Chapter 4

AN ANALYSIS OF STRAWBERRY CREEK'S WATER QUALITY

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Introduction

"If there is magic on this planet, it is in water" (Miller, 1982, p. 357). Indeed, the quality of life that we enjoy depends to a great extent upon the quality of our water. Strawberry Creek, flowing through the beautiful U.C. Berkeley campus, seems to relax the hurried atmosphere of the academic institution. The creek originates in the Berkeley Hills and flows westward until it eventually reaches San Francisco Bay. Historically, Strawberry Creek was once "choked with fish" and provided an important resource for Berkeley (Stine, 1984, pers. comm.). Today, however, the diversity and abundance of all organisms are greatly decreased. One reason for the decline in numbers of species and populations is that the creek serves as a catchment for urban runoff, which carries pollutants along with it.

This project focuses on the water quality of Strawberry Creek on the U.C. Berkeley campus and at its outflow into San Francisco Bay via the University Avenue storm drain (Figure 1). The research investigated the differences in the levels of total coliform counts, dissolved oxygen, and pH at three study sites on campus and at one site near the storm drain. Water samples were collected during and after rainy periods to determine if water quality is affected by the increased runoff. The results of this project were compared with those of past studies to see if changes in water quality are occurring.

Background

Coliforms are a group of microorganisms that serve as indicators of microbial diseases transmitted via water. The more commonly known diseases include typhoid fever, cholera, salmonellosis, and infectious hepatitis (Brock and Smith, 1984). None of the microorganisms causing these diseases are easily isolated from water nor readily enumerated. Because of the difficulty in determining the presence of these microorganisms directly, indicator microorganisms are used. Their presence can be easily determined, their density can be estimated, and their occurrence is indicative of human or animal wastes (APHA, 1976).

The coliform group are suitable indicators because they are common inhabitants of the intestinal tract of both humans and other warm-blooded animals and are generally present in large numbers. It is therefore likely that if coliforms are found in water, the water has received fecal contamination and may be unsafe for potable or recreational use. The Regional Water Quality Control Board (RWQCB) standard for water contact sports (REC-1 water uses) is 240 organisms per 100 ml for total coliforms (RWQCB, 1982).

