Chapter 5

WATER QUALITY IN STRAWBERRY CREEK

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Introduction

Strawberry Creek flows from the Berkeley Hills west, through the University of California campus, to San Francisco Bay (see map, p. viii). The creek flows above ground through stretches of riparian vegetation in the hills and is culverted for a short distance before flowing on the surface most of the way through the university. As Strawberry Creek reaches the western edge of campus, it is culverted underground, flowing on the surface once more for a short distance between Sacramento and San Pablo Avenues, before emptying into the bay. Where culverted, the creek passes under a portion of downtown Berkeley, under a large residential area and, finally, under a small industrial section.

Ths purpose of this paper is to assess water quality problems at different locations along Strawberry Creek. Historically, the water in the creek has been used as an important resource in Berkeley. Present-day uses of the creek include receiving urban runoff and providing a natural setting for recreation. However, this resource might be threatened by possible health hazards and other water quality problems that might be present in the creek.

Water Quality Parameters

There are many parameters with which to assess water quality. The six parameters mentioned in this report present a good representation of the quality of water in Strawberry Creek, yet by no means cover the entire question of water quality. The decision of what tests to run was enhanced by consultation with Professor Jerome Thomas of the Sanitary Engineering Department at the University of California at Berkeley.

The Water Quality Control Plan for the San Francisco Bay Basin (RWQCB, 1975) has set objectives for the water quality in the bay. These objectives can be compared to results of tests on Strawberry Creek in order to determine if the water in the creek is within the recommendations of the Regional Water Quality Control Board (RWQCB).

One objective the Board has set is that pH levels should not be less than 6.5 nor greater than 8.5. This objective is important because most species live in an aquatic environment that has a pH reading between 6.5 and 8.5 (Bates, 1979).

The dissolved oxygen (DO) objective is set at a minimum of 5.0 mg/l (RWQCB, 1975). Dissolved oxygen is a fundamental requirement of life for plant and animal populations in any given body of water (Stoker and Seager, 1976). Therefore, DO is probably the most important test in determining the water quality. The primary cause of water deoxygenation is the presence of oxygen-demanding wastes, the two main being: (1) sewage (domestic and animal), and (2) industrial wastes (Stoker and Seager, 1976).

Another objective the RWQCB recommends is that all waters should have levels of turbidity that will not cause a nuisance or adversely affect beneficial uses. Turbidity measures the amount of clay and silt content in a body of water (Thomas, pers. comm., 1983). Thus, the amount of sedimentation and photosynthesis is affected by turbidity levels.

The RWQCB also has set objectives for toxic substances. The concentration of toxic substances is to be maintained at levels that cause no detrimental physiological responses in human, plant, animal, or aquatic life (RWQCB, 1975). The 1982 amendments for the water quality control plan include limitations on toxic material in effluent. The daily maximum for lead, mercury, and cadmium are 0.2, 0.002, and 0.03 mg/l respectively (RWQCB, 1982). Not only are these metals toxic at certain levels, they also tend to be biologically magnified as they travel up the food chain (Spiro and Stigliani, 1980).

The water quality objectives for fecal coliform bacteria are set at a level of not greater than 200 Most Probable Number (MPN) per 100 ml for nontidal recreation water (RWQCB, 1975). Coliforms can indicate whether or not water is contaminated by sewage. Contamination is determined by the total number of bacteria present and the presence or absence of common organisms of intestinal or fecal origin, such as viruses and parasites (Lee, 1982). Consequently, high levels of coliforms may present a health hazard because their presence would indicate that related diseases may also be present.

High nitrogen levels can lead to algae growth in the slower moving areas of the creek. Moreover, high nitrogen levels which flow into areas like Aquatic Park (as Strawberry Creek does during heavy runoff periods) may cause increased overfertilization that can produce an overgrowth of aquatic weeds and depletion of dissolved oxygen, with resulting loss of fish life when the algal overgrowth or blooms die off and decompose (Ehrlich et al., 1970).

Conductivity measures the mineral content in the water. Excellent quality "raw" water (i.e., natural water) has a conductivity rating of approximately 50 micro-mhos/cm, whereas seawater has a rating of approximately 50,000 micro-mhos/cm.

