## Chapter 5

# EFFECTS OF STORM DRAIN DISCHARGE ON WATER QUALITY

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## Introduction

The East Bay shoreline, with its magnificent view of San Francisco, its mild coastal climate, and its easy accessibility, is a prime area for public recreational use. A proposal for the acquisition and development of the East Bay shoreline as a state park incorporates many water-related recreational activities, as well as the preservation and enhancement of these coastal resources (CHNMB, 1982). Berkeley's storm drains, which empty directly into the bay, are sources of potential pollutants and contaminants to these areas. There is no routine monitoring of the Berkeley storm drains; thus, the effects of their discharge on the water quality are not well known.

Four storm drains empty along the Berkeley waterfront at Potter Street, University Avenue/Strawberry Creek, Virginia Street, and Gilman Street (Figure 1). This report concentrates on the Virginia Street and Gilman Street outfalls and their effects on water quality with respect to pathogenic microorganisms.

The Gilman Street and Virginia Street outfalls are situated on the north and south boundaries of the North Basin of the East Bay shoreline (Figure 1). The proposed plans for the North Basin include park space for recreational activities. There is a large demand for boating facilities and other water-related activities in this area (CHNMB, 1982). It is in the best interest of the prospective users to know the possible health hazards posed by storm runoff.

## Storm Water Components

Commonly, storm water is the major cause of water quality deterioration (Geldreich, 1970). Urban storm water runoff, in particular, contains high concentrations of pollutants and contaminants even if no sewage or waste water is discharged into the system. This is due to discharge of industrial and commercial wastes, termed point-source pollutants, and the discharge of non-point-source pollutants such as animal feces, fertilizer, soil, grease, and oil (Stephenson, 1981). The EPA estimates that 50% or more of water pollution is waste picked up from the land by rainfall and carried by runoff or seepage to surface and ground waters (Canter *et al*., 1980).

Contaminated substances conveyed to the bay by storm runoff are not delivered at constant rates or concentrations. Variations occur due to differing storm intervals, intensities, and differing land use and topography of the area. The first major storm of the rainy season will wash more contaminants into the estuary than succeeding storms. Most is washed off during the first two hours of the storm (Corps of Engineers, 1979).

Urban storm water has been found to contain microbial pathogens, which may be agents of typhoid fever, cholera, Salmonellosis, bacillary dysentery, amoebic dysentery, and infectious hepatitis. A high percentage of waterborne bacterial and viral diseases have symptoms characterized by vomiting, abdominal cramps, and diarrhea (Tartakow and Voperian, 1981). Fecal contamination from warm-blooded animals, indicated by the presence of bacteria from the coliform group, is a primary source of pathogenic microorganisms in polluted waters. Most storm water contains relatively large numbers of total coliforms and fecal coliforms. Most of the total coliforms are native soil organisms and most of the fecal coliforms are probably due to wild and domestic animals (Mallard, 1981).

The EPA Standards for coliform bacteria are set in relation to the presence of pathogenic microorganisms such as the Shigella and Salmonella species. Salmonellae contain a wide variety of species which are pathogenic to humans, the most common being Salmonella typhimurium, which causes acute gastroenteritis. Shigella species causes intestinal diseases such as bacillary dysentery. Other organisms that may be present in storm water include viruses and parasites. It is hypothesized that the higher the coliform density, the higher the risk is for disease by these pathogens (Cooper, 1983).

Much research has been done to determine the relationship of coliforms to enteric disease risk. Salmonellae are the only pathogens that can be easily detected and correlated to coliform data. The occurrence of Salmonellae in contaminated water is highly variable, but field data from numerous studies of fresh and estuarine waters indicate a sharp increase in the frequency of Salmonellae detection when fecal coliform densities exceed 200 per 100 ml sample. For estuarine waters, fecal coliform densities of 200 to 2000 per 100 ml sample show a 44% occurrence of Salmonellae. Fecal coliform densities greater than 2000 per 100 ml show a 60% occurrence of Salmonellae (Geldreich, 1970). The occurrence of Salmonellae has been found to be even greater in bottom sediments than in overlying waters. This correlates with the approximately 100 to 1000-fold increase in fecal colifor, densities in the bottom sediments (Geldreich and Van Donsel, 1971). Mixing of bottom sediments with overlying water can increase pathogenic microorganisms in surface waters, and thus must be considered when potential health risks for an area are determined.