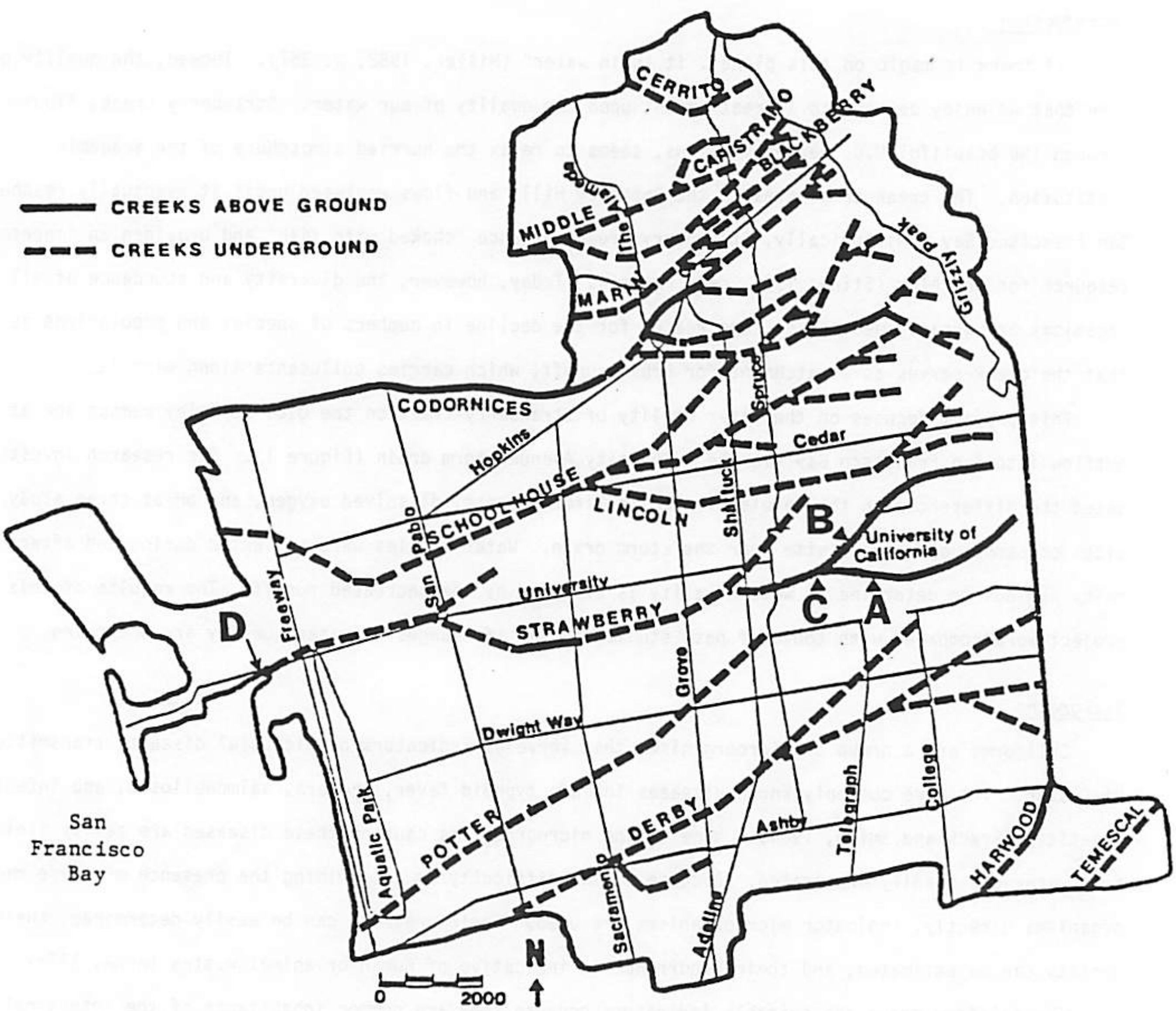

Figure 1. Map of the creeks of Berkeley showing the study sites located on the University of California campus and at the University Avenue storm drain.

Base Map: Master Plan Revision Committee, Berkeley Planning Dept., 1975

The three major causes of bacterial contamination of Strawberry Creek are: (1) the deposition of animal fecal material in areas subject to runoff, (2) cross connections with sanitary sewers, and (3) malfunctioning septic tanks (ABAG, 1978).

Dissolved oxygen (DO) is another important water quality factor to assess. DO, a fundamental requirement for plant and animal populations in a body of water, is dependent upon the physical, chemical, and biochemical activities prevailing in that water (Rand and Petrocelli, 1985). The primary cause of water deoxygenation is the presence of oxygen-demanding wastes, such as domestic sewage, animal wastes, and decaying plant matter. These wastes do not use DO directly, but the bacteria and other microorganisms that decompose them do (Miller, 1982). Consequently, if water systems are overloaded with wastes, the resulting population explosion of decomposers will consume much of the DO supply, with the result that fish and other aquatic life cannot survive. The DO standard set by the RWQCB for waters inland from the Golden Gate Bridge is 5 ppm (RWQCB, 1982).

The pH of natural water is an important index of acidity or alkalinity and is the result of the acidic/basic interaction of a number of mineral and organic components of water. In pure of slightly polluted water, the values of pH are determined mainly by the correlation between the concentrations of free carbon dioxide, bicarbonate, and carbonate ions (IHD-WHO, 1978). This correlation, in turn, depends on the intensity of photosynthesis and the biochemical oxidation of organic substances, as well as on the chemical conversions of some mineral substances. The RWQCB standard for pH is that it should not be less than 6.5 nor greater than 8.5 (RWQCB, 1982). The reason for this objective is that most aquatic organisms live in an aquatic environment within this range (Rand and Petrocelli, 1985). The pH of a solution is expressed as the logarithm of the reciprocal of the hydrogen ion activity in moles per liter. The pH scale extends from 0, very acidic, to 14, very alkaline, with 7 corresponding to exact neutrality at $25^{o}C$ (APHA, 1976).