One should not assume that the water quality is good or poor just by reviewing the result of several tests. These tests give an idea of what the water quality is at the time of the testing. However, because of the ever-changing influences on the condition of the water (e.g., amount of runoff and pollution entering), the quality of the water may change in a very short period of time. Therefore, in order to make valid estimates on what the water quality actually is, a series of tests should be run and should be well monitored and recorded. Hence, this report is just one step in many that are needed to get a consistent record of water quality in Strawberry Creek.

Past Studies of Water Quality

Several studies have been made of the water quality in Strawberry Creek. These past studies focused on biological parameters, namely coliforms. The testing for coliforms was done in order to determine if the water in Strawberry Creek posed a health hazard for its surrounding environment. These studies indicate that the creek, at times, has exceeded what is considered the safe level of coliforms.

The results of tests conducted by the UC Berkeley Office of Environmental Health and Safety in 1970, 1971, and 1972 show that, at various times, coliform and fecal streptococci counts were well above 200 MPN and commonly exceeded 1,000 MPN (Herrera, 1970, 1971, 1973). Studies done in 1976, 1977, and 1978 by Gerber (1978) also show extremely high levels of coliforms (Table 1). The results of these tests indicate fecal coliform levels well above the RWQCB's objective of 200 MPN for nontidal recreational water. Moreover, total coliforms were well above 60,000 MPN during two of the test dates.

MPN

Location	7/1/76 Total Colif.	7/1/76 Fecal Colif.	12/14/76 Total Colif.	12/14/76 Fecal Colif.	8/25/77 Total Colif.	8/25/77 Fecal Colif.	4/18/78 Total Colif.	4/18/78 Fecal Colif.
Strawberry Creek near Strawberry Creek Lodge	70,000	6,200	23,000	500	24,000	7,000	23,000	6,200
Strawberry Creek near Oxford St.	13,000	2,300	23,000	6,200	24,000	7,000	62,000	2,300

Table 1. Strawberry Creek Water Quality Survey, 1976-1978.

Source: Gerber, 1978.

Total coliform tests done on three dates in 1977 are summarized in Tables 1 and 2. These results indicate a considerably lower level of total coliforms than the Gerber results of the same general time period. In fact, when one examines the data closely, one can see a tremendous difference in the levels of coliforms in the same general area of the creek (within 250 yards) over a 24 hour period. On August 25, 1977, Gerber got results for total coliforms equaling 24,000 MPN, whereas the Environmental Health and Safety's testing on the previous day resulted in a total coliform level of 130 MPN. This is an example of how the water quality of the creek can change over a relatively short time period.

TOTAL COLIFORMS
MPN

Location	8/24/77 warm and sunny	9/12/77 warm and sunny	9/19/77 two days after rainfall
South Fork of Strawberry Creek	540	920	540
Near bridge in front of Giannini Hall	130	920	350

Table 2. 1977 Study of Strawberry Creek Water Quality.

Source: University of California, Berkeley, Office of Environmental Health and Safety.

Tests conducted in 1982 by Lee also show a high level of coliforms (Table 3). The results include fecal coliform/fecal streptococci ratio that indicates the origin of fecal matter. A ratio approxi-ating one indicates bacteria from animal, rather than human, wastes. Although this is not considered sewage," it still poses a health threat in that animal feces contain viruses and parasites as does

MPN

Location	Total Coliform	Fecal Coliform(FC)	Fecal Streptococci(FS)	FC/FS
Strawberry Creek storm drain outlet I	16,000	1,300	5,400	1
Strawberry Creek storm drain outlet II	9,200	1,100	3,500	1
Open Creek near Alston Way and West Street	3,500	1,100	3,500	1
University of California Berkeley, near bridge by Giannini Hall	3,500	1,300	5,400	1

Table 3. 1982 Study of Strawberry Creek Water Quality.

Source: Lee, 1982.

sewage.

