EVALUATION OF URBAN WATER QUALITY
TASK 4 REPORT

SAN LORENZO RIVER WATERSHED MANAGEMENT PLAN UPDATE

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San Lorenzo River Watershed Management Plan Update 2000
Evaluation of Urban Water Quality
Task 4 Report

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SUMMARY

The County of Santa Cruz prepared a Watershed Management Plan for the San Lorenzo River which was adopted in 1979. That Plan addressed various water quality issues affecting the San Lorenzo River, including septic systems, urban runoff, erosion, and other nonpoint pollution sources. Since Plan adoption, many of the recommended measures for water quality protection have been implemented and other water quality protection efforts have also been implemented. However, the River continues to experience chronically high levels of bacteria, particularly in the urban areas which are served by sanitary sewers. The County received a Section 205(j) Water Quality Planning grant to update the Watershed Plan, with a particular emphasis on investigation and control of contamination from urban runoff. This report presents the results of those investigations of microbiological contamination, toxic contaminants, lagoon water quality, and urban runoff management. Other programs which address septic system management, nitrate reduction, and water supply protection are discussed in the Plan update and supporting documents.

<u>Pathogens and Microbiologic Contamination</u> - High levels of fecal coliform and other bacteria, in excess of established standards for safe body contact, occur in the lower San Lorenzo River and cause that area to be posted as unsafe for swimming on a year round basis. Elevated fecal coliform bacteria levels also occur at times in other suburban areas of the San Lorenzo Valley. Based on studies here and in other areas, the presence of a high fecal coliform bacteria level does not reliably indicate the actual public health threat or the source of contamination. There have been limited reports of illness that could be linked to swimming in local waters but links to present indicators have been weak. For this project additional sampling was conducted using <u>fecal coliform</u>, <u>*E. coli*</u>, <u>total coliform</u>, and <u>enterococcus</u> bacteria as indicators. Different potential source areas were investigated and comparative testing was done in other lagoons and in Monterey Bay. Water quality sampling using the four standard bacteria indicators listed above was coupled with a health risk survey of water users to determine the health of swimming areas adjacent to the San Lorenzo Rivermouth as well as other swimming/surfing areas for comparison.

The lower river tends to have a consistently high level of fecal coliform and enterococcus bacteria from the San Lorenzo River/Branciforte Creek confluence to the ocean. Sources of high bacteria are concentrations of birds and storm drain discharges. Sources of bacteria in the storm drain system include sewage spills, subsurface sewage leaks, and nonspecific, nonpoint sources of bacteria in urban areas from pet waste, garbage, decaying vegetation, organic fertilizer, and other sources. High levels of bacteria were found in most of the storm drains tested. The storm drains had generally high levels of all of the indicator bacteria and many were tidally influenced by incoming tides leading to a continual input of contaminants. The high levels of bacteria discharged to Monterey Bay from the San Lorenzo River are rapidly diluted by the Bay water.

<u>Health Risk Survey</u> - The health risk survey performed as part of this study showed that there are generally low levels of indicator bacteria producing a good quality swimming water in the beaches adjacent to the mouth of the San Lorenzo River as well as upstream of the City of Santa Cruz in the San Lorenzo River. While the safe swimming standard was almost always exceeded at the mouth of the river only one person out of the 165 persons interviewed that had been swimming or wading in that area became ill. The study included interviews of 1325 people at 58 different dates and locations along the coast. Only 11 people out of the total 1325 probably became ill from contact with water. More than half of the illnesses occurred from swimming during winter runoff periods, which presented an overall risk of illness of 4.89%. Risk of illness during the summer was only 0.41%. Incidence of illness was significantly more likely with fecal coliform levels over 200 cfu/100ml and enterococcus levels over 104 cfu/100ml. Enterococcus concentrations showed a strong statistical significant correlation with observed risk of illness. In general, the occurrence of illness was low relative to studies conducted in other areas.

Lagoon Water Quality - The lower River lagoon is a valuable aquatic habitat area and also has aesthetic values for the City. It is designated as critical habitat for steelhead trout. These values can be threatened by stagnation, excessive algae growth, and depressed dissolved oxygen levels. Sampling of conductivity, dissolved oxygen, temperature, pH, turbidity, and nitrate were conducted in conjunction with bacteriologic monitoring described above. An evaluation of lagoon water quality from 1988- 2000 showed a significant influence of the volume of freshwater inflow from upstream on conductivity, dissolved oxygen and fecal coliform levels. However, no particular degradation was observed, and more work would be needed to determine the desired level of inflow to be released downstream from the City's diversion above Highway 1.

Toxic Compounds and Other Urban Runoff Contaminants - Past studies in the San Lorenzo River Watershed have indicated low to nondetectable levels of heavy metals, pesticides, PCB's, oil, and grease in the San Lorenzo River and/or its biota. There have been no documented impacts on organisms or beneficial uses of the River resulting from urban runoff constituents. Follow-up studies were conducted as a part of this project to investigate possible accumulation of toxic compounds in resident and transplanted clams located in reaches of the River subject to urban runoff. Tests for heavy metals and trace organic compounds showed results similar to previous studies. Very low levels of only a small number of trace organic compounds (pesticides and PCB's) were found. The two compounds found were 2-7% of the level considered hazardous. Elevated levels of lead, zinc, and cadmium were found, but none of the compounds were found at levels that are known to cause a threat to human or biotic health. Zinc and cadmium are of geologic origin, while lead is a likely result of historic accumulations from vehicle emissions and occurs in significant levels in River sediments.

Conclusions and Recommendations for Urban Runoff Management - The primary impact of urban runoff is elevated bacteria during both summer and winter periods. Management measures to improve lagoon water quality and reduce bacteria levels fall into three broad categories: lagoon management, source control, and monitoring. Lagoon management involves managing water levels, tidal influence, freshwater inflow, vegetation, channel conditions, and public access in a manner to promote conditions that lead to improved water quality. The objective of water quality improvement needs to be balanced with other objectives for lagoon management, including water supply, public safety, recreation opportunity, aesthetics, fish and wildlife habitat, and budget constraints. Source control involves reducing the influx of contaminants into the storm drain system to the greatest extent possible, removing accumulations of contaminants before they reach the River, and potentially diverting storm drain flow to the sanitary sewer system for treatment at the sewer treatment plant and discharge through the ocean outfall. Ongoing monitoring is important to identify causes of contamination and evaluate effectiveness of management measures.

The City of Santa Cruz, and to a lesser extent the County, have implemented a number of efforts to improve lower River water quality and should pursue the following efforts:

1. Continue implementation of sanitary sewer upgrades, sewer maintenance and storm drain maintenance practices.
2. Conduct follow up monitoring of bacteria levels in storm drains and investigate sewer and storm drain conditions in locations where storm drains have high bacteria levels. Investigate and correct infiltration and illicit connections between sanitary sewers systems and storm drains.
3. Reduce other sources of bacterial contamination through education, ordinance, and agency practices for proper management of pet waste, garbage, storm drain inlets, and food facilities
4. Develop and implement a strategy to eliminate potetnial water quality impacts from camping and loitering in flood plain areas.
5. Implement a comprehensive urban runoff management program to reduce dry weather and wet weather pathogen levels in urban and suburban areas.
6. Consider requiring evaluation and repair of private sewer laterals, particularly in areas subject to high groundwater.
7. Consider implementing dry weather diversion of storm drain discharge to the sanitary sewer system where other control measures are unsuccessful at reducing bacteria levels.
8. Regularly monitor storm drains that discharge to the River to evaluate the effectiveness of improved management practices and to identify new or ongoing sources of contamination. Volume of flow and bacteria loading from various source areas should be measured or estimated to determine the relative contribution of the different sources.
9. Monitor overall lagoon water quality and the effects of improved lagoon management measures.
10. Complete the pathogen TMDL, and implement Phase II Storm Water Regulations.

<u>Other Water Quality Concerns</u> - Additional water quality issues are not addressed in this report because they are addressed elsewhere: impacts of erosion and sedimentation were addressed under Task 5 of this project; the introduction of pathogens and nitrates from in basin sewage disposal which may adversely effect recreational use and drinking water supply have been addressed through adoption of the San Lorenzo Wastewater Management Plan (1995) and the San Lorenzo Nitrate Management Plan (Plan); and other water quality impacts on water supply are addressed through the City of Santa Cruz Watershed Sanitary Survey. All of these water quality efforts and concerns are synthesized under the overall watershed management plan update that is the final task of this project.

MICROBIOLOGICAL CONTAMINATION

Surface water monitoring of the San Lorenzo River has revealed frequent occasions when levels of fecal coliform bacteria exceed safe body contact standards. These elevated levels indicate a potential public health hazard from the possible presence of microbiologic pathogens (bacteria, virus, fungi, or protozoa) from sewage or other sources. The highest bacteria levels occur persistently in the lower River as it runs through the sewered and highly urban area of Santa Cruz. These elevated bacteria levels significantly limit use of the River for swimming and wading. A major component of the Watershed Plan Update has been to evaluate sources and potential health hazard of high bacteria levels from urban runoff in the lower River.

Potential for Disease and Use of Indicator Organisms

Swimming in water which contains pathogenic micro-organisms can cause a variety of different illnesses including cholera, dysentery, typhoid, shigella, salmonella, hepatitis a, nonspecific gastroenteritis, respiratory illness, or skin rashes. Disease-causing micro-organisms may originate from human sources, including sewage or other swimmers, animal contamination, or natural sources. Most of the diseases that cause human illness are viral in nature but some are bacterial (*Legionella, Salmonella*). Algal blooms, due to ecotoxins produced, have also been known to cause symptoms that mimic gastrointestinal problems, including vomiting and diarrhea (Hellawell, 1986). Algae have also been associated with respiratory stress in some individuals, and have caused illness and death due to the ingestion of infected shellfish meats (National Indicator Study, 1993). The potential for disease and use of indicator organisms is further discussed in Appendix A.

In order to prevent the occurrence of water borne disease from swimming, public health agencies test swimming areas for possible contamination and seek to control any potential sources of pathogenic organisms. Because of the unknown number of organisms believed to cause waterborne disease and the complexity of most testing, it would be impossible to detect each organism potentially present. To regularly test for individual pathogenic organisms would be cost prohibitive and time consuming. Therefore agencies typically test for other organisms which ideally will reliably indicate whether there is contamination from human sewage or animal fecal sources. If such contamination is present, there is a high probability that pathogenic organisms could also be present. If the level of indicator organisms exceeds established standards, the probability of water borne illness is judged to be significant, and the agency may post a swimming area as unsafe until follow up samples show that the number of indicator organisms has dropped to “safe” levels.

Various water quality standards for safe swimming have been established using total coliform, fecal coliform, *E. coli*, and/or enterococcus organisms. Each of these indicators is found at levels exceeding one million organisms per gram in human fecal matter and has been assumed to be present when possible pathogens are present. One of the major problems with any of these indicators is that they are also found in very high levels in every warm blooded animal including birds and other animals found in nature as well as some found associated with the decomposition of vegetative matter (Rheinheimer, 1991). Numerous studies have shown that these indicators are not necessarily reliable in determining potential health risk or confirming sources of contamination, as discussed in Appendix A.

Without reliable indicator organisms, agencies seek to determine health risk based on knowledge of the causes of elevated indicator levels. If there is a confirmed discharge of sewage to a swimming area, there is a definite potential for disease. At such times, there is also an elevated concentration of fecal coliform and other indicator organisms originating from the sewage. However, there are frequently elevated indicator levels with no known sewage discharge or other source of contamination. A source can sometimes be identified through additional sampling to determine where the high levels of bacteria originate. For example sampling above and below a concentration of sea gulls may confirm that high levels of fecal coliform come from the sea gulls. Sampling within a storm drain network may pinpoint the location where leaking sewage enters the storm drain. Unfortunately, in many instances, the episode of high bacteria levels may pass without a source being identified. This is particularly true for dry weather urban runoff, stormwater, and other nonpoint sources of contamination.

Urban runoff carries high levels of inorganic and organic contaminants. Santa Cruz County studies of stormwater have recovered total and fecal coliform, and enterococcus microbial contaminants in numbers ranging from non-detectable to over 700,000 organisms per 100 milliliters of water. This is similar to results from similar studies performed in the U.S. and in Canada (Gold, 1992, Makepeace, 1995). The Canadian study included analysis for many more organisms but did not find pathogenic organisms other than *Salmonella*. The conclusion was that most of the contaminants were naturally occurring in birds and small animals and probably have little health risk implication to humans although without a health risk survey associated it is difficult to determine risk involved.

Santa Cruz County Testing Methodologies

Indicator monitoring using fecal coliform bacteria as a standard has been used in the Santa Cruz County Environmental Health monitoring programs on a weekly basis since 1970, and intermittently prior to that. Prior to 1970 there were several sanitary surveys conducted by different agencies in the watershed dating back to 1951 (Aston and Ricker, 1979). There have been several different organisms and methods used to determine the extent of contamination of various bodies of water throughout Santa Cruz County. These methods have been chosen based on the California Code of Regulations, proposed indicators believed by other researchers to be more indicative of human sewage contributions to the watershed, and through a comparison of bacterial indicators that the County EHS conducted on samples collected at ocean monitoring sites.

The County of Santa Cruz Environmental Health Services conducts water monitoring efforts at approximately 120 sites each month throughout Santa Cruz County encompassing both fresh and marine water environments. Prior to 1993, marine waters were examined using the multiple-tube method of analysis for total coliform bacteria and fresh water sites were examined using membrane filtration to determine levels of fecal coliform bacteria. Due to the extended period of time it takes to receive results via multi-tube analysis (up to 96 hours), the need for a rapid turn around time, and the non-specificity of the total coliform bacteria it became necessary to evaluate other indicators to determine the sanitary condition of a body of water.

Environmental Health conducted a parallel study on indicator bacteria from October 1992 to October 1993. During this period water collected from several ocean sampling sites was examined for total coliform bacteria, fecal coliform bacteria, *E. coli*, enterococcus bacteria, and fecal streptococcus bacteria by membrane filtration method and total coliform bacteria by multi-tube fermentation. Fecal streptococcus analysis was eliminated early in the study due to a lack of correlation with any of the other indicators. The results of the study found that when one of the indicators analyzed by membrane filtration exceeded recommended standards, generally the others would also exceed standards. The poor correlation of multi-tube analysis with any of the other membrane filtration results, and the length of time to get results led County staff to eliminate multi-tube analysis of total coliform from the program.

After eliminating multiple-tube fermentation, staff determined that testing for fecal coliform bacteria was probably the best method of determining water quality. This method was chosen over total coliform bacteria because of the ubiquitous nature of total coliform bacteria (Rheinheimer, 1991). Likewise, analysis for enterococcus bacteria was eliminated because it is also found in nature and there has not been a long history of test results. Fecal coliform bacteria was then chosen over *E. coli* because the former represents four different organisms believed to be intestinal in nature and includes *E. coli*, the test method is slightly easier, and during the parallel study it was noted that there was an almost 1:1 ratio of fecal coliform to *E. coli*. The four different genera represented by the fecal coliform group are: *Escherichia, Citrobacter, Enterobacter, and Klebsiella* (Rheinheimer, 1991). *E. coli* is the only organism in the fecal coliform bacteria group that has not been believed to survive and reproduce in nature (Rheinheimer, 1991). However, County Environmental Health personnel have found that most of the fecal coliform bacteria found in their testing are probably *E. coli* and believe that *E. coli* may be quite capable of surviving outside a warm-blooded host.

SCCEHS has used the recommended standard of 200 colony forming units (cfu) per 100 milliliters of water for both fresh water and marine water testing when testing for fecal coliform bacteria. A level of 200 cfu/100 ml indicates a need for follow up testing and investigation; a level exceeding 400 cfu/100ml requires posting of warning signs pending the outcome of further testing and investigation. If levels between 200 and 400 cfu/100ml. persist to the point that the 30 day logmean is likely to exceed 200 cfu/100ml., the area must also be posted. Since 1999, standards for enterococcus and total coliform are also required to be applied to ocean waters during the summer months, pursuant to AB 411.

Bacteria in the San Lorenzo River

Historical Trends

The first report of poor water quality in the lower San Lorenzo River was presented to the County Health Officer by the State Department of Public Health by letter report dated October 1, 1953. An investigation was conducted after a routine beach survey had revealed high levels of coliform organisms "exceeding numbers generally considered safe for recreational purposes".

Santa Cruz County Environmental Health Service has conducted regular testing of freshwater and saltwater swimming areas since 1968. Fecal coliform has been used as the test for freshwater during that whole period. Total coliform was used in salt water until 1994, when it was replaced by fecal coliform testing. Testing at swimming areas was performed weekly during the summer and intermittently at other times. Since 1986, weekly testing has been performed year round at regular sample sites on the Bay and in the San Lorenzo Watershed.

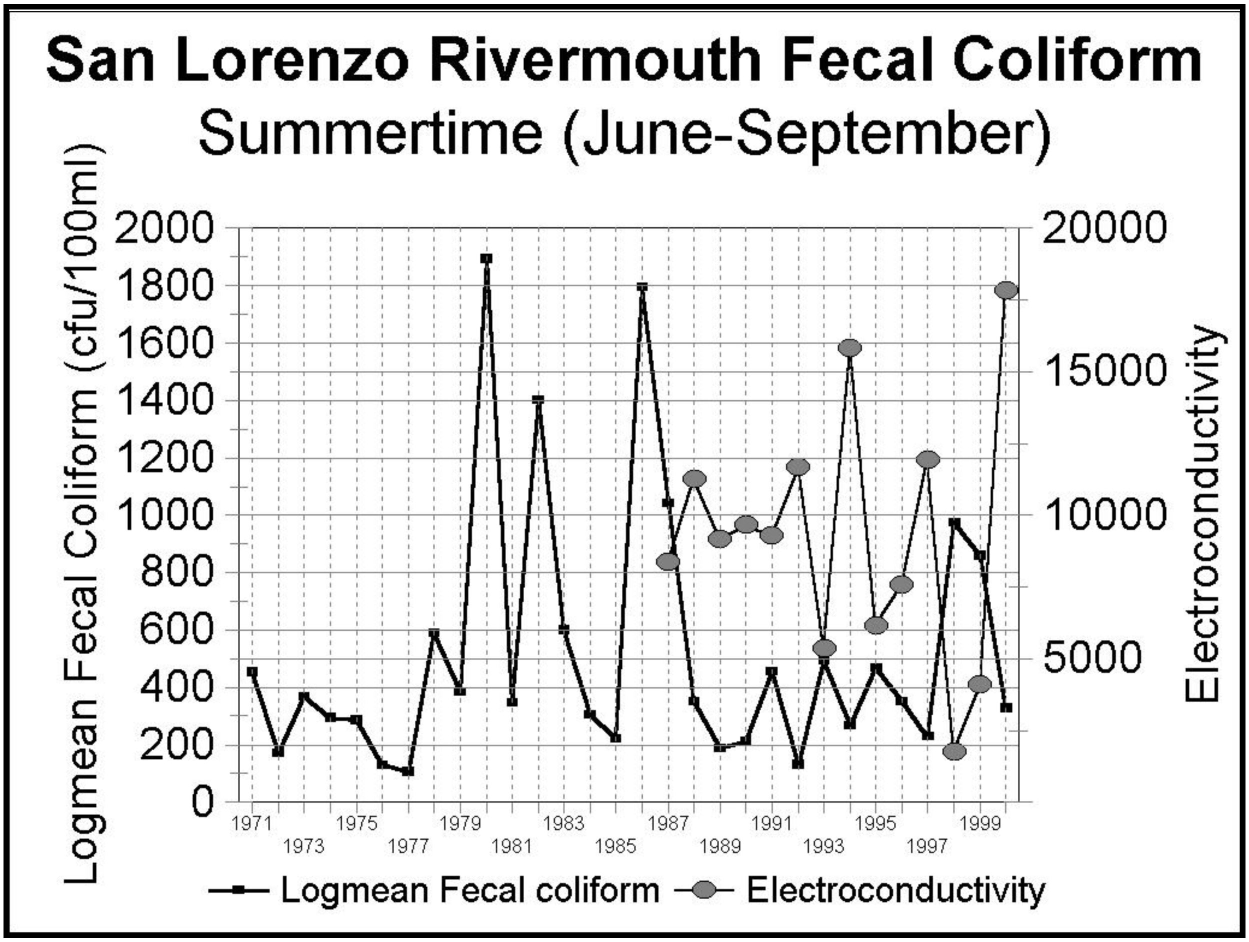
The fecal coliform standard for safe body contact contained in the Water Quality Control Plan for the Central Coast Basin states that the logmean of at least 5 samples in a thirty day period should not exceed 200 cfu/100ml and that not more than 10% of the samples should exceed 400 cfu/100ml. In actual practice, Santa Cruz County staff consider any level over 200 cfu/100ml as a potentially problematic and will conduct immediate follow-up testing. If two consecutive samples exceed 200 cfu/100ml, an area will generally be posted as potentially unsafe for swimming.