Past Studies

Many of the past water quality tests performed on Strawberry Creek focused on the microbiological aspect, namely, coliform levels. Presently, few data are available on dissolved oxygen and pH values at these locations.

Coliform tests at the University Avenue storm drain were conducted by the East Bay Municipal Utility District (EBMUD) (Sharpe, 1977) and Reed (1985). Coliform studies on the U.C. Berkeley campus were done by the U.C. Berkeley Office of Environmental Health and Safety (Herrera, 1977), the City of Berkeley (Gerber, 1978), and Lee (1982).

The only DO and pH data available for Strawberry Creek are those of Frazier (1983).

Methodology

Three study sites are located on the U.C. Berkeley campus and one at the University Avenue storm drain (Figure 1). The map of the campus shows study sites A, B, and C in greater detail (Figure 2).

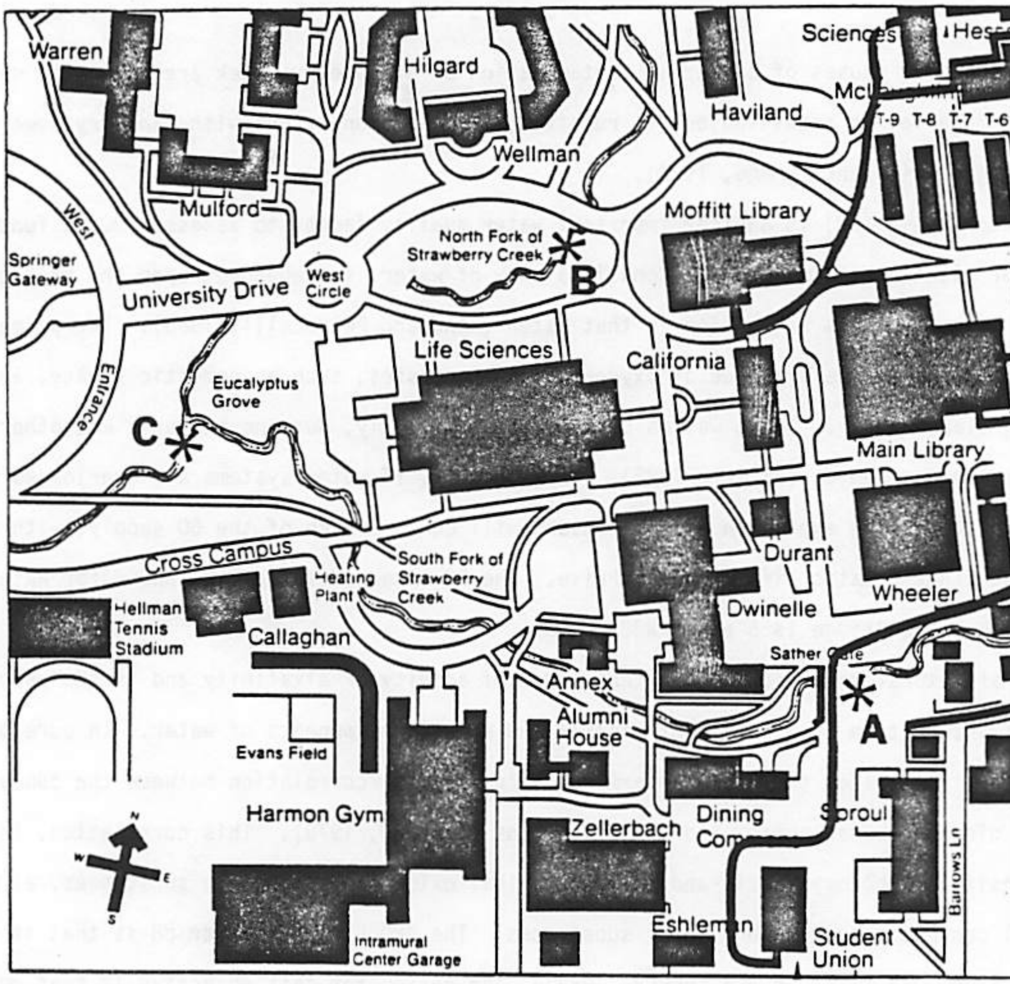

Figure 2. Map of the U.C. Berkeley campus showing study sites A, B, and C.

