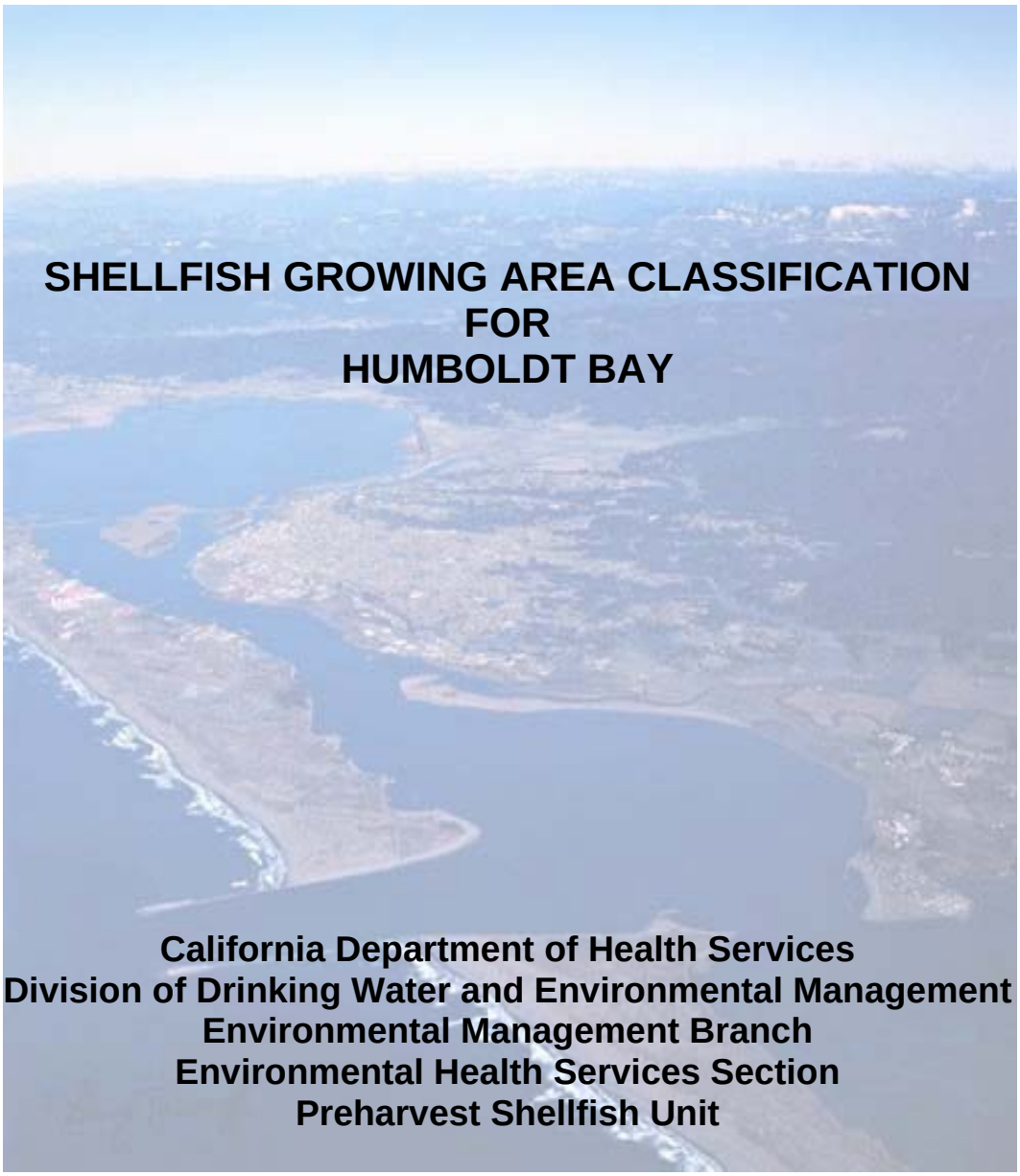
Technical Report # 06-11

TWELVE-YEAR SANITARY SURVEY REPORT



SHELLFISH GROWING AREA CLASSIFICATION FOR HUMBOLDT BAY

California Department of Health Services
Division of Drinking Water and Environmental Management
Environmental Management Branch
Environmental Health Services Section
Preharvest Shellfish Unit

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I. EXECUTIVE SUMMARY

This report is the Sanitary Survey report for the commercial shellfish growing operations located in Humboldt Bay, Humboldt County, California. This document is issued in conformance with requirements of the National Shellfish Sanitation Program (NSSP) Model Ordinance (2003). The NSSP requires that the shellfish authority perform a complete Sanitary Survey at least every 12 years. In California, this authority is the California Department of Health Services, Environmental Management Branch, Preharvest Shellfish Program.

The Sanitary Survey is the written evaluation report of all environmental factors, including actual and potential pollution sources, which have a bearing on water quality in a shellfish growing area. The Sanitary Survey Report includes the data and results from a shoreline survey, a survey of bacteriological water quality, an evaluation of the hydrographic, meteorological, and geographic characteristics, and an analysis of all these data. The results of this evaluation and analysis are used to determine the appropriate growing area classification.

Humboldt Bay is potentially impacted by both point and non-point sources that may result in elevated concentrations of fecal coliform bacteria in the certified growing area. There are four permitted municipal wastewater treatment plants, which collect or discharge wastewater within the Humboldt Bay watershed. They are the City of Arcata Wastewater Treatment Plant, the Elk River Wastewater Treatment Plant (for the City of Eureka), the College of the Redwoods Wastewater Treatment Plant, and the Manila Community Sewage Collection and Treatment System. These potential point sources have effluent limitations on constituents and properties for protection of marine life and human health. The City of Arcata plant is the only major point source discharging directly to the North Bay, where all of the certified growing areas currently are located. Humboldt Bay is also impacted by sewage collection system overflows (“upsets”) that could affect the growing areas. Thresholds have been established for the various tributaries that directly or indirectly feed into the bay, and a notification and response procedure has been established that provides the criteria for closing the various growing areas during an event. Non-point sources associated with rainfall have the potential to affect the water quality in this area. During significant rainfall events, fecal coliform pollution is washed into the various creeks and storm drains that discharge to the North Bay. Rainfall thresholds have been established that close the growing areas to harvesting when specific amounts of rainfall have occurred.

This Sanitary Survey has determined that based on an analysis of water quality compliance data, the growing areas continue to meet water quality standards of the *Conditionally Approved* classification.

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City of Arcata
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College of the Redwoods
Humboldt County Health Department, Division of Environmental Health
California Department of Fish and Game
Emerald Coast Seafoods
U.S. Food and Drug Administration
Humboldt Bay Harbor Recreation and Conservation District
Humboldt Bay Oyster Company
Humboldt Community Services District
Manila Community Services District
North Bay Shellfish Company
Regional Water Quality Control Board

III. ABBREVIATIONS AND DEFINITIONS

This document contains many acronyms and abbreviations. In general, an acronym or abbreviation will be given in parentheses () following the first time a title or term is used, and the abbreviation will be used in almost all cases in place of that term later. The following alphabetical list of abbreviations used in this document is provided to assist the reader:

ABBREVIATION	DESCRIPTION
AMWS	Arcata Marsh and Wildlife Sanctuary
APC	Adverse Pollution Condition Sampling
ARF	Aqua Rodeo Farms
CDHS	California Department of Health Services
CDHS/DDWEM	Division of Drinking Water and Environmental Management
CDHS/EHSS	Environmental Health Services Section (within CDHS/EMB)
CDHS/EMB	Environmental Management Branch (within CDHS/DDWEM)
CDHS/FDB	Food and Drug Branch (within CDHS)
CDHS/PSU	California Department of Health Services, Preharvest Shellfish Unit
CSC	Coast Seafoods Company
DEH	Division of Environmental Health (within County Health Department)
DFG	California Department of Fish and Game
ECS	Emerald Coast Seafoods
ELAP	Environmental Laboratory Accreditation Program
FC	Fecal coliform
FDA	U.S. Food and Drug Administration
H&S §	Section of the California Health and Safety Code
HBHRCD	Humboldt Bay Harbor Recreation and Conservation District
HBOC	Humboldt Bay Oyster Company
HCSD	Humboldt Community Services District
MGD	Million Gallons Per Day
mL	Milliliters
MOU	Memorandum of Understanding
MPN	Most Probable Number
NBSC	North Bay Shellfish Company
NSSP	National Shellfish Sanitation Program
PSP	Paralytic Shellfish Poisoning
RDO	Rainfall duty officer (a designated staff person in CDHS/PSU)
RWQCB	Regional Water Quality Control Board, North Coast Region
SOP	Standard Operating Procedures
SRS	Systematic Random Sampling
SSP	Shellfish Sanitation Program
WDRs	Waste Discharge Requirements
WWTP	Wastewater treatment plant

The following definitions shall apply to this document:

Harvest. The act of removing shellstock from growing waters and placing the shellstock on or in a manmade conveyance or other means of transport.

Shall. The term “shall” is used in this report in its legal or regulatory sense to denote a mandatory requirement.

Shellfish grower or **harvester**. For the purposes of this report, the terms “grower” and “harvester” refer to the same persons or firms and may be used interchangeably. Because the report relates primarily to the management of shellfish harvesting, the term “harvester” will be found most frequently.

Direct marketing. Direct marketing means the sale of shellfish harvested without undergoing purification (relaying or depuration).

IV. DESCRIPTION OF THE GROWING AREA

A. LOCATION AND SITE DESCRIPTION

Humboldt Bay is located along the far north coast of California, and is the second-largest coastal estuary in the state, with an area of 24.1 square miles at mean high tide. In comparison to the size of the bay, the watershed area is quite small, about 223 square miles. The average depth of the bay is about 11 feet. The average tidal prism of the bay is 44 percent. Humboldt Bay has been described as a tidally-driven, well-mixed estuary (Barnheart *et al* 1992).

The watershed drains portions of the cities of Arcata (population 17,000), Eureka (population 26,000), as well as unincorporated land within the County of Humboldt (Figure 1). The major natural arteries for freshwater input to the bay are the Mad River Slough, McDaniel Slough, Butcher Slough, Gannon Slough, Jacoby Creek, Eureka Slough, and the Elk River. In addition, numerous storm drains discharge to the bay from the City of Eureka.

All of the existing certified Humboldt Bay shellfish growing areas are located in “North Bay”, also known as “Arcata Bay”, which is the prominent northern arm of Humboldt Bay. All of the commercially grown shellfish in Humboldt Bay are aquacultural products, typically grown suspended in the water column on horizontal long-lines or on the substrate in mesh bags. Five commercial shellfish harvesters are operating in the bay: Aqua Rodeo Farms (ARF), Coast Seafoods Company (CSC), Emerald Coast Seafood (ECS), Humboldt Bay Oyster Company (HBOC), and North Bay Shellfish Company (NBSC). Commercial shellfish production in North Bay is primarily Pacific oysters (*Crassostrea gigas*). Each of the growers also produces Kumamoto oysters (*C. sikamea*) and limited quantities of Manila clams (*Tapes semidecussata*). NBSC also produces Mediterranean or “southern” bay mussels (*Mytilus galloprovincialis*), and is involved in limited production of European flat oysters (*Ostrea edulis*) and Eastern oysters (*C. virginica*).

The certified growing areas in Humboldt Bay are shown in Figure 2. The total area leased or owned for shellfish mariculture use is approximately 4200 acres:

> North Bay Shellfish Company’s certified growing areas consists of the south portion of Growing Area C (Parcel #1), and the entirety of Area D. Area D consists of a five-acre portion of Parcel #2, located within and alongside the Arcata Channel, and an area in the Mad River Slough consisting of a floating platform used for wet storage of harvested shellstock and for mussel culture.
>
> Aqua Rodeo Farm’s certified growing area is in Growing Area C and consists of the central section of Parcel #1 immediately south of Water Quality Station #31.

Emerald Coast Seafood's certified growing areas is in Growing Area C and consists of the northern section of Parcel #1 immediately north of Water Quality Station #31.

Coast Seafood Company's certified growing areas consists of growing area A in its entirety (the southern half of the Mad River beds, the Bird Island beds, and the eastern-most portion of the East Bay beds); Area B in it's entirety (the north half of the Mad River beds, including the "island" in the Mad River Channel, the southwest third of the Sand Island beds, the Arcata Channel beds, the Gunther Island beds, and the western-most portion of the East Bay beds); and a portion of Area E (the northeast two thirds of the Sand Island beds).

Humboldt Bay Oyster Company's certified growing area consists of portions of Growing Area C and E along the west side of the Mad River Channel, and a wet storage area for harvested shellstock and for a mussel culture area.

B. CLASSIFICATION HISTORY

Prior to 1974, the regulation of shellfish harvested for human consumption was accomplished by limiting the extent of the areas designated as *Conditionally Approved* for direct marketing of shellfish. Initially, the only times that the beds were closed were after a reported failure of a sewage treatment plant. In 1974, rainfall closures rules were first implemented with the completion of a series of bay water quality studies conducted during the rainy seasons. In 1978, seasonal closures were initiated for certain regions of the bay for which the rainfall closure rules did not suffice in assuring that certified beds met the water quality and shellfish meat standards. The California Department of Health Services (CDHS) has implemented numerous modifications to the rainfall thresholds and seasonal closures over the years.

The shellfish growing areas of Humboldt Bay are currently classified as *Conditionally Approved.* Harvest closures are implemented for rainfall events of defined intensity, when the bay experiences elevated levels of fecal coliform bacteria from rainfall run-off. There are no seasonal closures currently in effect for Humboldt Bay. Sewage "upsets" (e.g., due to system breaks, blockages, pump failures, etc.) in the sewage collection systems operated by the cities of Arcata and Eureka and the Humboldt Community Services District (HCSD) may also result in growing area closures. In addition, closures are implemented on a case-by case basis for other events such as various WWTP failures and spills of hazardous materials. All of these criteria used by CDHS to determine harvest closures are detailed in the current Management Plan (January 2006).

V. POLLUTION SOURCE SURVEY

A. POTENTIAL POINT SOURCES

Sources of pollution that can be attributed to a specific site or location are known as "point sources". The two major cities in the Humboldt Bay watershed, the City of Arcata and the City of Eureka, with populations of approximately 17,000 and 26,000 (in 2003), respectively, are served by three wastewater treatment plants (WWTPs) that discharge to Humboldt Bay: the City of Arcata WWTP, the City of Eureka, Elk River WWTP, and the College of the Redwoods WWTP. In addition, a smaller potential point source is the Manila Community Services District. Collectively, these WWTPs are the four permitted point sources that collect or discharge wastewater within the Humboldt Bay watershed. These WWTPs are issued permits from the Regional Water Quality Control Board (RWQCB). These permits include waste discharge requirements (WDRs) that impose discharge limitations on the WWTPs' effluent.

The City of Arcata WWTP is the only major point source discharging directly to North Bay. A *Prohibited* area is established as a safety zone around this outfall (see Figure 2). The critical performance standards for this facility, as stated in its WDR, include the requirements that no discharges of untreated sewage are permitted from the collection system, and the treatment and disinfection of the effluent is in conformance with the National Shellfish Sanitation Program (NSSP) approved growing area standard for fecal coliform (FC) of 14 most probable number (MPN) FC bacteria per 100 milliliters (mL). The failure to meet these critical performance standards may cause an immediate closure of the bay to commercial harvesting.

The City of Eureka WWTP receives sewage from the City of Eureka and from unincorporated areas south and east of the city under a contract with HCSD. It discharges into the North Bay on the outgoing tide near the mouth of the Elk River. Because the plant outfall is located more than 4 miles from the nearest shellfish growing area, and because the WWTP synchronizes the release times of its treated effluent discharges to coincide with the ebb tide only, causing effluent to clear Humboldt Bay on each tidal exchange, no closure zone has been established around the outfall. The critical performance standards for this facility and its collection system incorporated in its WDRs include the requirements that no discharge of untreated sewage is permitted from the collection system, and that after treatment and disinfection the effluent meets the NSSP *Approved* growing area standard for fecal coliform. Failure to meet these critical performance standards may cause CDHS to implement an immediate closure of the bay to commercial harvesting.

The College of the Redwoods has a small "package plant" of 0.1 mgd capacity which discharges into White Slough, a tributary to the South Bay. Disinfection limits for the discharge are based on NSSP standards for shellfish growing waters. An immediate closure implemented by CDHS to commercial harvesting may not always be necessary when the WWTP fails to meet its performance standards. The treatment facility's

relatively small discharge and long distance (6 miles) from its location in the South Bay watershed to the growing areas does not warrant such action. Any discharge of effluent that has not received full disinfection in accordance with the facility's WDRs would be evaluated by CDHS as possible cause for a closure of the North Bay.

1. City of Arcata Wastewater Treatment Plant

The City of Arcata discharges advanced secondary treated and disinfected effluent to the North Bay via Butcher Slough at the northeast shore of North Bay. The City of Arcata WWTP achieves advanced secondary treatment using primary clarifiers and oxidation ponds with advanced wetland polishing. After a minimum 2-week retention in the 55-acre oxidation pond, the effluent receives treatment to remove additional suspended solids and biological oxygen demand within three parallel treatment marshes (TMs). Thus, the resulting fecal coliform concentration of the oxidation pond water is likely to be orders of magnitude lower than the primary influent due to the long retention time with exposure to sunlight. The retention time in the TMs is approximately one day. Effluent from the three TMs is then combined and chlorinated, is split with a portion of dechlorinated effluent from enhancement marshes (EMs) depending on plant flow rate, and finally discharged to Butcher Slough. The portion of chlorinated effluent pumped to a series of EMs located within the Arcata Marsh and Wildlife Sanctuary (AMWS) is retained for 10 to 30 days depending on plant flow rate. After the effluent has reached the end of the last EM, the effluent is returned to the WWTP and combined with TM effluent, and chlorinated once again, and finally dechlorinated before being discharged to the bay via the Butcher Slough outfall.

The dry-weather design flow is currently 2.3 million gallons per day (MGD), with a maximum hydraulic capacity of 5.0 MGD. During the past three years, the average dry-weather (May through October) flow was about 1.6 MGD in the summer, and the average wet weather (November through April) flow was about 3.3 MGD. Flows in excess of 5.0 MGD bypass the primary clarifiers and discharge directly to the oxidation ponds. During a period of record rainfall for the Eureka area, a total monthly rainfall for the month of December 2002 was 23.31 inches, and the maximum daily flow of effluent discharged through the bay outfall during this month was 14.851 MGD.

