Assessment of Sources of Bacterial Contamination At Santa Cruz County Beaches

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Table of Contents

Tables

Figures

Assessment of Sources of Bacterial Contamination At Santa Cruz County Beaches

Executive Summary

Santa Cruz County Environmental Health Services was awarded $173,560 by the State Water Resources Control Board under Proposition 13 Nonpoint Source Assessment program to determine the source and health threat of elevated bacteria levels at Santa Cruz County beaches. This document combines background information along with the results and findings from the current effort. As a part of the current study, over 2000 water samples were analyzed, 1200 bacterial isolates were tested to identify their source, over 2100 swimmers were interviewed for occurrence of illness, and 4700 feet of sewer main and associated laterals were evaluated.

The primary Santa Cruz County beaches experienced elevated levels of enterococcus, *E. coli*, fecal coliform and/or total coliform in exceedence of State standards 5-20% of the time from 2000-2004 (Table 4). During that period, beaches were posted as unsafe for 50-100 days (beach-days) each year (Table 2). The coastal lagoons that discharge to the beaches exceeded standards 50-80% of the time and are permanently posted as unsafe for body contact (Table 5). Interviews of over 2100 beachgoers in 2003-04 indicated that, overall, 3.83% of swimmers reported illness that was likely caused by water contact (Table 10b). Occurrence of illness doubled during winter periods to 6.86% (Table 11). Illness at specific beaches ranged from 0% at Harbor Beach to 11% at both Capitola and San Lorenzo Rivermouth beaches in the winter. There was no statistical correlation of illness to concentration of bacterial indicators (Table 13).

The sources and causes of elevated bacteria levels were assessed by sampling of beaches, stormdrains and stream reaches, assessment of circulation patterns, and use of microbial source tracking by ribotyping. The primary sources of contamination for the beaches are the coastal lagoons that discharge to the ocean with additional contributions from birds, marine mammals, kelp, and possibly boats. For all three major lagoons (San Lorenzo Soquel, and Aptos) approximately 75% of the bacteria load originates within the urban areas near the mouth, with less than 25% of the loading coming from upstream areas (Tables 20-22).

Microbial source tracking using ribotyping provides an indication of the relative magnitude of the fecal coliform contribution from various types of animals, with an estimated accuracy of at least 75-90%. The results indicate that birds are the major source of contamination at all locations, averaging 60% (Table 15). Human contribution to the bacteria load averages about 5%, with higher amounts in the San Lorenzo River, Soquel Creek, and Cowell/Main Beach during the summer (Table 16). Most of the human loading also comes from the urban areas, with the proportion of human contribution more than four times higher in winter than in summer (Table 16). Other significant sources of bacteria that on average each contribute 7% of the load are dogs, rodents, and wildlife (Table 15). Only 15% of the bacteria assessed could not be attributed to specific sources.

Sampling within some storm drains in Santa Cruz and Capitola showed very high bacteria levels in many drains, including dry weather periods (Table 8). A limited amount of ribotyping information from storm drain samples indicated birds, dogs, and human sources of contamination. An allocation of bacteria load based on measured flows and bacteria concentration indicates a very substantial contribution (40-70%) of bacteria load from non-specific sources in the lagoon areas (Table 18). This may come from storm drains, direct bird input, and/or growth of bacteria in the lagoon environment. Sampling of 7 shallow monitoring wells in Santa Cruz and Rio del Mar did not show any indication of widespread bacteria contamination in shallow groundwater (Table 17b), but the close proximity of storm drains and sanitary sewers creates the possibility for localized contamination to move from a sewer leak to a nearby crack in the storm drain. Video evaluations of both storm drain systems and sanitary sewer systems in Santa Cruz, Capitola and Rio del Mar show widespread leaks, cracks, and potential for cross-contamination. Repairs of many of the problematic lines have been completed or are planned. Additionally, in many instances, private sewer laterals also showed signs of leakage or cracks. Sewer overflows and spills to gutters and storm drains also have the potential to contribute to the bacteria load in the storm drain system.

Based on the above assessments, the following recommendations are made to reduce levels of bacteria contamination in coastal lagoons and adjacent beaches:

1. Continue evaluation of sanitary sewers and laterals that have not already been evaluated and implement additional sanitary sewer upgrades where problem areas are identified..
2. Maintain improved sewer and storm drain maintenance practices.
3. Consider requiring evaluation and repair of private sewer laterals, particularly in areas subject to high groundwater
4. Reduce non-point sources of bacterial contamination through education, ordinance, and agency practices for proper management of pet waste, garbage, storm drain inlets, and food facilities.
5. Develop and implement a strategy to eliminate potential water quality impacts from camping and loitering in flood plain areas.
6. 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.
7. Implement dry weather diversion of storm drain discharge to the sanitary sewer system where feasible, and where storm drains have been found to contribute significant dry weather bacteria load..
8. Implement comprehensive stormwater management programs to reduce dry weather and wet weather pathogen levels in urban and suburban areas.
9. Consider options to reduce birds on beaches and lagoons.
10. Inspect and maintain wharf sanitation systems.
11. Consider providing education and surveillance to reduce discharge from anchored boats.
12. Regularly monitor storm drains and waterways to evaluate the effectiveness of improved management practices and to identify new or ongoing sources of contamination.
13. Provide public education programs regarding the needs for source control, animal waste control, septic system and lateral maintenance, limits on feeding birds and wildlife, and support for funding of infrastructure upgrades and water quality protection programs.

Introduction

Santa Cruz County beaches have been periodically affected by elevated bacteria levels and beach closures, frequently caused by unknown sources. Elevated bacteria levels indicate a potential threat to public health and beach closures can have a detrimental economic effect on the tourist industry and local merchants. Previously identified sources of contamination affecting Santa Cruz County Beaches have included: sanitary sewer overflows, storm drains, bird populations, transients, domestic animals, recreational vehicle sewage dumping, septic system failure, and unidentified sources. This project evaluates the health risk presented by elevated bacteria levels, assesses the contribution from various sources, and makes recommendations to reduce the sources of contamination.

This project focused on the following beaches (and contributing creeks): Santa Cruz Main Beach (San Lorenzo River and Neary Lagoon), Twin Lakes Beach (Schwan Lagoon), Capitola Beach (Soquel Creek), and Rio del Mar Beach (Aptos Creek). The project included:

- Preparation of a Quality Assurance Project Plan (Task 2, submitted separately);
- Preparation of an Assessment and Evaluation Plan (Task 4, included in this report);
- Summary of past water quality monitoring results (Task 5.1, included) and preparation of a monitoring and reporting plan (Task 5.5, submitted separately);
- Presentation of Analytical Results and Report of Findings (Task 6.5, included) based on sampling of beach areas, lagoons, creeks, monitoring wells, bluff seeps, and storm drains, including assessment of indicators to estimate relative contributions from humans and animals;
- Evaluation of sewer integrity in areas of suspected sewer leakage (Tasks 7.1, 7.2, 7.3, detailed results submitted separately);
- Survey of beach users to measures incidence of potential water borne illness in relation to water quality parameters (Tasks 8.1 and 8.3, included); and,
- Preparation of this project report (Task 9) summarizing monitoring results, evaluating health risk at beaches, identifying sources of contamination, and presenting recommendations for source remediation.

Assessment and Evaluation Plan

The Assessment and Evaluation Plan provides a summary of the nonpoint sources of pollution to be addressed, the baseline water quality, and the manner in which the project will be effective. Additional supporting material is provided in subsequent sections on background conditions, monitoring efforts, and results.

Nonpoint Pollution Addressed in the Study

The study is primarily designed to evaluate and identify sources of microbiologic pollution: indicator bacteria and the pathogens that may also be present. Indicator organisms to be assessed will include total coliform, fecal coliform, *E. coli*, and enterococcus. The potential sources to be investigated include sewer leaks and overflows, septic systems, storm drain discharges, wildlife, domestic animals, and non-specific urban sources. Identification of sources of microbiologic contamination will also indirectly identify potential sources of nutrients in coastal lagoons.

Baseline Water Quality

Many of Santa Cruz County beaches experience elevated levels of bacteria. In 2002 this resulted in approximately 100 beach-days of posting as potentially unsafe for body contact, out of a total of 2310 beach-days in the 2002 swimming season. (The number of beach-days indicates how many beaches are posted for how many days, e.g. 2 beaches posted for 2 days each would represent 4 beach-days of posting.) Past monitoring indicates that the majority of the contamination originates from discharges of major creeks, which generally become contaminated as they pass through urban areas and coastal lagoons before discharging into the ocean. In 2002, the percent of time that fecal coliform levels exceeded standards in Soquel Creek, Aptos Creek and the San Lorenzo River were 72%, 56%, and 42%, respectively. Other small streams and storm drains from urban areas had high bacteria levels, but these did not generally cause significant beach contamination, probably due to the low volume of discharge.

Project Approach for Pollution Reduction

A sampling program was developed to identify the extent, sources, and public health significance of microbiologic contamination at the beaches. This sampling plan involved sampling of: ocean water at beaches subject to beach closures, lower reaches of contributing streams to identify source areas, storm drains to determine the contribution of wet weather and dry weather storm drain discharge, groundwater wells installed near the lagoons to look for the subsurface transmission of contaminated water, and drainage from bluff seeps to determine if there is groundwater contamination that affects the beaches through hillside seeps. Bacteria from a subset of samples was assessed through ribotyping methods to determine the source organisms. Sampling was also done in conjunction with a health risk survey to assess the actual incidence of illness relative to water quality.

This project was designed to identify specific sources of contamination to beaches and creeks so that these sources can be reduced or eliminated through capital improvements and management actions. This work built on a similar investigation previously completed in the Lower San Lorenzo River, where storm drain discharge (including likely sewage leaks) was identified as a primary source of contamination. Subsequent video investigation of selected sewer lines confirmed their poor condition and high potential for leakage. Funds through the Clean Beach Initiative are now being directed to upgrade sewer lines, line storm drains and provide for dry weather diversion of storm drain discharge away from the River to the sanitary sewer system and treatment plant. It is expected that the present investigation will result in similar capital improvements in other areas adjacent to the San Lorenzo River, Soquel Creek, and Aptos Creek.

Project Effectiveness

The project was effective in characterizing the levels of bacteria found in various areas and the actual incidence of illness that occurred at the primary beaches. The project was also very effective at characterizing the extent to which bacterial contribution comes from birds, wildlife, domestic animals, humans and other sources. The human contribution to overall bacteria levels is small but significant. The project identified the poor conditions of sewers and laterals in the areas near the coastal lagoons. The specific pathway for human contamination to reach the lagoons was not confirmed, but information obtained that suggests that the storm drain system is a likely conduit. Recommendations are made to reduce human and other sources of bacterial contamination.

Background on Indicator Organisms and Water Quality Standards

Surface water monitoring of Santa Cruz County beaches has revealed frequent occasions when levels of fecal indictor 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 at the beaches that will be focus of this study. These elevated bacteria levels can significantly limit use of the beaches for swimming and other water contact sports. Due to the potential significance of this problem, a major component of this study is to determine the sources and potential health hazard of high bacteria levels from all sources.

Swimming in water that contains pathogenic microorganisms can cause a variety of different illnesses including cholera, dysentery, typhoid, shigellosis, salmonellosis, hepatitis, nonspecific gastroenteritis, respiratory illness, or skin rashes. Disease-causing microorganisms 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). Toxic algal blooms have also been known to 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).

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. The variety of potential pathogens and the complexity of most testing, make it impossible to detect each organism potentially present. Viruses are parasitic and need a host to survive and reproduce (Berg, 1976) and some organisms are fragile in the aquatic environment and short-lived. To regularly test for individual pathogenic organisms would be cost prohibitive and time consuming. Therefore agencies test for other organisms that can indicate whether there is contamination from human 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 close or 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.

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 might 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 non-swimmers. 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 therefore recommended as the indicators to use.

A study conducted at Australia marine beaches during 1989 and 1990 concluded that there was a slight linear correlation between all symptoms other than gastrointestinal upsets. The 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, based on interviews with 16,089 subjects concluded that swimming slightly increased risk of stomach upsets, sore throats, ear and eye infections, and skin rashes, and that swimming at freshwater lakes would cause a slightly higher incidence 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 affected beaches more significantly 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 analyzed total and fecal coliform bacteria, enterococcus bacteria, F2 male-specific bacteriophage, and human enteric virus. The study 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). As with many other studies, high levels of 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 than the usual indicators. 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 away. They found that illness correlated with concentration of enterococcus, and with total coliform levels over 1000 if the ratio of fecal coliform to total coliform was greater than 0.1. Much of this work served as the basis for the standards later established for California in AB 411.

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 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 at that time because it is also found in nature and there had 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 *E. coli* appear to be quite capable of surviving outside a warm-blooded host.

The fecal coliform standard for safe body contact in freshwater 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. The California Ocean Plan includes the above fecal coliform standard for water contact in marine water, and a similar standard for total coliform: the 30-day logmean shall not exceed 1000/100ml. and no single sample shall exceed 10,000/100ml. Santa Cruz County Code Chapter 7.72 states that: "samples of water from freshwater contact sports areas shall have a count of fecal coliform organisms less than 200/100ml, provided that not more than 20% of the samples at any sampling station, in any 30 day period, may exceed 200/100ml."

SCCEHS historically 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 indicated a need for follow up testing and investigation; a level exceeding 400 cfu/100ml required posting of warning signs pending the outcome of further testing and investigation. In actual practice, Santa Cruz County staff considered any level over 200 cfu/100ml as a potentially problematic and conducted immediate follow-up testing. If two consecutive samples exceeded 200 cfu/100ml, an area was generally 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 marine waters, pursuant to AB411. AB411 requires all California coastal counties to test for three indicator species of bacteria on at least a weekly basis at heavily used ocean beaches (over 50,000 visitors per year) that are affected by year-around drainages. Drainages can be either man-made storm drains or natural bodies of water, such as rivers or creeks. Santa Cruz County EHS has identified five drainages that affect county beaches and thirteen beaches that are affected by those drainages.

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.

AB411 also requires that a beach be posted and closed any time a sewage spill occurs.

In order to gain a better understanding of the relative significance of each standard, data from Capitola for 2002 was reviewed to determine the frequency that each standard was exceeded. Data was organized by week to eliminate bias from the multiple samples collected during periods of standard exceedence. Exceedence of enterococcus standards accounted for almost half of all the instantaneous standard violations and almost one third of the long term logmean exceedences. It also appeared that the beach should have been posted more than it was. If the rainy weather exceedences are eliminated, the beach should have been posted an additional 13 weeks, primarily based on exceedence of long term logmean standards and/or the fecal coliform/total coliform ratio. Typically, posting is not done during the winter, as all beaches generally exceed standards during wet weather. Press releases are periodically issued to warn the public to stay out of the water for 3 days after significant rainfall and runoff.

Table 1: Exceedence of Individual Standards at Capitola Beach in 2002

	Number of Occurrences	Percent of Weeks	Percent of All Exceedences	Percent of Instantaneous Exceedences
Weeks with Results	50	100%		
Weeks with Any Standard Exceedence	30	60%		
Total Number of Standards Exceeded	105			
Enterococcus logmean (35/100ml)	31	62%	30%	
E.coli/Fecal Coliform Logmean (200/100ml)	13	26%	12%	
Total Coliform Logmean (1,000/100ml)	32	64%	30%	
Standards for Instantaneous Posting:				
Enterococcus (104/100ml)	13	26%	12%	45%
E.coli/Fecal Coliform (400/ml)	6	12%	6%	21%
Total Coliform (10,000/100ml.))	2	4%	2%	7%
TC/FC Ratio > 0.1 and TC > 1,000/100ml)	8	16%	8%	28%
Weeks with Instantaneous Exceedence	17	34%		
Number of Individual Instantaneous Exceedences	29			100%
Weeks with Rain	9	18%		
Exceedences With Rain	9	18%		
Instantaneous Exceedences with rain	3	6%		
Weeks Beach Posted	8	16%		

Santa Cruz County Water Quality Conditions

Santa Cruz County Environmental Health Service (EHS) 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 the more specific fecal coliform bacteria testing. Testing at swimming areas was performed weekly during the summer and intermittently at other times. In 1999, EHS began testing marine waters for total coliform, *E.coli* and enterococcus, pursuant to AB 411. EHS currently conducts water monitoring efforts at approximately 120 sites each month throughout Santa Cruz County encompassing both fresh and marine water environments. In the past, this has included detailed investigations and extensive sampling of Lower San Lorenzo River (1997), Lower Soquel Creek and Capitola Lagoon (1987), and Lower Aptos Creek (1987). These areas were also the focus of more intensive monitoring conducted for the current study.

Water quality has been a concern for many years. 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". Although beach water quality tends to fluctuate from year to year there does not appear to be any long term trend. Although the number of postings was higher in 2002, the number of postings declined in 2003 and 2004 (Figure 1 and Table 2). Overall ocean water quality for the entire year was about average in 2003 and 2004 (Table 4).

Figure 1: Beach Postings, 1991-2004

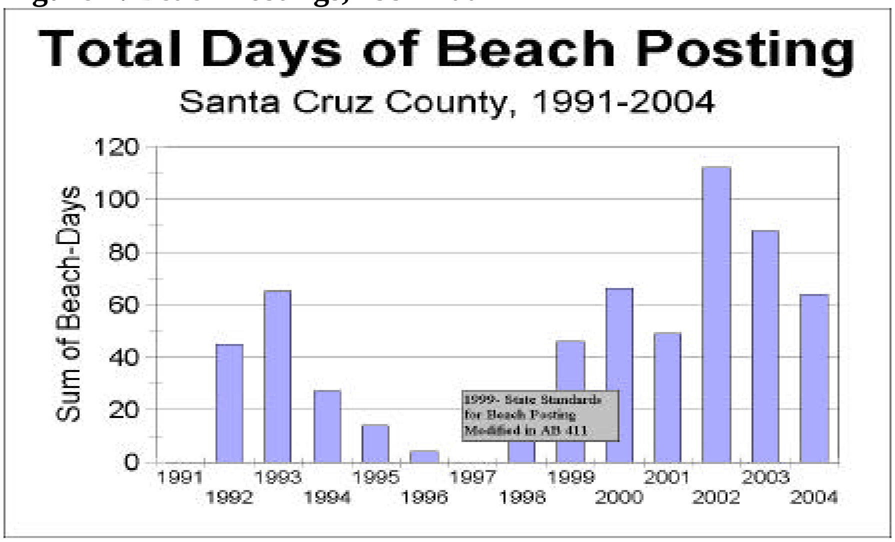


Table 2: Days Santa Cruz County Beaches Posted by Year 1991-2004

	1991-1999	2000	2001	2002	2003	2004	Total
Natural Bridges Beach	0	0	0	0	0	0	0
Cowell Beach	9	15	5	36	0	26	91
Santa Cruz Main Beach	10	5	2	23	0	20	60
Seabright Beach	0	0	2	5	0	4	11
Twin Lakes Beach	0	0	2	1	0	1	4
Capitola Beach	52	17	35	45	31	8	188
New Brighton Beach	0	0	0	0	2	0	2
Seacliff Beach	17	8	0	1	5	0	31
Rio del Mar Beach	27	21	1	1	42	5	97
Pajaro Beach	14	0	1	0	0	0	15
Total	129	66	48	112	80	64	499

Table 3: Causes of Beach Posting, 2003-04

Cause	Number	Percent
Sewage Spill	48	34%
River Breach (2004)	37	26%
Elevated Bacteria Levels	58	41%
Total	143	

Table 4: Exceedence of Standards (2001-04)

% of Time Enterococcus Standard Exceeded (>=104) *% of Time E. coli Standard Exceeded (>=400)*	**Water Year**				**Average**	**Occurrence of Illness 2003-04**
	00-01	**01-02**	**02-03**	**03-04**		
Average	**7%**	**10%**	**12%**	**9%**	**9%**	**3.8%**
For all Stations	*3%*	*3%*	*6%*	*7%*	*5%*	
O110	**25%**	**20%**	**24%**	**15%**	**21%**	**4.9%**
RDM BEACH@APTOS C MOUTH	*5%*	*8%*	*17%*	*13%*	*11%*	
O140	**0%**	**8%**	**10%**	**7%**	**6%**	**5.9%**
SEACLIFF BEACH @ CEMENT SHIP	*2%*	*4%*	*9%*	*0%*	*4%*	
O170	**4%**	**11%**	**14%**	**9%**	**9%**	**0.0%**
NEW BRIGHTON BEACH	*0%*	*4%*	*9%*	*7%*	*5%*	
O240	**15%**	**29%**	**30%**	**21%**	**24%**	**4.1%**
CAPITOLA BEACH	*5%*	*22%*	*18%*	*14%*	*15%*	
O410	**10%**	**8%**	**10%**	**7%**	**9%**	**1.2%**
TWIN LAKES BEACH	*6%*	*2%*	*3%*	*4%*	*4%*	
O440	**5%**	**8%**	**7%**	**7%**	**7%**	**0.8%**
SEABRIGHT (CASTLE) BEACH	*0%*	*2%*	*0%*	*4%*	*2%*	
O450	**5%**	**13%**	**7%**	**9%**	**8%**	
SAN LORENZO RIVERMOUTH BEACH	*5%*	*6%*	*2%*	*9%*	*5%*	
O460	**4%**	**6%**	**7%**	**7%**	**6%**	**1.2%**
MAIN BEACH (@ BOARDWALK)	*0%*	*2%*	*2%*	*9%*	*3%*	
O490	**0%**	**6%**	**2%**	**5%**	**3%**	**2.9%**
COWELL BEACH	*4%*	*6%*	*0%*	*10%*	*5%*	
O494	**0%**	**4%**	**3%**	**2%**	**2%**	
COWELL @ STAIRS	*0%*	*0%*	*2%*	*4%*	*2%*	

The lagoons and creeks are the primary source of elevated bacteria levels at the beaches. All of the major urban creeks are permanently posted as unsafe for body contact (with the exception of the Pajaro River). Table 5 indicates the percent of time that the standard for fecal coliform is exceeded at the major creeks.