Beginning in 1999, the County was mandated to also use total coliform and enterococcus bacteria in its testing of heavily used ocean beaches (over 50,000 visitors per year, pursuant to AB 411). Beaches are posted as potentially unsafe for swimming if any one of the following standards is exceeded:

- 30-day logmean of fecal coliform exceeds 200 cfu/100 ml
- 30-day logmean of total coliform exceeds 1,000 cfu/100 ml
- 30-day Logmean of enterococcus exceeds 35 cfu/100 ml
- one sample has a fecal coliform level exceeding 400 cfu/100
- one sample has a total coliform level exceeding 10,000 cfu/100
- one sample has an enterococcus level exceeding 104 cfu/100
- one sample has a total coliform level exceeding 1,000 cfu/100 and the ratio of fecal coliform to total coliform exceeds 0.1.

The levels of fecal coliform contamination in the River vary significantly with season and location. During winter storm periods, the River has high fecal coliform levels throughout most of the watershed, ranging from 1000-3000 cfu/100ml. During a first flush storm on September 19, 1977, fecal coliform levels reached 70,000 cfu/100ml in the middle reaches of the River at Felton and 100,000 cfu/100ml in Santa Cruz (Aston and Ricker, 1979). However, during nonstorm periods, fecal coliform levels are typically well below standards immediately upstream from Santa Cruz with a log mean of 50-100 cfu/100ml. Higher levels (approximately 200 cfu/100ml) also occur in upstream suburban areas of the San Lorenzo Valley. At the Rivermouth, the log mean has averaged approximately 400 cfu/100ml, twice the level considered safe for swimming. Storm drains discharging to the River in Santa Cruz have had levels ranging from 100 to 13,000 cfu/100ml. Ocean waters near the mouth of the River generally meet standards except during and immediately after storm events. Historical fecal coliform levels at the San Lorenzo Rivermouth (at the trestle) from 1971- 2000 are shown in Figure 1.

Figure 1: Historical Trends in Fecal Coliform, San Lorenzo Rivermouth, 1971-2000



The lagoon at the Rivermouth has been posted as unsafe for swimming on a permanent basis since at least the 1980's. The ocean beach has only been posted as unsafe for swimming during the summer on two occasions since 1985. County Environmental Health issues a regular warning through the media during winter months to warn people that River waters and the ocean in the vicinity of the River are unsafe for swimming due to high bacteria levels during and immediately after storm events.

The levels of fecal coliform and other indicator organisms found in the Lower San Lorenzo River are typical of two other large coastal streams in Santa Cruz County which flow through dense urban areas: Aptos Creek and Soquel Creek. All three of these creeks seem to consistently experience the highest levels of fecal coliform right at the mouth, in an area which is subject to some marine influence. Smaller urban creeks which do not generally experience such high levels of bacteria are Corcoran Lagoon (Rodeo Gulch) and Moran Lake. Further analysis and comparison of these different lagoons may help to better understand the cause and significance of the elevated bacteria levels.

Focused Lower River Monitoring

A detailed sampling program was conducted in 1995-97 to further identify the extent, sources, and public health significance of microbiologic contamination in the lower San Lorenzo River. Bacteriologic monitoring in the upper watershed continued as a part of the County's routine sampling program. While there are considerable efforts being undertaken to identify a better indicator of sewage contamination and potential public health hazard, the County has, in the meantime, continued to use the standard indicators of fecal coliform, enterococcus and *E. coli*. Despite the limitations of these indicators, there is substantial comparative data available for Santa Cruz County and in the literature. They provide useful information, particularly when used in conjunction with source investigations and health risk assessments. The use of more elaborate microbiological methods will be further explored and pursued in the future as appropriate.

Basic River and Ocean Monitoring

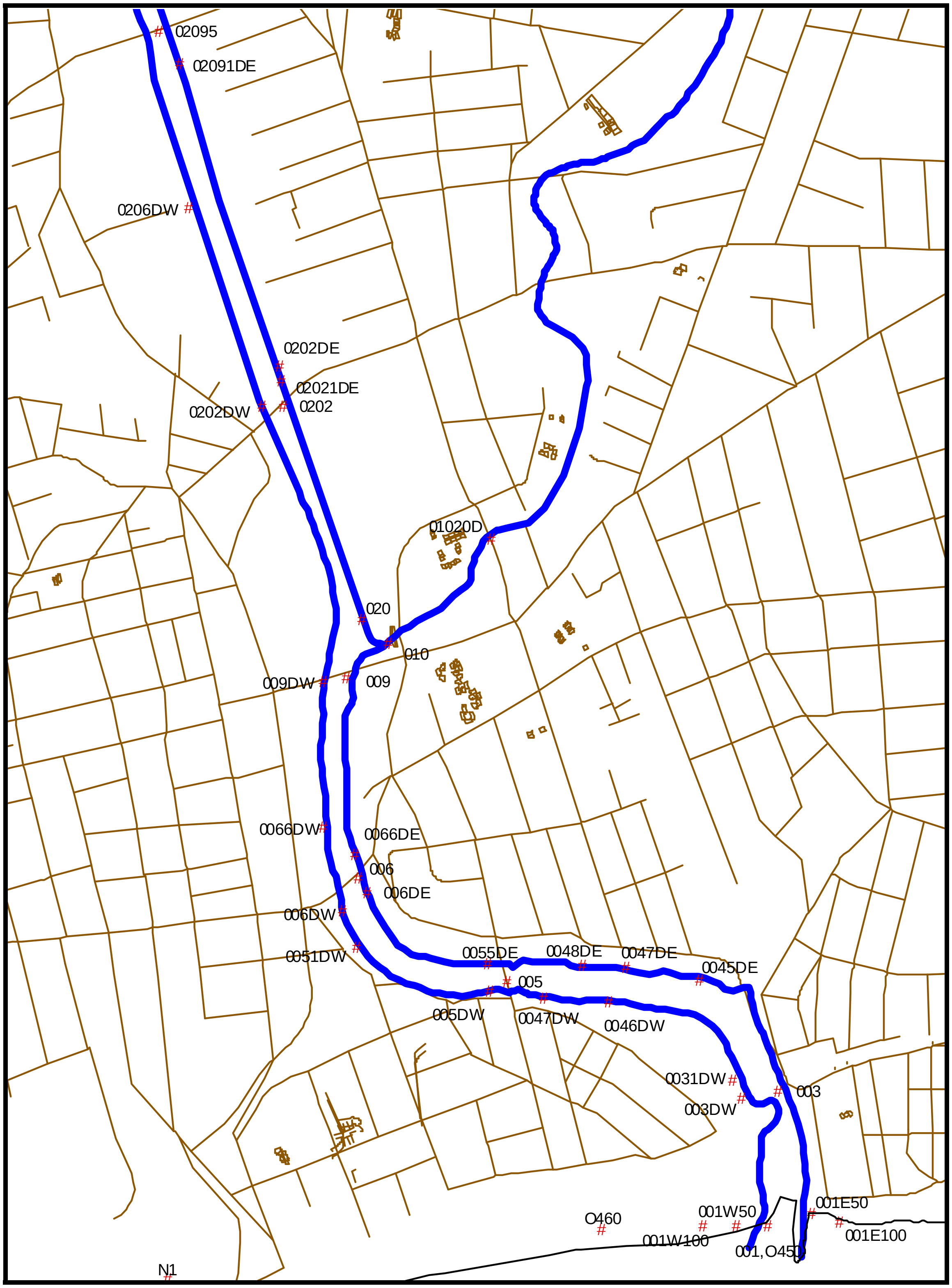
In order to provide a good basic data set on microbiologic conditions, samples were taken from December 1995 through March 1997 at ten primary sites on the Lower San Lorenzo River and four primary sites adjacent to the discharge point of the San Lorenzo Rivermouth at Monterey Bay. (See Figure 2)

Samples were taken every two weeks during an ebb tide and as close to the low tide as possible. Samples, in addition to these primary sites, were taken to investigate and bracket areas of high bacterial contamination and localize sources of contamination.

Samples were tested for fecal coliform bacteria, *E. coli* bacteria, enterococcus bacteria, and nitrate-nitrogen. Health risk survey sites were tested additionally for total coliform bacteria. All sites were measured for dissolved oxygen, pH, temperature, turbidity, and conductivity with each sample taken.

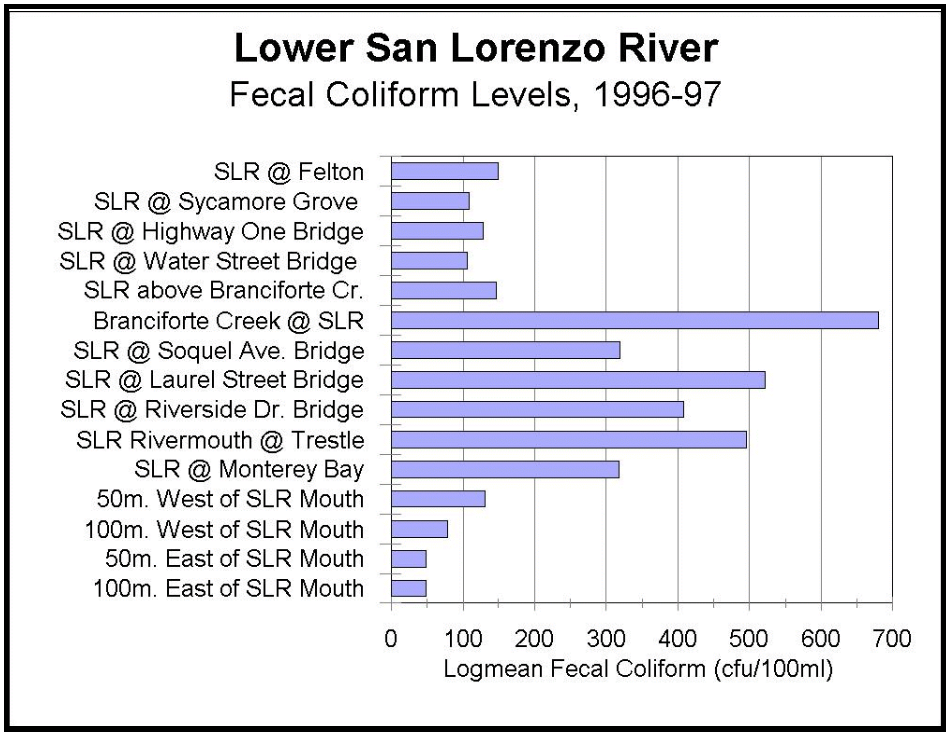
During several significant rainstorms, beaches adjacent to the San Lorenzo River were sampled and tested for fecal coliform bacteria, *E. coli* bacteria, and enterococcus bacteria to determine the extent of the impact of the San Lorenzo River on local beaches. Ten sites west and ten sites east of the point of discharge of the San Lorenzo River and spaced twenty five meters apart were tested for turbidity, fecal coliform bacteria, *E. coli* bacteria, and enterococcus bacteria. It was recognized that Neary Lagoon was discharging at this same time so discharge waters from Neary Lagoon were also tested. Visual analysis was made to separate the discharge plumes from the San Lorenzo River and Neary Lagoon. Testing was also run in conjunction with both the winter and summer Health Risk Surveys where water users were asked questions concerning any illness they may have contacted during exposure to possibly contaminated water. Water samples were taken knee-deep at the impact zone.

Figure 2: Lower San Lorenzo River Sampling Locations - Station Names and data are presented in in Tables 1 and 2 .



The lower river surface water sampling and analysis comprised 25 different sample days and resulted in 363 samples analyzed. Figure 3 graphically displays the fecal coliform data, showing the logmean (geometric mean) of fecal coliform results for all samples collected during that time period. . Mean contaminant levels for surface water sites are shown in Table 1. Data is separated into wet and dry conditions.

Figure 3: Fecal Coliform at Lower River Stations, 1996-97



During dry weather, the River showed a dramatic change in water quality in vicinity of the confluence with Branciforte and the Soquel Avenue bridge. Upstream, both the fecal coliform levels and enterococcus levels were relatively low and met fecal coliform standards for safe body contact. Downstream, both types of bacteria increased by a factor of 4 and exceeded standards for safe swimming, from Branciforte Creek to the Rivermouth. (It should be noted that limited sampling since January, 1996, has shown much improved bacteria levels in Branciforte Creek and at Soquel bridge, but continued elevated levels at the Laurel/Broadway Bridge.)

Table 1: Mean Contaminant Levels of Primary Surface Water Sites - Wet conditions are more than 0.2 inches of rain within the previous three days.

Station Number-Location (See Figure 2)	# Samples		Electrical Conductivity µohms		Fecal Coliform logmean cfu/100ml		*E.coli* logmean cfu/100ml		Total Coliform logmean cfu/100ml		Enterococcus logmean cfu/100ml		Nitrate mg-N/l	
	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**
022 - SLR @ Sycamore Grove	15	**2**	365	**260**	67	**2,903**	65	**3,041**	774	**--**	64	**18,600**	0.35	**0.65**
02028 - SLR @ Hwy 1 Bridge	16	**7**	385	**304**	53	**940**	69	**1,149**	362	**--**	57	**2,379**	0.32	**0.43**
0202 - SLR @ Water Street Bridge	17	**7**	395	**323**	59	**556**	67	**881**	396	**--**	50	**2,094**	0.31	**0.44**
020 - SLR above Branciforte Cr.	16	**7**	396	**307**	84	**530**	65	**939**	372	**--**	88	**1,319**	0.31	**0.44**
010 - Branciforte Cr. @ SLR	16	**6**	494	**313**	539	**1,266**	414	**1,329**	2,097	**--**	378	**2,320**	0.51	**0.99**
009 - SLR @ Soquel Ave. Bridge	16	**6**	463	**311**	280	**450**	280	**1,402**	1,600	**--**	172	**2,115**	0.46	**1.00**
006 - SLR @ Laurel St. Bridge	44	**17**	1,767	**500**	475	**633**	413	**652**	1,325	**8,400**	348	**2,229**	0.38	**0.78**
005W - SLR @ Riverside Dr. Bridge	16	**6**	5,282	**2,650**	245	**1,587**	305	**1,493**	1,372	**--**	206	**1,807**	0.43	**0.51**
003 - SLR @ Trestle, Rivermouth	47	**18**	6,966	**2,066**	345	**1,094**	320	**5,445**	1,320	**5,300**	140	**3,074**	0.30	**0.42**
001 - SLR @ Monterey Bay	33	**8**	15,986	**7,751**	206	**2,123**	189	**2,933**	801	**--**	115	**3,561**	0.32	**0.52**
001W50 - 50m. West of Mouth	21	**8**	38,587	**31,672**	58	**1,114**	56	**1,225**	75	**--**	29	2,270	--	0.48
001W100 - 100m. West of Mouth	19	**7**	44,860	**32,169**	37	**605**	57	**1,178**	83	**--**	31	**2,662**	--	0.54
001E50 - 50m. East of Mouth	22	**11**	33,564	**27,072**	22	**343**	39	**517**	132	**889**	**33**	**767**	0.35	0.93
001E100 - 100m. East of Mouth	18	**12**	37,307	**33,457**	24	**340**	41	**428**	203	**866**	**13**	**551**	--	**0.83**

The State and County bacterial standards for safe swimming are:

Fecal coliform: logmean of 200 cfu/100ml; single sample standard of 400 cfu/100ml
Enterococcus logmean of 35 cfu/100ml; single sample standard of 104 cfu/100ml
Total Coliform logmean of 1,000 cfu/100ml; single sample standard of 10,000 cfu/100ml
The EPA has proposed an additional standard for E. coli: logmean of 125 cfu/100ml

The nitrate objective for the San Lorenzo River is 0.33 mg-N/L

Factors which may cause the change in water quality in the lower reach are: the upper extent of tidal action, congregations of waterfowl on sandbars which are intermittently exposed and flooded, and discharge of storm drains. The areas adjacent to the River in this reach also are much lower, and more subject to elevated groundwater levels that periodically inundate storm drains and sanitary sewers. Average bacteria levels decline slightly toward the ocean from the Laurel Street/Riverside Reach, most likely as a result of dilution from incoming ocean water. The historical data for the Rivermouth shows lower bacteria levels with increased conductivity (more influence by ocean water) (see Figure 1).

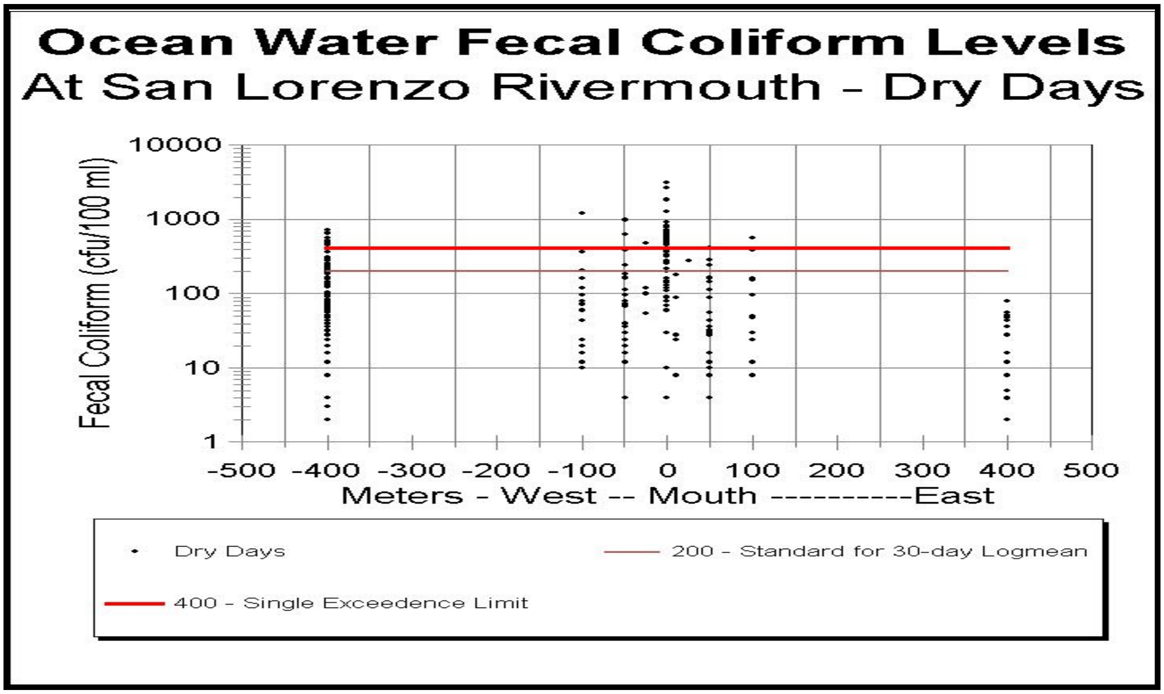
During storm periods, the River has elevated fecal coliform and enterococcus levels in excess of safe standards throughout its length in the lower River. Although the average data in Table 1 suggest that levels are higher upstream of Highway 1 at Sycamore Grove, an inspection of daily data shows that during most storm periods bacteria levels are typically higher in the downstream urban areas than they are upstream. Long term fecal coliform data for the River during storm periods show average levels (logmeans) of 872 cfu/100 ml. at Felton, 616 cfu/100 ml at Sycamore Grove, 1500 cfu/100 ml. at Laurel/Broadway Bridge, and 1014 cf/100 ml at the Rivermouth (Trestle).

It is interesting to note variations in the ratio of fecal coliform to enterococcus. The ratio between fecal coliform and enterococcus in the River above Branciforte is close to 1.0. In Branciforte, and downstream, during dry weather, the ratio is closer to 1.5-2.0. However, during storm periods, and in most dry weather storm drain discharges, the ratio of fecal coliform to enterococcus is 0.25-0.5. A limited number of samples collected from areas known to be subject to waterfowl show a ratio of 2-4 (San Lorenzo Park duck pond and Schwann Lake discharge). The higher ratio in the lower River may suggest a substantial influence from waterfowl. The use of this ratio needs further assessment.

The effect of the River discharge on ocean water quality is fairly limited during dry periods but more widespread during periods of runoff. Table 1 shows low levels of bacteria meeting standards, just 50 meters on either side of the River during dry conditions. However, during wet periods (with at least 0.2 inches of rain in the previous 3 days), standards are exceeded out to almost 400 meters from the Rivermouth (Figure 4). Bacteria counts to the west tend to rise further from the River, probably influenced by discharge from Neary Lagoon.

Bacteriologic data was also analyzed for other river and creek discharges in the County. This is presented in Tables 2 and 3, for summer periods only (June through September). Table 2 shows overall logmeans of fecal coliform and enterococcus for the period of 1987-2000 (enterococcus was only tested for in the latter years). Table 3 shows the summer fecal coliform logmean by year at each station to see if there are any parallels in trends. The River has relatively moderate levels of fecal coliform and enterococcus, compared to other urban creeks such as Aptos, Soquel, and Schwann Lake. Annual variations at different stations do not seem to follow any regional pattern.