The discharge from the City of Arcata WWTP through the outfall is regulated under a Waste Discharge Requirement permit (NPDES Permit # CA0022713) from the RWQCB, which expires in June 2009. The WDRs specify a monitoring and reporting program to allow the RWQCB to assess compliance with the terms of the permit. The WDR disinfection limits for the bay discharge requires that the effluent must not exceed a 30-day median of 14 MPN FC/100 mL, nor shall more than 10 percent of the samples collected during any 30-day period exceed 43 MPN FC/100 mL. The treated effluent is sampled for fecal coliform bacteria no less than five times per month and no more than 7 days apart with continuous, alarmed chlorine residual monitoring checked daily by WWTP staff (City of Arcata, personal communication). During the past 3 years, there have been only two bay discharge samples that have had detectable fecal coliform

concentrations. These occurred on October 25, 2000 with a concentration of 170 MPN FC/100 mL, and on December 5, 2003 with a concentration of 60 MPN FC/100 mL. On both of these occasions, these fecal coliform concentrations were detected despite chlorine residuals measured in the effluent. Because the chlorine residuals were measured in the effluent, the City of Arcata chose not to notify CDHS of the measured fecal coliform concentrations. This practice has been changed and CDHS is to be notified whenever exceedances occur.

2. Elk River Waste Water Treatment Plant

The Elk River WWTP receives and treats municipal wastewater generated by the City of Eureka and from surrounding unincorporated areas south and east served by the Humboldt Community Services District (HCSD). The total population served by the plant is approximately 45,000. This WWTP utilizes parallel arrays of primary clarifiers and aerobic trickling filters to produce a secondary level of treatment. Trickling filter effluent is then chlorinated, held in a 6 million gallon effluent holding pond prior to dechlorination, and discharged on the outgoing tide in a deep portion of the channel beyond the mouth of Elk River. The outgoing tide carries the treated wastewater past the mouth of Humboldt Bay and into the ocean.

The WWTP is designed for a dry-weather wastewater flow of 5.24 MGD, and a wet weather flow of 32 MGD. Of this flow, 12 MGD receives full secondary treatment and the remainder primary, re-blended effluent is disinfected and meets secondary limits. The WWTP discharges secondary quality effluent at all times with chlorine disinfection followed by dechlorination. The timed release of treated effluent is controlled by a computer to coincide with the ebb tide so that all the treated effluent clears the bay mouth. Once out of the bay, the long-shore current carries the treated effluent away before the tide reverses and returns only clean ocean water into the bay.

The maximum daily flow for the Elk River WWTP of influent received from January 2001 through December 2003 was 32 MGD. The maximum daily flow occurred in December 2002 during a period of exceptionally high rainfall recorded for the Eureka area, with a monthly total rainfall of 23.31 inches. This maximum daily flow is approximately 2.8 times greater than the maximum daily flow recorded during the month of December 1992, which was 11.6 MGD. The total monthly rainfall for December 1992 was 9.33 inches. The total monthly rainfall for December 2002 is approximately 2.5 times the total monthly rainfall for December 1992. This information suggests that the maximum daily flow for the WWTP is directly proportional to the total monthly rainfall for the Eureka area.

The discharge from the Elk River WWTP through the outfall is regulated under a Waste Discharge Requirement permit (NPDES Permit # CA0024449) from the RWQCB, which expires in March 2009. The WDRs specify a monitoring and reporting program to allow the RWQCB to assess compliance with the terms of the permit. The WDR disinfection

limits for the bay discharge requires that the effluent must not exceed a 30-day median of 14 MPN FC/100 mL, nor shall more than 10 percent of the samples collected during any 30-day period exceed 43 MPN FC/100 mL. The treated effluent is sampled for fecal coliform bacteria twice weekly with continuous, alarmed chlorine residual monitoring checked daily by WWTP staff.

Since completion of the Elk River WWTP in 1986, replacing three smaller plants, the City of Eureka no longer experiences the regularly predictable treatment plant failures due to overflows that formerly occurred at the old plants in association with significant rainstorms. In addition, the City has significantly improved the sewage collection and transport system. Potential deleterious impacts to water quality in the bay have recently been limited to sewage collection system “upsets”, the occasional discharge of effluent outside the discharge “window” established in the NPDES permit, the discharge of effluent that has not been fully dechlorinated, or to exceedances of the shellfish FC 90th percentile value for FC of 43 FC/100 mL MPN. However, during the past 4 years, discharges of effluent that were both outside the discharge window and exceeding the shellfish criterion have not occurred. The closure of the shellfish beds has not been necessary in these instances.

3. College of the Redwoods.

The College of the Redwoods operates a small package WWTP for small flows of up to 100,000 gallons per day. It discharges to the South Bay via White Slough. The discharge from the WWTP is regulated under a Waste Discharge Requirement permit (NPDES Permit # CA0006700) from the RWQCB, which expires in January 2007. The WDR disinfection limits for the bay discharge requires that the effluent must not exceed a 30-day median of 23 MPN TC/100 mL, nor a daily maximum of 230 MPN TC/100 mL. The treated effluent is sampled for total coliform bacteria weekly with the chlorine residual monitoring checked daily by grab sample. Except for in the most extreme cases, consideration of the relatively small volume discharged, the long distance (six miles) from the growing areas, and its hydrographic isolation from all of the North Bay growing areas, immediate closures of the growing areas in response to reported spills from this WWTP are not warranted. There have been several reported “bypass” events to CDHS, when non-dechlorinated (but fully disinfected) effluent was discharged to White Slough in the South Bay. It was not necessary to close the shellfish growing areas during these bypasses.

4. Manila Community Services District.

The Manila Community Services District operates an unusual community sewage collection and treatment system. Septic tank effluent is collected, treated and discharged by the district. The district pumps the septic tanks regularly based on tank size and the number of homes served to avoid backups of septic tank effluent. The district maintains the septic tanks and the effluent collection and treatment system.

The treatment system consists of two facultative oxidation ponds, three treatment wetland cells that may be run either in parallel or in series depending on flow conditions, and a final effluent infiltration system, which ultimately drains into the water table, then into the ocean. Historically, the Manila area was served by onsite sewage disposal systems, but the systems did not function adequately and were prone to failure. In 1978, approximately 270 septic tanks, a collection system, and a disposal leach field was installed under an EPA grant. Currently, there are a total of 296 septic tanks that serve the entire Manila area (except for about 10 homes on Vance Road on the south end still served by onsite systems), and receive domestic waste from Sierra Pacific Industries near the Mad River Slough. The original leach field failed shortly after installation, as did several subsequent replacement leach fields.

In 1996, the current system utilizing facultative oxidation ponds, water surface-flow wetlands, and surface infiltration basins was installed. To date, the upgrades to the system appear to have been providing effective treatment and disposal of the sewage effluent from the Manila area. Although the district lies within the Humboldt Bay watershed, the groundwater gradient beneath the disposal site is toward the ocean and the discharge point lies outside the Humboldt Bay watershed.

5. Summary of Point Sources

Collection system upsets, defined whenever inadequately treated wastewater has exited the confines of the wastewater/treatment system and has the potential to enter Humboldt Bay or one if its tributaries, continue to be a problem in the Humboldt Bay area. These upsets have reduced in frequency substantially in the last two years, a trend attributable to the ongoing repairs and upgrades to the system and the rapid response of the City of Arcata to minimize impacts when upsets do occur.

The range in reported volumes during this period, for those upsets that could be estimated, varied between 2 and 94,500 gallons with a mean of approximately 600 gallons over the last five years. The larger upset volumes are usually associated with periods of high rainfall and increased runoff infiltration into the sanitary sewer systems. During times of very intense high rainfall, agencies sometimes reported multiple simultaneous upsets from different locations. For example, during record rainfall on December 27, 2002, a total of 6.79 inches of rainfall was recorded for that day. On that day, at least 11 upsets were reported collectively by the cities of Eureka and Arcata, and HCSD. The total of 11 upsets events resulted in additional closure time beyond that required for rainfall closures. None of the upsets that occurred in 2005 resulted in additional closure times for the growing areas.

During the past three years, CDHS has worked cooperatively with the Cities of Arcata and Eureka, the Humboldt Community Services District, the shellfish growers, the Humboldt County Division of Environmental Health, and the Humboldt County Public Health Laboratory in an effort to develop a response protocol for collection systems

upsets. The potential for sewage upsets to adversely impact shellfish growing waters is related to the estimated volume of the discharge, the location of the discharge with respect to receiving waters (e.g., creeks, rivers, etc.), transport time to the growing areas, and the timing of the discharge with respect to rainfall closures of the growing areas. One of the goals of the workgroup was to develop a decision tree for use by the agencies responsible for the collection systems and CDHS staff in determining with consistency and predictability when a growing area should be closed, and if a closure is implemented, when an area can be reopened. The finalized response protocol has been incorporated into the *Management Plan for Commercial Shellfishing in Humboldt Bay* (2006).

The City of Arcata began collecting influent samples of sewage for FC assay in 2003. The goal of this effort was to determine whether the actual FC concentrations in sewage were lower than the theoretical value (1×10^8 MPN/100 mL) used in the original threshold calculations as part of the upsets protocol (Tables 1 - 2). CDHS worked with FDA engineers to analyze this data; a detailed account of this effort is provided in Appendix A. The data analyses allowed the determination of alternative FC maxima and the sewage upset thresholds were recalculated (Table 3) and are recommended for adoption in the next revision of the *Management Plan for Commercial Shellfishing in Humboldt Bay*. The thresholds for the City of Eureka waterways remain unchanged as influent FC data has not yet been collected at representative sites.

B. POTENTIAL NON-POINT SOURCES

Non-point sources of pollution are those sources that cannot be attributed to a specific discharge location. There are a number of actual and potential non-point sources of fecal contamination in Humboldt Bay. Some of the non-point sources may impact the bay irrespective of rainfall, e.g., on-site sewage disposal systems, sewage discharges from boats, industrial discharges, and wildlife. These potential sources are unpredictable and, thus, unmanageable with respect to the *Conditionally Approved* shellfish growing areas.

1. Boating

There is little recreational or commercial boating in the North Bay due to the difficult navigational conditions, especially during low tides. There are two marinas operating in the North Bay. The Woodley Island Marina contains 237 berths and can accommodate up to 270 boats. The Humboldt Bay Harbor Recreation and Conservation District (HBHRCD) operates the marina and prohibits the overboard discharge of sewage into the marina. HBHRCD allows no more than 10 percent of the berths to be occupied by live-aboards (24 live-aboard berths). A pump-out facility is maintained at the west end of the marina (which was not in operation at the time this report was written; boaters use the Eureka Marina's pump-out station). Public restrooms are available only to marina patrons due to recent vandalism of the restrooms, and restroom keys are issued to each berth lessee. An analysis of the occupation of the berths at the Woodley Island Marina indicated the following: 86 fishing vessels, 87 recreational sailing vessels, 39

recreational motor boats, and two row boats. Commercial fishing boats are allowed by the U.S. Coast Guard to dump there sanitary wastes at sea. All recreational craft that remain within the Bay must use the pump-out facility. The marina has no records of daily boat usage by patrons or of their utilization of the pump-out facility, but all lessees are given a copy of the Marina's rules regarding the proper disposal of sanitary wastes. Coast guard staff regularly patrol the marina and have not reported violations to the Harbor Master.

The second, smaller marina, the City of Eureka Marina, is located to the south of the Woodley Island Marina. The marina has 154 berths and, as of December 2004, has 135 boats leasing slips. Additionally, there are usually 4 to 5 transient boats in the marina. The City allows a maximum of 8 live-aboard permits. This marina also has a prohibition against the overboard discharging of sewage into the marina. As indicated above, the marina does have an operating pump-out station. There is a twice-daily foot patrol in the marina, and the Coast Guard inspects the area on a normally monthly basis.

2. Wildlife

Humboldt Bay supports a rich diversity of resident and seasonal populations of birds and wildlife. Common resident birds are various species of ducks, grebes, cormorants, and shorebirds. Birds and mammals are potential sources of fecal coliform that can impact the growing areas.

There is a resident population of harbor seals in North Bay. The seals are commonly found at sites along the tidal channel branch immediately south of the Gannon Slough Channel. There are no shellfish growing areas near the seal inhabited areas.

Humboldt Bay is located on the Pacific migratory bird flyway and serves as seasonal habitat for populations of waterfowl species. The largest numbers of waterfowl occur during the fall and on into the early winter months. Since the winter of 1997, the numbers of waterfowl in the North Bay has ranged from 3,714 in 2002 to 11,840 in 2003 birds per day (Jeff Dayton, California Department of Fish and Game, personal communication). The prevalent species are American widgeon, scaup, and bufflehead ducks.

During early 2000, CDHS conducted an intensive sampling of 25 bay stations in the area of North Bay known to harbor concentrations of seasonal wildlife. The water samples were collected during the months of February, March and April during relatively dry periods, and fecal coliform levels were not anomalously high. Thus, the presence of wildlife does not seem to result in adverse and unmanageable fecal coliform impacts in the growing waters. Consequently, the data in conjunction with additional regulatory samples collected from the growing waters allowed CDHS/PSU to eliminate the seasonal closures in 2003 that previously existed for several growing areas. Previously, all of Coast Seafood Company's Arcata Bay beds, except the Mad River beds, were closed the entire month of January. In addition, Coast Seafood Company's Sand Island

beds were closed the entire months of February and March.

3. Agriculture

The California Department of Finance reported in the 2003 California Statistical Abstract that, in 1997, of the 2,286,400 acres of land in Humboldt County, 584,538 acres (25.6 percent) of land were in farms. Agriculture has been the predominant land-use on the portion of the watershed to the north of North Bay and west of the city of Arcata (the "Arcata Bottoms"), on land east of State Highway 101 and west of Old Arcata Road, and on bottomland east of Highway 101 in the Elk River watershed. These areas have been used mostly for dairy cow pasture for decades. The number of cattle within the Humboldt Bay watershed is reported to have decreased during the past five to ten years to approximately 1,950 animals as the number of operating dairies has decreased (Richard Peterson, Resident Veterinarian, California Department of Food and Agriculture, Personal Communication June, 15, 2004). In the Arcata Bottoms area nearest the growing areas, cattle are held in stables on higher ground during the rainy season when the ground is wet. Later in the spring, when the ground begins to dry and pasture conditions improve, the cattle are allowed to graze the areas nearer the growing areas.

4. Onsite Sewage Disposal Facilities

Unincorporated areas outside the city limits of Eureka and Arcata and outside the Humboldt Community and Manila Community Services District are generally served by onsite sewage disposal systems. The majority of the onsite sewage disposal systems in the North Bay watershed are located east of State Highway 101 between the cities of Arcata and Eureka. There are perhaps an additional 20 systems in the Arcata Bottoms and about 10 systems on Vance Avenue immediately north of the Western terminus of the Samoa Bridge on the north spit.

According to the Humboldt County Environmental Health Division (HCEHD), there are approximately 1,500 systems on the east side of the bay between the cities. Systems in this area have a history of failures due to a combination of relatively small lot sizes and poor soil conditions for onsite sewage disposal. Within this area, HCEHD limits the types of systems installed to alternative systems designed to overcome the limited site conditions. HCEHD reports that during the past 10 years, approximately 120 permits for alternative systems have been issued, and that a significant number of these were to replace existing systems in failure. The tributaries that could be impacted by these systems are Beith Creek, Grotzman Creek, Gannon Slough, Jacoby Creek, Washington Slough, Faye Slough, Freshwater Creek, and Ryan Creek. The Humboldt Bay Shellfish Technical Advisory Committee (HBSTAC) intensively sampled these streams during the winter of 1999-2000 during several periods of rainfall runoff, when onsite systems are most prone to failure. The results of this study were that none of these tributaries experienced significantly higher FC concentrations when compared to other watershed areas with a lower density of onsite systems.

In addition, there are three community septic systems within the North Bay watershed: one is on the south spit near the town of Samoa, and two are located in the unincorporated area between the cities of Arcata and Eureka. NPDES permits have been issued by RWQCB to Samoa Pacific LLC, Samoa Town site, Eureka Mobile estates at 7600 Myrtle Avenue, and to Indianola Mobile Home Park at 3656 Old Arcata Road. Samoa Pacific LLC is responsible for a system that discharges domestic wastewater to an oxidation pond and leach field from approximately 65 homes in the town of Samoa. This discharge is located about a quarter mile from Humboldt Bay in a low-lying area and is not known to RWQCB or CDHS staff to discharge outside of its fenced enclosure.

The other two systems are monitored by the HCEHD, which responds to complaints if the systems are alleged to be discharging sewage onto the surface of the ground. The systems are pumped out regularly as required by HCEHD as a precaution to avoid failure. HCEHD has not reported any failures during the past three years.

5. Industrial

Several industrial facilities that process raw wood and wood pulp exist along the perimeter of North Bay. These facilities include the Fairhaven Power Plant, Simpson Timber CSD, Louisiana Pacific Samoa Pulp mill, Sierra Pacific Industries (Arcata Division), Simpson (Eureka Timber facility), and Sierra Pacific Industries (Eureka Dock). The Fairhaven Power Plant is a biomass electrical generating station that uses wood chips to generate electricity. It is located on the Samoa Peninsula at the intersection of New Navy Base Road and Bay Street south of the community of Samoa. It has an NPDES permit from RWQCB to discharge boiler blow-down condensate and industrial stormwater. Both discharges are to the ocean rather than to Humboldt Bay.

Simpson Timber CSD, located on land immediately to the east of the Fairhaven Power Plant and on property just south of Samoa, was formerly a “remanufacturing” facility for the milling of rough-cut timber to finished lumber dimensions. The facility has been inactive since 1993 and the facility buildings are scheduled for demolition. It has a current permit to discharge industrial stormwater to Humboldt Bay from the existing facility. The property has recently been purchased and the new owners have presented proposals to RWQCB to upgrade the system in the near future.

Louisiana Pacific Samoa Pulp Mill has recently been sold to a new owner, Stockton Pacific Enterprises, Inc. The facility is located on property near the intersection of Navy Base Road and LP Drive on the Samoa Peninsula south of the town of Manila. This facility has permits to discharge process water to the ocean, and for stormwater to the bay.

Sierra Pacific Industries (Arcata Division) is located at the confluence of the Mad River Slough and North Bay. The facility applies wood preservatives to raw lumber. There is a

history of soil contamination from past use of the preservative pentachlorophenol, when the dip tanks used in applying the preservative were not equipped with a secondary containment system, as is the practice today. In 1985, the use of pentachlorophenol was discontinued and the new dip facility was located inside a building equipped with secondary containment for any spilled preservative. The facility has an industrial stormwater permit.

Simpson (Brainerd Eureka Timber Facility) is located on a 40-acre parcel along the southeast shore of North Bay. The facility is mainly a kiln-dry operation for remanufactured lumber. Rough timbers received from off-site sawmills are end coated with paraffin at the facility prior to undergoing a several-week-long period of air-drying followed by a final kiln dry. Wood waste only is used to fuel the kiln. All boiler condensate is required by RWQCB to be confined in an on-site fire pond. The entire facility is surrounded on the bay side by a 4-foot high berm to exclude tidal water during high tides. Rainfall runoff from the site drains to Faye Slough, a tributary of Eureka Slough. During times of very heavy rainfall, a portion of the “moat” inside the berm can be isolated with gates to allow for the temporary retention of runoff. Approximately 60 persons are employed at the facility. The domestic wastewater generated by the employees is discharged via several onsite sewage disposal systems. The facility has a permit to discharge industrial stormwater only.