Fecal coliforms are good indicators of pathogenic enteric bacteria, but it is difficult to correlate their presence to the presence of viruses (Mandy, 1979). There are more than 100 different viral types excreted in feces and urine which can present a health hazard when they occur in recreational waters. Viruses are usually present in polluted waters in smaller numbers than bacteria, but virus particles can survive longer than bacteria, and it only takes a small dose to infect a susceptible individual (Mandy, 1979). When fecal coliform densities are very high there is a good probability that viruses of fecal origin are present.

## Background Data

Storm water does not have to be ingested to pose a health hazard. According to EPA criteria, as a minimum surface waters should be suitable for public recreation whether there is risk of ingestion or not (EPA, 1973). The North Basin area is predominantly a non-contact water recreation area. Non-contact uses include picnicking, boating, sunbathing, and other uses involving the presence of water, but which do not require contact with the water. Water-contact recreation includes all recreational uses such as swimming, wading, sport fishing, and other uses involving actual body contact with water (RWQCB, 1975).

Recreational standards for surface waters are such that total coliforms are not to exceed an MPN of 1000 per 100 ml for water contact activities and 10,000 per 100 ml for non-contact water activities (Stephenson, 1981). Standards outlined by the RWQCB for San Francisco Bay are more stringent. For water contact recreation, total coliform densities are not to exceed a median of 240 per 100 ml and no single sample is to exceed 10,000 per 100 ml (RWQCB, 1975).

In 1976 and 1977 the California State Health Department conducted bacteriological tests of the North Basin area to determine if the shoreline area met the water quality objectives. Total coliform numbers varied during 1976 and 1977, but most of the numbers exceeded the recommended standards (Figure 2). When total coliform counts exceed the recommended standards, the risk of waterborne disease greatly increases. Figure 2 illustrates the change in coliform counts during 1976.

Peak coliform densities occurred in the winter months when pollutants and contaminants that had been deposited and accumulated in urban areas were washed down to the bay the winter rains. Peak coliform densities also occurred in June and July when there is a high probability of recreational use for these areas. During the summer months of no rainfall, pollutants and contaminants can be washed to storm drain catchments by increased residential and commercial water use activities, such as lawn and garden watering and car washing.

1976 and 1977 were drought years for the Bay Area. Storm runoff was minimal when the previous bacteriological tests were ocnducted. The bacteriological tests for this study were completed during February and March of 1983. 1982 and 1983 have been extremely wet years for the Bay Area. This report contributes wet weather data to the bacteriological study of the North Basin.

## Methodology

There are a number of waterborn microbial diseases that are harmful to public health. The causative microorganisms are not readily isolated from water; thus, organisms which can easily be isolated and enumerated, and whose occurrence is indicative of the presence of human and animal wastes that have the potential of containing disease-producing microorganisms are used as indicator organisms (Cooper, 1983). The most commonly used indicators are the coliform bacteria. The presence of Escherichia coli is usually regarded as evidence of fecal contamination. Research investigations

| Outfall | Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MPN x $10^3$ | | | | | | | | | | | |
| Gilman Street | 1976[a] | .3 | 4.3 | 240 | 24 | 24 | 110 | 46 | 9.3 | 9.3 | 24 | 110 | - |
| | 1977[b] | 110 | 120 | - | - | - | - | - | - | - | - | - | - |
| Virginia Street | 1976[a] | 4.3 | 7.5 | 240 | .3 | .3 | 110 | 240 | 46 | 46 | 240 | 240 | - |
| | 1977[b] | 9.3 | 9.3 | 2.3 | 9.3 | 44 | - | - | - | - | - | - | - |