Figure 4: Fecal Coliform Levels in Ocean at San Lorenzo Rivermouth



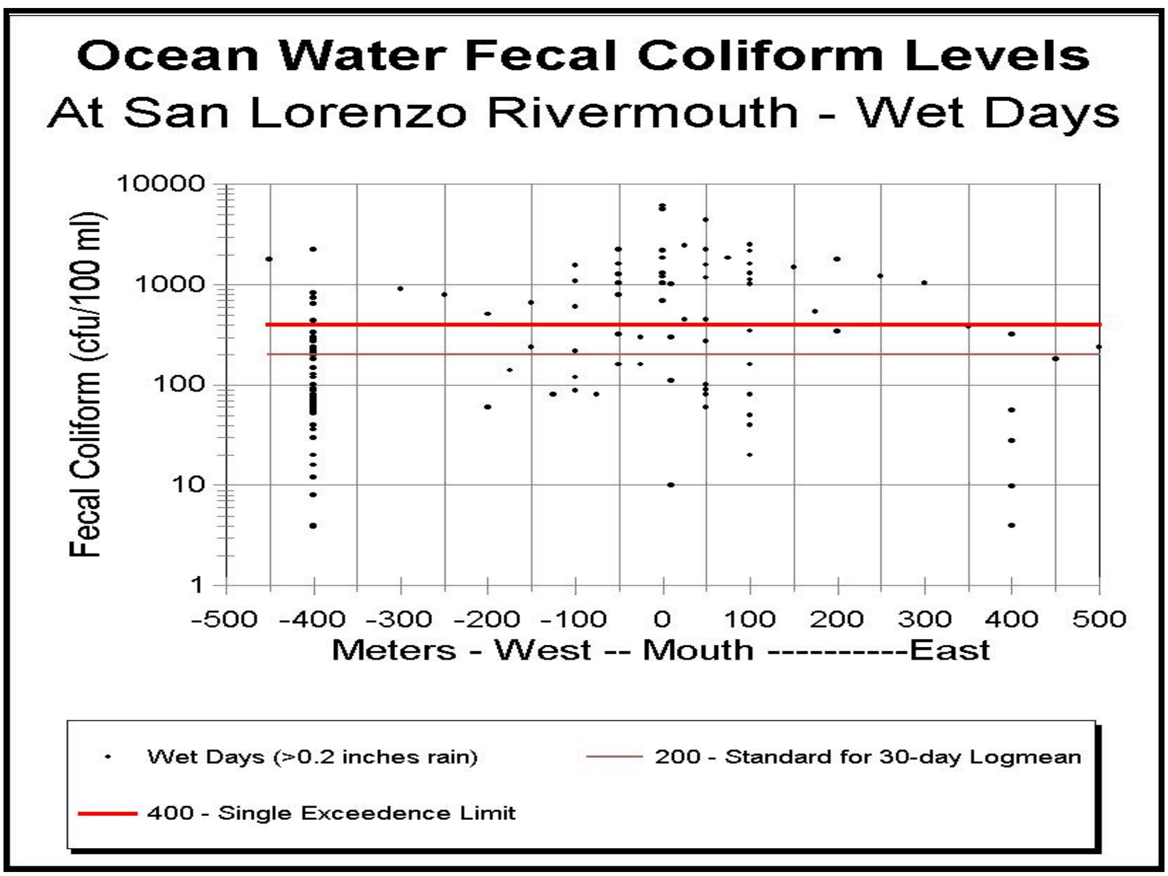


Table 2: Logmean of Summer Fecal Coliform and Enterococcus at Various County Creek Mouths, 1987-2000 (June-September)

Location	Number Fecal Coliform Samples	Logmean Fecal Coliform (cfu/100ml)	Number Entero-coccus Samples	Logmean Entero-coccus (cfu/100ml)
SLR Rivermouth @ Trestle	369	345	46	101
Pajaro R @ Mouth	98	109	2	--
Aptos Creek @ Mouth	283	635	19	1483
Soquel Cr @ Flume Outlet	112	455	16	251
Soquel Cr @ Flume Inlet (Mouth)	207	852	0	--
Corcoran L @ Mouth	93	80	3	--
Schwann Lake @ Mouth	187	887	11	362
Neary Lagoon @ Mouth	147	289	6	835
Woodrow Cr @ Mouth	114	436	1	--
Scott Cr @ Mouth	57	47	6	16
Waddell Cr @ Mouth	57	58	4	23

Table 3: Logmean of Summer Fecal Coliform (cfu/100ml) at Various County Creek Mouths, by Year, 1987-2000 (June-September)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
SLR Rivermouth, Trestle	902	445	266	203	330	204	365	213	532	464	221	514	653	195
Aptos Creek @ Mouth	632	348	621	990	968	1129	627	1336	833	458	505	242	570	365
Intel C @ Mouth	2939	595	1104	691	1053	311	1187	1690	973	288	170		521	44
Neary Lagoon @ Mouth	263	87	211	144	264	232	273	493	338	1114	328	561	160	564
Pajaro R @ Mouth	204	140	105	152	317	142	124	76	183	112	20	198	89	46
Corcoran L @ Mouth	385	62	33	56	20	805	61	120	222	137	31	84	19	188
Soquel Cr @ Mouth	1094	825	1100	1235	735	606	807	998	709	765	654			
Scott Cr @ Mouth	36	18	86	18	80	56	58	263	135	20	34	35	56	40
Schwann Lake @ Mouth	570	269	887	786	674	759	1440	1157	836	1561	1010	615	1045	815
Waddell Cr @ Mouth	67	32	32	87	311	50	71	136	98	84	39	34	79	35
Woodrow Cr @ Mouth	635	805	513	103	174	416	154	468	1638	529	678	263	53	168

Storm Drain Sampling

During and after periods of rainfall, storm drains were sampled to determine contamination. These samples were tested for fecal coliform bacteria, *E. coli* bacteria, enterococcus bacteria, and nitrate. Sample procedures were as in surface water sampling and included the monitoring for dissolved oxygen, pH, temperature, turbidity and conductivity. Testing for ammonia was added as an additional indicator of possible sewage contamination.

Additional storm drain sites were sampled when San Lorenzo River surface sampling indicated high bacterial contamination from the primary sites. The additional sites included gutters and ditches emptying into primary storm drains and other non-primary storm drain sites such as storm drains entering Branciforte Creek from the May and Market Street areas. Periodic sampling was also conducted during dry weather periods to assess non-storm contributions from storm drains. Some sites were sampled during high tide when the storm drain system is inundated with groundwater and the pump stations were operating. The effect of high tides is shown by the elevated conductivity values in the storm drain samples from the lower reaches. Data from storm drains is shown in Table 4, and is separated between dry weather and wet weather conditions. The data from dry weather conditions is somewhat limited in that there often was not enough flow to collect samples.

The data from storm drains shows a high level of variability, depending on the drain and the time sampled. For example, fecal coliform levels in the storm drain at Raymond Street ranged from 500 to 318,000 cfu/100ml. during dry weather, and from 220 to 13,300 during wet weather conditions. Upstream, fecal coliform levels in the Water Street storm drain ranged from 20-80 during dry weather, and from 660 to 17,060 cfu/100ml during wet weather. Storm drains on the west side of the River seemed to have more frequently elevated bacteria levels during dry weather.

Although ammonia was tested for at all storm drains, it was only detected in three drains: the Water Street Pump Sation (mean of 0.419 mg-N/l), Uhden Street (0.985), and the Trestle Pump Station (1.05). Nitrate levels at all storm drains were generally low to moderate. Neither the nitrate or ammonia levels are high enough to definitively indicate a major sewage contribution to any of the drains. The numbers could indicate a dilute contribution from swage, fertilizer, or other sources.

Sampling was also done of gutters and ditches to get a better determination of the contribution of surface runoff to the storm drains. Unlike storm drains, surface gutters and ditches are unlikely to be influenced by sewage (except in the case of recent spills). Two ditches and two storm water discharges are presented in Table 5 that were sampled on January 31, 1996 following a one day rainfall total of 3.54". The bacteria levels found in these ditches and the storm water discharges are similar to other random samplings taken over the past few years during rainfall events. Table 5 also shows three other sites that were sampled on January 16, 1996. The water sampled from the gutter at Emeline and Grant Streets had indicator bacteria levels tested that were too numerous to count, (TNTC). Other bacteria levels were much lower than the January 31, 1996 samples but still well above safe swimming levels. Recorded rainfall for January 16, 1996 was 4.41".

Table 4: Mean Contaminant Levels of Primary Storm Drain Sites - Wet conditions are more than 0.2 inches of rain within the previous three days. Sampling sites are shown in Fig. 2.

Storm Drain Location Station Number (See Figure 2)	# Samples		Electrical Conductivity µohms		Fecal Coliform logmean cfu/100ml		*E.coli* logmean cfu/100ml		Total Coliform logmean cfu/100ml		Enterococcus logmean cfu/100ml		Nitrate mg-N/l	
(w)=wet wells	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**	Dry	**Wet**
West- Josephine St.@ SLR (w) 0206DW	1	**3**	1,340	**349**	1,860	**826**	1,800	**617**	--	**20,000**	2,100	**1,663**	0.22	**0.92**
East - Pryce St. @ SLR(w) 02091DE	1	**3**	472	**314**	560	**7,891**	500	**3,634**	--	**--**	1,900	**9,592**	0.30	**1.64**
West - Water St. @ SLR(w) 0202DW	1	**6**	193	**202**	13,100	**9,144**	--	**12,203**	--	**--**	--	**10,476**	--	**1.18**
East - Water St. Gravity @ SLR(w) 02021DE	2	**7**	315	**254**	40	**1,709**	20	**1,658**	--	**--**	300	**4,557**	0.50	**1.09**
East - Water St. Pump @ SLR(w) 0202DE	2	**4**	393	**107**	--	**2,953**	81	**2,289**	--	**--**	100	**1,692**	0.07	**1.27**
Emeline St Gutter	--	**3**	--	**158**	--	**191**	--	**800**	--	**13,400**	--	**13,700**	--	**1.28**
East - Ocean St. @ Branciforte Cr. 01020D	--	**5**	--	**442**	--	**5,738**	--	**7,176**	--	**33,400**	--	**864**	--	**2.62**
West Side SLR @ Soquel Ave. 009DW	--	**2**	--	**659**	--	**1,597**	--	**1,400**	--	**--**	--	**4,600**	--	**0.48**
West - Broadway @ SLR(w) 0066DW	1	**3**	600	**813**	180	**2,051**	100	**2,105**	--	**--**	1,900	**16,293**	0.09	**1.62**
West-Broadway St. Pump Sta.(w) 006DW	1	**3**	1,500	**930**	460	**5,591**	480	**4,294**	--	**--**	100	**17,526**	0.09	**1.00**
East - Broadway (w) 0066DE	1	**3**	624	**667**	1,020	**1,975**	920	**1,767**	--	**--**	1	**4,880**	0.11	**0.91**
East - Below Broadway @ SLR(w) 006DE	1	**2**	2,080	**965**	120	**1,259**	80	**1,025**	--	**--**	500	**1,407**	0.87	**0.49**
West - Riverside @ SLR 005DW	1	**3**	1,880	**274**	20	**943**	120	**792**	--	**--**	1	**2,186**	0.03	**0.65**
West - Riverside/3rd @ SLR(w) 0047DW	5	**3**	14,506	**757**	8,639	**1,080**	9,347	**1,814**	--	**--**	5,456	**7,234**	0.41	**1.19**
West - Raymond St @ SLR(w) 0046DW	5	**3**	13,334	**520**	3,350	**1,977**	1,372	**2,169**	--	**--**	2,237	**3,035**	0.33	**0.63**
East - Bixby @ San Lor. Blvd(w) 0048DE	1	**3**	29,100	**353**	1	**767**	1	**916**	--	**--**	1	**774**	0.16	**0.84**
East - Ocean St. @ San Lor Blvd (w) 0047DE	1	**3**	9,500	**497**	540	**469**	600	**494**	--	**--**	300	**346**	0.28	**0.50**
East - Jessie St. Drain @ SLR(w) 0045DE	1	**6**	10,200	**494**	1,220	**884**	1,440	**1,388**	--	**32,015**	700	**2,775**	0.56	**0.40**
West - Trestle Pump Station(w) 003DW	2	**5**	8,075	**745**	170	**4,941**	148	**3,191**	340	**55,000**	556	**5,698**	--	**0.40**
West - Trestle Gravity Wet Well(w) 0031DW	2	**3**	7,745	**4,357**	14	**134**	13	**3**	780	**1,300**	18	**48**	--	**0.46**

Table 5: Bacteria Found in Ditches and Gutters

Date	Location	Fecal Coliform	*E.coli*	Enterococcus
January 16, 1996	Gutter at Emeline and Grant Streets	TNTC	TNTC	TNTC
January 16, 1996	SLR Trestle Levee Ditch	2,108	2,606	820
January 16, 1996	Gutter at Beach & 3rd Streets	2,232	1,488	160
January 31, 1996	Water St ditch @ County Parking Lot	19,600	14,740	8,500
January 31, 1996	Riverside Dr ditch @ Mike Fox Park	2,300	2,020	3,800
January 31, 1996	May St @ Branciforte Cr-North Storm Drain	18,400	20,800	12,700
January 31, 1996	May St @ Branciforte Cr-South Storm Drain	1,240	1,220	5,600
December 11, 1995	Gutter at Market St and Hubbard	7,015		
December 30, 1996	Gutter at Emeline and Button	8,800	10,300	19,000
December 30, 1996	Wendell and Emeline	1	200	1,400
January 25, 1996	San Lorenzo Park Duck Pond	2,400	2,600	600

Sediment Sampling

Studies in other areas have shown that indicator bacteria can survive and reproduce in bottom sediments, and can be a source of elevated bacteria levels when the sediments are resuspended. To determine the depth and extent of bacterial contamination and growth in sediment in the San Lorenzo River, sediment was sampled at several of the primary surface water sites at the end of the summer. Sediment sampling was conducted using sterile plastic tubes, pushed into the sediment to a given depth. Samples were then divided into segments and tested for fecal coliform bacteria, *E. coli* bacteria, total coliform, and enterococcus bacteria. This method of sampling is used by other researchers for chemical analysis and to characterize sediment composition. No nitrate analysis or dissolved oxygen/pH monitoring was done with sediment sampling.

Sediment collected from four locations was analyzed in 2 inch sections from 4 inch deep core samples taken on 28 October 1996. Samples were taken from the top 2 inches and bottom 2 inches of the sample core. Each section was homogenized, and one gram of soil removed and mixed with water. The water was then tested for bacterial concentration. Test results shown below in Table 6 indicates that the top layers of sediment from the Branciforte Creek and San Lorenzo River at Soquel Creek sites had between 10 and 20 times the bacteria populations found in the lower levels. The San Lorenzo Rivermouth had comparable results in both top and bottom layers.

Table 6: **Sediment Contamination in the Lower River** (cfu/gram of sediment)

LOCATION	FECAL COLIFORM	*E.COLI*	ENTERO-COCCUS	TOTAL COLIFORM
SLR @ Sycamore Grove 022-sand	<50	<50	<50	50
Branciforte Cr. 010-top	1400	2050	1200	5350
010-bottom	<50	150	50	350
SLR @ Soquel Ave. 009-top	600	550	800	1300
009-bottom	<50	<50	100	150
009-sand	300	100	100	550
SLR @ Trestle 003-top	50	100	950	3250
003-bottom	200	100	200	2950
003-sand top	<50	<50	50	250
003-sand bottom	50	<50	<50	1400

It is likely the difference in layering between the upper study areas and the San Lorenzo Rivermouth is due to the more turbulent environment and more complete mixing of the Rivermouth sediment than would be present in an area not subject to tidal influences and wave action. There also tends to be more bacteria in finer sediment than sand. During the summer, fine sediment, decaying organic matter, and bacteria would tend to settle and accumulate on the stream bottom in the quieter areas of the River and could provide a suitable environment for bacteria accumulation and growth. Similar conditions might also be expected in storm drains which tend to accumulate sediment and organic matter. Overall the River sediments show low to moderate levels of bacteria, that would probably not represent a major contribution to water column bacteria levels.

Bacterial Die-off

Some researchers have suggested that bacteria levels are highly influenced by die-off of indicator bacteria when they are exposed to the open environment. Table 7 shows the result of a study undertaken to determine the extent that bacteria from the San Lorenzo Rivermouth would survive under different conditions of salinity. This study commenced on 31 October 1996 and concluded on 4 November 1996 after 116 hours.

Water was collected from the Monterey Bay 25 meters west of the San Lorenzo Rivermouth and from a site approximately .5 miles up river from the mouth of the San Lorenzo River. Monterey Bay water was then used either at a full conductivity of 52,500 µms, mixed with San Lorenzo River water at a conductivity of 21,300 µms., or brackish from 0.5 miles up river from the mouth of the San Lorenzo River at a conductivity of 2,700 µms. Water taken from the San Lorenzo Rivermouth at the railroad trestle served as a control and as the bacteria source to innoculate the different waters.

With the exception of the Rivermouth water all water used in the study was autoclave sterilized prior to use to kill off any resident micro-organisms. The water taken from the Rivermouth was used as inoculum and was added to the three separate glass containers each with a different salinity. The Rivermouth water was also maintained in a sample container as a control.

Recovery rates were similar for the one and four hour testing but die-off began after 24 hours with the sample straight from the Rivermouth. The sample drawn from 0.5 miles up the San Lorenzo River showed a die-off after 48 hours. The bacteria that had been introduced into the bay water sample experienced the slowest die-off rates. After 72 hours recovery in all the different containers was similar at below 100 cfu. with the exception of the total coliform test where samples were too numerous to count for each site. This would indicate the presence of an opportunistic decomposer bacteria in the total coliform group. The initial total coliform plates were within a countable range after one hour and successive counts yielded most plates with plate bacteria populations at the "TNTC" (too numerous to count) level.

Other researchers have assumed that drastic salinity changes (indicated by conductivity) would cause lysing of the bacteria cells and immediate death of the bacteria. The results of this study indicate that the die-off rates were about the same in each of the three different conductivities with the greater die-off in the initial Rivermouth sample. The more rapid die-off in the Rivermouth sample may be related to the substantially greater initial bacteria concentration, which would lead to more rapid consumption of available organic matter. Bacteria serve a purpose to reduce organic material and decompose it to produce nutrients usable by primary producers, (plants). When the amount of organic material is low, the bacterial numbers are reduced to much lower levels due to lack of available food.

Table 7: **Seeded Receiving Water Die-off Study Results** (cfu/100 ml.)

	Conductivity µms	1 hr	4 hrs	24 hrs	48 hrs	72 hrs	92 hrs	116 hrs
Fecal Coliform								
fresh	2700	530	720	450	90	10	40	20
mix	21,300	530	480	520	430	140	60	30
salt	52,500	600	410	240	320	<10	60	10
Rivermouth	950	2730	2740	470	40	130	50	60
E.coli								
fresh	2700	770	890	640	20	30	60	20
mix	21,300	770	750	500	<10	100	40	60
salt	52,500	750	530	610	<10	10	10	no sample
Rivermouth	950	5990	4060	590	110	90	50	70
Total Coliform								
fresh	2700	3720	TNTC	TNTC	TNTC	900	400	3800
mix	21,300	16120	TNTC	TNTC	TNTC	20700	TNTC	7100
salt	52,500	4740	TNTC	TNTC	TNTC	TNTC	TNTC	no sample
Rivermouth	950	TNTC	TNTC	TNTC	TNTC	400	5100	1600
Entero-coccus								
fresh	2700	470	480	420	40	30	20	N/A
mix	21,300	580	530	TNTC	320	20	10	N/A
salt	52,500	640	470	570	400	20	10	N/A
Rivermouth	950	2480	1880	170	70	<10	<10	N/A

Sources of Bacteriologic Contamination

Ever since 1970, when elevated fecal coliform levels in the lower River were first documented, County and City staff have worked to identify and eliminate sources of River contamination. Very early on, it was apparent that the high fecal coliform levels during dry weather periods were originating within the urban areas. The flows coming in from upstream areas served by septic systems have much lower fecal coliform levels than those that occur in the urban area. In the upstream areas also it is believed that most of the elevated fecal contamination originates from nonpoint urban contamination (SCCHSA, 1989). During storm periods, bacteria levels are quite high in both the rural areas and the urban areas.

Elevated bacteria levels most likely come from a combination of sources, which may or may not present a significant public health hazard. The contribution of the various sources differs under wet versus dry conditions. Following are some of the likely sources of contamination in the lower River area:

1. Large congregations of waterfowl (particularly seagulls) occur in the shallows and exposed sand bars in the tidal area of the River.
2. Sewage spills and leaks from older sewer lines contributes sewage into some storm drains, particularly during conditions of high tide and elevated groundwater.
3. The storm drain pipes, catch basins, and wet wells serve as conveyances and likely reservoirs of indicator bacteria. Initial sources of bacteria likely include sewage spills and nonspecific, nonpoint sources of bacteria in urban areas from pet waste, garbage, decaying vegetation, organic fertilizer, and other sources
4. During storm periods there is substantial bacteria contribution from upstream suburban areas from nonspecific urban runoff and occasional septic system failures.
5. Miscellaneous contributions of fecal material from scattered sources such as wild and domestic animals, transients, or spills may cause intermittent fluctuations of bacteria levels in the River.
6. Any of the above bacteria sources may seed the River sediments, promoting ongoing growth and presence of bacteria. Very significant growth of fecal coliform bacteria in sediment has been found in estuaries in the Puget Sound area and to some extent in the San Lorenzo River, although levels in the San Lorenzo River do not seem particularly high.

