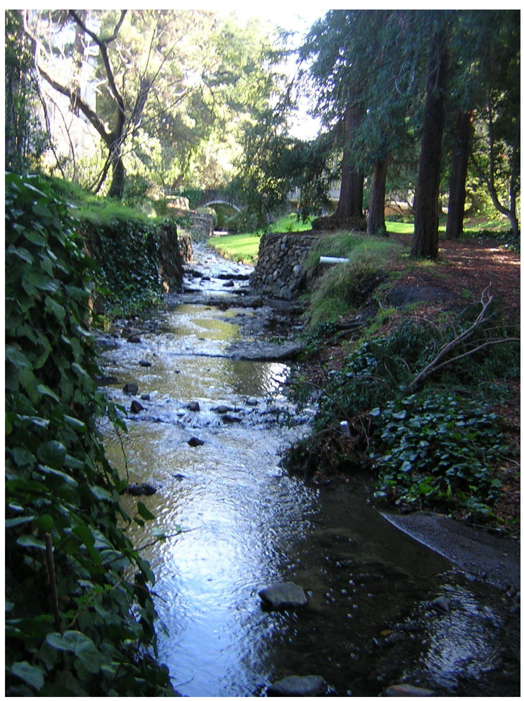
University of California, Berkeley
Strawberry Creek
Water Quality- 2006 Status Report



October 2006

Office of Environment, Health & Safety
University Hall, 3rd Floor
Berkeley, CA 94720

Strawberry Creek Water Quality- 2006 Status Report, October 2006
Completed by the University of California, Berkeley Office of Environment, Health & Safety (EH&S), http//www.ehs.berkeley.edu, strawberrycreek.berkeley.edu

Karl Hans, EH&S Senior Environmental Scientist
Steve Maranzana, EH&S Water Quality Specialist

With contributions from:
Tim Pine, EH&S Specialist
Erin Donley, EH&S Intern
Erin Lutrick, EH&S Intern
Robert Charbonneau, University of California Environmental Protection Services

Technical Consultation and Editorial Assistance by:
Urban Creeks Council, Berkeley, CA, http://www.urbancreeks.org/
Steve Donnelly, Executive Director
Kristen Van Dam, Outreach Coordinator
Junko Bryant

Review and approval by:
Greg Haet, EH&S Associate Director, Environmental Protection
Strawberry Creek Environmental Quality Committee

University of California, Berkeley Strawberry Creek Water Quality- 2006 Status Report

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Water Quality

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1.0 University of California, Berkeley Strawberry Creek Management

Strawberry Creek is a small urban creek draining the western slope of the East Bay Hills in the San Francisco Bay estuary watershed (see maps below). It is a major landscape feature of the University of California, Berkeley, and it was one of the main reasons the site was chosen in 1860 as the location for the campus. The 1163 acre (1.8 sq. mile) watershed draining through draining the campus and upstream headwaters, is approximately 40% urbanized (residential, commercial and institutional), with the remainder consisting of undeveloped, largely natural wildlands.

Urban creeks are increasingly valued for the aesthetic, recreational and wildlife benefits they bring to a city. Strawberry Creek has been the focal point of educational activities for years. More than 3,000 university students, and many elementary and high school students from surrounding communities, use Strawberry Creek each year as an outdoor laboratory for subjects as diverse as environmental studies, biodiversity restoration, landscape design, engineering, and art.

The greater Strawberry Creek ecosystem, consisting of neighboring watersheds, Tilden Regional Park to the east and tidal mudflats and salt marsh at the Berkeley Marina outfall, provides important habitat for plants and wildlife in the largely urban San Francisco metropolitan area. As a source of nutrients and fresh water, Strawberry Creek supports the fisheries of the San Francisco Bay, and continued pollution prevention and restoration in the watershed contribute to the health of the fisheries.

Urban creeks also provide storm water drainage and serve as a flood control system to prevent damage to the urban environment through which they flow. Historically the creek provided sanitary sewer drainage. These uses led to historic erosion, habitat loss and water pollution. By 1987, water quality and ecosystems were highly degraded and the creek was considered a public health risk due to chronic sewage pollution.

In response to campus and community concerns over the deteriorated environmental quality of Strawberry Creek, the campus Office of Environment, Health and Safety (EH&S) sponsored a comprehensive study of the creek. The results of the study completed by Robert Charbonneau were published in December 1987 as the "Strawberry Creek Management Plan" (1987 Strawberry Creek Management Plan). Implementation of the 1987 Strawberry Creek Management Plan significantly improved water quality in Strawberry Creek, as evidenced by the successful reintroduction of locally native fish species to the creek in 1989 – the first resident fish population in the creek in approximately 100 years.

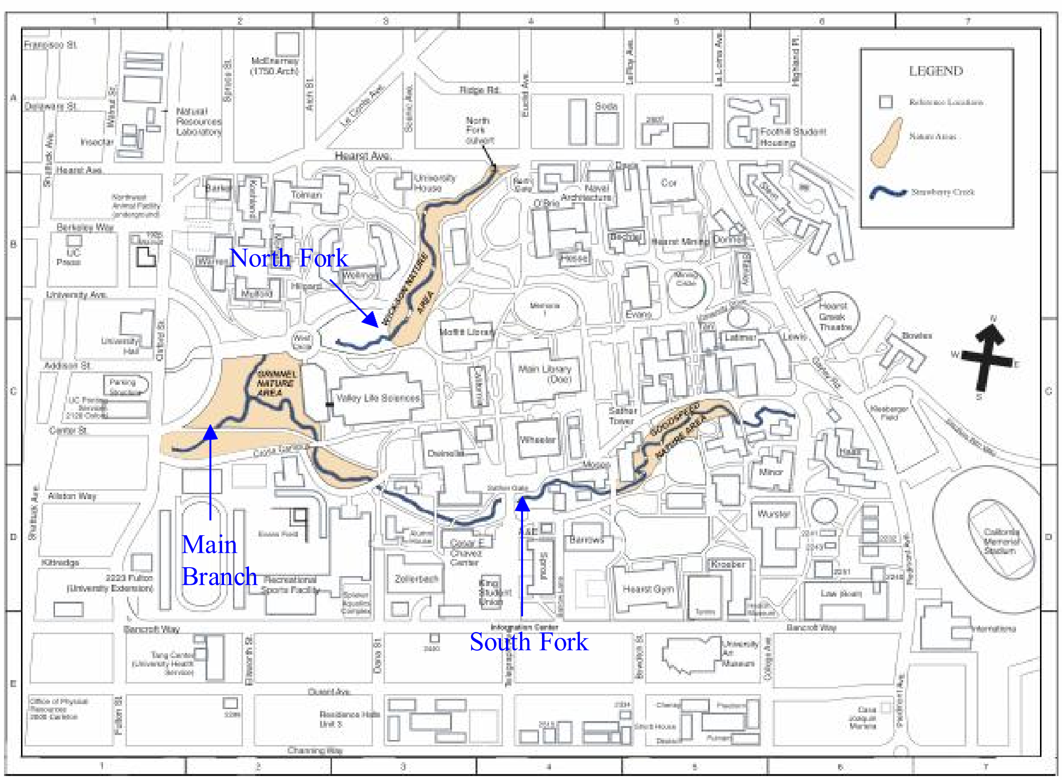
This status report provides a summary current conditions of the water quality in Strawberry Creek as well as a compilation of water quality improvements and monitoring completed since the implementation of the 1987 Strawberry Creek Management Plan. This is one of a series of technical reports being issued by the EH&S to commemorate the twentieth anniversary of the restoration program.