Table 5: Percent of Time Safe Body Contact Standards Exceeded at Creek Mouths (Fecal coliform >400/100ml) (Entire Year/ Swimming season)

Location	1999	2000	2001	2002	2003	2004
Soquel Creek mouth	61 / 55	75 / 78	79 / 79	72 / 59	71 /53	82/87
Aptos Creek mouth	71 / 69	86 / 63	88 / 74	56 / 58	59 / 83	73/92
San Lorenzo River mouth	67 / 85	46 / 53	62 / 66	42 / 39	50 / 61	25/14
Schwan Lake mouth	90 / 81	80 / 79	79 / 72	69 / 67	95 / 87	65/46

Safe body contact standards should not exceed an average (logmean of 200 bacteria per 100 milliliters of sample water when measured five times over a one-month period nor exceed 400 bacteria per 100 milliliters for any single-sample result. Bacteria measurements taken for fecal coliform bacteria or *E. coli* bacteria, a sub-set of fecal coliform bacteria.

Table 6 presents a summary of water quality data from 1987-2002 for all major beaches and creeks along the coast. All of the creeks exceeded standards for safe body contact except for the Pajaro River Mouth, Corcoran Lagoon, Scott Creek and Aptos Creek. The highest levels of contamination and resultant beach posting occur at Rio del Mar, Capitola, and Santa Cruz Main Beach, the focus areas of this study.

A summary of the data for all stations sampled as a part of this study is presented in Tables 7 and 8 and in Appendix A.

Table 6: Fecal coliform and Enterococcus at Beaches and Creek Mouths (1987-2002)

Results exceeding Chronic Standards are indicated in **bold**.

LOCATION	Logmean Fecal Coliform	Logmean Enterococcus	Percent Samples Standard Exceeded Fecal Coliform/E.coli	Percent Samples Standard Exceeded Enterococcus
Standard	**200**	**35**	**400**	**104**
Oceans				
Pajaro Dunes Beach	6	3	**24%**	0%
Manresa Beach	5	3	0%	0%
Hidden Beach	10			
RDM Beach @Aptos C Mouth	57	**48**	**25%**	**40%**
Seacliff Beach @ Cement Ship	41	9	7%	13%
New Brighton Beach	19	4	**12%**	**14%**
Capitola Beach	106	22	**25%**	**32%**
41st Ave, Beach	12			
Pleasure Point	11			
Moran Lake Beach	9			
Corcoran Lagoon Beach	10	4	8%	0%
Twin Lakes Beach	11	7	**11%**	**32%**
Main Beach (@ Boardwalk)	50	18	**18%**	**12%**
Cowell Beach	47	20	**19%**	**24%**
Lighthouse Beach	20			
Mitchell's Cove	16			
Natural Bridges Beach	11	4	**12%**	0%
Scott Creek Beach	3	4	0%	0%
Waddell Creek Beach	4	5	0%	8%
Creeks/Lagoons				
Pajaro R @ Mouth	109	20	**40%**	--
Aptos Creek @ Mouth	**635**	**1483**	**78%**	**100%**
Soquel Cr @ Flume Outlet	**455**	**251**	**68%**	**88%**
Soquel Cr @ Flume Inlet	**852**		**84%**	--
Corcoran L @ Mouth	80	21	**51%**	--
Schwan Lake @ Mouth	**887**	**362**	**81%**	**82%**
SLR Rivermouth @ Trestle	**345**	**101**	**66%**	**70%**
Neary Lagoon @ Mouth	**289**	**835**	**58%**	**83%**
Woodrow Cr @ Mouth	**436**	**646**	**67%**	--
Almar St Storm Drain	182	**331**	**44%**	--
Intel C @ Mouth	**820**		**75%**	--
Scott Cr @ Mouth	47	16	**23%**	**17%**
Waddell Cr @ Mouth	58	23	**28%**	--

Table 7: Results from Ocean Sampling October 2003 to September 2004.

STANUM	LOCATION	Total Number Samples	Number of Storm/ Turbidty Samples	Logmean Entero-coccus	% Entero Exceeding 104/ 100ml	Logmean E. Coli	% E.Coli Exceeding 400 /100ml	Logmean Total Coliform	% Total Coliform Exceeding 10,000/ 100ml
001E100	100M EAST OF 001	10	7	43	30%	81	20%	1102	0%
001E150	150M EAST OF 001	3	1	8	0%	38	0%	96	0%
001E200	200M EAST OF 001	4	3	41	25%	114	25%	1231	0%
001E50	50M EAST OF 001	9	7	96	67%	138	22%	1403	0%
001W100	100M WEST OF 001	10	6	44	40%	78	10%	683	0%
001W150	150M WEST OF 001	3	1	15	33%	21	0%	245	0%
001W200	200M WEST OF 001	3	2	27	0%	53	0%	657	0%
001W25	25M WEST OF 001	3	3	224	67%	136	0%	1420	0%
001W50	50M WEST OF 001	9	7	48	22%	59	0%	559	0%
O010	PAJARO DUNES BEACH	52	0	7	2%	11	0%	28	0%
O060	SUNSET BEACH	12	0	8	0%	8	0%	15	0%
O080	MANRESA BEACH	13	0	10	8%	13	0%	29	0%
O090	SEASCAPE BEACH	2	0	5	0%	12	0%	19	0%
O098	BEER CAN BEACH	2	0	7	0%	46	0%	88	0%
O099	HIDDEN BEACH	12	0	8	0%	19	0%	49	0%
O0993	RDM 30M EAST OF APTOS CRK	3	3	101	33%	208	0%	1727	0%
O0995	RDM 50M EAST OF APTOS CRK	10	7	102	50%	238	40%	1230	10%
O0997	RDM 100M EAST OF APTOS CRK	10	9	106	40%	344	40%	1812	30%
O0999	RDM 200M EAST OF APTOS CRK	2	2	129	50%	267	0%	2070	0%
O105	BETWEEN HIDDEN B & RIO DEL MAR	3	1	12	0%	55	0%	113	0%
O110	RDM BEACH@APTOS C MOUTH	55	0	16	15%	60	11%	167	4%
O113	RDM 30 M WEST OF APTOS CRK	3	3	44	0%	89	0%	1396	0%
O115	RDM 50 M WEST OF APTOS CRK	10	7	159	50%	280	44%	1098	20%
O117	RDM 100 M WEST OF APTOS CRK	10	7	63	40%	162	20%	520	10%
O120	BETWEEN RIO DEL MAR & SEACLIFF	3	1	31	0%	138	0%	301	0%
O140	SEACLIFF BEACH @ CEMENT SHIP	57	3	10	7%	28	2%	72	0%
O170	NEW BRIGHTON BEACH	53	0	11	8%	36	6%	138	2%
O2205	CAP BEACH E OF SMALL JETTY	3	3	37	33%	42	0%	618	0%
O2343	CAPITOLA 50M EAST OF CR	9	7	209	78%	183	22%	1269	0%
O2344	CAPITOLA 100M EAST OF CR	9	7	82	56%	116	11%	773	0%
O2345	CAPITOLA 25M EAST OF CR	2	2	192	100%	313	0%	3762	0%
O235	CAPITOLA BEACH @ JETTY	57	1	14	16%	45	7%	149	2%
O240	CAPITOLA BEACH	59	0	26	22%	121	20%	467	3%
O245	CAPITOLA BEACH @ SOQUEL C	3	0	13	0%	279	33%	612	0%
O246	CAPITOLA BEACH @ FLUME	6	0	14	0%	299	17%	551	0%
O2493	CAPITOLA BEACH 50M WEST OF CRK	9	7	59	22%	139	11%	725	0%
O2495	CAPITOLA BEACH 25M WEST OF CR	3	3	93	33%	325	33%	1885	0%
O260	CAPITOLA BEACH @ WHARF	10	7	36	20%	156	20%	605	0%
O271	HOOPER'S BEACH	8	4	10	0%	37	0%	128	0%
O320	PLEASURE POINT BEACH	12	0	9	0%	9	0%	26	0%
O340	MORAN LAKE, COUNTY BEACH	12	0	6	0%	7	0%	15	0%
O370	CORCORAN LAGOON BEACH	13	0	7	0%	9	0%	50	0%
O380	SUNNY COVE BEACH	12	0	7	0%	10	0%	22	0%
O410	TWIN LAKES BEACH	56	0	9	7%	19	4%	64	2%
O440	SEABRIGHT (CASTLE) BEACH	58	0	8	7%	27	7%	177	3%
O450	SAN LORENZO RIVERMOUTH BEACH	57	0	12	7%	57	9%	325	4%
O460	MAIN BEACH (@ BOARDWALK)	58	0	10	7%	100	12%	370	7%
O488	COWELL BEACH WEST OF WHARF	2	0	5	0%	167	50%	263	0%
O490	COWELL BEACH	60	0	11	3%	78	12%	320	2%
O494	COWELL @ STAIRS	58	0	8	3%	37	7%	154	2%
O510	LIGHTHOUSE BEACH	13	0	10	0%	31	0%	97	0%
O520	MITCHELL'S COVE BEACH	12	0	8	0%	17	0%	61	0%
O530	NATURAL BRIDGES BEACH	53	0	7	0%	14	0%	44	0%
O560	SAN VICENTE BEACH	12	0	8	8%	8	0%	39	0%
O580	SCOTT CREEK BEACH	12	0	8	0%	11	0%	46	0%
O590	WADDELL CREEK BEACH	12	0	10	0%	17	0%	74	0%

Table 8: Summary of Data for Lagoons and Stormdrains, October, 2003- March, 2005

STANUM	LOCATION	Number of Samples	Mean Electro-Conductivity	Number Enterococcus Samples	Logmean Enterococcus	Logmean *E. coli*	Logmean Total Coliform	Number Fecal Coliform Samples	Logmean Fecal Coliform	Number Nitrate Samples	Mean Nitrate	Maximum Nitrate	Number Ammonia Samples	Mean Ammonia	Maximum Ammonia
003	SLR RIVERMOUTH @ TRESTLE	89	16055	5	5	1535	10962	88	202	1	0.0	0.0	0		
0031DW	GRAVITY STORM DRAIN @ 003	13	2513	13	40	294	17769	0		13	0.3	1.1	11	0.42	3.05
0045DE	JESSIE ST STORM DRAIN	13	15341	13	26	308	4727	0		13	0.8	3.1	11	0.08	0.29
0046DW	UHDEN ST @ SLR (PUMP)	13	27777	13	32	178	8120	0		13	0.9	4.6	11	0.16	0.59
0047DW	RAYMOND ST @ SLR	14	14363	9	27	703	6960	1	9400	9	0.8	3.5	7	0.07	0.20
0048DE	NE PUMP BIXBY @ SAN LORENZO BL	13	8729	13	69	1156	21385	0		13	1.2	4.1	11	0.22	1.23
0051DW	LAUREL ST EXT @ SLR STRM DRN	12	10099	12	29	327	7618	0		12	0.5	1.5	10	0.10	0.45
005DW	STRM DRN @ RIVERSIDE WEST	12	14829	12	30	126	6433	0		12	0.7	3.7	10	0.20	1.19
006	SLR @ BROADWY/LAUREL ST BRIDGE	74	5429	2	5	1750	25000	72	281	71	0.5	3.7	0		
006DW	BROADWAY PUMP STATION STRM DRN	13	13324	12	71	815	11434	0		13	0.3	1.5	11	0.12	0.64
0202DE	WATER ST PUMP STATION @ SLR	13	356	6	32	200	21183	0		6	0.4	0.6	4	0.05	0.18
0202DW	WEST WATER ST STORM DRAIN	13	2352	12	38	223	10116	0		12	0.5	1.9	11	0.12	0.70
022	SLR @ SYCAMORE GROVE	95	396	0				98	71	90	0.3	2.1	0		
A0	APTOS CREEK @ MOUTH	100	9601	10	382	1014	8472	89	710	2	0.2	0.2	0		
A03	APTOS C @ BRIDGE ON SPRECKLES	13	532	1	30	97	422	12	199	3	0.1	0.1	0		
A1	VALENCIA C @ APTOS C	27	506	0				28	824	5	0.7	1.0	0		
A11	TROUT GULCH @ VALENCIA CREEK	9	328	0				9	1017	2	0.7	0.7	0		
A12	VALENCIA CREEK @ TROUT GULCH	7	445	0				7	275	2	0.4	0.4	0		
A2	APTOS C @ VALENCIA C	21	722	0				22	63	2	0.0	0.1	0		
S0	SOQUEL CR @ FLUME OUTLET	102	5894	15	107	429	3209	88	664	0			0		
S001	STORM DRAIN@CAPITOLA BATHROOMS	4	46	3	1072	2023	25000	2	3300	3	0.2	0.3	3	0.03	0.07
S0025D	ZELDA'S OUTFALL/CAPITOLA BEACH	2		1	302	25000	25000	2	10400	1	0.1	0.1	1	0.13	0.13
S002D	LAWN WAY OUTFALL/CAP. BEACH	4	47	3	205	988	25000	2	700	3	0.1	0.1	3	0.02	0.05
S005	STORM DRAIN AT CAPITOLA PIER	5	71	4	49	244	13968	2	917	4	0.9	2.5	3	0.03	0.07
S04	SOQUEL C ABOVE STOCKTON B EAST	4	489	0				4	192	0			0		
S07	SOQUEL C @ TRESTLE	4	458	0				4	154	0			0		
S1	NOBEL G @ SOQUEL C	11	480	4	756	3882	8716	8	1958	3	0.9	1.0	3	0.05	0.13
S12	NOBEL G @ TUNNEL @ BAY	7	474	2	333	959	5320	5	1500	2	0.9	1.1	2	0.01	0.02
S125	NOBEL GULCH @ ST. JOE'S CHURCH	6	393	1	74	85	1067	5	666	2	11.0	21.0	0		
S23	SOQUEL C @ NOB HILL	19	507	1	62	84	1081	18	153	1	2.2	2.2	0		

Health Risk Assessment

The specific health risk associated with any of the bacterial indicators or any of the 2600 bacteria identified to date and various other virus, protozoans, algae, and fungus found in water is not fully known. Many organisms are capable of producing disease in humans. Studies have been done to determine the infectious dose of several bacterial types in a hospital-controlled situation, where the number of organisms needed to cause infection has been estimated. 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 studies associating indicator bacteria with illness are varied and much work still needs to be done to find a suitable indicator of human health risk. Such studies are limited in west coast waters and areas not subject to treated sewage discharge.

Santa Cruz County EHS has maintained a database of anecdotally reported illness for the past ten years. In the past there have been campaigns to encourage swimmers, surfers, physicians, and the general public to report any suspected illness caused by swimming in county waters. A hotline and a website is maintained to facilitate reporting. During the past ten years, only 50 potential illnesses have been reported to the County. Although it would appear that illness from swimming does not occur frequently, this limited amount of anecdotal information is not adequate to draw strong conclusions. There are also many more anecdotal third party reports and a general public perception that water quality does pose a health risk, at least during wet periods of the year at locations like the San Lorenzo River mouth.

In order to provide better data on actual health risk, a health risk survey was performed as part of the 1997 San Lorenzo River Study. This focused on the Rivermouth and Main Beach, but other areas were also assessed for comparative purposes. This study showed that there are generally low levels of indicator bacteria producing 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. 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 (Table 9). 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. 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 occurrence of illness. In general, the occurrence of illness was low relative to studies conducted in other areas.

Table 9: Relative Risk of Illness with Swimming in Santa Cruz County Waters (1996-1997)

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

Table 10a: Occurrence of Illness at Santa Cruz County Beaches (2003-04)

Location	Number of Interview Dates	Total Persons Interviewed	Number Reporting Sick	Number Likely Sick from Water	Risk of Illness
Capitola - Winter	7	45	7	5	11.11%
SLR Mouth - Winter	12	47	8	5	10.64%
The Hook	1	15	3	1	6.67%
Seacliff	24	420	32	25	5.95%
Manresa	31	165	12	9	5.45%
Rio del Mar	19	267	18	13	4.87%
East Capitola	31	188	11	9	4.79%
Capitola Average	**48**	**363**	**23**	**15**	**4.13%**
Cowell's	29	272	9	8	2.94%
Twin Lakes	10	160	7	2	1.25%
SC Main	9	164	3	2	1.22%
E. Rio del Mar	16	93	3	1	1.08%
West Capitola	10	130	5	1	0.77%
Seabright	7	132	6	1	0.76%
Aptos Cr.	1	3	0	0	0.00%
Harbor	5	15	1	0	0.00%
New Brighton	2	27	0	0	0.00%
Rainy Weather	**26**	**129**	**11**	**6**	**4.65%**
Total	214	2143	125	82	3.83%

Rainy weather is defined as more than 0.1 inch of rain in the past 3 days.

Health Risk Results from Present Study

The current study involved an assessment of occurrence of illness year round at all of the primary beaches in the county. During the winter, most of the beach users were surfers and there was an emphasis on surf spots. Staff visited a beach and interviewed people using the water. A series of questions were asked of the participants, followed up by a telephone interview 10-14 days later. At the time of the initial contact, water samples were taken and analyzed for the three bacterial indicator species. Results were entered in a database that includes water quality, weather conditions, numbers of people reporting sick, and a determination of many were likely sick from contact with the water. An illness is considered likely to result from water contact when the interviewed person could recall no prior illness at the initial time of contact and has had no other illness source contacts for two weeks after initial contact. The data was analyzed to determine probability of illness relative to the different water quality parameters. This approach was similar to the survey of 1300 participants made in 1995-1997 at the San Lorenzo Rivermouth and other county beaches.

A total of 2143 interviews were completed on 214 different occasions. Interviews of beachgoers during this project showed an overall risk of getting sick from the water of 3.83 % (Table 10b). The overall risk was almost doubled in the winter periods (6.86%, Table 11). Occurrence of illness was highest (11%) right at the San Lorenzo Rivermouth and Capitola Beach during the winter. There did not seem to be any significant correlation to water quality, although this may be due to the fact that water quality standards were met when most interviews were conducted (Table 13). Symptoms were primarily cold-like symptoms, followed by flu-like symptoms and rashes. No serious illnesses were reported during the study. Both the frequency of illness and the lack of correlation to bacterial indictor are similar to results from a recent study of Mission Bay in Southern California (Colford, et.al., 2005). Birds were the predominant source of elevated bacteria levels in both the Mission Bay study and the present Santa Cruz study..