Sierra Pacific (Eureka Dock) is within the Eureka city limits just south of the intersection of Waterfront and Del Norte Streets. This facility produces wood fiber panels and has an industrial storm water permit from RWQCB.

6. Recreational

Recreational uses of the North Bay are quite limited as public access along the shorelines are limited, and navigation of a boat within the complex system of tidal channels and mud flats is difficult due to the constantly changing tides. The Department of Fish and Game reports very little recreational clamming in the North Bay. All of the popular clamming locations are located along the shores of Entrance Bay and South Bay. Sport harvesting of mussels is prohibited by CDHS from April 1 through October 31 each year to protect the public from paralytic shellfish poisoning.

7. Creeks and Storm Drains

The major creeks responsible for water transport in the North Bay watershed are Lamphere Slough, Liscom Slough, a tide gate located 100 yards south of the Mad River Slough bridge), McDaniel Slough, Butcher Slough, Gannon Slough, Jacoby Creek, Eureka Slough, and Elk River. In addition, at least 13 storm drains discharge to the Bay from the City of Eureka. The relative importance of each source is dependent on the predominant land uses within each subwatershed, stream flow rate (approximately proportional to the creek’s watershed area), and the location of the discharge with respect to the growing areas. All of these streams and storm drains contribute to fecal

coliform loading from the watershed during periods of rainfall, and the fecal coliform concentrations may exceed the shellfish water quality criteria by several orders of magnitude (HBSTAC study). In general, fecal coliform concentrations were more variable in those watercourses that are associated with urban or agricultural land uses in the lowlands close to the bay (90 to 3,000 MPN/100 mL), while fecal coliform concentrations appeared to be lower for sampling points that represented more rural upland areas of the watershed (200 to 260 MPN/100 mL), although there were relatively few sites from these areas. The location of the discharge of these sources with respect to the growing areas is also important. The further south of the growing areas that streams and storm drains discharge to Humboldt Bay, the less significant the stream or storm drain is as a source of pollutants to the growing areas because the water from these sources may be released to the ocean during the ebb tide rather than directly affecting the growing areas.

The Eel River discharges to the Pacific Ocean about 11 miles south of the Humboldt Bay Entrance. Although this river is known to produce sediment deposition within Entrance Bay, the six-mile long North Bay channel effectively isolates this source from the shellfish growing areas. The mouth of Mad River is about 12 miles north of Humboldt Bay entrance. Similarly, the length and large volume of the North Bay channel isolates the Mad River as a significant pollution source affecting the growing areas.

8. Summary of Non-Point Sources

Humboldt Bay is affected by a variety of non-point pollution sources. Wildlife, primarily migratory birds and resident seals do not appear to be contributing fecal coliform at levels high enough to result in non-compliance with the shellfish water quality criteria. The most important non-point source of fecal coliform pollution affecting the growing areas is the various creeks and storm drains that discharge to the North Bay. Urban and agricultural areas seem to be contributing higher concentrations of fecal coliform than less populated areas of the watershed, but without an analysis of all of the loading of each of these sources, it is not possible to assign relative contribution of fecal coliform to the shellfish growing areas from the various tributaries. It is recommended that a new study be accomplish to measure flow and fecal coliform to generate loading estimates for key tributaries.

VI. HYDROGRAPHIC AND METEOROLOGICAL CHARACTERISTICS

A. TIDES

Tidal action in Humboldt Bay is typical of coastal California in being semi-diurnal, ebbing and flooding twice each day, with unequal tidal ranges for each tidal cycle occurring in a lunar day (Barnhart et al 1992). The tidal range is smallest at the ocean inlet and increases as one proceeds up the bay in the North Bay Channel approximately to the mouth of Eureka Slough, where it thereafter decreases somewhat in the far North Bay. Table 4 illustrates the increase in tidal range as one proceeds north from the entrance.

Tidal stage is delayed by approximately 50 minutes at north Arcata Bay relative to the entrance. The average tidal prism for North Bay expressed as a proportion of Mean High Water is 44 percent.

B. WINDS

Strong winds from the north and northwest are common in spring and early summer. These winds typically result in upwelling along the nearshore environment, bringing high nutrient concentrations, low temperatures, high salinities, and low oxygen concentrations to the coastal waters (Barnhart et al 1992). During the summer and early fall, low intensity winds with no predominant direction are more common, the upwelling ceases, and nutrient levels and salinities fall, while water temperatures increase in the nearshore. During stormy periods typical in late fall and winter, the predominant wind direction is from the south and southwest. The wind fetch across the North Bay resulting from these strong winds, in combination with sediment loads contributed from the creeks carrying runoff, can entrain considerable quantities of material from the mud flats into the water column.

C. CIRCULATION AND FLUSHING

Although the North Bay's relatively large tidal prism, when compared to other estuaries, implies that there is considerable daily water exchange with the ocean, the presence of the long and deep tidal channel that separates the North Bay from the ocean results in a much lower water exchange rate. This is even more pronounced during times of rainfall and high freshwater input creating a halocline that may limit vertical exchange between water on the mudflats and deeper water in the system of tidal channels. Thus, it has been estimated that the flushing time for the Mad River Slough may require 85 tidal cycles (Barnhart *et al*, after Costa 1981). Bay salinities have been noted to remain depressed for several days following periods of high rainfall runoff. Because of the large tidal prism, the North Bay circulation is largely tidally driven meaning that prevailing currents in the North Bay tend to follow the tidal channels. However, evidence exists that storm systems with prevailing southeast winds may cause some advection of water perpendicular to the channels during high tides when the shallow mudflats are submerged (Anatec Laboratories *et al* 1982).

D. RAINFALL

Humboldt Bay has a Mediterranean type climate with relatively dry summers and wet winters. Snow falls infrequently. The mean annual rainfall is about 37 inches as recorded in Eureka. However, low lying Eureka is generally considered to be relatively dryer than most of the surrounding area of the Humboldt Bay watershed at higher elevations which tend to express more water from passing rain clouds. The relatively high rainfall results in a large number of days that shellfish areas are closed to harvest activities. The number of closed days per year is typically ranges from 60 to 120 days per rainfall season for the various harvest areas.

For Water Years 1987 to 2003 (October 1987 through September 2003), the annual total rainfall in the Eureka area ranged from 21.01 inches (Water Year 1991-92) to 55.98 inches (Water Year 1997-98), with an average annual total rainfall of 38.97 inches for the period (Figure 3).

Based on historical rainfall data from July 1, 1948 to March 3, 2004 obtained from the National Weather Service, the probability of a 24 hour total rainfall of at least 0.50 inch is close to zero during the months of July and August, and increases to approximately 15 percent during the months of November, December, January, and February (Figure 4a). For a 24-hour total rainfall of at least 0.75 inch, the probability is close to zero during the months of June, July, and August, and increases to approximately 10 percent during the months of November, December, and January (Figure 4b). For a 24-hour total rainfall of at least one inch, the probability is close to zero during the months of May, June, July, August, and September, and increases to approximately five to seven percent during the months of November, December, January, and February (Figure 4c). For a 24-hour total rainfall of at least 1.50 inches, the probability is close to zero for the months of May, June, July, August, and September, and increases to approximately one to three percent during the months of October, November, December, January, and February (Figure 4d).

For a 7-day total rainfall of at least 3 inches, the probability is close to zero during the months of May, June, July, August, and September, and increases to approximately 10 to 20 percent during the months of November, December, January, and February (Figure 5a). For a 7-day total rainfall of at least 5 inches, the probability is close to zero during the months of May, June, July, August, and September, and increases to approximately one to five percent during the months of October, November, December, January, and February (Figure 5b).

E. RIVER AND STORM DRAIN DISCHARGES

The relatively small size of the watershed means that there is a relatively short (i.e., hours) response time between peak rainfall and runoff entering the bay. Most of the rainfall falling on the watershed reaches the bay within 24 to 48 hours. Data from the 1999-2000 HBSTAC Study demonstrated peak fecal coliform concentrations in the bay and lower creek stations within one or two days of significant rainfall.

The creeks carrying the largest flows are Jacoby Creek, Freshwater Creek, and Elk River due to their larger watershed area. However, the watersheds of these creeks are less populated, forested areas that probably contribute less fecal coliform per unit area than the more urban and agricultural bottomlands nearer the bay. Despite its large volume, the mouth of Elk River is near the Humboldt Bay entrance, and probably has relatively little impact on the growing area water quality compared to the Jacoby and Freshwater creeks.

Urban areas of the City of Arcata are not dewatered with storm drains. Rather, a series of urban creeks kept in a relatively natural state (i.e., Janes, Jolly Giant, Campbell, and Grotzman creeks) convey stormwater to the bay during storm events. It has been noted that as water traverses the city from its source, the fecal coliform concentrations in Janes and Jolly Giant creeks increase. This suggests that the urban area contributes a greater load per unit area than the relatively unpopulated upland areas.

Urban areas of the City of Eureka are drained by at least 13 culverted storm drains. Because many of these storm drains discharge to the prohibited Marina areas, and are located down tide from the growing areas, their direct impact to the growing areas is much less than the creeks that empty nearer to the growing areas in the North Bay.

VII. CLOSURE CRITERIA

A. RAINFALL CLOSURES

The following closure criteria will be used to close and reopen the shellfish growing areas in Humboldt Bay. CDHS will contact the grower when the area is placed in a closed status. No harvesting or moving of product can occur during a closure unless as stipulated in the Management Plan for Commercial Shellfish Growing areas in Humboldt Bay. CDHS will also notify the grower when the area is reopened.

1. Closures Zones

Shellfish growing areas of Humboldt Bay are located in six rainfall closure zones.

a. Area A is operated by CSC and includes the south Mad River beds, the Bird Island beds and the east section of the East Bay growing area.

b. Area B is also operated by CSC and includes the north Mad River beds, the western portion of the East Bay beds, the Gunther Island beds, the south Sand Island growing area, and the Arcata Channel growing area.

c. Area C includes Parcel 1, operated by NBSC, ARF, and ECS, and the north Mad River beds operated by HBOC.

d. Area D is operated by NBSC and includes the Mad River wet storage area, and Parcel 2.

e. Area E includes the south portion of the Mad River beds operated by HBOC, and the north Sand Island growing area operated by CSC.

f. Area F includes the wet storage area operated by HBOC on the Mad River.

2. Closure Rules

All shellfish growing areas in Humboldt Bay are classified as *Conditionally Approved* and shall adhere to the established rainfall closures rules. Table 5 provides the history of the rainfall closure rules and Table 6 provides the current rules for each of the six growing areas. The shellfish growing areas located in Humboldt Bay shall be closed when the 24-hour rainfall amount exceeds the established threshold, as recorded by the National Weather Service (NWS) station in Eureka. The six-hour synoptic rainfall data from NWS Eureka can be obtained from their web site or by telephone. If the NWS rainfall data is not available, rainfall data is obtained from the CDHS Davis Instruments gauge, located on Woodley Island. Closure of a growing area shall occur when the rainfall exceeds the following thresholds:

a. Area A – six (6) hours after the 24-hour cumulative rainfall of 1.2 inches is exceeded.

b. Area B – six (6) hours after the 24-hour cumulative rainfall of 1.0 inch is exceeded.

c. Area C – six (6) hours after the 24-hour cumulative rainfall of .5 inches is exceeded.

d. Area D – the hour that the 24-hour cumulative rainfall exceeds .5 inches of rain.

e. Area E – six (6) hours after the 24-hour cumulative rainfall of .5 inches is exceeded.

f. Area F – the hour that the 24-hour cumulative rainfall exceeds .5 inches of rain.

B. OTHER CLOSURES

There are three additional types of closures in Humboldt Bay: 1) *Prohibited* zones have been established around the Arcata outfall and around the two marinas, where shellfish mariculture will always be prohibited. 2) Closures occur during emergency pollution events that adversely affect bay water quality, and will cause a closure of the *Conditionally Approved* growing areas. And 3) all parts of the bay not specifically designated as commercial shellfish growing areas are designated as *"unclassified"* and considered "*Prohibited".*

1. Marinas

Sewage discharged from boats poses a significant pollution threat to shellfish growing areas. Closure zones have been designated for each of the marinas in Humboldt Bay. Since discharging sewage in either of the two Humboldt Bay marinas is against federal law and marina regulations, on most days, the amount of raw sewage being illegally dumped into the Bay from the marinas is probably zero. Since accidental or illegal dumping could occasionally occur, two scenarios were evaluated to determine if the existing prohibited zone around the marinas would be adequate for these "worse-case" scenarios.

a. For Case #1, the possible number of boats performing illegal dumping of sewage at the Woodley Island Marina was determined by starting with the maximum number of berths (270) and reducing this by the number of commercial boats (80). It was then assumed that 50% of these boats were occupied and 50% were illegally discharging, equaling approximately 50 boats. Using the NSSP standard of 2×10^9 fecal coliform per person per day and two persons per boat, the potential FC loading to the marina waters is: 50 boats x 2 persons/boat x 2×10^9 FC/person = 200×10^9 FC. For the Eureka Marina, 154 boats were assumed to be berthed, and, of these, 50% were assumed occupied, and 50% were assumed illegally discharging, for a total of approximately 40 boats with the assumption that they are illegally discharging on any given day. The potential FC loading would be 40 boats x 2 persons/boat x 2×10^9 FC/person = 160×10^9 FC. The dilution volume required to reduce the FC loading to 14 MPN/100 mL calculates to be 2.5×10^9 liters.

b. For Case #2, the number of boats illegally discharging is based on the assumption that 25% of the live-aboards and 10% of the remaining pleasure crafts contribute to the discharges. For Woodley Island, there are a maximum of 24 live-aboards allowed in the marina. Assume 50% occupancy and 50% illegally discharging on any given day (6 boats). For the remaining pleasure crafts (190 boats), assume 10% of them are illegally discharging into the bay (19 boats). For Eureka Marina, live-aboards account for 8 of the berths. Assuming 50% of these are occupied and 50% illegally discharging on any given day (2 boats), and assume of the remaining boats (148), 10% of these are illegally discharging sewage into the bay (15). The potential FC loading for this scenario calculates to be 42 boats x 2 persons/boat x 2×10^9 FC/person = 168×10^9 FC. The dilution volume required to reduce the FC loading to 14 MPN/100 mL calculates to be 1.2×10^9 liters.

The extent of the marina closure zone is dependant on the recent bathymetry of the bay in the vicinity of the Marinas. A NOAA navigation depth chart was used for those areas outside the shipping channel areas surveyed by the U.S. Army Corps of Engineers. Recent bathymetric survey conducted in 2004 by the Army Corps of Engineers shows that the volume of the existing marina closure zone as described in the 1993 Sanitary Survey Addendum is approximately equal to $1.63 \text{ X } 10^8$ cubic feet, or 4.6×10^9 liters The existing combined marina closure zone for both marinas exceeds the minimum required dilution volume by nearly two-fold for Case #1 and more the 3 times for Case #2. The added safety factor is desirable since assumptions were used in the calculations, and therefore the existing marina prohibited area will remain unchanged.

As an additional verification of the existing marina closure zone, the Virginia Institute of Marine Sciences (VIMS) model for establishing buffer zones was applied to the two scenarios described above. Using this model, the closure distance out from the Woodley Island Marina is 1,607 feet and the dilution volume is 7.8×10^6 ft^3 for Case #1, and 1,119 feet with a dilution volume of 5.4×10^6 ft^3 for Case #2. For the Eureka Marina, the calculated distances were 683 feet and 334 feet, respectively and the dilutions

volumes were 9 x 10^6 ft^3 and 4.4 x 10^6 ft^3.respectively. These distances and volumes are within the existing closure zone for the marinas.

2. Wastewater Treatment Plants and Sewage Collection Systems

The *Conditionally Approved* classification of the shellfish growing areas is also dependent upon wastewater treatment plant performance. If a malfunction results in a release or has the potential of releasing raw or partially treated sewage to the bay, the responsible agency shall notify each of the shellfish growers, RWQCB, County DEH, and CDHS. CDHS will then determine the status of the growing area and will notify the growers when the determination has been made. Harvesting shall not occur until after CDHS/PSU has evaluated the event and determined the required actions.

Accidental sewage releases from wastewater collection systems operated by the City of Arcata, the City of Eureka, or by HCSD occurs periodically and may adversely affect the water quality in shellfish growing areas. The potential for these sewage “upsets” to adversely impact shellfish growing waters is related to the estimated volume of the discharge, the location of the discharge with respect to the growing areas, and the timing of the discharge with respect to rainfall closures of the growing areas. The criteria for determining whether an emergency closure will be implemented, the responsibilities for notification, and the criteria for reopening the areas are provided in the Management Plan. The wastewater upset notification and response procedures developed provides decision trees for use by the agencies responsible for the collection systems, the shellfish growers, and CDHS staff in determining with consistency and predictability when a growing area should be closed, and if a closure is implemented, when an area can be reopened.

VIII. WATER QUALITY STUDIES

A. SUMMARY OF PREVIOUS POLLUTION STUDIES

1. Humboldt Bay Wastewater Circulation Study

In 1979, a Humboldt Bay wastewater circulation study was conducted. The purpose of the study was to determine the behavior of three sewage treatment plant discharges on North Bay shellfish growing areas. Rhodamine-WT dye was injected on April 24-26, 1979, in each of the treatment plant outfalls. While only the Arcata WWTP outfall is still in existence, “upset” events still occur in the location of the former Hill Street WWTP. Therefore, results from only these two WWTPs are summarized. In addition, the former discharge point of the Arcata WWTP at the southern edge of the oxidation pond has since been relocated to the Butcher Slough channel. The findings relevant to the Arcata discharge are summarized as follows:

a. Dye injected 85 minutes after the start of the ebb tide from the Arcata WWTP outfall traveled 4,100 yards in 250 minutes by the following slack tide. Within this period, the

dye reached to approximately 400 yards west of the confluence of the Arcata and Jacoby Creek channels. Since the tide ebbed approximately 4.5 feet from the start of the injection, the water traveled about 4,100 yard per 4.5 feet, or 910 yard per foot, of tidal ebb.

b. The dilution ratios for the Arcata WWTP injection at the eastern edge of the Sand Island growing area and the northern portion of the East Bay growing area were 1:35,000 and 1:52,000, respectively.

c. Dye injected 50 minutes after the start of the ebb tide from the Hill Street WWTP outfall was detected near Murray Street at approximately 168 minutes after initial injection, 5,700 yards down the North Bay channel. This represents about 2,700 yards of travel per foot of tidal drop.

d. Dye was detected 150 minutes after the following flood tide following the Hill Street WWTP injection in the northern East Bay growing area, representing movement to the growing areas during which the associated tidal rise was about 2.8 feet.