Strawberry Creek Watershed

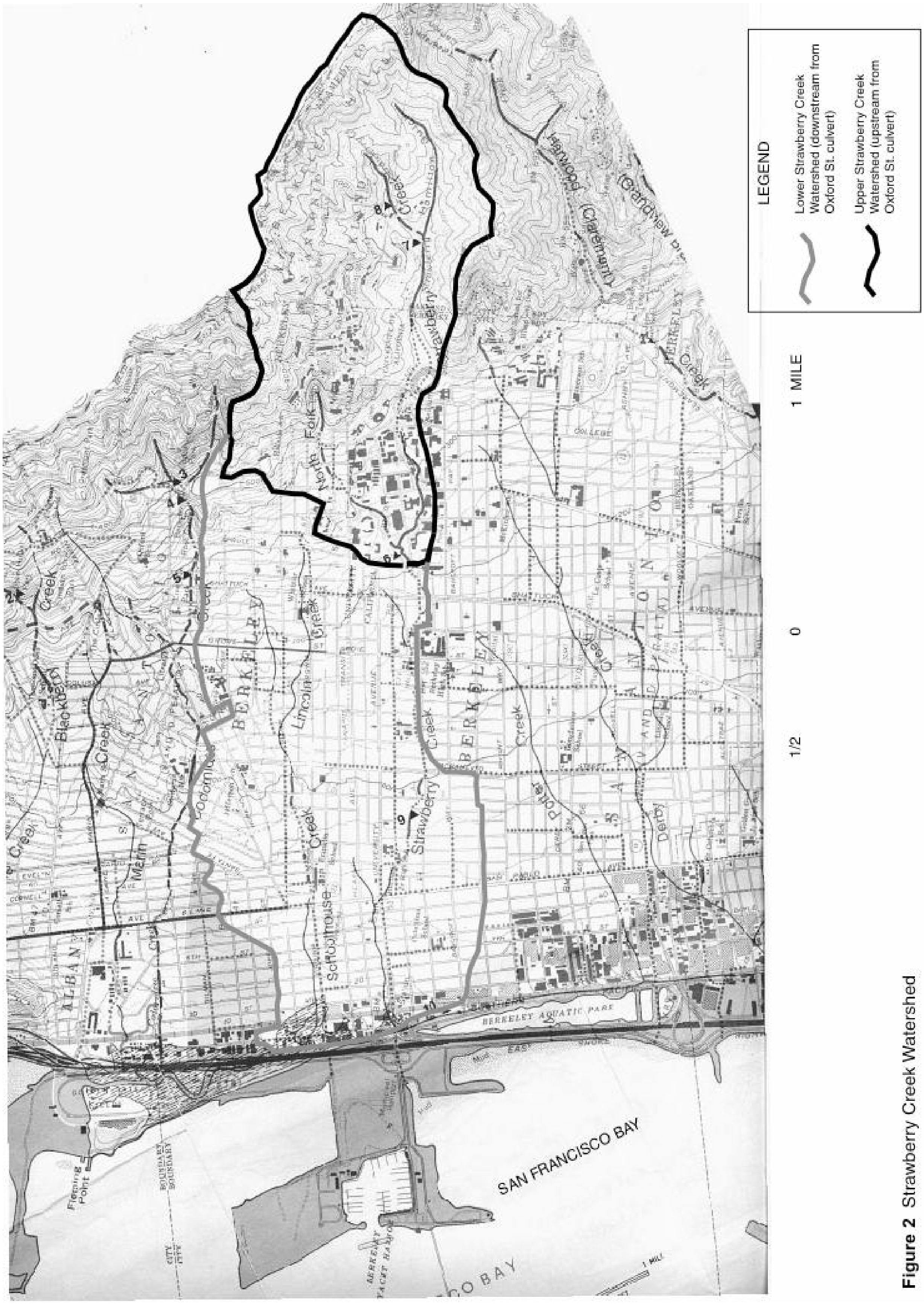
Strawberry Creek Watershed Facts

Strawberry Creek Watershed total area = 1,977 acres (CH2M Hill, 1994)
Length of Strawberry Creek = ~4.5 – 5 miles
Watershed area under jurisdiction of UC Berkeley = 1,163 acres
Watershed under jurisdiction of Lawrence Berkeley National Laboratory = 202 acres
Central Campus, Oxford to Gayley (base of Hill Campus) = ~ 165 acres
Change in elevation between headwaters and mouth (SF Bay) = 1,760 feet
Change in elevation from Grizzly Peak (1, 1760 ft) to Oxford St. (200 ft) = 1,560 ft

Strawberry Creek on University of California Campus Park



Strawberry Creek and Natural Areas on UC Berkeley Central Campus Park



Strawberry Creek Watershed. *Courtesy of the Oakland Museum, www.museumca.org.*

1.1 Strawberry Creek Water Quality Overview

Degraded water quality from over a century of Berkeley urbanization was one of the main problems that led to the creation of a Strawberry Creek Management Plan in 1987 and subsequent restoration program. By the 1980s, the creek water quality was so poor that City of Berkeley health officials advised against direct contact with the creek because of sewage and chemical contamination. While conditions on the campus have improved substantially, discharge of urban pollutants in San Francisco Bay watersheds continues to impair water and ecological habitat quality in creeks and the Bay. Water quality impairment is therefore major concern for campus and regional scientists and planners who continue to work on methods to reduce creek and Bay water pollution.

1987 Water Quality Conditions

In 1987 low flow water quality was found to be fairly good in the canyon areas but degraded in the urbanized downstream reaches by eutrophic nutrient levels and fecal bacterial contamination (Charbonneau and Resh, 1992). Water chemistry was constantly being altered by campus sewage and effluent from leaking pipes, including cooling tower discharge that diluted the natural flow. The Strawberry Creek Management Plan estimated that thirteen point sources contributed a measurable portion of wastewater to the average summer baseflow of the creek: 0.14 cfs* in the North Fork and 0.29 cfs in the South Fork, for a total of about 50% of the average baseflow of 0.89 in the Main Fork.

* Note: cfs = cubic feet per second, a measure of stream flow. One cfs equals 448 gallons per minute (GPM). The conversion from cfs to gallons per minute is: CFS X 448.8 = GPM

Strawberry Creek Management Plan Implementation Summary

Implementation of the Strawberry Creek Management Plan led to a rapid rerouting of pipes draining non-stormwater discharges to the creek, many of which were constructed prior to the availability of the EBMUD sewage treatment plant, which began operating in 1952, and part of the campus plumbing legacy. Corrective actions were prioritized, with high risk connections (including toilets and laboratory sink drains) addressed first and sources posing less significant risks (such as cooling tower drains) addressed next. By 1989 the water quality had improved sufficiently to allow reintroduction of fish.

Additionally, discharges to the creek were investigated to eliminate dumping of wastes, such as paint rinses, silt and mop water, from campus operations and construction sites. By the year 2000, most of the known pollutant discharges had been properly eliminated or rerouted to the sanitary sewer. The last sources to be addressed were the steam condensate discharges from the campus-wide system used to heat buildings. Although free of chemical contaminants, condensate discharges can contribute an unwanted heat load that is detrimental to aquatic life. Also in 2000, EH&S developed Construction Storm Water Pollution Prevention Specifications which are now incorporated into campus construction capital project contracts. This led to the elimination of significant discharges of silt and construction related pollutants, such as cement truck rinse water.

Current Conditions
Today, Strawberry Creek's water quality on the central Campus Park is good at most times, with few obvious signs of water quality degradation. Strawberry Creek supports a number of locally native fish species including California roach minnow, three-spined stickleback and Sacramento sucker which have been identified in recent fish surveys. Recent rapid bioassessment of macroinvertebrates showed that water quality on campus was "fair" to "good". The greatest threats to water quality appear to be shock loading from polluted urban stormwater runoff and spills such as water main breakage and sewage leaks.

1.2 Pollutant Sources: Historical Background

Development of the upper Strawberry Creek watershed began in the late 1700s when ranches were established by Spanish settlers and land cleared for grazing of cattle. Strawberry Creek was most likely first affected by urbanization in the mid 1800's, when it was converted into the sewage conveyance line for the post- Gold Rush burgeoning city of Berkeley. The University of California, Berkeley campus was founded in 1868 and as buildings were constructed, Strawberry Creek became the discharge channel for campus sewage and other wastewater. By 1900, the creek was severely degraded and was polluting the San Francisco Bay at its mouth due to the volume of effluent it carried from the growing city industries, businesses and residents. Construction of the University of California buildings added to the creek's water quality problems. University effluent, raw sewage and laboratory remnants continued to pollute the creek until the connections were finally rerouted through implementation of the management plan.

Strawberry Creek served as an open sewer until a separate sanitary sewer system was constructed beginning in the 1890s. Throughout the first half of the 20th century, untreated sewage from the East Bay, the City of Berkeley and the University was discharged directly to the Bay, creating what was known as "The Big Stench". The 1941 study (Hyde, Gray and Rawn, 1941) designed to solve this problem reported "because of this bad practice the shores and shore waters of the East Bay cities have become obnoxiously and notoriously foul and an affront to civic pride and common decency".

The report went on to state, "The foul conditions above noted have rendered the shores and shore waters hardly utilizable for recreational uses (boating, fishing and the like); completely unsuitable for bathing and a handicap to industrial development and shipping. In confined areas, especially near docks, the waters are particularly obnoxious; gases of decomposition break the surface with continuous bubbling; and gas-lifted sludge masses frequently boil up to the water surface."

Much of the sewage from the City of Berkeley and the University was diverted to the East Bay Municipal Utility District (EBMUD) wastewater treatment plant when it became fully operational in 1952. Numerous buildings were constructed on campus during this time period. All campus restrooms and laboratory sinks were plumbed to the sanitary sewer system. However, building codes and convenience resulted in other drains, such as floor drains, being routed to the storm drain system and Strawberry Creek. At the initiation of the Strawberry Creek Management Plan in 1987, these and other direct discharges to storm drains and the creek from the City continued to be a problem, particularly from sewage discharges.

OUTLET OF UNIVERSITY AVENUE SEWER, BERKELEY, ABOUT MID-TIDE
Note the sludge banks to the right of the sewer outlet, buoyed up sludge at the outlet and the nearness of the East Shore Highway. The sewage from a population of 18,500 and a small amount of industrial waste is discharged here.