Base Map: Publications Office, U.C. Berkeley, 1986.

Site A is located in front of the amphitheater, 10 m east of the Sather Gate bridge on the south fork of Strawberry Creek. Site B is 15 m downstream from the bridge located between Giannini Hall and the Life Sciences Building on the north fork. Site C is on the southwest corner of the Eucalyptus Grove, 5 m below the merger of the north and south forks of the creek. Site D is 10 m southeast of the University Avenue storm drain in the sheltered inlet.

Water samples were collected in 70 ml sterile plastic bottles which were rinsed with the sample two times before the water was collected. The samples from sites A, B, and C were taken in the middle of the creek in flowing water. The samples from site D were taken 0.5 m away from the water's edge in moving water. The samples were collected by immersing the bottles 3 cm below the water's surface and allowing them to fill. The water was brought back to a U.C. Berkeley Department of Public Health laboratory for coliform analysis. The tests were begun within 2 hours of collection.

DO and pH tests were performed at the study areas. A Leeds and Northrup Portable Dissolved Oxygen Meter Model Number 7932 was used to determine the DO of the water. A Leeds and Northrup Portable pH Meter was used to determine pH. The probe of each meter was placed directly into the creek for a direct and accurate reading. At each site, three readings were taken and the average recorded.

Water quality tests were conducted on October 23, November 1, and November 22, 1985 during a dry period and on February 20, 1986 after a rainstorm. A DO test was not conducted on February 20 due to equipment malfunctions. The February 20 tests were not made during the first storm of the year. During 1986 the total amount of precipitation prior to the wet weather sample was 16.28 inches (U.S. Weather Bureau, U.C. Berkeley Station).

At site D the water is subject to tidal influence. Tests conducted during the late afternoon of October 23 and November 22 occurred during a low tide. Tests were performed during high tide on the late afternoon of November 1 and the late morning of February 20.

The Most Probable Number (MPN) method was used to examine the water for coliform counts. There are three parts to this technique: the presumptive test, the confirmed test, and the completed test. Usually, only the first two tests are carried out, the procedure followed in this project. For the presumptive test, ten-fold dilutions of the water sample were planted in lauryl tryptose fermentation tubes and incubated for 24 $\pm$ 2 hours at $35^{\circ}C \pm 0.5^{\circ}C$. If no gas was produced or if gas production was doubtful, the tubes were incubated another 24 hours. For the confirmed test, a small portion of the media from the positive presumptive tubes was inoculated in brilliant green bile broth and incubated for 48 $\pm$ 3 hours at $35^{\circ}C \pm 0.5^{\circ}C$. If gas appeared, the coliform group was confirmed. The MPN of coliforms is calculated by referring the combination of positive tubes and the dilutions used to tables in Standard Methods for Examination of Water and Wastewater (APHA, 1976).

Results

Not all of the water quality parameters tested in Strawberry Creek met RWQCB standards. Coliform levels were exceedingly high and violated the standard; however, DO and pH were within standards at the time of testing.

The data collected from the coliform tests (Table 1) show that the coliform levels were all above the RWQCB standard of 240 MPN/100 ml. Sites A, B, and C had similar coliform levels throughout the study. Most MPN values were either of the same magnitude or differed by 10 times. The coliform densities at the campus sites ranged from $.09 \times 10^4$ to 110×10^4 MPN/100 ml. The Sather Gate bridge site (site A) had the least contamination with a mean density of 1.5×10^4 MPN/100 ml. The storm drain site (site D) had the greatest mean density, 1600×10^4 MPN/100 ml.

The dissolved oxygen data (Table 2) indicate that all of the sites met the RWQCB standard of 5 ppm. Sites A, B, and C had relatively high DO levels, ranging from 8.5 to 10.0 ppm. The highest DO concentrations were at site A on each testing date. Site A had a mean DO level of 9.5 ppm. Both sites B and C had a mean DO level of 9.2 ppm. The lowest DO concentrations were at site D with a mean DO level of 7.4 ppm.