2. Humboldt Bay Non-Point Source Study Project

In 1982, a dye study was conducted in which fluorescent dye was injected at a constant rate into North Bay near the confluence of Jacoby and Arcata Channels for 5 days, and dye concentrations were monitored at high and low tide daily. Dye injection was discontinued at day 5, and dye concentration monitoring continued for 7 days thereafter. Significant findings included:

a. Dilution discharge of North Bay (equivalent to ocean flushing rate is about 4,000 to 5,000 cubic feet per second). The “half-life” of injected dye was found to be about 2.5 days.

b. By the third day after the dye was released, dye concentrations were generally higher shoreward of the discharge point (between the discharge point and the Arcata sewage outfall), with dye concentration about an order of magnitude lower in the upper reaches of Mad River Slough.

c. After a storm with strong easterly wind, dye concentrations were observed to decrease in the eastern stations near the Arcata outfall, but increase in the Mad River Slough. This may have been indicative of wind-driven currents driving water from near the Arcata outfall westward to Mad River Slough. Thus, currents in North Bay may at times be oriented transverse to the tidal channels rather than parallel to them, as is the usual situation.

3. Onsite Wastewater System Pollution Study in the Indianola and Walker Point Areas of Humboldt County

In 1990, a study was conducted to assess the impact of septic systems on surface and groundwater in an area long known to contain a large concentration of malfunctioning septic systems. The area was not ideally suited for septic systems due to high seasonal groundwater during the wet season and slowly permeable soils. The area of the study included land parcels on Walter Point Road, Indianola Road, Indianola Cutoff Road, Old Arcata Road, Ole Hanson Road, and Redmond Road. All of the study area was included in the “waiver prohibition area” with respect to the issuance of permits for septic systems by the Division of Environmental Health (DEH). Less flexibility is granted to the DEH by RWQCB in granting septic permits for new construction septic systems as a result of such a waiver.

The study included a file review of septic system permits and the tallying of questionnaires mailed to each parcel owner, and fecal coliform analyses of surface and well water samples from the area. The study concluded that of 195 septic systems for which questionnaires were completed by the owners and/or for which site inspections were completed, 46 percent (90 total) of the systems were found to have problems. These problems included liquid on the ground near septic components, the need for frequent septage pumping, odors, sluggish wastewater, and the discharge of gray water onto the ground surface. Also included in the study were a small number (26) of surface water samples representing ”upstream” stations (5 samples from 3 stations) and “downstream” stations (21 samples) from 6 stations. The fecal coliform concentrations of the upstream samples ranged from 2 to 220 MPN/100 mL, and the concentrations of the downstream samples ranged from 4 to 900 MPN/100 mL.

4. Humboldt Bay Shellfish Technical Advisory Committee

On October 10, 1993, legislation was passed by the California legislature that enacted the Shellfish Protection Act of 1993 (SB 417, Marks). This bill requires the RWQCB to form a technical advisory committee for any commercial shellfish growing area that is determined to be “threatened”. Pursuant to this legislation, the Humboldt Bay Shellfish Technical Advisory Committee (HBSTAC) was formed in 1995. The purpose of the HBSTAC is to advise and assist RWQCB in developing an investigation and remediation strategy to reduce pollution affecting the shellfish growing areas.

One of the criteria for a "threatened" area is the number of days the area is closed to shellfish harvesting due to pollution threats. The Shellfish Protection Act states that a shellfish area shall be designated as threatened if it is closed to harvesting for more than thirty days in each of three consecutive calendar years. The following table shows the number of closure days for each growing area for the most resent rainy seasons:

RAINY SEASON	GROWING AREA					
	A	B	C	D	E	F
2002-2003	65	92	105	114	-	-
2003-2004	61	78	109	117	99	127
2004-2005	37	59	101	120	83	133

The HBSTAC designed and carried out a study to compare the fecal coliform concentrations in tributary and bay waters during dry periods, and during periods when rainfall runoff discharges to the bay. In addition, a relatively small number (50 total) of shellfish samples were collected and analyzed for fecal coliform during dry and wet events. Thirty-five sampling stations were designated to represent all potential significant tributary sources affecting the bay, and sixteen bay sampling stations were selected to represent shellfish growing water quality. Sampling was conducted on two dates representing dry weather events, and 16 days (four days for each of four wet-weather events) representing wet weather periods. Thus, a total of 918 water samples were collected during the duration of the study period from October 1999 to June 2000. The first day of sampling during each of the wet events occurred the first day that at least one-half inch of rain fell during the previous 24 hours and continued for the next two successive days (Day 1, Day 2, and Day 3). The final wet event samples were collected on the day that the growing areas were scheduled to reopen according to the current rainfall rules (Day-X).

The data collected from the study showed that, in general, the tributary sites had the highest fecal coliform concentration on the first day of the rainfall events. In contrast, the bay stations showed the highest fecal coliform concentrations on Day 2 for each event, with fecal coliform concentrations diminishing by Day-3 and Day-X. In two creeks that flow through the City of Arcata (Janes and Jolly Giant creeks), fecal coliform concentrations increased at downstream locations compared to upstream sites, suggesting that urban runoff from the City of Arcata contributes a greater concentration of fecal coliform than upstream natural areas.

The estimation of flow rates of the various streams sampled in the study was not attempted. Thus, the derivation of mass loading contributions of fecal coliform derived from different areas of the watershed and the correlation of the observed fecal coliform loading as a function of land use was not possible. Therefore, the HBSTAC could not make specific recommendations to identify and control sources of fecal coliform for improvement of water quality in the growing areas.

The study results concluded the following: 1) the existing shellfish harvesting area rainfall closure criteria are effective in the protection of public health; 2) water quality requirements of the RWQCB are consistently meet during periods when the growing areas are open for harvesting; 3) water quality in the Bay is degraded during rainfall events, but dispersion of the stormwater runoff, tidally induced circulation and mixing, and organism die-off result in water quality meeting the requirements within the timeframes established by DHS/PSU during rainfall closures; and 4) fecal coliform levels indicated that there are a variety of non-point sources within the watershed.

5. Arcata Bay Dye Studies of 2004

The purposes of these studies were to determine the path and dilution of potential

sewage spills and how these discharges affect the certified shellfish growing areas. In addition to tracking the dye during the initial outgoing tide, dye intensity readings were also obtained during the subsequent flood tide. As most sewage overflows normally occur during periods of heavy rainfall, the original design of the studies were to determine these factors during periods of wet weather and, consequently, high flow in the tributaries. Due to planning and scheduling constraints, the actual Arcata Bay Dye Studies were conducted under dry weather conditions, and very low flow conditions during March 9 through 16, 2004. Dye studies were conducted at Jolly Giant Slough, Gannon Slough, and Eureka Slough.

a. Gannon Slough Hydrographic Study – March 10, 2004. The dye addition started about mid-ebb tide, approximately 3 hours after high tide. This corresponded to the opening of the tide gate on Gannon Slough, allowing slough water to exit. The limit of the dye travel was only about 1.2 nautical miles from the mouth of Gannon Slough at the highway. The dye from the Gannon Slough Study did not extend far west of the road, remained around the bridge, and was pushed back up toward the tide gate on the flood tide. The tide gate was operating well during the study and allowed little dye to enter Gannon Slough through the tide gate on flood tide. The travel excursion is related to the elevation of the fresh water behind the tide gate. The limit of excursion for this dry weather study was only 1.2 miles. If a sewage upset occurred under the conditions of this study, the excursion would be expected to not exceed that found in the study. However, most sewage overflows occur during times of rainfall. In this case, the water level could build up higher behind the tide gate and start to discharge earlier after the tide changed from flood to ebb, with an expected increase in the excursion length.

b. Eureka Slough Hydrographic Study – March 11, 2004. The dye was released from a boat moored just downstream of the railroad bridge in Eureka Slough. The dye did reach the mouth of the Bay during the ebb tide, considerably diluted, and then was pushed into the Mad River Slough channel, Arcata channel, and the channel south of Daby Island during the subsequent flood tide. Dye concentrations taken later in the flood tide (approaching high tide) were less than the readings taken earlier on the flood tide. This is due to the dye concentrations being reduced as tidal water, entering at the mouth, pushed and diluted the dye during flood tide and toward the end of the flood tide more incoming ocean water could come behind the dye tagged plume, resulting in greatly diminished concentrations. Dye concentration readings indicated that there was considerably less tendency for the dye to be carried up the Mad River Slough channel than Arcata, Indian, and the channel south of Woodley and Daby Islands.

The results of the Eureka Slough dye test show that a significant amount of dye was measured at Mad River Slough. When translated to fecal coliform concentrations using a calculated dilution factor of 6.23×10^4, an assumed sewage discharge of 1.547 cubic feet per second (1 mgd), an assumed raw sewage fecal coliform concentration of 5×10^6 Most Probable Number (MPN) per 100 milliliters (mL), and a sewage discharge duration of about 3.5 hours (this was the amount of time that it took to apply the dye), the estimated fecal coliform concentration at Mad River Slough was 124 MPN per 100

mL. This concentration was much greater than the water quality requirements for a *Conditionally Approved* growing area. See Table 7 for additional projected fecal coliform concentrations at key locations at low tide. These projected fecal coliform counts represent anticipated values in the Bay at low tide at locations resulting from an estimated sewage discharge of 1 million gallons per day that could originate near the location of the dye release. These dilution values and fecal coliform values will then be subject to further dilution on the change of the tide from low to flood tide. All of the fecal coliform concentrations are above the growing water criteria of 14 MPN/100 mL

c. Jolly Giant Hydrographic Study – March 16, 2004. The dye feed started as the tidal water started out at Jolly Giant Slough. The tidal excursion was expected to be further than for the study done at Gannon Slough, when dye feed was started at about mid-ebb tide when the tide gate opened. The dye from Gannon Slough did not reach the intersection with the Jolly Giant channel. The excursion of the dye was 2.25 nautical miles from Jolly Giant for the full ebb tide. This leads to a reasonable comparison with the study at Gannon Slough, where the excursion was about 1.2 nautical miles for essentially one half of a tidal excursion. If other factors were considered equal, a larger excursion would be expected for the Jolly Giant Slough study. The furthest northerly of the channel leading from Jolly Giant Slough that appreciable dye was found was about 0.25 miles. There was little indication that appreciable dye concentrations crossed the flats separating Jolly Giant Slough channel and the Mad River Slough channel during the ebb tide.

d. Under the limited conditions of the studies, the results appear to show that there was no significant amount of dye measured at Mad River Slough when dye was applied at Jolly Giant Slough and at Gannon Slough. While there may be an issue on the timing of dye application at Gannon Slough, the results still show that no significant amount of dye was measured at Mad River Slough.

Any interpretation of the results of these studies would apply only to the low flow conditions under which these studies were conducted. The impacts to Mad River Slough under other environmental conditions are unknown. More studies during other conditions would need to be conducted to determine these potential impacts.

B. SUMMARY OF CONTAMINANT TRANSPORT STUDIES

A variety of studies on contaminant movement in the North Bay watershed have shown that fecal coliform concentrations greatly exceeding the water quality criteria for shellfish growing areas emanate from the watershed during rainfall events. However, a study that successfully quantifies the total contributions of each drainage or source type has not yet been performed. Comparison of the fecal coliform concentrations found in the Indianola study from “downstream” sites with the concentrations found among the various tributaries monitored in the HBSTAC study do not show that the water quality in the Indianola area is far more degraded than that found in other areas.

Past dye studies have shown that discharges from near the location of the Arcata WWTP can reach as far as the Sand Island growing area on a typical ebb tide, and that wastewater will be considerably more than 1,000 fold diluted by the time it reaches the growing areas. For discharges affecting the Eureka Slough during an ebb tide, a very small flood tide is sufficient to bring contaminants to the east bay growing area. Due to the larger volume of water involved, the dilution is likely to be at least as great as that determined for the Arcata Channel.

The sewage upset protocol, provided in the *Management Plan*, will continue to be used to determine growing area closures based on the established thresholds for each tributary. These thresholds may be modified as additional data is obtained on the level of fecal coliform loading that could be attributed to each stream. Follow-up evaluation of the upset event, and the actions taken, will factor in the conclusions reached from the previous dye studies. For example, Table 8 indicates several scenarios, based on different spill rates and different sewage concentrations, which could be used in conjunction with the dye concentration maps generated during the study, to determine where the “less than 14 MNP” boundary line is located. This evaluation could then be used to reduce or eliminated the areas initially closed using the upset protocol.

IX. SAMPLE DATA AND ANALYSIS

A. WATER QUALITY MONITORING

Prior to May 1998, samples were collected whenever possible during periods of adverse pollution conditions, such as immediately following a rainstorm that does not exceed the closure threshold, or on the first day of reopening following a rainfall closure. Compliance with this Adverse Pollution Condition (APC) sampling strategy was difficult because of the large number of days that the growing areas were closed due to rainfall and the need to collect samples on the days of reopening. Thus, CDHS, in cooperation with the shellfish growers, changed the sampling strategy to SRS after May 1998.

The water quality criteria under SRS allows for some variability in the data set, but only due to random variability inherent in the MPN method. If higher concentrations of bacteria are caused by predictable events such as rainfall runoff, the area must be managed to prevent harvest during these events. The NSSP requires that the growing area be closed to harvest during times when water quality is impacted by pollution events that are capable of carrying pathogens into the growing water.

The NSSP specifies the following water quality standards for a *Conditionally Approved* growing area with water samples collected under the Systematic Random Sampling (SRS) strategy:

1. The geometric mean of the sample fecal coliform (FC) MPN values cannot exceed 14 MPN/100 mL; and

2. The 90th percentile of the data set consisting of the past three years of data cannot exceed a value of 43 MPN/100 mL for FC .

Under the SRS schedule for Humboldt Bay, samples are collected on the first Tuesday of each month during open status. If a given growing area is closed on the scheduled date, then samples are to be collected at the earliest possible time after reopening for the given area. Sampling requirements and the schedule for water quality monitoring are contained in the sampling plans for water quality monitoring by Coast Seafoods Company, North Bay Shellfish Company (which includes the growing areas leased to Emerald Coast Seafoods, and Aqua Rodeo Farms), and Humboldt Bay Oyster Company. Table 9 presents the results of the last 30 samples from the 17 primary sample sites as of February 2006. The levels of fecal coliform, as represented by the geometric mean and the 90th percentile, are well below the limits established in the NSSP for *Conditionally Approved* areas for all 17 sites.

Currently, 17 water quality monitoring stations are monitored under SRS (Figure 2). The majority of the sampling stations are sited along the edge of tidal channels adjacent to the mud flats, which contain the shellfish growing beds. With the exception of four stations, these water quality stations are expected to experience more direct adverse water quality impacts than that in the middle of the shellfish beds away from the channels. The exceptions include NBSC's Parcel #1 lease (Stations #31 and #33), which is relatively isolated from major tidal channels, and CSC's Mad River Station #22 and East Bay Station #51.

Coast Seafoods currently samples at nine sample sites (#21, #22, #24, #28, #34, #45, #5, #52, and #53). Station #28 was added in June 2004 to obtain additional water quality information in Growing Area B. Sampling at Water Quality Station #31, covering Emerald Coast Seafoods and Aqua Rodeo Farms growing areas, is performed by North Bay Shellfish, in addition to their three other sites (#33, #43, and #2Ta). Humboldt Bay Oyster Company was originally certified in June 2003, and has four water quality stations associated with its operations (#20, #25, #26, and #27). Table 10 summarizes the water quality of Humboldt Bay shellfish growing areas as reported in past annual and triennial sanitary survey update reports since the last 12-Year Sanitary Survey Report was issued.

B. WATER QUALITY DATA ANALYSIS

1. Evaluation of Rainfall Closures Rules

Until 1974, the growing areas were managed by implementing closures in response to reported releases of inadequately treated sewage from WWTPs. Then, in 1974, rainfall closure rules were implemented. At that time, the rainfall closure rules were established knowing that the existing wastewater treatment plants were inadequate to handle the wastewater volume during moderate rainfall events (i.e., 0.5 or 1.0 inch in 24 hours), and inadequately disinfected effluent was frequently released to the bay from several of the WWTPs during these events. Thus, the rainfall closure rules were originally

designed to protect against these predictable point-source events. The rainfall closure rules were not specifically designed to address pollution from non-point sources during rainfall events.

In 1986, new wastewater treatment facilities for the Cities of Eureka and Arcata were placed online to replace the malfunctioning plants, effectively ending the historical problems of rainfall–related releases to the bay from the WWTPs. In light of the WWTP upgrades, sufficient data reevaluate the thresholds necessary to protect water quality in shellfish beds had not been collected until relatively recently. Beginning in 1999, such data targeted during these rainfall events were collected as part of the HBSTAC study. Subsequently, from fall 2000 through spring 2004, CSC has contributed a large number of samples toward this effort. These samples were generally collected during times when one or more of CSC's growing areas were closed to harvesting. In many cases, samples were collected during consecutive days of closure. As a result of this effort, CDHS has been able to perform an analysis of the existing rainfall closure rules, and has been able to justify raising the rainfall thresholds for many of CSC's growing areas. The methods and results of this analysis are detailed in Appendix B. The most current rainfall closure criteria for Humboldt Bay growing areas are shown in Table 6.

2. Evaluation of Water Quality Trends

Water quality data has been collected in the North Bay since the early 1980s. To investigate general trends in water quality, a running geometric mean of fecal coliform was plotted for each primary station (Appendix B). The geometric mean is based on the most recent 30 samples for each station. These data represent times that the respective growing areas were in the open status for each primary station.

Fecal coliform geometric means have remained stable or tended to decline slightly during the past 13 to 15 years for stations #24, #52, and #53. A shorter duration of monthly data exists for stations #22 (from 1997) and for station #51 (from 1993), and significant data gaps exist for stations #21 (1994 to1997) and #34 (1993 to 1998). Stations #31 and #33 show more pronounced downward trends, especially from the years 2000 to 2004. Finally, Stations #T2a and #45 show relatively stable trends over the past 8 to 10 years, but also appear to be demonstrating a shorter-term increase from late 2001 to early 2004 compared to the other stations.

One caveat in the interpretation of these plots is that these resulting trends do not take into account year-to-year variation in seasonal rainfall totals and in rainfall intensity. Wetter years can be expected to result in a greater proportion of water samples collected when the respective growing areas are under the influence of non-point source rainfall runoff affecting the bay. Additionally, in reviewing these trends, it is important to note that the interpretation of apparent trends may be complicated due to a change in sampling strategy. Prior to May 1998, the APC strategy was used. From May 1998 through November 2000, the data sets consisted of samples collected under both APC and SRS strategies; while from December 2000, all the samples were collected

under SRS. APC requires that samples be collected under “adverse pollution” conditions such as immediately before or after a rainfall closure. The apparent lower proportion of samples exceeding the 43 MPN criterion during the period after May 1998 compared to samples collected prior to May 1998 is likely to be somewhat attributable to the change in sampling strategy.