Table 10b: Occurrence of Illness at Santa Cruz County Beaches, 2003-04, geographically

Location	Number of Interview Dates	Total Persons Interviewed	Number Reporting Sick	Number Likely Sick from Water	Risk of Illness
Cowell's	29	272	9	8	2.94%
SC Main	9	164	3	2	1.22%
SLR Mouth - Winter	12	47	8	5	10.64%
Seabright	7	132	6	1	0.76%
Harbor	5	15	1	0	0.00%
Twin Lakes	10	160	7	2	1.25%
The Hook	1	15	3	1	6.67%
West Capitola	10	130	5	1	0.77%
Capitola - Winter	7	45	7	5	11.11%
East Capitola	31	188	11	9	4.79%
Capitola Average	**48**	**363**	**23**	**15**	**4.13%**
New Brighton	2	27	0	0	0.00%
Seacliff	24	420	32	25	5.95%
Aptos Cr.	1	3	0	0	0.00%
Rio del Mar	19	267	18	13	4.87%
E. Rio del Mar	16	93	3	1	1.08%
Manresa	31	165	12	9	5.45%

Table 11: Occurrence of Illness by Season (2003-04)

Season	Interviews	Percent of Total Interviews	Likely Sick from Water	Percent Sick
Spring	515	24%	19	3.69%
Summer	1351	63%	44	3.26%
Fall/Winter	277	13%	19	6.86%

Table 12: 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

Table 13: Relationship of Illness to Exceedence of Bacterial Standards (2003-04)

Bacteria Level	Contacts	% of Total Contacts	Number Sick	% Risk	% of Total Illness	Correlation Coefficient
Total Study	**2143**	**100%**	**82**	**3.83%**	**100%**	
E. coli >400 MPN/100ml	137	6.39%	6	4.38%	7.32%	
E. coli >200 MPN/100ml	263	12.27%	21	7.98%	25.61%	-0.02
Enterococcus >104 MPN/100ml	70	3.27%	1	1.43%	1.22%	
Enterococcus >35 MPN 100ml	84	3.92%	2	2.38%	2.44%	-0.03
***E. coli* <200 and Enterococcus <35**	**1851**	**86.37%**	**59**	**3.19%**	**71.95%**	

Assessment of Bacteria Sources by Microbial Source Tracking

There is a general perception that the greatest amount of health risk comes from exposure to water with human fecal contamination, although animal sources can also present risk. It is also necessary to know the source of contamination in order to develop appropriate control measures. This project included a substantial effort to characterize the sources of contamination using microbial source tracking.

Background on Microbial Source Tracking

None of the indicators typically used are particularly indicative of the type of contamination. Many researchers are skeptical of finding a single organism or chemical indicator that is specific to human 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 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. A number of other compounds have been suggested to assess presence of human contamination: caffeine, cholesterol, laundry whiteners, antibiotics, etc. None of these has yet confirmed to be consistently useful.

Many researchers and agencies are looking at various microbiological source tracking methods to characterize sources of contamination. A variety of methods assess the compounds produced by microorganisms (phenotypic methods), or evaluate genetic material (genotypic methods) to determine the source of the microorganism. The Southern California Coastal Water Research Project (SCCWRP) completed an evaluation of various methods of microbial source tracking to determine how accurately the different methods identified sources of fecal contamination in prepared water samples (Griffith, 2003). It appeared that genotypic methods were much more accurate that phenotypic methods. The most accurate method was Pulsed-Field Gel-Electrophoresis, followed by the ribotyping method, which was a little less accurate. The best methods were 75% accurate and all methods had false positives, indicating more human contribution than there was. The techniques require comparison of samples to a library of known genotypes linked to particular classes of organisms. The study found that the libraries should include samples from known sources from the same geographic area that the unknowns come from. In order to accurately characterize the relative contribution from different sources of fecal contamination at a particular location, it is important to analyze 50-100 bacterial isolates (individual colonies) collected from that location over time.

Ribotyping is a method of microbiological source tracking that differentiates human *E. coli* from other types of *E. coli*. Dr. Mansour Samadpour of the University of Washington Public Health Department has worked with over 80,000 samples of *E. coli* and has developed genetic fingerprinting that he believes specific to human *E. coli*. Ribotype matching is a method of analyzing band patterns of RNA 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 bacteria contamination in a stream system in Washington from human and various animal sources. He can separate *E. coli* found in domestic dogs and cats and other animals from humans based on these RNA band comparisons. Numerous other agencies in the State of California have used Dr. Samadpour's method with great success in Southern California and Morro Bay, among other places.

Dr. Samadpour uses the RT-ecoRI method of ribotyping. This method of ribotyping uses two restrictive enzymes to obtain a more accurate identification: EcoRI and PvuII. In a comparative study done by Stoeckel et al. (2004), this method correctly identified 90% of the samples for which it attempted a match. Because the background library used in the study was restricted to only 90 knowns, the method only identified 6% of the samples provided with the rest designated as unknown. In Santa Cruz County studies, which use an expanding library of over 80,000 knowns, the proportion of unknowns has decreased from 13% in 2002-03 to 8.5% in 2003-04. In the 2003 comparative study (Griffith, 2003), the ribotypiing method had a low level of false negatives for human contamination (10%) but a higher level of false positives (75%). The method would be expected to overestimate the human contribution. Also in that study, ribotyping correctly identified the dominant source of fecal contamination in 70% of the samples.

Method for Microbial Source Tracking

Since 2002, Santa Cruz County Environmental Health has collected and submitted samples for ribotyping by Dr. Samadpour of University of Washington (Molecular Epidemiology, Institute of Environmental Health). The method for performing this work is described as follows:

Task 1: Santa Cruz County Environmental Health personnel collected water samples from surface water and ocean water (10 locations) for a period of one year beginning in the fall of 2003. Approximately 300 water samples were processed for fecal coliform bacteria using the membrane filtration method of analysis with mFC broth as the growth medium. Live bacteria on plates with 10-60 colonies per plate were shipped to Molecular Epidemiology for ribosomal RNA typing.

Task 2: Santa Cruz County Environmental Health personnel collected fecal samples from potential sources of contaminants to the study area. All samples were identified by source, sample location, and sample date and shipped to Molecular Epidemiology for ribosomal RNA typing.

Task 3: Molecular Epidemiology picked three to five colonies from each plate shipped for confirmation of *E. coli* bacteria. From the positive *E. coli* colonies Molecular Epidemiology analyzed at least two strains (isolates) for ribosomal RNA typing to produce a genetic fingerprint of the culture, using the RT-ecoRI method of ribotyping.

Task 4: Molecular Epidemiology compared results from ribotyping of unknown source *E. coli* with *E. coli* bacteria isolated from known local sources and from their library of known sources to match bacteria strains. Molecular Epidemiology provided those results to Santa Cruz County Environmental Health Service. The results include for each isolate analyzed, the sample date, the sample location, and the source that that isolate matched (or "unknown", if there was no match).

Task 5: From the results provided by Molecular Epidemiology, Santa Cruz County Environmental Health Services prepared an analysis of the contributions from each source for each location. This was also compared to the measured fecal coliform level at the time the sample was collected and the overall logmean for all samples from that location during the sample period.

Results of Microbial Source Tracking

As a part of an earlier study, Santa Cruz County EHS contracted with Dr. Samadpour to conduct an assessment of bacteria samples collected from several locations in the San Lorenzo River in the winter of 2002-03. Approximately 100 samples from four locations on the River collected on 12 different dates were submitted for analysis, along with 100 samples from known local sources of fecal material. During the present study from fall of 2003 to fall of 2004, over 1000 E. coli isolates were analyzed by ribotyping to determine the likely source of the particular organism. Results are reported for the two different sample episodes (Table 14 and Table 15). The relative load of bacteria from each source at each location is displayed in Figures 2 and 3.

Birds accounted for about 60% of the contamination, particularly in the coastal areas. Human contamination was less than 5% on average, and was undetected in many areas. The highest percentages of human contribution are in the San Lorenzo River, Soquel Creek, and Cowell/Main Beach during the summer. Both San Lorenzo River and Soquel Creek show a very significant increase in human contribution at the downstream stations in the urban areas. Aptos Creek only shows human contribution right at the mouth. Human contributions to the lower River were higher in the first study, possibly because the majority of samples were collected in the winter and spring period when more runoff was occurring. An analysis of all samples collected from 2002 to 2004, showed a higher level of human contamination during runoff periods (Table 16).

Table 14: Contribution from Sources of *E. coli* Bacteria - San Lorenzo River (2002-03)

Based on Ribotyping (Most samples collected during wet periods with some rain in the previous 3 days). Results of this method are estimated to be at least 75-90% accurate.

	Station				
	Rivermouth	**Sycamore Grove**	**Felton**	**Boulder Creek**	**Combined**
	Station 003	**Station 022**	**Station 060**	**Station 245**	
Source					
Avian	39%	29%	23%	34%	31%
Bovine	1%	5%	1%	0%	1%
Canine	5%	6%	12%	9%	8%
Feline	0%	1%	1%	1%	1%
Horse	1%	1%	10%	1%	4%
Human	30%	21%	21%	26%	25%
Rodent	4%	9%	7%	5%	6%
Unknown	15%	17%	11%	10%	13%
Wildlife	4%	11%	15%	13%	11%
Total Isolates	147	114	151	140	552
Logmean E.coli	434	84	181	117	
(cfu/100ml)					
Human x Logmean	130	18	38	31	
(Hum.+unk) x Logmean	195	32	59	43	

Figure 2: Sources of Bacteria Loading to the San Lorenzo River (2002-03)

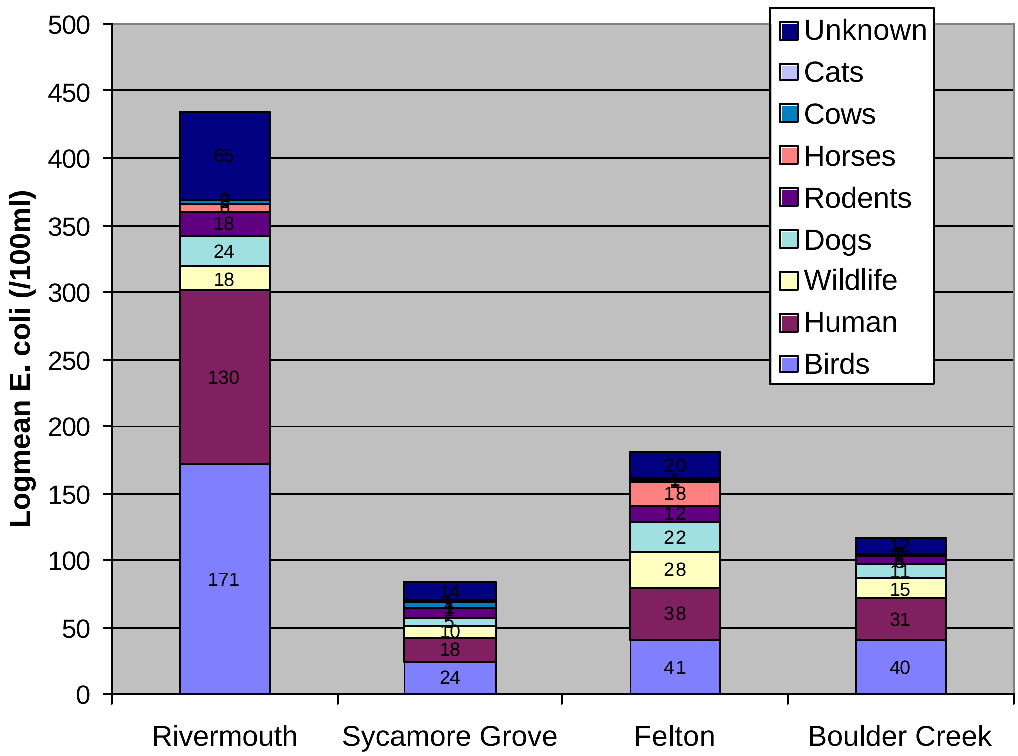


Figure 3: Contribution of Fecal Coliform from Various Sources by Station (2003-04)

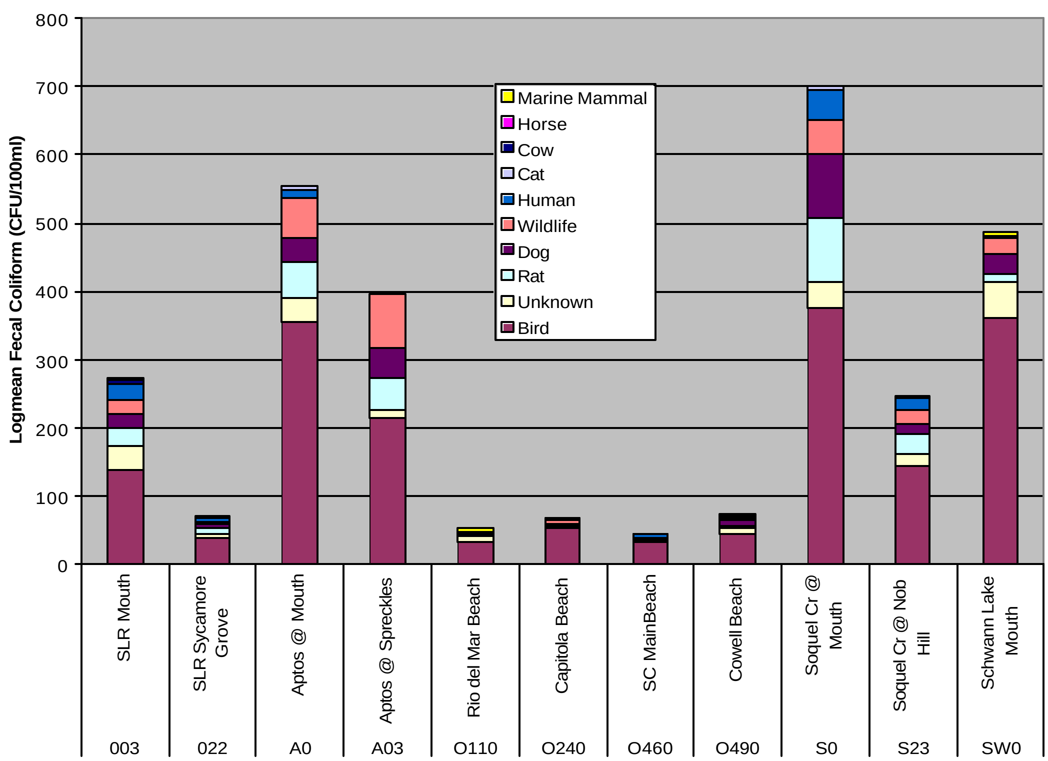


Table 15: Results of Microbial Source Identification 2003-04

Load is the product of the % contribution and the logmean of fecal coliform. Results of this method are estimated to be at least 75-90% accurate.

Stanum	Location	Total Samples	Total Isolates	Logmean Fecal Coliform	Bird	Cat	Cow	Dog	Horse	Rodent	Marine Mammal	Unknown	Wildlife	Human
	Total	**109**	**1047**		**646**	**4**	**8**	**78**	**2**	**73**	**18**	**89**	**80**	**49**
	Overall Occurrence				**61.7%**	**0.4%**	**0.8%**	**7.4%**	**0.2%**	**7.0%**	**1.7%**	**8.5%**	**7.6%**	**4.7%**
003	SLR Mouth	15	135	272	51.1%	0.0%	2.2%	7.4%	0.7%	9.6%	0.0%	12.6%	7.4%	8.9%
		Load			139	0	6	20	2	26	0	34	20	24
022	SLR Sycamore Grove	6	43	69	55.8%	0.0%	0.0%	7.0%	2.3%	14.0%	0.0%	7.0%	7.0%	7.0%
		Load			38	0	0	5	2	10	0	5	5	5
A0	Aptos @ Mouth	11	109	553	64.2%	0.9%	0.0%	6.4%	0.0%	9.2%	0.0%	6.4%	11.0%	1.8%
		Load			355	5	0	36	0	51	0	36	61	10
A03	Aptos @ Spreckles	9	89	375	53.9%	0.0%	0.0%	11.2%	0.0%	11.2%	0.0%	3.4%	20.2%	0.0%
		Load			202	0	0	42	0	42	0	13	76	0
O110	Rio del Mar Beach	9	84	52	63.1%	0.0%	0.0%	3.6%	0.0%	1.2%	10.7%	15.5%	4.8%	1.2%
		Load			33	0	0	2	0	1	6	8	2	1
O240	Capitola Beach	9	97	67	77.3%	0.0%	0.0%	5.2%	0.0%	0.0%	2.1%	5.2%	6.2%	4.1%
		Load			52	0	0	3	0	0	1	3	4	3
O460	SC Main Beach	9	86	45	68.6%	0.0%	2.3%	3.5%	0.0%	1.2%	3.5%	5.8%	4.7%	10.5%
		Load			31	0	1	2	0	1	2	3	2	5
O490	Cowell Beach	9	92	74	58.7%	0.0%	3.3%	10.9%	0.0%	4.3%	3.3%	12.0%	3.3%	4.3%
		Load			43	0	2	8	0	3	2	9	2	3
S0	Soquel Cr @ Mouth	11	112	701	53.6%	0.9%	0.0%	13.4%	0.0%	13.4%	0.0%	5.4%	7.1%	6.3%
		Load			376	6	0	94	0	94	0	38	50	44
S23	Soquel Cr @ Nob Hill	10	88	241	58.0%	1.1%	0.0%	5.7%	0.0%	11.4%	0.0%	8.0%	8.0%	8.0%
		Load			140	3	0	14	0	27	0	19	19	19
SW0	Schwann Lake Mouth	11	112	486	74.1%	0.9%	0.0%	6.3%	0.0%	2.7%	0.9%	10.7%	4.5%	0.0%
		Load			360	4	0	30	0	13	4	52	22	0

Table 16: Variation of Bacterial Sources in Response to Rain and Season

	All Samples, 2002-04		Dry Weather (<0.1 inch rain in previous 3 days)		Wet Weather (>=0.1 in)		Summer Season		Winter Season	
Source	Number of Isolates	Percent of Occurrence	Number of Isolates	Percent of Occurrence	Number of Isolates	Percent of Occurrence	Number of Isolates	Percent of Occurrence	Number of Isolates	Percent of Occurrence
Bird	937	51.6%	792	58.9%	145	30.8%	345	65.6%	282	41.6%
Cat	8	0.4%	6	0.4%	2	0.4%	1	0.2%	4	0.6%
Cow	17	0.9%	12	0.9%	5	1.1%	3	0.6%	10	1.5%
Dog	140	7.7%	105	7.8%	35	7.4%	36	6.8%	53	7.8%
Horse	22	1.2%	6	0.4%	16	3.4%			19	2.8%
Human	198	10.9%	97	7.2%	101	21.4%	20	3.8%	115	17.0%
Rodent	142	7.8%	101	7.5%	41	8.7%	31	5.9%	62	9.1%
Marine Mammal	18	1.0%	18	1.3%			7	1.3%	1	0.1%
Unknown	183	10.1%	111	8.3%	72	15.3%	51	9.7%	77	11.4%
Wildlife	150	8.3%	96	7.1%	54	11.5%	32	6.1%	55	8.1%
Subtotal	1815		1344		471		526		678	
No. of Sample Dates	29		21		8		9		11	
Logmean Fecal Coliform	204		200		224		293		152	

	Ocean Data		Cowell and Main Beach		SLR at Mouth		SLR @ Sycamore Grove	
Source /Percent of Occurrence	**Winter**	Summer	**Winter**	Summer	**Winter**	Summer	**Winter**	Summer
Bird	**65.1%**	71.1%	**57.6%**	62.5%	**41.6%**	40.0%	**32.1%**	65.0%
Cow	**1.6%**	2.0%	**3.0%**	4.2%	**1.6%**	4.0%	**7.4%**	0.0
Dog	**9.5%**	3.9%	**9.1%**	8.3%	**3.2%**	4.0%	**4.9%**	0.0
Horse	0.0	0.0	0.0	0.0	**1.6%**	0.0	**1.2%**	0.0
Human	**1.6%**	6.6%	**3.0%**	12.5%	**28.0%**	4.0%	**24.7%**	0.0
Rodent	**1.6%**	0.7%	**3.0%**	0.0	**5.6%**	16.0%	**7.4%**	10.0%
Marine Mammal	**1.6%**	3.9%	0.0	2.8%	0.0	0.0	0.0	0.0
Unknown	**14.3%**	8.6%	**18.2%**	5.6%	**13.6%**	20.0%	**17.3%**	15.0%
Wildlife	**4.8%**	3.3%	**6.1%**	4.2%	**5.6%**	12.0%	**3.7%**	10.0%
No. of Isolates	**63**	152	**33**	72	**125**	55	**81**	20
No. of Sample Dates	**2**	4	**2**	4	**9**	6	**7**	2
Logmean Fecal Coliform	**65**	66	**32**	70	**236**	194	**82**	64
Mean Human FC Load	**1**	4	**1**	9	**66**	8	**20**	0

Assessment of Contamination Sources

Although the relative contribution of bacterial contamination from various human and animal sources is indicated by microbial source tracking, additional information is needed to determine how those contributions occur, how they enter waterways, and how those contributions can be modified by improved management practices. Although there are periodic episodes of direct contamination in the marine environment, most of the beach contamination in Santa Cruz County is caused by discharge from the creeks, with a high urban runoff component during both wet and dry weather. A number of investigations were conducted during this study and in the past to better characterize these contributions. These are discussed in the following sections.