	Total Coliforms (MPN x 10^4/100 ml)				
	October 23 (0.28 ins)	November 1 (0.00 ins)	November 22 (0.02 ins)	February 20 (2.00 ins)	mean
Site A	3.9	1.4	0.09	0.75	1.5
Site B	2.3	11	2.1	12	27
Site C	4.3	3.9	4.6	110	30
Site D	1500	4600	15	200	1600

Table 1. Total coliform levels at the study sites. The amount of precipitation 48 hours prior to the testing date is in parenthesis. 10^4 = 10,000.

	Dissolved Oxygen (ppm)			
	October 23 (0.28 ins)	November 1 (0.00 ins)	November 22 (0.02 ins)	mean
Site A	9.5	9.0	10.0	9.5
Site B	9.2	8.7	9.7	9.2
Site C	9.4	8.5	9.6	9.2
Site D	7.5	8.0	6.7	7.4

Table 2. Dissolved oxygen levels at the study sites. The amount of precipitation 48 hours prior to the testing date is in parenthesis.

The pH values ranged from 7.2 to 8.2 (Table 3) and were within the RWQCB standard range of 6.5 to 8.5. The pH at site D was consistently lower than that at the othe three sites, except on November 22 when the pH at site D was the highest of the four sites.

pH

	October 23 (0.28 ins)	November 1 (0.00 ins)	November 22 (0.02 ins)	February 20 (2.00 ins)
Site A	8.2	8.0	7.2	7.9
Site B	8.2	8.0	7.3	8.0
Site C	8.0	7.9	7.2	8.0
Site D	7.6	7.8	7.5	7.5

Table 3. pH levels at the study sites. The amount of precipitation 48 hours prior to the testing date is in parenthesis.

Discussion

Generally somewhat lower water quality was found in the present study than in past studies performed on Strawberry Creek. Compared with previous studies, this study showed an increase in the density of coliforms, a lower dissolved oxygen level, and a relatively constant pH.

At most sites the rainfall did not have much of an effect on the densities of coliforms. The wet weather samples taken in this study varied only by 10-fold from the dry weather samples. I expected higher coliform densities because of the increased runoff which probably carried more pollutants. The most likely reason why there wasn't a marked effect was because the water quality was not assessed after the first big rainstorm, which could have flushed the bulk of the pollutants into the Bay. This hypothesis probably applies to other past studies which have found lower coliform densities after rainstorms (Herrera, 1977).

Site C had a 100-fold increase in coliforms after the rainfall; the likely cause was that untreated water was overflowing from a manhole cover located upstream from the site in the Eucalyptus Grove on the day of testing.

The high coliform levels (Table 1) indicate that the creek is bacteriologically contaminated and unfit for human contact. The data show that north and south forks of Strawberry Creek are about equally contaminated. The reason why the campus sites had similar MPNs throughout the study may be due to their close proximity to each other. The low density of coliforms at site A on November 22 was unexpected because the other campus sites had 100 times greater MPNs on the same day. Perhaps there was an increased flow of clean water into site A which diluted the number of coliforms that day. Discharge at the University Avenue storm drain (site D) was exceedingly contaminated. On October 23 and November 1 it had 100,000 times more coliforms per 100 ml than the RWQCB standard. Coliform densities at site D are expected to be higher than at the campus sites because water collects pollutants, such as fecal matter, on the way downstream and with increased runoff. Side D is also a location where untreated wastes from the local streets drain into the Bay.

Past studies also demonstrated extreme contamination at the storm drain but with relatively lower coliform densities than found in the present study (Table 4). On the basis of EBMUD's 1976 data, it is impossible to be certain that densities are increasing over time because the data are not sufficiently detailed. EBMUD found that coliforms generally exceeded 24 x 10^4 MPN/100 ml but did not specify what

Total Coliforms (MPN x 10^4/100 ml)

Month	1976[a]	1977[a]	1985[b]
January	11	4.3	-
February	2.4	9.3	46
March	24 +	-	2.4
April	2.4	-	-
May	24 +	-	-
June	24 +	-	-
July	11	-	-
August	24 +	-	-
September	24 +	-	-
October	2.4	-	-
November	11	-	-

