering San Francisco Bay.

The sampling stations in the non-urban area were affected by substantially smaller quantities of the monitored pollutants. These stations receive most of their runoff from undeveloped and agricultural land, whereas the downstream stations receive runoff from urban areas (in addition to the pollutants from the upstream undeveloped and agricultural areas). The calculated pollutant contributions to the creek which effect the urban area stations are substantially greater than the quantities affecting the stations in the non-urban area. As an example, the total solids contribution to the

Table 5-1. **RUNOFF WATER QUALITY AFFECTING COYOTE CREEK***

	Minimum	Maximum	Average
pH	6.0	7.6	6.7
Oxidation Reduction Potential, (mv)	40	150	120
Temperature (°C)	14	17	16
Total solids	110	450	310
Total dissolved solids	22	376	150
Suspended solids	15	845	240
Volatile suspended solids	5	200	38
Turbidity (NTU**)	4.8	130	49
Specific Conductance (μmhos/cm)	20	660	160
Calcium	2.8	19	13
Magnesium	1.4	6.2	4.0
Sodium	<0.002	0.04	0.01
Potassium	1.5	3.5	2.7
Bicarbonate	<1	150	54
Carbonate	<0.001	0.05	0.019
Sulfate	6.3	27	18
Chloride	3.9	18	12
Dissolved oxygen	5.4	13	8.0
Biochemical Oxygen Demand, 5-day	17	30	24
Chemical Oxygen Demand	53	520	200
Total Organic Carbon	19	290	110
Kjeldahl nitrogen	2	25	7
Nitrate	0.3	1.5	0.7
Orthophosphate	0.2	18	2.4
Lead	0.10	1.5	0.4
Zinc	0.06	0.55	0.18
Copper	0.01	0.09	0.03
Chromium	0.005	0.04	0.02
Cadmium	<0.002	0.006	<0.002
Mercury	<0.0001	0.0006	<0.0001

Source: (1)

*Tabulated values are in mg/l unless otherwise noted.
**Nephelometric Turbidity Units

Table 5-2. **PREDICTED, FLOW-AVERAGED SOLUBLE URBAN RUNOFF CHARACTERISTICS**

Parameters	Minimum	Maximum	Average
pH	6.3	7.0	6.8
Oxidation Reduction Potential	78	140	120
Temperature (°C)	15	15	15
Specific conductance (μmhos/cm)	33	130	93
Turbidity (NTU)	37	86	49
Total solids	110	680	300
Total dissolved solids	34	160	91
Suspended solids	41	570	210
Volatile suspended solids	5	40	23
Dissolved oxygen	6.5	9.9	8
Biochemical Oxygen Demand, 5-day	17	30	24
Chemical Oxygen Demand	77	350	200
Total Organic Carbon	19	290	110
Total calcium*	2.8	19	13
Ca^{++}	2.8	18.5	12.2
$CaSO_4$	<0.1	1.7	1.1
$CaHCO_3^+$	<0.1	0.4	0.1
Total magnesium	1.4	6.2	4.0
Mg^{++}	1.4	5.9	3.9
$MgSO_4$	0.1	1.1	0.6
$MgHCO_3^+$	<0.1	0.2	<0.1
Total sodium	2.1	27	15
Na^+	2.1	27	15
Total potassium	1.5	3.5	2.7
K^+	1.5	3.5	2.6
Total carbonate	<0.001	0.055	0.019
Total bicarbonate	<0.001	150	53
HCO_3^-	<0.001	0.01	0.007
Total sulfate	6.3	27	18
SO_4	6.2	25	17
Total chloride	3.9	18	12
Cl^-	3.9	18	12
Kjeldahl nitrogen	3.1	15	6.7
Total nitrate	0.3	1.5	0.7
NO_3^-	0.3	1.5	0.7

Table 5-2. **PREDICTED FLOW-AVERAGED SOLUBLE URBAN RUNOFF CHARACTERISTICS** (concluded)

Parameters*	Minimum	Maximum	Average
Total orthophosphate	0.2	6.0	2.4
$H_2PO_4^-$	0.2	4.4	1.7
$MgHPO_4$	<0.001	0.008	0.002
Total lead*	0.20	0.76	0.42
Pb++	<0.001	0.01	0.003
$PbCO_3$	<0.001	0.02	0.01
Total zinc	0.10	0.32	0.18
Zn++	0.10	0.31	0.18
$ZnPO_4$	<0.001	0.003	0.001
$ZnSO_4$	<0.001	0.02	0.011
Total copper	0.013	0.05	0.03
Cu+	0.01	0.05	0.02
Cu++	<0.001	0.01	0.004
$CuCO_3$	<0.001	0.01	0.005
$CuHPO_4$	<0.001	0.001	<0.001
CuOH+	<0.001	0.001	<0.001
Total chromium	0.009	0.03	0.04
$Cr(OH)_2$	<0.001	0.05	0.02
CrOH+	<0.001	0.03	0.006
Total cadmium	<0.002	0.004	0.002
Cd++	<0.002	0.004	0.002
$CdSO_4$	<0.001	0.001	<0.001
CdCl+	<0.001	<0.001	<0.001
Total mercury	<0.0001	0.0002	<0.0001

Source: (1)

*The above compounds are all soluble, except for the "total" values which include soluble and insoluble compounds.
The following compounds are expected to occur in urban runoff in solid form and are therefore not shown on the above table:

(1) $CaHPO_4$
(2) $PbCO_3$
(3) $Pb_3(PO_4)_2$

The "total" values represent all valence states.

Table 5-3. PREDICTED FORMS OF METALS AND LIGANDS IN URBAN RUNOFF (%)

	Minimum	Maximum	Average
Calcium:			
Ca++	91.0	98.4	95.7
$CaSO_4$	<1	3.2	2.0
$CaHCO_3$	<1	1.0	0.2
$CaHPO_4$ (a solid)			
Total	98.4	100.0	99.4
Magnesium:			
Mg++	95.2	97.9	96.5
$MgSO_4$	1.2	3.9	2.8
$MgHCO_3$+	<1	1.1	0.2
Total	99.1	100.0	99.5
Sodium:			
Na+	99.9	100.0	99.9
Potassium:			
K+	99.7	99.9	99.8
Carbonate:			
HCO_3	14.1	99.6	63.9
H_2CO_3	<1	84.3	35.1
$PbCO_3$ (a solid)	<1	1.4	0.4
Total	98.4	99.8	99.4
Sulfate:			
SO_4	91.9	97.8	93.6
$CaSO_4$	1.0	5.5	3.6
$MgSO_4$	1.1	3.5	2.4
Total	99.5	99.9	99.6

Table 5-3. PREDICTED FORMS OF METALS AND LIGANDS IN URBAN RUNOFF (%) (concluded)

	Minimum	Maximum	Average
Chloride:			
Cl^-	100.0	100.0	100.0
Phosphate:			
$Pb_3(PO_4)$(a solid)	<1	27.6	14.2
H_2PO_4	37.9	98.4	67.9
$CaHPO_4$ (a solid)	<1	38.2	14.8
$MgHPO_4$	<1	1.2	0.2
Total	98.4	99.5	97.1
Nitrates:			
NO_3	100.0	100.0	100.0
Lead:			
Pb^{++}	<1	1.5	0.8
$PbCO_3$	<1	8.0	3.6
$PbCO_3$ (a solid)	<1	96.1	37.2
$Pb_3\ (PO_4)_2$ (a solid)	<1	98.8	57.6
Total	98.8	99.5	99.2
Zinc:			
Zn^{++}	96.3	97.6	97.1
$ZnPO_4$	<1	1.3	0.3
$ZnSO_4$	<1	3.1	2.0
Total	98.8	99.9	99.4
Copper:			
Cu^+	54.5	95.0	66.0
Cu^{++}	4.5	32.1	19.1
$CuCO_3$	<1	17.9	12.2
$CuHPO_4$	<1	2.5	0.5
$CuOH^+$	<1	2.9	1.3
Total	97.2	99.7	99.1
Chromium:			
$Cr(OH)_2$	<1	100.0	80.0
$Cr(OH)+$	<1	99.8	20.0
Total	99.8	100.0	100.0

Source: (1)

Table 5-4. ANNUAL URBAN RUNOFF YIELD AFFECTING EACH STATION (metric tons/year)

	Urban Area Unit Yield (kg/hectare/yr)*	Non-Urban Area Sampling Stations			Urban Area Sampling Stations				
		Cochran	Miramonte	Metcalfe	Sylvandale	Senter	Derbe	William	Tripp
Total solids	280	<1	<1	<10	1	220	490	600	690
Chemical Oxygen Demand	90	<1	<1	<10	40	70	150	190	220
Biochemical Oxygen Demand (5-day)	45	<1	<1	<10	20	40	78	100	110
Kjeldahl nitrogen	2.8	<0.1	<0.1	<0.1	1.1	2.2	4.9	6.0	6.9
Ortho-phosphate	1.5	<0.01	<0.01	<0.1	0.6	1.2	2.5	3.2	3.6
Lead	1.1	<0.01	<0.01	<0.01	0.4	0.8	2.0	2.5	2.7
Zinc	0.11	<0.001	<0.001	<0.01	0.04	0.08	0.2	0.3	0.3
Chromium	0.11	<0.001	<0.001	<0.01	0.04	0.08	0.2	0.3	0.3
Copper	0.16	<0.001	<0.001	<0.01	0.06	0.1	0.3	0.4	0.4
Cadmium	0.0011	<0.0001	<0.0001	<0.0001	0.0004	0.0008	0.002	0.003	0.003

*Sources: (1, 2).

creek, in the urban area is more than one hundred times the equivalent contribution affecting the non-urban area stations. Similarly, the lead contribution affecting the urban area stations was several thousand times the equivalent contribution affecting the non-urban area stations.

Water quality data from the previous demonstration study's (1) monitoring program were reviewed to assess potential effects of urban runoff on Coyote Creek. Tables 5-1 through 5-3 show the ranges and average values for runoff pollutant concentrations for several previously-monitored storms in San Jose. During storms, water quality concentrations in the creek (within the urban area reach) were similar to the runoff conditions. This similarity occurs only during wet weather; during dry weather water quality in the urbanized area of Coyote Creek improves somewhat.

BENEFICIAL USE IMPAIRMENTS

Urban runoff pollution is not thought of as being an important local problem, perhaps because beneficial uses are not obviously being impaired. People are not likely to swim in the creek during storms (largely because the rainy season in the Bay Area corresponds to the period of coldest weather), but aquatic life could well be impacted. Table 5-5 presents pollutant concentrations measured in the urban runoff and compares these data to water quality criteria established to protect various beneficial uses. The criteria values shown are recommended limits intended to protect the beneficial uses with a reasonable degree of safety. If a stream's contaminant concentrations should exceed these criteria, it does not mean a problem necessarily exists; rather it should be interpreted as indicating that a problem may occur and additional monitoring may be warranted (to define the relationships between water quality and impairment of the beneficial uses).

The heavy metals cadmium, chromium, lead, mercury and zinc, along with phosphates, BOD, suspended solids and turbidity can exceed recommended criteria. The constituents potentially most responsible for water quality impairment in runoff are solids, cadmium, lead and mercury for aquatic life uses; orthophosphates for marine life; and orthophosphates for recreational use (eutrophication). Coyote Creek receiving water data show that, during wet weather, suspended solids and phosphate concentrations in the non-urban area also significantly exceed the criteria for aquatic and marine life, respectively. Phosphate concentrations may also exceed the criteria for recreational use. Appendix E presents a detailed discussion of the effects of various urban runoff constituents on aquatic organisms known to occur in Coyote Creek.

LOCAL MEASUREMENTS AND YIELDS OF SOURCE AREA PARTICULATES TO URBAN RECEIVING WATERS

Numerous studies indicate that urban atmospheric deposition rates are high enough to contribute substantially greater quantities of pollutants than are found in the total urban runoff load for the watershed. For example, Rolfe and Reinbold (3) report that of the total lead deposited within an urban watershed, more than 90 percent remained within the watershed. The

Table 5-5. RUNOFF WATER QUALITY COMPARED TO BENEFICIAL USE CRITERIA
(mg/l unless otherwise noted)

	Observed Runoff Water Quality			Beneficial Use Criteria[a]				
	Minimum	Maximum	Average	Irrigation	Livestock	Wildlife	Aquatic Life	Marine Life
pH	6.0	7.6	6.7	4.5 - 9.0 desired[a]	-	6.0 - 9.0 desired	6.0 - 9.0 desired	6.5 - 8.5 desired
Temperature (°C)	14	16.5	16	Narrative[b]	-	Maintain natural pattern	Narrative	Narrative
Total dissolved solids	22	376	150	500 - 5000 max.	-	-	Narrative	-
Suspended solids	15	845	240	Narrative	-	-	80	-
Turbidity (NTU)	4.8	130	49	-	-	-	Small change	-
Dissolved oxygen	5.4	12.8	8.0	-	-	-	Usually >5.0	6.0 min.
Biochemical Oxygen Demand (5-day)	17	31	24	-	-	-	10	Narrative
Nitrate	0.3	1.5	0.7	Narrative	450 (including NO_2)	-	-	-
Phosphate	0.2	17.6	2.4	-	-	-	-	0.0003
Sulfate	6.3	27	18	-	-	-	-	-
Chloride	3.9	17.6	12	-	-	-	-	-
Sodium	2.1	26.8	15	Narrative	-	-	-	-
Lead	0.10	1.5	0.4	5.0 - 10.0 max.	0.1	-	0.03	Narrative
Zinc	0.06	0.55	0.18	-	25	-	Narrative	0.1
Copper	0.01	0.09	0.03	0.02 - 5.0 max.	0.5	-	Narrative	0.05
Chromium	0.005	0.04	0.02	0.1 - 1.0 max.	1.0	-	0.03	0.1
Cadmium	<0.002	0.04	0.01	0.01 - 0.05	0.05	-	0.004 - 0.03 max. for soft - hard water	0.01
Mercury	<0.0001	0.0006	<0.0001	-	0.001	Narrative	0.00005	0.1

Sources: (4, 5, 6, 1).

[a] Maximum limits unless stated as desired range or minimum values.

[b] The term "narrative" implies a potential conflict between the parameter and beneficial use, but lack of data or too many important site specific conditions do not allow a specific value to be used as a general criterion.

lead reportedly accumulated in soils, vegetation, and organisms and was not washed off during rain events.

The previous San Jose demonstration study (1) measured the pollutants that washed off street surfaces during various monitored rains (the test areas drained into Coyote Creek). This resulted in information on the effectiveness of rain in removing street dirt and indicated the importance of different types of street surfaces and storm characteristics. It was found that rainfall is typically less effective in removing materials from rough pavement (e.g., streets surfaced with oil and screens) than from smooth pavement (e.g., asphalt). It is thought that the increased roughness mechanically traps particulate matter and also reduces scour velocities at the pavement/water interface. Such mechanisms have the effect of preventing materials, which have eroded from surrounding areas, from reaching the storm sewer system. Accordingly, the test areas with smooth asphalt streets showed relatively high removals of street dirt during all monitored storms (1).