In the absence of data using 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 isolated episodes in the ocean, dry weather urban runoff, stormwater, and other nonpoint sources of contamination.

Marine Sources

In addtion to discharges from creeks and storm drains, bacteria in the marine environment may originate from direct input from birds, marine mammals, boat discharges, or sewage leaks from wharves. All of these sources except boat discharges have been confirmed at times in Santa Cruz County waters. Concentrations are further influenced by tidal action, wave action, currents, and potential for bacteria regrowth in kelp. Extensive testing around the offshore sewage outfall has previously confirmed that it is not a source of bacterial contamination to Santa Cruz County beaches.

A Santa Cruz County pilot study has shown that there is potential for very significant growth of bacteria in accumulations of kelp on beaches or in the water (Appendix C). Samples of kelp and water were collected from many locations throughout Santa Cruz County and allowed to sit for 24 hours. The initial bacteria levels were generally all less than 100 cfu/ ml, but after 24 hours the concentrations exceeded 24,192 cfu/100 ml for all samples containing kelp for E. coli, total coliform and fecal coliform. Only about 25% of the samples resulted in high enterococcus levels. None of the samples without kelp showed any increase in bacteria levels over 24 hours.

A recent study in Southern California showed that levels of enterococcus were significantly higher during greater tidal range (spring tides) than during periods of lower tidal range (neap tides) at 50 out of 60 beaches studied (Boehm and Weisberg, 2005). It was suggested that the higher levels during spring tides could result from increased contaminated groundwater flow or more flushing of contaminants from the beach surface from bird feces and wrack (including kelp and litter). Given that Santa Cruz beach area groundwater sampling did not show significant bacterial contaminants, the latter is the more likely mechanism, at least in Santa Cruz. On the other hand, in lo-circulation areas like Cowell Beach, it has been observed that greater circulation resulting from spring tides or increased swell has resulted in diffusing localized plumes of contaminated water and ending posting events.

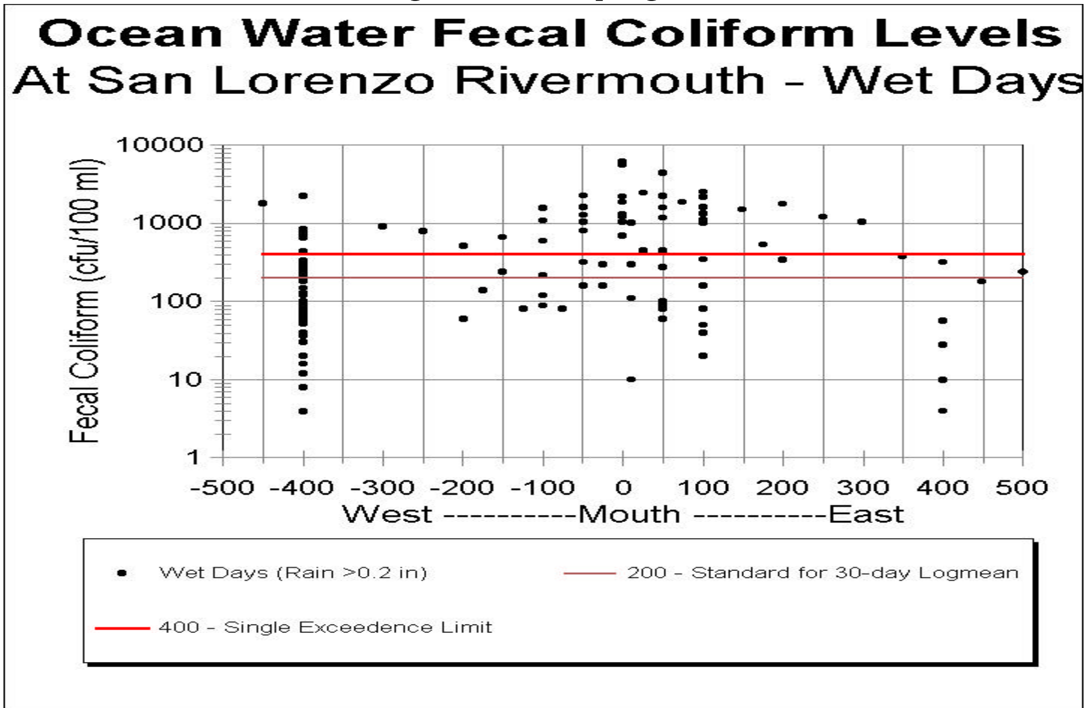
The proportion of loading from the various sources as shown in Tables 15 and 16 were evaluated in an attempt to estimate how much of the bacteria load in the ocean originates from the creek discharges and how much comes from sources in the marine environment. An inspection of the overall logmean fecal coliform levels between Aptos and Soquel Creek mouths and receiving waters at the adjacent beaches indicate that fecal coliform levels in the ocean average about 10% of the overall bacteria levels in the contributing creek, indicting significant dilution. At Santa Cruz Main Beach, the bacteria levels are about 15% of the levels found at San Lorenzo Rivermouth indicating either less dilution or more input of bacteria from sources in the marine environment. Terrestrial sources of bacteria (rodents, wildlife, etc.) are also diluted to 5-10% in the marine environment, suggesting an even greater dilution of creek input. The amount of contribution from birds in the marine environment shows only about a 15% dilution relative to freshwater sources, suggesting that 30-50% of the bacteria contribution from birds in the marine environment comes directly from birds in that environment and not from creek discharge.

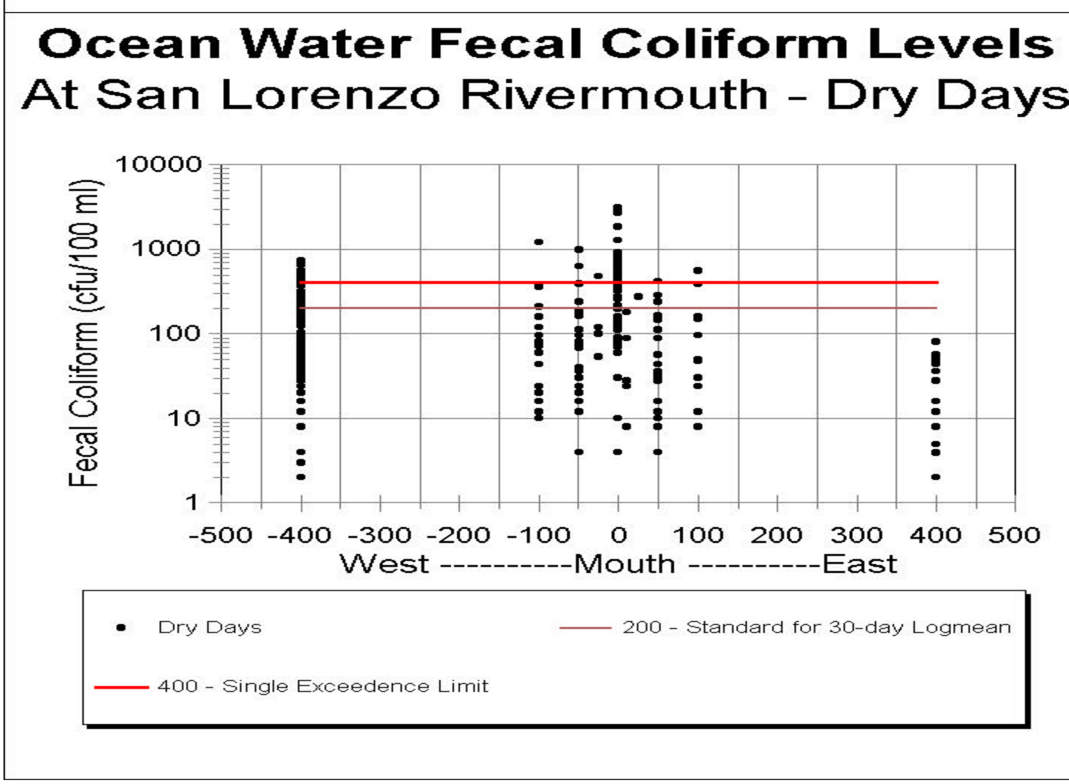
The human contribution at Santa Cruz Main Beach is elevated relative to diluted River water and relative to the other beaches, suggested there is some source of human contamination other than the River discharge. Additionally, 90% of the human bacteria detected during the summer season in the oceans were found at Cowell and Main Beaches with only one summer detection of human origin at Rio del Mar, and none at Capitola. There are generally numerous transient boats anchored off Santa Cruz in the summer, with limited access to shore facilities. Capitola also has offshore boat mooring in the summer, but the moorings are rented for longer term use and the operator provides water taxi service, making shore rest room facilities more accessible. Sewage leaks from both Santa Cruz and Capitola wharves have occurred in the past, but those have been promptly repaired soon after discovery. High concentrations of swimmers could also be a potential source of direct fecal bacteria input to the marine environment, although this seems less likely.

Creek Discharges

The most significant source of beach contamination in Santa Cruz County is discharge from the creeks, with a high urban runoff component during both wet and dry weather. This is indicated by the spatial distribution of bacteria levels in the vicinity of the San Lorenzo Rivermouth, which shows the highest bacteria levels closest to the River, with generally rapid reduction to either side (Figure 4). This was also evident in the results of stormwater sampling in the vicinity of Aptos Creek and Soquel Creek (Table 7). The breach of the San Lorenzo River lagoon in July 2004 caused 26% of the beach-days of beach posting for the two-year period of 2003-04. Improvement of beach water quality will require improvement of creek and lagoon water quality.

Figure 4: Ocean Bacteria Levels in Proximity to San Lorenzo Rivermouth
The station at 400 meters west is the Main Beach sampling location, the location at 400 meters east is the Seabright Beach sampling location.





Elevated bacteria levels in the creeks and storm drains 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 creek areas:

Large congregations of waterfowl (particularly seagulls) occur in the shallows and exposed sand bars in the tidal areas of the An Lorenzo River and Aptos Creek mouth. They also occur extensively in Capitola lagoon near its mouth.

Sewage spills and leaks from older sewer lines contribute sewage into some storm drains, particularly during conditions of high tide and fluctuating groundwater.

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

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 creeks.

Any of the above bacteria sources may seed the 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 sediments do not seem particularly high. 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 consistent with 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*. This would be consistent with the finding of predominant contamination from birds in storm drain water during the Santa Cruz microbial source tracking study. The Canadian study concluded that most of the contaminants were naturally occurring in birds and small animals and probably pose minimum health risk to humans, although this was not confirmed by an associated health risk survey.

Waterfowl

Microbial source tracking has shown that birds are the predominant source of bacterial contamination in all areas, including the beaches (Table 14). There is also a high component of bird contamination in storm drain discharges, indicating wash off from urban surfaces. During dry periods of the year, large bird populations, predominately seagulls, populate the exposed flats and shallow water in the lower San Lorenzo lagoon. Capitola Lagoon and Aptos Creek lagoon also experience very high concentrations of seagulls throughout the summer and other times. Birds also rest on the ocean surface and roost directly on beaches, where their feces are transported to the water by high tide and wave action.

On December 5 and 7, 1995, bird droppings were collected from the intertidal areas and directly from the water in the lower San Lorenzo River. 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. Soquel Creek showed similar impacts below the old Soquel Drive Bridge, which supported large concentrations of roosting pigeons before it was replaced. Fecal coliform levels upstream of the bridge averaged less than 200 cfu/100ml and were consistently greater than 600 cfu/100ml downstream of the bridge.

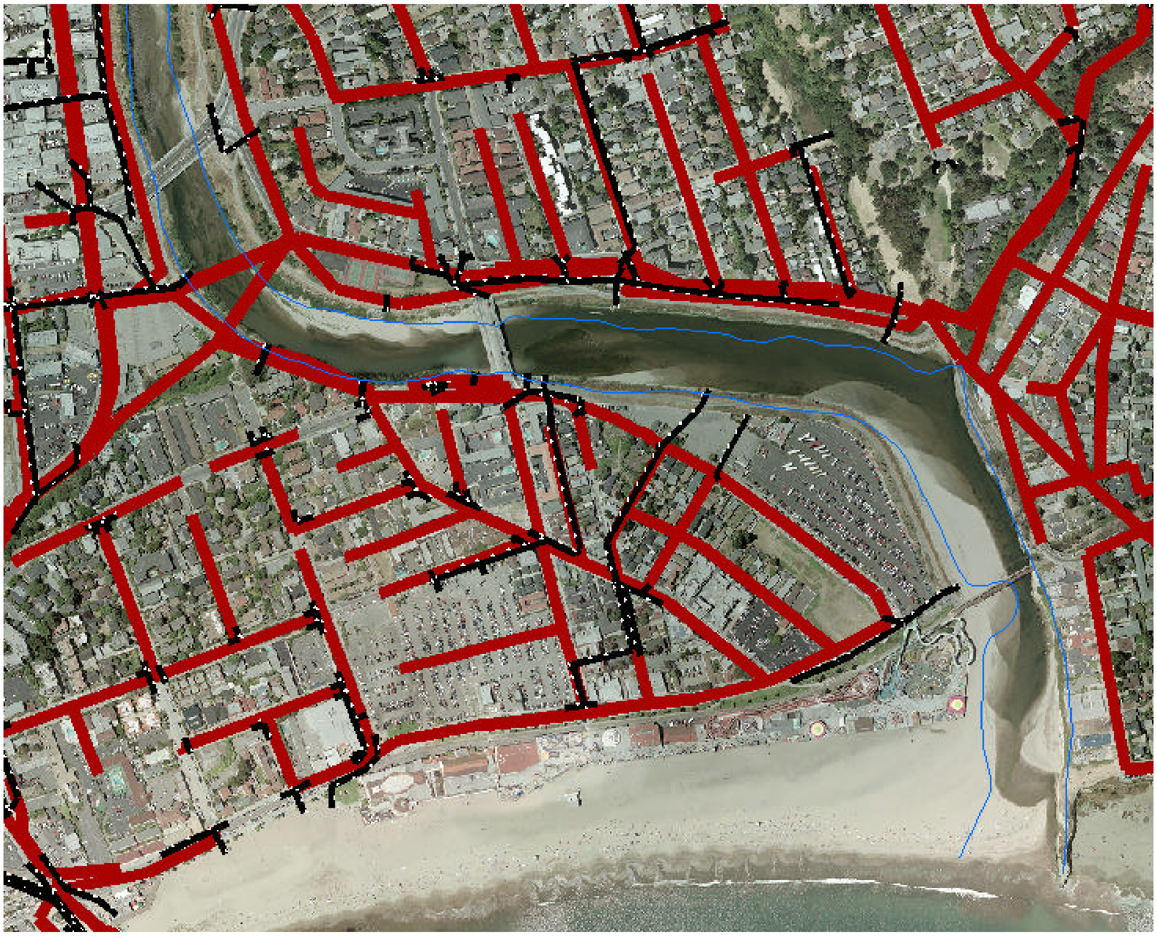
Sewage Spills and Leaks

While there have been substantial direct discharges of sewage from overflows or breaks in lines adjacent to lagoons or creeks, the most common mechanism for sewage to reach the creeks or beach, particularly during dry periods, 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 San Lorenzo 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 San Lorenzo 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 of Santa Cruz has done considerable sewer rehabilitation in areas along the River to correct those problems. 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 declined somewhat from the 1980's to the 1990's, and have further declined, likely as a result of the sewer improvements that have been made.

Figure 5: Sewer lines and Storm Near Lower San Lorenzo River

Sewers are solid lines and storm drains are dotted lines.



The City of Santa Cruz has continued to make improvements to the storm drain and sewer system since 1997, when a second round of extensive sampling of the storm drains was completed. Since that time, sewer improvements have been completed on Market Street, River Street, Water Street, Lower Ocean Street, San Lorenzo Boulevard, Laurel Street Extension, Third Street and some additional Beach Flats areas. There are plans to upgrade the storm sewer system along the River to reduce potential for infiltration and to divert storm drain water during the summer months to the sanitary sewer system. Sewer evaluations have been completed with upgrades underway in both the Capitola and Rio Del Mar areas (see below).

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. Past 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 creeks and damage aquatic life. Both the County and City have implemented new spill response procedures that include blocking the spill, vacuuming up the spill and collecting all the wash down water used to clean the spill area. In most cases the spill has no contact with a waterway.

Table 17 shows the past history of sewage spills within the City of Santa Cruz and the County Sanitation District, which serves the area that drains into Soquel and Aptos Creeks. The sanitation district typically does not report spills from private laterals, but the City does. The number and volume of spills are for the full jurisdiction and do not necessarily reflect the amount that actually goes to water bodies.. In the two year period of 1996-1997, the area of the City of Santa Cruz 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.

Table 17a: Reported Sewage Spills, 1991-2004

	Santa Cruz City		County Sanitation District	
Year	Number	Volume	Number	Volume
1991	41	2,675	4	850
1992	151	13,268	10	10,386
1993	131	21,610	26	18,790
1994	179	56,158	47	88,855
1995	123	13,178	67	199,093
1996	44	4,625	5	6,435
1997	26	5,223		
1998	112	38,932	17	166,244
1999	123	31,406	11	167,570
2000	159	12,616	5	391,830
2001	133	74,981	7	3,065
2002	108	12,455	21	20,280
2003	96	4,549	13	170,160
2004	73	4,205	17	9,765
Average	107	21,134	19	96,409

The larger volume discharges from the Sanitation District that occurred in 1995 and 2000, typically result from large scale failure or overflow of main pump stations. In the past these occur during storm events and are caused by power failures, or extensive infiltration of stormwater into sewer lines, exceeding the capacity of the pumps. Since those times, the District has implemented a program to upgrade sewer lines to reduce wet weather infiltrations, upgrade pump stations and provide emergency power sources at the major pump stations.

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 sewer agencies are 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. County staff will also attempt to open private laterals if requested to do so by the Health Officer. 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 Burlingame and Pacific Grove these programs indicate that 90% of the laterals require 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. The County is developing an ordinance to require improved inspection and maintenance of large private collection systems, such as those serving shopping centers, trailer parks, rest homes and apartments.

Recent Sewer Evaluations

The present study included funds for evaluations of sewers in order to better determine the likelihood of sewage leaks. The work funded by this study focused on the Rio del Mar area, as other water quality grants had already funded evaluations near the San Lorenzo River (Clean Beach Initiative) and Soquel Creek (Proposition13). The evaluations using video technology have indicated substantial deficiencies in mainlines and private laterals. Cracks, roots, sediment buildup and winter time seepage all indicate a high likelihood for sewage to exfiltrate out of the system where it could enter groundwater and/or enter the storm drain system.

Almost 4700 linear feet of sewer line was video-tested in the Rio del Mar near Aptos Creek. After a review of the logs and videos, Sanitation District staff concluded that, “there are many avenues for high groundwater to enter the sewers and to also flow out of the sewer mains/laterals.” As a result, over 2350 linear feet of line is recommended to be replaced. Funding for the design is included in the 2005-06 budget and the replacement is anticipated to be constructed in 2006-07. Replacement of all the lines and reconnection of the existing laterals is estimated to cost $1,015,000. Logs and videos of the Rio del Mar sewer evaluation have been submitted separately.