The current study has shed more light on these various sources, as will be discussed in the following sections. However, further investigation is still needed to determine the relative contributions of those different sources and to evaluate the public health implications, during wet weather and dry weather periods. Work also needs to be done to estimate the flows associated with various bacteria sources in order to calculate loading and determine which sources contribute the most to overall elevated conditions. It is expected that the County and State Regional Water Board will undertake this work as a part of developing a pathogen loading and reduction plan (TMDL).

Waterfowl

During dry periods of the year, large bird populations in the lower river area are likely to be significant contributors to high levels of fecal bacteria. This is especially true from the San

Lorenzo River at the Soquel Avenue Bridge to the mouth of the River when several hundred birds, predominately seagulls, populate the exposed flats and shallow water at any time.

On December 5 and 7, 1995, bird droppings were collected from the intertidal areas and directly from the water. The reason for sampling both dry and wet areas is that dry sand and ultraviolet light from the sun are believed to have an anti-microbial effect on bacteria. This analysis revealed a level of 6540 fecal coliform bacteria colonies in 100 ml. of water from a sample of a single seagull dropping in water and a non-detectable level when sampled from dry sand. With the hundreds of birds that can inhabit an intertidal area, the contribution of fecal coliform bacteria can cause even a large volume of flowing water to be grossly contaminated.

When concentrations of waterfowl were observed, sampling was also conducted both upstream and downstream to assess the influence of waterfowl on bacteria levels. Bacteria levels are substantially elevated below the birds. For example, on November 26, 1996, the enterococcus, E. coli, and fecal coliform levels in the River at Soquel Bridge were 550, 400, and 490 cfu/100 ml, respectively. Downstream of a large congregation of seagulls, the levels at the Laurel Street Bridge were 1820, 1910, and 1640 cfu/100ml, respectively.

Sewage Spills and Leaks

While there have been occasional direct discharges of sewage from breaks in lines adjacent to the River, the most common mechanism for sewage to reach the River is through the storm drain system as a result of surface spills, subsurface leaks, or cross-connections. There has been a past history of sewage reaching the River through the storm drain system. During an assessment of a portion of the sewer system on the west side of the River in 1987, many of the sewer lines were found to have cracks, breaks, and misalignments. In some cases cross-connections between the sewers and the storm drain system were found. These situations can contribute to overloading of the sewer system by rainfall and groundwater infiltration, which can lead to sewer system overflows. During drier times, there is potential for sewage to exfiltrate out of the sewer system into underlying groundwater, and enter the storm drain system, especially in low lying areas and areas where the storm drains and sewers are in close proximity to each other. Problems in the lines are identified by flow testing, smoke testing, and inspecting the line by video camera. Leaky sewer lines are typically corrected by replacing the line or lining it on the inside to seal off openings.

Over the years the County has conducted a number of investigations and sampled extensively points along the lower River, Branciforte Creek, and storm drains discharging to each. In the 1970's and early 1980's, a number of situations were identified where sewers were leaking into storm drains and discharging sewage to the River. As a result, the City has done considerable sewer rehabilitation in areas along the River to correct those problems. These efforts are summarized in Appendix B. In one case, storm drain discharge was blocked and diverted to the sewer treatment plant until the necessary sewer repairs could be completed. The fecal coliform levels appear to have declined somewhat from the 1980's to the 1990's, possibly as a result of the sewer improvements that have been made (Figure 1).

Sample results from the 1995-97 study indicate that storm drains typically have bacteria levels in excess of body contact standards. Some of the drains have very high levels, suggesting some continuing potential sewage contamination that should be further investigated:

- storm drains from Beach Flats in the vicinity of Riverside Avenue Bridge (dry weather and wet weather)
- pump station at the Trestle (wet weather).
- Jessie Street (dry weather)
- Ocean Street at Branciforte (wet and dry weather)
- Laurel/Broadway Pump Station (wet weather)
- Northwest Water Street at the San Lorenzo River (wet and dry)
- Pryce Street (wet and dry)
- Josephine Street (dry)

The City has continued to make improvements to the storm drain and sewer system since 1997, when the bulk of the sampling for this report was completed. It may be that some of the problem areas identified above have been corrected and now have lower bacteria levels. The County still be conducting follow up testing. Sewer improvements since 1997 have been completed on Market Street, River Street, Water Street, Lower Ocean Street and some additional Beach Flats areas.

Sewage spills are another source of sewage entering the storm drain system. Blockages can occur in main lines and private laterals due to cracks, roots, buildup of grease or other causes. When this occurs, sewage flows out onto the street area and into gutters and storm drains. The standard practice is to wash down the contaminated area with freshwater. Typically chlorine disinfectant is not used due to the potential for it to be washed into the River and damage aquatic life. In the two year period of 1996-1997, the area of the City that drains into the San Lorenzo River experienced about 50 reported sewage overflows, with a total volume of about 5000 gallons. About 75-80% of the overflows were from blockage and overflow of private sewer laterals.

Laterals are the smaller lines that run from the home or business out to the sewer main, which is typically located in the street. Construction and maintenance of the lateral is primarily the responsibility of the property owner. The City is responsible for maintenance of the mains. However, the City of Santa Cruz staff will open a blockage in a lateral to eliminate a spill if it is relatively easy to do so. If the work is more complicated, requiring excavation, the property owner is required to hire a plumbing service to do the work. It should be kept in mind that even though main lines have been rehabilitated in many areas, private laterals likely continue to be in poor shape and be sources of sewage leakage and infiltration. Some jurisdictions have implemented programs to require inspection and upgrade of laterals at time of sale. In the City of Burlingame, California, this program indicated that 90% of the laterals required upgrade. The City of Santa Cruz is considering a similar program. |In the meantime, Santa Cruz has already rehabilitated about 50 private laterals and is scheduled to rehabilitate 50 more.

Storm Drain System

The storm drain system has the potential to collect, store, incubate and convey bacteria and virus to the River from surface and subsurface sources in the urban areas. High levels of bacteria and virus originating in urban areas and then draining into the San Lorenzo River at storm drains can contaminate the adjacent beaches in the near shore Monterey Bay waters.

Bacteria are introduced into storm drains by sewage spills, pet and animal droppings, garbage accumulation, exposed dumpsters, discharge of washwater, or other sources; and may continue to thrive and multiply in the decomposing organic material in the storm drain system. Decaying vegetation is also known to produce bacteria that will test positive in tests for fecal coliform and other indicators. Most of the gutters, ditches, and drains in the lower river area have been found to have bacteria well in excess of what is considered to be a level safe for swimming. While some of these conditions may be related to sewage leaks, nonspecific elevated levels from non-sewage sources have been documented in many studies and have been confirmed in sampling of residential street gutters in Santa Cruz. While these types of sources are very difficult to establish and control, their public health significance is unknown.

Although bacteria levels in storm drains are greatly in excess of the bacteria levels in the River, the influence of storm drains during the summer months is generally limited by the normal low flow volumes of the storm drains. At the River's typical late summer flow of 8 cubic feet per second (cfs) and a bacteria level of 400 cfu/100ml, a storm drain flow of 0.05 cfs (22.5 gallons per minute) with a bacteria concentration of 8,000 cfu/100ml would only increase the River's bacteria concentration to 450 cfu/100ml. The influence can be much greater during periods of tidal inundation, when the storm drain pump systems come on, and during flushing storm periods.,

Since 1998, the City of Santa Cruz has initiated a program of regular cleaning of catch basins and wet wells. Substantial buildups of sediment and organic material have been removed and taken to the sewage treatment plant or landfill for disposal. It is expected that these practices would substantially reduce bacteria contributions originating from intermittent, nonsewage sources.

Upstream and Floodplain Areas

The bacteria contribution to the lower River from upstream areas is minimal during dry periods. However, during storms, the contribution is substantial with bacteria levels greatly exceeding safe body contact standards for several days. These high levels originate from watershed wash off, non-specific urban sources (as describes above), and probably some limited contribution from septic systems and livestock operations. Bacterial contributions can also come from direct deposition of human fecal matter, garbage, and pet droppings from people camping and accessing the River within the flood control channel and upstream floodplain areas.

There are over 13,000 septic systems in the San Lorenzo Watershed upstream from Santa Cruz. Under current wastewater management programs, the occurrence of septic system failures is relatively low, approximately 1-5% during wet periods (SCCHSA, 2000). However, during rainfall periods, partially treated sewage which comes to the ground surface from septic failures can be readily washed into ditches, roadways, creeks and then the River. For brief periods after storms and in the early spring when water tables are high, ditches may continue to run, conveying diluted sewage to creeks. During dry periods, sewage from failing septic systems would not reach a waterway unless the failure were right on the banks of the creek. Programs implemented since 1986 have required system upgrades, improved setbacks from creeks and early identification of failures. Summer bacteria levels have shown substantial improvement, and the River generally meets standards for safe swimming at all areas upstream from Santa Cruz. Subsurface contribution of bacteria from apparently functioning septic systems has not been found to occur in the San Lorenzo Watershed (SCCHSA, 1089). Dry season bacteria in the upstream areas is most likely from nonspecific urban sources. Bacteria levels drop substantially as the River flows out of the suburban areas and through the State Parks or other low density areas.

Livestock operations are also a potential source of bacterial contribution during storm periods. It is estimated there may be some 400-600 head of livestock kept in the watershed, primarily horses in commercial stables and small homeowner operations. Runoff from paddock areas, trails and manure stockpiles during storms can contribute elevated levels of fecal coliform, Cryptosporidium, and other organisms. Except where animals are allowed into creeks, stables are not a significant source of microbiologic contamination during nonstorm periods. County Environmental Health has had success with improvement of runoff and manure management at many of the larger operations. However, additional effort is needed. A cooperative education and technical assistance project will soon get underway as a joint effort between the Santa Cruz County Resource Conservation District and the Sant Cruz Horsemen's Association.

The San Lorenzo River flood control channel and flood plain areas immediately upstream are heavily used by homeless persons and others for camping, bathing, recreation, and loitering. This results in significant deposition of litter, human waste, and pet waste, all of which can contribute to high bacteria levels and public health hazard, particularly when the lagoon backs up or winter flushing flows occur.

Health Risk Study

Levels of indicator bacteria regularly exceeded the standards for safe swimming in the River and in the ocean right at the Rivermouth. These elevated levels indicate a potential public health hazard from the possible presence of microbiologic pathogens (bacteria, virus, fungi, or protozoa) from sewage or other sources. The elevated bacteria levels significantly limit use of the River for swimming and wading due to the permanent posting of the Rivermouth as unsafe for swimming, and the periodic warning to stay out of the ocean during winter storm periods. However, many of the potential sources of elevated bacteria may or may not pose an actual public health risk. It is important to evaluate the actual incidence of disease in order to determine the significance of the elevated bacteria levels, to evaluate the severity of the contamination, and to help determine the likely sources. This study performed a standardized and controlled evaluation of the actual incidence of disease among people swimming and wading in the lower River, the Rivermouth, and other beaches of the County.

Background on Health Risk

Swimming in water which contains pathogenic microorganisms can cause a variety of different illnesses including cholera, dysentery, typhoid, shigella, salmonella, hepatitis, nonspecific gastroenteritis, respiratory illness, or skin rashes. Disease-causing micro-organisms may originate from human sources, including sewage or other swimmers, animal and bird contamination, or natural sources. Most of the diseases that cause human illness are viral in nature but some are bacterial (*Legionella*, *Salmonella*, various *Vibrio* bacteria). Algal blooms can produce ecotoxins which cause symptoms that mimic gastrointestinal problems, including vomiting and diarrhea (Hellawell, 1986). Microalgae have also been associated with respiratory stress in some individuals, and have caused illness and death due to the ingestion of infected shellfish meats (National Indicator Study, 1993). Table A-1 in Appendix A provides a more complete list of possible water borne diseases and their causes.

To regularly test for all possible individual pathogenic organisms would be cost prohibitive and time consuming. Therefore agencies typically test for other organisms which will reliably indicate whether there is contamination from human sewage or animal fecal sources. If such contamination is present, there may be a high probability that pathogenic organisms could also be present. If the level of indicator organisms exceeds established standards, the probability of water borne illness is judged to be significant, and the agency is required to post a swimming area as unsafe until follow up samples show that the number of indicator organisms has dropped to “safe” levels.

Various water quality standards for safe swimming have been established using total coliform, fecal coliform, *E. coli*, and/or enterococcus organisms. Each of these indicators is found at levels exceeding one million organisms per gram in human fecal matter and has been assumed to be present when possible pathogens are present. Although they have all been associated with human fecal matter, other pathogenic organisms could be still be present in the absence of indicators. There has been a general assumption that when there are no indicator bacteria present that the water is free of other pathogenic organisms, but this is not always the case.

One of the major problems with any of these indicators is that they are also found in very high levels in every warm blooded animal including birds and other animals found in nature, (Table A-2 in Appendix A), as well as some found associated with the decomposition of vegetative matter (Rheinheimer, 1991). Numerous studies have shown that these indicators are not necessarily reliable in determining potential health risk or confirming sources of contamination, as discussed in Appendix A.

Prior Incidence of Water-Borne Disease in Santa Cruz

Despite the posting of the Rivermouth and adjacent beach areas as unsafe for swimming, both areas get considerable use by swimmers. Children are frequently observed wading or swimming in the lagoon in the immediate vicinity of warning signs. During the winter months, the Rivermouth is a popular surfing spot, and many surfers are observed there when health officials have designated the water as potentially unsafe through published warnings. Even with this use, prior to this study there had been no confirmed reports of waterborne illness from waters in or near the San Lorenzo River.

The apparent incidence of waterborne disease from swimming throughout Santa Cruz County is quite low. County Environmental Health staff and Public Health Nursing staff document and investigate any reports received. The number of reports ranges from two to six per year. Many of these cannot be confirmed as being directly related to water contamination. During most of the reported incidents the ocean water or fresh water where the infection is alleged to have occurred has been found to meet fecal coliform standards for safe water contact.

There is a higher incidence of anecdotal reports of illness, particularly from the surfing community. Surfers are typically the only water users during winter months when the likelihood of water contamination is highest. The Santa Cruz Chapter of Surfrider Foundation has made a substantial effort to better document waterborne illness in local surfers, and has encouraged people to formally notify the Health Department of possible illness. However, the number of reports has not increased significantly. The Surfrider Foundation did conduct a survey of surfers in attempt to standardize and compile many of the anecdotal types of illness reports. Information was compiled by area. Findings from this effort were inconclusive, particularly as they related to water quality.

Health Risk Survey Methods

As a part of this study, a health risk survey was conducted to provide a more comprehensive and objective assessment of water-borne illness in swimmers near the San Lorenzo River and other beaches in the County. Water quality sampling was accompanied by interviews of swimmers at the Rivermouth lagoon and at ocean beaches potentially impacted by the River to the east and west of the mouth. Several sites at Santa Cruz Main Beach and Seabright Beach were chosen for the study. Several freshwater beaches along the San Lorenzo River were also included in the study although they did not provide the number of contacts that came from the ocean beach areas. To provide comparisons to marine water beaches, Capitola Beach, and Rio del Mar, Waddell Creek and Scott Creek Beaches were also analyzed.

In order to produce a comprehensive survey, the participation of 1000 to 5000 individuals was needed. During the course of the study almost 1500 participants were contacted. During the winter it became apparent that the same individuals would be contacted repeatedly, since only a relatively few people use the water and the same people use it regularly. Several other user groups such as Junior Guard Programs, surfing groups, and regular swim program groups were contacted but this information was anecdotal due to the delayed nature of the contacts and the lack of concurrent bacteria testing.

Survey results were obtained by student workers employed by the County of Santa Cruz Environmental Health Service under the direction of the County Water Quality Specialist. As was expected more participants came from the beaches adjacent to the San Lorenzo River, rather than the beaches in the San Lorenzo River due to the greater number of persons who recreate at the marine beaches. Other persons, such as beachgoers who had not entered the water, were utilized during the follow up interviews to help assess whether any reported illness was likely to be from swimming or other causes.

Surveyors made initial contact with the participants at the beach. If the participants expressed willingness to participate, the interviewer recorded their name, phone number, best time to be reached, location, date, time, and type of activity. Water quality samples were collected from that location the same day that the initial contacts were made. A follow-up call was made two weeks later to determine if the participants had experienced any type of illness after water contact. Information was recorded and entered into a database for further summary and analysis.

Following are the questions that were asked:
1. Previous participation in this survey (limited to a single participation per sampling).
2. Name(optional).
3. Age/gender.
4. Phone (for follow-up).

5. Location.
6. Type of recreation (swimming, diving, surfing, skimboarding, wading).
7. Length of time in water.
8. Occurrence of disease after swimming (symptoms, period of onset, duration)
   a. Previous exposure to water within past two weeks (locations).
   b. Potential exposure to illness not water related (related symptoms, family illness, vacations).

Health Risk Survey Results

The Health Risk Survey was conducted from July 2, 1996 to January 1997 and included 58 "sample events" on 22 different dates at 23 different sample locations with 1436 persons initially contacted for the survey. The detailed results of the survey are contained in Appendix C. Figure 5 show the water quality encountered during the surveys, and the relationship between occurrence of illness and water quality.

Of the 1436 persons contacted initially, 1325 were included in the database. Of these, 11 illnesses were *probable* (most likely resulting from water contact) and 20 were illnesses that were *possible* but not *probable*. An illness was *probable* when the interviewed person could recall no prior illness at the initial time of contact and had no other illness source contacts for two weeks after initial contact and *possible* when they indicated that they had been ill prior to swimming, they had visited other sites, or they had engaged in other activities or associations which could have made them ill.

Of the 11 individuals who had *probable* illness from swimming; four had flu-like or fever symptoms, three had a mucousy cough, two had a rash or microscopic bumps, 1 became lethargic with no other symptoms, and one had a sore throat. Two of the eleven *probable* illnesses occurred on one day, July 11, 1996, at the San Lorenzo Rivermouth beach and beaches adjacent to the Rivermouth; two occurred at the Rivermouth on November 20, 1996, and two occurred in Capitola on January 3, 1997.The other episodes showed only one isolated occurrence of illness. It is important to note that more than half of the illnesses (6) occurred during the winter, during storm runoff conditions. Only 120 swimmers were interviewed during 13 events during the winter. During the winter period the risk of illness was 4.89%, and bacterial standards were exceeded for more than half the events. Table 8 below is a list of the areas, dates, types of illness and age and sex of the 11 *probable* illnesses.

Table 8: List of Probable Illnesses, Santa Cruz County Beaches, July 1996 - January 1997

Location	Date	# Interviewed	Type of Illness	age/sex	fecal coliform
San Lorenzo Rivermouth	7-11-96	20	rash/small bumps	3 yr old female	608
50 meters west of Rivermouth	7-11-96	20	lethargic-two weeks	16 yr old male	72
Capitola beach west of Soquel Creek	7-16-96	19	sore throat	13 yr old female	412
100 meters west of SLR Rivermouth	7-18-96	51	gastro-intestinal illness	6 yr old female	88
25 meters west of SLR Rivermouth	8-13-96	70	stomach rash	5 yr old female	480
Cowell Beach	11-20-96	23	fever	27 yr old male	208
Capitola Beach Jetty	11-20-96	10	mucous cough dry heaves, diarrhea	23 yr old male 48 yr old male	708
10 meters east of SLR Rivermouth	1-3-97	12	mucous cough sore throat	47 yr old male 34 yr old male	300
Manresa Beach	1-9-97	15	flu-like symptoms	43 yr old male	4

The New Jersey Department of Health concluded in a study done in the 1980's that for every 1000 swimmers 12.1 would experience some sort of health problems. This was based on over 16,000 interviews at nine ocean and 2 fresh water swimming areas. There was no bacterial indicator correlation found since the water tested was of generally high quality. None of the study areas was located near areas of heavy urban run-off. This lead the authors to believe that the observed effects were due to natural consequences of swimming and not the result of contaminated water.