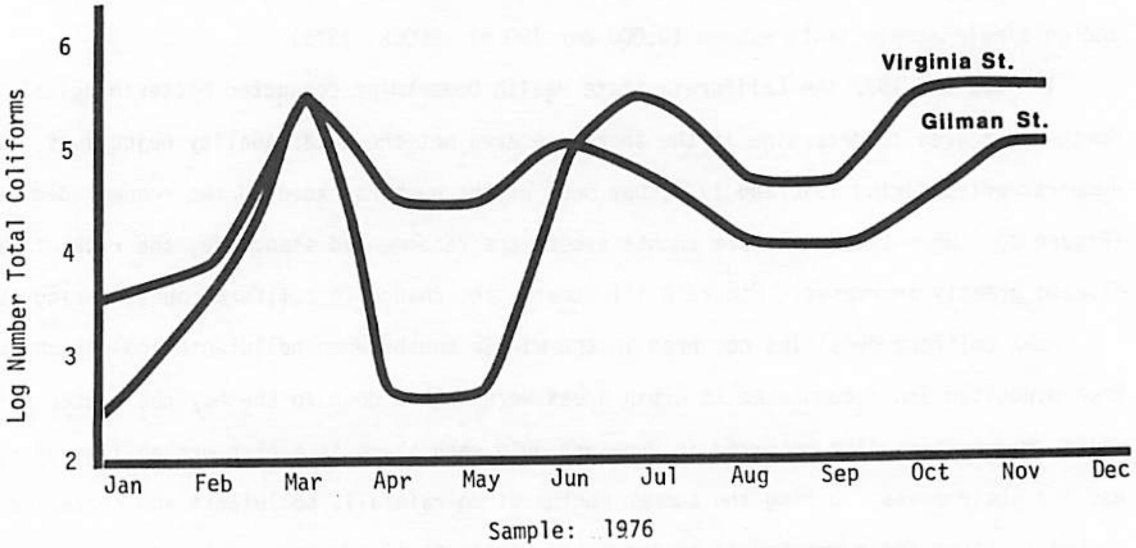

Figure 2. Total Coliforms Along the East Bay Shoreline. MPN = Most Probable Number.

a) EBMUD Shoreline Sampling Results (Sharpe, 1977)
b) EBMUD Wet Weather and Storm Sewer Study (Sharpe, 1977)

on the significance of fecal coliform bacteria in the environment have demonstrated that fecal coliforms correlate positively with warm-blooded animal fecal contamination. There is sufficient evidence from the literature to indicate that pathogenic organisms present in animals may be equally pathogenic to humans and can be acquired from contaminated water (Geldreich, 1970).

The methods for determination and enumeration of the coliform group are described in <u>Standard Methods for the Examination of Water and Wastewater</u> (APHA, 1980). The coliform group is differentiated from other enteric microorganisms by its activity on lactose. Fecal coliforms are further differentiated by incubating inoculated tubes at 44.5$^{o}$ C. Incubation at elevated temperatures optimizes *E. coli* growth while minimizing growth of other coliform bacteria.

Sample 1 was taken on February 22 after four consecutive days of dry weather. Samples 2-5 were taken on February 24, February 26, March 1, and March 3 after 1, 2, 4, and 6 days of wet weather, respectively. All wet-weather samples were taken at low tide when runoff was flowing into the receiving waters. The dry-weather sample was not collected at low tide, and bay water was backed up into the storm drain. Therefore, the dry-weather sample is not indicative of discharge quality, but rather, describes the quality of the receiving waters.

Samples for a bacteriological survey of Virginia Street and Gilman Street storm drain discharge were gathered in plastic 250 ml, wide-mouth bottles 2 to 4 hours prior to inoculation. Serial dilutions of 100- to 10,000-fold were made using sterile buffered dilution water. Each dilution was inoculated into five tubes of Lauryl Tryptose Broth for the presumptive test. Tubes were incubated at 35° C for 48 hours. All positive presumptive tubes were then confirmed by inoculation into Brilliant Green Bile Broth and *E. coli* Broth. The broths were incubated at 35° C and 44.5° C, respectively, for 48 hours. Total coliforms and fecal coliforms were enumerated using the most probable number (MPN) method (APHA, 1980).

### Data and Discussion

Figure 3 illustrates the changes in total coliform densities over the two week period. It appears that the densities increased to a threshold point as the rain continued. Usually, one would expect the counts to be highest at the onset of a storm and then steadily decrease.