Storm Drain System

The storm drain system has the potential to collect, store, incubate and convey bacteria and virus to the creeks and beaches from surface and subsurface sources in the urban areas. Bacteria are introduced into storm drains by sewage spills, pet and animal droppings, garbage accumulation, exposed dumpsters, discharge of wash water, or other sources. Once in the system, bacteria 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 urban areas 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 bacteria levels from non-sewage sources have been documented in many studies and have been confirmed in sampling of residential street gutters in Santa Cruz (SCCHSA, 2001). These types of sources are very difficult to identify and control and their public health significance is unknown.

Limited microbial source tracking was done for select storm drain discharges. One drain from the Beach Flats side of the San Lorenzo River indicated substantial contribution from birds and dogs, with no human contribution. One sample from another drain on the east side of the River after a storm event showed 30% human contribution and 30% rodent contribution. Additional follow up microbial source tracking for storm drains is being conducted.

While the sample results from the 1995-97 San Lorenzo River Study and the current 2003-04 study indicate that most storm drains typically have bacteria levels in excess of body contact standards, some of the drains have extremely high levels, suggesting some continuing potential sewage contamination or other source of high bacteria that should be further investigated.

Although bacteria levels in storm drains are greatly in excess of the bacteria levels in the River and creeks, the impact of storm drains during the summer months is somewhat limited by the normal low flow volumes of the storm drains. As an example, at the San Lorenzo River's typical late summer flow of 8 cubic feet per second (cfs) and a bacteria level of 300 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 350 cfu/100ml. However, the influence of storm drains can be much greater during flushing storm periods and during summer periods of tidal inundation, when groundwater rises and the storm drain pump system pumps large volumes of water from the storm drains into the River.

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 should substantially reduce bacteria contributions originating from intermittent, non-sewage sources. The County is beginning to implement similar practices in Capitola and the unincorporated areas. Grant funds were received which will fund the purchase and use of two new Vactor trucks for cleaning lines and catch basins.

Groundwater Contamination

Monitoring wells to test shallow groundwater quality were constructed in the area near the lower San Lorenzo River with funding from the Clean Beach Initiative. These wells were monitored during this study, along with two other monitoring wells that were found in the Rio del Mar area near Aptos Creek. The wells showed somewhat elevated levels of nitrate and ammonia, but generally low levels of bacteria. This would suggest that there is not widespread contamination of groundwater. However, it is likely that there could still be narrow and localized movement of contamination from leaking sewer lines across relatively short distances to storm drains that were located in close proximity to the sewer leak. There are a number of locations in Santa Cruz, Capitola, and Rio del Mar where sewer lines and storm drains are located adjacent or above each other. These locations have been mapped and are being further evaluated.

Table 17b: Results of Shallow Groundwater Testing

Station Number	LOCATION (in Santa Cruz unless otherwise indicated)	Number of Samples	Mean Electro-Conduc-tivity	Logmean Entero-coccus	Logmean E. coli	Logmean Total Coliform	Mean Nitrate	Mean Ammonia
B-28	SW CORNER MOOSEHEAD @ SEAWALL- Rio del Mar	5	33833	6	6	8	0.5	0.29
B-29	SW CORNER MOOSEHEAD @ SEAWALL – Rio del Mar	5	28520	5	5	11	2.0	0.10
MW1	BEACH ST @ WASHINGTON ST	15	1056	5	7	12	7.8	0.53
MW2	115 CLIFF ST EAST SIDE OF ST	15	818	5	7	9	0.4	3.68
MW3	160FT NW BEACH ST ON RAYMOND	15	1707	5	6	7	0.5	0.59
MW4	SE CORNER PARK PL @ UHDEN	15	3071	5	6	8	0.1	0.42
MW5	150FT W BEACH ST ON PARK PLACE	15	1796	5	5	9	0.1	2.79

Upstream and Floodplain Areas

The bacteria contribution to the lower San Lorenzo River from upstream areas is generally less than 25% of the total load in the lower River. Similarly, Soquel Creek and Aptos Creek both have much lower bacteria levels at Nob Hill (20%) and Spreckles (28%), respectively. However, during storms, the contribution from upstream areas is substantial with bacteria levels greatly exceeding safe body contact standards for several days. There is also a very substantial input form urban areas during storms, resulting in higher bacteria levels at the mouth as compared to where the River enters the City. These high levels originate from watershed wash off, non-specific urban sources (as described above), and probably some 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 stream areas. The human contribution to the overall bacteria load is much higher in rainy periods than dry periods (Table 15), but the human contribution from the rural areas on septic systems is still only 25-30% of the total human contribution measured in the urban area of the lower River.

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 that 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 failures 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). No human contribution was found in the 58 samples from the upper San Lorenzo River during the summer months that were analyzed as a part of the microbial source study. The same study suggested that summer season bacteria in the upstream areas appear comes primarily from birds (64%), wildlife (24%), and dogs (7%). Total bacteria levels drop substantially as the River flows out of the suburban areas and through the State Parks or other low density areas. Microbial source tracking results also confirm relatively low human contributions from upstream areas for Soquel (7%), and Aptos Creeks (0%) (see Table 14).

Livestock operations are also a potential source of bacterial contribution during storm periods. Microbial source tracking indicated some contributions from both horses and cows in the San Lorenzo River (Table 14). It is estimated there may be some 400-600 head of livestock kept in the San Lorenzo watershed, primarily horses in commercial stables and small homeowner operations. Similar amounts probably exist in the Soquel and Aptos watersheds. 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 non-storm periods. County Environmental Health has had success with improvement of runoff and manure management at many of the larger operations. A cooperative education and technical assistance project is underway as a joint effort between the Santa Cruz County Resource Conservation District, Ecology Action, and the Santa Cruz Horsemen's Association.

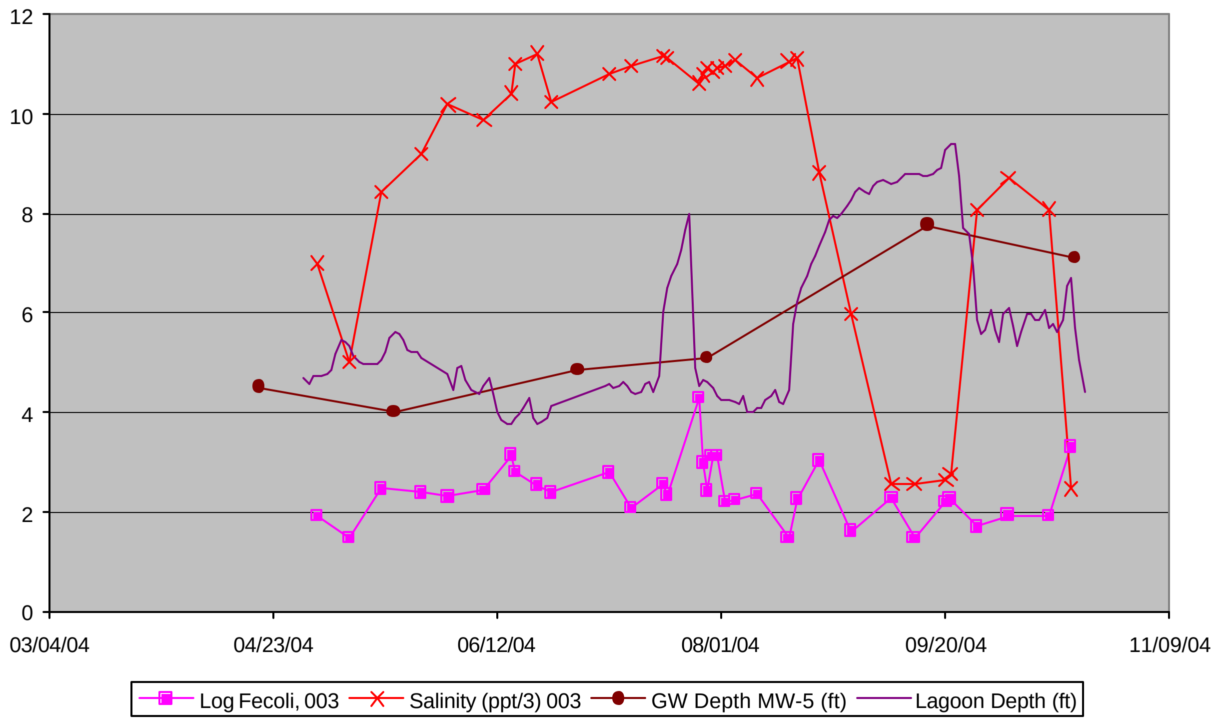
The San Lorenzo River flood control channel and riparian areas along other creeks are used by homeless persons and others for camping, bathing, recreation, and loitering. This results in significant deposition of litter, human waste, and pet waste, all of which can contribute to high bacteria levels and public health hazard, particularly when the lagoon backs up or winter flushing flows occur. However, investigative monitoring to date has not confirmed a direct impact from upstream encampments during dry periods.

San Lorenzo Lagoon and Breaching

The state of the San Lorenzo River lagoon and the other lagoons can have a significant effect on bacteria levels in the lagoon and the adjacent beaches. Figure 6 shows trends in bacteria levels at the San Lorenzo River mouth in summer of 2004, relative to the condition of the lagoon. The lagoon closed for about a week in the last half of July, indicated by a peak in water level. However, it did not convert to freshwater as indicated by the continued high salinity levels. It built up to a depth of over 8 feet before it breached early in the morning of July 26. When it breached, the level dropped four feet in four hours and fecal coliform levels jumped to over 19,000 cfu/100ml. *E. coli* levels in the ocean ranged from 700 to 3000 from Cowell Beach to Twin Lakes Beach that first day of the breaching. Total coliform levels were also elevated, but enterococcus levels remained low. Ocean water quality improved at the beaches to the east within several days, but the *E. coli* levels did not drop below 200 at Cowell, Main Beach and the Rivermouth until a week after the breaching. The rapid breaching may have caused scour and suspension of bacteria from the sediment and the high lagoon level and then rapid decline may have caused flushing and backflow from the storm drain system.

The lagoon formed for a much longer period of time in August into September until it was manually breached in a controlled manner. That breaching occurred at a slower rate and only partially dropped the level in the lagoon. The bacteria levels started low and remained low. The groundwater levels in Beach Flats rose almost 4 feet to within 3 feet of the ground surface during the latter lagoon closure, as indicated by the plot of MW-5. It is likely that the groundwater levels were so high above the level of the sanitary sewers, that conditions induced infiltration to the sewer system and preventing any leakage of sewage out of the sewers and into the storm drains system and then the River. Keeping the lagoon level higher during the controlled breach may also have prevented scour and suspension of bottom sediment and bacteria, and may have limited the flushing of the storm drain system.

Figure 6: Water Quality Conditions at SLR Rivermouth During Lagoon Closure (2004)



Calculation of Loading

An effort was made to estimate bacteria loading from various sources in the lower San Lorenzo River (Table 18). Estimates of summer flow from various pump stations are available from pump logs. However, because flow is variable, flow estimates from many of the stations have been increased for consistency. Even though upstream bacteria concentrations are relatively low, the percent contribution is fairly high as a result of the large flow contribution. Almost half of the load appears to come from non-specific, unmeasured sources. This could be from birds in the lagoon, which would be consistent with results from microbial source tracking. It is also likely that bacteria levels in turbulent pump discharges may be higher than levels contained in samples from quiescent wet wells.

Data for storm drain discharges is not available for Aptos and Soquel Creeks, but a rough budget for each has been estimated based on limited flow measurements and changes in concentrations from upstream to downstream (Table 18). For Aptos Creek changes in logmean fecal coliform concentrations indicate that 72% of the fecal coliform originates in the lower urban areas downstream from Spreckles Drive. For Soquel Creek, 77% of the bacteria load at the mouth originates in the lower reach downstream of Nob Hill. Table 19 shows estimates of loading from various sources as indicated by ribotyping data.

Table 18: Estimated Bacteria Loads Based on Flow and Bacteria Concentrations
(See Table 20 for Loading by Source)

Lower San Lorenzo River Location	Summer Flow (cfs)	Fecal Coliform (cfu/100ml)	Fecal Coliform Load (cfs X cfu)	Percent Contribution to Load	
SLR ab Hwy 1	5	70	350	18%	
Branciforte Cr.	1	300	300	15%	
Non-specific	0.2	4200	840	43%	Birds?
Pump 1b-Uhden	0.2	178	35.6	2%	
Pump 3 Water St.	0		0	0%	
Pump 1-Laurel	0.2	815	163	8%	
Pump 1a-Boardwalk	0.2	200	40	2%	
Pump 2-Bixby	0.2	1156	231.2	12%	
Total Calculated Load			1959.8		
Rivermouth (Measured)	7	280	1960		

Soquel Creek Location	Flow (cfs)	Fecal Coliform (cfu/100ml)	Fecal Coliform Load (cfs X cfu)	Percent Contribution to Load
Soquel Cr @ Nob Hill	4	150	600	21%
Nobel Gulch	0.2	1900	380	13%
Non-Specific Sources	0.1	18500	1850	65%
Total Calculated Load			2830	
Soquel @ Mouth (Measured)	4.3	664	2855	
Aptos Creek Location	Flow (cfs)	Fecal Coliform (cfu/100ml)	Fecal Coliform Load (cfs X cfu)	Percent Contribution to Load
Aptos Cr	2.5	63	158	8%
Valencia Cr	0.5	825	413	20%
Aptos At Spreckles	3.0	200	600	29%
Non-Specific Sources	0.1	14500	1450	71%
Total Calculated Load			2050	
Aptos @ Mouth	3.1	664	2058	

Bluff Seep Monitoring

Water samples were taken from seeps discharging from coastal bluffs at various locations on 1/26/2004, 3/17/2004, and 11/15/2004. The number of bluff water samples was limited because there were few sites that would flow and were in proximity to the ocean to have a potential affect on the ocean waters. Sites chosen for bluff sampling were:

1) Water draining from the hillside at Depot Hill accessible from the beach at Capitola.
2) Water draining from a lateral drain placed in a concrete seawall below homes east of the stairway leading to Private's Beach in the Opal Cliff Beach area.
3) Water draining from a lateral drain placed in a concrete seawall below homes west of the stairway leading to Private's Beach in the Opal Cliffs Beach area.

Sample results for all sites indicated non-detectable levels of enterococcus and E. coli bacteria, with elevated levels of total coliform bacteria in samples taken from the Depot Hill site and the lateral drain placed in the seawall east of the stairway to Private's Beach.

The seep in the bluff at Depot Hill runs all year around starting at a level about 20 feet above sea level. Due to the constant flow of water at this site there is a well-established wall of vegetation, which could account for the high level of total coliform bacteria.

Two of the three samples taken from the lateral drain in the seawall east of the stairway to Private's Beach had total coliform bacteria over 1000 MPN. There was also a light vegetation covering on this wall. Water ran at this site during the winter months but did not flow during dry periods.

There were no detectable bacteria of any of the three indicator types found from the samples taken from the lateral drain in the seawall west of the stairway to Private's Beach.

In conclusion, the sample taken bluff seeps would indicate that there was not any contamination of shallow groundwater by sewage leaks at those locations.

Current and Circulation Assessment

Beach water quality is also influenced by circulation patterns and potential offshore sources such as birds, marine mammals, boat discharges, and wharf discharges. County staff have conducted assessments of the direction of near shore currents in relation to observed water quality. The highest bacteria levels are found in the direction that the current moves from the creek discharge. Although the currents generally flow to the southeast, there can be reversals, and the bacteria levels tend to be worse during periods of calm weather, and low tidal fluctuation particularly in locations of reduced circulation like Cowell Beach and Capitola Beach. During most periods, when creek discharges are blocked by sand bars at Aptos Creek, San Lorenzo River, and/or Neary Lagoon, the water quality in the ocean improves significantly. Occasionally high bacteria levels occur at the beaches, which seem to be related to seasonal concentrations of birds during periods of red tide and high biological activity in the nearshore environment. No impact from ocean sewer outfalls has been observed since the outfalls were extended offshore and the treatment and dispersal process was upgraded.

Video analysis of stormwater runoff plumes in the ocean was made twice after periods of heavy rainfall. Analysis was made in late December 2003, after 4.23" of rain had fallen in a 24 hour period and in late February 2004, after about 2.64 " of rain had fallen in a 72 hour period. Video analysis was made from bluffs approximately 50 feet above the mouths of the San Lorenzo River, Soquel Creek, and Aptos Creek.

Current movement was also tracked using oranges as a tracking method on several occasions after heavy rainfall. To monitor current from the mouths of the San Lorenzo River, Soquel Creek, and Aptos Creek oranges were thrown into the body of water during an ebbing tide and tracked until they either returned to the beach or met with another body of water. The tracking of oranges coincided with the mud plume from the mouths but was easier to track at periods due to the visibility of the oranges.

At Soquel Creek the flow ran east parallel to the beach and out about 20 feet and ran into flow coming from the mouth of Porter Gulch. Flow from both the San Lorenzo River mouth and Aptos Creek mouth returned to the beach east of those mouths at 25-50 meters depending on the strength of the flow.

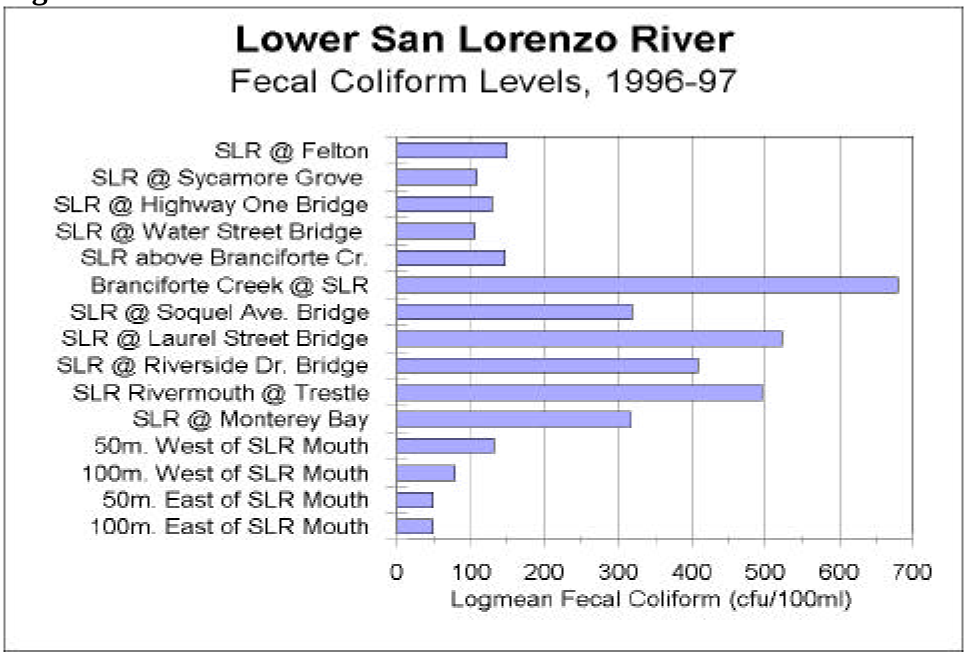
During the summer, flow from the San Lorenzo River seemed to primarily flow west toward the wharf and Cowell's Beach, as indicated by the pattern of elevated bacteria levels after the July 26, 2004, breach.

Conditions at Specific Areas

Cowell Beach, Santa Cruz Main Beach, Seabright Beach: An extensive investigation of the San Lorenzo River in 1997 showed that 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 (Figure 7). Sources of high bacteria are concentrations of birds and storm drain discharges. Likely sources of bacteria in the storm drain system include sewage spills, subsurface sewage leaks, and nonspecific, nonpoint sources of bacteria in urban areas from bird droppings, 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, and generally meet standards within 50 meters either side of the Rivermouth. When episodes of bacterial contamination occur on the main beach, they usually correlate with River discharge and bacteria levels drop significantly when the sand bar is in place and the River is not discharging.

Moving west away from the Rivermouth, bacteria levels tend to decline, and then start to increase again in the vicinity of the wharf and Cowell Beach. Cowell Beach is under the influence of discharge from Neary Lagoon during the wet months, but during the summer, the Neary Lagoon discharge is pumped to the sewage treatment plant for treatment and ocean discharge. Circulation is diminished at Cowell and bacteria levels can be elevated as a result of birds, marine mammals, or discharges from the wharf or anchored boats. Kelp decomposition can also exacerbate the elevated bacteria levels, particularly at times of poor water circulation.