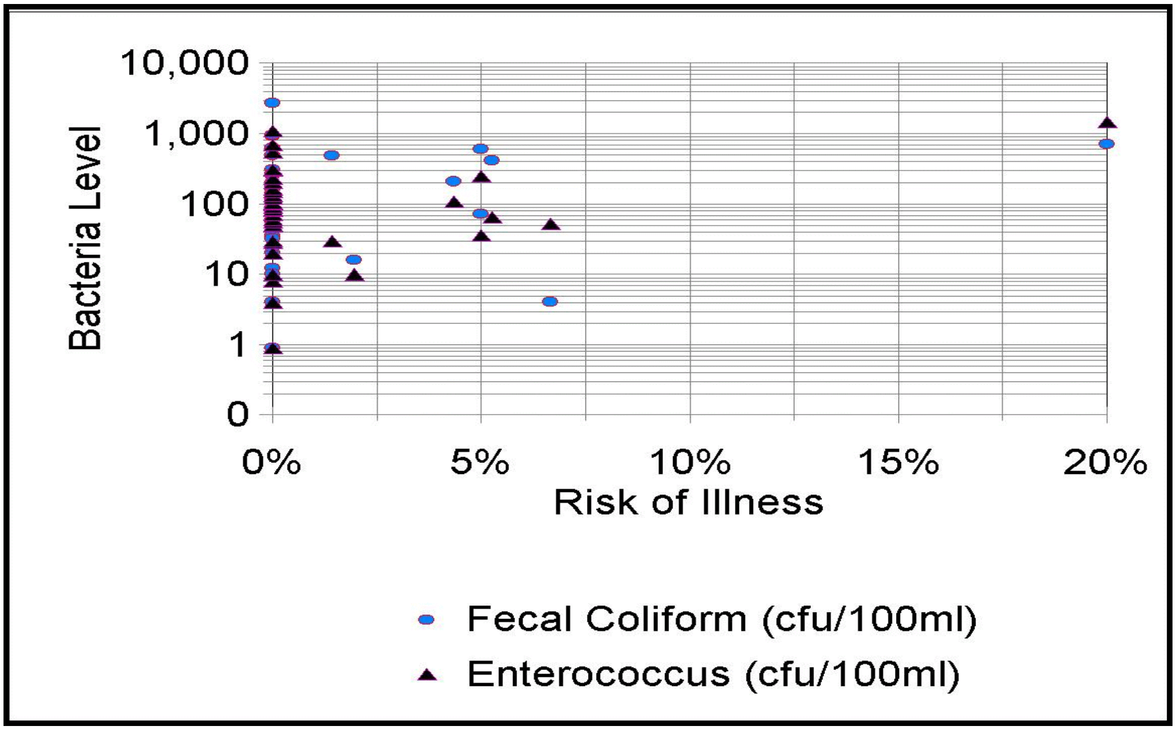
The 12.1 illnesses per 1000 swimmers translates to a relative risk of 1.21% chance of contacting some type of illness while swimming. This is three times greater than the observed 0.41% risk of getting some illness from swimming at bathing areas during the summer in Santa Cruz County. The observed risk at Santa Cruz County beaches during the winter portion of the study was 4.89%. Table 9 below shows the relative risk of swimming at various Santa Cruz County areas based on reported illnesses, interviews conducted, and the season that the illness occurred during the 1996-1997 Environmental Health study done in Santa Cruz County.

Table 9: Relative Risk of Illness Associated with Swimming in Santa Cruz County Waters

Location	**Relative Risk**	**Interviewed**	**Illness**	**Season**
Manresa Beach	6.66%	15	1	Winter
Capitola Jetty	5.88%	34	2	Summer
Capitola Beach west of Soquel Cr	5.26%	19	1	Summer
10 meters east of San Lorenzo Rivermouth	2.86%	35	2	Summer
100 meters west of San Lorenzo Rivermouth	1.47%	68	1	Summer
25 meters west of San Lorenzo Rivermouth	1.43%	70	1	Summer
50 meters west of San Lorenzo Rivermouth	1.03%	97	1	Summer
Cowell's Beach	0.64%	157	1	Fall
San Lorenzo Rivermouth	0.61%	165	1	Summer

(The results for Manresa Beach and Capitola, the sites of the highest relative risk of illness, are not as reliable because those sites were sampled a limited number of times during the course of the study. It would be difficult to conclude that these areas are subject to a higher incidence of illness due to water contact based on a limited number of interviews.)

Figure 5: Observed Water Quality Indicators During Health Risk Study



<u>Relationship of Illness to Indicator Levels</u>

Even though accepted or proposed bacterial indicators were exceeded in several of the *probable* incidents of illness, there were many other times when indicators were exceeded and no reports of illness were received. The opposite was also true when *probable* illnesses occurred and bacteria indicators were not exceeded. Table 10 shows the occurrence of illness relative to exceedence of bacterial indicator levels. The two best indicators of probable illness were fecal coliform levels over 200 cfu/100ml and enterococcus levels over 135 cfu/100ml. In both cases, a relatively small number of the total sample population was included (28-34%), but a relatively large sample of the occurrence of illness was included (73-82%). In assessing statistical correlations among the different factors, the only significant correlation between risk of illness and bacterial concentration was found with enterococcus. Despite the relatively strong relationship between illness and exceedence of fecal coliform standards, there was not a strong correlation between risk and fecal coliform concentration.

Regression analyses were also run to look for any significant relationship between water quality and relative risk of illness. The only moderate correlation was between enterococcus and *probable* illness (R^2 coefficient of 0.53). This relationship held true for the whole data set and for just the data from the Rivermouth beaches. There was no significant correlation with the other water quality parameters, and no correlation between enterococcus and the number of swimmers *possibly* sick, further supporting the idea that the possible illnesses were not likely related to swimming.

Table 10: Exceedence of Bacterial Indicators Relative to Occurrence, of Illness, 1996-97

Data Subset	Events	%	Swimmers Surveyed	Swimmers Sick	% of Sick	% Risk	Correlation Coefficient to Illness
Entire Study	58	100%	1325	11	100%	0.83%	
Fecal Coliform >=200 cfu/100ml	16	28%	277	8	73%	2.89%	0.14
Fecal Coliform >=400 cfu/100ml	10	17%	191	5	45%	2.62%	
E.coli >= 135 cfu/100ml	21	36%	338	7	64%	2.07%	0.27
Enterococcus >=35 cfu/100ml	35	60%	529	9	82%	1.70%	
Enterococcus >= 104 cfu/100ml	20	34%	206	6	55%	2.91%	0.73

This assessment showed relatively low incidence of illness near the River and other County beaches. Water quality during this assessment was relatively good, which is representative of normal conditions. However, it would be useful to conduct a more extensive study during the winter and during more varied water quality conditions to get a better assessment of relationships between water quality and incidence of illness. The relatively high number of participants from the San Lorenzo Rivermouth beaches makes the findings fairly reliable for that areas. A higher level of participants at other locations would make the findings more statistically reliable there.

GENERAL LAGOON WATER QUALITY

The lower River lagoon is a valuable aquatic habitat area and also has aesthetic values for the City. These values can be threatened by stagnation, excessive algae growth, and depressed dissolved oxygen levels. The condition and water quality of the lagoon is affected by sedimentation, freshwater flow and nutrients from upstream; discharge from the stormdrains; tidal influence and condition of the sand bar at the Rivermouth; presence of waterfowl; maintenance of the flood control channel; and, access and use by people and their pets.

Most of the year the Rivermouth is generally open to the ocean, and water level tends to fluctuate with the tides. Although the water was frequently brackish, and occasionally very salty as far up as the Laurel/Broadway Bridge, the presence of saltwater was not detected at any time at the Soquel Bridge. Except during wet years, a sand bar generally forms causing the lagoon to eventually convert to freshwater and backing standing water all the way up to the Water Street Bridge. At these high levels, groundwater in the adjacent areas rises, causing some flooding of basements and stormdrains, and causing the flood control pumps to regularly pump large volumes of water from the stormdrains and ditches into the River. Conductivity and bacteria levels were observed to be quite high in these discharges from the lower west side of the River. In order to reduce summer flooding, the City in previous years would breach the sand bar. This breaching has been discontinued, but the bar continues to breach naturally, or with surreptitious assistance from beachgoers. After breaching, the bar generally quickly reforms, but a persistent lens of salt water may result in elevated temperatures and depressed dissolved oxygen in part of the lagoon, threatening its value for salmonid nursery area.

Conditions in the lower River vary from year to year, depending on the amount of freshwater inflow and the formation of the sandbar, which is also influenced by waves and tidal conditions. Long term data was reviewed to assess factors which influence water quality in the Lower River, and to determine how the study period compared to other years (Table 11).

A correlation analysis was run to determine the extent to which the water quality factors may be related. Although there is a longer period of record for the Trestle station, it is under more immediate influence of the ocean, and the data for the Laurel/Broadway Bridge is more representative of overall lower River conditions. Mean conductivity, mean dissolved oxygen, and fecal coliform logmean all had a very strong relationship to the mean September flow, measured just downstream from the City's water diversion above Highway 1. (It should be noted that there is also typically an additional inflow of 1.5 cfs from Branciforte Creek.) The relationship was particularly strong at Laurel for conductivity (with a correlation coefficient of -0.91) and dissolved oxygen (0.80). These relationships were strong at the Trestle, with an additional strong correlation of mean flow to logmean fecal coliform (0.77) and inverse correlation to temperature (-72). With higher freshwater inflow, there is less opportunity for dilution of fecal coliform by incoming seawater. The study period of fall 1995 to winter 1997 appears to have been a moderately wet period with average fecal coliform levels at the Trestle. The presence of saltwater, with a higher temperature and lower dissolved oxygen level, was noted as far inland as the Riverside Bridge in November, 1995 (Table 12).

The occurrence of maximum and minimum conditions during the period of 1987 through 2000 was also assessed. During that time, 218 out of 1020 temperature measurements from the lower River were over 20 °C, 19 were over 25°C, and a high of 31°C was measured in 1988 at the

Trestle during a time of high salinity, and very low flow. During the same time period, 10 out of 980 measurements had a dissolved oxygen level less than 5 ppm, a level considered as the lower limit for salmonids. Half of these low levels were during periods of high salinity. It should be noted that these measurements are typically taken from water near the edge at about knee depth. Greater occurrence of depressed dissolved oxygen would likely have been found if measurements were taken near the bottom.

The City's water supply diversion at Tait Street appears to have an influence on lower River water quality. The City is entitled to take up to 12.2 cfs. at this diversion, which provides almost 60% of the City's water supply. During dry years, such as 1988-1992, the natural flow of the River is less than that, and the City is currently faced with potential supply shortages. Although the reduction in flow seems to have an effect on water quality, significant degradation was not apparent. More work is needed to evaluate the full effects of the flow reductions, and to determine what an appropriate minimum bypass flow should be.

Table 11: Summer Water Quality in the Lower San Lorenzo River 1987-2000

Year	Mean September Flow(cfs.)	Mean Conductivity μs.	Mean Dissolved Oxygen (ppm)mg/l	Mean Temper-ature ºC	Fecal Coliform Logmean (cfu/100ml)	Mean Nitrate (mg-N/l)
San Lorenzo Rivermouth at Trestle						
1987		8,359	8.68	18.9	1043	0.09
1988	0.9	11,252	9.29	23.7	351	0.08
1989	4.3	9,153	9.57	21.8	188	0.09
1990	1.6	9,642	9.07	22.9	211	0.13
1991	1.4	9,278	10.81	22.0	457	0.42
1992	1.7	11,652	10.16	21.8	132	1.48
1993	8.0	5,353	9.22	19.6	493	0.20
1994	1.37	15,830	8.84	21.0	267	
1995	16.7	6,161	9.34	20.8	469	0.20
1996	16.8	7,582	9.59	18.0	352	0.06
1997	10.8	11,926	8.21	21.6	228	
1998	27.2	1,776	7.73	19.6	975	
1999	17.1	4,087	8.26	18.0	860	
2000	16.8	17,846	9.40	17.6	327	
San Lorenzo River at Laurel/Broadway Bridge						
1996	16.8	1,265	12.97	18.7	336	0.33
1997	10.8	2,801	9.06	22.1	294	0.18
1998	27.2	657	16.88	20.1	237	0.11
1999	17.1	1,401	7.49	17.7	667	0.18
2000	16.8	4,863	8.67	19.5	282	0.19

In order to provide additional information on the general water quality of the lower River lagoon, sampling of salinity, dissolved oxygen, temperature, pH, turbidity, and nitrate was conducted in conjunction with bacteriologic monitoring described previously. In addition, a set of early morning measurements were made when conditions would be expected to be the worst to determine the extent of depressed dissolved oxygen. Oxygen results from near the water surface suggest that all sites would be capable of maintaining the minimum amount of oxygen required by most fish. The only notable exception was the area in the San Lorenzo River between Riverside Drive and the Rivermouth Trestle. Depressed dissolved oxygen may have occurred deeper in the water column. At 5.17 ppm dissolved oxygen the area is about 3% above the accepted minimum value of 5.00 ppm. Results are presented in Table 12. Monitoring was conducted on November 23, 1995 beginning at 6:15 A.M., just after sunrise, and was completed by 7:45 A.M. No samples were taken for bacteria or nitrate analysis. The San Lorenzo River @ Highway 1 Bridge was measured at the beginning and at the end of the monitoring run. A slight increase was found in three of the four parameters with pH having an almost one unit difference. This one unit difference translates to a pH level about 10 times more basic than the reading one and one-half hours prior. The observed difference is likely attributed to instrument error.

Table 12: Early Morning Physical Measurements - November 23, 1995

Time	Location	D.O. mg/l	pH	Temp ºC	Conductivity µs.	Comments
6:15 a.m. 7:45 a.m.	SLR @ Hwy 1	9.03 9.09	7.38 8.30	11.3 10.9	431 448	Blue Heron, 4 mallards
6:20 a.m.	SLR between Hwy 1 & Water St	8.90	7.74	11.1	440	10 mallards
6:30 a.m.	SLR @Water St Bridge (east side)	8.24	7.64	11.1	454	very sandy
6:35 a.m.	SLR @Water St Bridge (west side)	8.57	7.68	10.8	439	
6:45 a.m.	SLR above Branciforte Cr (west side)	8.29	7.70	10.9	475	
6:50 a.m	SLR above Branciforte Cr(east side)	8.28	7.66	10.6	490	oily sheen in stagnant pool
6:55 a.m.	SLR @ Soquel Bridge (west side)	8.29	7.69	10.6	613	Enteromorpha algae, ducks
7:00 a.m.	SLR @ Soquel Bridge (east side)	8.53	7.58	10.5	559	tules
7:10 a.m.	SLR @ Laurel St Bridge	8.19	7.53	10.6	5,210	hundreds of gulls up river
7:15 a.m.	SLR @ Riverside Bridge	6.48	7.52	12.3	20,000	Lots of fishermen, few birds
7:25 a.m.	SLR between Riverside Dr & Trestle	5.17	7.55	13.2	47,300	deep water, <20 birds
7:30 a.m.	SLR @ Trestle	9.16	7.92	12.9	53,300	30 fishermen, lots of foam
7:35 a.m.	SLR @ Monterey Bay	9.50	7.97	12.7	52,500	no fishermen, no birds

Nitrate levels in the lower River are not particularly noteworthy (Table 1). Mean summer levels are consistent with the rest of the watershed, with a mean of about 0.35 mg-N/l. Levels are slightly higher coming out of Branciforte (and Carbonera) Creek. Nitrate is the limiting nutrient in the San Lorenzo River, given the relatively high levels of phosphate from natural geologic sources. The low to moderate nitrate levels present in the lower River are high enough to support growth of algae, but there is no documentation of any impacts from excessive algae growth or eutrophication. Nitrate levels did not show any significant fluctuation during summer months, again suggesting that nitrate levels are not particularly influenced by biologic activity in the lower River. During some years the River has had extensive growth of water fern, duckweed, and/or water cress in the freshwater areas above and below Water Street, with no obvious adverse impact.

The City of Santa Cruz has conducted numerous studies of the lower River regarding flood control and habitat condition, and has prepared an overall River Enhancement Plan. The limited availability of funds and issues of potential liability have limited the City's ability to implement many of the proposed management measures. The City's Enhancement Plan is currently being reviewed and updated, in conjunction with the completion of upgrades to the levee system. The levee project includes more vegetation on the levees and enclosing most of the toe ditches in subsurface pipes. This may affect the quality of the storm drain discharge, although at this time, it is unclear the extent to which the levee improvements will affect water quality.

CHEMICAL CONSTITUENTS IN URBAN RUNOFF

In addition to investigating the transport of pathogens in urban runoff, a related task of the San Lorenzo River Watershed Management Plan Update is to evaluate the need for control of toxic substances entering the River in urban runoff. In order to determine the need for such control, it is necessary to define which toxic substances are present in the urban runoff and if they are present in concentrations large enough to damage environmental or public health.

Urban runoff can contain a bewildering array of civilization derived chemicals. Broadly, the ones that are of most concern are heavy metals, pesticides and PCBs, oil and grease and products of combustion, specifically polynuclear aromatic hydrocarbons. All of these can be present in runoff from urbanized areas, in dry weather flows, and in storm flows. All of these substances can, by various mechanisms of action in a dose-dependent manner, be damaging to the environment. Most of these are water insoluble, very dilute, and widely distributed; i.e. there are no point sources of contamination. During dry weather some of these compounds can originate from point source discharges, either accidental or illicit in nature. Many of these compounds are most readily transported in storm waters attached to soil particles. Concentrations tend to be the highest during "first flush" storms which wash off all the compounds that have been accumulating in the drainage area, but which have relatively low flows and less dilution.

Past Findings in the San Lorenzo River

A review of stormwater, ambient water and tissue monitoring records shows that some of these toxic substances have had a minor presence in the San Lorenzo River Watershed. A synopsis of previous findings by substance class is presented below. Most findings are likely the product of urban runoff, unless otherwise indicated. If anthropogenic toxics are detectable, they might be compromising the environment. However, all findings should be evaluated mindful of dose-dependency requirements. The EPA has established water quality criteria for many of these compounds, which are noted below.

Heavy Metals

Heavy metals include copper, lead, zinc, chromium, mercury, silver, arsenic, selenium, nickel and cadmium. Many of these are toxic to organisms and may also present human health concerns in drinking water. They originate from automobiles, house paints, many other human related sources, and some natural sources. Criteria are from USEPA Section 304(a) Criteria for Priority Toxic Pollutants.

Stormwaters

Dec. 2-4, 1975 - Zinc was slightly elevated above the maximum limit (120 micrograms/liter(µg/l)) for freshwater habitat protection during a "first flush" storm in 4 out of 13 stations sampled in the SLR watershed. The stations above the limit were Boulder Cr. at Boulder Creek (164 µg/l) and above Jamison Cr. (140 µg/l), Fall Cr. at Hwy. 9 (162 µg/l) and San Lorenzo R. at Big Trees (Felton) (142 µg/l). The elevated levels at these particular stations, particularly the undeveloped Fall Creek, suggest that there may be a geologic source from the granitic rocks of Ben Lomond Mountain. All other measured metals were less than water quality criteria protection limits. Measured metals were copper, lead, zinc and chromium. Metals not measured were silver, arsenic, selenium, mercury, nickel and cadmium. Source - Santa Cruz County Water Quality Database

Dec. 29-30, 1976 - The results of a first flush storm sampling in waters draining from the City of Santa Cruz to the lower San Lorenzo River showed that all measured metals (the same four) except for chromium were well above maximum water quality protection limits (copper 25-60 µg/l, limit 18 µg/l; zinc 195-520 µg/l, limit 120 µg/l; and lead 310-580 µg/l, limit 82 µg/l). These samples were collected from the storm drain system. It is likely that significant dilution would occur in the River itself. Source - San Lorenzo River Watershed Management Plan, Water Quality Technical Section (Aston and Ricker, 1979); Santa Cruz County Water Quality Database

Ambient Waters
Of the tested metals, no SLR watershed surface water has exceeded the limits for water quality habitat protection except for a cadmium rich spring which drains near the Ben Lomond Landfill. The spring's receiving water (Newell Cr.) quickly dilutes the discharged cadmium to below habitat protection limits. The cadmium has a geologic (natural) origin. Metals not measured were silver, mercury and nickel. Source - Santa Cruz County Water Quality Database, (ca. 17 yrs. of record) Santa Cruz County Public Works, Ben Lomond Landfill Monitoring Program

Animal Tissues
1980-83: cadmium detected in elevated concentrations in resident fish (sculpin and trout) from the SLR in Felton and Newell Cr. above and below the Ben Lomond Landfill. The cadmium was traced to its geologic origin. All heavy metals which have water quality criteria were tested, but no other metals were present in elevated concentrations. Source - State Toxic Substances Monitoring Program (STSMP)

Pesticides and PCBs

Pesticides in this watershed are mostly from household use for termite, beetle and fungus control. The limited number of agricultural operations use organic methods. PCBs are from old P.G.&E. power pole transformers. The presence of organochlorine pesticides (e.g. DDT) and PCBs represents usage or contamination that is decades old. Water quality criteria are from USEPA, Guidelines for Assessing Chemical Contamination Data for Use in Fish Advisories.

Stormwaters
Never done by any agency.

Ambient Waters
Feb. 1989 - SLR @ Big Trees and Carbonera CR.. @ Hwy 1 were screened for organochlorine pesticides and PCBs. None were found. No other class of pesticides or toxics were measured. Source - Santa Cruz County Water Quality Database

Animal Tissues

1989 - DDE, a DDT breakdown product was detected in resident fish (suckers) from the SLR in Felton. The tissue concentration was 9.5 parts per billion(ppb). The EPA limit for fish advisories is 300 ppb (fresh wt.) Source - STSMP.