Figure 1.1 *1940 Strawberry Creek (?) outfall, Berkeley Marina. From: Hyde, G.C., Gray, H.F., Rawn, A.M., "East Bay Cities Sewage Disposal Survey, Report Upon the collection, Treatment and Disposal of Sewage and Industrial Wastes of the East Bay Cities, California" The Board of Consulting Engineers, June 30, 1941, Page 177*

The 1987 Strawberry Creek Management Plan included an extensive sanitary engineering investigation, focusing on point source pollution and non-stormwater discharge elimination. Over 100 pipes were located and mapped (Charbonneau, 1987, Figure 15, Central Campus Point Source Locations). All were inspected for continuous dry weather flows, and dry weather flows were further investigated with 24-hour composite sampling. Many were dye tested and re-routed as appropriate. This work continued through the decade of the 1990's, eliminating all significant direct discharges to the creek from the campus by 2000.

Because most leaks and improper pipe connections have been eliminated, the main sources of water pollutants in Strawberry Creek today are non-point source runoff, spills and illicit dumping. These sources continue to result in a perceptible "shock loading" of chloraminated water, sediment, nutrients, bacteria, soap, and other pollutants during spills. During rain events the shock load of soap, metals, oils and atmospheric deposition leads to visibly polluted water as well as measurable increases in pollutants such as heavy metals and bacteria, which present challenges to the struggling aquatic life that call it home. Control of these shock loads require management strategies that treat stormwater runoff from roads, campus impervious surfaces, and construction sites and non-stormwater discharges from accidents and illicit dumping.

To help determine how Strawberry Creek's water quality changed over time, EH&S implemented weekly fecal coliform monitoring on Strawberry Creek in 2000. The results showed that bacterial pollution has decreased greatly from levels measured in 1987, believed to be due mainly to a reduction in leaks and illicit connections that previously allowed raw sewage to flow into the creek from the City of Berkeley and UC campus.

In 1987, 2000 and 2001, EH&S also analyzed water samples for metals, oil and grease, turbidity, and nitrogen and phosphorous levels. Analyses of grab samples from 2000 and 2001 were compared to those from 1987. These limited results suggest that low-flow water characteristics and quality remained nearly the same—generally good except during spills—and that wet weather water quality generally improved with most wet weather pollutant levels lowered. However, levels of copper, zinc, and lead are still above Regional Water Quality Control Board instantaneous water quality objectives for those pollutants, probably due to rainwater transport of automotive pollutants from streets and rooftops.

1.3 Ambient Conditions: Microbiological

Bacteria, viruses, protozoa and fungi present in Strawberry Creek water may come from a variety of man-made and natural sources. Coliform bacteria are present in soils and animals. The aquatic environment itself is a source of naturally occurring bacteria and protozoa (including *Giardia*, *Pseudomonas aeruginosa, Staphylococcus* sp., *Legionella* sp. *Naegleria fowleri*, *Mycobacterium* sp., and *Vibrio* sp.) that can cause waterborne illnesses, such as gastroenteritis, dermatitis and conjunctivitis.

Fecal matter from sewage leaks or feces from domestic and wild animals and homeless encampments, when deposited on lawns or banks and washed into the creek by irrigation water or rainfall, will lead to an increase in measurable bacteria over background levels. This includes coliform bacteria found in the intestines of humans and other warm-blooded animals. Coliform bacteria can be indicators of conditions that pose a public health hazard from exposure to pathogenic (disease causing) bacteria (such as *Shigella*, *E. coli 0157:H7*, and *Salmonella*), protozoa (such as *Giardia)* and viruses (such as Norwalk, Cocksackie and Hepatitis A) if the water is ingested.

The 1987 Strawberry Creek Management Plan included an extensive sanitary engineering investigation that used dye testing to find deteriorating sanitary sewer lines leaking to Strawberry Creek or directly plumbed to the creek. The most dramatic example was found at Memorial Stadium, where leaking sewers led to huge bacteriological counts in the Creek during football games. As a result of the Strawberry Creek Management Plan, many sewer lines were rerouted or repaired.

In 2000, EH&S completed spill response protocols describing procedures for response, agency notification and posting of public health warnings after sewage spills. Also, in 2000, EH&S began regular sampling of both forks of Strawberry Creek to allow early detection of minor sewage leaks and to better characterize routine bacteriological conditions.

While the campus has implemented an effective monitoring and response program to minimize sewage impacts to Strawberry Creek, sewage overflows still occur from urban activities, primarily by obstruction with foreign objects at construction sites and by obstruction due to root intrusion. In order to minimize the potential for sewage releases in a university setting, a systematic preventive maintenance program is needed to insure root intrusion is cleared on a timely basis, particularly before the start of Fall semester when sewer flows increase.

Bacteriological Standards

Strawberry Creek provides many benefits to the University and the surrounding community, including being the focal point of many educational activities. A beneficial use of Strawberry Creek is Noncontact Water Recreation, also known as "passive recreation" and identified as REC2 in the San Francisco Basin Water Quality Control Plan (http://www.waterboards.ca.gov/sanfranciscobay/Download.htm.) Passive recreation includes activities such as picnicking, hiking, aquatic life study, and aesthetic enjoyment. Strawberry Creek is not expected to be used for recreational activities involving body contact with water where ingestion of water is reasonably possible (it is shallow which generally precludes swimming and is not a freshwater beach).

The Basin Plan Water Quality Objective for REC 2 Non-contact Water Recreation is*:

Fecal Coliform (MPN/100ml)
Mean < 2,000
90^{th} percentile < 4,000

*These standards are for non-sewage spill conditions. After a sewage spill has resolved [from decay over time or from flushing after a significant rainfall event (~> 0.25 inches in 24 hours)] comparison to these levels should be based on a minimum of three samples taken at the same time from different sections of the assessed portion of the creek. In the event of elevated levels during non-spill conditions, comparison should be made on at least 5 equally spaced samples in a 30 day period [excluding any samples taken within 72 hours of rainfall discharging water to the creek (based on Department of Health Services Fresh Water Beaches Guidance, November 1999 draft, section 2.3 reported rate of dissipation of microbiological contamination from significant rainfall)].

Analytical results of dry weather and wet weather samples collected between 2000 and 2004 (see figures in Appendix 1) show that dry weather background concentrations are normally well below the REC 2 Non-contact Water Recreation standard of 2000 MPN/100ML fecal coliform. Fecal coliform concentrations have dropped substantially since those measured during the 1987 Strawberry Creek Management Plan. Wet weather concentrations are on average an order of magnitude greater than dry weather concentrations. Average concentrations for both dry and wet weather at the University

House outfall of drainage from City of Berkeley Northside and Woolsey (Blackberry) Canyon is elevated relative to other sampling locations. The campus began completing in-house coliform analyses in 2004 using an IDEXX QuantiTray 2000 System that analyzers for e. coli. and total coliforms. Results of 2004 and 2005 sampling are presented in Appendix 1.

Compared to other monitored water quality parameters, fecal coliform concentrations are the most thoroughly documented constituent analysis and along with biological assessments, demonstrate the significant improvement in Strawberry Creek water quality since 1987. Fecal coliform contamination was greatly reduced in Strawberry Creek primarily because of repairs in sanitary sewer line leaks and rerouted flows from the campus and the City of Berkeley that were discharging to the storm drain system. Almost all of these repairs of continuous discharges were completed between 1987 and 1989 (Charbonneau & Resh, 1992). Routine surveillance implemented by UC Berkeley EH&S has likely limited the amount of sewage spilled into the creek from non-continuous sources, such as a broken Foothill Dining Hall grease trap influent line that was leaking coliform and grease laden water into the Cross Campus Culvert. Additionally, a reduction in irrigation runoff has reduced washing of bacteria from campus lawns into the creek.

Coliform data suggests that Strawberry Creek is generally well within RWQCB water quality standards (REC2) for this indicator of pollutants during dry weather. However, as in 1987 North Fork levels at the University House where the creek drains from the City of Berkeley are higher compared to other portions of the creek. In 1987, Charbonneau performed additional inspections and water quality analyses of the old creek tunnel along Euclid Street in the City of Berkeley and concluded (Strawberry Creek Management Plan, page 51) that the old tunnel was a suspect area for sewage infiltrations or illegal connections. While Charbonneau also concluded that animal activity may be the source of elevated bacteria, the fecal coliform/fecal streptococcus ratio used to draw this conclusion is no longer considered valid for discriminating animal and human. (Reference Standard Methods for the Examination of Water and Wastewater, 20th Ed. Page 9-75 " FC/FS ratio … should not be used as a means of differentiating human animal sources of pollution.")

The elevated levels of fecal coliform from the Hearst/Euclid discharge compared to the rest of the creek indicate that some future efforts should focus on finding the sources in the North Fork. This will entail cooperation with the City of Berkeley as coliform levels are usually elevated where the creek enters the campus at University House. A speciation of coliform bacteria may be necessary to differentiate between animal and human sources.