Table 4. Results of coliform tests performed at the University Avenue storm drain in past studies.
Source: a) Sharpe, 1977; b) Reed, 1986.

the actual densities were. Other data, however, indicate that coliform densities are indeed increasing over time. EBMUD's 1977 study found MPNs 1,000 times less than the densities obtained in the present study (Sharpe, 1977). In 1985, Reed found a coliform density 100 times less than the densities shown in the present study (Reed, 1985). Perhaps the increase in bacterial contamination is due to an increase in the number of pets roaming the streets or perhaps the sewer lines are deteriorating quickly, leaving untreated sewage to flow freely into the storm drain. EBMUD has identified the gradual deterioration of sewer systems, accompanied by a chronic under-investment in sewer system maintenance and improvements, as one of the East Bay's greatest water quality problems (EBMUD, 1983).

Past coliform studies performed on the U.C. Berkeley campus do not give a clear picture of general trends in bacterial contamination. The coliform levels found in the present study are either comparable to those of past studies or show an increase in the density of coliforms (Table 5). The MPNs found in the present study are of the same magnitude as the MPNs of Gerber (1977). However, both Herrera (1977) and Lee's (1982) data show coliform densities that are less than the levels found in the present study, suggesting that bacterial contamination is worsening over time.

Total Coliforms (MPN x 10^4/100 ml)

Location	7/1/76	12/14/76	8/24/77	8/25/77	9/12/77	4/19/82
Strawberry Creek near Oxford St.[a]	1.3	2.3	-	2.4	-	-
South fork of Strawberry Creek[b]	-	-	0.054	-	0.092	-
Bridge across from Giannini Hall[c]	-	-	-	-	-	0.35

Table 5. Results of coliform tests performed on the U.C. Berkeley campus in past studies.

Source: a) Gerber, 1977; b) Herrera, 1977; c) Lee, 1982.

The mean dissolved oxygen values in the present study are lower than those of Frazier (1983). Frazier found DO levels near or at saturation level: DO readings ranged from 9.8 ppm to 11.4 ppm on campus, whereas levels at the storm drain ranged from 8.8 ppm to 10.5 ppm. Frazier (1983) attributes the lower DO values at the storm drain to the lower DO level of the Bay. One reason why DO concentrations may be lower in the present study than in Frazier's is that there may be more oxygen-demanding substances in Strawberry Creek today than in 1983. Site D probably has the most oxygen-demanding wastes flowing into it from the high amount of urban runoff that it receives.

The pH has remained relatively stable over time and did not change significantly after the wet weather on February 20. The pH levels found in the present study and in Frazier's study (1983) both indicate that the water is nearly neutral to slightly alkaline. Frazier's pH levels ranged from 7.6 to 8.4 in Strawberry Creek, slightly lower than levels in the present study.

Conclusion

According to the results obtained in this report, the greatest danger in Strawberry Creek's water quality is the high coliform levels. The exceedingly high levels, especially at the University Avenue storm drain, pose a potential health hazard. Since most of the water that flows through the creek eventually reaches San Francisco Bay, any pollution present in Strawberry Creek also affects the water quality of the Bay.

Recent proposals for a shoreline park at the Berkeley waterfront include an option to open Strawberry Creek up and to channel it across the Brickyard area (Siefken, 1986, pers. comm.). Strawberry Creek would greatly enhance the atmosphere of the park, allowing visitors the opportunity to enjoy the beauty and sound of the flowing water. The creek and the riparian vegetation along it would probably attract birds and other animals to the site which otherwise would not be present.

A management plan to decrease the high levels of coliforms should be implemented as soon as possible to decrease the health hazard involved. The Association of Bay Area Governments (ABAG) has recommended 17 major types of surface runoff control measures including: treatment and storage of runoff, improvement of street sweeping, and management of sewer lines and septic tanks (ABAG, 1975). All eight Bay Area counties in the ABAG study reported a bacterial contamination problem. Thus, the problem is widespread and should be dealt with in the near future.

The San Francisco Bay ecosystem is a unique place--there are biological, physical, and social aspects to this ecosystem that do not occur anywhere else. Water quality must be managed effectively so that future generations can enjoy the Bay.

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