The results from both the San Jose demonstration study (1) and the more recent Castro Valley NURP study (7) indicate that the amount and character of runoff-borne pollutants from a given site depend on factors such as the intensity and duration of the storm event and the length of the antecedent dry period (i.e., the period of pollutant accumulation). Large storms (ones with high intensity and/or large rainfall volumes) resulted in small contributions of the street surface particulates, relative to the total runoff particulate yield. This pattern is more pronounced when the antecedent dry periods are short. During such conditions, the street surfaces stay relatively clean (because of the frequent rains). A large rain will result in significant erosion from the surrounding saturated pervious areas, so that eroded materials become deposited on the streets during the rains, with some of it remaining on the streets after the storm's end. It is hypothesized that areas with moderate rainfall intensities and long periods of accumulation (i.e., dirty street surfaces and dry surrounding soil conditions) would have most of their urban runoff output associated with street surface washoff.

During storms of moderate to low intensity, the amount of traffic has been found to have an important influence on the degree to which pollutants will be transported into the storm sewerage system. Traffic can supply the energy needed at the street surface to loosen particulates (i.e., there are high scour and shear velocities at the water/street interface). When light storms occur at night (or at other times of low traffic), very little street dirt would be loosened, and there would be little opportunity for it to be transported along the street and gutter system. In summary, it has been concluded that estimated yields from different source areas in a watershed are very site and time dependent (i.e., it is necessary to consider pavement characteristics, antecedent weather conditions, current storm characteristics, and traffic conditions).

Among the most important information needs for urban runoff studies is knowing the relative contributions from different pollutant sources in the watershed in the outfall (i.e., how much of the total yield observed at the outfall is attributable to each source). Sources far from the inlet to the storm sewerage system require overland flow. Accordingly, they contribute relatively small fractions of the potential pollutant amounts (based on observations at the outfall). Conversely, parking lots or street surfaces are impervious and are typically located adjacent to the storm sewerage inlets (directly-connected impervious). Hence, most of the pollutants from such source areas contribute to the outfall yield.

A sub-study was conducted to examine potential sources of pollutants. This involved collecting runoff samples during rain storms and dry samples from various areas in the Coyote Creek watershed (in San Jose). These sources were small areas such as building roofs, parking lots, vacant parcels, and gutters. Rainfall samples and outfall samples were also collected and analyzed for various constituents. Results of this sub-study are summarized in Tables 5-6, 5-7 and 5-8. The rain itself (in most cases) was found to have the lowest pollutant concentrations, whereas the parking lot and gutter flows had the highest (for most of the constituents studied here). Puddles in a city park were also sampled and were found to have much greater specific conductance and concentrations of total solids and nitrates than the other samples.

The observed lead concentrations (shown in Table 5-6) ranged from less than 0.01 to over 1.0 mg/l. The rain and rooftop runoff samples had less than 0.02 mg/l lead, which is at the low end of the reported rain and bulk precipitation data reported in other studies. The zinc concentrations in rain and roof runoff were also less than 0.02 mg/l, again at the low end of data reported elsewhere. The rain and roof runoff COD values extended over a wider range than the bulk precipitation data. The orthophosphate concentration values for the rain and roof runoff were smaller than reported elsewhere, but the total Kjeldahl nitrogen concentrations were mostly within the range reported elsewhere.

The pollutant concentrations in source area particulate samples from the San Jose area (shown on Table 5-7 and 5-8) were typically greater than the corresponding concentrations in local soils. The lowest lead concentrations were about 30 mg/kg in the test area, while general rock and soil values averaged about 10 to 15 mg/kg (8, 9, 10). However, the maximum values for lead in soil can be as high as 200 mg/kg (close to the highest values observed). The lowest zinc concentrations (about 70 to 100 mg/kg) were about twice as high as the average soil and rock values, but well within the range of conditions reported elsewhere. The observed orthophosphate values in the study area were all much less than the reported ranges in typical soils. As expected, the values shown on Tables 5-7 and 5-8 show that the concentrations of most of the constituents increased as the degree of urbanization increased. An exception to this pattern was the relatively high lead value observed in a school turf area. This value was nearly one half the observed lead value for street surface particulates. No cause for this was found.

Tables 5-9 and 5-10 are qualitative summaries that show the types of urban runoff pollutants generally associated with different source areas. Both tables are based on information from this and various other studies. They indicate that no single source area should be viewed as contributing

Table 5-6. POLLUTANT CONCENTRATIONS IN RUNOFF FROM MAJOR AREAS (mg/l, unless otherwise noted)

	Outfall	Gutter Flow	Parking Lots	Park Puddles	Commercial Tar and Gravel Roofs	Residential Composition Shingle Roofs	Rain
pH	7.8	7.5	7.0	7.3	7.5	6.5	6.4
Specific conductance (μmhos/cm)	185	130	45	2400	155	11.2	10.4
Turbidity (NTU)	29	100	26	21	1	<1	<1
Total solids	162	235	340	2140	186	18	30
Biochemical Oxygen Demand (5-day)	8	13	22	3	7	3	3
Chemical Oxygen Demand	97	172	176	69	131	19	12
Total phosphate	0.34	0.31	0.49	0.42	0.07	0.10	0.03
Orthophosphate	0.23	0.12	0.47	0.32	0.02	0.08	0.03
Kjeldahl nitrogen	1.52	2.41	1.47	1.32	4.37	0.71	0.64
Ammonia nitrogen	0.25	0.42	0.35	1.23	1.06	0.50	0.36
Nitrate	0.74	0.42	0.13	285	0.22	0.09	0.09
Sulfur	4	2	<1	15	5	<1	<1
Sulfate	13	7	<1	38	21	<1	<1
Arsenic	<0.01	<0.01	0.02	0.10	<0.01	0.01	<0.01
Lead	0.08	0.67	1.09	0.035	0.019	0.017	<0.01
Zinc	0.06	0.14	0.23	0.01	0.08	0.18	0.04
Copper	0.013	0.029	0.046	0.031	0.11	<0.005	0.010
Chromium	0.009	0.049	0.071	0.010	<0.005	<0.005	<0.005
Total coliform bacteria (MPN/100ml)	>2400	>2400	540	49	170	<2	8
Fecal coliform bacteria (MPN/100ml)	>2400	920	350	49	9	<2	2
Fecal strep. bacteria (MPN/100ml)	>2400	>2400	<2400	920	17	920	<2
Ratio of fecal coliform to fecal strep. bacteria	-	<0.4	<0.2	0.5	0.5	<0.002	>1

Table 5-7. STRENGTHS OF PARTICULATES FROM VARIOUS UNPAVED SOURCE AREAS (mg constituent/kg total solids)

	Rural Vacant Lots				Urban Vacant Lots		Urban Residential Contruction Site	Unpaved Urban Driveways	Unpaved Urban Parking Lots	Residential Lawn	School Turf	Residential Gardens	Landscaped Park
Chemical Oxygen Demand	14,000	83,000	35,000	43,000	18,000	28,000	25,000	29,000	37,000	103,000	110,100	66,000	80,000
Total Kjeldahl nitrogen	900	21,000	1400	2400	1200	1100	160	800	500	3000	11300	2100	18,00
OrthoPhosphate	16	19	21	<5	58	18	19	<5	<5	30	393	41	10
Lead	33	53	110	34	36	180	47	286	260	220	666	87	70
Zinc	70	123	203	91	192	127	90	194	178	154	205	108	122

Source: (7)

Table 5-8. STRENGTHS OF PARTICULATES FROM VARIOUS PAVED SOURCE AREAS (mg constituent/kg total solids)

	Paved Driveways	Paved Parking Lots	School Playground	Typical City Street	Rural Roads[a]	Highway[a]	Airport Taxiway and Runway[a]
Chemical Oxygen Demand	59,000	73,000	38,000	86,000	49,000	46,000	(b)
Total Kjeldahl nitrogen	1300	900	600	640	500	650	(b)
Orthophosphate	11	8	6	5	(b)	(b)	(b)
Lead	640	1140	360	1900	65	500	110
Zinc	172	392	322	300	70	190	75

[a] Source: (11)

[b] Not analyzed.

Table 5-9. SOURCES OF URBAN RUNOFF POLLUTANTS

	Rooftops	Street Surfaces	Parking Lots	Landscaped Areas	Vacant Land	Contruction Sites
Sediment		X			X	X
Oxygen Demanding Matter				X		
Nutrients				X	X	
Bacteria	X	X	X	X	X	
Heavy metals		X	X			
Pesticides and herbicides				X		
Oils and grease		X	X			X
Floating matter				X		
Other toxic materials	X	X	X			X

Table 5-10. SOURCES OF MATERIALS WHICH LEAD TO URBAN RUNOFF POLLUTION

	Lawn and Landscaped Areas	Vacant Lots	Rooftops	Sidewalks	Parking Lots	Street Surfaces
Dustfall	X	X	X	X	X	X
Precipitation	X	X	X	X	X	X
Tire Wear	X (Adjacent)			X	X	X
Auto Exhaust Particulates	X (Adjacent)			X	X	X
Other Auto Use (Fluid Drips, Wear Prod.)				X	X	X
Vegetation Litter	X	X		X	X	X
Construction Erosion		X				
Other Litter		X		X	X	X
Bird Feces	X	X	X	X		
Dog Feces	X	X				X
Cat Feces	X	X				
Fertilizer Use	X					
Pesticide Use	X					
Approximate portion of precipitation which reaches outfall*	5%	5%	30%	45%	50%	75%

*Percentage of the total precipitation (falling on this type of surface) which will reach the outfall. For example, only 5% of the precipitation which falls on vacant lots will reach the outfall (the remaining 95% will be lost through infiltration and other process).

the majority of any given type of pollutant, despite the fact that certain areas are consistently important sources of certain pollutants. For example, street surfaces are consistently shown to be responsible for significant contributions of many heavy metals. Similarly, oxygen demanding materials and nutrients are shown to originate mostly from landscaped and vacant areas. Table 5-9 defines the urban runoff pollutants in terms of general classes of water quality parameters (e.g., nutrients, bacteria, heavy metals). Table 5-10 is similar but defines the urban runoff pollutants in terms of various common materials (e.g., auto exhaust, litter, feces).

Table 5-10 also presents estimates of how much of the precipitation falling on a given source area is likely to arrive at the storm sewer outfall. For example, only about 5 percent of the rainfall volume that lands on vacant lots will arrive at the storm sewerage outfall. The other 95 percent will be "lost" as a result of numerous factors (principally infiltration). Accordingly, relatively impervious areas will contribute larger proportions of the precipitation they receive. A source area's proximity to the storm sewerage system is also an important factor. The farther the runoff has to travel, the greater the opportunity to be "lost". Streets and parking lots are normally in close proximity; landscaped areas and vacant lots are not as close. If most of the pollutants that get into the runoff stay with the runoff as it drains to the outfall, the distribution pattern given for volumes (in Table 5-10) probably also reflects the likelihood of these areas' ability to contribute their pollutant loads to the receiving waters.

Table 5-10 summarizes the following observations. Vacant lots and landscaped areas are typically located relatively distant from the urban drainage system (in comparison with street surfaces, for example). Therefore, they contribute relatively little flow. Despite the fact that such areas make up almost half of the total land area in the urbanized portion of San Jose, only about 5 percent of the rainfall that falls on these areas is expected to contribute to the outfall flow. Similarly, only a small fraction of the potential pollutant yield from these areas is expected to affect the outfall. At present, it would be speculative to try to quantify this fraction, but it is probably on the order of the 5 percent estimate given for volumetric yield. Rooftops, which make up 15 to 20 percent of the urban area, are also located a relatively long distance away from the storm sewerage system. Rooftops are impervious, virtually all of their precipitation runs off, and most of the roof drainage systems in San Jose are not directly connected to the storm sewerage system. Therefore, the water has to drain across pervious areas, and the outfall runoff yield from rooftops is expected to be only about 30 percent. Sidewalks, which make up about 5 percent of the urban area, are located closer to the storm drainage system, but some of their runoff drains onto adjacent landscaped or other pervious areas. Therefore, only about half of the runoff yield from sidewalks enters the receiving waters. Parking lots make up about 7 percent of the urban area and are mostly paved and impervious. Again, because some of the runoff from the parking areas drains onto adjacent pervious areas, only about half of the precipitation that falls there is expected to reach the receiving waters. Street surfaces, however, are in close proximity to the storm drainage system and are generally quite impervious. Street surfaces constitute about 15 to 20 percent of the urban area, and most of the rainfall that lands thereon is expected to reach the outfall. Some is lost through evaporation and infiltration through surface imperfections (e.g., cracks and potholes).

Table 5-11 presents estimates of the percentage contribution of the principal pollutants from various source areas. Rooftops are thought to contribute the least amount of pollutants. Parking lots, street surfaces, and sidewalks are expected to contribute the majority of the heavy metals, bacteria, and some nutrients to the total overall runoff yield. Landscaped areas and vacant lots contribute the majority of the solids, oxygen demanding materials, and some nutrients.

Relative deposition values for the principal pollutants from various source areas are summarized in Table 5-12. The tabulated values are estimates of the percentage of the total pollutant deposited in the urban areas. The deposition rates are much larger than the pollutant yields to the outfall as discussed earlier. As a comparison, Table 5-13 shows the relative yields from these source areas to the total outfall runoff yield. The deposition rates for some of the pollutants are shown to be relatively high for some of the impervious areas, but these source yields are reduced substantially by infiltration. Automobile activity and street wear are responsible for most of the heavy metal yield in the runoff and about half of the total solids yield. Vegetation sources contribute most of the oxygen demanding materials, while dog feces and fertilizers are expected to contribute most of the nitrogen in urban runoff.

Table 5-14 summarizes estimated San Jose urban runoff yields and characteristics. Although conditions are expected to vary substantially for other areas of the country, these estimates serve to indicate some important considerations about urban runoff. If all of the total solids pollutant depositions in an urban area were added together, only about one-third might reach the outfall. Only about 10 percent of the nutrients and oxygen demanding materials deposited might affect the receiving water quality, but most of the heavy metals deposited in the area might affect the receiving waters. The remaining deposited pollutants washed off the source areas (and not reaching the outfall) would accumulate in other areas in the urban environment. The most significant of such pollutant "sinks" in the urban area are expected to be soils, groundwater, plants, and animals. Many studies (3, 12, 13, 14) have shown significant concentrations of heavy metals in roadside soils, vegetation, and animals. As noted earlier, much of this material (about 15 percent of the total deposition of total solids) can be associated with dustfall. Most of this dustfall, however, is resuspended particulates from the streets and vacant areas and is not an actual source of urban runoff pollutants, except for point source air pollution emissions that may settle out.