The campus should consider using the REC1 standard as a water quality goal as opposed to the REC2 or an alternative standard due to the use of the creek by children. The Environmental Protection Agency (U.S. EPA, May 2002, page 24) explains: "Children are more likely to engage in activities where ingestion of water is likely, even in waterbodies where ingestion would not be likely for adults. Children splash and swim in shallow waters that may otherwise be considered too shallow for full body immersion."

Lessons Learned: Sewage Spill Response

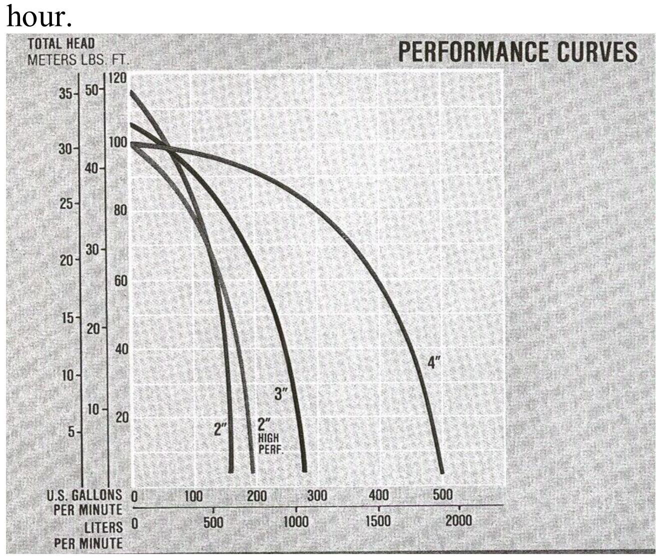
In the 1980s, the campus and City of Berkeley response to sewage spills was primarily one of stopping it at the source. Sewage was allowed to drain down the creek and decay over time or be washed away by rains. In the early 1990s, agencies such as the Department of Fish and Game began to require that sewage released to the creek be pumped out of the creek back into sanitary sewers downstream of the blockage. Pumping of the creek is performed by damming the creek with sandbags in a location in proximity to the sanitary sewer and pumping the sewage and creek water into the sanitary sewer. Pumping continues until the sewage leak is repaired and most of the sewage pumped from the creek.

SEWAGE SPILL RESPONSE PUMPING CALCULATIONS

The Multiquip centrifugal pumps have a maximum capacity of 16,000 Gallons Per Hour (GPH, ~260 GPM), maximum lift of 25 ft and maximum head of 105 ft. In general, the pumps are expected to operate at less than maximum capacity, in part due to the need to lift the water from creek pools 10- 15 feet to the sanitary sewer. Assuming 200 GPM operating conditions, all three pumps would be required to divert flow from the central campus sanitary sewer draining to side sewer #1 (SS#1, MH 384) when that sewer is running at maximum capacity of around 500 GPM and the North Fork is contributing typical dry weather flow of around 50-100 GPM. [Daily sewer discharge from campus is 785,000 (Source: 2002 EBMUD UC Berkeley Wastewater Discharge Permit). Assume 75% drains to SS#1 and 25% to other side sewers. SS#1 daily average flow is = 400 GPM with diurnal fluctuations and peak flows in the early afternoon (assume 500 GPM maximum). North Fork dry weather flow = 50- 100 GPM. South Fork dry weather flow = 125-200 GPM. (Quick conversion CFS X 448.8 = GPM)]. This would be a worst-case scenario. However, usually two centrifugal pumps are needed, and in some cases these have been supplemented by use of plumber's sump pumps, which are especially useful in providing a pump around to divert clean upstream water around the impacted area.

While normal dry weather flows are low enough to allow pumping the creek using pumper trucks or portable gas powered "trash" pumps, contractor response time was historically poor. It would often take 4 to 6 hours for contractors to arrive with trucks and set up before pumping began, and by that time a significant portion of sewage flowed out of campus and into the City and the Bay.

Because of the slow response time, in 1999 EH&S purchased three Multiquip 3" X 3" centrifugal pumps with 5.0 H.P. Honda GX-140 engines (77 lbs. dry weight) and a quick cleaning capacity for sewage response. With two engines stored in a secure centrally located room allowing for quick access to the creek and one kept on a Physical Plant-Campus Services truck, response time between sewage spill discovery and creek pumping has shortened from many hours to 30 minutes to an hour.



MultiQuip Pump Performance Curve

1.4 Ambient Conditions: Chloramines

Domestic supply water can contain substances that can be harmful to creek organisms or affect water quality, including chlorine, ammonia, chloramines, elevated pH, and sulfides. In sufficient concentrations, chlorine and ammonia can be toxic to creek organisms. Due to presence of residual chlorine, direct discharges of significant quantities of drinking water can pose a risk to aquatic organisms. Risk increased in 1998 when EBMUD converted drinking water disinfection from chlorine to chloramines.

An ecological risk assessment of drinking water releases performed by the Canadian Environmental Protection Agency (see Assessment Report – Inorganic Chloramines Synopsis, http://www.ec.gc.ca/substances/ese/eng/psap/final/chloramines.cfm) concluded that "even very small (10-20 gallons/minute) discrete discharges of chloramines-treated potable water could result in impacts if dilutions are less than 1:10 to 1:100". The report noted that most of these low flow discharges tend to be indirect and chloramines react with dirt and other materials (the flow is subject to chemical demand) en route to surface waters. The report also identified larger releases that would have a greater possibility of producing impacts: main breaks, fire hose discharge, main flushing and street washing.

On Strawberry Creek a 1:100 dilution is equivalent to a ~1.0 gallon per minute (GPM) North Fork discharge of ~2.0 GPM South Fork discharge during typical dry weather conditions. These flows are equal to residential fully open household garden hose discharges. This compares to the following rates for other typical potable water discharges:

- Main dewatering (new construction or maintenance) = 200-300 GPM per location.
- Main flushing (in response to taste complaints, for disinfection) = 300- 1000 GPM.
- Hydrant testing = 700- 1600 GPM
- Water main breaks = 5- 200 GPM
  (Source: Draft EBMUD Environmental Impacts of Potable Water Discharges, March 11, 1998, Table 1)

The Canadian EPA study also reported that "severely negative consequences to freshwater ecosystems have occurred in the Lower Mainland of British Columbia, where releases of chloramines –treated potable water due to water main breaks resulted in the mortality of many thousands of salmonids and several thousand invertebrates."

In April 1998, EBMUD converted its drinking water disinfection from chlorine to chloramines. Following is a summary of information regarding potable water discharges, chloramines and other constituent concentrations, toxicity and dechlorination recommendations presented in the March 11, 1998 draft of EBMUD's "Environmental Impacts of Potable Water Discharges".

- "Inorganic chloramines are believed to be among the most toxic forms of combined chlorine and, in most cases, more toxic than free chlorine. LD (Lethal Dose) 50 concentrations for fish exposed to monochloramines at difference life stages range from 0.01 mg/L (American oyster larva) to 20.0 mg/L (pike perch fry), with a median of 0.65 mg/L and 53% (20 of the 38 species tested) at or below the median." (Section 1.2)

- The EBMUD chlorine residual goal is 0.5 mg/L at the far reaches of the distribution system and levels as high as 2.0 mg/L are anticipated within the system. (Section 1.3) (Note: these are the levels that would be expected to be found in a discharge. The Federal EPA aquatic life water quality criteria for chlorine is 0.011 mg/L.)

- Chlorine residual in chloraminated discharges is reduced only marginally by contact with the soil. EBMUD found chlorine residual of 1.4 mg/L in muddy water from main repair trench water from a distribution system with a concentration of 1.7 mg/L. (Section 1.5)

- An attenuation study of fire hydrant discharge showed a small reduction of chlorine residual over the distance of 2,414 feet (1.39 mg/L to 0.86 mg/L) attesting to the persistence of chloramines. (Table 2)

- EBMUD's goal of dechlorination is to ensure that no potable water with a detectable total chlorine residual enters a receiving water. Given a residual concentration of 1-2 mg/L and assuming the chlorine residual will not drop to zero under any set of conditions until the water has traveled well over one-half mile, there are no locations within the District at which active dechlorination will not be required due to proximity of receiving waters (creeks, lakes, bay shoreline and reservoirs). (Section 1.5)

- EBMUD anticipates a total ammonia concentration of 0.5 mg/ml in the distribution system. The percent of un-ionized ammonia is pH and temperature dependent with an upper end of 0.14 mg/L (pH 9.0, 20 C), which is below the regulatory limit of 0.16 mg/ml.

- pH of potable water may be as high as 9.5 (which exceeds the Basin Plan limit of 8.5). Dechlorination is expected to reduce pH since hydrochloric acid is a byproduct of dechlorination. (Section 1.3) (Monochloramine dechlorination with sodium thiosulfate assuming dissociation of ammonia and chlorine ions: $4NH_3 + 12Cl_2 + 3Na_2S_2O_3 + 15H_2O \Leftrightarrow 6NaHSO_4 + 20HCl + 4NH_4Cl$)

- Dechlorination can suppress dissolved oxygen levels (Note: sodium thiosulfate is a weak oxygen scavenger and presents a lower occupational exposure risk than other dechlorination chemicals due to its low toxicity; therefore it is preferred for campus dechlorination operations.)