1991 - Chlordane 11.4 ppb (limit 80 ppb), DDT 11.2 ppb (limit 300 ppb), PCBs 9.8 ppb (limit 10.0 ppb) and traces of heptachlor (organochlorine insecticides) and hexachlorobenzene (a fungicide) were detected in transplanted freshwater clams in the SLR in Felton. Source - State Mussel Watch (SMW) For both agencies measuring tissue pesticides and PCBs, all synthetic organic substances for which water quality and/or tissue level criteria exist were tested. Conspicuous by its absence was diazinon (an organophosphate insecticide). It is a common find in fish, clam or mussel tissues elsewhere in the State, including areas subject to urban runoff.

Oil and Grease

Oil and grease originates from automobiles, gas stations, parking lots, and many other sources. Massive spills are definitely hazardous to an aquatic environment. There have been no documented problems from the levels of oil and grease encountered in SLR watershed stormwaters. There is no established numerical limit for oil and grease in surface waters. The standard contained in the Regional Water Quality Control Board's Basin Plan is a narrative objective which states that: "Waters shall not contain oil, greases, waxes or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses."

Stormwaters
Nov. 1976, Sept. 1977 SLR @ Big Trees, average concentration of 10 samples was 0.9 milligrams per liter (mg/l) range 0.1-3.9 mg/l. Source - Santa Cruz County Water Quality Database. It is unlikely that the levels recorded during these storms were large enough to produce a visible oil sheen.

Ambient Waters
Never done by any agency

Animal Tissues
Not applicable

Products of Combustion

Polynuclear aromatic hydrocarbons (PAH or PNA) are some of the many products of incomplete combustion that can be found in smoke from woodstoves, motor vehicle exhaust or any other combustion source. Many, such as benzo(a)pyrene, are carcinogenic. As with organochlorine pesticides and PCBs, PAHs can cause immune system dysfunction in a variety of animals. These substances are continuously released to the watershed as an aerosol constituent of air pollution. Their importance as environmental toxins has only recently been appreciated.

Stormwaters
Never done by any agency.

Ambient Waters
Jan. 1995 - SLR @ Felton Diversion Dam, none detected. Source - City of Santa Cruz Water Dept.

Animal Tissues
1991 - Total PAH’s of 58.5 ppb were detected in transplanted freshwater clams in the San Lorenzo River at Felton. Source - State Mussel Watch

Findings from Current Study

It is apparent that most discoveries of toxic substances have come not from water testing, but from tissue testing. This is not surprising, as most urban runoff toxics (esp. organics) in water are generally too dilute to be detected or have fleeting occurrence which makes them easily missed by usual sampling methods. Effective sampling can be quite expensive requiring frequent sampling and/or automatic sampling equipment. However, fish and clams are ever present and have the ability to concentrate these chemicals in their tissues to levels which are readily detectable. Concentrations in aquatic organisms also provide a better indication of the cumulative effect and significance of toxic compounds that may be present. Although tissue monitoring is an effective method, the State Toxic Substance Monitoring Program and the State Mussel Watch agencies had largely suspended central coast tissue monitoring efforts by 1995 due to funding limitations.

As part of the San Lorenzo River Watershed Management Plan Update, The Health Services Water Quality Laboratory measured trace metals and synthetic trace organic compound levels in tissues from resident freshwater clams (RFC) and transplanted freshwater clams (TFC). Animal tissue testing is done because it is a far more sensitive method for contamination detection than water testing. Also, resident animals (fishes, clams and crayfishes) are preferred because they are more sensitive than those same creatures transplanted to the study site (they have much more time to equilibrate to ambient water quality conditions). TFC were used in the present study because RFC could not be found at one site of interest (San Lorenzo River (SLR) @ Soquel Ave.).

Work of a similar nature has been done in the SLR before by the State Water Quality Control Board, Toxic Substances Monitoring Program (TSMP) using resident fishes and crayfish as test animals, and the State Department of Fish and Game, State Mussel Watch (SMW) using transplanted freshwater clams (TFC). Both agencies had shown a vanishingly small presence of synthetic organic compounds (pesticides and PCBs), with all finds (few) being at or near detection limits. Metals discovered in amounts suggesting contamination were cadmium (Cd) by TSMP (1979), chromium (Cr) and possibly lead (Pb) by SMW (1991). Cadmium was shown to have a geologic (natural) source. (See “Santa Cruz County Soil Cadmium Study,” 1983, Santa Cruz County Planning Department.) Chromium and lead are most likely from urban runoff. The current study was done to see if water quality conditions have changed since the last tissue testing was done (Feb. 1991, SMW).

Sites on the San Lorenzo River that were tested for this study include Mt. Cross, between Ben Lomond and Felton; Big Trees, at Felton; and Soquel Avenue (Station 009,for metals only), which is downstream of Branciforte Creek and any influence from the urban areas of Scotts Valley.

Methods

On November 5, 1996, RFC and TFC (*Corbicula fluminia)* were collected at three sites on the San Lorenzo River: RFC from SLR @ Big Trees (TSMP's and SMW's station) and SLR @ Mt. Cross. TFC were harvested from SLR @ Soquel Ave. The TFC were discovered (soon after placement) to be too high in trace organics to be useful as indicators of synthetic organic contamination. TFC for this study were collected from the Sacramento River at Rio Vista. The Dept. Of Fish and Game suggested that clams from this area would be suitable for use in this study, however they were later found to be too high in pesticides to yield meaningful results when used in an area as uncontaminated as the SLR. They were however low in trace metals, and were used for that purpose. TFC were in place for seventy-one days.

Clam tissues were processed for trace metals and trace organic compounds according to published SMW methods. Trace metals extracts were analyzed for metals of interest at the County Water Quality Laboratory. Trace organic extracts were analyzed at the State Fish and Game Laboratory at Rancho Cordova, California.

Results

Trace Organic Compounds

Trans-nonachlor (a component of chlordane) and p,p'-DDE (a DDT breakdown product) were the only substances found in RFC tissues (see Table 13). Both are banned insecticides and both are present in levels about as low as any reported thus far in the SMW database. In 1991, besides the present findings, SMW detected low levels of six other chlordane components plus the insecticides chlorpyrifos and heptachlors, the fungicide hexachlorobenzene and the PCB numbered 1254 (see Table 13). TSMP, from 1979 to 1989 has never detected anything but low or nonexistent levels of DDTs in resident fishes and crayfish (see Table 14).

It is unlikely that the levels of trace organics (insecticides, fungicides, herbicides and PCBs) found here pose any threats to public health or the San Lorenzo River's ecosystem. The only regulated substance found, p,p'-DDE, is present at 1/200 the National Academy of Sciences limit for protection of DDT sensitive birds and 1/1000 the limit for human foods.

Initially, it was wanted to measure tissue levels of polyaromatic hydrocarbons, but the extensive (and costly) sample clean up procedures were beyond the scope of this project. Tissue testing for PAHs would require a major expenditure to be made for additional equipment (ca. $50,000). No tissue testing for PAHs is planned at this time due to the high cost and limited ability to address air pollution constituents through the water quality planning process.

Table 13: Synthetic Organic Compounds: San Lorenzo River Resident Freshwater Clams (*Corbicula fluminia)*, November 5, 1996 (County of Santa Cruz Data), and Transplanted Freshwater Clams (*Corbicula fluminia)*, February 16, 1991, (State Mussel Watch Data).

COMPOUND	FRESH WEIGHT QUANTIFI-CATION LIMIT (QL)	TRANSPLANTED CLAMS SLR@BIG TREES, IN PLACE 75-DAYS, 1991	RESIDENT CLAMS SLR @ BIG TREES, 1996	RESIDENT CLAMS SLR @ MT. CROSS, 1996
	ppb (ng/g)	ppb (ng/g)	ppb (ng/g)	ppb (ng/g)
aldrin	5	<QL	<QL	<QL
cis-chlordane	0.1	3.1	<QL	<QL
trans-chlordane	0.1	2.8	<QL	<QL
oxychlordane	0.1	0.1	<QL	<QL
cis-nonachlor	0.1	1.2	<QL	<QL
trans-nonachlor	0.1	3.6	5.0	5.8
alpha chlordane	0.1	0.2	<QL	<QL
gamma chlordane	0.1	0.3	<QL	<QL
chlorpyrifos	0.5	0.6	<QL	<QL
dicofol	100	<QL	<QL	<QL
dichlorobenzophenone	30	<QL	<QL	<QL
dacthal	5	<QL	<QL	<QL
diazinon	50	<QL	<QL	<QL
dieldrin	5	<QL	<QL	<QL
endosulfan I	5	<QL	<QL	<QL
endosulfan II	70	<QL	<QL	<QL
endosulfan sulfate	85	<QL	<QL	<QL
endrin	15	<QL	<QL	<QL
ethion	50	<QL	<QL	<QL
alpha lindane	2	<QL	<QL	<QL
beta lindane	10	<QL	<QL	<QL
gamma lindane	2	<QL	<QL	<QL
delta lindane	5	<QL	<QL	<QL

Table 13: Synthetic Organic Compounds: San Lorenzo River Resident Freshwater Clams (*Corbicula fluminia)*, November 5, 1996 (County of Santa Cruz Data), and Transplanted Freshwater Clams (*Corbicula fluminia)*, February 16, 1991, (State Mussel Watch Data).

COMPOUND	**FRESH WEIGHT QUANTIFI-CATION LIMIT (QL)**	**TRANSPLANTED CLAMS SLR@BIG TREES, IN PLACE 75-DAYS, 1991**	**RESIDENT CLAMS SLR @ BIG TREES, 1996**	**RESIDENT CLAMS SLR @ MT. CROSS, 1996**
	ppb (ng/g)	ppb (ng/g)	ppb (ng/g)	ppb (ng/g)
o,p'-DDD	1	<QL	<QL	<QL
p,p'-DDD	1	1.2	<QL	<QL
o,p'-DDE	1	<QL	<QL	<QL
p,p'-DDE	5	6.1	5.4	5.8
p,p'-DDMU	5	<QL	<QL	<QL
o,p'-DDT	0.5	0.8	<QL	<QL
p,p'-DDT	1	3.0	<QL	<QL
heptachlor	0.1	0.7	<QL	<QL
heptachlor epoxide	0.1	0.1	<QL	<QL
hexachloroben-zene	0.1	0.1	<QL	<QL
methoxychlor	15	<QL	<QL	<QL
oxadiazon	5	<QL	<QL	<QL
ethyl parathion	10	<QL	<QL	<QL
methyl parathion	10	<QL	<QL	<QL
PCB 1248	9	<QL	<QL	<QL
PCB 1254	9	9.8	<QL	<QL
PCB 1260	9	<QL	<QL	<QL
tetradifon	10	<QL	<QL	<QL
toxaphene	100	<QL	<QL	<QL
phenol	1	2.6	-	-

Table 14: Total DDT's from Resident Fishes and Crayfish, San Lorenzo River @ Big Trees Toxic Substances Monitoring Program Data

SPECIES	DATE	ppb TOTAL DDT's (ng/g) wet wt.
sucker	7-18-78	7
sculpin	7-18-78	29
crayfish	7-18-78	none detected
sculpin	7-18-79	20
crayfish	7-18-79	none detected
trout	6-18-81	14
sucker	8-3-89	9.5

Trace Metals

Zinc and lead were present in elevated amounts in RFC tissues (see Table 15). Zinc has a geologic source; it as well as cadmium are associated with Monterey Formation rocks, soils and sediments. Monterey Formation derived sediments are common to both study sites. Both zinc and lead exceed the 'elevated data level' (EDL) for RFC. The EDL is an internal comparative measure which ranks a given concentration of a particular substance with previous data in the SMW database. An EDL 85 means that the reported value is greater than 85% of the reported values for a substance recorded thus far in the SMW database. EDLs are not directly related to adverse human or animal health issues; they are only a way to compare findings in a particular area with the larger database of findings from all over the state. Cadmium is also elevated but does not exceed the 'elevated data level' (EDL) for RFC. This is because most of the RFC data in the Department of Fish and Game's database is from Lake San Antonio, a southern Monterey County lake that is over Monterey Formation rocks. RFC from Lake San Antonio are very high in Cd and make it appear that this is 'normal' for the species; it is not. TSMP, in resident fishes and crayfish has found only Cd in elevated amounts (see Table 16).

The elevated lead levels are probably the result of decades of urban runoff enriched with lead from automobile exhaust. SMW (see Table 15) saw an elevated lead level in TFC and associated sediments. This is a new finding and should perhaps be followed up with sediment sampling to map the extent of lead contamination.

The elevated chromium level reported by SMW in TFC and associated sediments (see Table 15), was seen neither in the present study nor in the TSMP studies (see Table 16). It is possible that SMW placed their clams on a site that for some (unknown) reasons, was enriched with Cr. The elevated Cr level reported by SMW probably is not representative of average water or sediment conditions.

TFC from the lower SLR did not show any unusually high concentrations of trace metals (see Table 15). With regard to Zn and Cd, this is not an unexpected result as the lower river sediments are not as rich in Monterey Formation (high Zn, Cd) sediments as are found in the upper river. For unknown reasons, lead and nickel are also present in lesser concentrations than those found in the upper river. In such a highly-urbanized area as the lower river, this is an unexpected result.

It is not known if the elevated amounts of zinc, cadmium and lead in the upper SLR compromise human or environmental health, as no standards have been established for tissue levels of these metals. The only metal regulated in foods is mercury (Hg). The U.S. Food and Drug Administration action level for Hg is 1.0 ppm. SMW in 1991 in TFC found only 0.04 ppm Hg (see Table 15).

The sediments of the SLR @ Big Trees contain enough Cd and Pb to be classified as hazardous waste if these sediments were an industrial waste product. (The Cd and Pb levels at which a soil or sediment is considered a hazardous waste are 1.0 and 5.0 ppm respectively. The levels found in sediment at the SLR @ Big Trees were: Cd 1.69 ppm and Pb 12.00 ppm (see Table 15).)

Table 15: Trace Metals in San Lorenzo River Resident and Transplanted Freshwater Clams (*Corbicula Fluminia)* November 5, 1996 (County of Santa Cruz Data), and Transplanted Clams (*Corbicula Fluminia)* and Associated River Sediments, December 3, 1990 (State Mussel Watch Data)

Trace Metal	Quantitation Limit, Ppm (Mg/kg) Fresh Wt.	Transplanted Clams, San Lorenzo River @ Big Trees (In Place 75 Days) 12-3-90 Ppm (Mg/kg)	Sediment, San Lorenzo River @ Big Trees 12-3-90 Ppm (Mg/kg)	Resident Clams, San Lorenzo River @ Mt. Cross 11-5-96 Ppm (Mg/kg)	Resident Clams, San Lorenzo River @ Big Trees 11-5-96 Ppm (Mg/kg)	Transplanted Clams, San Lorenzo River @ Soquel Ave. (In Place 71 Days) 11-5-96 Ppm (Mg/kg)
lead	0.01	0.15	12.00	0.21*	0.20*	<0.01
cadmium	0.005	0.20	1.69	0.92	0.86	0.12
nickel	0.05	-	-	0.69	0.92	0.14
chromium	0.02	2.60***	12.00	0.26	0.17	0.37
copper	0.02	6.60	4.30	7.35	5.29	8.52
zinc	0.005	15.00	36.00	33.55**	27.60**	15.34
arsenic	0.05	-	-	0.58	0.55	-
selenium	0.10	-	-	0.33	0.37	-
silver	0.005	0.10	0.60	-	-	-
mercury	0.01	0.04	0.20	-	-	-
aluminum	0.1	120.0	49000.0	-	-	-
manganese	0.10	12.0***	130.0	-	-	-

* Exceeds EDL 85 for resident freshwater clams. (This is an Elevated Data Level, which means that in the SMW database, 85% of the levels in RFC for this constituent, are less than this value. EDLs generally have no public or animal health significance.)
** Exceeds EDL 95 for resident freshwater clams.
*** Exceeds EDL 85 for transplanted freshwater clams.

Table 16: Trace Metals in San Lorenzo River Fish and Crayfish: Liver Trace Metals from Resident Fishes and Whole Body Trace Metals from Resident Crayfish, San Lorenzo River @ Big Trees. Toxic Substances Monitoring Program Data. Metals Are Expressed as ppm (µg/g) Wet Wt.

SPECIES	DATE	Ag	As	Cd	Cr	Cu	Ni	Pb	Zn
sculpin	7-18-78	<0.04	<0.1	0.98	<0.1	4.9	0.62	-	38.0
crayfish	7-18-78	<0.04	0.24	0.36	<0.1	10.0	<0.7	<0.1	20.0
sculpin	7-18-79	<0.02	<0.1	1.19	<0.02	6.4	0.10	<0.1	43.0
crayfish	7-18-79	0.03	<0.1	0.05	<0.02	9.3	<0.1	0.1	14.0
trout	8-11-80	-	-	0.20	-	-	-	-	-
crayfish	8-11-80	0.12	0.30	1.50	<0.02	25.0	0.7	<0.1	28.0
trout	6-18-81	0.22	<0.1	0.17	<0.02	42.0	-	0.15	26.0

Conclusions Regarding Chemical Contamination from Urban Runoff

Prior sampling results do not seem to indicate a significant contribution of toxics from most of the San Lorenzo Watershed. There have been no documented impacts on beneficial uses or the ecosystem from urban runoff or other toxic constituents. The greatest potential for problems is in the lower River lagoon during a low volume first flush storm which creates little diluting runoff from upstream areas. However, no problems attributable to urban runoff have ever been documented there. In other locations, pollution peaks resulting from storm runoff are very short-lived and carried right out of the River system. There have been no studies of the effects of urban runoff on Monterey Bay, although it may be a problem (CDM, 1993). Such studies are expected to be undertaken in the next few years under the guidance of the Regional Water Quality Control Board.

Conclusions and Recommendations

This section summarizes the key findings of this study, discusses possible management measures to address those problems, describes current efforts to date, and makes recommendations for maintenance and enhancement of efforts.

Observed Levels of Impairment

The most significant water quality impairment that results from urban runoff in the San Lorenzo River is the bacteria contamination that occurs during both dry weather and storm runoff conditions. The Lower San Lorenzo River is subject to elevated levels of fecal coliform and enterococcus bacteria, significantly in excess of body contact standards. The River is formally designated by the State and federal government as impaired due to elevated pathogen levels (303d list). The high bacteria levels occur downstream from the confluence with Branciforte Creek. Most upstream reaches of the River and its tributaries generally meet bacterial standards during dry periods, although there can be episodes of elevated counts.

Although the immediate Rivermouth is posted as unsafe for swimming year round, the ocean water quality generally meets standards for safe swimming within 50 meters of the River outflow. During storm periods, bacteria levels are greatly elevated above standards throughout the length of the River and for several hundred meters in the ocean on either side of the River. Elevated bacteria levels in the lower San Lorenzo River are similar although less severe than those found at the mouths of the other major creeks in urban areas of Santa Cruz County.

A health risk study of 1325 swimmers at the San Lorenzo Rivermouth and other county beaches found that the incidence of swimming related illness was generally low: 0.5% during the summer and 4% during the winter. Of all the locations where the incidence of illness was assessed, the San Lorenzo Rivermouth showed one of the lowest overall rates of illness at 0.6%. Risk of illness showed a statistically significant correlation with enterococcus concentration. The risk was 2.9% during the episodes when the instantaneous enterococcus standard of 104 cfu/100ml was exceeded (34% of the study episodes). There was not a significant correlation of risk to other bacteria indicators, although the risk was also 2.7% when the fecal coliform standard of 200 cfu/100ml was exceeded (28% of the study episodes).

Lagoon water quality is influenced by the amount of freshwater inflow, the formation and stability of the sand bar at the mouth, and the influence of tides. During years with less flow, the lower lagoon is more salty, with higher temperatures, lower dissolved oxygen levels, and reduced bacteria levels at the mouth as a result of dilution by greater tidal influence. From 1987 to 2000, temperatures exceeded 25°C for only 2% of the sample days, and dissolved oxygen levels were less than 5.0 ppm for 1% of the samples. However, these samples were generally taken from the surface of the lagoon. When conditions are not suitable for the lagoon to rapidly convert to freshwater, a salt water layer can form at the bottom, with elevated temperatures and low dissolved oxygen levels that are harmful to aquatic life.

Past studies in the San Lorenzo River Watershed have indicated low to nondetectable levels of heavy metals, pesticides, PCB's, oil, and grease in the San Lorenzo River and its biota. There have been no documented impacts on organisms or beneficial uses of the River resulting from urban runoff constituents other than bacteria. Follow-up studies conducted as a part of this project to investigate possible accumulation of toxic compounds in resident and transplanted clams located in reaches of the River subject to urban runoff found very low levels of only a small number of trace organic compounds (pesticides and PCB's). None of the compounds were found at levels that are known to cause a threat to human or biotic health.