Although the samples varied in total coliform counts, all but one count were in excess of the non-contact water standard of 10,000 per 100 ml. All samples were in excess of the water contact standard of 1000 per 100 ml (Figure 3).

Figure 4 is a summary of fecal coliforms for the two sites. The fecal coliform standard for non-contact water activities is 2000 per 100 ml and 200 per 100 ml sample for water-contact activities (EPA, 1973). San Francisco Bay fecal coliform standards for water-contact recreation are such that densities are not to exceed a median of 50 per 100 ml, and no single sample is to exceed 400 per 100 ml (RWQCB, 1975). Samples from the two sites tested differ in fecal coliform densities, but all counts are greater than the non-contact standard of 2000 per 100 ml sample (Figure 4). The high fecal coliform densities can mean a high risk of enteric disease; thus, they indicate a potential health hazard.

In comparing the 1983 data between the two sites tested (Figure 3 and Figure 4), one can deduce that both sites contribute to high total and fecal coliform densities. The total coliform densities for the two sites show similar trends over time (Figure 3). The fecal coliform densities for the two sites are not as similar (Figure 4). When one site showed high fecal coliform densities the other site showed relatively low fecal coliform densities. These differences between the two sites may be due to their different localities. The Gilman Street drain runs through industrial, as well

| | Sample (MPN x $10^3$) | | | | |
|---|---|---|---|---|---|
| Outfall | 1 | 2 | 3 | 4 | 5 |
| Gilman Street | 76 | 7 | 35 | 170 | 63 |
| Virginia Street | 76 | 23 | 92 | 94 | 49 |

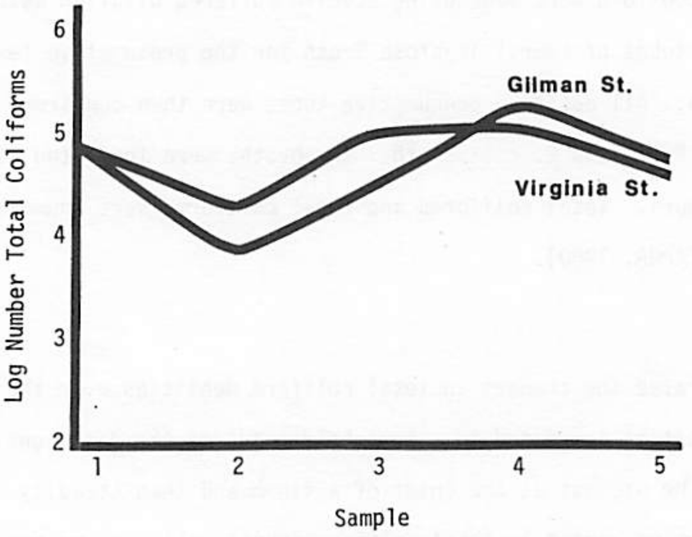

Figure 3. Total Coliforms for the North Basin Storm Drains

as urban areas of Berkeley, whereas the Virginia Street drain runs through a predominantly residential area.

In comparing the data of the 1976 and 1977 tests (Figure 2) and the 1983 data (Figure 3), one can deduce that both wet-weather and dry-weather conditions during the rainy season contribute to high coliform densities.

Conclusion and Recommendations

Urban runoff contains a variety of organic compounds, chemicals, and microorganisms. Potential contaminants and pollutants are deposited and accumulated in urban areas between rain storms. These substances are conveyed at flows and loads determined by the interval time between storms, as well as intensity and duration of storms. From the results, it is evident that urban storm runoff does greatly contribute to water quality deterioration in relation to indicator organisms of potential pathogens.