1.5 Ambient Conditions: Other Constituents

This section provides a summary of the sampling and analysis for a variety of constituents, including pollutant concentrations in water and sediment since 1987.

In 2000 and 2001, EH&S analyzed water samples for a variety of constituents including metals, oil and grease, turbidity, and nitrogen and phosphorous levels. The results of the analyses compared to early Strawberry Creek Management Plan sampling (1987 and 1992) are presented in Tables 1 - 3.

Table 1: Dry Weather South Fork
1987, 1992 and 2001 water quality sampling results at the Eucalyptus Grove

Constituent	1987	1992	2001	Reporting Limit 2001	Water Quality Criterion
pH (std. units)	7.8	7.8	7.5		6.5- 8.5
Biochemical oxygen demand	<3.3	<3.0	ND	6.0	
Chemical oxygen demand	<10	30	24	10.0	
Total alkalinity (mg/L $CaCO_3$)	86	80	120	1.7	
Hardness	92	85	160	3.3	
Spec. conductance (umhos/cm)	238	198	330	1.0	
Dissolved solids	150	144	240	10.0	
Suspended solids	12.8	4	ND	5.0	
Turbidity (NTU)	9.8	2	14	0.2	50
Chloride	10.1	11	19	0.4	
Oil and grease	8.6	-	ND	5.1	Visible film
Total Kjeldahl-nitrogen	0.65	<1.4	ND	1.0	
Ammonia-nitrogen (NH_3-N)	0.22	<0.1	ND	0.1	
Nitrate (NO_3)	3.6	1.3	0.5	0.05	
Total phosphorous	0.34	0.19	ND	0.20	
Total coliform (MPN/100 ml)	52000	16000	8100		
Fecal coliform (MPN/100 ml)	24500				< 2,000 MPN

Notes: All analytical results in mg/L unless otherwise specified. 1987 and 1992 results are based on a varying number of discrete samples, reported in Charbonneau & Resh (1992), with analyses performed by the California Department of Health Services Sanitation and Radiation Laboratory in Berkeley. 2001 concentrations are based on one discrete sample collected on July 26, 2001 and analyzed at Curtis & Tompkins, Ltd., Certified Analytical Laboratory in Berkeley. 2001 coliform concentrations are averages of discrete samples collected during dry weather in 2000 and 2001.

Table 2: Dry Weather Metals North and South Forks
1987 and 2001 dry weather priority pollution metals analysis results at the Eucalyptus Grove

Metal	North Fork 1987	North Fork 2001	South Fork 1987	South Fork 2001	Reporting Limit 2001	AWQC Max/Cont.
Antimony		ND		ND	60	
Arsenic		ND		ND	530	340/150
Beryllium		ND		ND	2	
Cadmium	<1	ND	<1	ND	5	4.3/2.2
Chromium	<1	ND	1	ND	10	550/180
Copper	4.0	ND	13	ND	10	16/11
Iron	34.0	-	131.5	-	-	
Lead	15.0	ND	<10	ND	3	65/2.1
Manganese	13.5	-	56	-	-	
Mercury	0.05	ND	0.07	ND	0.2	
Nickel	4.0	ND	<2	ND	20	470/52
Selenium		ND		ND	5	5.0
Silver		ND		ND	5	3.4
Thallium		ND		ND	5	
Zinc	7.0	22	19.5	ND	20	120/120

Notes: All results are micrograms/liter. 2001 samples collected July 27, 2001. Federal Ambient Water Quality Criteria (AWQCs) are presented as maximum concentrations and continuous concentrations.

Table 3: Wet Weather North and South Forks
1987 and 2000 shock load results at the Eucalyptus Grove reach of Forks.

Metal	North Fork 1987	North Fork 2000	South Fork 1987	South Fork 2000	RWQCB Basin Plan 4d /1hr	Federal AWQC max/cont.
Copper (ug/L)	450	130	280	300	6.5/9.2	13/9.0
Lead (ug/L)	440	68	200	140	~3.2/81	65/2.5
Mercury (ug/L)	8.8	0.77	2.5	2.5	0.025/2.4	
Oil & Grease	12	4	5	< 5		
TSS	760	330	980	860		
Turbidity (NTU)	260	230	290	590		
Zinc (ug/L)	1400	620	580	550	23/21 58 (24 hour) 170 instan-taneous)	120/120
Fecal coliform (MPN./100 ml)	4900	2775	54000	850	2000	

Notes: RWQCB Basin Plan Water Quality Objectives are presented as 4-day averages and 1-hour averages (only nickel, silver and zinc have instantaneous objectives in the Basin Plan). Federal Ambient Water Quality Criteria (AWQCs) are presented as maximum concentrations and continuous concentrations. 2000 samples collected September 1.

Dissolved Oxygen

Dissolved oxygen (D.O.) is a general index of the state of the health of receiving waters. Although minimum concentrations of 5 mg/l and 7 mg/l are frequently used as objectives to protect fish life, higher concentrations are generally desirable to protect sensitive aquatic forms. The San Francisco Basin Water Quality Control Plan Water Quality Objective for dissolved oxygen in waters designated as coldwater habitat is 7.0 mg/l.

In 1987, results of water quality sampling for D.O. (Charbonneau, 1987, page 44) indicated concentrations were quite high in both forks. The North Fork presented slightly lower concentrations than the South Fork, and both forks show slightly decreased concentrations downstream.

There has been no regular D.O. monitoring on Strawberry Creek since 1987. The results of student investigations using direct reading D.O. meters have shown D.O. levels over 8 mg/L in most areas on the creek during both wet and dry weather.

These levels meet the RWQCB objectives for cold freshwater habitats. Because Strawberry Creek is a fast moving, small creek, D.O. levels will likely remain sufficient, and will not be major barrier to ecological restoration, as the 1987 Strawberry Creek Management Plan concluded. This could change during drought conditions if the creek baseflow drops dramatically. Additional D.O. monitoring will be warranted under such conditions.

pH

A range of pH from 6.5 to 8.2 is optimal for most organisms. Most organisms have adapted to life in water of a specific pH and may die if it changes even slightly. The toxicity level of ammonia to fish, for example, varies tremendously within a small range of pH values. Acidic water can cause toxic heavy metals such as copper and zinc to be released into the water.

The San Francisco Basin Water Quality Control Plan Water Quality Objective states that the pH shall not be depressed below 6.5 nor raised above 8.5. pH levels in Strawberry Creek have been in compliance with this objective.

In 1987 the Strawberry Creek Management Plan reported pHs in the creek as slightly alkaline, averaging 8.1 in the South Fork and 8.0 in the North Fork, higher than the average pH found in other East Bay creeks, but a suitable habitat for most aquatic life (Charbonneau, 1987, page 46). At that time, a contribution to elevated pHs may have been domestic EBMUD water, which is slightly alkaline (pH 9.1-9.5, EBMUD 2001 Annual Water Quality Report).

In 2001, dry weather sampling found pH levels of 7.5 in the North Fork and 7.8 in the South Fork. The lower pHs in 2001 compared to 1987 (and 1992) are possibly due to the elimination of most domestic supply water discharge.

Hardness, Alkalinity, Phosphorus and Nitrates

These parameters measure the amount of dissolved salts and ions in the water. There are many natural sources of these compounds in the soil but there is the potential for additional loading (or dilution) from human sources. Currently there are no Water Quality Objectives for these constituents in the San Francisco Basin Water Quality Control Plan.

While there is no water quality index associated with conductivity, some values may be better than others for a particular body of water. Abrupt changes in conductivity can indicate that water or wastes are being diverted into the stream from a new source. Conductivity can be used as a measure of total dissolved solids (TDS). These solids are usually composed of the sulfate, bicarbonate, and chlorides of calcium, magnesium, and sodium. The TDS measurement differs from the total solids measurement in that total solids also includes suspended material that is not dissolved. Conductivity is also a good measure of salinity in water. The measurement detects chloride ions from the salt. Salinity affects the potential dissolved oxygen levels in the water. The greater the salinity, the lower the saturation point.

Phosphorus is usually present in natural water as phosphates (orthophospates, polyphosphates, and organically bound phosphates). Phosphorus is a plant nutrient needed for growth and a fundamental element in the metabolic reactions of plants and animals (hence its use in fertilizers). Sources of phosphorus include human and animal wastes (i.e. sewage), industrial wastes, soil erosion, and fertilizers. Excess phosphorus causes extensive algal growth called "blooms," which are a classic symptom of cultural eutrophication and lead to decreased oxygen levels in creek water.