Table 5-11. CONTRIBUTIONS OF VARIOUS SOURCE AREAS TO OUTFALL RUNOFF YIELDS (Percent)

	Street Surfaces and Sidewalks	Parking Lots	Landscaped Areas and Vacant Lots	Rooftops
Total solids	40	10	50	2
Chemical Oxygen Demand	25	15	50	5
Biochemical Oxygen Demand (5-day)	25	20	50	2
Total Kjeldahl nitrogen	50	10	25	15
Ammonia nitrogen	50	10	20	20
Nitrate	20	1	75	2
Orthophosphate	45	30	20	10
Total phosphate	65	20	15	5
Total sulfur	45	<1	50	5
Sulfate	50	<1	40	5
Arsenic	<1	15	70	10
Lead	80	20	<1	<1
Zinc	60	20	1	20
Copper	60	20	10	10
Chromium	80	20	2	<1
Total coliform bacteria	>95	<5	<1	<1
Fecal coliform bacteria	>95	<3	<1	<1
Fecal strep. bacteria	>60	>10	<3	<30

Note: The tabulated values are estimates of generalized conditions. In some cases, they do not total 100%.

Table 5-12. RELATIVE ANNUAL SOURCE DEPOSITIONS (percent)

	Precipitation	Tire Wear	Auto and Street Use	Vegetation	Construction Erosion	Bird Feces	Dog Feces	Cat Feces	Fertilizer Use	Other
Total solids	10	5	20	40	20	2				3
Biochemical Oxygen Demand (5-day)	3	<1	1	95	<1					1
Kjeldahl nitrogen	5		1	15	<1	<1	40	<1	40	
Lead	<1	10	90		<1	<1				
Zinc	15	80	1		2	<1				
Copper	10	5	50		2					30
Chromium	<1	10	70		10					10

Note: The tabulated values are estimates of generalized conditions. In some cases they do not total 100%.

Table 5-13. RELATIVE ANNUAL RUNOFF YIELD CONTRIBUTIONS (percent)

	Precipitation	Tire Wear	Auto and Street Use	Vegetation	Construction Erosion	Bird Feces	Dog Feces	Cat Feces	Fertilizer Use	Other
Total solids	10	5	50	30	5	5				3
Biochemical Oxygen Demand (5-day)	10	1	10	70		<1				5
Kjeldahl nitrogen	20		10	10	<1	1	30	<1	30	
Lead	<1	1	100		<1	<1				
Zinc	20	80			<1	<1				
Copper	5	2	80		<1					15
Chromium	<1	3	90		1					5

Note: The tabulated values are estimates of generalized conditions.
In some cases they do not total 100%.

Table 5-14. ESTIMATED SAN JOSE URBAN RUNOFF YIELDS

	Expected Outfall Runoff Yield (kg/ha/yr)[a]	Percentage of Desposition Yield to Outfall	Major Sources Contributing to Runoff Yield
Total solids	280	30	Auto and street use
Biochemical Oxygen Demand (5-day)	45	10	Vegetation
Kjeldahl nitrogen	2.8	10	Dog feces and fertilizer use
Lead	1.1	90	Auto and street use
Zinc	0.11	20	Tire wear
Copper	0.16	60	Auto and street use
Chromium	0.11	70	Auto and street use

[a] Multiply kg/ha/yr by 0.892 to obtain lb/acre/yr.

SECTION 6

CONDITIONS IN COYOTE CREEK

This section describes the findings of a series of field programs conducted to determine conditions in Coyote Creek. Emphasis was placed on obtaining information that reflects the effects of urban runoff on the following: water quality, sediment quality, fish, benthic organisms, and algae. Studies included an effort to assess possible bioaccumulation effects.

WATER QUALITY

The purpose of the water quality monitoring program on Coyote Creek was to define receiving water conditions in the urban and non-urban areas during dry weather conditions. Dry weather conditions were studied because they tend to be more effective than wet weather conditions in reflecting long-term water quality characteristics in the creek. This is largely because they are less strongly influenced by any given urban runoff event which might give a biased indication. Nonetheless, some data on wet weather water quality conditions were obtained from other sources (1, 7, 2, 15, 16, 17).

Table 6-1 summarizes Coyote Creek water quality data for the wet and dry weather conditions and for both the urban and non-urban reaches. Dry weather concentrations of many constituents exceeded corresponding wet weather concentrations by factors of 2 to 5 times. For example, during dry weather, many of the major constituents (e.g., major ions, hardness, alkalinity, total solids, total dissolved solids, specific conductance, ammonia nitrogen, and orthophosphate) were significantly greater in both the urban and non-urban reaches. These constituents were all found substantially lower in concentration in the urban runoff and in the rain. The rain and the resultant runoff apparently dilute those constituent concentrations in the creek during wet weather. Temperature, pH, dissolved oxygen, nitrate nitrogen, and arsenic were found to be about the same for wet and dry weather, for both the urban and non-urban areas. Within the urban area, several constituents were found in greater concentrations during wet weather than during dry weather (e.g., suspended solids, volatile suspended solids, and turbidity). This effect is assumed to be evidence of soil erosion products in urban runoff. Chemical Oxygen Demand and organic nitrogen were also present in the urban area in greater abundance during wet weather than dry, as were heavy metals (e.g., lead, zinc, copper, cadmium, mercury, iron, and nickel).

Similar differences between wet and dry weather were also noted for the non-urban area. However, the wet weather concentrations were typically much higher in the urban area than in the non-urban area. Several other constituents were also found in higher concentrations in the urban area than in the

Table 6-1. TYPICAL COYOTE CREEK WATER QUALITY CONDITIONS BY LOCATION AND SEASON
(mg/1 unless otherwise noted)

	Urban Area		Non-Urban Area	
	Wet Weather	Dry Weather	Wet Weather	Dry Weather
Common Parameters and Major Ions:				
pH	7	8	-*	8
Temperature	16	17	-	16
Calcium - dissolved	20	100	40	100
Magnesium - dissolved	6	70	20	60
Sodium - dissolved	0.01	-	-	20
Potassium - dissolved	2	4	2	2
Bicarbonate	50	150	-	200
Sulfate	20	60	-	40
Chloride	10	60	-	20
Total hardness	70	500	200	600
Total alkalinity	50	300	150	300
Residuals:				
Total solids	350	1000	600	1000
Total dissolved solids	150	1000	300	1000
Suspended solids	300	4	600	20
Volatile suspended solids	60	2	90	10
Turbidity (NTU)	50	15	-	20
Specific conductance (μmhos/cm)	200	500	-	400
Organics and Oxygen Demand Materials:				
Dissolved oxygen	8	7	-	9
Biochemical Oxygen Demand (5-day)	25	-	5	-
Chemical Oxygen Demand	100	40	90	30
Total organic carbon	110	-	-	0.6
Nutrients:				
Total Kjeldahl Nitrogen	7	0.5	2	<0.3
Nitrate (as N)	0.7	0.8	-	1.2
Nitrite (as N)	-	0.02	-	<0.002
Ammonia (as N)	0.1	0.8	0.1	0.3
Orthophosphate	0.2	0.5	0.1	0.4
Heavy Metals:				
Lead (μg/1)	2000	40	200	2
Zinc (μg/1)	400	30	200	20
Copper (μg/1)	20	10	50	5
Chromium (μg/1)	20	10	5	5
Cadmium (μg/1)	5	<1	5	<1
Mercury (μg/1)	1	0.2	1	0.2
Arsenic (μg/1)	4	3	5	2
Iron (μg/1)	10,000	1000	20,000	2000
Nickel (μg/1)	40	<1	80	<1

Sources: Most of this information is based on Coyote Creek monitoring results from this study. Some of the information, however, is from other sources: (7, 2, 15, 16, 17).

*Blanks signify no data were available.

non-urban area during wet weather (e.g., lead, zinc, chromium, Biochemical Oxygen Demand, and total Kjeldahl nitrogen).

Table 6-2 summarizes water quality criteria which have been established for the principal constituents studied in Coyote Creek. Appendix E is a comprehensive summary of the effects of various urban runoff pollutants on Coyote Creek aquatic organisms. These provide some basis for evaluating the quality of the creek. Comparing the observed and estimated water quality data (Table 6-1) with these criteria led to the following conclusions. The significant turbidity increases in the urban reach of Coyote Creek (during wet weather) exceed the criteria for recreational use and aquatic life. Lead concentrations in the non-urban reach may also exceed the water quality criteria for both livestock and aquatic life during wet weather.

Prior to this study, only very limited data were available concerning Coyote Creek water quality (during either wet or dry weather). Early in this study (spring of 1977), a pilot water quality survey was conducted along Coyote Creek. The pilot survey developed data pertinent to the reach which extends from Anderson Dam down to San Francisco Bay. Water quality samples were obtained at ten sites and analyzed for major constituents (e.g., pH, carbonate and biocarbonate alkalinity, total hardness, chlorides, sulfates, nitrates, nitrites, ammonia, turbidity, and total coliform bacteria). Dissolved oxygen, temperature, and specific conductance were measured in the field.

These preliminary data indicated several potential water quality problems. In most cases the water was very turbid (most values between 15 and 20 NTU). The water was also hard to very hard (typical of Santa Clara County surface and ground waters). Chloride concentrations at the lower most (Dixon) station were high, due to tidal influences (mixing with San Francisco Bay water). Free ammonia concentrations ranged from 0.01 to 0.11 mg/l, with the highest value in the downstream reach. About half of the observed ammonia values were equal to or greater than the established criteria for aquatic life (0.02 mg/l). Total coliform bacteria populations were also high at most of the sampling sites.

Figure 6-1 is a plot which shows how selected constituents varied with distance along Coyote Creek (based on data from this pilot survey). It is evident that the water quality upstream of the urbanized area was fairly consistent from site to site, and that the quality changed markedly as the creek passed through the urbanized area. The reach which extends from Trimble through Hellyer stations, was influenced only by urban runoff. The water quality within this reach was generally poorer than at the stations upstream of the urban area. The Tully sampling site was found to be an exception in many cases. The site has a large pool which is thought to receive a significant contribution from ground water and only a minor contribution of creek flow from upstream. The lower temperature and the better water quality measured at the location support the above hypothesis. Note that the Dixon sampling site was adversely influenced by the tidal action of the Bay and the discharge from the sewage treatment plant (it characteristically showed the poorest water quality).

Table 6-2. WATER QUALITY CRITERA

	Irrigation Use	Livestock Use	Wildlife Use	Aquatic Life Use	Recreational Use
pH	4.5 to 9.0 desired		6.0 to 9.0 desired	6.0 to 9.0 desired	5.0 to 9.0 desired
Turbidity				small change	
Temperature (°C)	narrative[1]		maintain natural patterns	narrative[1]	<30°C
Dissolved Oxygen (mg/1)				usually >5.0	
Total coliform bacteria (MPN/100ml)		<5000	<2000		
Total Phosphate (mg/1)					<0.3 (for streams)
Nitrate (mg/1)	narrative[1]	<450 including NO_2			
Arsenic (mg/1)	<0.1 to 2.0 (crop dependent)	<0.2			
Lead (mg/1)	<5.0 to 10 (crop dependent)	<0.1		<0.03 mg/1	
Zinc (mg/1)		<25		narrative[1]	
Copper (mg/1)	<0.02 to 5.0 (crop dependent)	<0.5		narrative[1]	
Iron (mg/1)	<5 to 20 (crop dependent)	narrative[1]			

Sources: (4, 5, 6).

[1] Narrative implies a potential conflict between the parameter and beneficial use, but lack of data or too many important site-specific conditions do not allow a specific value to be used as a general criterion.

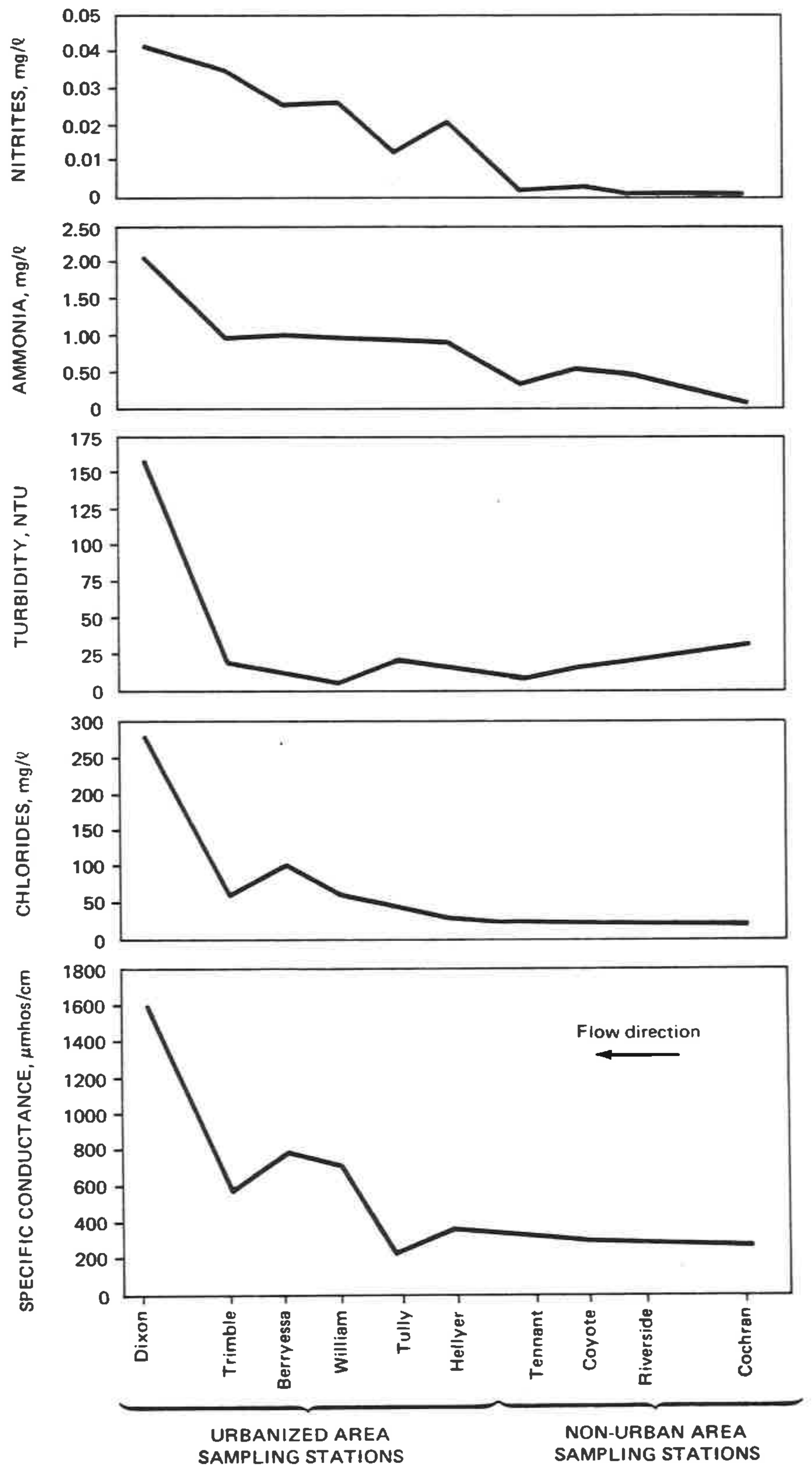

Figure 6-1. Water quality trends along Coyote Creek (March 31, 1977).