Because the data sets beginning in December 2000 contain only data collected under SRS, the trends should be truly representative of open period water quality from this date. Considering only the period from 2001 through 2005, the majority of the stations appear to exhibit stable or decreasing trends (Stations #21, #21, 31, #33, #34, #51, 352, and #53). As stated above, two stations (#45 and #T2a) appear to show a recent upward trend, although the fecal coliform concentrations at all of the stations are well below the NSSP criterion of 14 MPN/100 mL.

3. CDHS Sanitary Surveys

The last complete Sanitary Survey report for Humboldt Bay was issued by CDHS in 1993. Since then, CDHS has issued annual and triennial sanitary survey update

reports. The 1999 Annual Sanitary Survey Update report was the first update report after the conversion from APS to SRS. These reports contain compilations and evaluations of water quality data for each of the growing areas. Based on the water quality data evaluations, any necessary changes in closure rules or other management strategies are implemented to keep the growing areas in compliance with the NSSP water quality standards.

X. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. This Sanitary Survey has determined from an analysis of water quality data that the growing areas continue to meet the water quality standards for the *Conditionally Approved* classification.

2. Evaluations of water quality monitoring data confirm that the current rainfall closure rules have been successful in keeping the certified shellfish growing areas within NSSP standards for water quality during the times the bay is open for shellfish harvesting.

3. The primary pollution sources continue to be from non-point sources during rainfall events, and sewage collection system failures resulting in untreated sewage entering the bay.

4. The WWTP effluent discharges have consistently meet their WDR limits for fecal coliform, which are set at the NSSP limit for an *Approved* growing area. The Eureka WWTP continues to meet their requirement to discharge only during outgoing tides.

Their discharge timing requirements, along with their fecal coliform requirements, eliminate the need to establish a closure zone around the outfall. It should be noted that there are no growing areas in the vicinity of this outfall. The closure zone around the discharge stream from the Arcata WWTP remains as is from the previous Sanitary Survey Report. The occurrence of sewage collection system upsets have been reduced, mainly through improvements to the collection systems, and a greater awareness to repair and eliminate problems in the systems as soon as possible. The notification procedure between the effected agencies and the growers has been implemented, and is working extremely well in ensuring the appropriate actions are taken when an upset occurs.

5. Reevaluation of the closure zones around the two marinas concluded that the existing closure zones were satisfactory. A conservative approach was taken in assessing the potential impact on water quality from sewage discharges from vessels in the marinas. Existing marina, state, and federal regulations prohibit the discharge of sewage from boats located within the marinas; determination of the closure zone assumed the possibility that illegal discharging could occur.

B. RECOMMENDATIONS

1. Continue with the *Conditionally Approved* classification of the certified shellfish growing areas in Humboldt Bay, California.

2. Continue with the systematic random sampling design for compliance monitoring of growing area water quality.

3. Continue with the current rainfall closure rules as established in the current *Management Plan for Commercial Shellfishing in Humboldt Bay, California*.

4. Continue with the current procedures for managing the shellfish growing areas in response to accidental wastewater water discharges, as outlined in the current *Management Plan for Commercial Shellfishing in Humboldt Bay, California*.

5. adopt the revised sewage upset thresholds for the City of Arcata waterways (Table 3).

6. Continue to monitor City of Arcata influent station E to determine nature of variability relative to the sewage upset threshold for this drainage area.

7. Continue to evaluate rainfall related water quality impacts to the growing areas during times of rainfall closure by collecting water quality samples at primary and secondary sampling stations.

8. Continue to evaluate water quality data on an annual basis to determine if any necessary changes in closure rules are to be implemented to keep the growing areas in compliance with the NSSP water quality standards.

XI. REFERENCES

Barnhart, Roger A.; Milton J. Boyd; and John E. Pequegnat. 1992. The Ecology of Humboldt Bay, California: An Estuarine Profile. U.S. Fish and Wildlife Service, Biological Report 1. 121 pp.

Costa, Steven L. 1982. The physical oceanography of Humboldt Bay. In: Proc. of the Humboldt Bay Symposium, March 26, 1982. The Humboldt Bay Symposium Comm. and The Center for Community Devel., Humboldt State U., Arcata, CA. pp. 2-31.

NOAA. 1992. Local climatological data, Annual summary with comparative data, Eureka, California. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC.

Pequegnat, John E. 1988. Humboldt Bay: Pristine or polluted? In: Proc. of the Symposium, Managing Inflows to California's Bays and Estuaries, Monterey, CA, Nov. 13-15, 1986. The Bay Inst., Sausalito, CA. pp. 112-115.

Shapiro and Associates, Inc. 1980. Humboldt Bay wetlands review and baylands analysis, final report. U.S. Army Corps of Engineers, San Francisco. 668 pp. + appendices.

U.S. Army Corps of Engineers. 1976. Environmental statement--navigation improvements, Humboldt Harbor and Bay, California, August 1976. U.S. Army Corps of Engineers, San Francisco, CA. 95 pp.

U.S Department of Commerce. 1963. Local climatological data -- annual summary, Eureka, California. National Climatic Center, Asheville, NC.

TABLES

Table 1. Original upset thresholds for the City of Arcata waterways.

Tributary	Threshold Volume (Gallons)	Sampling Sites
Tide Gates (Arcata bottoms)	27	All primary sites plus T2
Janes Creek	211	All primary sites plus 41
McDaniel Slough	211	All primary sites plus 41
Jolly Giant Creek	241	All primary sites plus 41
Butcher Slough	241	All primary sites plus 41
Campbell Creek	406	All primary sites plus 41 and 44
Fickle Hill Creek	406	All primary sites plus 41 and 44
Grotzman Creek	406	All primary sites plus 41 and 44
Beith Creek	406	All primary sites plus 41 and 44
Gannon Slough	406	All primary sites plus 41 and 44
Jacoby Creek	406	All primary sites plus 41 and 44

Table 2. Original upset thresholds for the City of Eureka and Humboldt Community Services District waterways.

Tributary	Threshold Volume (Gallons)	Sampling Sites
Storm Drains	21	All primary sites plus T11
Ryan Creek	4	All primary sites plus T11
Ryan Slough	4	All primary sites plus T11
Freshwater Creek	4	All primary sites plus T11
Freshwater Slough	4	All primary sites plus T11
Eureka Slough	4	All primary sites plus T11
Fay Slough	4	All primary sites plus T11
Martin Slough	1,957	All primary sites
Swain Slough	1,957	All primary sites
Elk River	1,957	All primary sites

Table 3. Revised upset thresholds for the City of Arcata waterways.

Tributary	Threshold Volume (Gallons)	Sampling Sites
Tide Gates (Arcata bottoms)	30	All primary sites plus T2
Janes Creek	200	All primary sites plus 41
McDaniel Slough	500	All primary sites plus 41
Jolly Giant Creek	600	All primary sites plus 41
Butcher Slough	600	All primary sites plus 41
Campbell Creek	1,000	All primary sites plus 41 and 44
Fickle Hill Creek	1,000	All primary sites plus 41 and 44
Grotzman Creek	1,000	All primary sites plus 41 and 44
Beith Creek	1,000	All primary sites plus 41 and 44
Gannon Slough	1,000	All primary sites plus 41 and 44
Jacoby Creek	1,000	All primary sites plus 41 and 44

Table 4. Humboldt Bay tidal range.

LOCATION	TIDAL RANGE (feet)
Entrance	3.3
North Spit	3.74
City of Eureka	3.94
Eureka Slough	4.01
North Shore of Arcata Bay	3.8

Table 5. History of rainfall closure rules for *Conditionally Approved* areas of Humboldt Bay.

Note: Previous to 1974 management of shellfish harvesting consisted exclusively of revising the extent of the approved area and to temporary closures due to reported sewage spills.

Date	Rainfall Rules		Seasonal closures
	24-hr rainfall threshold	Closure duration	
March 2004	0.5, 0.7, 1.0, 1.2	3-9 days	None
2003-Mar 2004	0.5, 0.7, 1.0	2-9 days	None
2002-2003	0.5, 1.0	2-8 days	None
Dec 1998-2002	0.5, 1.0	2-8 days	January, January-March
Dec 1995-Dec 1998	0.5, 1.0	2-8 days	January, January-February
Mar 1995	0.5, 1.0	2-8 days	January, January- February
Dec 1993	0.4, 0.5, 1.0	2-7 days	January, January- February
1987- Nov 1990	0.5, 1.0	2-7 days	January, January-February
1978-1987	0.5	5-days	Entire Bay, November -March
1974-1978	0.5	5-days	None
1974 (see Report to the 1988 Legislature…)	None	N/A	None

Table 6. Rainfall closure criteria for Humboldt Bay growing areas.

Growing Area	Grower Description of Area	Start Closure	24-Hour Cumulative Rainfall Threshold >	Closure Length = End of Storm plus	7-Day Cumulative Rainfall	
					If > 3.0 inches, add to closure:	If > 5.0 inches, add to closure:
A	Coast Seafood Company South Mad River growing area, Bird Island Growing area, and the east section o East Bay growing area	Six (6) hours after the 24-hour cumulative rainfall of 1.2" is exceeded	1.2 Inch	96 hrs (4 days)	24 hrs	48 hrs
B	Coast Seafood Company north Mad River growing area, western portion of East Bay growing area, Gunther Island growing area, south Sand Island Growing area, and the Arcata Channel growing area	Six (6) hours after the 24-hour cumulative rainfall of 1.0" is exceeded	1.0 Inch	96 hrs (4 days)	24 hrs	48 hrs
C	Parcel 1 Northbay Shellfish, Aqua Rodeo Farms, and Emerald Coast Seafoods; Humboldt Bay Oyster Company, north growing area	Six (6) hours after the 24- hour cumulative rainfall of 0.5" is exceeded	0.5 Inch 0.75 Inch 1.0 Inch	72 hrs (3 days) 96 hrs (4 days) 120 hrs (5 days)	24 hrs 24 hrs 24 hrs	48 hrs 48 hrs 48 hrs
D	North Bay Shellfish, wet storage area; North Bay Shellfish, Parcel 2	The hour that the 24-hour cumulative rainfall of 0.5" is exceeded	0.5 Inch 0.75 Inch 1.0 Inch	96 hrs (4 days) 120 hrs (5 days) 144 hrs (6 days)	24 hrs 24 hrs 24 hrs	48 hrs 48 hrs 48 hrs
E	Humboldt Bay Oyster Company, south growing area; Coast Seafoods Company, north Sand Island growing area	Six hours after the 24-hour cumulative rainfall of 0.7" is exceeded	0.7 Inch	120 hrs (5 days)	24 hrs	48 hrs
F	Humboldt Bay Oyster Company, wet storage area	The hour that the 24-hour cumulative rainfall of 0.5" is exceeded	0.5 Inch 0.75 Inch 1.0 Inch	120 hrs (5 days) 144 hrs (6 days) 168 hrs (7 days)	24 hrs 24 hrs 24 hrs	48 hrs 48 hrs 48 hrs

Table 7. Projected fecal coliform concentrations at key locations.

Assumptions: A discharge rate of 1 mgd (1.547 cfs) occurs from a lift station near Eureka Slough. The fecal coliform level is 5 x 10^6 MPN/100 mL.

Location of Interest	Dye Conc. (ppb)	Dye Feed Rate (ft^3/sec)	Conc. Raw Dye (ppb)	Flow at Location (cfs)	Assume 1 mgd Discharge (cfs)	Assume Raw Sewage 5 x 10^6 FC (MPN/100 mL)	Estimate FC Conc. (MPN/100 mL)
Mad River Slough	0.37	0.0000961	2.40E+04	6.23E+04	1.547	5.00E+06	124
Arcata Channel	0.57	0.0000961	2.40E+04	4.05E+04	1.547	5.00E+06	191
Indian Channel	1.26	0.0000961	2.40E+04	1.83E+04	1.547	5.00E+06	423
South of Woodley Is.	4.0	0.0000961	2.40E+04	5.77E+04	1.547	5.00E+06	1341
South of Daby Is.	4.8	0.0000961	2.40E+04	4.81E+04	1.547	5.00E+06	1610

Table 8. Theoretical calculations for sewage upset impacts.

Spill Volume (gallons)	Spill Duration (hours)	Spill Rate (gal/hr)	Spill Rate (cfs)	Dye Feed Rate (cfs)	Conc. Raw Dye (ppb)	Raw Sewage FC (MPN/100 mL)	Fecal Coliform (MPN/100 mL)	Dye Conc (ppb)
2,000	1	2,000	0.074	0.0000961	2.40E+08	5.00E+06	14	0.88
2,000	2	1,000	0.037	0.0000961	2.40E+08	5.00E+06	14	1.75
2,000	3	667	0.025	0.0000961	2.40E+08	5.00E+06	14	2.63
2,000	4	500	0.018	0.0000961	2.40E+08	5.00E+06	14	3.51
10,000	1	10,000	0.368	0.0000961	2.40E+08	5.00E+06	14	0.18
10,000	2	5,000	0.184	0.0000961	2.40E+08	5.00E+06	14	0.35
10,000	3	3,333	0.123	0.0000961	2.40E+08	5.00E+06	14	0.53
10,000	4	2,500	0.092	0.0000961	2.40E+08	5.00E+06	14	0.70
10,000	1	10,000	0.368	0.0000961	2.40E+08	1.00E+07	14	0.09
10,000	2	5,000	0.184	0.0000961	2.40E+08	1.00E+07	14	0.18
10,000	3	3,333	0.123	0.0000961	2.40E+08	1.00E+07	14	0.26
10,000	4	2,500	0.092	0.0000961	2.40E+08	1.00E+07	14	0.35
10,000	1	10,000	0.368	0.0000961	2.40E+08	1.00E+08	14	0.01
10,000	2	5,000	0.184	0.0000961	2.40E+08	1.00E+08	14	0.02
10,000	3	3,333	0.123	0.0000961	2.40E+08	1.00E+08	14	0.03
10,000	4	2,500	0.092	0.0000961	2.40E+08	1.00E+08	14	0.04

Table 9. summary of fecal coliform compliance monitoring data for preceding 30 samples from February 2006, for certified shellfish growing areas in Humboldt Bay.

Company	Growing Area	Sample Station	Number of Samples	Geometric Mean[1]	90th Percentile[2]
Coast Seafoods Company	A	22	30	2.8	7.4
	A	24	30	3.7	11.6
	A	51	30	2.5	5.2
	B	21	30	2.9	6.1
	B	28	30	3.1	7.9
	B	34	30	4.4	20.3
	B	52	30	3.6	10.3
	B	53	30	3.2	8.4
	E	45	30	4.1	18.8
Aqua Rodeo Farms; Emerald Coast Seafoods	C	31	30	3.4	10.6
North Bay Shellfish Company	C	33	30	3.9	15.6
North Bay Shellfish Company	D	43	30	4.7	18.2
North Bay Shellfish Company	D	T2a	30	5.4	16.4
Humboldt Bay Oyster Company	C	20	30	3.5	8.3
Humboldt Bay Oyster Company	E	25	30	3.3	8.0
Humboldt Bay Oyster Company	E	26	30	2.7	6.7
Humboldt Bay Oyster Company	F	27	30	5.4	17.7

Notes:

1. The geometric mean is the antilog of the mean of the logs of the sample fecal coliform (FC) MPN values. This value cannot exceed 14/100 ml for shellfish growing waters within the *Approved* classification.

2. The 90th percentile is the antilog of the mean of the logs of the FC values summed with the product of the FC standard deviation multiplied by 1.28. This value cannot exceed 43 for shellfish growing waters within the *Approved* or *Conditionally Approved* classification.

Table 10. Summary of water quality results from previous sanitary survey reports.

	1993		1994/1995		1996		1997		1998		1999	
Station	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean
C1/24			20	4.7	40	5.9	45	6.4	42	6.3	57	6.3
C1 and C1A	23	3.6										
C3/21									9	4.8	38	3.8
C3 and C3B	22	3.2										
C3B/30			17	3.8	37	3.7	46	3.6	35	3.5	35	3.5
C3C/22									3	8.3	32	4.2
C4A/33	18	8.0	24	9.1	41	7.7	44	6.1	38	6.8	38	6.8
C4 and C4A	25	7.6										
C4B/31									7	4.8	7	4.8
C6/45			20	3.9	35	5.1	36	5.3	31	5.1	38	7.2
C6 and C6A	22	4.5										
R7	13	5.5										
R7A	13	14.2	21	12.8								
R7 and R7A	26	8.9										
C8/53	21	3.9	23	4.4	41	5.5	43	5.4	38	5.7	38	5.7
C9/52	20	5.9	21	4.5	39	4.4	43	4.7	39	4.5	39	4.5
C10A/51			16	3.8	34	4.3	43	4.3	38	4.0	38	4.0
T2	18	3.6	18	6.2								
T2A	16	3.4	19	7.1	28	8.4	24	5.9	31	5.6	31	5.6

	2000		2001		2002		2002/2003		2003/2004		2004/2005	
Station	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean	# of Samples	Geo Mean
C1/24	30	5.1	33	4.3	33	3.6	34	3.0	36	3.4	35	3.3
C3/21	30	3.8	36	3.1	36	3.3	36	2.7	33	2.4	32	2.4
C3C/22	30	3.8	36	3.1	36	2.9	36	2.5	36	2.7	35	2.7
C4A/33	30	7.2	36	4.9	36	3.6	36	2.7	36	3.1	36	3.2
C5/34	30	4.7	30	4.8	30	4.0	34	3.2	33	3.3	32	3.8
C4B/31	30	5.8	36	4.4	36	3.0	36	2.4	36	2.7	36	3.1
C6/45	30	4.7	30	4.9	30	4.5	30	3.0	31	4.0	30	3.5
C8/53	30	4.8	32	4.2	33	3.8	34	3.3	35	2.8	35	2.8
C9/52	30	3.7	33	3.7	33	3.3	34	3.3	34	3.5	35	3.4
C10A/51	30	2.9	31	2.5	33	2.6	34	2.6	36	2.6	35	2.6
T2A	30	5.3	35	4.2	35	3.4	35	3.7	35	5.4	36	5.5
43					35	3.7	35	3.0	34	3.4	35	3.6
20									30	4.3	30	3.3
25									36	4.1	30	3.4
26									35	3.8	30	3.2
27									30	6.4	30	6.0
28											30	5.4

FIGURES

Figure 1. Location of Humboldt Bay, California.