Nitrogen occurs in natural waters as nitrate (NO^3), nitrite (NO^2), ammonia (NH^3), and organically bound nitrogen. As aquatic plants and animals die, bacteria break down large protein molecules containing nitrogen into ammonia. Ammonia is then oxidized by specialized bacteria to form nitrites and nitrates. Sewage is the main source of nitrates added by humans to waterways. Another important source is fertilizers, which can be carried into creeks by stormwater runoff. Excessive nitrates stimulate growth of algae and other plants, which later decay and increase biochemical oxygen demand as they decompose.

Hardness, alkalinity, phosphorous, and nitrate concentrations have all increased since 1987. (See dry weather water quality tables at the front of this section for details.) It is likely that the increase in these parameters was due to the elimination of domestic water inputs from Strawberry Creek since 1987. East Bay Municipal Utilities District water is very soft and contains low levels of salts and ions (Hardness as CaCO3= 18 – 30 mg/L). The relatively large domestic water sources present in 1987 may have diluted the creek's natural characteristics during dry weather low flows.

Temperature

Temperature affects many physical, biological, and chemical characteristics of a creek: amount of oxygen that can be dissolved in water, rate of photosynthesis of plants, metabolic rates of animals, and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Thermal pollution is an increase in water temperature caused by adding relatively warm water to cooler stream water. The warm water can be stormwater running off warmed urban surfaces, such as streets and parking lots, which are often constructed of black, heat-absorbing asphalt. The cutting down of trees that shade a river will expose it to sunlight and increase temperature. Turbidity in water increases the amount of heat absorbed from sunlight. Measurement of temperature change can help detect sources of thermal pollution and suggest the size of habitat available for organisms that are more sensitive to temperature variation.

The San Francisco Basin Water Quality Control Plan (RWQCB, 1997) Water Quality Objective for surface waters temperature is:

- "The natural receiving water temperature of inland surface waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such alteration in temperature does not adversely affect beneficial uses.

- The temperature of any cold or warm freshwater habitat shall not be increased by more than 5°F (2.8°C) above natural receiving water temperature."

In 1987, sampling of the creek for the Strawberry Creek Management Plan found that water temperatures increased slightly downstream compared to the canyon headwater stations, with the South Fork slightly cooler than the North Fork. Temperatures at the headwater stations ranged from 51.8-60.1 °F (11.0-15.6 °C) during the summer. Downstream temperatures ranged from 57.6-65.5 °F (14.2-18.6 °C) during the summer. The largest increase in temperature 2.7-7.9 °F (1.5-4.4 °C) in either fork was found to be the effluent from the Cross Campus Culvert on the North Fork, which the Strawberry Creek Management Plan concluded "could have a deleterious impact on the suitability of downstream waters" but did not exceed the RWQCB water quality objective.

Temperature studies were completed in 1996 and 1999 in order to determine the effect of hot water discharges from the campus steam system into Strawberry Creek. Three Optic Stowaway thermometers were placed in the creek for a week, one at the University House on the North Fork, one at the retention dam in Strawberry Canyon on the South Fork, and one at the Oxford Culvert in the Main Fork. The temperature loggers recorded water temperature every fifteen minutes. The average Oxford Culvert temperature was found to be 63.0˚F (17.2˚C). The average increase in temperature between upstream samples and the Oxford Culvert was 4.5 ˚F (2.5 ˚C). This temperature increase includes natural solar and conductive heating as the creek courses through the campus. Therefore, the contribution of heated water did not appear to have a significant effect on the creek temperature (as compared to the RWQCB water quality objective). The hot water discharges were found to have local effects at the outfalls where slightly degraded macroinvertebrate family biotic indexes were found, which may have been due to multiple factors, including elevated temperature. Most of the steam condensate discharges were removed from the creek since 1987 and significant discharges have been eliminated.

2003 sampling results show that Strawberry Creek's temperatures vary between 55 and 65 °F (13 to 18°C), fluctuating with cloud cover, flow, and air temperature.

In addition to Water Quality Objectives, temperature is a factor in Basin Plan Beneficial Uses for cold and warm freshwater habitat and fish spawning, as follows:

Habitat Beneficial Uses:

Cold Freshwater Habitat (COLD):
Uses of water that support cold water ecosystems, including but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. (COLD)

Cold freshwater habitats generally support trout and may support anadromous salmon and steelhead fisheries as well. Cold water habitats are commonly well – oxygenated. Life within these waters is relatively intolerant to environmental stresses. Often, soft waters feed cold water habitats. These waters render fish more susceptible to toxic metals, such as copper, because of their lower buffering capacity.

Warm Freshwater Habitat (WARM):
Uses of water that support warmwater ecosystems, including but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. (WARM)

The warm freshwater habitats supporting bass, bluegill, perch and other panfish are generally lakes and reservoirs, although some minor streams will serve this purpose where stream flow is sufficient to sustain the fishery. The habitat is also important to a variety of non-fish species, such as frogs, crayfish, and insects, which provide food for fish and small mammals. This habitat is less sensitive to environmental changes, but more diverse than the cold freshwater habitat, and natural fluctuations in temperature, dissolved oxygen, pH, and turbidity are usually greater.

Fish Spawning (SPWN):
Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish. (SPWN)

> Dissolved oxygen levels in spawning areas should ideally approach saturation levels. Free movement of water is essential to maintain well-oxygenated conditions around eggs deposited in sediments. Water temperature, size distribution and organic content of sediments, water depth, and current velocity are also important determinants of spawning area adequacy."

The Basin Plan does not define the temperature range of cold and warm habitat, but today, Strawberry Creek may best be described as a coolwater habitat. The summertime temperatures (55.4 to 64.4 °F, 13 to 18°C) are near the upper limit of the optimal range for cold water fish such as rainbow trout and steelhead salmon (53.6 to 64.4 °F, 12-18°C optimal) and below the lethal limit (77°F, 25°C, reference: Habitat Requirements for Freshwater Fish, Morrow, James V. and Fischenich, Craig, May 2000). It is expected that temperatures in exposed pools during intermittent low-flow drought conditions will reach levels tolerated by fish assemblages adapted to warm water conditions including the California roach assemblage (77-86°F, 25-30°C), and Sacramento suckers which can be found in streams with temperatures ranging from 59-86°F (15 - 30°C) (Moyle 2002).

Turbidity

In 1987, Strawberry Creek Management Plan monitoring found turbidity levels "generally lower than those reported for other Bay Area creeks and lower than previously observed levels." Turbidity tended to increase downstream in both forks, ranging from 1.1 to 9.8 NTU during dry weather. Turbidity during wet weather increases to 230- 590 NTU.

Since 1987, turbidity has generally been very low (much less than 50 NTU) during dry weather, but occasionally increased greatly when construction sites, water main breaks, and spills produce fine sediment laden runoff. Until the campus implemented storm water construction specifications in 2000, silted water from construction sites was routinely discharged to storm drains, causing the creek to become very turbid during dry conditions and covering the creek bed with fine sediments.

Metals

Metals in Strawberry Creek can be toxic to creek dwelling organisms and contribute to metal loadings in San Francisco Bay. SF Bay is listed on the Clean Water Act 303d list of impaired water bodies for a number of organic compounds and two metals, mercury and copper. While California native soils contain natural concentrations of metals that can cause toxicity, several urban point and non-point sources, such as automotive tire and brake dust, can contribute to unacceptably high concentrations of metals that can present a human health or ecological health risk.

In 1987, Strawberry Creek Management Plan dry weather monitoring found that "metals concentrations in both forks of Strawberry Creek were low compared to natural background levels found in California rivers and concentrations observed in other East Bay creeks. Average metals concentrations were similar in both forks and were generally higher downstream compared to the canyon sampling locations." Elevated mercury and lead were found in some samples. Wet weather sampling found that "metal concentrations generally increased significantly over baseline" with higher concentrations in the North Fork and overall higher average wet weather concentrations that other East Bay creeks. Wet weather metals concentrations greatly exceeded RWQCB standards. Elevated metals concentrations were also found in discharges from two point sources (Zellerbach/ Sproul #68, believed to be a cooling tower discharge) and the Cross Campus Culvert.

Dry weather water quality samples taken on July 27, 2001 from the north and south fork showed levels of metals below detection limits, except for zinc (22 µg/L) on the North Fork. (Table 2) (Note: detection limits for some of the metals, including arsenic, copper, mercury and silver were higher than RWQCB objectives. Future analyses should have lower detection limits to determine whether objectives are met.)

Wet weather samples were purposefully taken during the first rain of the year in order to determine concentrations in the "first flush", when pollutant concentrations are likely higher than any other time in the rainy season from washing of accumulated pollutants on surfaces. Samples taken on September 1, 2000 showed that both forks of Strawberry Creek near their confluence had levels of some metals exceeding RWQCB and EPA objectives. Results of this sampling are displayed in Table 3 along with SF Basin Plan Water Quality Objectives and Federal Ambient Water Quality Criteria for inland surface waters. Both the 1987 and 2000 water samples were gathered during the first flush rainfall, so contaminant concentrations are presumably comparable. Average concentrations during the rainy season would be expected to be lower than these results.