Turbidity levels in the creek were found to be fairly consistent, due to the turbid water discharged from Lake Anderson. Because this pilot survey was conducted during a period of low flow following a 3-week dry spell, the observed water quality trends were probably somewhat less pronounced than what would be expected during or soon after a typical runoff event.

During this project, many additional samples were obtained, and many measurements were made within the urban and non-urban reaches of Coyote Creek. About 80 temperature and specific conductance observations were made throughout the creek, along with more than 30 velocity, flow, and dissolved oxygen observations. Many observations of the other constituents were also obtained. Table 6-3 summarizes the results of these observations, while Appendix B presents the water quality data. Table 6-3 also presents the calculated ratios between the average urban and non-urban area measurements for each constituent and a measure of the data's statistical significance (i.e., the percent confidence that the mean values for the urban area are significantly different than the mean values for the non-urban area).

Lead concentrations were found to be more than 7 times as great in the urban reach than in the non-urban reach during dry weather, with 75 percent confidence that the observations were not equal. Nitrite concentrations were almost 7 times as great in the urban area, with a confidence of 99 percent. Ammonia nitrogen values in the urban area were 2.8 times as great as the non-urban area, with a confidence of more than 99 percent. Other significant increases in urban area concentrations include chloride, nitrate, orthophosphate, Chemical Oxygen Demand, specific conductance, sulfate, and zinc. Conversely, the dissolved oxygen measurements were about 20 percent less in the urban reach than in the non-urban reach of the creek, with a confidence of more than a 99 percent.

Tables 6-4 and 6-5 present data on Penitencia and Silver Creeks. Both are tributaries to Coyote Creek (within the urban reach) which were selected for study because they are similar to Coyote Creek in their upstream reaches. Biological monitoring was conducted in these creeks to assess the abundance and diversity of aquatic organisms in the unpolluted areas near their headwaters. Temperature and dissolved oxygen levels were found to be similar to observations in Coyote Creek.

The dissolved oxygen levels in the uppermost reach of Penitencia Creek were low, because the study site was located near the headwater spring (i.e., little aeration had occurred). The specific conductance in Penitencia Creek was found to increase with distance downstream, but this was primarily because of the abundance of mineral springs that flow into the creek (rather than the effect of urban runoff).

The Silver Creek measurements were obtained over a significant length. The lowermost study site was located in a heavily urbanized area near the confluence with Coyote Creek. The relative low dissolved oxygen value observed at this downstream location was thought to be associated with a large quantity of suspended and settled organic material which was present at the time. The specific conductance level was also found to be significantly greater at this location than in the upper and middle reaches.

Table 6-3. OBSERVED COYOTE CREEK WATER QUALITY CONDITIONS

	Non-Urban Area Stations Below Anderson Dam						Urban Area are Stations Above Silver Creek						Urban/Non-Urban Differences	
	Number of Observations	Mean	Minimum	Maximum	Standard Deviation	Relative Standard Deviation (%)[1]	Number of Observations	Mean	Minimum	Maximum	Standard Deviation	Relative Standard Deviation (%)	Ratio of Urban to Non-urban Mean Values	Confidence That Urban Does Not Equal Non-urban Mean Values (%)
Velocity (m/sec)	11	0.7	0.3	1.2	0.28	40	20	0.3	<0.1	0.9	0.4	100	0.4	97
Creek Flow Rate (m^3/sec)	11	2.0	0.3	3.6	3.4	170	20	0.2	0.01	0.8	0.24	150	0.1	98
Temperature(°C)	30	17	13	24	3.5	21	50	19	13	28	2.8	15	1.1	>99
Specific Conductance (mhos/cm)	30	330	250	400	58	18	49	590	215	1900	280	47	1.8	>99
Total solids (mg/l)	4	270	244	299	25	9.3	10	590	280	1200	262	44	2.2	98
Turbidity (JTU)	8	17	6.6	33	7.8	46	13	18	4.5	104	26	140	1.1	<60
pH (pH units)	8	median 8.2	7.9	8.6	—	—	13	median 7.8	7.6	8.3	—	—	median —	NA
ORP (mv)	2	172	166	177	—	—	5	197	160	220	23	12	1.2	90
Dissolved oxygen (mg/l)	14	8.6	6.5	10.6	1.1	12	26	6.8	1.5	11.0	2.0	29	0.8	>99
Chemical Oxygen Demand (mg/l)	4	17	12	23	5.1	30	10	30	19	53	12	40	1.8	98
Total hardness (mg/l)	4	215	200	240	19	8.8	3	233	140	340	100	43	1.1	60
Total alkalinity (mg/l)	4	160	120	200	33	21	6	226	120	360	102	45	1.4	80
Carbonate (mg/l)	4	21	<24	36	15	71	3	<24	<24	<24	0	0	—	85
Bicarbonate (mg/l)	4	70	37	98	25	36	3	126	73	220	82	65	1.8	85
Chloride (mg/l)	4	<20	<20	<20	0	0	3	43	30	60	15	35	>2.2	98
Sulfate (mg/l)	8	40	28	50	7.7	19	13	68	14	110	34	51	1.7	98
Total phosphate (mg/l)	4	<0.2	<0.02	0.59	<0.3	130	10	0.25	<0.02	0.54	0.18	72	>1.3	65
Orthophosphate (mg/l)	2	<0.1	<0.1	0.1	—	—	5	0.18	0.1	0.4	0.13	72	>1.8	80
Total Kjeldahl nitrogen (mg/l)	4	<0.3	<0.05	0.50	<0.3	100	10	0.45	<0.05	0.78	0.28	62	>1.7	85
Ammonia (mg/l)	4	0.33	0.05	0.50	0.20	61	3	0.93	0.90	0.95	0.03	3	2.8	>99
Nitrate (mg/l)	4	0.44	<0.01	1.7	0.84	190	3	0.84	<0.01	1.3	0.72	85	1.9	70
Nitrite (mg/l)	4	0.003	<0.002	0.004	0.001	33	3	0.020	0.012	0.027	0.008	38	6.7	>99
Total coliform bacteria (MPN/100 ml)	4	>1400	240	>2400	>1200	80	3	>1900	1600	>2400	>460	20	—	NA
Arsenic (mg/l)	8	<0.005	<0.002	0.006	0.004	80	13	<0.006	<0.002	0.027	0.006	100	—	80
Lead (mg/l)	2	<0.05	0.001	0.002	—	—	7	0.036	0.003	0.10	0.039	110	>7	75
Zinc (mg/l)	2	0.019	0.019	0.019	—	—	6	0.033	0.010	0.075	0.022	67	1.7	80
Copper (mg/l)	4	<0.01	<0.01	<0.01	0	0	3	<0.02	<0.01	0.02	—	—	—	96
Iron (mg/l)	4	1.5	0.51	2.8	0.97	65	3	0.85	0.37	1.1	0.42	49	0.6	80

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[1] The relative standard deviation is the "standard deviation" divided by "mean". This ratio is multiplied by 100 when expressed as a percentage.

Table 6-4. PENITENCIA CREEK OBSERVED WATER QUALITY (October 3, 1979)

Location	Temperature (°C)	Specific Conductance (µmhos/cm)	Dissolved Oxygen (mg/l)
Alum Rock Park - creek headwaters (underground river coming to surface)	16.5	600	4.8
Alum Rock Park - at mineral springs	20.5	1050	8.1
Alum Rock Park - lower reaches	20.0	1950	9.5

Table 6-5. SILVER CREEK OBSERVED WATER QUALITY (October 3, 1979)

Location	Temperature (°C)	Specific Conductance (µmhos/cm)	Dissolved Oxygen (mg/l)
Upper reach	24.0	900	10.4
Middle reach	18.0	850	8.1
Lower reach (directly above confluence with Coyote Creek)	20.0	1725	4.2

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APPENDIX A

SEDIMENT QUALITY CONDITIONS IN COYOTE CREEK

Table A-1. COMMON PARAMETER CONCENTRATIONS IN SEDIMENTS (June, 1978)
(mg/kg unless otherwise noted)

	Station					
Parameter	Cochran	Miramonte	Metcalfe	Derbe	William	Tripp
Volatile Solids (%)	21.2	27.3	20.6	16.1	10.5	9.6
Biochemical Oxygen Demand (5-day)	94	420	126	305	619	1850
COD	37,000	98,000	67,000	46,000	62,000	131,000
TOC	9600	28,000	14,000	28,000	18,000	42,000
NH_3	120	310	110	40	79	150
NO_3 (dissolved)	<0.04	0.39	0.04	<0.03	<0.05	0.12
Kjeldahl Nitrogen	6000	29,000	9100	3900	8100	14,000
Organic Nitrogen	5900	29,000	9000	3900	8000	14,000
Ortho PO_4	0.46	1.7	1.4	1.2	2.9	6.6
Sulfate ($mgSO_4$/kg)	4.4	2.5	0.84	150	83	110
Median Size (μ)	210	240	220	90	70	90

Table A-2. PARAMETERS GENERALLY WITHIN 0.1 TO 1.0 mg/kg CONCENTRATION RANGE* IN SEDIMENTS (June, 1978)

	Station					
Parameter	Cochran	Miramonte	Metcalfe	Derbe	William	Tripp
Beryllium	0.50	<0.48	0.53	<0.48	<0.48	0.48
Bismuth	0.52	0.42	<0.42	<0.42	<0.42	1.0
Cadmium	0.48	0.54	<0.44	0.62	1.1	1.4
Erbium	0.57	0.57	0.44	1.1	1.0	2.0
Europium	0.83	0.83	0.35	0.41	0.2	1.6
Holmium	0.30	0.46	0.26	0.53	0.61	0.61
Lutecium	0.16	0.16	0.15	0.16	0.19	0.33
Selenium	0.37	0.82	0.47	0.36	1.1	1.1
Silver	<0.1	<0.1	<0.1	<0.1	0.17	0.35
Tantalum	0.51	0.20	0.45	2.6	0.45	0.60
Tellurium	<0.20	0.17	<0.20	<0.20	<0.12	0.10
Terbium	0.44	1.7	0.38	0.66	0.66	1.9
Thallium	0.76	<0.76	0.76	<0.76	0.96	0.96
Thullium	0.27	0.23	<0.19	0.23	0.23	1.1
Tungsten	0.56	0.58	<0.46	0.66	0.66	1.5

*Parameters less than 0.1 mg/kg at all stations:
Gold, Iridium, Osmium, Palladium Platinum, Rhodium, Ruthenium.

Table A-3. PARAMETERS GENERALLY WITHIN 1.0 TO 10 mg/kg CONCENTRATION RANGE IN SEDIMENTS (June, 1978)

	Station					
Parameter	Cochran	Miramonte	Metcalfe	Derbe	William	Tripp
Antimony	1.4	1.4	0.30	1.2	3.0	3.0
Arsenic	6.1	1.5	<1.0	1.5	13	13
Bromine	6.0	28	6.9	2.4	14	14
Cesium	4.3	4.3	0.43	1.6	3.2	1.8
Chlorine	6.0	25	14	6.0	47	42
Dysprosium	2.2	2.7	0.72	1.3	1.4	3.1
Gadolinium	2.1	2.1	1.1	1.9	1.9	4.0
Gallium	5.4	2.3	1.1	2.0	5.4	4.6
Germanium	1.0	0.60	0.60	0.52	0.60	1.0
Hafnium	4.0	1.7	1.7	4.0	7.9	7.9
Iodine	7.0	16	6.2	1.6	7.0	12
Lanthanum	7.1	5.7	3.8	3.8	8.1	14
Mercury	1.1	8.4	1.6	6.6	4.3	13
Molybdenum	0.98	1.1	0.98	1.1	1.1	1.3
Neodymium	9.0	5.1	1.8	2.6	9.0	6.0
Niobium	3.2	3.6	3.6	3.6	7.7	6.8
Praseodymium	2.7	2.7	1.2	1.2	2.7	12
Samarium	4.3	5.4	1.1	2.6	4.3	5.4
Thorium	6.0	6.9	1.6	4.8	16	16
Tin	2.3	2.3	0.53	2.3	2.3	4.0
Uranium	2.3	2.3	0.99	2.3	2.0	4.4
Ytterbium	2.0	0.85	0.74	1.7	1.7	3.0
Yttrium	6.1	6.1	5.4	5.4	12	14

Table A-4. PARAMETERS GENERALLY WITHIN A 10 TO 100 mg/kg CONCENTRATION RANGE IN SEDIMENTS (June, 1978)

Parameter	Station					
	Cochran	Miramonte	Metcalfe	Derbe	William	Tripp
Cerium	20	23	11	23	23	23
Copper	42	42	24	42	48	48
Lead	28	37	16	37	370	400
Lithium	43	86	29	-	57	-
Rubidium	37	66	13	20	28	37
Scandium	14	14	27	7.2	7.2	7.2
Strontium	59	140	59	120	69	120
Sulfur	69	320	69	1200	660	870
Zinc	70	70	14	30	120	70
Zirconium	40	40	17	35	40	37

Table A-5. PARAMETERS GENERALLY WITHIN A 100 TO 1000 mg/kg CONCENTRATION RANGE IN SEDIMENTS (June, 1978)

Parameter	Station					
	Cochran	Miramonte	Metcalfe	Derbe	William	Tripp
Barium	270	480	270	740	400	580
Boron	170	91	59	33	83	91
Chromium	130	120	780	240	130	120
Fluorine	260	820	260	300	530	450
Manganese	750	500	≃1300	250	150	380
Nickel	560	150	≃1200	98	120	120
Vanadium	130	126	71	71	71	71

Table A-6. PARAMETERS WITH CONCENTRATIONS GENERALLY GREATER THAN 1000 mg/kg IN SEDIMENTS (June, 1978)

Parameter	Station					
	Cochran	Miramonte	Metcalfe	Derbe	William	Tripp
Aluminum	≃3000	>10,000	>10,000	>10,000	>10,000	>10,000
Calcium	≃4700	>10,000	>10,000	>10,000	>5,000	>5,000
Cobalt	≃4400	31	89	16	31	18
Iron	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000
Magnesium	>10,000	>5,000	>10,000	>10,000	>10,000	>10,000
Phosphorus	≃1600	690	480	690	≃1200	690
Potassium	≃4000	>10,000	≃2700	≃3400	>5000	>5000
Silicon	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000
Sodium	≃2800	>10,000	≃3200	≃2800	>10,000	>5,000
Titanium	≃1500	≃1300	≃1300	≃1100	≃1500	≃2200