Although the impact has not been confirmed, there is concern that the lower River water quality could be significantly degraded to the detriment to aquatic life, if the conditions were such during a first flush event early in the season that there was just enough flow to wash accumulated organic material and other contaminants from the storm drain system into the lagoon, without significant dilution from upstream flows. This could result in dangerously low dissolved oxygen levels and possibly other impacts. Such an event did occur on Soquel Creek. A fish kill of returning adult steelhead in the lower San Lorenzo River did occur during a first flush event in the 1980's, but the cause of the die-off is unknown.

Sources of Microbiologic Contamination

Elevated bacteria levels in the lower San Lorenzo River come from a combination of sources, which may differ under wet versus dry conditions. Sampling during this study identified locations where bacteria levels were high, indicating significant sources:

1. Large congregations of hundreds of waterfowl (particularly seagulls) occur in the shallows and exposed sand bars in the tidal area of the River. Substantial increase in fecal coliform has been measured downstream from the birds. Fecal contamination by birds, seals, and other wildlife can pose a risk of illness to humans.
2. The storm drain pipes, catch basins, and wet wells serve as conveyances and likely reservoirs of indicator bacteria and potential pathogens. Sources of bacteria in the storm drain system include sewage spills, subsurface sewage leaks, and nonspecific, nonpoint sources of bacteria in urban areas from pet waste, garbage, decaying vegetation, organic fertilizer, and other sources. Subsurface sewage leaks were a likely source of the very high bacteria levels during the summer in the storm drains on the west side of the River near the mouth. This area is subject to high, salty groundwater during the summer.
3. During storm periods there is substantial bacteria contribution from upstream suburban areas from nonspecific urban runoff, pets, livestock, and occasional septic system failures. However, the bacterial contribution from the urban storm drains is even greater. Even during storms, bacteria levels tend to increase as the River flows through Santa Cruz.
4. Accumulations of human waste, pet waste and garbage were observed in and adjacent to the River within the flood control channel and upstream floodplain areas. These sources represent a significant threat to water quality and public health, although chronically elevated bacteria counts could not be directly tied to these sources.

Management Measures

Management measures to improve lagoon water quality and reduce bacteria levels fall into three broad categories: lagoon management, source control, and monitoring. Lagoon management involves managing water levels, tidal influence, freshwater inflow, vegetation, channel conditions, and access in a manner to promote conditions that lead to improved water quality.

The objective of water quality improvement needs to be balanced with other objectives for lagoon management, including water supply, public safety, recreation opportunity, aesthetics, fish and wildlife habitat, and budget constraints. Source control involves reducing the influx of contaminants into the storm drain system to the greatest extent possible, removing accumulations of contaminants before they reach the River, and potentially diverting storm drain flow to the sanitary sewer system for treatment at the sewer treatment plant and discharge through the ocean outfall. Ongoing monitoring is important to identify causes of contamination and evaluate effectiveness of management measures. The City of Santa Cruz, and to a lesser extent the County, have implemented a number of efforts to improve lower River water quality and are currently pursuing additional efforts.

Reduction of Sewer Spills and Leaks

In order to maximize public health protection it is important to reduce the amount of sewage discharge to the storm drain system and the River to the greatest extent possible by reducing the likelihood and duration of sewer overflows and preventing subsurface leaks from the sanitary sewer system to the storm drain system. This includes the following measures:

1. **Upgrade public sewer lines to provide adequate capacity, reduce wet weather infiltration and overload, and reduce leakage to groundwater and storm drains.** The City of Santa Cruz implemented a program in 1986, to identify deficient sewer lines and to plan the upgrade or replacement of the worst lines. Much of the work has been completed (see Appendix B). If it has not been recently done, it would be appropriate to assess the status of the sewer upgrade program, and consider increasing the priority for additional projects in areas that are identified as still likely to be contributing to water quality problems.
2. **Maintain a high level of oversight and maintenance for sewer lines which have a higher probability of overflow or leakage.** The City of Santa Cruz has an excellent sewer line maintenance program, with prompt response to spills, documentation of chronic problem areas, and scheduling of preventative cleaning and maintenance for problem areas.
3. **Maintain programs to reduce discharge of grease or other materials that can cause blockages and overflow of sewer lines.** The City has a comprehensive program of regulations, inspections, enforcement, and education to reduce grease discharge to the sewer system.
4. **Maintain programs for prompt cleanup of sewage spills and correction of problems with private sewer laterals that cause chronic spills.** City crews rapidly cleanup spills and correct problems with sewer mains under City jurisdiction. City crews also cleanup spills from private lines and attempt to open blockages in those private sewer laterals. Frequently chronic spills result from private sewer laterals in poor condition that should be replaced. Replacement is the responsibility of the property owner and is frequently delayed. Spills could be further reduced if the City had the authority to correct problems with private laterals and bill the property owner.
5. **Consider providing for testing of private laterals and correction at time of sale and/or in areas subject to contamination by subsurface sewage leakage.** Although the City has upgraded most of its sewer mains, the potential remains for leakage from private laterals in poor condition. Some jurisdictions have implemented programs for inspection or testing and upgrade at time of property transfer. This would reduce dry weather leakage and wet weather infiltration.

Other Source Reduction

In addition to sewage, microbiologic contaminants can enter the storm drain system and the River from other sources, including pet waste, garbage, fertilizer, decaying vegetation, other nonspecific urban sources, and human activity in and adjacent to the River. Because treatment of stormwater is generally unsuccessful at reducing bacteria, it is important to remove the sources of elevated bacteria before they get into street gutters or the storm drain system:

6. **Encourage pet owners to collect and properly dispose of pet waste.** In urban areas, pet waste should be collected and flushed down the toilet or bagged for disposal at the landfill. The City provides bags at all of its public park areas, but further encouragement is likely needed through education and possible regulation.
7. **Maintain trash receptacles, and dumpsters in a sanitary condition that prevents garbage and leachate from entering the storm drain system.** Dumpsters and trash can should be kept covered. If dumpsters for restaurants or other facilities are found to discharge leachate, they should be kept in a covered area with a drain that discharges to the sanitary sewer system.
8. **Residents and businesses should be encouraged (and required as necessary) to prevent discharge of anything but storm water to the storm drain system.** Even discharge of relatively clean water to gutters can pick up accumulated contaminants and carry them to the storm drain system and the River.
   b. Prevent over watering and runoff of irrigation water into the street.
   c. Take cars to a carwash or wash them in areas that won't run into the street.
   d. All washwater from carpet cleaning, mop buckets, floor mat washing, etc, should be discharged to the sanitary sewer system.
   e. Clean up spills with mops or absorbent material, without washing the spill into a gutter or storm drain inlet.

   The City has an educational program to promote these measures for restaurants and auto service shops. A storm drain ordinance is in preparation. The County needs to begin to pursue such measures.
9. **Maintain stenciled warnings on storm drain inlets as a reminder not to discharge to the inlet**. The City has recently upgraded its stenciling using long-lasting materials.
10. **Maintain street sweeping programs to remove accumulated lifter, garbage, leaves and other material, particularly before the first rains of the season.**
11. **Take measures necessary to eliminate camping and loitering in floodplain areas.** This is a complicated effort that will need to involve community leaders, law enforcement, homeless services providers.

Storm Drain Maintenance

Storm drain catch basins, pipes, and pump station wet wells all have the potential to accumulate debris, garbage, and organic material, particularly during dry periods. These accumulations provide an environment for indicator bacteria and potentially pathogens, which can lead to very high bacterial concentrations when discharge to the River occurs. Heavy metals and other urban contaminants can also accumulate in these conditions.

12. **Provide for regular cleaning of storm drains and removal of accumulations of silt and organic material, particularly before the first storm of the season**. The City has

implemented a program of wet well and catch basin cleaning in the last three years using their sewer vacuum trucks. Tremendous volumes of material have been removed and transported to the sewage treatment plant and landfill for disposal. Significant improvement in water quality in discharge water has been reported.

13. **Consider dry weather diversion of storm drain water to the sanitary sewer system on a temporary or permanent basis.** Control of sewer leaks and other sources of bacterial contamination requires considerable effort and expense. Even with the best control efforts, storm drains may continue to have elevated bacteria levels. In many cases a simple solution is to divert the dry weather and first flush discharge to the sanitary sewer system. The sewer system and treatment plant will always have substantial excess capacity during the summer and early winter before the wet weather infiltration increases. In some cases flow can be diverted with a weir that allows peak storm flows to continue to discharge to the River. In other cases, the storm drain may need to be physically blocked, with a pump system installed to periodically pump the contents of the backed up storm drain to the sanitary system. The City already does this with the discharge from Neary Lagoon, and has done it several times on a temporary basis in the lower River area. This should again be considered for dealing with storm drains with very high bacteria levels, particularly if efforts are pursued to maintain the freshwater in the lagoon at an elevated level.

Urban Runoff Management Program

All of the above efforts should be combined under a comprehensive urban runoff program. Such a program is required to be in place for all urban areas by March, 2003, under the federal Phase II Storm Water Rule. The City of Santa Cruz has already begun implementing a program with the assistance of the State Coastal Commission and the Monterey Bay National Marine Sanctuary Water Quality Protection Program. The Program has developed an Urban Runoff Management Plan for areas draining into the Sanctuary. This Plan will eventually be implemented by the City, the County, and other jurisdictions The City has already established a stormwater utility charge to finance flood control and urban runoff management.

The USEPA Storm Water Phase II Final Rule requires that the following elements be included in a storm water program:

- Public education and outreach on the impacts of urban runoff and methods for improving water quality.
- Public participation and involvement in program development.
- Detection and elimination of illicit discharges of anything other than stormwater to the storm drain system, including unintentional discharges or leaks.
- Construction site runoff control to contain sediment and other contaminants.
- Post-construction runoff control to implement measures to help keep runoff quality and quantity at predevelopment levels.
- Pollution prevention and good housekeeping for municipal operations.

Urban stormwater and runoff programs will also need to be implemented in the upper San Lorenzo Watershed. While a program will be mandatory for the City of Scotts Valley, it has not yet been determined whether it will be required for the unincorporated communities of the San Lorenzo Valley, which do not have storm drain networks. However, implementation of urban runoff management programs is advisable, particularly the implementation of measures to reduce bacterial contamination during both dry weather and wet weather.

Lagoon Management and Enhancement Plan

Although for many years, the lower River was seen by many as a sterile flood control channel, it has come to be recognized as a potentially valuable resource for aesthetics, recreation, wildlife and fish habitat. The City is currently working with the Army Corps of Engineers to upgrade the level of flood protection afforded by the levee system, and at the same time improve other values of the lower River. The California Coastal Conservancy has funded an effort to update the City's Lagoon Enhancement Plan, particularly with the objective of improving the value for salmonid nursery habitat. The City will also be developing a Habitat Conservation Plan (HCP) over the next several years that will address protection of habitat for salmonids and other endangered species.

It is anticipated that these efforts will address several aspects of lagoon management that would also affect overall lagoon water quality:

- **Maintenance of lagoon water surface elevations** and minimized breaching of the sand bar may be done to promote freshwater conditions and salmonid nursery habitat. This might lead to reduced presence of seagulls and associated bacterial contribution, but could lead to less ocean dilution and increased saturation and discharge from the storm drain system. Depending on the success of efforts to clean up storm drains, and depending on the water surface elevation maintained, increased consideration may need to be given to dry weather diversion to the sanitary sewer system.
- **Establishing targets for maintenance of adequate freshwater inflow** will need be balanced with water supply needs and other opportunities to enhance summer baseflow in the upstream watershed.
- **Vegetation restoration and public access** could degrade water quality as a result of increased litter and encampments in the River channel. Substantial regrowth of vegetation in the channel area could encourage more camping and loitering in that area, without additional law enforcement measures. On the other hand, increased access and use of the River by the general public might discourage camping and other illegal activity along the River.
- **Reduction of non-native waterfowl**, such as domestic geese could improve water quality.

Completion of the management plans affecting the lagoon should take into account possible impacts on water quality. Because the overall impact may be difficult to predict, any plan should include ongoing monitoring and the potential to modify the plan or mitigate the impacts if water quality impacts are found.

Pathogen Total Maximum Daily Load (TMDL)

The San Lorenzo River and the River Estuary are designated as impaired due to levels of pathogens (indicator bacteria) in excess of safe body contact standards. As a result, the federal Clean Water Act requires that a TMDL be prepared to:

- quantify the amount of contribution from different sources of the pathogens (indicator bacteria),
- determine how much the contribution from each source needs to be reduced using best available technology in order to achieve a bacterial load that meets standards, and

S develop an implementation plan to meet the loading objectives and, ultimately, the water quality standards.

The State's Central Coast Regional Water Quality Control Board is the lead agency for the development of the pathogen TMDL for the San Lorenzo River. The Regional Board expects to begin development of the TMDL in 2001 and complete it within one to two years. Responsibility for implementation will likely lie with the local agencies. It is suggested that the TMDL development should distinguish between storm runoff and dry weather conditions, as the loadings and the sources vary significantly under the different conditions. The emphasis should be on meeting standards during dry weather, as it is extremely unlikely body contact standards could ever be met during wet conditions.

Ongoing Monitoring

Although regular monitoring of several of the lower River stations has been ongoing since 1986, the intensive monitoring that was done for this study was largely discontinued in early 1997. Improvements to significant parts of the storm drain and sanitary sewer system have been completed since that time, and substantial levee and drainage work is soon to be completed. Although bacteria levels have improved in some areas, bacteria concentrations from Laurel/Broadway on downstream remain in excess of safe swimming standards. Additional monitoring will be needed to identify current bacteria sources, support preparation of the pathogen TMDL, and guide lagoon management efforts. The following monitoring efforts are needed:

1. Follow up monitoring of storm drain outlets and wet wells should be done to verify whether the same storm drains still have high levels and whether there may be other sources of contamination, particularly during dry weather conditions. Where particularly high levels are found, further testing upstream in the storm drain system should be done to identify possible locations of leakage or illicit connections.
2. Measurement and/or estimates of flow from various sources are needed to calculate bacteria loading and the overall significance of contribution from different sources. This will be needed for completion of the pathogen TMDL.
3. Monitoring of water level, sand bar condition, tidal affect, flow, temperature, salinity and dissolved oxygen should be done to better characterize overall lagoon water quality. Measurement at various depths in the water column should be done to assess the occurrence of water stratification.
4. Additional diurnal testing should be done, particularly during the summer to evaluate fluctuations in dissolved oxygen.
5. Sampling for dissolved oxygen, Biological Oxygen Demand, nutrients, and possibly heavy metals should be done at several locations in the lagoon and storm drain discharge during the first flush storm of the season.
6. Sampling under the auspices of the Regional Water Quality Control Board will be done over the next several years to monitor the contribution of urban contaminants to t Monterey Bay from the San Lorenzo River and other discharges.

Monitoring could be done through a cooperative arrangement between the City and the County, with the possible assistance of citizen volunteers for measurement of lagoon conditions.

Recommendations

1. Continue implementation of sanitary sewer upgrades, sewer maintenance and storm drain maintenance practices.
2. Conduct follow up monitoring of bacteria levels in storm drains and investigate sewer and storm drain conditions in locations where storm drains have high bacteria levels. Investigate and correct infiltration and illicit connections between sanitary sewers systems and storm drains.
3. Reduce other sources of bacterial contamination through education, ordinance, and agency practices for proper management of pet waste, garbage, storm drain inlets, and food facilities.
4. Develop and implement a strategy to eliminate potential water quality impacts from camping and loitering in flood plain areas.
5. Implement a comprehensive urban runoff management program to reduce dry weather and wet weather pathogen levels in urban and suburban areas.
6. Consider requiring evaluation and repair of private sewer laterals, particularly in areas subject to high groundwater.
7. Consider implementing dry weather diversion of storm drain discharge to the sanitary sewer system where other control measures are unsuccessful at reducing bacteria levels.
8. Regularly monitor storm drains that discharge to the River to evaluate the effectiveness of improved management practices and to identify new or ongoing sources of contamination. Volume of flow and bacteria loading from various source areas should be measured or estimated to determine the relative contribution of the different sources.
9. Monitor overall lagoon water quality and the effects of improved lagoon management measures.
10. Complete the pathogen TMDL, and implement Phase II Storm Water Regulations.

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Appendix A
Potential for Disease and Use of Indicator Organisms, a Literature Review

Swimming in water which contains pathogenic micro-organisms can cause a variety of different illnesses including cholera, dysentery, typhoid, shigella, salmonella, hepatitis a, nonspecific gastroenteritis, respiratory illness, or skin rashes. Disease-causing micro-organisms may originate from human sources, including sewage or other swimmers, animal contamination, or natural sources. Most of the diseases that cause human illness are viral in nature but some are bacterial (*Legionella, Salmonella*). Algal blooms, due to ecotoxins produced, have also been known to cause symptoms that mimic gastrointestinal problems, including vomiting and diarrhea (Hellawell, 1986). Algae have also been associated with respiratory stress in some individuals, and have caused illness and death due to the ingestion of infected shellfish meats (National Indicator Study, 1993). Table A-1 provides a more complete list of possible water borne diseases and their causes.

In order to prevent the occurrence of water borne disease from swimming, public health agencies test swimming areas for possible contamination and seek to control any potential sources of pathogenic organisms. Because of the unknown number of organisms believed to cause waterborne disease and the complexity of most testing, it would be impossible to detect each organism potentially present. Virus are parasitic and need a host to survive and reproduce (Berg, 1976) and some organisms are fragile in the aquatic environment and short-lived. Ten different virus were isolated and believed responsible for the 1992 meningitis outbreak in California (Calif. Dept. of Health Services, 1992).

To regularly test for individual pathogenic organisms would be cost prohibitive and time consuming. Therefore agencies typically test for other organisms which ideally will reliably indicate whether there is contamination from human sewage or animal fecal sources. If such contamination is present, there is a high probability that pathogenic organisms could also be present. If the level of indicator organisms exceeds established standards, the probability of water borne illness is judged to be significant, and the agency may post a swimming area as unsafe until follow up samples show that the number of indicator organisms has dropped to "safe" levels.

Various water quality standards for safe swimming have been established using total coliform, fecal coliform, *E. coli*, and/or enterococcus organisms. Each of these indicators is found at levels exceeding one million organisms per gram in human fecal matter and has been assumed to be present when possible pathogens are present. One of the major problems with any of these indicators is that they are also found in very high levels in every warm blooded animal including birds and other animals found in nature (Table A-2) as well as some found associated with the decomposition of vegetative matter (Rheinheimer, 1991). Numerous studies have shown that these indicators are not necessarily reliable in determining potential health risk or confirming sources of contamination, as discussed in a subsequent section.

Table A-1: Potential Waterborne Disease-Causing Organisms

Name of Organism or Group	Major Disease	Major Reservoirs and Primary Sources
Bacteria		
Salmonelli typhi	Typhoid Fever	Human feces
Salmonella paratyphi	Paratyphoid Fever	Human feces
Other Salmonella	Salmonellosis	Human and animal feces
Shigella	Bacillary Dysentery	Human feces
Vibrio cholera	Cholera	Human feces
Enterpoathogenic *E.coli*	Gastroenteritis	Human feces
Yersinia enterocolitica	Gastroenteritis	Human and animal feces
Campylobacter jejuni	Gastroenteritis	Human and animal feces
Legionella pneumophila and related bacteria	Acute respiratory illness	Thermally enriched waters
Mycobacterium tuberculosis other atypical) mycobacteria	Tuberculosis	Human respiratory exudates
Opportunistic bacteria	Variable	Natural waters
Enteric Viruses		
Enteroviruses		
Polioviruses	Poliomyelitis	Human feces
Coxsackievirus A&B, Echovirus	Aseptic meningitis	Human feces
Other enteroviruses	Encephalitis	Human feces
Reoviruses	Mild upper respiratory and gastrointestinal illness	Human and animal feces
Rotaviruses	Gastroenteritis	Human feces
Adenoviruses	Upper respiratory and gastrointestinal illness	Human feces
Hepatitis A virus	Infectious hepatitis	Human feces
Norwalk and related Gastrointestinal viruses	Gastroenteritis	Human feces
Protozoans		
Acanthamoeba castellani	Amoebic meningoencephalitis	Soil and water
Balantidium coli	Dysentery	Human feces
Cryptosporidium	Cryptosporidiosis	Human and animal feces
Entamoeba histolytica	Amoebic dysentery	Human feces
Giardia lamblia	Giardiasis(Gastroenteritis)	Human and animal feces
Naegleria fowleri	Primary amoebic meningoencephalitis	Soil and water
Algae(Blue-green)		
Anabaena flos-aquae	Gastroenteritis	Natural waters
Microcystis aeruginosa	Gastroenteritis	Natural waters
Alphanizomenon flos-aquae	Gastroenteritis	Natural water
Schizothrix calciola	Gastroenteritis	Natural waters

Table A-2: Estimates of Microbial Flora of Animal Feces (Average Density (per gram))

Animal Group	**Fecal Coliform**	**Streptococci**	***Clostridium perfringens***	**Bacteroides**	**Lactobacilli**
Farm animals					
Cow	230,000	1,300,000	200	<1	250
Pig	3,300,000	84,000,000	3,980	500,000	251,000,000
Sheep	16,000,000	38,000,000	199,000	<1	79,000
Horse	12,600	6,300,000	<1	<1	10,000,000
Duck	33,000,000	54,000,000	-	-	-
Chicken	1,300,000	3,400,000	250	<1	316,000,000
Turkey	290,000	2,800,000	-	-	-
Animal Pets					
Cat	7,900,000	27,000,000	25,100,000	795,000,000	630,000,000
Dog	23,000,000	980,000,000	251,000,000	500,000,000	39,600
Wild Animals					
Mice	330,000	7,700,000	<1	795,000,000	1,260,000,000
Rabbits	20	47,000	<1	396,000,000	<1
Chipmunks	148,000	6,000,000	-	-	0
Human	13,000,000	3,000,000	1,580	5,000,000,00	630,000,000

Without reliable indicator organisms, agencies seek to determine health risk based on knowledge of the causes of elevated indicator levels. If there is a confirmed discharge of sewage to a swimming area, there is a definite potential for disease. At such times, there is also an elevated concentration of fecal coliform and other indicator organisms originating from the sewage. However, there are frequently elevated indicator levels with no known sewage discharge or other source of contamination. A source can sometimes be identified through additional sampling to determine where the high levels of bacteria originate. For example sampling above and below a concentration of sea gulls may confirm that high levels of fecal coliform come from the sea gulls. Sampling within a storm drain network may pinpoint the location where leaking sewage enters the storm drain. Unfortunately, in many instances, the episode of high bacteria levels may pass without a source being identified. This is particularly true for dry weather urban runoff, stormwater, and other nonpoint sources of contamination.