Figure 7: Fecal Coliform Levels in Lower San Lorenzo River and Beach, 1997



Twin Lakes Beach: The small lagoon on the beach in front of Schwan Lake has the highest average bacteria levels of any of the coastal lagoons. The apparent source of this is the large concentration of domestic geese and other waterfowl that occurs in that general area. However, the water quality in the ocean there at Twin Lakes Beach is generally quite good. This is probably due to the lack of significant flow from the lagoon to the ocean. Past sampling of discharge from the harbor dredge to the ocean at Twin Lakes Beach also shown low bacteria levels.

Capitola Beach: Figure 8 shows the results of intensive sampling for Soquel Creek, Capitola Lagoon and the Capitola Beach. Most of this was done in 1987, in support of the development of the Lagoon Management Plan. Since that time sewage leaks were corrected along Nobel Gulch, Venetian Apartments and on the wharf. In addition, the Soquel Drive Bridge was reconstructed, eliminating the bird roosting area under the old bridge, which contributed to a very significant jump in bacteria levels below the bridge. Although that extent of sampling has not been repeated in recent years, basic monitoring has continued with some expansion during the recent study and other studies conducted by the City of Capitola. Bacteria levels continue to be significantly elevated near the mouth, with much lower levels upstream. Potential sources are storm drain discharge, restaurant discharge, sewer leaks, and continuing high concentrations of birds in the lagoon, on the beach, and on the adjacent restaurants. Microbial source tracking has confirmed birds to be the most significant source, followed by pets, wildlife and humans.

Sewer evaluations in 2004 and 2005 showed sewer lines in poor condition near the creek. These are currently scheduled for replacement. An attempt was made to sample storm drains during the current study, but most were inaccessible or dry except for storm periods. Nobel Gulch continues to show elevated bacteria levels from birds, wildlife, dogs, and potential urban discharges. Bacteria levels decline in the ocean, particularly to either side of Soquel Creek discharge. In 1987, the levels tended to be lower to the east of the creek, whereas in 2003, they have tended to be lower to the west of the creek.

Rio del Mar Beach: Recent studies of Aptos Creek lagoon showed high levels of nitrate and bacteria, strongly suggesting a sewage source near the mouth (Swanson, 2003). The results of a fairly intense sampling program in 1987 are shown in Figure 9. Recent spot sampling shows similar results. Birds appeared to the primary source of elevated bacteria levels in the lagoon. This was confirmed by the microbial source sampling. Limited past sampling suggested high levels of bacteria in the storm drains, but investigations during the present study found the drains to be dry during the summer period. However, sewer lines and laterals in the Rio del Mar area were found to be in poor condition and are potential sources of sewage leaks to the creek. Due to poor condition or other technical problems, several sewer lines adjacent or under the creek could not be investigated and are also potential sources.

Bacteria levels in Aptos Creek are considerably lower further upstream at Spreckles Drive, indicating that only about 25% of the bacterial loading comes from upstream sources. Valencia Creek has low flow but intermittently high bacteria levels, potentially suggesting upstream bacterial sources from septic systems, wildlife and/or domestic animals. During the present study, no significant human contribution was been found entering from upstream areas and wildlife seem to be a major contributor to the intermittently flowing channel of Valencia creek. During the past several years there have been periodic sewer overflows from several private shopping center sewer systems near the lower reaches of Aptos and Valencia Creeks. A higher level of maintenance of these systems will be required in the future.

Bacteria levels discharging from Aptos Creek generally decline rapidly once the creek enters the ocean. This beach here is more open and exposed, with better potential for dilution and mixing than in Capitola and Santa Cruz.

Figure 8: Historic Fecal Coliform Levels in Lower Soquel Creek

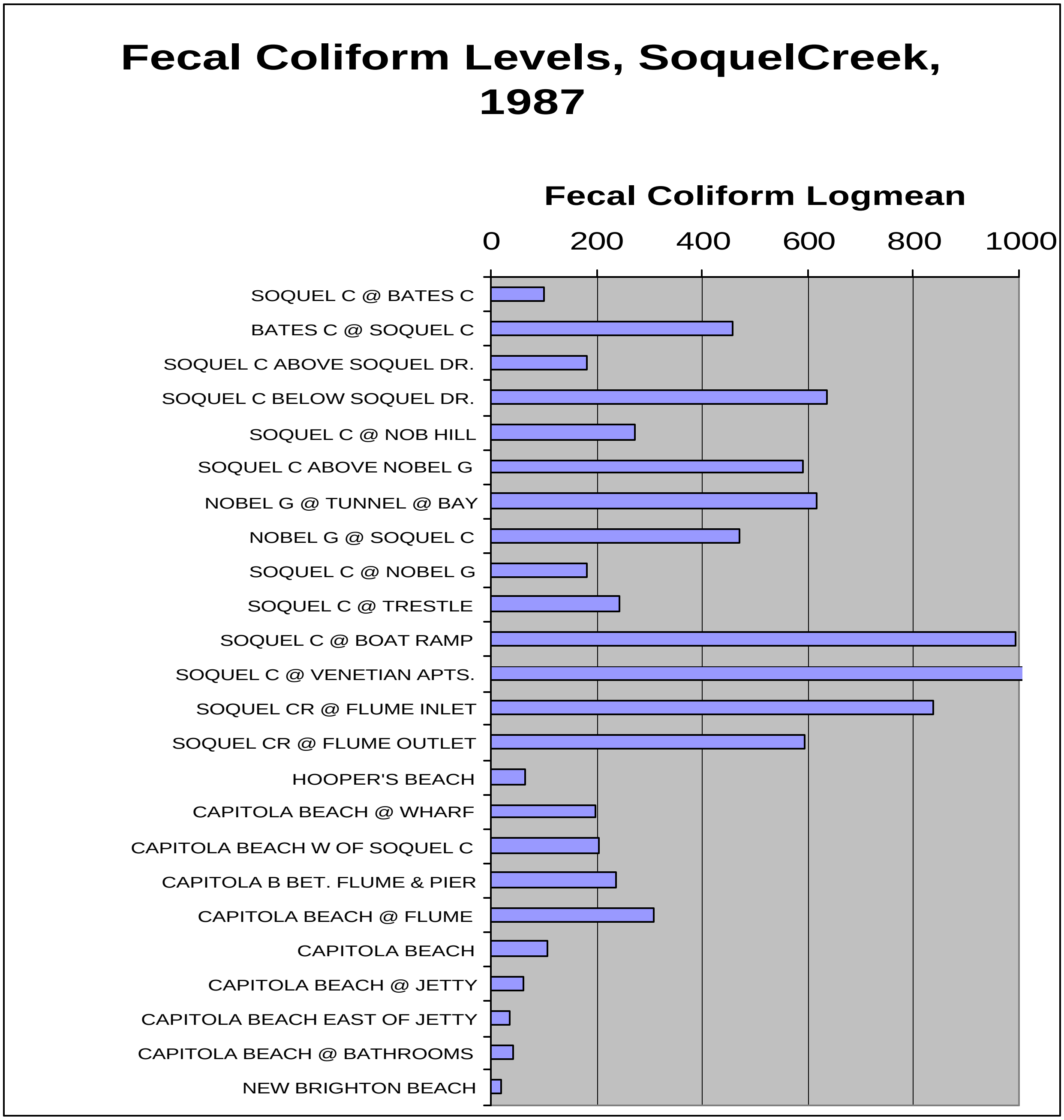
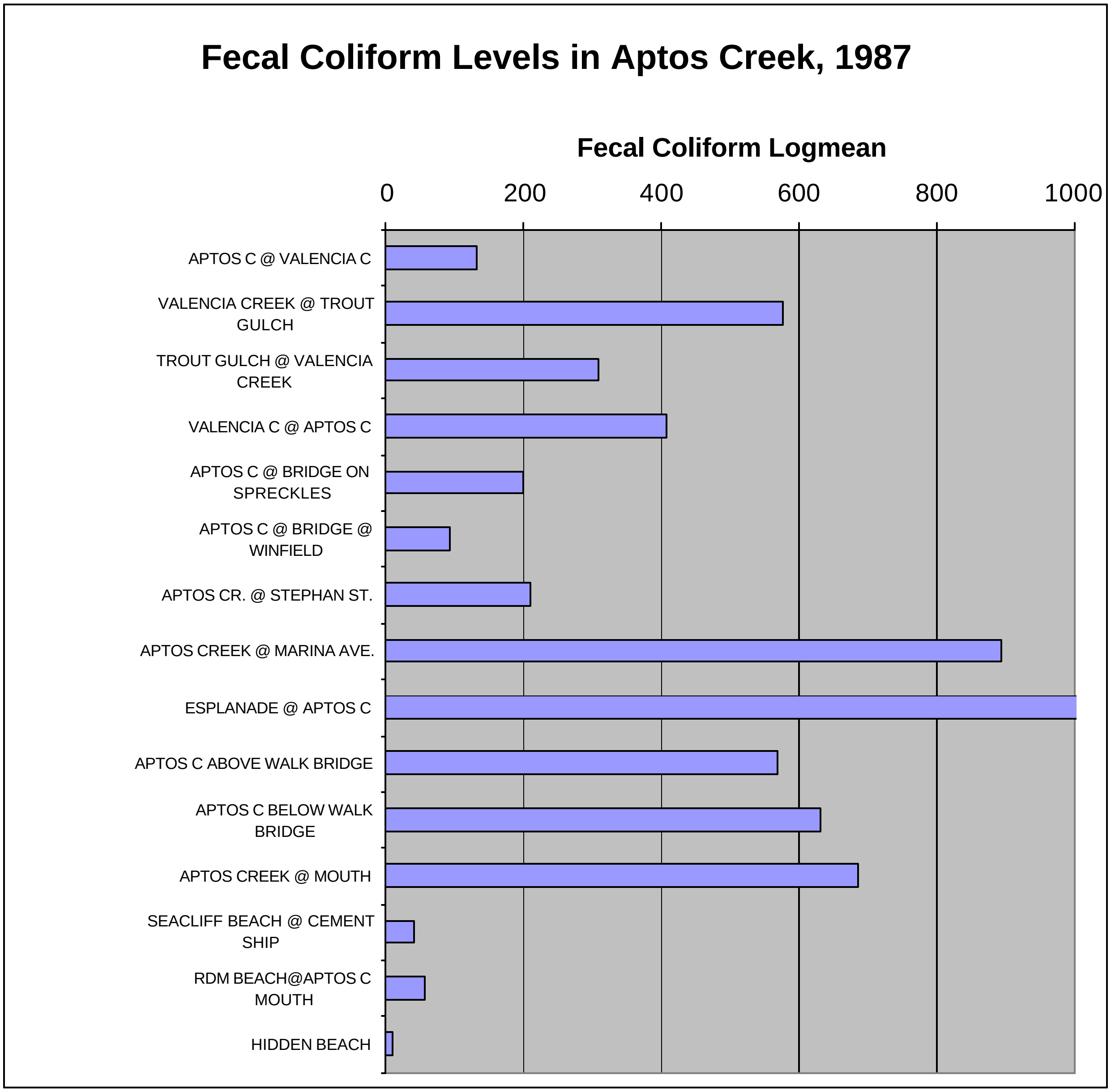


Figure 9: Historic Fecal Coliform Levels in Lower Aptos Creek, 1987



Strategies for Improvement of Beach Water Quality

Sources, Mechanisms of Input, and Potential Control Measures

A number of different sources are likely contributing to elevated bacteria levels in the lagoons and at the beaches. Table 19 shows a summary of the likely sources of bacterial contamination based on the findings of this study and previous studies. Tables 20-22 show likely loading based on the microbial source data.

Table 19: Confirmed, Likely or Potential Sources of Contamination for Each Beach area

Source -- Beach	Rio del Mar	Capitola	Twin Lakes	Santa Cruz Main/SLR	SC – Cowell Neary Lagoon
Storm Drains	Likely	Likely		Confirmed	Likely
Sewage Leaks	Likely	Likely	Potential	Likely	Potential
Birds	Confirmed	Confirmed	Confirmed	Confirmed	Confirmed
Poor Circulation		Confirmed		Low	Confirmed
Wharf, Jetty, Boats	Limited	Low	Limited	Low	Likely
Septic or Upland	Limited	Low		Low	

Table 20: Bacteria Source Allocation for San Lorenzo Rivermouth

			cfu/100ml		cfu/100ml
Contributing Area/Source	%Contribution	%Contribution	Load	%Controllable?	Target Load
Upstream Areas (Station 022)	In sub area	25%	70		
Birds	56%		39	0%	39
Wildlife	7%		5	0%	5
Rodent	14%		10	25%	7
Human	7%		5	100%	0
Pets	7%		5	75%	1
Livestock	4%		3	75%	1
Unknown	5%		4	0%	4
Subtotal	100%		70	19%	57
Urban Areas (Calculated by subtraction of results at 022 from results at station 003)		75%	210		
Birds	49%		104	30%	73
Wildlife	7%		15	50%	7
Rodent	9%		18	50%	9
Human	10%		20	90%	2
Pets	7%		15	90%	1
Livestock	3%		6	90%	1
Unknown	16%		33	0%	33
Subtotal	100%		210	40%	126
Total (Measured/projected for 003)			280	35%	183

Table 20 was prepared to show the relative bacteria loading for different geographic areas and source categories and their contribution to bacteria levels in the lower San Lorenzo River. This information is based on the monitoring results and loads, which have then been broken down to different source types based on the results of the microbial source tracking investigations. Estimates have been made about the extent to which these contributions could be reduced through improved management measures (% controllable). Target reductions had to be set at a high level for controllable sources of bacteria, as many of the sources (birds and wildlife) have a significant contribution, but will be difficult to control. Results of this analysis are similar for the other lagoons, although Aptos and Soquel Creeks have a much higher component from birds and wildlife, and it will be more difficult, if not impossible, to reduce bacteria levels from those sources in order to meet standards (Tables 21 and 22).

Table 21: Bacteria Source Allocation for Lower Soquel Creek

			Cfu/100ml		cfu/100ml
Contributing Area/Source	%Contribution	%Contribution	Calculated Load	%Controllable	Target Load
Upstream Areas (Station S23)	In sub area	22%	154		
Birds	59%		91	0%	91
Wildlife	8%		12	0%	12
Rodent	11%		17	25%	13
Human	8%		12	90%	1
Pets	7%		11	75%	3
Livestock	0%		0	75%	0
Unknown	7%		11	0%	11
Subtotal	100%		154	16%	130
Urban Areas (Calculated by subtraction of results at S23 from results at station S0)		78%	546		
Birds	53%		287	50%	144
Wildlife	7%		37	50%	18
Rodent	14%		74	50%	37
Human	5%		30	90%	3
Pets	16%		87	90%	9
Livestock	0%		0	90%	0
Unknown	4%		24	0%	24
Subtotal	99%		539	56%	235
Total (Measured/projected for S0)			693	47%	364

Table 22: Bacteria Source Allocation for Lower Aptos Creek

			cfu/100ml		cfu/100ml
Contributing Area/Source	%Contribution	%Contribution	Calculated Load	%Controllable	Target Load
Upstream Areas (Station A03)	In sub area	28%	196		
Birds	56%		110	0%	110
Wildlife	20%		39	0%	39
Rodent	10%		20	25%	15
Human	0%		0	90%	0
Pets	10%		20	75%	5
Livestock	0%		0	75%	0
Unknown	4%		8	0%	8
Subtotal	100%		196	10%	176
Urban Areas (Calculated by subtraction of results at A03 from results at station A0)		72%	504		
Birds	64%		268	50%	134
Wildlife	11%		10	50%	5
Rodent	9%		71	50%	36
Human	2%		42	90%	4
Pets	7%		78	90%	8
Livestock	0%		0	90%	0
Unknown	7%		27	0%	27
Subtotal	100%		497	57%	214
Total (Measured/projected for A0)			693	44%	390

Based on the most significant sources of contamination identified through monitoring and microbial source tracking, following is an outline of potential pathways and possible control measures that should be considered to reduce the contribution from those sources. The details of implementing such programs and specific recommendations are discussed in subsequent sections.

1. Birds
   a. Keep lagoons full to minimize exposed sand bars
   b. Minimize roosting areas in bridges, buildings, and areas adjacent to waterways and beaches.
   c. Maintain good sanitation at beaches and areas adjacent to waterways: provide regular litter pickup, maintain bird proof trash receptacles
   d. Utilize falcons or other means of deterring or reducing bird populations in critical areas
2. Humans
   a. Sewer leaks or spills to streets and storm drains
      i. Upgrade sewers and laterals
      ii. Clean storm drains more frequently
      iii. Provide for dry weather diversions from storm drains to sanitary sewers
      iv. Improve spill reporting, control and clean up

b. Septic Systems
    i. Maintain and expand programs for septic system monitoring, management and upgrade
    ii. Identify any old septic systems within urban areas and require sewer connection
c. Direct input
    i. Redirect homeless out of creek areas
    ii. Work with homeless service providers to provide education to homeless populations regarding proper sanitation and water quality protection
    iii. Consider providing facilities for homeless people near waterways
    iv. Provide accessible recreational vehicle dump stations
    v. Regularly check for sewage leaks under wharves.
    vi. Provide outreach to anchoring boaters to prevent sewage discharge.

3. Pet Waste
    a. Provide education, ordinances, and adequate supplies for proper handling of pet waste.
    b. Provide dry weather diversions from storm drains to sanitary sewers
    c. Provide for storm drain cleaning
4. Livestock
    a. Maintain and enhance livestock water quality programs and manure management efforts
5. Wildlife and Rodents
    a. Provide education on not attracting nuisance levels of wildlife
    b. Dry weather diversion of storm drain discharge
    c. Litter control and sanitation to reduce rats
6. Nonspecific Contamination
    a. Dry weather diversion
    b. Improved stormwater management
    c. Storm drain cleaning
    d. Reduce dry weather flows from over irrigation, car washing, etc.
    e. Maintain and expand vacuum street sweeping programs

Management measures to improve the water quality of creeks, lagoons and adjacent beaches fall into three broad categories: source control, lagoon management, and monitoring. 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. 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. Ongoing monitoring is important to identify causes of contamination and evaluate effectiveness of management measures. The various agencies already have implemented a number of efforts to improve lagoon and beach water quality and are currently pursuing additional efforts.

Reduction of Sewage Spills and Leaks

Sewer systems are operated and maintained by the City of Santa Cruz (City) and the County Sanitation District (County), which also serves the City of Capitola. In order to maximize public health protection it is important to reduce the amount of sewage discharge to the storm drain system, waterways and beaches 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 and County have implemented programs to identify deficient sewer lines and to plan the upgrade or replacement of the worst lines. Much the work has been completed. Efforts are now being targeted to the remaining lines in the vicinity of the creeks and lagoons, with the assistance of grants for water quality improvement through the Clean Beach initiative and Proposition 13. The City recently replaced 5400 linear feet of sewer line in the lower River area, including replacement of 72 laterals from the main to the sidewalk, at a cost of $780,000, funded by the Clean Beach Initiative. Within 100 feet of rivers and creeks, the Cities and County should evaluate all sewer and storm drain pipelines and rehabilitate (if pipe is not competent). Pipelines that have recently been evaluated or upgraded would be a lower priority but should still be reevaluated at an appropriate interval.

2. **Maintain a high level of oversight and maintenance for sewer lines.**

    a. **Provide preventative maintenance for areas with a higher probability of overflow or leakage.** The City and County have excellent sewer line maintenance programs, with prompt response to spills, routine inspection and flushing of lines, documentation of chronic problem areas, and scheduling of more frequent preventative cleaning and maintenance for problem areas.

    b. **Maintain programs to reduce discharge of grease or other materials that can cause blockages and overflow of sewer lines.** The City and County have comprehensive programs of regulations, inspections, enforcement, and education to reduce grease discharge to the sewer system.

    c. **Maintain programs for prompt cleanup of sewage spills.** City and County crews rapidly clean up spills and correct problems with sewer mains under public jurisdiction. City crews also cleanup spills from private lines and attempt to open blockages in those private sewer laterals. The County cleans up spills from laterals if they flow into a public area. The City and County have implemented improved spill response procedures, including blocking the spill, vacuuming up the spill and collecting all the wash down water used to clean the spill area.