Table A-7. SEDIMENT QUALITY CONDITIONS OBSERVED DURING STUDY

Parameter (mg constituent/kg dry sediment, except as noted):

Station	Chemical Oxygen Demand			Total Phosphate			Orthophosphate			Total Kjeldahl Nitrogen			Sulfate			Arsenic			Lead			Zinc			Median Particle Size (μ)		
	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979	June 1978	July 1979	Nov 1979
Cochran(1)	37,000	—	—	—	—	—	0.46	—	—	6000	—	—	4.4	—	—	6.1	—	—	28	—	—	70	—	—	210	—	—
Miramonte	98,000	10,000	20,000	—	234	7.5	1.7	—	—	29,000	624	322	2.5	478	<200	1.5	10	25	37	15	13	70	83	66	240	4700	8760
Metcalfe	67,000	7400	9000	—	344	7.8	1.4	—	—	9100	320	138	0.84	464	<200	<1.0	7	28	16	6.7	16	14	90	55	220	8570	7770
Sylvandale(2)	—	4600	109,000	—	225	14	—	—	—	—	465	1370	—	<200	<200	—	11	45	—	29	230	—	77	170	—	7880	334
Senter	—	62,000	12,000	—	275	8.0	—	—	—	—	1570	164	—	748	<200	—	8	15	—	39	20	—	110	64	—	8030	8430
Derbe	46,000	12,000	12,500	—	311	29	1.2	—	—	3900	419	146	150	825	<200	1.5	8	11	37	65	36	30	120	64	90	6420	7780
William	62,000	8600	14,000	—	406	44	2.9	—	—	8100	495	921	83	<200	<200	13	8	9.9	370	36	90	120	100	83	70	6150	8600
Tripp	131,000	21,000	16,000	—	349	14	6.6	—	—	14,000	635	229	110	3670	<200	13	9	17	400	33	100	70	100	135	90	1720	2680
Berryessa(3)	—	4900	—	—	317	—	—	—	—	—	404	—	—	1090	—	—	4	—	—	27	—	—	75	—	—	2940	—

(1) These stations are all non-urban, below Anderson dam.
(2) These stations are all urban, above Silver Creek.
(3) This is an urban station, below Silver Creek.

APPENDIX B

WATER QUALITY CONDITIONS IN COYOTE CREEK

Table B-1. WATER QUALITY CONDITIONS OBSERVED DURING STUDY

Station	Total Solids		pH			ORP (mV)	COD		Turbidity (NTU)			Total Hardness	Total Alkalinity	CO_3	HCO_3	Cl	SO_4			Total Phosphate		PO_4
	July 1979	Nov 1979	March 1977	July 1979	Nov 1979	Nov 1979	July 1979	Nov 1979	March 1977	July 1979	Nov 1979	March 1977	March 1977	March 1977	March 1977	March 1977	March 1977	July 1979	Nov 1979	July 1979	Nov 1979	July 1979
Cochran[1]	—	—	8.2	—	—	—	—	—	33	—	—	220	160	<24	73	<20	40	—	—	—	—	—
Miramonte	244	255	—	8.0	7.9	177	23	12	—	15	13	—	—	—	—	—	—	28	39	<0.1	<0.02	<0.1
Riverside	—	—	8.5	—	—	—	—	—	18	—	—	200	160	24	73	<20	38	—	—	—	—	—
Coyote	—	—	8.6	—	—	—	—	—	14	—	—	200	120	36	37	<20	42	—	—	—	—	—
Metcalfe	282	299	—	8.1	8.1	166	18	13	—	23	17	—	—	—	—	—	—	31	49	<0.1	0.59	0.1
Tennant	—	—	8.3	—	—	—	—	—	6.6	—	—	240	200	24	98	<20	50	—	—	—	—	—
Hellyer[2]	—	—	8.2	—	—	—	—	—	16	—	—	220	180	<24	85	30	38	—	—	—	—	—
Sylvandale	287	559	—	7.7	8.0	195	20	53	—	8.4	16	—	—	—	—	—	—	14	71	0.1	0.54	0.1
Senter	280	477	—	8.0	8.3	160	22	46	—	20	104	—	—	—	—	—	—	32	48	<0.1	0.10	0.1
Tully	—	—	7.6	—	—	—	—	—	18	—	—	140	120	<24	73	40	22	—	—	—	—	—
Derbe	1200	729	—	7.6	7.7	220	25	39	—	15	14	—	—	—	—	—	—	81	110	0.4	<0.02	0.4
William	546	655	7.6	7.8	7.8	210	24	19	5.5	8.1	6.0	340	360	<24	220	60	80	100	110	0.2	0.40	0.2
Tripp	504	707	—	7.9	7.9	200	33	23	—	4.5	4.7	—	—	—	—	—	—	70	110	0.2	0.48	0.1
Berryessa[3]	557	—	7.7	7.9	—	—	27	—	13	5.5	—	300	320	<24	195	100	70	91	—	0.2	—	0.1
Trimble	—	—	8.0	—	—	—	—	—	18	—	—	260	200	<24	98	60	65	—	—	—	—	—
Dixon	—	—	8.2	—	—	—	—	—	170	—	—	440	400	48	195	280	70	—	—	—	—	—

[1] These are non-urban stations, below Anderson Dam.

[2] These are urban stations, above Silver Creek.

[3] These are urban stations, below Silver Creek.

Table B-2. PARAMETER: COYOTE CREEK VELOCITY (m/sec)

Coyote Creek Station	Distance Upstream from Mouth (km)	Dates and Observed Values				
		March 3, 1977	May 9 & 10, 1979	July 2 & 3, 1979	Sept. 20, 1979 (night)	Sept. 24, 1979
Below Dam[1]	61.2					
Cochran	60.1	1.0				
Burnett	58.3					
Miramonte	54.7		0.5	0.4	0.3	0.8
Riverside	51.2					
Coyote	46.9	0.6				
Metcalfe	45.4		0.5	0.8	0.6	1.2
Tennant	41.9	1.0				
Crosslees[2]	37.9					
Coyote Rd. (gage)	36.7					
Coyote Rd. (above lakes)	35.2					
Hellyer	34.6	0.3	0.4			0.4
Sylvandale	33.4			0.5	pools	
Capitol	32.0					
Senter	30.9			pools	pools	pools
Tully	29.6	0.03				
Derbe	28.0			0.5	0.3	0.4
Story	26.4					
Martha	25.3		0.3			
William	24.6	0.3		0.3	0.9	0.4
Tripp	21.9			slow	1.5	0.2
Mabury[3]	20.6					
Berryessa	20.1	0.6		0.8		
Oakland	18.1					
Trimble	15.3	0.6				
SR 237	7.5					
Dixon	6.4	0.6				

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[1] These are non-urban stations, below Anderson dam.

[2] These are urban stations, above Silver Creek.

[3] These are urban stations, below Silver Creek.

Table B-3. PARAMETER: COYOTE CREEK FLOW

Coyote Creek Station	Distance Upstream from Mouth (km)	Dates and Observed Values				
		March 3, 1977	May 9 & 10, 1979	July 2 & 3, 1979	Sept. 20, 1979 (night)	Sept. 24, 1979
Below Dam[1]	61.2					
Cochran	60.1	12				
Burnett	58.3					
Miramonte	54.7		1.4	0.3	0.4	0.5
Riverside	51.2					
Coyote	46.9	3.6				
Metcalfe	45.4		0.05	1.3	1.1	1.3
Tennant	41.9	0.4				
Crosslees[2]	37.9					
Coyote Rd. (gage)	36.7					
Coyote Rd. (above lakes)	35.2					
Hellyer	34.6	0.1	0.5			0.02
Sylvandale	33.4			0.01	pool	
Capitol	32.0					
Senter	30.9			pools	pools	pools
Tully	29.6	0.3				
Derbe	28.0			0.02	0.02	0.01
Story	26.4					
Martha	25.3					
William	24.6	0.6	0.3	0.03	0.3	0.02
Tripp	21.9			low	0.8	0.02
Mabury[3]	20.6					
Berryessa	20.1	1.0		0.2		
Oakland	18.1					
Trimble	15.3	0.9				
SR 237	7.5					
Dixon	6.4	6.0				

[1] These are non-urban stations, below Anderson dam.

[2] These are urban stations, above Silver Creek.

[3] These are urban stations, below Silver Creek.

Table B-4. PARAMETER: COYOTE CREEK TEMPERATURE (°C)

Coyote Creek Station	Distance Upstream from Mouth (km)	Oaks and Observed Values								
		March 3, 1977	May 8, 1979	May 9 & 10, 1979	June 16-25, 1979	July 2 & 3 1979	Sept. 20, 1979 (night)	Sept. 24, 1979	Sept. 25-27, 1979	Oct. 3, 1979
Below Dam[1]	61.2				12.0				19.0	
Cochran	60.1	11.0	11.0		12.5				19.0	
Burnett	58.3				14.3				19.5	
Miramonte	54.7		12.5	18.5	16.0	13.0	19.0	18.0	20.0	
Riverside	51.2				23.5				23.0	
Coyote	46.9	14.0			18.0					
Metcalfe	45.4		13.0	16.5	18.5	14.0	21.0	19.0	21.0	
Tennant	41.9	14.5	15.5		20.0				18.0	
Crosslees[2]	37.9				19.0				20.5	
Coyote Rd. (gage)	36.7				23.0					
Coyote Rd. (above lakes)	35.2				20.0				19.0	
Hellyer	34.6	17.5	16.0	19.0	19.0			21.5	21.5	
Sylvandale	33.4				21.0	20.0	19.5			
Capitol	32.0		15.5		21.0					
Senter	30.9			19.5	22.0	25.0	23.0	28.0	21.5	
Tully	29.6	13.0	15.0		21.0					
Derbe	28.0		15.5	15.5	20.0	21.0	21.0	21.0	20.0	
Story	26.4				19.0					
Martha	25.3								18.0	
William	24.6	14.5	15.5	15.0	20.0	19.0	19.5	19.0	18.0	
Tripp	21.9		15.5	15.0	19.0	19.5	20.0	19.0	18.5	19.5
Mabury[3]	20.6				19.0				19.0	
Berryessa	20.1	14.0			19.0	20.0				19.0
Oakland	18.1				18.0					
Trimble	15.3	14.0			18.0				20.5	
SR 237	7.5				19.0				21.0	
Dixon	6.4	14.0				25.0			19.0	18.0

[1] These are non-urban stations, below Anderson dam.

[2] These are urban stations, above Silver Creek.

[3] These are urban stations, below Silver Creek.

Table B-5. PARAMETER: COYOTE CREEK SPECIFIC CONDUCTANCE (μmhos/cm)

		Oaks and Observed Values								
Coyote Creek Station	Distance Upstream from Mouth (km)	March 3, 1977	May 8, 1979	May 9 & 10, 1979	June 16-25, 1979	July 2 & 3 1979	Sept. 20, 1979 (night)	Sept. 24, 1979	Sept. 25-27, 1979	Oct. 3, 1979
Below Dam[1]	61.2				260				350	
Cochran	60.1	280	250		270				340	
Burnett	58.3				280				340	
Miramonte	54.7		250	300	290	290	335	340	330	
Riverside	51.2				325				350	
Coyote	46.9	300			310					
Metcalfe	45.4		340	350	320	310	400	400	390	
Tennant	41.9	325	370		550				370	
Crosslees[2]	37.9				490				385	
Coyote Rd. (gage)	36.7				420					
Coyote Rd. (above lakes)	35.2				425					
Hellyer	34.6	360	330	360	550			450	380	
Sylvandale	33.4				550	390	750			
Capitol	32.0		335		550					
Senter	30.9			320	600	410	500	500	400	
Tully	29.6	215	360		600					
Derbe	28.0		390	600	440	1900	1000	1000	450	
Story	26.4				550					
Martha	25.3								900	
William	24.6	700	410	490	550	800	920	900	480	
Tripp	21.9		600	600	700	750	900	1000	800	650
Mabury[3]	20.6				850				950	
Berryessa	20.1	750			900	900				550
Oakland	18.1				820					
Trimble	15.3	580			900				810	
SR 237	7.5								900	
Dixon	6.4	1600			900	1200			950	580

[1] These are non-urban stations, below Anderson dam.

[2] These are urban stations, above Silver Creek.

[3] These are urban stations, below Silver Creek.

Table B-6. PARAMETER: COYOTE CREEK DISSOLVED OXYGEN (mg/1)

Coyote Creek Station	Distance Upstream from Mouth (km)	Dates and Observed Values					
		March 3, 1977	July 2 & 3, 1979	Sept 20, 1979	Sept 24, 1979	Sept 25 & 27, 1979	Oct 3, 1979
Below Dam[1]	61.2						
Cochran	60.1	10.6				8.5	
Burnett	58.3					8.1	
Miramonte	54.7		9.4	7.6	9.0	9.7	
Riverside	51.2					9.2	
Coyote	46.9	9.4					
Metcalfe	45.4			7.3	8.4	8.5	
Tennant	41.9	9.3				6.5	
Crosslees[2]	37.9					8.3	
Coyote Rd (gage)	36.7						
Coyote Rd (above lakes)	35.2					6.6	
Hellyer	34.6	11.0			7.5	7.4	
Sylvandale	33.4		8.7	5.5			
Capitol	32.0						
Senter	30.9		8.3	7.6	11.0	8.1	
Tully	29.6	7.2					
Derbe	28.0		6.6	4.5	4.6	7.4	
Story	26.4						
Martha	25.3						
William	24.6	6.8	6.3	5.5	6.0	5.5	
Tripp	21.9		9.2	5.8	5.5	3.9	1.5
Mabury[3]	20.6						
Berryessa	20.1	4.8	7.0			4.0	7.2
Oakland	18.1						
Trimble	15.3	8.2				8.5	
SR 237	7.5						
Dixon	6.4	6.7				5.8	7.4

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[1] Non-urban stations, below Anderson dam