Methodology

The purpose of this study was to determine changes in water quality along Strawberry Creek as it flows to San Francisco Bay. Four locations were sampled (Figure 1). Site I is located on the University of California campus above the Strawberry Pool Complex, approximately forty-five feet east of the beginning of a culvert (which diverts the water underground past the football stadium, until it reaches the main campus where it again flows above ground). Site II is located on the west end of the campus, approximately thirty-five feet east of the beginning of a second culvert that diverts the flow until it reaches the proximity of site III. The Strawberry Apartments, located near Allston Way and West Street, tower above the open creek where site III is located. Site IV is located at the Strawberry Creek storm drain outlet, just west of I-80 on the south side of University Avenue.

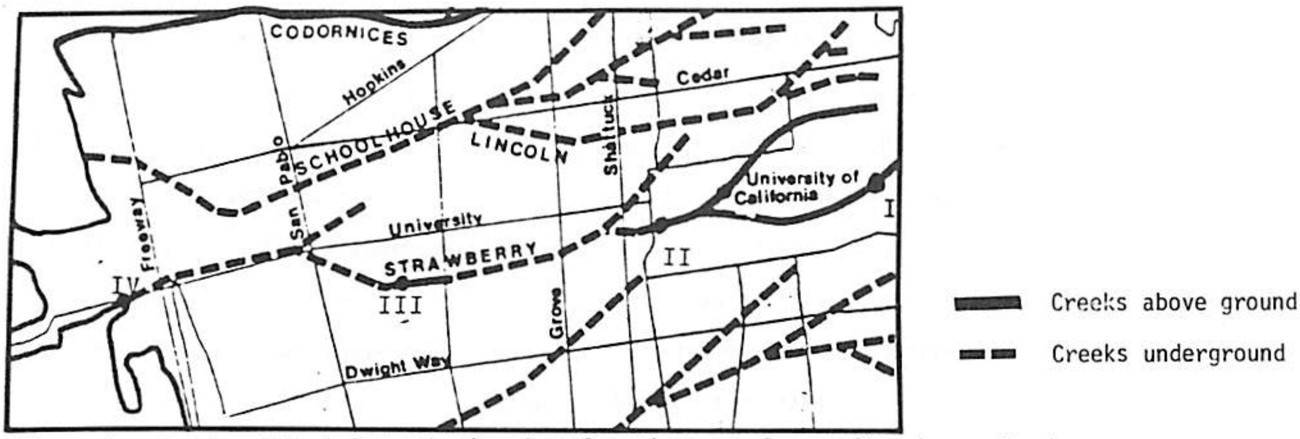

Figure 1. Creeks of Berkeley, showing four locations samples on Strawberry Creek.
Source: Master Plan Revision Committee, Berkeley Planning Dept., 1975

To give an idea of the changes that occur in the water quality of Strawberry Creek during periods of relatively high precipitation and periods of little or no precipitation, three sampling dates were used--two in "wet" periods and one in a "dry" period. The amount of rainfall up to the test dates and the amount 48 hours before the testing period is given in Table 4.

A pH meter and a Leed's and Northrup (model 179-32) Dissolved Oxygen Meter were used to make direct readings of pH and dissolved oxygen levels (APHA, 1978). At each site, three readings were taken for each test and the average recorded. Water samples were collected in one gallon plastic bottles and sealed with parafilm. A Bridge Conductivity Meter (YSI, Model 131) was used to measure the conductivity of the samples and a Turbidimeter (HACH Model 2100A) was used to measure turbidity levels. Three readings were taken for turbidity and conductivity, and the average recorded. The Kjeldahl test for organic nitrogen was also made (APHA, 1978). Only one set of tests was made at three of the sampling sites because of the nearly negligible amount of nitrogen present at each site, and the relatively long process in carrying out the test.

PRECIPITATION TOTALS (inches)

Test Date	Seasonal Total to Test Date	48 Hours Before Testing
3/3/83	32.87	2.22
3/18/83	39.02	1.07
4/8/83	45.0	0.0

Table 4. Precipitation for Berkeley, 1983.

Source: U.S. Weather Bureau, University of California at Berkeley Station.

This study on the water quality of Strawberry Creek also includes tests for three heavy metals--cadmium, mercury, and lead. Samples from one "wet" period and one "dry" period were tested. The Perkin Elmer 360 Atomic Absorption Spectrophotometer was used for the heavy metal testing. (This test is not listed for mercury in APHA, 1978, but it is consistently used by the Chemistry Department of the University of California at Berkeley). A total of six readings were taken for calibrating the spectrophotometer for each sample site in each sample period. Six concentration readings were taken for each sample. The average of the concentration readings and calibration readings were subtracted and multiplied by a correction factor to get the results.