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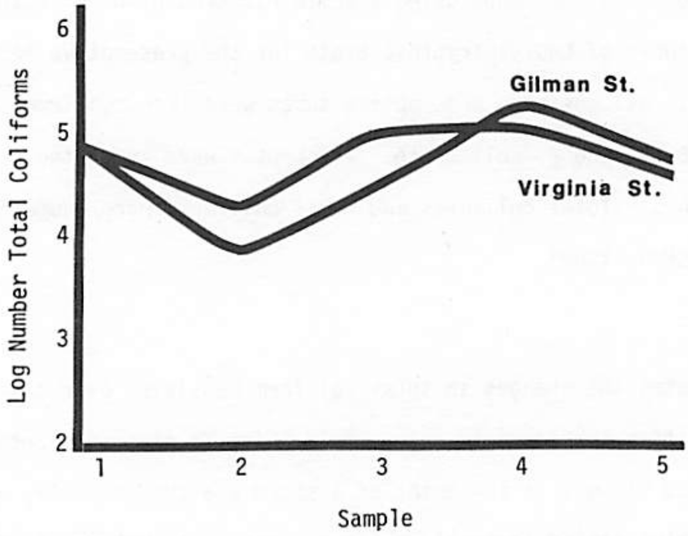

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| | Sample (MPN x $10^3$) | | | | |
|---|---|---|---|---|---|
| Outfall | 1 | 2 | 3 | 4 | 5 |
| Gilman Street | - | 4 | 33 | 79 | 5 |
| Virginia Street | 7 | - | 92 | 33 | 5 |

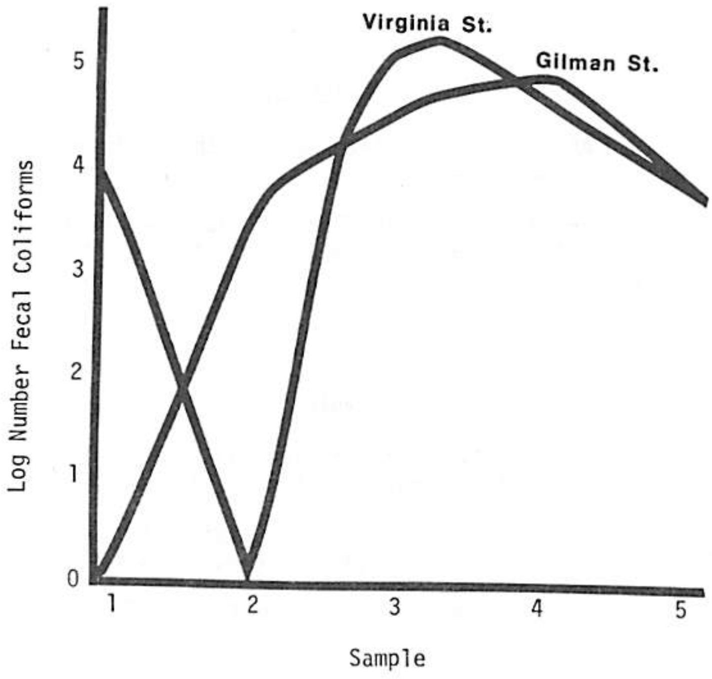

Figure 4. Fecal Coliforms for the North Basin Storm Drains

The total coliform counts obtained for the Gilman Street and Virginia Street storm drains ranged from 7,000 to 170,000 per 100 ml sample. Fecal coliform counts ranged from 3,000 to 92,000 per 100 ml sample. All of the fecal coliform counts and all but one of the total coliform counts were far greater for the two sites than both the RWQCB and the EPA standards recommend. These standards are set to alleviate the risk of disease when engaging in water-related activities. Since high coliform densities indicate increased occurrence of pathogens, the North Basin area should not be used as an area of water-related recreational activities until coliform densities are within recommended standards. To achieve lower coliform densities, programs must be implemented to clean up point-source and non-point-source pollution contributions to storm runoff (see Tom Holsen's report, this volume).

This survey of the two storm drains is in no way meant to be a complete survey. Restrictions of time and variable weather conditions made it difficult to obtain adequate dry weather samples. Therefore, it is impossible to predict how the water quality would be affected by discharge during the summer months after a heavy rainy season, but it was shown by the 1976-1977 data that dry-weather conditions during the rainy season do not necessarily mean lower coliform densities. For the North Basin area to be used as a recreational site, more research is required to obtain a full understanding of the water quality and a plan must be implemented to clean up, monitor, and control excessive contamination.

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