[2] Urban stations, above Silver Creek

[3] Urban stations, below Silver Creek

APPENDIX C

PRIORITY POLLUTANTS NOT DETECTED OR NOT ANALYZED IN COYOTE CREEK

Table C-1. PRIORITY POLLUTANTS NOT DETECTED OR NOT ANALYZED IN COYOTE CREEK

Purgable Organics	Sediment Analyses	Water Analyses
Acrolein	NA*	ND**
Acrylonitrile	NA	ND
Benzene	NA	ND
Toluene	NA	ND
Ethylbenzene	NA	ND
Carbon Tetrachloride	NA	ND
Chlorobenzene	NA	ND
1,2-Dichloroethane	NA	ND
1,1,1-Trichloroethane	NA	ND
1,1-Dichloroethylene	NA	ND
1,1,2-Trichloroethane	NA	ND
1,1,2,2-Tetrachloroethane	NA	ND
Chloroethane	NA	ND
2-Chloroethyl vinyl ether	NA	ND
Chloroform	NA	ND
1,2-Dichloropropane	NA	ND
1,3-Dichloropropene	NA	ND
Methylene chloride	NA	ND
Methyl chloride	NA	ND
Methyl bromide	NA	ND
Bromoform	NA	ND
Dichlorobromomethane	NA	ND
Trichlorofluoromethane	NA	ND
Dichlorodifluoromethane	NA	ND
Tetrachloroethylene	NA	ND
Trichloroethylene	NA	ND
Vinyl chloride	NA	ND
1,2-trans-Dichloroethylene	NA	ND
Bis (Chloromethyl) ether	NA	ND
Base-Neutral Extractable Organics		
1,2-Dichlorobenzene	ND	ND
1,3-Dichlorobenzene	ND	ND
1,4-Dichlorobenzene	ND	ND
Hexachloroethane	ND	ND
Hexachlorobutadiene	ND	ND
Hexachlorobenzene	ND	ND
1,2,4-Trichlorobenzene	ND	ND
Bis (2-Chloroethoxy) methane	ND	ND
Napthalene	ND	ND
2-Chloronapthalene	ND	ND
Isophorone	ND	ND
Nitrobenzene	ND	ND

*NA - Not Analyzed
**ND - Not Detected

Table C-1. (Continued)

Base-Neutral Extractable Organics	Sediment Analyses	Water Analyses
2,4-Dinitrotoluene	ND	ND
2,6-Dinitrotoluene	ND	ND
4-Bromophenyl phenyl ether	ND	ND
Di-n-octyl phthalate	ND	ND
Dimethyl phthalate	ND	ND
Acena phythylene	ND	ND
Acenaphthene	ND	ND
Fluorene	ND	ND
Chrysene	ND	ND
Benzo(a)anthracene	ND	ND
Benzo(b)fluoranthene	ND	ND
Benzo(k)fluoranthene	ND	ND
Indeno(1,2,3-c,d) pyrene	ND	ND
Dibenzo(a,h)anthracene	ND	ND
Benzo(g,h,i) perylene	ND	ND
4-Chlorophenyl phenylether	ND	ND
3,3'-Dichlorobenzidine	ND	ND
Benzidine	ND	ND
Bis (2-Chlorethyl) ether	ND	ND
1,2-Diphenylhydrazine	ND	ND
Hexachlorocyclopantadiene	ND	ND
N-Nitrosodiphenylamine	ND	ND
N-Nitrosodimethylamine	ND	ND
N-Nitrosodi-n-propylamine	ND	ND
Bis (2-Chlorosopropyl) ether	ND	ND
Acid Extractable Organics		
2-Nitrophenol	NA	ND
4-Nitrophenol	NA	ND
2,4 Dinitrophenol	NA	ND
4,6 Dinitro-o-cresol	NA	ND
p-Chloro-m-cresol	NA	ND
2-Chlorophenol	NA	ND
2,4-Dichlorophenol	NA	ND
Pesticides/PCB's		
Alpha - Endosulfan	ND	ND
Beta - Endosulfan	ND	ND
Endosulfan sulfate	ND	ND
Alpha - BHC	ND	ND
Beta - BHC	ND	ND
Delta - BHC	ND	ND
Gamma - BHC	ND	ND

Table C-1. (Concluded)

Pesticides/PCB's	Sediment Analyses	Water Analyses
Aldrin	ND	ND
Dieldrin	ND	ND
4,4'-DDE	ND	ND
4,4'-DDD	ND	ND
4,4'-DDT	ND	ND
Endrin	ND	ND
Endrin aldehyde	ND	ND
Heptachlor	ND	ND
Heptachlor epoxide	ND	ND
Chlordane	ND	ND
Toxaphene	ND	ND
Aroclor 1016	ND	ND
Aroclor 1221	ND	ND
Aroclor 1232	ND	ND
Aroclor 1242 PCB's	ND	ND
Aroclor 1248	ND	ND
Aroclor 1254	ND	ND
Aroclor 1260	ND	ND
2,3,7,8-TCDD	ND	ND
Heavy Metals		
Antimony	NA	ND
Beryllium	NA	ND
Chromium	NA	ND
Nickel	NA	ND
Selenium	NA	ND
Silver	NA	ND
Thallium	NA	ND
Miscellaneous		
Total cyanides	NA	NA
Asbestos	NA	NA
Total phenols	NA	NA

APPENDIX D

COMPARISON OF MAJOR POINT AND NONPOINT SOURCES OF POLLUTANTS AFFECTING SAN FRANCISCO BAY

Table D-1 presents a comparison between secondary sanitary wastewater effluent and urban runoff for much of the urban study area. The average and peak one-hour runoff concentrations observed and the average secondary sanitary wastewater effluent concentrations are shown, along with the ratios between them. The sanitary wastewater treatment facility is a modern, advanced secondary treatment plant serving the study area. The short-term effects of urban runoff on receiving water occur (by definition) during and immediately following a runoff event: short-term effects are associated with instantaneous concentrations. A comparison between the urban runoff average concentrations and the sanitary wastewater treatment plant effluent average concentrations shows that the concentrations of lead, suspended solids, chemical oxygen demand, cadmium, TOC, turbidity, zinc, chromium, and 5-day biochemical oxygen demand are all higher in the runoff than in the sanitary wastewater effluent. Copper and Kjeldahl nitrogen, in addition to the previously listed constituents, have greater runoff peak concentrations than the wastewater average concentrations. Therefore, urban runoff may have more important short-term effects on receiving waters than average treated sanitary wastewater effluent.

The annual yield for the different sources gives a measure that indicates potential long-term problems. Table D-1 also shows the annual sanitary wastewater treatment plant effluent yield expressed in weight per year (derived from monthly average concentrations and effluent quantities), and the calculated street surface portion of the annual urban runoff yield, also expressed in weight per year for a similar service area in San Jose. On an annual basis, the total orthophosphate and Kjeldahl nitrogen yields associated with the street surface runoff are less than 4 percent of the total sanitary wastewater treatment plant effluent plus street surface runoff yield. Total solids, cadmium, and mercury in the street surface runoff contribute from 5 to 15 percent of the total, respectively, while chemical oxygen demand, biochemical oxygen demand, and copper contribute from 10 to 50 percent of this total. Suspended solids, chromium, zinc, and lead in the street surface runoff contribute more than 50 percent of the total.

Table D-2 summarizes the 1975 total San Francisco Bay municipal discharges by type of treatment. The total Bay municipal discharges were about 1.9 billion liters per day (about 500 million gallons per day). About 43 percent of the total municipal discharges were treated by biological secondary facilities.

Table D-1. COMPARISON OF URBAN RUNOFF, STREET SURFACE YIELDS AND WASTEWATER TREATMENT PLANT EFFLUENT

Parameter	Runoff Concentration (mg/l unless otherwise noted)		STP Effluent Concentration (mg/l unless otherwise noted Average	Ratio of Avg. Runoff to STP Conc.	Ratio of Peak Runoff to Avg. STP Conc.	Annual Street Surface Runoff (Tonne/yr)	Annual STP Effluent (Tonne/yr)	Ratio of Street Surface Runoff to STP Annual Yield
	Avg.	Peak (1-hr)						
Ca^{++}	13	19	65	0.20	0.29	260	7,300	0.04
K^{+}	2.7	3.5	24	0.11	0.15	54	2,900	0.02
Mg^{++}	4.0	6.2	35	0.11	0.18	82	4,300	0.02
Na^{+}	15	27	220	0.07	0.12	300	27,000	0.01
Cl^{-}	12	18	330	0.04	0.05	250	41,000	0.006
SO$_4^{-}$	18	27	150	0.12	0.18	390	18,000	0.02
HCO$_3$	54	150	230	0.23	0.66	1100	29,000	0.04
HO$_3$	0.7	1.5	4.9	0.14	0.31	15	600	0.03
BOD$_5$	24	30	21	1.1	1.4	560	2,500	0.2
COD	200	350	35^c	5.6	10	2300	4,300^c	0.5
KN	6.7	25	24	0.28	1.1	100	2,900	0.03
Ortho PO$_4$	2.4	18	19	0.13	0.92	36	2,400	0.02
Total Solids	350	950	1000	0.34	0.92	7100	130,000	0.04
TDS^d	150	380	1000	0.15	0.37	3000	130,000	0.02
Suspended Solids	240	850	26	9.2	32	5400	3,200	1.7
Cd	0.01	0.04	0.002	5	20	0.03	0.25	0.1
Cr	0.02	0.04	0.016	1.3	2.5	2.8	2.0	1.4
Cu	0.03	0.09	0.081	0.37	1.1	4.3	10	0.4
Pb	0.4	1.5	0.0098	41	150	28	1.2	24
An	0.18	0.55	0.087	2.1	6.3	4.3	11	0.4
Hg	<0.0001	0.0006	0.0019	<0.05	0.32	<0.002	0.24	<0.008
Specific Conductance (μmhos/cm)	120	660	1900	0.06	0.36	--	--	--
Turbidity (NTU)	49	130	20	2.5	6.5	--	--	--
pH (pH Units)	6.7	7.6	7.6	--	--	--	--	--
TOC^e	110	290	30	3.5	9.7	2300	3,700	0.6

Source: (1)

[a] San Jose/Santa Clara secondary sanitary wastewater treatment plant serving 850,000 people. These values could vary substantially for other facilities.

[b] About 200 people correspond to 1 curb-mile (2880 curb-miles in San Jose/575,000 population). Therefore, a population of 850,000 corresponds to about 4250 curb-miles, with about 1100 curb-miles of streets surfaced with oil and screens, and about 3150 curb-miles of streets surfaced with asphalt. The city of San Jose has about 62,000 urbanized acres.

[c] Estimated.

[d] Total dissolved solids.

[e] Total organic carbon.

Table D-2. CURRENT SAN FRANCISCO BAY MUNICIPAL DISCHARGES

Type of Treatment	Total Annual Average Flow 10^6 liter/day	Percentage Treatment Category	Number of Dischargers
Primary	570	31	10
Primary plus chemicals added to primary sed. tank	310	17	2
Primary plus oxidation ponds	72	4	1
Biological secondary	790	43	27
Biological secondary plus physical-chemical	19	1	1
Biological secondary plus oxidation ponds	68	4	3
TOTAL	1850	100	44

Source: (35)

Table D-3 summarizes 1975 total San Francisco Bay industrial discharges, by major source categories. The total industrial discharge into the Bay was about 4 billion liters per day (about 1,000 MGD). Seventy percent of this industrial flow was associated with the discharges from six electrical power generation facilities.

Tables D-4 and D-5 summarize the quality and total quantities of pollutant discharges for each of these municipal and industrial treatment categories. Power facility discharges account for most of the industrial flow and refinery operations contribute 75 percent of the industrial suspended solids and 60 percent of the industrial biochemical oxygen demand discharges.

Table D-6 summarizes the expected San Francisco Bay area urban runoff discharges. These urban runoff discharge estimates are based upon the land-use distribution for urban and non-urban areas within the San Francisco Bay watershed, as shown on the table.

Table D-7 combines all point and nonpoint water pollution categories, including treated municipal wastewaters, untreated municipal overflows associated with combined sewers in San Francisco, treated industrial wastewater discharges and urban runoff. Urban runoff is seen to contribute more of the suspended solids discharges into the Bay than any of the other discharge categories. Treated industrial wastewaters are seen to contribute most of the biochemical oxygen demand, while treated municipal wastewater discharges contribute most of the total nitrogen, total phosphorus and zinc discharges. Urban runoff contributes almost all of the lead discharges into San Francisco Bay. This analysis does not include Sacramento River flow into the Bay and the effects of polluted sediments on Bay quality. In addition, the importance of San Francisco's combined sewer overflows (CSO) is underestimated on Table F-7, because no information is readily available for bacteria discharges. It is expected that the CSO discharges contribute most of the fecal coliform bacteria discharges into San Francisco Bay waters.

These data show that for a receiving water receiving both secondary treated sanitary wastewater and untreated urban runoff, additional improvements in the sanitary wastewater effluent may not be as cost effective as some urban runoff treatment (except for nutrients and bacteria). This is especially true for lead, where more than 95 percent of the total lead discharge is due to street surface runoff. If all of the lead were removed from the sanitary wastewater effluent, the total annual lead discharge would only decrease by about 4 percent.

Table D-3. CURRENT SAN FRANCISCO BAY INDUSTRIAL DISCHARGES

Type of Treatment	Total Average 10^6 liter/day	% in Category	Number of Dischargers
Power Generation	2600	70	6
Refinery	790	21	7
Chemical	42	1	8
Food	120	3	8
Rock	6.4	<1	3
Miscellaneous Industrial	83	2	8
Metals	4.5	<1	5
TOTAL	3700	100	45

Source: (35)

Table D-4. CURRENT SAN FRANCISCO BAY MUNICIPAL WASTE LOADS

Treatment Category	Flow	Suspended Solids	BOD_5	Total Nitrogen	Total Phosphates	Lead	Zinc
Raw conc.		300 mg/1	200 mg/1	50 mg/1	30 mg/1	0.01 mg/1	0.1 mg/1
Primary conc.	570 x 10^6 liters/day	100 mg/1	140	48	28	0.01	0.01
Discharge	208 x 10^9 liters/yr	23,000 metric tons/yr	29,000	10,000	5,800	2	21
% of total	31%	50%	58%	33%	34%	27%	31%
Primary, plus conc.	380 x 10^6 liters/day	90 mg/1	100	48	25	0.01	0.1
Discharge	140 x 10^9 liters/yr	13,000 metric tons/yr	15,000	6,800	3,600	2	15
% of total	21%	28%	29%	23%	21%	27%	22%
Secondary conc.	790 x 10^6 liters/day	30 mg/1	20	45	23	0.01	0.01
Discharge	290 x 10^9 liters/yr	9,100 metric tons/yr	5,700	13,000	6,600	3	29
% of total	43%	19%	11%	42%	38%	41%	43%
Secondary, plus conc.	87 x 10^6 liters/day	30 mg/1	15	25	23	0.01	0.1
Discharge	30 x 10^9 liters/yr	9,100 metric tons/yr	450	730	730	0.3	3
% of total	4%	2%	1%	2%	4%	4%	4%
Total Discharge	1850 x 10^6 liters/day 680 x 10^9 liters/yr	45,000 metric tons/yr	50,000	30,000	17,000	7.3	67

Sources: (35, 36).