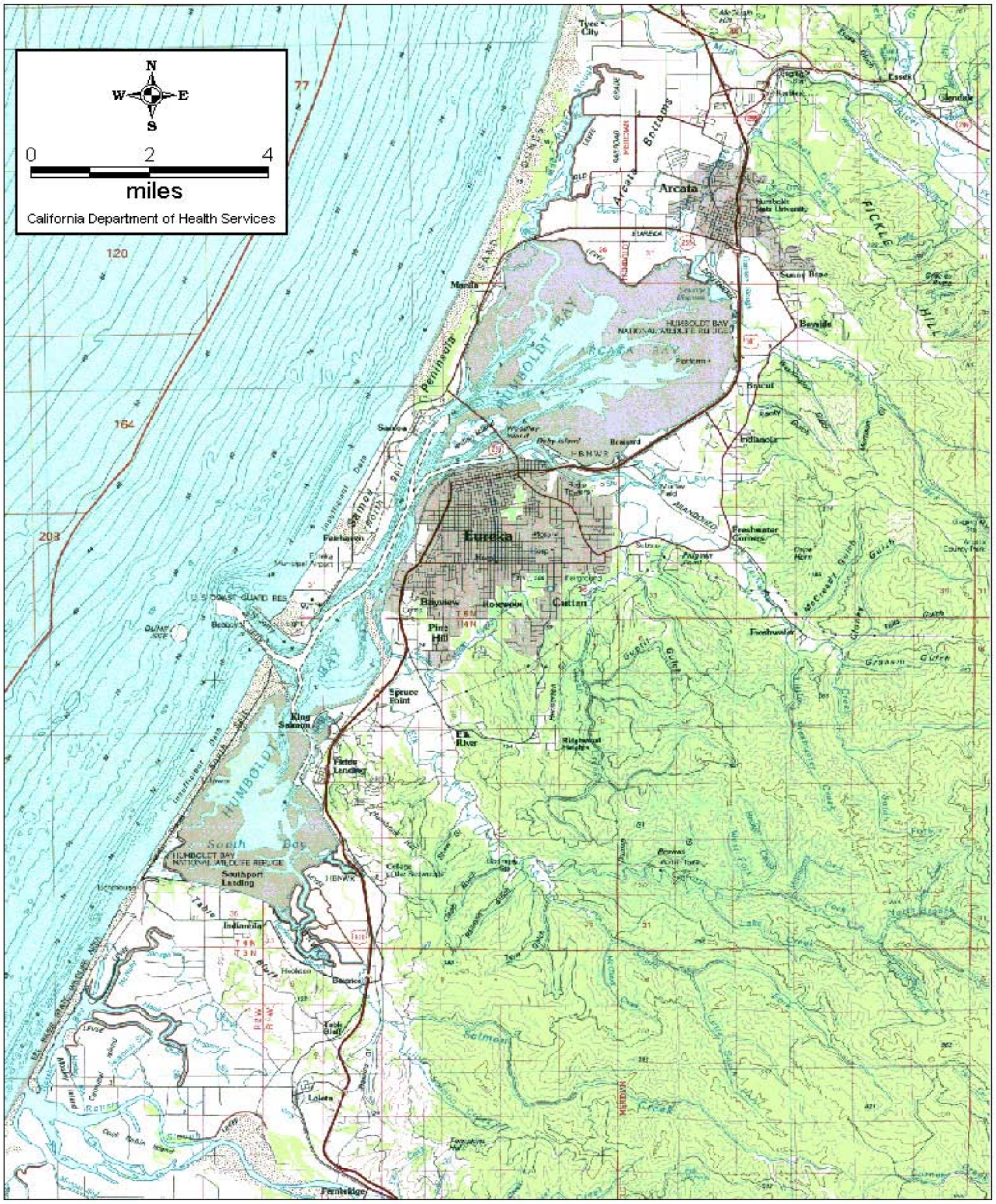


Figure 2. Humboldt Bay Shellfish growing areas, classifications, primary sampling stations, and Prohibited safety zones.

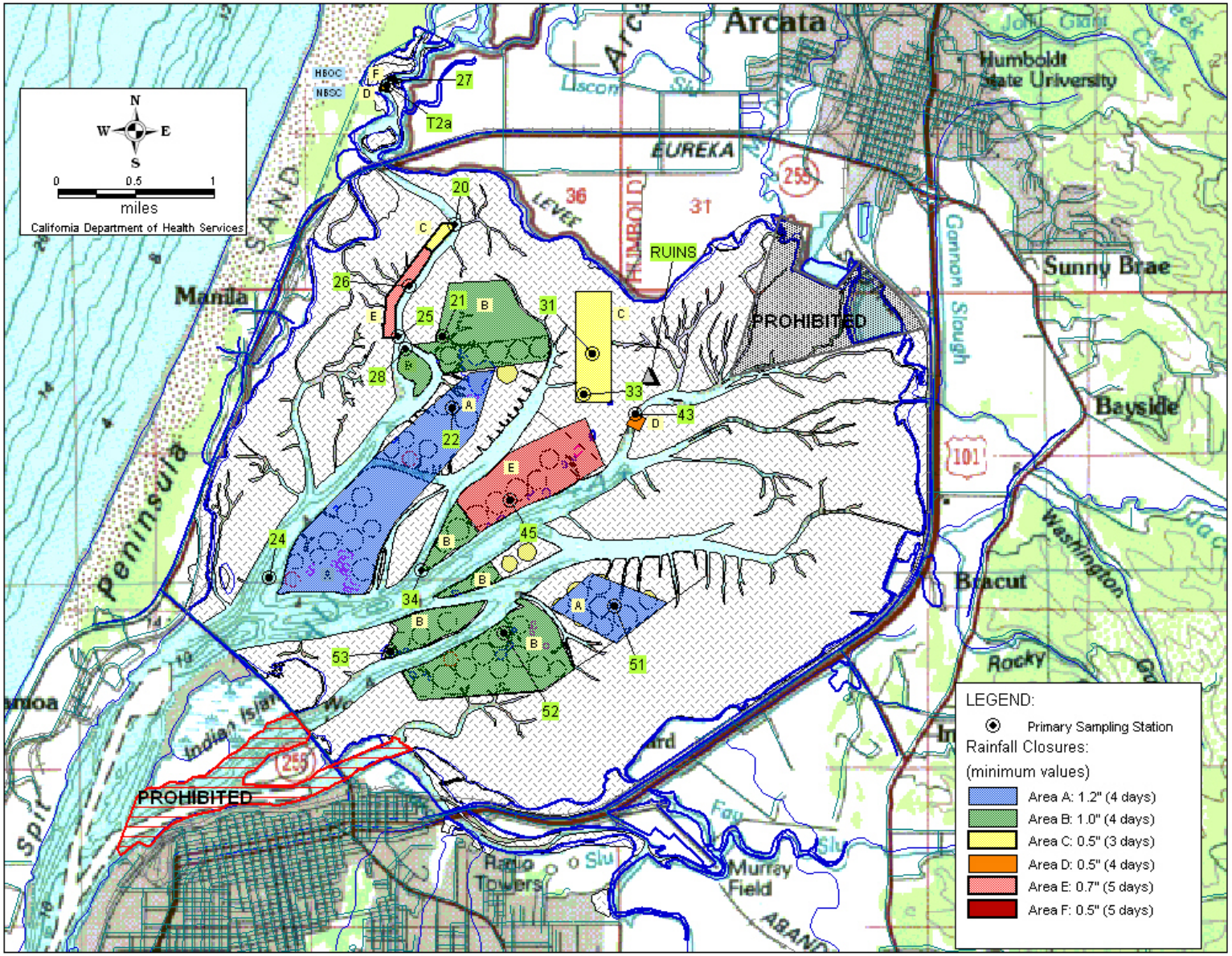


Figure 3. Eureka Monthly Total Rainfall (Water Years 1987 – 2003).

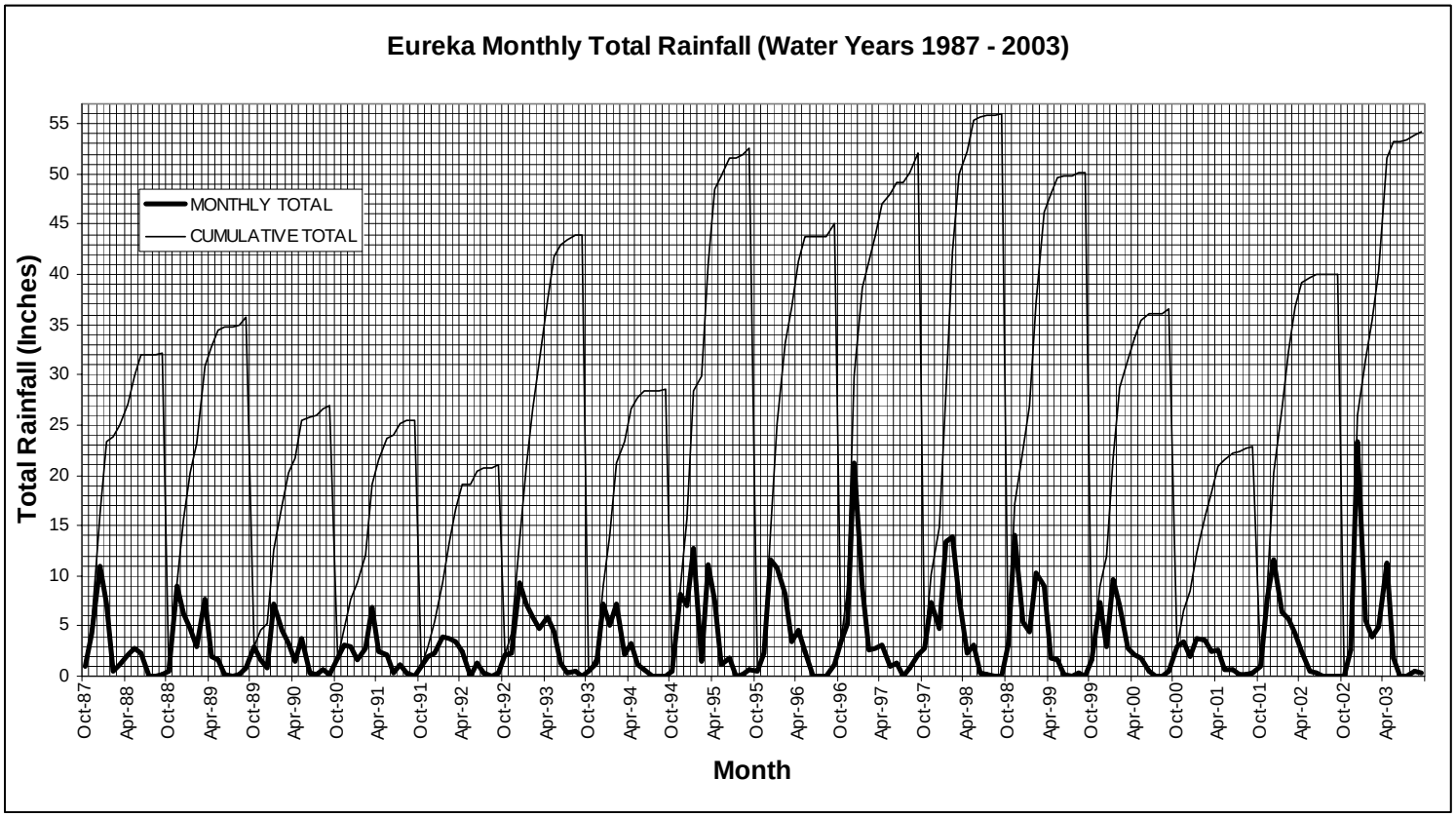


Figure 4a. Probability of a 24-Hour Total Rainfall of at least 0.50 Inch by Month.

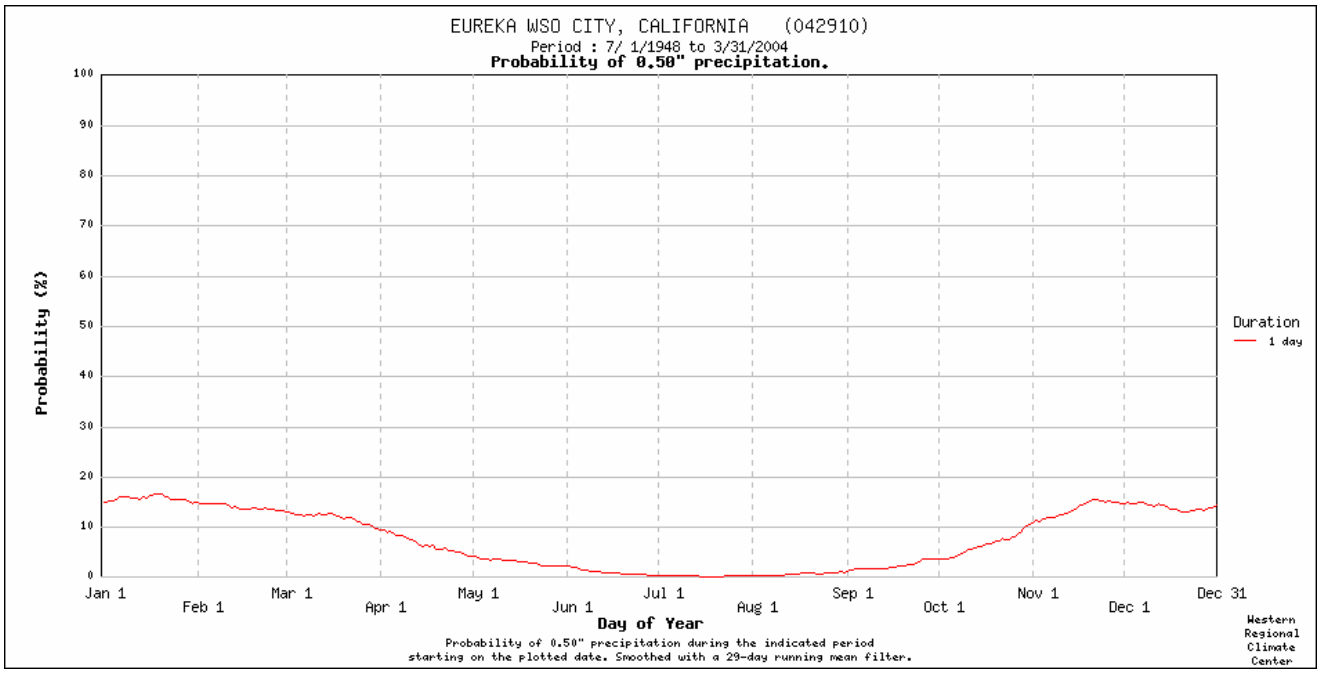


Figure 4b. Probability of a 24-Hour Total Rainfall of at least 0.75 Inch by Month.

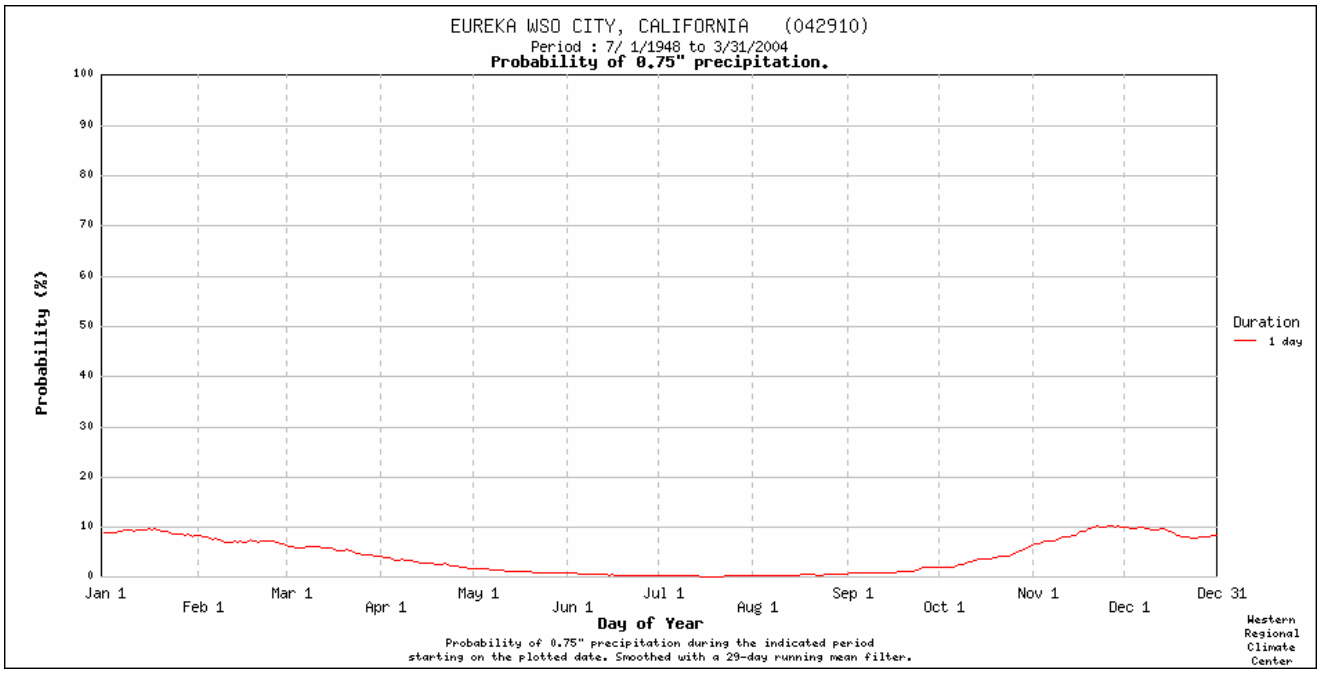


Figure 4c. Probability of a 24-Hour Total Rainfall of at least 1.00 Inch by Month.