The first standard established for determining safety of swimming areas used the measurement of total coliform. The total coliform standard was set at 1000 colony forming units per 100 milliliters of water when it was discovered that swimming in water with a total coliform level above 2300 cfu per 100 milliliters of water may cause gastrointestinal problems (USEPA, 1986). The number 1000 was chosen as a conservative figure even though persons swimming in water with a total coliform level of 815 showed no excess of illness. The fecal coliform number was established at 20% of the total coliform number under the assumption that the total coliform/fecal coliform ratio would be constant. No illness survey was conducted to confirm the fecal coliform standard (USEPA, 1986).

A 1988 study conducted at fresh and salt water beaches in Rhode Island found results similar to those found in the Santa Cruz County Study(Deacutis, 1988). This study concluded that enterococcus was not an effective indicator for salt water beaches since results showed low levels at beaches known to be impacted by sewage and the enterococcus indicator group represents organisms found in vegetation, insects, and soils, (primarily *Streptococcus faecalis* var. *liquifaciens*). *E. coli* testing was not a part of this study but fecal coliform was.

In the EPA study of 1986 (USEPA, 1986), there was not a consistent relationship between incidence of disease and bacterial levels. In several areas that exceeded the recommended standard for enterococcus fewer people became ill from swimming than from not swimming. Although generally, when recommended standards were exceeded, the reported illness level was slightly higher for swimmers than non-swimmers, there were two occasions when incidence of disease was greater in nonswimmers. This study concluded that for each 1000 swimmers in an area where bacterial standards were exceeded, approximately 19 would become ill with gastrointestinal symptoms. This study found no significant correlation between incidence of disease and levels of total coliform or fecal coliform. E. coli and enterococcus were then recommended as the indicators to use.

In a study conducted at Australia marine beaches during 1989 and 1990, it was concluded that there was a slight linear correlation between all symptoms other than gastrointestinal upsets and that length of time in the water irrespective of fecal coliform levels accounted for increased complaints of stomach illness (Corbett, 1993). Australia uses 300 colony forming units as their fecal coliform standard. This study recruited 2839 individuals and made initial contact at the study beaches with a telephone follow-up within 10 days of the initial contact to allow time for incubation of illness. This study also concluded that respiratory symptoms in adults over 25 years of age increased with increasing levels of contamination. The study was made of individuals who frequented 12 different beaches with varying proximity to sewage treatment plant outfalls. The study did not compare illness rates at outfall impacted beaches with beaches not close to an outfall.

A 1987/1988 health risk study conducted at nine marine and two freshwater beaches by the New Jersey Department of Health (1990) reached a similar conclusion to the Australian study. This study, consisting of interviews from 16,089 subjects concluded that swimming alone slightly increases risk of illness for stomach upsets, sore throats, ear and eye infections, and skin rashes, and that swimming at freshwater lakes would cause a slightly higher incident of illness. The symptom rate for swimmers for all symptoms was 120/1000 for marine beaches and 162/1000 for freshwater beaches. Study areas included areas in close proximity to treated sewage outfalls. Overall water quality during the study period was very good. Water was tested for fecal coliform bacteria, enterococcus bacteria, F2 male-specific bacteriophage, and *Clostridium perfringens*. The conclusion was that stormwater impacted beaches more heavily than sewage treatment plants and that stormwater was a significant source of all indicator species except bacteriophage. During the study period, there was a sewage treatment plant malfunction and all indicators were present during sampling. They then concluded that bacteriophage was probably a better indicator of human-related contamination than the other organisms. As with the Australian study, there was no comparison of beaches at varying distances from treatment plants close with beaches that had treatment plants discharging treated effluent offshore.

A three-year study conducted within the Santa Monica Bay Watershed and concluded in 1992 showed that F2 male-specific bacteriophage is not a reliable measure of human pathogen contamination since low levels of this indicator were found on days when human enteric viral pathogens were found, yet at times when high levels of this indicator were present no virus was found (Gold, 1992). This study analyzed for total and fecal coliform bacteria, enterococcus bacteria, F2 male-specific bacteriophage, and human enteric virus. As with many other studies, high levels of presently used bacterial indicators were found in stormwater run-off draining into study areas. They concluded that human fecal contamination in storm drains was more severe than previously believed and that testing for human-specific enterovirus (particularly Coxsackie B) was a better indicator of human sewage contamination. They also found that persons swimming in front of a storm drain had a 57% higher risk of illness than those swimming over 400 yards further away.

The County of Santa Cruz has conducted three surveys searching for the organism responsible for causing cholera (Kenyon, 1983, Austin, 1990). These were initiated after a human case of cholera was reported in Santa Cruz County in January 1983. *Vibrio cholerae* was isolated from six of seven marine water beaches and river and creek mouths in Santa Cruz County and within Monterey Bay in the winter and summer of 1983 (Table A-3). Several isolates were taken from water sampled at the mouths of the San Lorenzo River or Soquel and Aptos Creeks with the highest levels isolated from water sampled at the San Lorenzo Rivermouth and Aptos Creek. From December 1988 to December 1989 a similar study was conducted in the San Lorenzo River with sample sites extending up to Boulder Creek (Austin, 1990). All samples were taken from surface water on the San Lorenzo River. During three of the samplings on the San Lorenzo River, 83-100% of all sites had positive readings for *Vibrio cholera*. All three studies were able to isolate the *Vibrio cholerae* organism on a regular basis and most notably with each sample taken from a body of water that has oceanic influence. In addition both studies concluded that there was a strong correlation between historical indicators (total or fecal coliform) and the prevalence of the cholera organism. Cholera-like symptoms can be associated with several other species of the *Vibrio* genus. Although studies are somewhat limited some researchers believe that many members of the *Vibrio* family, including *Vibrio cholerae,* are endemic to the marine environment and the direction of research has recently uncovered their presence. It should be noted that all samplings detected non-01 variety of *Vibrio cholera* that is non-toxigenic, but there is no information on what the mechanism is that turns the non-01 organism to the toxigenic 01 organism.

Epidemics of cholera occurred in developing coastal countries in eastern Africa and southern Asia in the early 1970's and in 1991 were transported to South America in the bilge of a Chinese freighter that discharged millions of cholera infected algal cells into the Peruvian waters in a Lima harbor. The cholera organism adapted to feed on the egg sacs of algae and could remain dormant on the algae until conditions were right for its reemergence (Garrett, 1994). Although cholera has not become a problem in Santa Cruz County the organism does exist and could possibly present a future problem. Cholera has rarely been known to infect recreational water users possibly because of the relatively high dose needed to initiate a response and a generally healthy individual's immune system will fight off the infection.

Table A-3: *Vibrio cholera* (non-01) Isolated from Marine Waters During Winter and Summer Months of 1983

Site(14-liter sample	Date	Salinity	Temperature ©	pH	*V.cholera* non-01(MPN/liter	Total coliform/fecal coliform per100mils
Davenport Landing	1/26/83	31.78	16	ND	0.04	ND
	8/29/83	33.68	18.7	7.8	0.04	<30.0
San Vicente Beach	2/8/83	33.17	14.0	ND	<0.03	230/ND
	8/29/83	32.47	17.3	8.0	<0.03	<30.0
Rio del Mar Rivermouth	2/8/83*	9.04	16	ND	0.93	2,400/ND
	9/20/83	32.65	19.8	7.9	0.43	230/23/
San Lorenzo Rivermouth	2/24/83	7.43	13.8	ND	4.6	ND
	8/15/83	14.14	18.9	7.8	>24	2,400/930
Cowell's Beach	2/24/83	28.83	14.6	ND	<0.03	ND
	8/22/83	33.33	16.5	8.0	2.4	11,000/2,100
Santa Cruz Yacht Harbor	3/16/83	30.39	ND	ND	0.04	ND
	8/22/83	33.59	16.9	7.9	0.43	40/40
Capitola/Soquel Cr. Breakwater	3/16/83	<3.0	ND	ND	0.43	ND
	8/15/83	<3.0	19.2	8.1	>24.0	11,000/750

ND= Not determined
*Sewer line break occurred at this site 2/7/83

Urban runoff carries high levels of inorganic and organic contaminants. Santa Cruz County studies of stormwater have recovered total and fecal coliform, and enterococcus microbial contaminants in numbers ranging from non-detectable to over 700,000 organisms per 100 milliliters of water. This is similar to results from similar studies performed in the U.S. and in Canada (Gold, 1992, Makepeace, 1995). The Canadian study included analysis for many more organisms but did not find pathogenic organisms other than *Salmonella* (Table A-4). The conclusion was that most of the contaminants were naturally occurring in birds and small animals and probably have little health risk implication to humans although without a health risk survey associated it is difficult to determine risk involved. This study detected some viruses of unspecified nature (Table A-4).

Table A-4: **Microorganisms Found in Stormwater**

	(/100 ml)
Total coliforms	7 – 1.8E7
Fecal coliforms	0.2 – 1.9E6
Fecal streptococci	3 – 1.4E6
Enterococci	1.2E2 – 3.4E5
HPC (#/ml)	6.9E4 – 4.9E5
Pseudomonas aeruginosa	1 – 1.1E7
Escherichia coli	1.2E1 – 4.7E3
Salmonella (MPN/10L)	5.7 – 4.5E3
Shigella	Not detected
Klebsiella	4E3 – 1.9E5
Enterobacter	Not detected
Citrobacter	Not detected
Yersinia enterocolitica	Not detected
Staphylococcus aureus (MPN/100 mL)	1 – 1.2E2
Legionella	Not detected
Streptococcus	Detected
Viruses	Detected
Giardia	Not detected
Cryptosporidium	Not detected
Fungi	6E2 – 1.2E7
Parasites — nematodes	Detected

[a] Range (/100 ml).

Bacterial isolates from streams and storm drains were speciated in a Santa Cruz County study conducted from February 1994 to October 1995. This testing identified only gram-negative bacteria and did not evaluate organisms in the *Streptococcus or Staphylococcus* genera. Speciation involves identifying bacterial organisms to species through a series of biochemical reactions and then analyzing with a ten digit profile. Fifty-seven isolates showing growth on fecal coliform plates were streaked onto Blood Agar media plates, incubated and identified using the BBL Identification Method for Determining Gram-Negative Bacteria. The results of this testing showed that most (56%) of the identified organisms were *E. coli*. Thirteen other organisms were represented including members of the *Klebsiella, Proteus, Enterobacter,* and *Serratia* genera (Table A-5). All genera identified have been associated with clinically isolated disease in humans although there is no evidence that any illness was derived from these organisms found in nature.

Table A-5: Speciation of Coliform Colonies found in Streams and Storm Drains in Santa Cruz County

E.coli	56%	*Kluvyera ascorbata*	3.5%
Acinetobacter baumanni	7%	*Aeromonas veronii*	3.5%
Klebsiella pneumoniae	7%	*Flavobacterium odoratum*	1.8%
Acinetobacter lwoffi	5.3%	*Flavimonas oryzihabitans*	1.8%
Klebsiella oxytoca	5.3%	*Serratia rubidaea*	1.8%
Proteus mirabilis	3.5%	*Cedecea lapagei*	1.8%
Serratia marcesens	3.5%	*Enterobacter sakazakii*	1.8%

The health risk associated with the finding of any of the organisms identified in the Santa Cruz study or the 2600 other bacteria identified to date and various other virus, protozoans, algae, and fungus is unknown. Many organisms are capable of producing disease in humans and studies have been done to determine the infectious dose of several bacterial types in a hospital controlled situation using. This work has used humans to determine the number of organisms needed to cause infection. The result is that each organism has a different infectious dose with much lower doses, (as low as ten organisms), needed for viral infection. However, although people recreate in waters that do not meet safe swimming standards, very few illnesses are reported. The results of the few studies associating indicator bacteria with illness is meager at best and much work needs to be done to find a suitable indicator. Such studies were particularly lacking in west coast waters, and areas where elevated indicator levels result in illness have been associated primarily from non-point pollution in the areas of storm drain discharge. Many researchers are skeptical of finding a single organism or chemical indicator that is specific to contamination but believe that a suite of several indicators may provide a specific look at the severity of contamination.

Enterococcus, *E. coli, and Clostridium* have all been suggested as potential replacement indicators for fecal coliform bacteria. Researchers argue that each has merit as an indicator but there is relatively little information on health risk associations. In addition, all three of these organisms are found in high levels in most warm-blooded animals (Table A-2) and with the exception of *E. coli* are also found on decaying vegetative matter. The fact that no indicator has yet been proven to be human specific makes the replacement of present indicators very difficult.

The Environmental Health Service has met with some success by isolating and speciating bacteria. This has been limited to the gram-negative group of bacteria but could include other types of bacteria. These methods do not identify human-specific organisms, virus, protozoans, or algae capable of causing disease in humans. No work identifying virus was done as part of this project.

PCR (Polymerase Chain Reaction) has been used to identify and speciate bacterial and viral contaminants and pathogenic protozoans (Bej, 1991). PCR allows the amplification of discrete fragments of DNA or RNA strands to detect nucleic acid sequences present in minute quantities of sample by denaturing the strands through heating and then adding synthetic primers to bind to the denatured DNA or RNA at specific sites. This method is able to detect organisms in quantities as small as 1 organism in 100 milliliters of water. *E. coli, Giardia, Cryptosporidium,* and various pathogenic viruses have been identified by this method.

Work is being done by the Public Health Department in Washington that differentiates human *E. coli* from other types of *E. coli*. Dr. Mansour Samadpour of the State of Washington Public Health Department has worked with over 9000 samples of *E. coli* and is developing a genetic fingerprinting that he believes is human specific to human *E. coli*. Ribotype matching is a method of analyzing band patterns of DNA extracted from *E. coli* isolates collected from contaminated sites on a stream and matching them to band patterns from *E. coli* extracted from a known source. He has used this to assess the relative contributions of fecal coliform contamination in a stream system in Washington from human and various animal sources and believes he can separate *E. coli* found in domestic dogs and cats from humans based on these DNA band comparisons.

While a human-specific indicator has been difficult to detect it seems as though technology has almost advanced to the point where organism identification could be used to determine specific source of microbiologic contamination in surface waters. A confirmed human source does not necessarily mean that pathogenic organisms are present but it does sufficiently confirm a potential public health hazard from human fecal contamination and would give public health agencies confidence to take appropriate actions.

It would be possible but quite expensive to test for a suite of the few organisms responsible for waterborne disease based on morbidity reports. These diseases would include, but not be limited to: Hepatitis A, viral meningitis, cholera, Norwalk virus, and bacterial dysentery. Testing for the organisms that cause these diseases would detect their presence or absence and could be done on a seasonal basis. A more reasonable approach, though, would be to search for a human-specific organism or chemical. PCR seems to the method that holds the most promise for specific detection of such organisms. Vaccine poliovirus is detectable in water and occurs only in recently vaccinated children. The limitations of this test are there needs to be a population of recently vaccinated persons in the study area. Since primates are the only known hosts of this virus, (Dr. R. D. Ellender-pers. comm.), there would be a recent link to human contamination. Also, studies funded by the National Indicator Study showed that analyzing for Human Immunoglobin, a human specific antigen, could determine human contamination. This assay was run using a fairly simple ELISA type test but has a limitation of being short lived (Dr. R.D. Ellender-pers. comm.).

The Santa Monica Bay study (Gold, 1992) found that human enterovirus, particularly Coxsackie B virus, was usually present in human sewage. Testing for this virus along with other indicators may indicate the presence of human sewage. Since many illnesses are caused by virus and the Coxsackie B virus has been responsible for many diseases including gastroenteritis, meningitis, and pericarditis, it would make sense to analyze for Coxsackie B virus. A suitable method of detection would be to analyze using PCR. It would also be important to quantify the amount of virus present if a suitable method was available to do that. Along with analysis for Coxsackie B or another human-specific enterovirus, fecal coliform, *E. coli*, and enterococcus testing should be included for comparative purposes.

Appendix B

Lower San Lorenzo River: Chronology of Water Quality And Improvements

9/71 Santa Cruz City Council discuss concerns relayed by County Environmental Health Service (EHS) of high pollution counts in lower San Lorenzo River, Branciforte, and Carbonera Creek.

6/72 Wm. Leonard (RWQCB) - report shows high counts (FC) at lower San Lorenzo River.

7/72 Sewer line/grease trap repair at Golden West Restaurant at Branciforte confluence with San Lorenzo River.

1974 -1978 Annual reports from EHS to Santa Cruz City Council shows 80% of San Lorenzo Rivermouth samples > 200 FC/100 ml.

3/79 EHS sampling isolates sewer line/storm drain cross-connections in lower Branciforte Creek.

8/80 Sewer/storm drain cross-connection found at Soquel Avenue Bridge storm drain outfall at San Lorenzo River. High counts noted at Jessie Street and Barson Street, lower San Lorenzo River.

6/81 -8/82 Intensive sampling by EHS of storm drains within Santa Cruz City Limits reveals numerous cross-connections to storm drains.

2/82 EHS find Santa Cruz Transit District Yard discharging into San Lorenzo River (repaired 12/82).

4/82 -9/82 EHS sampling reveals sewage infiltration from Santa Cruz Beach Flats Area into Flood Control pump wells at lower San Lorenzo Rivermouth. EHS finds sewer line infiltration at Soquel Avenue Bridge storm drain. EHS finds sewer line infiltration at Salz Tannery discharging into San Lorenzo River.

8/84 EHS samples reveal major sewage infiltration at Cut Bias (Crescent) Bridge (subsequent investigation reveals broken sewer line at Brook Street - sewage flowing thru old Chinese Dug sewer cave into San Lorenzo River). EHS samples again isolate Soquel Avenue Bridge at San Lorenzo River and Branciforte at Senior Citizens sewer/storm drain cross-connections.

1983 -84 Grand Jury report cites concern on-going pollution of lower San Lorenzo River: “A critical problem exists in the unexpectedly high level of fecal coliforms found in the San Lorenzo River ... which for 80% of the period between May, 1982 and June, 1983, exceeds current standards for body contact recreation.”

7/84- 9/84 Extensive smoke testing of sewer lines in Santa Cruz Beach Flats reveals many broken lines. Storm drain samples at Beach Flats reveal further sewer cross-connections and a major line break at 3rd Street and at Mardi Gras Hotel. Smoke testing at Branciforte Creek reveals cross-connection at Senior Citizen's Center.

12/84 Further EHS sampling at Riverside Bridge, Soquel Avenue Bridge reveal continued sewer/storm drain cross-connections - Repairs not yet completed..

1/85 EHS investigation finds main line damaged and leaking at Cut Bias Bridge at Lower San Lorenzo River - previous repair did not hold. Sewer lines at Beach Flat still not repaired.

3/85 EHS meets with Ed Jankowski, RWQCB - joint sampling and tour Lower San Lorenzo River to survey problems within City limits reveal city non-compliance in making repairs.

11/85 Smoke testing again at Beach Flats - extensive broken lines/cross-connections - City submits written program for repairs.

4/86 City implements correction plan for Wastewater Collection System.

1993- Park Place, Beach Flats,
Lower Ocean

1995?-Water Street Storm Drain replacement, downtown

1997 - Regular cleanout of wet wells, catch basins implemented

?? - Market Street Sewer replacement

?? Sewer leak at Storm Drain NW Water and San Lorenzo fixed

1999 - Sewer leak to Pryce Street Ditch fixed

2000 - Lined sewer on river Street, cooper Street to San Lorenzo Lumber
- Bad lateral at Veterans Building Fixed, was just discharging subsurface

Appendix C: Health Risk Survey Results