Table D-5. SAN FRANCISCO BAY INDUSTRIAL WASTE LOADS

Industrial Category	Flow	Suspended Solids	BOD_5	Total Nitrogen
Refinery				
raw conc.	870 x 10^6 liters/day	400 mg/l	1500 mg/l	100 mg/l
Raw loading	300 x 10^9 liters/day	120,000 metric tons/yr	440,000 metric tons/yr	27,000 metric tons/yr
Typical treatment[1]		75%	60%	10%
Discharge		27,000	180,000	23,000
Food Industries				
raw conc.	130 x 10^6 liters/day	800 mg/l	500 mg/l	100 mg/l
Raw loading	45 x 10^9 liters/yr	36,000 metric tons/yr	23,000	4,500
Typical treatment[2]		65%	30%	5%
Discharge		14,000 metric tons/yr	14,000	4,300
Chemical				
raw conc.	42 x 10^6 liters/day	300 mg/l	300 mg/l	4 mg/l
Raw loading	15 x 10^9 liters/yr	4,500 metric tons/yr	4,500	63
Typical treatment[3]		65%	30%	5%
Discharge		1,800 metric tons/yr	3,200	61
Metals				
raw conc.	4.5 x 10^6 liters/day	2,000 mg/l	1,000 mg/l	100 mg/l
Raw loading	1.5 x 10^9 liters/yr	2,750 metric tons/yr	1,400	140
Typical Treatment[4]		75%	60%	10%
Discharge		680 metric tons/yr	540	120
Total				
Raw loading		160,000 metric tons/yr	470,000 metric tons/yr	32,000 metric tons/yr
Discharge	360 x 10^6 liters/day	44,000 metric tons/yr	200,000	27,000

Sources: (35, 36, 2).

[1] Neutralization, sedimentation, filtration, and aeration.

[2] Sugar: chemical coagulation, oil separation and neutralization

[3] Neutralization and sedimentation.

[4] Sedimentation plus.

Table D-6. SAN FRANCISCO BAY URBAN RUNOFF DISCHARGES

Parameter	Runoff Factor (kg/hectare/yr)	Total Bay Area Urbanized Discharges (metric tons/yr)
Suspended Solids	270	60,000
BOD_5	27	6,000
Total Nitrogen	3.5	800
Total Phosphorus	1	200
Lead	1	200
Zinc	0.1	20

* <u>LAND AREA:</u>

Land Use	Hectares	% of Total Bay Area
Residental	120,000	11
Commercial	21,000	2
Industrial	32,000	3
Total Urban	173,000	16
Irrigable	190,000	17
Suitable for urban development	50,000	5
Remaining	690,000	62
Total	1,100,000 ha	100

Sources: (37, 38, 2 39).

Table D-7. SUMMARY OF SAN FRANCISCO BAY WASTEWATER DISCHARGES: METRIC TONS/YEAR AND PERCENTAGE OF TOTAL

Parameter	Treated Municipal	Untreated Municipal Overflow*	Treated Industrial	Urban Runoff	Total
Suspended Solids	45,000 29%	6800 4%	44,000 28%	60,000 38%	160,000
BOD_5	50,000 19%	4500 2%	200,000 76%	6,000 29%	260,000
Total Nitrogen	30,000 51%	1200 2%	27,000 46%	800 1%	59,000
Total Phosphorous	17,000 95%	680 4%	———	200 1%	18,000+
Lead	6.6 3%	0.23 <19%	———	200 96%	210+
Zinc	67 74%	2.3 3%	———	20 22%	90+

*From the city of San Francisco only.

APPENDIX E

THE POTENTIAL EFFECTS OF VARIOUS URBAN RUNOFF CONSTITUENTS ON COYOTE CREEK AQUATIC ORGANISMS

This appendix briefly describes the potential effects of various urban runoff constituents on aquatic organisms present in Coyote Creek. This discussion is based upon summaries of the literature presented by the EPA (40). The information presented here is restricted to those urban runoff constituents of most importance and the aquatic organisms that have been found in Coyote Creek. Most of the information presented is for fish. Care was taken to select information pertaining to the specific water quality of the creek. As an example, hardness is a major factor in fish toxicity and only those literature results applicable to the Coyote Creek hardness range were considered.

TEMPERATURE

The observed temperature conditions in both the non-urban and the urban reaches of Coyote Creek were quite similar, with the urban reaches being slightly warmer. The non-urban temperature range observed was 13 to 24 degrees C, while the urban range observed was 13 to 28 degrees C. The temperature of the runoff affecting Coyote Creek was monitored in an earlier study (1) and ranged from 14 to 16.5 degrees C. These were all spot temperature measurements from many locations and represent several seasons.

The two critical times of the year for fish are summer months when water temperatures can reach their highest and during the spawning season when temperatures are very important for spawning success. Both of these seasons have recommended criteria based on weekly temperature averages and short term temperature maximums. Table E-1 lists these EPA recommended criteria for 8 fish species that have been reported to occur in Coyote Creek. Rainbow trout are seen to have the most critical temperature requirements with a short time period spawning temperature requirement of 13 degrees C. This temperature requirement can be exceeded in all regions of Coyote Creek. White crappie may also have its short-term temperature requirement exceeded by several degrees during the spawning season. None of the observed temperature measurements would exceed the recreational water quality criteria of 30 degrees C. The temperature measurements closest to the dam release were always the lowest observed. The water then warmed as it flowed toward and through San Jose. The major temperature differential observed was, therefore, mostly a function of the water temperature at the release point in the dam and the amount of overstory shading, cloud cover, sunlight and air temperature. Temperature measurements were also made at night to better obtain a representative range of typical temperature conditions. The observed nighttime

Table E-1. **RECOMMENDED TEMPERATURE CRITERIA FOR VARIOUS COYOTE CREEK FISH SPECIES**

	Summer Season		Spawning Season	
Fish Species	**Max. Average weekly temp. for growth**	**Max. short period temp. for survival of juveniles and adults**	**Max. average weekly temp. for spawning**	**Upper limit for successful incubating and hatching**
Black Crappie	27°C	--	--	--
Bluegill	32	35°C	25°C	35°C
Largemouth Bass	32	34	21	27
White Crappie	28	--	18	23
Carp	--	--	21	33
Channel Catfish	32	35	27	29
Rainbow Trout	19	24	9	13
Threadfin Shad	--	--	18	34

Source: (40)

temperatures were not signifcantly different from the daytime observed temperature conditions (September 1979 measurements).

In summary, it was observed that the potentially warm conditions during the spawning season may inhibit successful spawning of rainbow trout for most locations tested in Coyote Creek. White crappie may also be affected by high temperatures in some locations.

DISSOLVED OXYGEN

The observed dissolved oxygen concentrations in the non-urban stretch of Coyote Creek ranged from 6.5 to 10.6 mg/l, while in the urban section, dissolved oxygen concentrations ranged from 1.5 to 11 mg/l. Urban runoff affecting Coyote Creek was seen to range from about 5.5 to 13 mg/l.

Dissolved oxygen has been one of the key constituents studied in assessing the impacts of urban runoff on receiving waters. Dissolved oxygen can be successfully used as a short-term measure of urban runoff effects. The relatively high immediate oxygen demand of urban runoff, along with the potential resuspension of high sediment oxygen demand benthic materials by scouring, can create substantial oxygen consumption in the receiving waters during storm events. However, in-situ sediments can exert appreciable oxygen demands at relatively long time periods after deposition of the sediment material. The dissolved oxygen measurements collected in the receiving waters during this study were all made during dry weather conditions and, therefore, reflect a long-term effect of deposited sediments on receiving water oxygen concentration.

Dissolved oxygen has always been an important indicator of water quality. Insufficient dissolved oxygen can cause anaerobic decomposition of organic materials which can in turn cause the formation of noxious gases, such as hydrogen sulfide and the development of carbon dioxide and methane in the sediments. Dissolved oxygen in the water column can also cause chemical oxidation and subsequent leaching of iron and manganese from sediments. The effects of dissolved oxygen on freshwater fish is complicated because they can vary in their oxygen requirements according to the specific species, their age, activity, water temperature and by the amount of food present. Fish are capable of surviving for short periods of time at very low oxygen conditions. Most researchers, however, report a dissolved oxygen concentration of at least 4 mg/l needed to support a varied fish population. However, greater concentrations will usually result in a greater variety of species present. Fish embryonic and larval stages are especially vulnerable to low oxygen conditions because of their lack of mobility. In addition, low dissolved oxygen levels can adversely affect aquatic insects and other animals upon which fish feed. Some researchers have shown that as long as dissolved oxygen concentrations remain sufficient for fish, no significant impairment of the fish's resources, due to dissolved oxygen, are likely to occur (40).

In summary, the only dissolved oxygen measurements likely to be lower than the 5 mg/l aquatic life beneficial use water quality criteria would occur in the urban section of Coyote Creek. Many of the dissolved oxygen concentrations observed were supersaturated due to aeration during turbulent flow and to the presence of abundant algae. Nighttime dissolved oxygen and temperature measurements made in September, 1979 resulted in lower dissolved oxygen concentrations than observed during the day. In the non-urban reaches, the nighttime dissolved oxygen measurements were at most 1.4 mg/l lower than daytime observations. In this urban reach of Coyote Creek, the difference was as great as 3.4 mg/l lower during the night, but averaged about 1.3 mg/l lower. Nighttime dissolved oxygen concentrations are lower because aquatic plants consume oxygen in the absence of sunlight.

ALKALINITY

Observed alkalinities in Coyote Creek ranged from 120 to 200 mg/l in the non-urban area and from 120 to 360 mg/l in the urban area. The alkalinity of runoff affecting Cayote Creek was in the range of less than 1 to 150 mg/l. The creek values are relatively high and major pH changes due to urban runoff are, therefore, not expected. The non-urban pH values ranged from 7.9 to 8.6, while the urban pH values ranged from 7.6 to 8.3. The runoff pH values were observed to be lower, in the range of 6.0 to 7.6.

Alkalinity, like hardness, temperature and pH, affects the toxicity of many chemical compounds to aquatic organisms. Alkalinity is a measure of the buffering capacity of water, which restricts radical pH changes and is expressed as calcium carbonate equivalent. As the pH limit in the water system is restricted, the solubilities of many toxic materials are reduced if equilibrium conditions are reached. In addition, some of the major components of alkalinity, such as carbonate and bicarbonates, will complex some of the toxic heavy metals and directly reduce their toxicities.

HARDNESS

Observed hardness values in Coyote Creek ranged from 140 to 340 mg/l in the urban area and from 200 to 240 mg/l in the non-urban area. Hardness is also expressed as calcium carbonate equivalent. Coyote Creek water can, therefore, be considered hard to very hard. The observed hardness of runoff affecting Coyote Creek ranged from 13 to 73 mg/l, and averaged 50 mg/l, all values being considered "soft".

Hardness usually acts to decrease the toxic effects of various heavy metals on aquatic organisms. As an example of the effects of hardness on reducing the toxicity of metals, a 40-hour 50 percent toxicity value for rainbow trout is about four times greater for copper and zinc when the hardness is increased 10 times from 10 to 100 mg/l (40). The effects of hardness on freshwater fish and other aquatic life appear to be related to the ions causing the hardness, rather than the composite measure of hardness itself. It is difficult to determine if toxicity of various metal ions is reduced because of the formation of metallic hydroxides and carbonates caused by the associated increases in alkalinity, or because of an antagonistic effect of some of the principle cations contributing to hardness, such as calcium, or other bivalent metals.

In summary, the high levels of hardness observed in Coyote Creek are expected to substantially decrease the toxicity of most heavy metals on aquatic organisms present. Many surface and groundwaters in southern Santa Clara County are hard; urban runoff itself is not likely to increase hardness.

SUSPENDED SOLIDS

Estimated suspended solids concentrations in Coyote Creek can range from 4 to 300 mg/l in the urban area and between 20 and 600 mg/l in the non-urban area during both dry and wet weather. Higher suspended solids values in the non-urban area are associated with the appreciable erosion in the upper Coyote Creek watershed, while the smaller stream gradient in the lower parts of the Creek reduce the sediment solids content by encouraging sedimentation.

Suspended solids can affect fish life by directly killing the fish or reducing their growth rate, their resistence to disease or other factors. Suspended solids also affect fish by limiting successful development in fish eggs and larvae. Suspended solids can also modify natural movement and migration of fish and can reduce the abundance of fish food available. The most direct effects of suspended solids are the reduction of light penetration into the water column and the heating of the surface waters. Settleable materials associated with suspended solids blanket the bottom of waterbodies and damage the invertebrate populations, ruin gravel spawning beds and, if they are organic, can remove substantial quantities of dissolved oxygen from overlaying water (40). The most important effect of suspended solids in Coyote Creek appears to be the contribution of settleable materials to the silt and clays in the sediments.

AMMONIA NITROGEN

Observed total ammonia nitrogen values in the non-urban reach of Coyote Creek ranged from 50 to 500 μg/l, but because of temperature and pH conditions, the total unionized ammonium concentration is expected to range from 1 to 75 μg/l (2 to 15 percent of the total ammonia). The total ammonia concentrations in the urban reach of the creek ranged from 900 to 950 μg/l and the associated urban area unionized ammonium concentration is expected to range from about 10 to 100 μg/l (1 to 10 percent of the total ammonia).

Rainbow trout have been reported to be the most sensitive fish to unionized ammonium (the most toxic form of ammonia). Concentrations of 200 μg/l ammonium are lethal to rainbow trout, while values less than this can exert adverse physiological or histopathological effects. At concentrations of 3,000 μg/l total ammonia, trout have been reported to become hyperexcitable and, at 8,000 μg/l total ammonia, 50 percent of the trout died within 24 hours. Carp, of the fish studied, are the least sensitive to ammonium. Sublethal exposures to ammonium can cause extensive necrotic changes and tissue degradation in various organs. Concentrations of 2000 μg/l un-ionized ammonium can be lethal to Carp (40).

In summary, the total ammonia concentrations in Coyote Creek are very high, but because of the temperature and pH conditions, the most toxic form (unionized ammonium) is only about 1 to 15 percent of the total ammonia. The relatively high unionized ammonium concentrations can be expected to adversely affect rainbow trout. However, the monitored concentrations are not expected to be directly lethal to any of the potential fish species in Coyote Creek.

NITRATE AND NITRITE NITROGEN

Observed nitrate plus nitrite nitrogen concentrations in the non-urban reaches of Coyote Creek ranged from less than 10 to up to 1,700 μg/l. More than 99 percent of this total was nitrate. In the urban reaches of Coyote Creek, the total nitrate plus nitrite nitrogen ranged from 10 to 1,300 μg/l; again, the nitrate ion was responsible for most of the total.