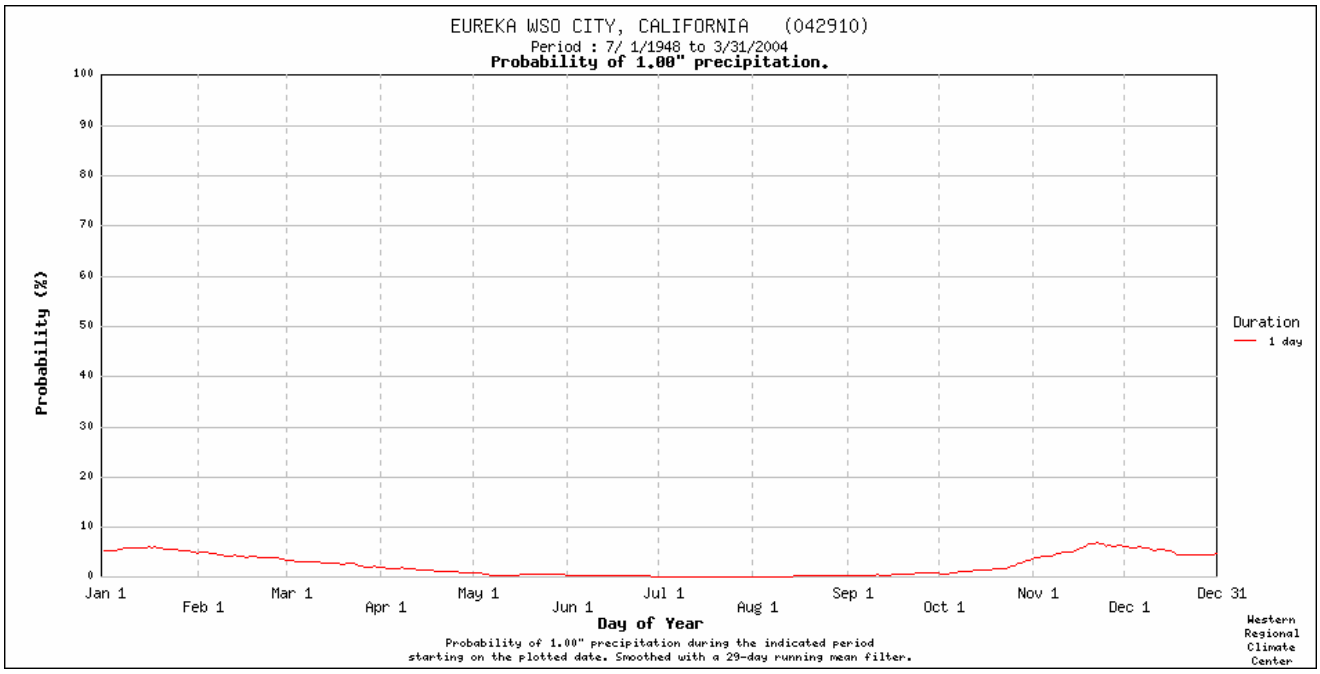


Figure 4d. Probability of a 24-Hour Total Rainfall of at least 1.50 Inches by Month.

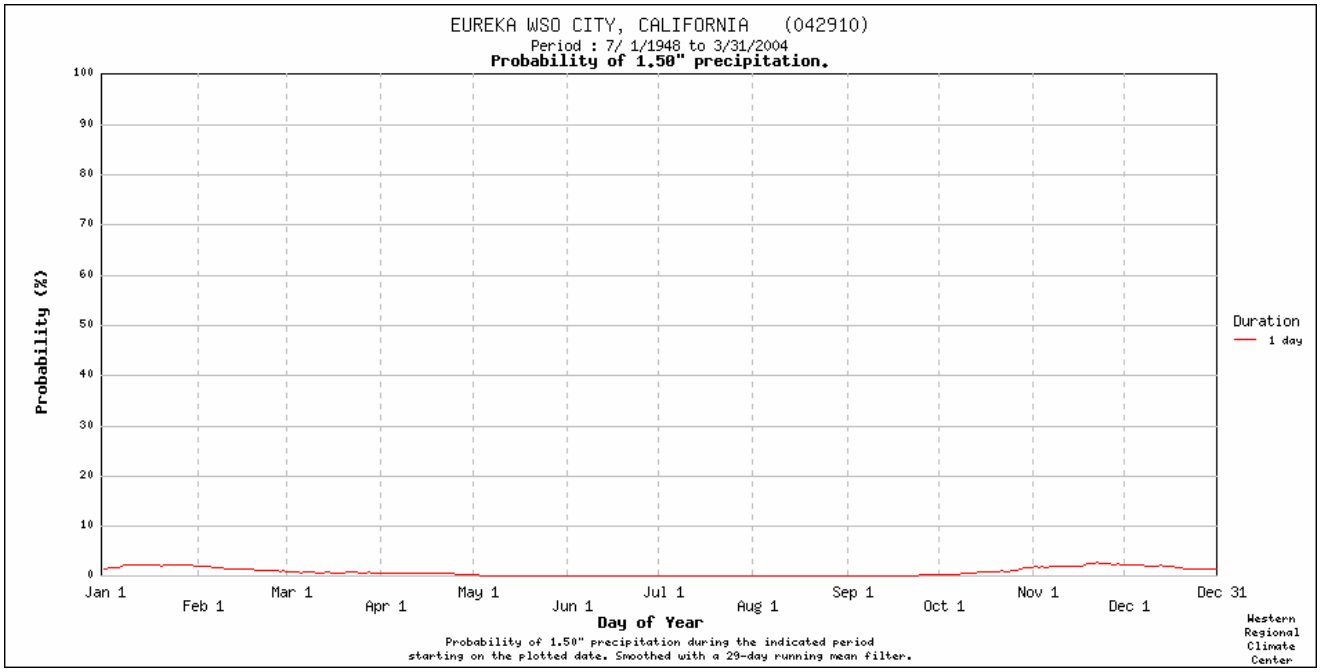


Figure 5a. Probability of a 7-Day Total Rainfall of at least 3.00 Inches by Month.

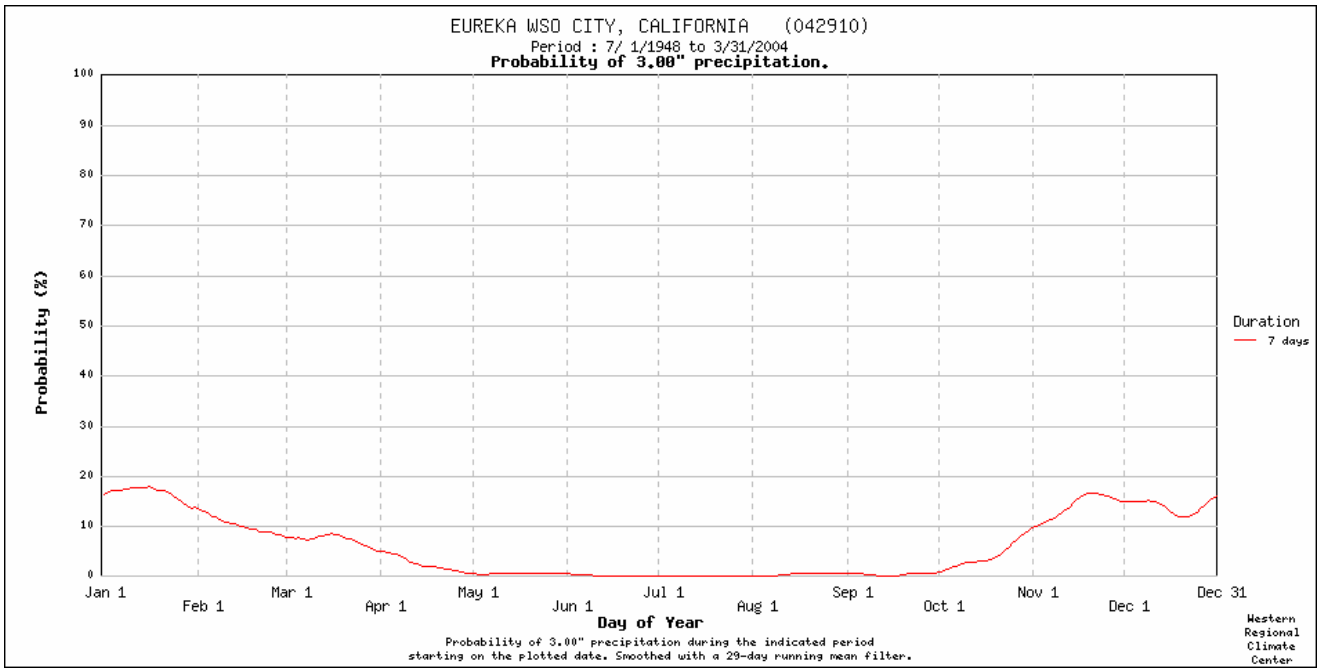
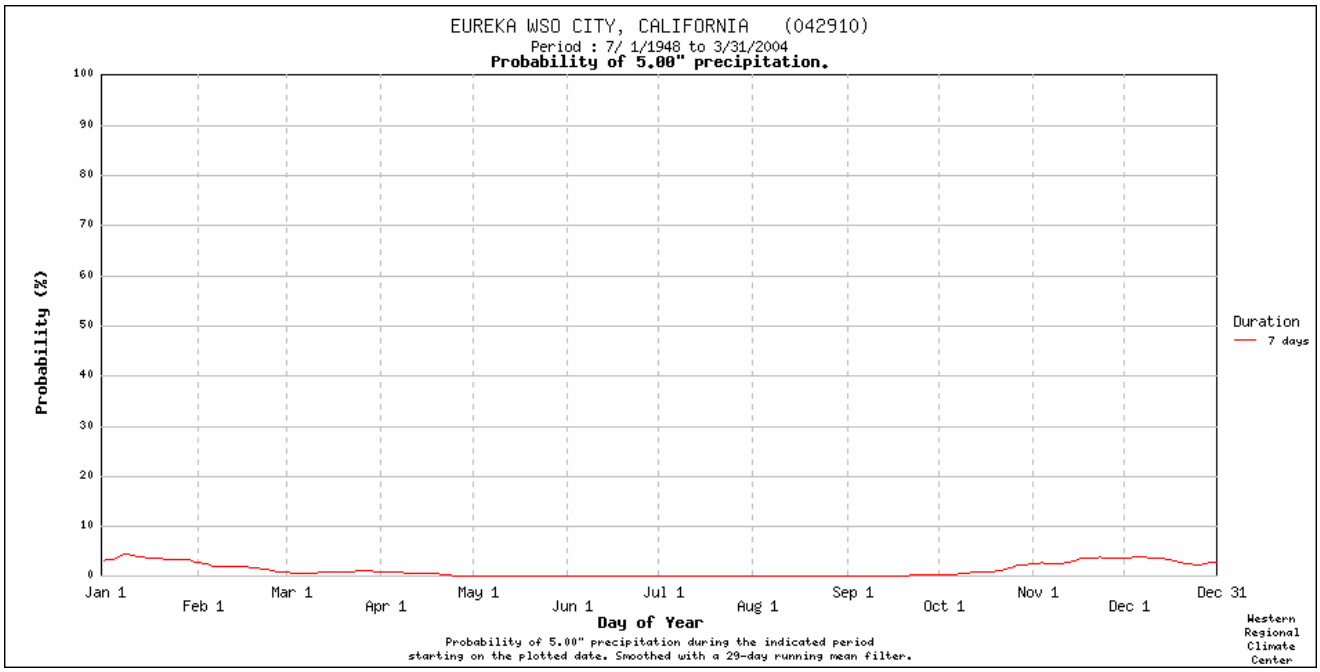


Figure 5b. Probability of a 7-Day Total Rainfall of at least 5.00 Inches by Month.



APPENDICES

Appendix A. Summary of upset protocol thresholds development

Accidental sewage releases from wastewater collection systems operated by the City of Arcata, the City of Eureka, or by HCSD occurs periodically and may adversely affect the water quality in shellfish growing areas. The potential for these sewage "upsets" to adversely impact shellfish growing waters is related to the estimated volume of the discharge, the location of the discharge with respect to the growing areas, and the timing of the discharge with respect to rainfall closures of the growing areas. Determination of the threshold volumes of sewage that would necessitate the closing of the shellfish growing areas was based on an initial fecal coliform concentration in raw sewage of 1×10^8 MPN/100 mL. The thresholds were then calculated for different drainages based on proximity to the North Bay growing areas (Tables 1-2).

To determine the actual FC concentration in the influent sewage, in 2003 the City of Arcata began taking influent samples at 6 locations within the Arcata sewage collection system (Table A-1). Evaluation of the first year of data indicated that the maximum FC concentration detected was 1×10^7 MPN. The threshold volumes were recalculated based on this estimate, resulting in a ten-fold increase in the threshold volumes for the Arcata tributaries. In July 2005, the Humboldt County Public Health Laboratory notified the City of Arcata and CDHS that the reported sewage sample results prior to June 1, 2005 were incorrect due to a dilution calculation error, which resulted in the reported results being 10% lower. In November 2005, CDHS issued a revised threshold table for Arcata, revising the threshold volumes back to their original levels.

At the end of 2005 CDHS worked with water quality engineers with the technical support unit of FDA to conduct more thorough analyses of the influent FC data. The following is a summary of these efforts.

Graphical Analysis of Microbiological Data

The data set contained a total of 145 samples collected over a span of 2 years. There were 24 samples from three locations (A, B, C) and 25 from three other locations (D, E, F; Table A-2). FDA engineers initially evaluated all the data as a single set, since it was samples of raw sewage taken from the sewerage system and assumed to have similar properties. In that analysis 130 samples were considered (Table A-1). The two highest samples, both at Point A, and three lower value samples were determined by CDHS analyses to be outliers and were excluded from the data set[1]. The analysis of the remaining data was done by plotting the points on logarithmic probability paper and then plotting the Velz line, which represents the variability of the MPN test results, to determine the graphical geometric mean for the samples. The Velz line was projected from the 98th percentile of the data plot intersection, and the graphical geometric mean

[1] Using SPSS software, box plot and stem and leaf plot on log FC data.

was taken as the 50th percentile. The results are shown in Figure A-1. The graphical geometric mean was 1.5 x 10^7 MPN FC/100 ml.

To determine the appropriateness of treating all the samples from the six locations as a single set for analysis, the data for each of the sample locations were plotted individually (Figures A-2 through A-7).

It should be noted that the following discussion of data analyses does not take into account the physical settings or descriptions of the sampling locations. From the results of Table A-3 and the probability plots that there are some similarities and differences among the locations. First of all the slope of the probability lines for Points A, F, B, and C are very similar and very close to the slope of the overall probability line in Figure A-1. Although the slopes are relatively steep compared to the Velz line, similar slopes indicate that the same situations may have contributed to the variability. Sewage strengths appeared to be similar at points A and F (graphical geometric means of 35 and 24 millions respectively) and similar for Points B and C (graphical geometric means of 6.6 and 7.8 millions respectively). The differences in geometric means between the pairs of sample points show a rather dramatic difference in sewage strength. The difference is demonstrated by overlaying either Point A or F onto Point B or C and noting that plots for B and C are well below those of A and F. The geometric means of A and F are a little greater than the 1.5 x 10^7 FC/100 ml overall. Note that samples previously identied as outliers were both collected at Point A. Those two points were not used to sway the placing of the line through the rest of the points in Figure 2.

The data for points D and E show a break in the data at about the 70 to 80 percentile (Figures A-5 and A-6). The graphical geometric means for Points D and E were determined by replotting the values at the break and larger, then applying the same method of overlaying the slope of the Velz line at the 98th percentile and finding the 50th percentile. These geometric means were 3.8 and 9.0 x 10^7 FC MPN/100 ml for stations for D and E respectively.

No similarities were visually noted (e.g., sampling dates) that would explain the breaks in the data at Points D and E. Three of the highest values that occurred at Point D related to the break were from 8/04 to 03/05. However the three highest values at Point E contributing to the break occurred from 1/04 to 8/04. The high values at these two stations did not occur simultaneously. However there could be a connection between Point A and Point D. The highest two values for Point A of 1.6 and 2.4 x 10^8 thought to be outliers were accompanied by the single highest and third from the high values found at point D, 2.4 and 5 x 10^7 FC MPN/100 ml. Thus accompaniment of high values at Point A at the same time as for Point D makes one reconsider whether the 1.6 to 2.4 x 10^8 FC/100 ml could have really occurred in raw sewage at point A. Additional observation at sampling site A is recommended.

Locations of Samples

From Table 1, it appears that there were really three different strengths of sewage:

Points A, F, and D = 3.8×10^7 FC/100 ml
Points B and C = 8.0×10^6 FC/100 ml
Point E = 9.0×10^7 FC/100 ml

Point E has a very definite break in the data at the 70th percentile, indicating added contributions of fecal coliforms about 30 % of the time. To illustrate the significance of this break in the data plot, the data from the 70th percentile and less (n=18) was replotted in Figure A-6 for comparison with the values at 70th percentile and greater (n=7). It was found that there was a great difference in expected sewage strength that occurred 70% of the time (1.8×10^6 FC/100 ml) compared to the 9.0×10^7 FC/100 ml for the remaining 30%. The conditions at sampling appear to be very different for about 30% of samples. If samples for site E were collected from a small pipe originating from a few apartments then collection times and conditions could be a factor; for example, infiltration at early morning samples before activity had commenced in the apartments could show lower counts, whereas periods of less infiltration at other times of the day could cause the higher counts. This could be a factor for a relatively small flow from a rather small apartment complex.

These analyses indicate that there is site-specific variability in the data set and that it would be inappropriate to treat the entire data set as deriving from the same population.

Statistical Analysis of Microbiological Data

Independent of the graphical analyses performed by FDA, CDHS analyzed the influent fecal coliform data statistically[2]. Outliers (Table A-4) were identified and removed for each of the six sets of data. An analysis of variance (ANOVA) was performed on the remaining data and it was determined that there was a highly significant difference ($P<0.001$) among the six sources of influent FC data (Table A-5).

To investigate the site-specific variability, significance testing was conducted using multiple comparisons among means of unequal sample sizes (S-N-K Test). Preliminary analysis tables are provided in Tables A-6a through A-6c. Determination of Least Significant Range (LSR) based on critical values of the Studentized range (Table A-6d) showed that site C (rank #1) was significantly different from A, F, and D (ranks 4, 5, and 6) but not significantly different from B or E (ranks 2 and 3). Site B was significantly different from site D but not from the remaining sites (Table A-6e).

This statistical grouping of sample sites, with C, B, and E in one group and A, F, and D

[2] SPSS Statistical Software, V.10; Biometry, Sokal and Rolf

in another, was in agreement with the independent graphical determination made by FDA. Both analyses support the conclusion that there is significant variability among the six influent sampling stations that precludes combining this data for analysis and determination of a single measure (e.g., a geometric mean) for FC concentration in influent sewage. The analyses further established that there are similarities in groups of sites that may allow the application of different maximum FC concentrations for determination of sewage upset thresholds for each group. FDA's determination that site E was unusual was not verified by the statistical analysis, however this site contained the greatest number of outliers and CDHS agrees that this site warrants further investigation and should be considered separately at present.

Using the Velz line projected from the 98th percentile of the data plot intersection, and the graphical geometric mean taken as the 50th percentile, the strengths of the three data groupings ([C, B], [A, F, D], [E]) are as follows:

[A, D, F] = 3.8×10^7 MPN/100 mL
[C, B] = 8.0×10^6 MPN/100 mL
[E] = 9.0×10^7 MPN/100 mL

Based on these FC concentrations, the revised threshold volumes in Table 3 (and Table A-7) are recommended.

Table A-1. Location of City of Arcata influent sewage sampling sites.

Site Designation	Location
A	Buttermilk Ln., Bayside
B	Humboldt Green Apt.
C	16th and G St.
D	Highway 255
E	L.K. Wood Blvd. (Fawn Creek Apts.)
F	Greenview area

Table A-2. Influent FC data.