Current Pollution Data on Strawberry Creek

The present compilation of data on the water quality of Strawberry Creek indicates relatively good water quality for most of the parameters tested (Table 5). However, it must be reiterated that these tests give results of the water quality at the time of the testing and in relation to the parameters tested only.

In the tests for dissolved oxygen, the data show counts well above the 5.0 mg/l (ppm) minimum objective set by the RWQCB. In fact, most of the dissolved oxygen readings are near or at saturation level (Figure 2). Thus, if dissolved oxygen levels were the only stipulation governing the presence of aquatic life, such good results would indicate that aquatic life could be readily supported in Strawberry Creek during the time of testing. Although there is not a consistent pattern in dissolved oxygen levels among creek sites, there is a consistent lowering of dissolved oxygen levels at the storm sewer outlet (site IV) in comparison to the DO readings at the other three sites. It is also interesting to note that at site IV, as the tide increased, the dissolved oxygen level decreased.

The pH for the testing periods is also well within the objective set by the RWQCB. The pH recorded in these tests ranges from 7.4 to 8.4, with the objective being a level not lower than 6.5 nor greater than 8.5.

Date	Time	Site	Dissolved Oxygen	°C	pH	micro-mhos/cm	NTU
3/3/83	12:30pm	I	8.9	13.6	7.4	240	52
	4:05pm	II	9.8	16.1	7.6	390	34
HIGH TIDE	2:00pm	III	10.1	14.1	7.7	390	36
	2:35pm	IV	8.8	16.1	7.6	470	28
3/18/83	2:20pm	I	11.7	10.0	7.9	250	68
	1:50pm	II	11.4	11.7	8.0	330	48
LOW TIDE	1:30pm	III	11.4	11.4	8.0	370	45
	12:15pm	IV	10.0	13.1	8.4	3100	33
4/8/83	12:40pm	I	11.0	10.0	8.0	440	13
	12:26pm	II	11.1	11.8	8.4	440	9
VERY LOW TIDE	12:15pm	III	11.2	11.5	8.2	430	4
	11:22pm	IV	10.5	12.6	8.0	1010	8

Table 5. 1983 Water Quality study at four sites along Strawberry Creek.

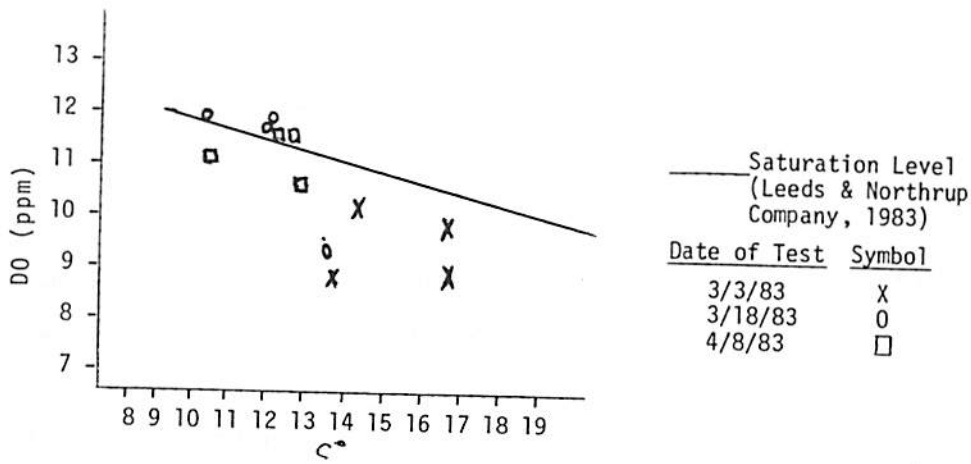

Figure 2. Dissolved Oxygen Levels in Strawberry Creek, 1983.