On September 1, 2000, zinc concentrations were found to be over three times the EPA instantaneous objective of 170 µg/L on both forks. On the South Fork, instantaneous concentrations of copper, lead and mercury concentrations exceeded the EPA's 1-hour average maximum objectives, while only copper exceeded objectives on the North Fork. The EPA and RWQCB do not provide instantaneous maximum objectives for these metals, and a comparison to one-hour objectives is useful only for a rough estimate of the degree to which metal levels are elevated in the creek's water. Mercury levels on both forks exceeded the RWQCB objective of 0.05 ug/L. Concentrations averaged 0.77µg/L on the North Fork and 2.50 µg/L on the South Fork.

In conclusion, the limited sampling results to date indicate that metals in Strawberry Creek water are not a significant pollutant, except possibly during the shock loading of early portions of rain events. More extensive water quality monitoring for these metals on different sites on both forks would be useful to determine their source and to assess toxicity impacts and mass loading to the San Francisco Bay. It is recommended that future monitoring also include biological assays to determine whether these discharges are affecting the ecological health of creek.

1.6 Ambient Conditions: Sediments

As a sink or reservoir for trace metals, pesticides and other urban pollutants, sediments are a potential source of direct toxicity to aquatic organisms and a source of bioaccumulative toxic compounds through the food chain to higher trophic organisms, such as Cooper's hawks and red tail hawks, known to feed on the campus.

In 1987, Strawberry Creek Management Plan monitoring found that concentrations of most trace metals in creek sediments were generally within expected background ranges. Lead and zinc appeared to be elevated above background in both forks, probably from urban pollutants. Mercury was found to be elevated in the North Fork, and this was attributed to a possible multiple sources.

In 2001, EH&S sampled sediment on the North and South Forks in the Eucalyptus Grove near their confluence to determine metal concentrations. Composite sediment samples from the top six inches of the creek bed were taken and sent to a California certified laboratory. Results are presented in Table 4.

Table 4: Sediment Metals North and South Forks

	1987		2001					
	North Fork DS	South Fork DS	North Fork Black-berry Cyn	North Fork Univ. House	North Fork DS	South Fork DS	RL	LBNL Bkd.
Antimony	-	-	ND	ND	ND	ND	3.00	5.5
Arsenic	-	-	2.2	2.7	1.8	2.4	0.25	19.1
Beryllium	-	-	0.25	0.23	0.21	0.21	0.10	1.0
Cadmium	<0.5	<0.5	0.93	1.1	1.4	1.2	0.25	2.7
Chromium	27	21	12	21	33	21	0.50	99.6
Copper	31	37	15	25	17	12	0.50	69.4
Iron	13,000	11,000	11,000	12,000	1,300	11,000	5.00	-
Lead	52	35	12	24	91	8.3	0.15	16.1
Magnesium	-	-	-	-	3,700	2,800	25	-
Mercury	2.1	<0.4	0.15	0.14	0.19	0.073	0.019	0.4
Nickel	24	19	15	30	27	24	1.00	119.8
Selenium	-	-	ND	ND	ND	0.27	0.25	5.6
Silver	-	-	ND	0.33	ND	ND	0.25	1.8
Thallium	-	-	ND	ND	ND	ND	0.25	27.1
Zinc	150	110	79	85	74	44	1.00	106.1

Notes:
All results in mg/kg (ppm).
RL= laboratory reporting limit. DS= Downstream (Eucalyptus Grove).
1987 samples reported in Charbonneau (1987) and obtained on August 13, 1987.
2001 samples obtained by UC Berkeley EH&S on July 27, 2001 and Sept. 7, 2001.
LBNL background metal concentrations from soil samples at 71 monitoring wells. From LBNL (1995).

Sediment metal concentrations measured in 2001 were generally within expected background levels in the soil and rocks near the headwaters of Strawberry creek as compared to those measured in 1995 at LBNL (LBNL 1995). The only metal in the creek's sediment found to significantly exceed these background levels was lead on the North Fork near its confluence with a sediment concentration of 91 mg/kg, which is equal to the NOAA Freshwater Sediment Probable Effects Level of 91.3 mg/kg, indicating that it could pose a risk to benthic invertebrates. Whether this is the result of a pollutant source or within the range of naturally occurring background cannot be determined without further sampling. The only other metal exceeding NOAA freshwater sediment reference values is nickel, which has been analyzed consistently between the Threshold Effects Level (TEL) of 18.0 mg/kg and the probable effects level (PEL) of 35.9. This level may be due to normally occurring background concentrations.

In conclusion, limited sediment sampling has been performed through the fifteen years of Strawberry Creek Management Plan implementation and analysis has been restricted to metals. As screening data these results indicate that metal concentrations in sediment do not appear to be present at levels that would pose a significant ecological risk. However, there has not been sufficient sampling to conclusively rule out ecotoxicity, particularly if concentrations fluctuate on a seasonal basis.

Dry weather water quality, wet weather water quality, and sediment sampling suggests that metal concentrations have not significantly changed between 1987 and 2001 in Strawberry Creek. Most of the priority pollutant metals present in Strawberry Creek are associated with urban runoff, suggesting that there has been little change in urban runoff quality in the Strawberry Creek watershed since 1987.

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Appendix 1 : Strawberry Creek 2006 Water Quality Status Report- Coliform Analyses

Total Coliform and E-coli Analysis Using IDEXX QuantiTray 2000 System
April 2004 to November 2005

Sampling Location Key
UHOSE = North Fork by University House
VLSB = North Fork by Valley Life Science Building
INCH = South Fork by Men's Faculty Club
HAAS = South Fork by Haas Pavilion
NFEG = North Fork in Eucalyptus Grove
SFEG = South Fork in Eucalyptus Grove
OXFORD = Main Branch before entering Oxford culvert

Sampling Date	Sampling Location	Total Coliforms	E-coli
4/5/04	UHOSE	>2419	980
4/5/04	VLSB	185	4.1
4/5/04	INCH	261	33.1
4/5/04	HAAS	1120	93.2
4/5/04	NFEG	1986	90.7
4/5/04	SFEG	1732	118.7
4/5/04	OXFORD	2419	146.7
5/3/04	UHOSE	>2419.2	2419.2
5/3/04	VLSB	2419.2	25.9
5/3/04	INCH	>2419.2	387.3
5/3/04	HAAS	2419.2	488.4
5/3/04	NFEG	>2419.2	344.8
5/3/04	SFEG	2419.2	290.9
5/3/04	OXFORD	>2419.2	184.2
6/7/04	UHOSE	>2419	290.9
6/7/04	VLSB	2419	16.1
6/7/04	INCH	2419	1046.2
6/7/04	HAAS	2419	517.2
6/7/04	NFEG	2419	21.6
6/7/04	SFEG	>2419	410.6
6/7/04	OXFORD	>2419	160.7
7/6/04	UHOSE	>2419	727
7/6/04	VLSB	>2419	53
7/6/04	INCH	>2419	435.2
7/6/04	HAAS	>2419	613.1
7/6/04	NFEG	>2419	35
7/6/04	SFEG	2419	214.2