The 96-hour concentration capable of killing half of the bluegills in a test (96-hr LC-50) was 2,000 μg/l, while a value of 90 μg/l nitrate plus nitrite had no significant effect on growth or feeding habits of largemouth bass and channel catfish (40). However, rainbow trout are much more susceptible to nitrate concentrations. Two hundred gram trout experienced no mortalities after 10 days with nitrate plus nitrite concentrations of 60 μg/l. Smaller two gram rainbow trout did not experience any mortalities after being exposed to 140 μg/l nitrate plus nitrite for 10 days, but 12 gram rainbow trout experienced an 8-day lethal concentration of about 150 μg/l. In another study, four sizes of rainbow trout had LC-50 toxicity values after 96 hours exposure in hard water of 190 to 300 μg/l nitrate plus nitrite. Fingerling rainbow trout experienced a 50 percent mortality after 24 hours exposure (24 hour-LC 50) to 1,600 μg/l nitrate plus nitrite and yearling rainbow trout experienced a 55 percent mortality after 24 hours at concentrations at 550 μg/l. Carp are more tolerant and survived 48 hour exposures to 40 mg/l (40,000 μg/l). Mosquito fish experienced 96 hour LC-50 toxicity values of about 1,500 μg/l (40).

The maximum observed nitrate concentrations in both the urban and non-urban reaches of Coyote Creek could be lethal to rainbow trout under certain conditions. In addition, mosquitofish could be killed after 4-day exposures to the maximum nitrate concentrations observed, in both the urban and non-urban areas. As reported in Section 6 (aquatic life observed in Coyote Creek), mosquitofish were found in abundance throughout the urban stretches of Coyote Creek and are, therefore, not typically adversely affected.

PHOSPHORUS

Observed total phosphate concentrations in Coyote Creek ranged from less than 20 to 590 μg/l in the non-urban area and less than 20 to 540 μg/l in the urban area.

The EPA (40) recommends a maximum value of 100 μg/l total phosphorus for streams to prevent plant nuisance growths (eutrophication). They also note that most uncontaminated lakes have surface water phosphorus concentrations of less than 30 μg/l. Therefore, almost all of the observed Coyote Creek phosphate concentrations are capable of creating nuisance algae growths. This was observed during the field studies in areas of slower creek movement, or backwater areas.

ARSENIC

Observed Coyote Creek arsenic concentrations in the non-urban areas ranged from less than 2 to a maximum of 6 μg/l and in the urban area from less than 2 to 27 μg/l. The sediment arsenic concentrations ranged from less than 1 to 28 μg/g in the non-urban area and as high as 45 μg/g in the urban area.

The EPA (40) reports that benthic organisms can survive sediment arsenic concentrations as high as 2,000 μg/g. Fish food organisms can be adversely affected by arsenic concentrations as low as 1,000 μg/l in the water. Daphnia (a freshwater crustacean) has its mobility impaired with arsenic concentrations of 4,000 μg/l. About 2,300 μg/l sodium arsenate reduces the survival and growth of fish and reduces bottom plant populations. The EPA (40) aquatic life criteria for arsenic is 50 μg/l. None of the observed arsenic concentrations exceeded this criteria.

CADMIUM

Observed cadmium concentrations in Coyote Creek ranged from less than 1 to 5 μg/l in both the urban and non-urban areas.

The EPA (40) reported that fathead minnow developing embryos experience decreased survival at 57 μg/l cadmium, but that no adverse effect on survival, growth or reproduction was observed at 4.5 to 37 μg/l with hard water conditions. Bluegills survived 31 μg/l cadmium, while 50 percent died after 11 months exposure at 80 μg/l in hard water. The hatchability of bluegill eggs was not measurably affected at 80 μg/l, but the survival and growth of the resulting larvae was severely reduced after an exposure of two months at this concentration. Channel catfish, in hard water, were not affected by cadmium concentrations of 12 μg/l while the growth and survival of fry was reduced significantly after a exposure of 17 μg/l. The EPA (40) cadmium water quality criteria for aquatic life is 12 μg/l and was not exceeded in either the urban or non-urban creek regions during this study.

COPPER

Observed copper concentrations in Coyote Creek were less than 10 μg/l in the non-urban area and less than 10 to 20 μg/l in the urban area.

Salmonids are the most sensitive fish to copper while centrarchids are the least sensitive to copper (40). Copper concentrations of 600 μg/l were very toxic to rainbow trout in very hard water conditions and 50 percent of the rainbow trout died after two days exposure to 400 to 500 μg/l copper. Brown bullhead juveniles experienced no detectable effect after a 600 day exposure in hard water with copper concentrations ranging from 16 to 27 μg/l. A 96-hour, LC-50 value of 180 μg/l copper sulfate was noted for brown bullheads. One to two gram bluegills had 24 to 96-hours LC-50 values for 10.2 to 10.7 mg/l copper sulfate in very hard water. One to two gram fathead minnows had LC-50, 24-hour to 96-hour values of 1.5 to 2.2 mg/l using anhydrous copper sulfate, also with very hard water (40).

The EPA (40) copper water quality criteria for aquatic life is 4 µg/l and can be expected to be exceeded in the urban area of Coyote Creek, even though no direct fish mortalities for the above-mentioned fish species are expected.

CHROMIUM

Observed Coyote Creek chromium concentrations ranged from 5 µg/l in the non-urban area to 10 to 20 µg/l in the urban area. Urban runoff affecting Coyote Creek had total chromium concentrations of 9 to 40 µg/l. These chromium values are total chromium and include both the trivalent and hexavalent chromium forms.

Fish are relatively tolerant of chromium, but invertebrates are quite sensitive (40). Fathead minnows have LC-50, 96-hour values of 27 µg/l for both trivalent and hexavalent forms of chromium, while 1 µg/l trivalent chromium has been reported to be safe. Bluegills have hexavalent chromium LC-50, 96-hour value of 133 µg/l (40).

The EPA (40) water quality criteria for chromium and aquatic life is 100 µg/l, substantially greater than any reported chromium concentrations in Coyote Creek.

IRON

The observed total iron concentrations in the urban reach of Coyote Creek ranged from 1,000 to 10,000 µg/l and in the non-urban reach 2,000 to 20,000 µg/l. Almost all of this iron was of the trivalent iron form (insoluble ferrous) or the bivalent iron form (soluble ferrous) because of the pH conditions. The water quality criteria and observed effects of iron on aquatic life are all based on soluble ferrous iron and are much lower than these observed values.

Various insects (mayflies, stoneflies and caddisflies) have 96-hour, LC-50 values of 320 µg/l ferrous iron. One to 2 µg/l ferrous iron have been reported lethal to trout. Generally, ferrous iron concentrations lower than 10 µg/l are necessary to support a good fish population.

The EPA (40) water quality criteria for ferrous iron is 1 mg/l. Because the reported iron concentrations in Coyote Creek are so very high and only a small fraction of this total iron is in the soluble ferrous form, the actual effects of iron in Coyote Creek on these aquatic organisms is uncertain. There is a good potential, however, that iron can adversely affect Coyote Creek organisms, especially if the pH values decrease. Because of the high observed total iron concentrations and the small difference in iron concentrations between the urban and non-urban areas, urban runoff is not likely to create any additional iron problems in Coyote Creek.

MERCURY

Estimated mercury concentrations in Coyote Creek are 3 to 4 µg/l in the urban area and 2 to 5 µg/l in the non-urban area. Runoff with mercury concentrations of less than 0.1 to 0.2 µg/l discharges into Coyote Creek.

Under hard water conditions, rainbow trout LC-50 values of 8.5 μg/l phenylmercuric acetate have been reported. LC-50 values of 30 and 310 μg/l have also been reported for methylmercuric chloride and mercuric chloride, respectively. Newly hatched rainbow trout fry experience LC-50, 96-hour values of 24 μg/l methylmercuric chloride. Rainbow trout fingerling have 96-hour, LC-50 values of about 40 μg/l elemental mercury. Reported LC-50 values for fathead minnows are substantially less than those for trout, being about 0.8 μg/l methylmercuric chloride (40).

The EPA's water quality criteria for mercury is 0.05 μg/l for aquatic life. It is seen that the elemental form of mercury is very important in determining the toxicity of mercury to fish. However, almost all mercury discharged to a receiving water has the potential of becoming methylated by benthic organisms. Mercury in both the urban and non-urban reaches of Coyote Creek has a potential of adversely affecting the resident fish population. Because of the relatively low mercury concentrations observed in the urban runoff affecting Coyote Creek, it is questionable if that source significantly increases the mercury problem in Coyote Creek. Cinnabar, the principal form of mercury ore, has been mined in areas south of San Jose, but not within the Coyote Creek watershed.

LEAD

Lead concentrations in the non-urban reach of Coyote Creek range from 1 to 2 μg/l, while 3 to 100 μg/l were observed in the urban reach of Coyote Creek. Runoff affecting Coyote Creek has lead concentrations of 20 to 75 μg/l. Hardness substantially affects the toxicity of lead in aquatic systems and the following summarized criteria is only applicable for very hard water conditions, similar to Coyote Creek hardness values.

Fathead minnow 24 to 96-hour, LC-50 values of 480 mg/l have been reported, using lead chloride and from 1 to 2 gram, 38 to 64 millimeter, fathead minnow specimens. A 96-hour, LC-50 value for rainbow trout in very hard water was also about 470 mg/l. However, 120 to 360 μg/l lead nitrate was the highest concentration not having adverse effects on survival, growth and reproduction of rainbow trout. Concentrations of free lead of 1,400 μg/l and total lead of 470 mg/l are LC-50, 96-hour values for rainbow trout. Organic methylated forms of lead can have much more toxic effects on fish. The LC-50, 24-hour and 48-hour value for bluegills in hard water ranged from 1,400 to 2,000 μg/l organic lead for 1 and 2 gram fish. Similar exposure times of lead chloride produced much greater LC-50 values of about 450 to 500 mg/l (40).

Based on the effects on lead on various elements of the aquatic life food chain, the EPA (40) has established an aquatic life recommended criteria for the Coyote Creek fish species of 30 μg/l. Therefore, only the urban lead concentrations are likely to exceed this criteria. The highest lead concentrations observed in Coyote Creek, however, are not expected to create direct toxic effects on fish, unless methylated lead forms are present (which may occur).

ZINC

Observed zinc concentrations in the non-urban reach of Coyote Creek were about 19 μg/l and ranged from 10 to 75 μg/l in the urban reach of the creek. Runoff affecting Coyote Creek had zinc concentrations of 100 to 320 μg/l. Rainbow trout have been reported to be the most sensitive fish to zinc in hard waters, with lethal concentrations for coarse fish being 3 to 4 times the rainbow trout values. Immature insects seem to be less sensitive than many of the test fish. 96-hour, LC-50 values for fathead minnows in hard water was reported to be 33,000 μg/l. However, at the much reduced zinc concentration of 180 μg/l, an 83 percent reduction in egg production was found, as compared to a zinc concentration of 30 μg/l. One to two gram fathead minnows had 96-hour, LC-50 values of 8,200 to 21,000 μg/l anhydrous zinc sulfate. Fathead minnow eggs experienced LC-50, 24- to 96-hour values of 1,800 to 4,000 μg/l, also with anhydrous zinc sulfate. Fathead minnow fry LC-50, 24- to 96-hour values were less, at 870 to 950 μg/l anhydrous zinc sulfate. Two to three gram fathead minnows LC-50, 96-hour values were greater, at about 9,000 to 13,000 μg/l, anhydrous zinc sulfate. Juvenile rainbow trout LC-50, 96-hour values in hard water were about 7,200 μg/l zinc sulfate and were reduced to 3,200 μg/l for 48- exposures to elemental zinc. One to two gram bluegills experienced LC-50, 24- to 96-hour values of about 41,000 μg/l anhydrous zinc sulfate (40).

The EPA (40) has established aquatic life zinc water quality criteria for the fish species present in Coyote Creek at 10 μg/l. Therefore, the urban reach in Coyote Creek substantially exceeds this water quality critera, while the non-urban reach may slightly exceed this criteria.

ORGANIC PRIORITY POLLUTANTS

PCP and its sodium salt are highly toxic to aquatic life (41). Phthalate esters (PAEs) are also reported to be acutely and chronically toxic to freshwater aquatic organisms at low concentrations (41). DEHP impairs reproduction in the cladoceran Daphnia by 60 percent at a concentration as low as 3 μg/l. 2,4-DMP is also acutely toxic to freshwater plants, invertebrates and vertebrates. 2, 4-DMP toxic concentrations range from about 200 to 2,500 mg/l.

The EPA (41) has established aquatic life water quality criteria for some priority pollutants. The criteria for PCP is 6.2 μg/l, while values of about 1 μg/l were observed in Coyote Creek and runoff. No criteria for DEHP has been established, but concentrations of 3 μg/l can impair reproduction of sensitive aquatic insects. DEHP concentrations of about 8 μg/l were observed in the creek, and about 30 μg/l were observed in runoff effecting Coyote Creek. The aquatic life criteria for 2, 4-DMP is 38 μg/l, while Coyote Creek concentrations of this substance were reported to be 0.7 μg/l with slightly lower values observed in the runoff. Therefore, none of the observed concentrations of these organic priority pollutants exceeded the established water quality criteria, but observed concentrations of DEHP may adversely affect sensitive aquatic organisms.

SUMMARY

No one pollutant appears to be responsible for the significant decrease in aquatic life abundance and diversity observed in Coyote Creek as it passes through San Jose. This appendix only reviewed the water quality conditions observed (during wet weather) during long-term stable situations. Short-term peak concentrations, as presented in Table 6-1 are seen to be substantially greater for many of the toxic pollutants. However, information on the effects and established criteria for short-term exposures, in the order of just a few hours, is not available. In addition, very significant concentrations of these toxic pollutants in the sediments were observed and cannot be conveniently related to water quality criteria or published test results on water quality effects. The reported water quality effects on aquatic organisms present in Coyote Creek do not consider antagonisms or synergisms that are likely to occur, except for the antagonistic effect of hardness on heavy metal toxicity. A combination of effects of various heavy metals can, in many cases, be greater than the effects of each one individually. Some of the constituents observed that are likely to create water quality problems occur in potential problem concentrations in both the non-urban and urban reaches of Coyote Creek (temperature, ammonia, nitrates, phosphorus and mercury). The most important constituents in the urban area that exceeded criteria, which are not exceeded in the non-urban area, include dissolved oxygen, copper and lead. Zinc concentrations exceed the water quality criteria in both the urban and non-urban areas, but the urban zinc concentrations exceed the criteria by a much greater amount.

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16. ABSTRACT

This report presents the final results and conclusions from an EPA-sponsored demonstration study of the water quality and biological effects of urban runoff on Coyote Creek, near San Jose, California. Various field procedures were used during the project to evaluate water, sediment, and biological changes in the creek as it passed through the urban area. The report describes the characteristics and sources of urban pollutants which affect the creek, and the effects and potential controls for urban runoff.

The study sampled and analyzed runoff and dry particulate materials from many sources (e.g., street surfaces, parking lots, landscaped areas, vacant land, rooftops, rain). A major element of the project involved the use of various short- and long-term biological sampling techniques to evaluate the fish, benthic macroinvertebrates, and attached algae at many stations in the creek, above and within the urban area. It was concluded that the urbanized portion of the creek has been significantly degraded and that urban runoff is an important causative factor.

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