Measurements of conductivity range from 240 to 440 micro-mhos/cm at the creek sites (I, II, III) and from 470 to 1,010 micro-mhos/cm at the storm drain outlet site (IV). Conductivity readings generally increase down the creek and then rise significantly at the storm drain outlet. In fact, during two of the test periods, the conductivity levels for site IV are larger by a factor of ten than the three respective creek readings. With the level of conductivity approximating 100 micro-mhos/cm for "raw" water, the results obtained from the testing indicate expected conductivity levels.

Turbidity levels range from 4 to 68 NTU's at the creek sites and from 8 to 33 NTU's at the storm drain outlet site (Figure 3). Turbidity measurements show high levels in the upper part of the creek,

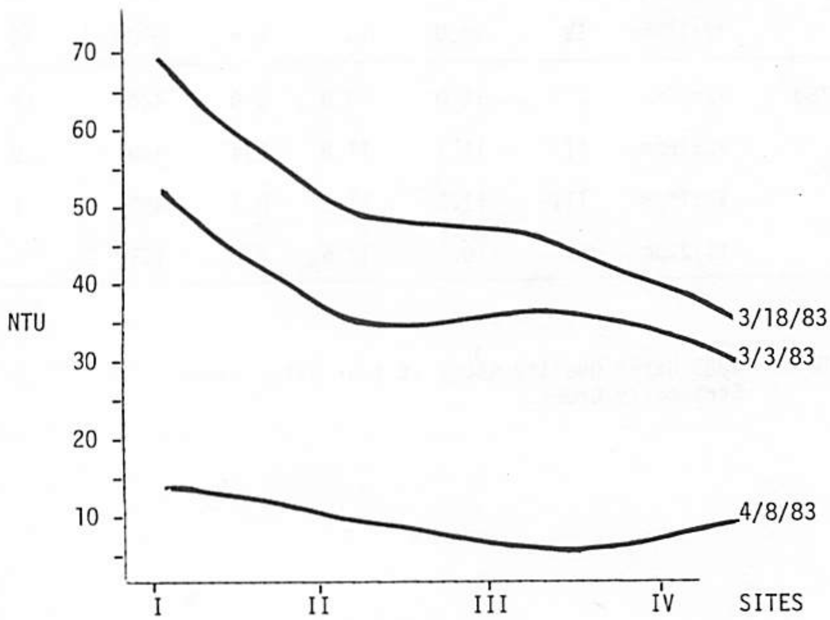

Figure 3. Turbidity levels in Strawberry Creek, March and April 1983.

with decreasing counts toward the bay. As expected, the counts were higher in the "wet" periods and lower in the "dry" period. The turbidity levels are undoubtedly higher than what they would be if unurbanized conditions existed because of increased flow due to urban runoff (Leopold, pers. comm., 1983).

The organic nitrogen levels are very low for the one sample tested compared to the effluent maximum (Table 6). Results range from 1.1 to 1.4 mg/l (ppm) with the effluent standard being 10 mg/l (APHA, 1978).

The heavy metal data (Table 7) present interesting results when compared to the effluent limitations set by the RWQCB. The results for lead range from 0 or "undetectable" to .06 ppm, which are well under the .2 ppm daily maximum limit. Although lead was well under the effluent standard at all

Date	Site	Organic Nitrogen ppm
3/3/83	I	1.4
	III	1.1
	IV	1.1

Table 6. Nitrogen levels at three sites along Strawberry Creek, 1983.

Date	Site	PPM Cd	Pb	Hg
3/18/83	I	.01	0	.95
"WET" PERIOD	II	.03	.01	1.1
	III	0	0	0.5
	IV	0	.04	1.8
4/8/83	I	0	.01	1.2
"DRY" PERIOD	II	.07	.02	0.4
	III	0	.04	0
	IV	.01	.06	0.8

Table 7. Heavy metal levels in Strawberry Creek, 1983.

the sites tested, two patterns may be seen when one looks at downstream trends. One is the increase (though minimal) of concentration from site I to site IV. During the "wet" period, the lead concentration goes from 0 at site I to a .04 ppm at site IV; whereas, during the "dry" period, the lead concentration goes from .01 ppm at site I to .06 ppm at site IV (increasing at each site along the way). Another pattern that the lead data show is the increase in concentration during the "dry" period when compared to the "wet" period.