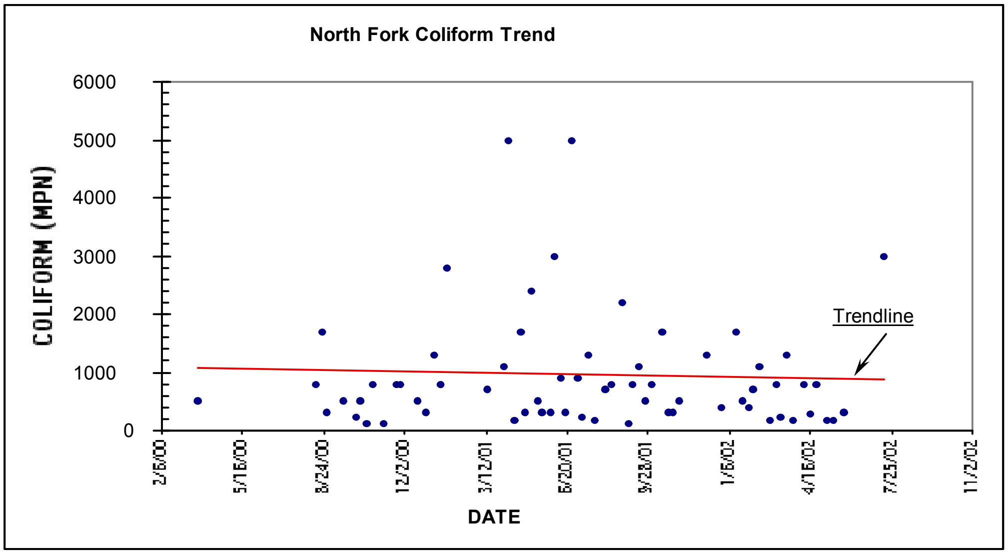
7/6/04	OXFORD	>2419	71.2
Sampling Date	**Sampling Location**	**Total Coliforms**	**E-coli**
8/2/04	UHOSE	>2419	1413.6
8/2/04	VLSB	>2419	69.7
8/2/04	INCH	>2419	248.1
8/2/04	HAAS	>2419	344.8
8/2/04	NFEG	>2419	816.4
8/2/04	SFEG	>2419	816.4
8/2/04	OXFORD	>2419	517.2
9/7/04	UHOSE	>2419	1986.3
9/7/04	VLSB	>2419	410.6
9/7/04	INCH	>2419	368.1
9/7/04	HAAS	>2419	1732.9
9/7/04	NFEG	>2419	648.8
9/7/04	SFEG	>2419	1553.1
9/7/04	OXFORD	>2419	579.4
10/5/04	UHOSE	>2419	>2419
10/5/04	VLSB	2419	142.1
10/5/04	INCH	1986	101.9
10/5/04	HAAS	>2419	290.9
10/5/04	NFEG	>2419	137.6
10/5/04	SFEG	>2419	488.4
10/5/04	OXFORD	>2419	209.8
11/1/04	UHOSE	>2419.2	248.1
11/1/04	VLSB	1553..1	40.4
11/1/04	INCH	>2419.2	248.9
11/1/04	HAAS	>2419.2	204.6
11/1/04	NFEG	>2419.2	69.7
11/1/04	SFEG	>2419.2	328.2
11/1/04	OXFORD	>2419.2	285.1
12/6/04	UHOSE	>2419.2	387.3
12/6/04	VLSB	>2419.2	93.3
12/6/04	INCH	>2419.2	190.4
12/6/04	HAAS	>2419.2	1413.6
12/6/04	NFEG	2419.2	63.8
12/6/04	SFEG	2419.2	980.4
12/6/04	OXFORD	2419.2	238.2
1/3/05	UHOSE- Wet	>2419.2	1203.3
1/3/05	VLSB- Wet	>2419.2	770.1
1/3/05	INCH	>2419.2	122.3
1/3/05	HAAS - Wet	>2419.2	461.1
1/3/05	NFEG- Wet	>2419.2	435.2
1/3/05	SFEG - Wet	2419.2	686.7

1/3/05	OXFORD - Wet	>2419.2	686.7
Sampling Date	**Sampling Location**	**Total Coliforms**	**E-coli**
2/7/05	UHOSE- Wet	>2419.2	648.8
2/7/05	VLSB- Wet	>2419.2	1732.9
2/7/05	INCH - Wet	>2419.2	517.2
2/7/05	HAAS - Wet	>2419.2	920.8
2/7/05	NFEG- Wet	>2419.2	1299.7
2/7/05	SFEG - Wet	>2419.2	1299.7
2/7/05	OXFORD - Wet	>2419.2	1553.1
3/7/05	UHOSE	1413.6	387.3
3/7/05	VLSB	>2419.2	920.8
3/7/05	INCH	1553.1	156.5
3/7/05	HAAS	1553.1	275.5
3/7/05	NFEG	>2419.2	105
3/7/05	SFEG	1413.6	214.2
3/7/05	OXFORD	1299.7	238.2
4/4/05	UHOSE- Wet	>2419.2	>2419.2
4/4/05	VLSB- Wet	1986.3	313
4/4/05	INCH	1986.3	117.8
4/4/05	HAAS - Wet	1986.3	184.2
4/4/05	NFEG- Wet	>2419.2	410.6
4/4/05	SFEG - Wet	2419.2	196.8
4/4/05	OXFORD - Wet	>2419.2	248.1
5/2/05	UHOSE	>2419.2	547.5
5/2/05	VLSB	410.6	62
5/2/05	INCH	920.85	307.6
5/2/05	HAAS	1203.3	290.9
5/2/05	NFEG	488.4	90.9
5/2/05	SFEG	>2419.2	325.5
5/2/05	OXFORD	2419.2	148.3
6/6/05	UHOSE	>2419.2	>2419.2
6/6/05	VLSB	>2419.2	122.3
6/6/05	INCH	1553.1	206.3
6/6/05	HAAS	1413.6	137.6
6/6/05	NFEG	>2419.2	56.1
6/6/05	SFEG	1732.9	275.5
6/6/05	OXFORD	1986.3	193.5
7/5/05	UHOSE	>2419.2	2419.2
7/5/05	VLSB	>2419.2	29.2
7/5/05	INCH	1732.9	166.9
7/5/05	HAAS	1986.3	129.1
7/5/05	NFEG	1413.6	54.5
7/5/05	SFEG	2419.2	83.3

7/5/05	OXFORD	1732.9	272.3
Sampling Date	**Sampling Location**	**Total Coliforms**	**E-coli**
8/1/05	UHOSE	>2419.2	>2419.2
8/1/05	VLSB	>2419.2	344.8
8/1/05	INCH	1986.3	517.2
8/1/05	HAAS	>2419.2	866.4
8/1/05	NFEG	>2419.2	67
8/1/05	SFEG	>2419.2	488.4
8/1/05	OXFORD	>2419.2	260.2
9/6/05	UHOSE	>2419.2	1986.3
9/6/05	VLSB	866.4	7.4
9/6/05	INCH	1732.9	157.6
9/6/05	HAAS	1413.6	172.3
9/6/05	NFEG	613.1	82
9/6/05	SFEG	2419.2	222.4
9/6/05	OXFORD	1413.6	104.3
10/2/05	UHOSE	>2419.2	275.5
10/2/05	VLSB	1553.1	5.2
10/2/05	INCH	>2419.2	1732.9
10/2/05	HAAS	>2419.2	410.6
10/2/05	NFEG	387.3	2
10/2/05	SFEG	>2419.2	201.4
10/2/05	OXFORD	2419.2	155.3
11/7/05	UHOSE	>2419.2	2419.2
11/7/05	VLSB	488.4	12.2
11/7/05	INCH	>2419.2	365.4
11/7/05	HAAS	1553.1	410.6
11/7/05	NFEG	365.4	15.8
10/2/05	SFEG	980.4	172.2
11/7/05	OXFORD	1413.6	98.8

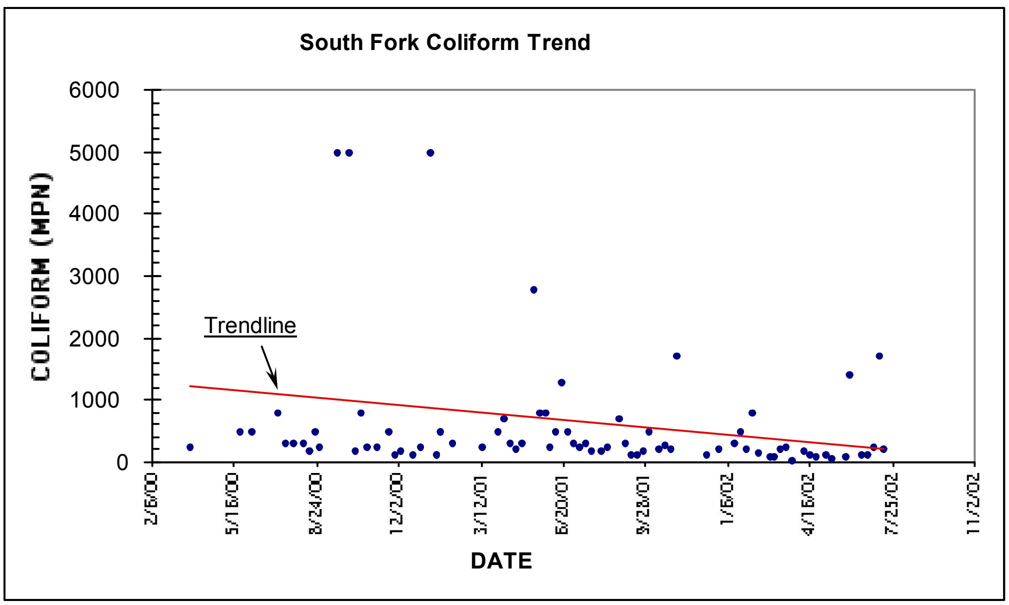
The following graphs (*figures 1 & 2)* were derived using the two years of Coliform data collected from the north and south forks of Strawberry Creek near the Eucalyptus grove. Wet weather events (rain in the last 72 hours) and sewage discharges were omitted from the data set[1]. Note that the average for both forks is below the **Water Quality Control Board**'s standards of 2000 MPN/100mL.

fig 1



Average Coliforms North Fork: 1550 MPN/100mL

fig 2



Average Coliforms South Fork: 1040 MPN/100mL

[1] Wet weather events that are preceded by extended dry periods show significant spikes in Coliform. This can be attributed to the accumulation of Coliform from sources such as fertilizers and animal waste. Similarly, sewage spills that reach the creek give high Coliform counts. Samples taken during precipitation events and sewage spills are not indicative of the "normal" Coliform amounts in the creek and are thus omitted from the data set used to create the graphs.