3. **Promote upgrade of private laterals as needed.** Although the City and County are upgrading sewer mains, the potential remains for leakage from private laterals in poor condition. The City and County should consider implementing a program to require

inspection or testing and upgrade at time of property transfer. This would reduce dry weather leakage and wet weather infiltration. A program for targeted testing in areas subject to contamination by subsurface sewage leakage could also be considered. The City and County should also implement a two or three strikes program to require lateral replacement after two or three spills. If they are not corrected, the City and County could exercise authority to correct problems with private laterals and bill the property owner. The County is starting with a program to require inspection and maintenance of large private sewage collection systems.

4. **Provide adequate funding assistance for upgrade of sewer mains and private laterals.** State and federal agencies should be requested to restore grant and low interest loan programs to help finance collection system upgrades, including private laterals. Some funding has been provided by the State Water Resources Control Board for specific projects.

   The following amounts of grant funds have been received or allocated for projects and programs that will reduce bacteria levels in lagoons and beaches:
   - $173,560 for Assessment of Sources of Bacterial Contamination at Santa Cruz Beaches (Prop 13)
   - $100,000 for Reduction of Contamination Sources at Capitola (CBI)
   - $1,500,000 for Sewer Improvements and Dry Weather Diversions in Santa Cruz (CBI)
   - $1,000,000 Additional Dry Weather Diversions in Santa Cruz (CBI, Prop 40)
   - $210,000 Capitola Lagoon Water Quality Improvement (Prop 13)
   - $858,000 Implementation of Stormwater Management Program for Santa Cruz County (with Capitola sewer assessments) (Prop 13

5. **Maintain and expand programs for septic system maintenance and upgrade.** County Environmental Health Services already implements programs to investigate sources of elevated bacteria in areas served by septic systems and to investigate complaints of failing septic systems. A higher level of funding provides for more frequent area-wide inspections in the San Lorenzo Watershed. With additional funding programs could be expanded to other problem areas in the county, identified by water quality testing and history of septic system performance.

6. **Consider providing facilities for recreational vehicle waste disposal to reduce potential for illicit discharges.** Only one or two dump stations are presently available in the northern and mid-count region and these have limited hours of operation.

Source Reduction

In addition to sewer leaks and spills, 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:

7. **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 Cities of Santa Cruz and Capitola provide bags at all of its public park areas, but further encouragement is likely needed through education and possible regulation. This topic is being addressed through public education and ordinances in the city and county stormwater management programs.

8. **Maintain trash receptacles, and dumpsters in a sanitary condition that prevents garbage and leachate from entering the storm drain system.** Dumpsters and trashcans should be kept covered to minimize potential for leachate, rodents, birds and wildlife. . 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. This will also be addressed in stormwater ordinances, with oversight by county health inspectors and sanitation inspectors, who both conduct periodic restaurant inspections.

9. **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 waterways.
   a. Prevent over watering and runoff of irrigation water into the street.
   b. Take cars to a carwash or wash them in areas that won't run into the street.
   c. All wash water from carpet cleaning, mop buckets, floor mat washing, etc, should be discharged to the sanitary sewer system.
   d. Clean up spills with mops or absorbent material, without washing the spill into a gutter or storm drain inlet.
   e. The cities and county have educational programs to promote these measures for restaurants and auto service shops.
   f. The City of Santa Cruz has adopted a stormwater ordinance to prohibit inappropriate discharges. The County's ordinance is in preparation.

10. **Maintain street sweeping programs to remove accumulated lifter, garbage, leaves and other material, particularly before the first rains of the season.** The City of Santa Cruz sweeps about 35 miles of streets per day. In the winter and spring they collect 5 tons per day of material that is mostly mud and leaves, which has the potential to incubate bacteria.

11. **Consider use of new stormwater technologies to reduce bacteria in storm drains.** Although previous storm drain treatment devices have had little effect on bacteria, a product has recently become available which utilizes treated anti-bacterial filter fabric to reduce bacteria concentrations in storm drains. Preliminary testing suggests good effectiveness, with annual replacement at $150/10 foot length (not including installation and disposal costs). The City of Capitola is proposing a treatment wetland with lagoon water recirculated through the wetland for bacteria reduction. Other methods such as filtration and ultra-violet disinfection have been utilized in other areas, but they tend to be more expensive than dry weather diversion, if that option is available.

12. **Take measures necessary to eliminate impacts of camping and loitering in floodplain areas.** This is a complicated effort that will need to involve community leaders, law

enforcement, and homeless services providers. More outreach and education to homeless campers regarding proper sanitation and water quality protection may also be beneficial. Although monitoring has not confirmed this as a source, confirmed presence of human waste in riparian areas presents a hazard. Additional monitoring in the reach between Water Street and Sycamore Grove would provide more information.

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 waterways occurs. Heavy metals and other urban contaminants can also accumulate in these conditions. Stormdrain maintenance is under the jurisdiction of the City of Santa Cruz Public Works Department within the Santa Cruz City Limits. Most storm drains within Capitola are maintained by the City of Capitola, with a few large facilities outside of road right-of-ways maintained by the County Public Woprks Department. Storm drains in Aptos/Rio del Mar and other areas outside the cities are under the jurisdiction of the County Public Works Department.

13. **Evaluate storm drains for potential sanitary sewer leaks and other sources of contamination.** Complete mapping of storm drain systems and sewer systems. Mapping of storm drains, outfalls and sanitary sewer systems provides an opportunity to track the source of elevated bacteria levels and the path of sewage spills. Electronic maps and databases also allow for tracking of completed and needed maintenance as well as chronic problem areas for future investigation or upgrade. Locations where sanitary sewers lie in close proximity to storm drains can particularly be targeted for investigation of possible subsurface leaks. 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.

14. **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 of Santa Cruz has implemented a program of wet well and catch basin cleaning 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. The County has received a grant to purchase vacuum trucks and is beginning to implement a program of more frequent storm drain cleaning.

15. **Implement dry weather diversion of storm drain water to the sanitary sewer system on a temporary or permanent basis where storm drains are identified to contribute a significant bacterial load during dry weather.** Control of sewer leaks and nonpoint 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. Capitola has done this on a temporary basis near the lagoon. There is a concern that without adequate safeguards automatic discharge to the sanitary sewer, petroleum spills or other contaminants could reach the sewage treatment plant and cause substantial disruption of the treatment process. Clean Beach grants were received by both cities to implement dry weather diversions on a more extensive and permanent basis. Santa Cruz has completed a dry weather diversion for Pump Station 2, which drains much of the downtown area and diversions will be completed in summer of 2006 for two other major pump stations.

Beach Sanitation and Marine Source Control

There are a number of natural and anthropogenic sources of contamination in the ocean, on the beaches and in the coastal lagoons that are not directly related to the surrounding urban environment. These include birds, marine mammals, boats, wharves, litter, and accumulations of kelp. Although some of these are natural in origin and most are difficult to control, there are a number of management measures that could be taken to reduce bacterial input from these sources:

16. **Continue to provide for regular inspection of sewer systems under Santa Cruz and Capitola wharf and take other measures to minimize discharge of sewage, garbage, or other contaminants from wharves.** Consider redesigning wharf structure to eliminate hauling areas for sea lions at the time of reconstruction. City of Santa Cruz is in the process of installing a new pressure force main system under the wharf that will be more reliable and easier to maintain then the existing system. Installation is scheduled to be completed by September 2006.

17. **Investigate various means to reduce the number of birds congregating on beaches and in lagoons.** The City of Capitola has already implemented programs to reduce bird input through limiting feeding of birds, constructing bird barriers on restaurants and providing drains to capture runoff when roofs and outdoor patios are washed off at the time creekside restaurants are remodeled. Additional building retrofits could be pursued. Additional measures might include replacing all trashcans with bird proof trashcans and increasing the frequency of beach cleaning. Methods of bird deterrents such as noise makers, falcons, or dogs could be considered, but these have an ongoing cost as well as an adverse impact on beachgoers. It is estimated that a program using falcons to keep bird populations low might cost $150,000 per year for up to three beach locations.

18. Provide for more aggressive removal of kelp accumulations, particularly on beaches with limited circulation, such as Capitola and Cowell. Some current effort is pursued to remove kelp from beaches, but this could be increased. Removal of loose kelp from water could have adverse impacts on the marine environment. The trade-offs of impacts and benefits should be further evaluated. It may be that times or circumstance could be identified, particularly during the swimming season and/or when bacteria levels are high that kelp removal could be implemented with limited impact on the marine environment.

19. **Consider methods to reduce the potential for discharge of toilet waste from anchored boats.** Capitola has a concessionaire who operates the boat mooring off the beach and provides a regular taxi service to shore. This approach seems to be successful in preventing and significant human contamination during summer months. Commercial and transient cruising boats anchor off the Santa Cruz wharf , which does not have a shore boat service. The potential for sewage discharge could be reduced by providing informational flyers regarding water quality concerns and providing more surveillance. Both of these efforts could be relatively costly, with limited return on the amount of effort expended.

Planning and Management Programs

There are a number of planning and management programs currently underway that provide a framework for development and implementation of various measures to improve lagoon and beach water quality, including many of those described above.

Stormwater Management Program

Most of the above efforts, particularly regarding storm drain management, source control and sewer spills and leaks, are being addressed through comprehensive stormwater management programs, as required under the federal Phase II Storm Water Rule. The City of Santa Cruz began developing and implementing a program in 2000 with the assistance of the State Coastal Commission and the Monterey Bay National Marine Sanctuary Water Quality Protection Program. The resulted in an Model 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 of Santa Cruz has already established a stormwater utility charge to finance flood control and urban runoff management. The County has developed a countywide Stormwater Management Plan, which also includes the City of Capitola. The County and City received a water quality grant to facilitate the initial stages of implementation of the plan. The City of Santa Cruz Plan and the County Plan are still awaiting formal review and approval by the Regional Water Quality Control Board.

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.

Lagoon Management

There are a number of efforts underway to improve management of coastal lagoons in the Santa Cruz County, with the objective of restoring biotic and recreational values. Funding assistance for all of these efforts has been provided by the California Coastal Conservancy. The City of Capitola first developed a Lagoon Enhancement Plan in 1989 and completed an update of the Plan in 2003. The City of Santa Cruz completed its Lower San Lorenzo River & Lagoon Management Plan in 2002. Both of these plans call for ongoing monitoring and adaptive management. The Resource Conservation District is currently completing a Comparative Lagoon Ecological Assessment Project that is assessing habitat value and water quality of 5 coastal lagoons, including San Lorenzo Soquel and Aptos.

Although bacteriologic water quality has not been a key focus management efforts for the San Lorenzo Rive lagoon involve several aspects of lagoon management that also affect overall lagoon water quality:

1. **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 on sand bars and associated bacterial contribution, but could lead to less ocean dilution. In the San Lorenzo it could lead to 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.
2. **Establishing targets for maintenance of adequate freshwater inflow** will need to be balanced against water supply needs and other opportunities to enhance summer baseflow in the upstream watershed.
3. **Vegetation restoration and public access** could degrade water quality as a result of increased litter and encampments in the San Lorenzo River channel. Substantial regrowth of vegetation in the channel area could encourage more camping and loitering in that area if there are not additional law enforcement or other 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.
4. **Reduction of non-native waterfowl**, such as domestic geese could improve water quality.

Implementation of the management plans affecting the lagoons 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)'s

The San Lorenzo River, the San Lorenzo River Estuary, Capitola Lagoon, and Aptos Creek 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:

1. Quantify the amount of contribution from different sources of the pathogens (indicator bacteria),
2. 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
3. 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 these water bodies. The Regional Board is in the process of completing the draft TMDL's at this time. The TMDL's will make use of information and recommendations generated during this project. Responsibility for implementation will likely lie with the local agencies.

Ongoing Monitoring

Although regular monitoring is conducted for beaches and creek mouths, intensive monitoring is generally limited to special studies and specific projects. Additional monitoring will be needed to confirm current bacteria sources, guide implementation efforts, and evaluate the effectiveness of efforts. The following monitoring efforts are needed:

1. Follow up monitoring of storm drain outlets, wet wells, and selected stream reaches should be done to identify priority sources of contamination and areas where follow up work is needed. 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. Monitoring of water level, sand bar condition, tidal affect, flow, temperature, salinity and dissolved oxygen should continue to be done at the time of sample collection 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.
3. Sampling under the auspices of the Regional Water Quality Control Board and the CCLEAN program is being done over the next several years to monitor the contribution of urban contaminants to the Monterey Bay from the San Lorenzo River, Soquel Creek, Aptos Creek, and other discharges.

Monitoring is being done through cooperative arrangements between the cities and the county, with some funding provided by State grants, and some assistance from citizen volunteers.

Summary of Recommendations

1. Continue evaluation of sanitary sewers and laterals that have not already been evaluated and implement additional sanitary sewer upgrades where problem areas are identified.
2. Maintain improved sewer and storm drain maintenance practices.
3. Consider requiring evaluation and repair of private sewer laterals, particularly in areas

subject to high groundwater

4. Reduce non-point sources of bacterial contamination through education, ordinance, and agency practices for proper management of pet waste, garbage, storm drain inlets, and food facilities.
5. Develop and implement a strategy to eliminate potential water quality impacts from camping and loitering in flood plain areas.
6. 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.
7. Implement dry weather diversion of storm drain discharge to the sanitary sewer system where feasible, and where storm drains have been found to contribute significant dry weather bacteria load.
8. Implement comprehensive stormwater management programs to reduce dry weather and wet weather pathogen levels in urban and suburban areas.
9. Consider options to reduce birds on beaches and lagoons.
10. Inspect and maintain wharf sanitation systems.
11. Consider providing education and surveillance to reduce discharge from anchored boats.
12. Regularly monitor storm drains and waterways to evaluate the effectiveness of improved management practices and to identify new or ongoing sources of contamination.
13. Provide public education programs regarding the needs for source control, animal waste control, septic system and lateral maintenance, limits on feeding birds and wildlife, and support for funding of infrastructure upgrades and water quality protection programs.

Table 23: Summary of Recommendations

	Action	Agency	Cost	Target Date	Cost-Effect	Status
1	Complete testing and upgrade of sewer lines.	Santa Cruz City, County Sanitation	$200,000/1000 lf, for rehab, $3000/1000lf for inspect.	2007	1	In progress, additional funding needed
2	Ensure sewer line maintenance, spill prevention and cleanup	Santa Cruz City, County Sanitation		Ongoing	1	Ongoing, Stronger programs recently implemented
3	Promote upgrade of private sewer laterals at time of property transfer and/or in problem areas.	Santa Cruz City, County Sanitation, Property Owners	Testing: est. $1000/lateral Repair: est. $5000/lateral	2006-2010	2	Pending
4	Provide funding assistance for upgrade of sewers and laterals	SWRCB, USEPA	est. $10 million	2006-2010	2	Funding is being provided through grant assistance, more may be needed.
5	Maintain and expand septic system maintenance and upgrade	SCCo. Env. Hlth., Property Owners	$50,000/yr	Ongoing	2	Ongoing
6	Provide more RV Dump stations			2008	3	Limited number of private dump stations have restricted hours
7	Provide education, incentive and requirements for proper disposal of pet waste	Residents, Parks Depts., Public Works, Env. Hlth	$220,000 Prop 13 funds received by county	2005-07	2	Educational programs in progress, More waste bag dispensers needed, ordinance?
8	Maintain trash receptacles in sanitary condition	Restaurants, Public Works, Env. Hlth		2007	2	In progress, evaluation of current efforts needed.
9	Limit non-stormwater discharges	City Public Works, County Public Works, Env. Hlth		2007	2	City has ordinance and education, County ordinance pending, education in progress
10	Maintain and expand street sweeping programs	City Public Works, County Public Works, Commercial owners		2006	2	In progress
11	Consider use of new stormdrain treatment technologies	City Public Works, County Public Works, Env. Hlth		2007	3	Although previous storm drain treatment devices have had little effect on bacteria, some new anti-microbial filter fabric products may be promising
12	Reduce impacts of camping and loitering in riparian areas.	Env. Hlth, Health Services Agency, Police, Sheriff		2007	3	Work with homeless service providers and law enforcement officials to develop appropriate strategies
13	Evaluate storm drains for sources of contamination	City Public Works, County Public Works, Env.Hlth		2005-06	1	In progress: Mapping of stormdrains and sanitary sewer systems is being completed, along with testing for high bacteria levels
14	Provide for routine storm drain cleaning	City Public Works, County Public Works	$100,000/vactor truck	Ongoing	1	Ongoing programs in process of expansion with County
15	Install dry weather diversions from storm drains to sanitary sewer systems where feasible.		est. $300,000/ diversion (5 in Santa Cruz, 2-3 Capitola)	2006	1	Diversions completed for Neary Lagoon and SLR Pump St 2; Grants received for other primary drains. Construction pending
16	Continue regular inspection and maintenance of wharf sanitary systems	City of Santa and Capitola		Ongoing	2	Ongoing, New pressure main to be installed in 2006
17	Implement bird control measures on beaches, lagoons and adjacent buildings	Capitola, Santa Cruz, State Parks (Aptos)	Falcons: $150,000/yr $5-10,000/building	2008	2	Some building improvements completed in Capitola, Other work pending. Falcons under consideration
18	Remove excessive kelp from beaches	Capitola and Santa Cruz Public Works and Lifeguards		2006	2	Explore opportunities to expand current programs
19	Address potential for sewage discharge from anchored boats	Coast Guard, Lifeguards		2006	3	No present effort. New effort may be needed, if problem can be confirmed.
20	Implement comprehensive stormwater management programs	City Public Works, County Public Works	$500,000/yr	2007	2	Ongoing in Santa Cruz, underway in County and Capitola
21	Include water quality concerns in lagoon management programs	Capitola, Santa Cruz, Coastal Conservancy		2006	2	Ongoing, further explore opportunities to maintain summer lagoon levels
22	Maintain ongoing monitoring to identify priority problem areas and evaluate program effectiveness	Env. Hlth, Capitola and Santa Cruz	$25,000/yr	Ongoing	1	Ongoing
23	Provide public education on individual actions to control sources of pollution and support for funding community solutions.	All agencies and public		Ongoing	1	Expand, current efforts. Many existing programs already have a significant public education component

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Appendix A: Summary of Sample Results, 2003-05

STANUM	LOCATION	Number of Samples	Mean Electro-Conductivity	Number Enterococcus Samples	Logmean Enterococcus	Logmean E. coli	Logmean Total Coliform	Number Fecal Coliform Samples	Logmean Fecal Coliform	Number Nitrate Samples	Mean Nitrate	Maximum Nitrate	Number Ammonia Samples	Mean Ammonia	Maximum Ammonia
001	SLR RIVERMOUTH @ MONTEREY BAY	12	17634	12	47	306	6002	0		0			1	0.00	0.00
001E100	100M EAST OF 001	10	41100	10	43	81	1102	0		0			0		
001E150	150M EAST OF 001	3	53550	3	8	38	96	0		0			0		
001E199D	MOTT ST STORM DRAIN MOUTH	2	420	2	234	1405	13649	0		1	0.3	0.3	1	0.05	0.05
001E200	200M EAST OF 001	4	42367	4	41	114	1231	0		0			0		
001E25	25M EAST OF 001	3	13763	3	496	313	5718	0		0			0		
001E50	50M EAST OF 001	9	30428	9	96	138	1403	0		0			0		
001W100	100M WEST OF 001	10	48600	10	44	78	683	0		0			0		
001W150	150M WEST OF 001	3	53700	3	15	21	245	0		0			0		
001W200	200M WEST OF 001	3	52150	3	27	53	657	0		0			0		
001W25	25M WEST OF 001	3	46500	3	224	136	1420	0		0			0		
001W50	50M WEST OF 001	9	48263	9	48	59	559	0		0			0		
003	SLR RIVERMOUTH @ TRESTLE	89	16055	5	5	1535	10962	88	202	1	0.0	0.0	0		
003 DRY	DRY SAND @ 003	2		2	5	5	5	0		0			0		
0031DW	GRAVITY STORM DRAIN @ 003	13	2513	13	40	294	17769	0		13	0.3	1.1	11	0.42	3.05
003WET	WET SAND @ 003	2		2	5	14	51	0		0			0		
0045DE	JESSIE ST STORM DRAIN	13	15341	13	26	308	4727	0		13	0.8	3.1	11	0.08	0.29
0046DW	UHDEN ST @ SLR (PUMP)	13	27777	13	32	178	8120	0		13	0.9	4.6	11	0.16	0.59
0047DW	RAYMOND ST @ SLR	14	14363	9	27	703	6960	1	9400	9	0.8	3.5	7	0.07	0.20
0048DE	NE PUMP BIXBY @ SAN LORENZO BL	13	8729	13	69	1156	21385	0		13	1.2	4.1	11	0.22	1.23
0051DW	LAUREL ST EXT @ SLR STRM DRN	12	10099	12	29	327	7618	0		12	0.5	1.5	10	0.10	0.45
005DW	STRM DRN @ RIVERSIDE WEST	12	14829	12	30	126	6433	0		12	0.7	3.7	10	0.20	1.19
006	SLR @ BROADWY/LAUREL ST BRIDGE	74	5429	2	5	1750	25000	72	281	71	0.5	3.7	0		
006DW	BROADWAY PUMP STATION STRM DRN	13	13324	12	71	815	11434	0		13	0.3	1.5	11	0.12	0.64
0110	CARBONERA CR @ BRANCIFORTE CR	5	472	0				0		5	0.6	0.8	0		
0121	BRANCIFORTE CR. @ ISBEL DR.	17	608	0				12	187	17	0.3	1.0	0		
0202DE	WATER ST PUMP STATION @ SLR	13	356	6	32	200	21183	0		6	0.4	0.6	4	0.05	0.18
0202DW	WEST WATER ST STORM DRAIN	13	2352	12	38	223	10116	0		12	0.5	1.9	11	0.12	0.70
022	SLR @ SYCAMORE GROVE	95	396	0				98	71	90	0.3	2.1	0		