Cadmium levels range from 0 ppm to .07 ppm, with two readings equaling or surpassing the objective limit of .03 ppm. An interesting downstream trend is the increase of cadmium levels at site II (the site on the west end of campus). Although two test periods are not totally indicative, it is interesting to observe the increase from .01 ppm to .03 ppm during the "wet" period and the increase from 0 ppm to .07 ppm during the "dry" period when site I and site II are compared.

Unlike the results for lead and cadmium, the mercury levels are exceedingly high in comparison to the effluent limit. Results range from 0 ppm to 1.8 ppm with seven of the eight levels exceeding the .002 ppm effluent limit. The data on mercury also suggest a possible trend. The mercury levels in the creek are highest at sites I and II and then drop off at site III before increasing at site IV.

Discussion of Water Quality Studies

Although most of the information in this study indicates relatively good water quality for Strawberry Creek, there are several indications that the water quality is not within set standards and that the quality of water changes at various sites along the creek. One indicator that the water quality is not very good can be found in the mercury results. It is alarming to note that most of the results obtained are greater than one thousand times the .002 ppm effluent limit. These results are ominous because mercury can damage the nervous system, bind easily with DNA structures (which can cause birth defects), and be biologically magnified as it moves up the food chain (Spiro and Stigliani, 1980). Another indicator that Strawberry Creek water is poor in quality can be found in the past studies done on the creek. As noted above, there has been a large coliform presence in the water at several different times. The presence of coliforms suggests that diseases, viruses, and parasites associated with coliforms may also be present. The mercury and coliform results indicate that, at times, the water of Strawberry Creek can pose a health hazard to people and animals who come in contact with the water.

There are several possible reasons for the various trends mentioned above. The lower dissolved oxygen levels at site IV are probably due to the lower DO level of the bay. Interestingly, to find high dissolved oxygen levels for the "wet" periods was somewhat unexpected, because DO levels are usually depressed during rainy periods, due in part to oxygen-demanding substances carried into receiving waters by storm runoff (RWQCB, 1975). A reason for the increase in conductivity at site IV is undoubtedly due to the salt content of the bay. The greater amount of turbidity in "wet" periods is probably due to the quick rate of runoff due to urbanization and the greater volume of runoff in "wet" periods. The result of site II having the highest level of cadmium strongly suggests that the concentration of cadmium increases as the water passes through campus. Higher amounts of lead at sites closer to the bay are most likely from the increased amount of street runoff (the lead originating from car exhaust) that occurs toward the bay. Furthermore, the trend of a lower concentration of lead in the "wet" period versus the "dry" period may be due to dilution. The increases and decreases in the concentration of mercury is probably due to the fact that mercury is heavy and settles out as the creek proceeds to the bay. Possible origins of mercury in the higher parts of the creek include the remnant of mercury-coated seedlings that might be used at the Botanical Garden (located above the test sites). Moreover, mercury levels are greater in the storm drain outlet reading (site IV), probably due to the increased amount of mercury in the bay (Ehrlich <u>et al</u>., 1970). These are but a few of the conclusions one can derive from the above mentioned data.

Recommendations

Since Strawberry Creek receives most pollutants from urban runoff, the quality of water would definitely be enhanced if there were some type of control over the level of pollutants in urban runoff in the areas surrounding the creek (see Tom Holsen's paper for more information on urban runoff control). A few approaches suggested by the Regional Water Quality Control Board (1975) are as follows:

1. Prevent contaminants from reaching urban land surfaces.
2. Improve street cleaning and the flushing of other areas where significant amounts of contaminants may be present.
3. Treat runoff prior to discharging into receiving waters.
4. New controls on land use and development.

Conclusion

The open areas of Strawberry Creek provide a special setting that is enjoyed by a number of people. It is upsetting to know that at times the water flowing down the creek may present a health hazard for the people wishing to enjoy its presence. Not only is it important to attempt to prevent potential health hazards from occurring in the creek, but it is also important to prevent the degradation of the creek's water quality in general. Most of the water that flows down Strawberry Creek ends in San Francisco Bay. Therefore, any pollution present in Strawberry Creek will also affect the water quality of the bay, especially in the area of the Strawberry Creek storm sewer outlet.

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