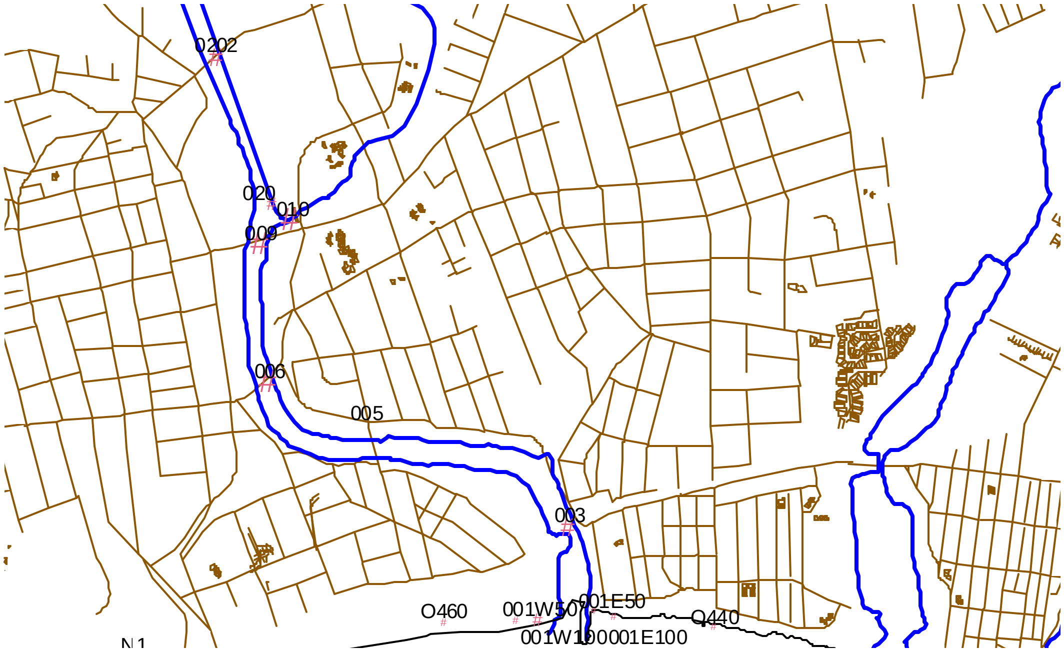
STANUM	LOCATION	Number of Samples	Mean Electro-Conduc-tivity	Number Entero-coccus Samples	Logmean Entero-coccus	Logmean E. coli	Logmean Total Coliform	Number Fecal Coliform Samples	Logmean Fecal Coliform	Number Nitrate Samples	Mean Nitrate	Maximum Nitrate	Number Ammonia Samples	Mean Ammonia	Maximum Ammonia
A0	APTOS CREEK @ MOUTH	100	9601	10	382	1014	8472	89	710	2	0.2	0.2	0		
A0 DRY	DRY SAND @ A0	2		2	5	5	5	0		0			0		
A0 WET	WET SAND @ A0	2		2	10	26504	48663	0		0			0		
A03	APTOS C @ BRIDGE ON SPRECKLES	13	532	1	30	97	422	12	199	3	0.1	0.1	0		
A1	VALENCIA C @ APTOS C	27	506	0				28	824	5	0.7	1.0	0		
A103	VALENCIA CREEK @ 2ND TUNNEL	2		0				2	450	0			0		
A11	TROUT GULCH @ VALENCIA CREEK	9	328	0				9	1017	2	0.7	0.7	0		
A111	TROUT GULCH BEHIND VALENCIA S	2		0				2	2494	0			0		
A1125	TROUT GULCH 100 M BELOW A113	3		0				3	1172	0			0		
A113	TROUT GULCH @ VALENCIA ROAD	4	305	0				4	315	2	0.6	0.6	0		
A113D	TROUT GULCH INFLOW @ VALENCIA	5		0				5	47	0			0		
A118	TROUT GULCH @ END OF BAKER ROA	2	303	0				2	112	2	0.5	0.5	0		
A12	VALENCIA CREEK @ TROUT GULCH	7	445	0				7	275	2	0.4	0.4	0		
A121	VALENCIA CREEK BEHIND SCHOOL	3	455	0				3	470	1	0.3	0.3	0		
A1213	VALENCIA CR. @ FORK	2	408	0				2	182	2	0.5	0.5	0		
A122	VALENCIA CREEK @ TOP OF SCHOOL	2		0				2	54	0			0		
A123	VALENCIA CREEK 200YDS AB. SCHO	4		0				4	330	0			0		
A1234	VALENCIA CR 400M UP(1.5" GAL)	2		0				2	157	0			0		
A2	APTOS C @ VALENCIA C	21	722	0				22	63	2	0.0	0.1	0		
B-28	SW CORNER MOOSEHEAD @ SEAWALL	5	33833	4	6	6	8	0		4	0.5	1.5	4	0.29	0.77
B-29	SW CORNER MOOSEHEAD @ SEAWALL	5	28520	5	5	5	11	0		5	2.0	5.4	5	0.10	0.36
COW1	COWELL' STORM DRAIN	5	589	5	36	219	7571	0		5	6.6	8.4	4	0.01	0.04
MW1	BEACH ST @ WASHINGTON ST	15	1056	15	5	7	12	0		15	7.8	17.2	15	0.53	6.39
MW2	115 CLIFF ST EAST SIDE OF ST	15	818	15	5	7	9	0		15	0.4	1.1	15	3.68	14.29
MW3	160FT NW BEACH ST ON RAYMOND	15	1707	15	5	6	7	0		15	0.5	1.5	15	0.59	4.48
MW4	SE CORNER PARK PL @ UHDEN	15	3071	14	5	6	8	0		14	0.1	0.3	14	0.42	4.48
MW5	150FT W BEACH ST ON PARK PLACE	15	1796	15	5	5	9	0		15	0.1	0.6	15	2.79	7.61
N0	NEARY LAGOON @ MOUTH	42		3	9	387	6887	36	409	2	0.6	1.2	0		

STANUM	LOCATION	Number of Samples	Mean Electro-Conductivity	Number Enterococcus Samples	Logmean Enterococcus	Logmean E. coli	Logmean Total Coliform	Number Fecal Coliform Samples	Logmean Fecal Coliform	Number Nitrate Samples	Mean Nitrate	Maximum Nitrate	Number Ammonia Samples	Mean Ammonia	Maximum Ammonia
O0993	RDM 30M EAST OF APTOS CRK	4	32433	4	67	199	1770	0		0			0		
O0995	RDM 50M EAST OF APTOS CRK	10	32933	10	102	238	1230	0		0			0		
O0997	RDM 100M EAST OF APTOS CRK	10	38600	11	85	319	1788	0		0			0		
O0999	RDM 200M EAST OF APTOS CRK	2	36700	2	129	267	2070	0		0			0		
O105	BETWEEN HIDDEN B & RIO DEL MAR	3	53200	3	12	55	113	0		0			0		
O110	RDM BEACH@APTOS C MOUTH	87		80	18	65	201	9	54	0			0		
O113	RDM 30 M WEST OF APTOS CRK	4	50067	4	26	68	740	0		0			0		
O115	RDM 50 M WEST OF APTOS CRK	10	41521	10	159	280	1098	0		0			0		
O117	RDM 100 M WEST OF APTOS CRK	11	47925	11	50	148	463	0		0			0		
O120	BETWEEN RIO DEL MAR & SEACLIFF	3	53900	3	31	138	301	0		0			0		
O140	SEACLIFF BEACH @ CEMENT SHIP	82	47033	82	10	28	86	0		0			0		
O170	NEW BRIGHTON BEACH	78		78	14	37	190	0		0			0		
O2205	CAP BEACH E OF SMALL JETTY	3	45567	3	37	42	618	0		0			0		
O2343	CAPITOLA 50M EAST OF CR	9	35725	9	209	183	1269	0		0			0		
O2344	CAPITOLA 100M EAST OF CR	9	40963	9	82	116	773	0		0			0		
O2345	CAPITOLA 25M EAST OF CR	2	9600	2	192	313	3762	0		0			0		
O235	CAPITOLA BEACH @ JETTY	82	54200	82	17	51	205	0		0			0		
O235S	SEEP IN WALL DEPOT HILL	2		4	5	5	12035	0		0			0		
O240	CAPITOLA BEACH	92		84	25	115	492	9	83	0			0		
O245	CAPITOLA BEACH @ SOQUEL C	3		3	13	279	612	0		0			0		
O246	CAPITOLA BEACH @ FLUME	6		6	14	299	551	0		0			0		
O2493	CAPITOLA BEACH 50M WEST OF CRK	9	48075	9	59	139	725	0		0			0		
O2495	CAPITOLA BEACH 25M WEST OF CR	4	47467	4	45	247	1049	0		0			0		
O260	CAPITOLA BEACH @ WHARF	11	48800	11	30	141	528	0		0			0		
O271	HOOPER'S BEACH	8	52100	8	10	37	128	0		0			0		
O410	TWIN LAKES BEACH	81	5	80	10	21	88	0		0			0		
O440	SEABRIGHT (CASTLE) BEACH	81		83	9	29	204	1	218	0			0		
O450	SAN LORENZO RIVERMOUTH BEACH	82		83	12	61	333	0		0			0		
O455	LIFEGUARD TOWER 4	2		2	5	12	44	0		0			0		
O458	BTWN TOWER 3 AND 4	2		2	5	12	32	0		0			0		
O460	MAIN BEACH (@ BOARDWALK)	91		83	10	90	352	9	34	0			0		
O488	COWELL BEACH WEST OF WHARF	2		2	5	167	263	0		0			0		
O490	COWELL BEACH	93		85	10	81	311	10	62	0			0		
O494	COWELL @ STAIRS	81		83	7	36	167	0		0			0		

STANUM	LOCATION	Number of Samples	Mean Electro-Conduc-tivity	Number Entero-coccus Samples	Logmean Entero-coccus	Logmean E. coli	Logmean Total Coliform	Number Fecal Coliform Samples	Logmean Fecal Coliform	Number Nitrate Samples	Mean Nitrate	Maximum Nitrate	Number Ammonia Samples	Mean Ammonia	Maximum Ammonia
S0	SOQUEL CR @ FLUME OUTLET	102	5894	15	107	429	3209	88	664	0			0		
S0 DRY	DRY SAND @ S0	2		2	5	5	5	0		0			0		
S001	STORM DRAIN@CAPITOLA BATHROOMS	4	46	3	1072	2023	25000	2	3300	3	0.2	0.3	3	0.03	0.07
S0025D	ZELDA'S OUTFALL/CAPITOLA BEACH	2		1	302	25000	25000	2	10400	1	0.1	0.1	1	0.13	0.13
S002D	LAWN WAY OUTFALL/CAP. BEACH	4	47	3	205	988	25000	2	700	3	0.1	0.1	3	0.02	0.05
S005	STORM DRAIN AT CAPITOLA PIER	5	71	4	49	244	13968	2	917	4	0.9	2.5	3	0.03	0.07
S04	SOQUEL C ABOVE STOCKTON B EAST	4	489	0				4	192	0			0		
S07	SOQUEL C @ TRESTLE	4	458	0				4	154	0			0		
S1	NOBEL G @ SOQUEL C	11	480	4	756	3882	8716	8	1958	3	0.9	1.0	3	0.05	0.13
S12	NOBEL G @ TUNNEL @ BAY	7	474	2	333	959	5320	5	1500	2	0.9	1.1	2	0.01	0.02
S125	NOBEL GULCH @ ST. JOE'S CHURCH	6	393	1	74	85	1067	5	666	2	11.0	21.0	0		
S21	SOQUEL C ABOVE NOBEL G	3	451	0				3	84	0			0		
S23	SOQUEL C @ NOB HILL	19	507	1	62	84	1081	18	153	1	2.2	2.2	0		
S2303	STORM D #2 @ SOQUEL C @ HWY 1	2		0				2	650	0			0		
S2315	SOQUEL CR @ PORTER ST. BRIDGE	2		0				2	219	0			0		
S232	SOQUEL C @ 2525 MAIN ST.	4	451	1	63	74	359	3	46	0			0		
SW0	SCHWAN LAKE @ MOUTH	85		0				85	611	0			0		

Appendix B: Past and Present Monitoring Locations:

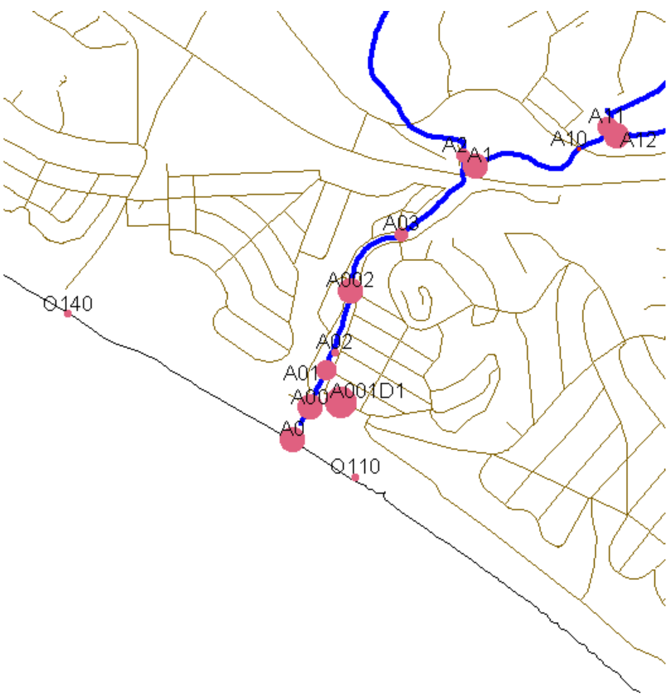
(Size of dot is proportional to past fecal coliform levels)



Lower San Lorenzo River

San Lorenzo Rivermouth, Santa Cruz Main Beach, Cowell Beach, Seabright, Twin Lakes Beach

Capitola Beach, Soquel Creek



Aptos Creek, Rio del Mar, Seacliff Beach

Appendix C:

Preliminary Assessment of Bacteria Regrowth in Kelp
Steve Peters, Water Quality Specialist
Santa Cruz County Environmental Health Services
August, 2005

The County of Santa Cruz Environmental Health Services conducted tests on kelp found in the tidal zone at several Santa Cruz County beaches to determine if decaying kelp could be one of the sources of elevated fecal indicator bacteria that has caused Capitola and Cowell Beaches to be posted with swimming advisories.

Kelp samples were collected and put into sterile Nasco Whirl-Pak sample bags form Capitola Beach, Hooper's Beach, the beach at 38th Avenue, Cowell Beach, Mitchell's Cove Beach, Natural Bridges Beach, and Waddell Beach.
Kelp samples were then taken back to the County of Cruz Public Health Lab for bacteria analysis. Samples were collected on five separate sample dates; June 27, July 6, July 11, July 19, and August 1, 2005. Along with the kelp collected on August 1 water samples were collected from each site to determine if there was an increase in bacteria populations after twenty-four hours as there was with kelp. The third set of data for kelp collected from 38th Ave., Natural Bridges Beach, and Waddell Creek reflect results from testing after sitting at room temperature for 48 hours.

After returning to the Public Health Lab a small amount of sterile, buffered water was added to each bag containing a small amount of kelp. The kelp was then mashed to break it up and the bag was filled to the 100ml. mark. Water from each bag was then analyzed using either Idexx Colilert-18, Idexx Enterolert, or membrane-filtration for fecal coliform bacteria.

The bags were sealed and left to sit at room temperature in the Public Health Lab for twenty-four hours and re-tested using the same type of analysis done initially, either Idexx Colilert-18, Idexx Enterolert, or membrane-filtration for fecal coliform bacteria.

Test results in all cases showed low levels of fecal indicator bacteria at initial testing and extremely high levels of bacteria as determined by Idexx Colilert-18 and membrane-filtration for fecal coliform bacteria. Idexx Enterolert analysis showed variable results. Waddell Beach results showed no bacteria initially or after 24 hours. Hooper's Beach, 38th Avenue Beach, and Waddell Beach were tested one time each.

Several samples were tested to species from colonies tested for fecal coliform bacteria and extracted from positive E. coli results in Idexx Colilert-18 testing. Organisms found were:
E. coli
Serratia rubidaea
Klebsiella oxytaca
Klebsiella pneumoniae

Sample results are shown below (samples included kelp unless otherwise indicated):

Date/Location/ (Sample type)	**E.coli (0/24hrs)**	**Total Coli(0/24hrs)**	**Entero (0/24hrs)**	**Fecal Coli (0/24hrs)**
27June/Capitola Beach	no sample	no sample	no sample	pos/TNTC
/ Cowell Beach	no sample	no sample	no sample	pos/TNTC
/ Hooper's Beach	no sample	no sample	no sample	pos/TNTC
/Mitchell's Cove	no sample	no sample	no sample	pos/TNTC
6July/Capitola Beach	5 / >24192	5 / >24192	5 / >24192	no sample
/ 38th Ave.	5 / >24192	10 / >24192	5 / >24192	no sample
/ Cowell Beach	5 / >24192	10 / >24192	5 / 5	no sample
/Mitchell's Cove	5 / >24192	5 / >24192	5 / 933	no sample
/ Natural Bridges	5 / >24192	30 / >24192	5 / 5	no sample
/ Waddell Beach	5 / 5	5 / 5	5 / 5	no sample
11July/ Capitola	31 / >24192	98 / >24192	5 / 3076	no sample
19July/ Capitola	5 / >24192	5 / >24192	5 / 5	no sample
/ Cowell Beach	10 / >24192	31 / >24192	5 / 379	no sample
/ Mitchell's Cove	5 / >24192	31 / >24192	5 / 5	no sample
/ Natural Bridges	5 / >24192	5 / >24192	5 / 467	no sample
1Aug/Capitola(H2O)	52/86	181/161	10/5	no sample
/Capitola(Kelp)	10/>24192	20/>24192	5/425	no sample
/Hooper's(H2O)	171/132	594/256	5/5	no sample
/Hooper's(Kelp)	5/1956	5/2046	5/5	no sample
/38th(H2O)	5/5	5/5	5/5	no sample
/38th(Kelp)	5/5/146	10/>24192/>24192	5/4352	no sample
/Cowell(H2O)	52/63	201/85	10/5	no sample
/Cowell(Kelp)	20/24192	20/>24192	5/>24192	no sample
/Mitchell's(H2O)	5/5	10/5	5/5	no sample
/Mitchell's(Kelp)	5/>24192	5/>24192	5/5	no sample
/Nat. Bridges(H2O)	5/5	5/5	5/5	no sample
/ Nat. Bridges(Kelp)	5/5/5	5/>24192/>24192	5/5	no sample
/Waddell(H2O)	5/5	5/5	5/5	no sample
/ Waddell(Kelp)	5/5/5	5 / >24192/>24192	5 / 5	no sample