FC	LOG FC	FC	LOG FC	FC	LOG FC
2.00E+03	3.30	8.00E+05	5.90	3.00E+06	6.48
2.00E+04	4.30	1.10E+06	6.04	3.00E+06	6.48
3.00E+04	4.48	1.10E+06	6.04	3.00E+06	6.48
4.00E+04	4.60	1.10E+06	6.04	3.50E+06	6.54
7.00E+04	4.85	1.30E+06	6.11	4.30E+06	6.63
7.00E+04	4.85	1.30E+06	6.11	5.00E+06	6.70
8.00E+04	4.90	1.30E+06	6.11	5.00E+06	6.70
1.30E+05	5.11	1.30E+06	6.11	5.00E+06	6.70
1.30E+05	5.11	1.30E+06	6.11	5.00E+06	6.70
1.30E+05	5.11	1.30E+06	6.11	5.00E+06	6.70
1.40E+05	5.15	1.30E+06	6.11	5.00E+06	6.70
2.00E+05	5.30	1.30E+06	6.11	5.00E+06	6.70
2.20E+05	5.34	1.30E+06	6.11	5.00E+06	6.70
2.30E+05	5.36	1.30E+06	6.11	5.00E+06	6.70
2.30E+05	5.36	1.30E+06	6.11	5.00E+06	6.70
2.30E+05	5.36	1.30E+06	6.11	5.00E+06	6.70
2.30E+05	5.36	1.40E+06	6.15	7.00E+06	6.85
3.00E+05	5.48	1.70E+06	6.23	7.00E+06	6.85
3.00E+05	5.48	1.70E+06	6.23	8.00E+06	6.90
3.00E+05	5.48	1.70E+06	6.23	8.00E+06	6.90
3.00E+05	5.48	1.70E+06	6.23	8.00E+06	6.90
3.00E+05	5.48	1.70E+06	6.23	8.00E+06	6.90
3.00E+05	5.48	1.70E+06	6.23	8.00E+06	6.90
3.00E+05	5.48	2.20E+06	6.34	8.00E+06	6.90
5.00E+05	5.70	2.20E+06	6.34	8.00E+06	6.90
5.00E+05	5.70	2.30E+06	6.36	8.00E+06	6.90
5.00E+05	5.70	2.30E+06	6.36	1.10E+07	7.04
5.00E+05	5.70	2.30E+06	6.36	1.30E+07	7.11
5.00E+05	5.70	2.30E+06	6.36	1.30E+07	7.11
5.00E+05	5.70	2.30E+06	6.36	1.30E+07	7.11
5.00E+05	5.70	2.30E+06	6.36	1.30E+07	7.11
5.00E+05	5.70	2.30E+06	6.36	1.70E+07	7.23
5.00E+05	5.70	2.30E+06	6.36	1.70E+07	7.23
7.00E+05	5.85	2.30E+06	6.36	2.40E+07	7.38
7.00E+05	5.85	2.30E+06	6.36	2.40E+07	7.38
7.00E+05	5.85	2.40E+06	6.38	2.80E+07	7.45
7.00E+05	5.85	2.80E+06	6.45	3.00E+07	7.48
7.00E+05	5.85	3.00E+06	6.48	5.00E+07	7.70
8.00E+05	5.90	3.00E+06	6.48	5.00E+07	7.70
8.00E+05	5.90	3.00E+06	6.48	5.00E+07	7.70
8.00E+05	5.90	3.00E+06	6.48	9.00E+07	7.95
8.00E+05	5.90	3.00E+06	6.48	1.60E+08	8.20
8.00E+05	5.90	3.00E+06	6.48	2.40E+08	8.38
8.00E+05	5.90	3.00E+06	6.48		
8.00E+05	5.90	3.00E+06	6.48		
8.00E+05	5.90	3.00E+06	6.48		

Table A-3. Geometric means of influent sewage samples from six City of Arcata locations, adjusted for 5-tube MPN variability.

Location	# of Samples	Graphical Mean[3] (x 10^6)	Notes
A	24	35	
F	25	24	
B	24	6.6	
C	24	7.8	
D	25	38	Break in Data
E	25	90	Break in Data

Table A-4. Identification of outliers in the log FC data, per sample site.

LOG A	LOG B	LOG C	LOG D	LOG E	LOG F
7.11	5.36	5.90	6.48	5.36	5.48
6.90	5.36	5.90	6.90	5.90	5.70
4.30	5.11	6.48	6.90	6.11	5.85
6.36	5.70	4.85	6.48	6.23	6.70
6.04	6.11	6.90	6.36	6.70	7.70
6.11	6.36	6.48	6.11	6.48	6.48
5.90	3.30	4.48	5.48	4.85	5.36
5.70	5.36	6.36	7.11	5.70	7.48
8.38	6.70	6.90	7.70	6.90	7.04
7.11	5.48	5.36	6.70	5.85	6.34
8.20	7.11	5.36	7.38	6.36	7.23
5.70	5.85	5.70	6.48	6.36	6.04
6.70	5.48	5.90	6.48	5.90	6.70
6.70	6.36	6.11	6.48	6.48	6.23
6.48	5.15	4.90	7.45	6.38	6.11
7.23	5.90	6.90	6.90	7.70	6.36
7.11	6.34	5.48	6.63	5.90	5.90
5.90	6.11	5.90	6.48	7.38	6.54
4.60	6.11	5.11	6.70	6.23	6.11
5.70	5.34	5.48	6.85	6.11	5.48
6.36	6.23	5.11	6.36	5.70	6.90
6.11	5.70	5.85	6.15	7.95	5.85
5.30	6.70	6.11	6.70	6.04	6.48
6.23	5.70	5.48	6.70	6.85	6.90
			6.45	5.90	6.23

outliers

[3] *Velz Line was projected from the 98th percentile to establish Graphical Geometric Mean.

Table A-5. Analysis of Variance Summary: analysis of log FC values, outliers removed.

Source of Variation	df	SS	MS	Fs	Sig. Dif.
Among	5	12.18	2.436436	6.115096 *	**Yes:**
Within	135	53.79	0.39843		**P<0.001**
Total	140	65.9702			

F.10[5,135]	1.85
F.05[5,135]	2.21
F.001[5,135]	4.1

Tables A-6a - c. Significance testing: multiple comparisons among means of unequal sample sizes (S-N-K Test).

Table A-6a. Intermediate calculations; sources ranked according to increasing log means.

	C	B	E	A	F	D
Mean	5.79	5.90	6.22	6.34	6.37	6.66
n	24.00	23.00	22.00	24.00	25.00	23.00
Variance(s2)	0.45	0.29	0.21	0.91	0.38	0.12
(n-1)s2	10.24	6.47	4.51	20.90	9.13	2.55
Sum (n-1)s2/Sum (n-1)	0.3984					

Table A-6b. Matrix for paired comparisons of ranks.

B.			**C**	**B**	**E**	**A**	**F**	**D**
		Rank	1	2	3	4	5	6
		Mean	5.79	5.90	6.22	6.34	6.37	6.66
Rank	**Mean**	**n**	24.00	23.00	22.00	24.00	25.00	23.00
1	5.79	24	---					
2	5.90	23	0.11	---				
3	6.22	22	0.43	0.32	---			
4	6.34	24	0.56	0.45	0.12	---		
5	6.37	25	0.58	0.47	0.15	0.02	---	
6	6.66	23	0.87	0.76	0.44	0.31	0.29	---

Table A-6c. Determination of Least Significant Range (LSR) based on critical values of the Studentized range.

k	2	3	4	5	6
Q.05[k,v]	2.8	3.356	3.685	3.917	4.096
sqrt Mswithin	0.631213				
(Q) sqrt MS	1.767396	2.118351	2.32602	2.472461	2.585448

Table A-6d. Least Significant Range (LSR) testing results.

1. Test total range of 6 means (1-6): (Q.05[6,v]) (see pg 244, Sokal and Rohlf)	**0.533458**	**< 0.87 so significant at 5% level**
2. Test total range of 5 means (1-5):	**0.499617**	**< 0.58 so significant at 5% level**
3. Test total range of 4 means (1-4):	**0.474797**	**< 0.56 so significant at 5% level**
4. Test total range of 3 means (1-3):	**0.442125**	>0.43 so not significant at 5% level
5. Test total range of 5 means (2-6):	**0.515544**	**< 0.76 so significant at 5% level**
6. Test total range of 4 means (2-5):	**0.475209**	>.470 so not significant at 5% level: no further tests will be significant below means 3-6.

Table A-6e. Matrix for paired comparisons of ranks (Table A-2b) with the significant pairs highlighted (red) and groups of sites that are not significantly different from one another shaded.

E. Table from "B.": red = significant

			C	B	E	A	F	D
		Rank	1	2	3	4	5	6
		Mean	5.79	5.90	6.22	6.34	6.37	6.66
Rank	**Mean**	**n**	24.00	23.00	22.00	24.00	25.00	23.00
1	5.79	24	---					
2	5.90	23	0.11	---				
3	6.22	22	0.43	0.32	---			
4	6.34	24	0.56	0.45	0.12	---		
5	6.37	25	0.58	0.47	0.15	0.02	---	
6	6.66	23	0.87	0.76	0.44	0.31	0.29	---

Table A-7. Revised upset thresholds for the City of Arcata waterways.

Tributary	Threshold Volume (Gallons)	Sampling Sites
Tide Gates (Arcata bottoms)	30	All primary sites plus T2
Janes Creek	200	All primary sites plus 41
McDaniel Slough	500	All primary sites plus 41
Jolly Giant Creek	600	All primary sites plus 41
Butcher Slough	600	All primary sites plus 41
Campbell Creek	1,000	All primary sites plus 41 and 44
Fickle Hill Creek	1,000	All primary sites plus 41 and 44
Grotzman Creek	1,000	All primary sites plus 41 and 44
Beith Creek	1,000	All primary sites plus 41 and 44
Gannon Slough	1,000	All primary sites plus 41 and 44
Jacoby Creek	1,000	All primary sites plus 41 and 44

Figure A-1. Probability plot for all influent FC data, excluding outliers.

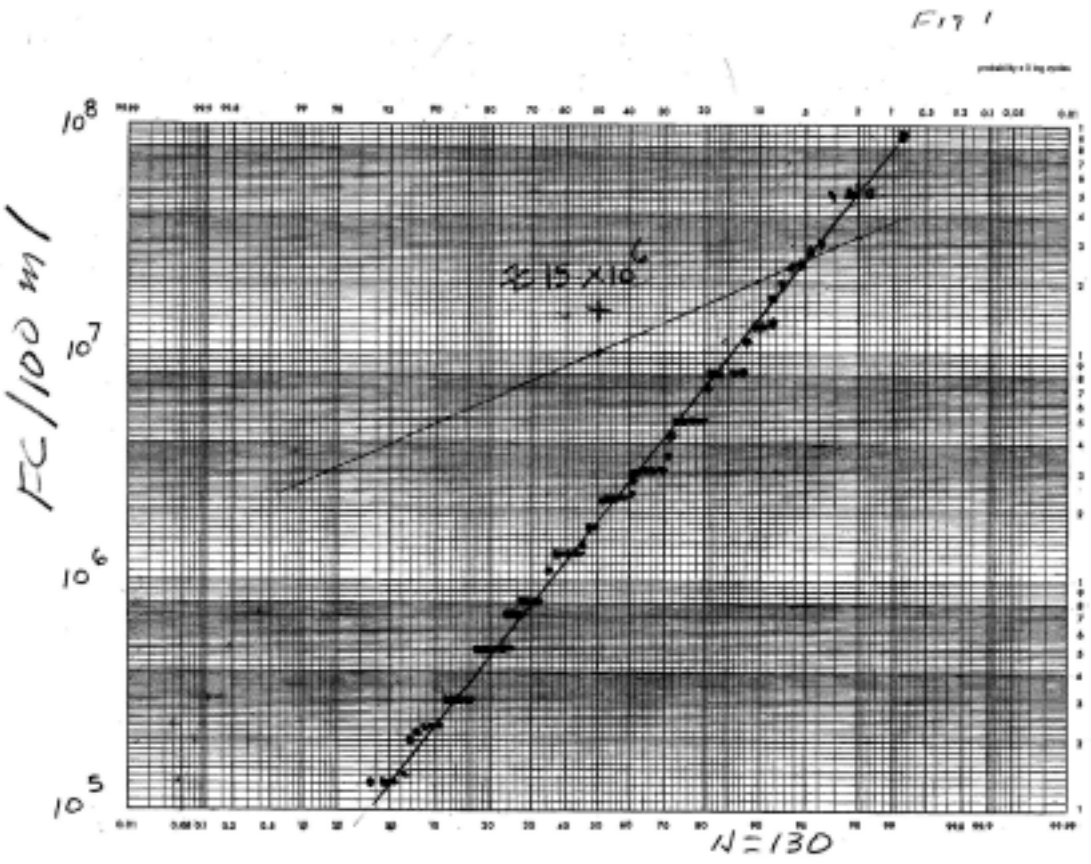


Figure A-2. Probability plot for sampling station A.

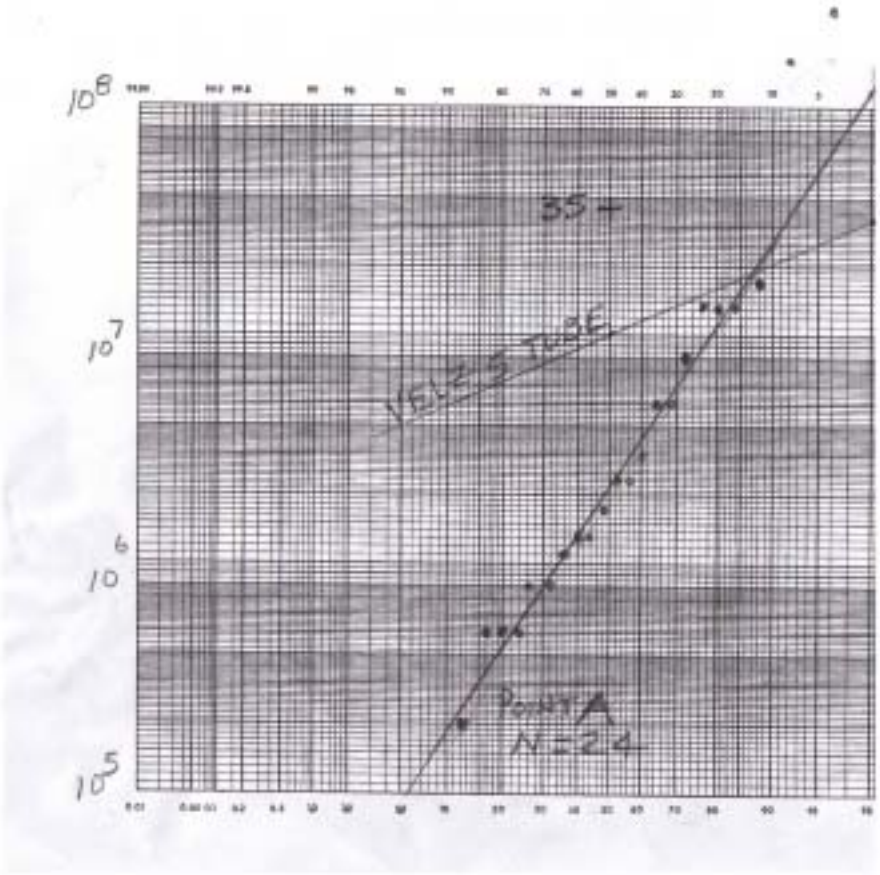


Figure A-3. Probability plot for sampling station B.

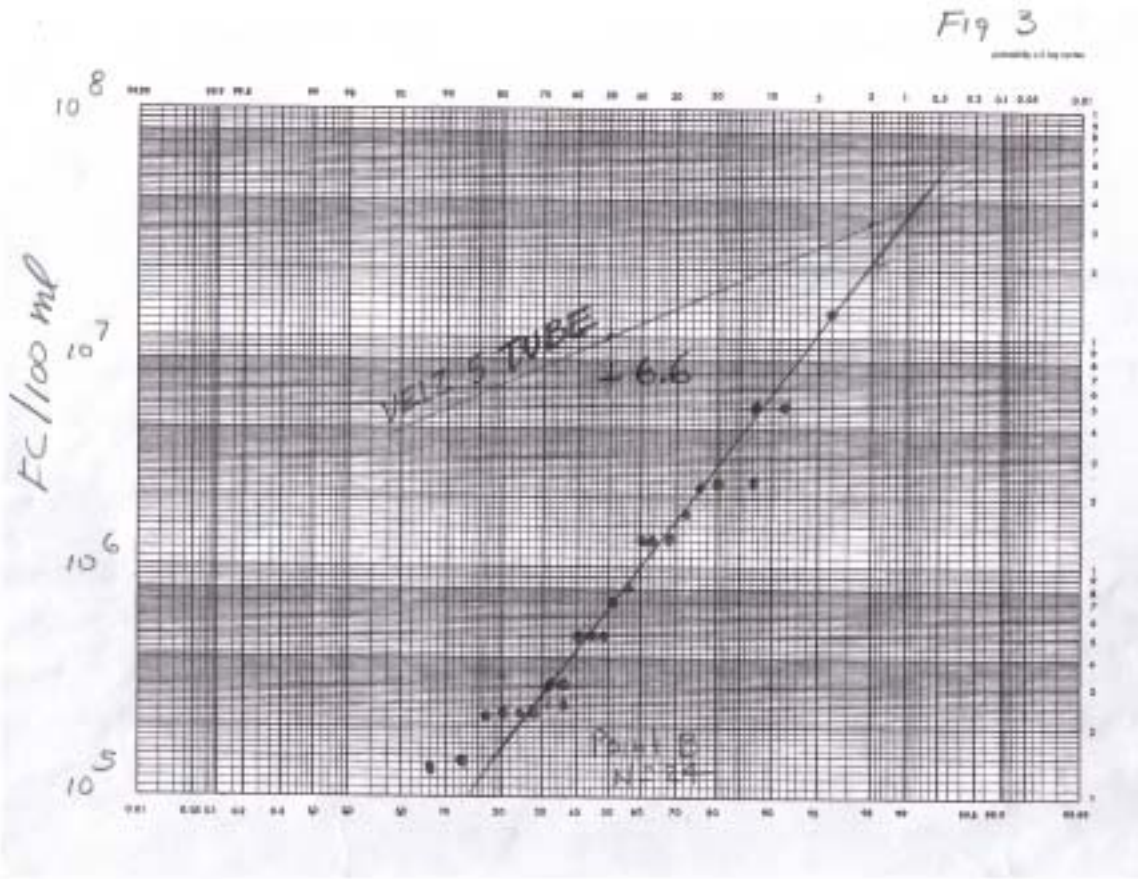


Figure A-4. Probability plot for sampling station C.

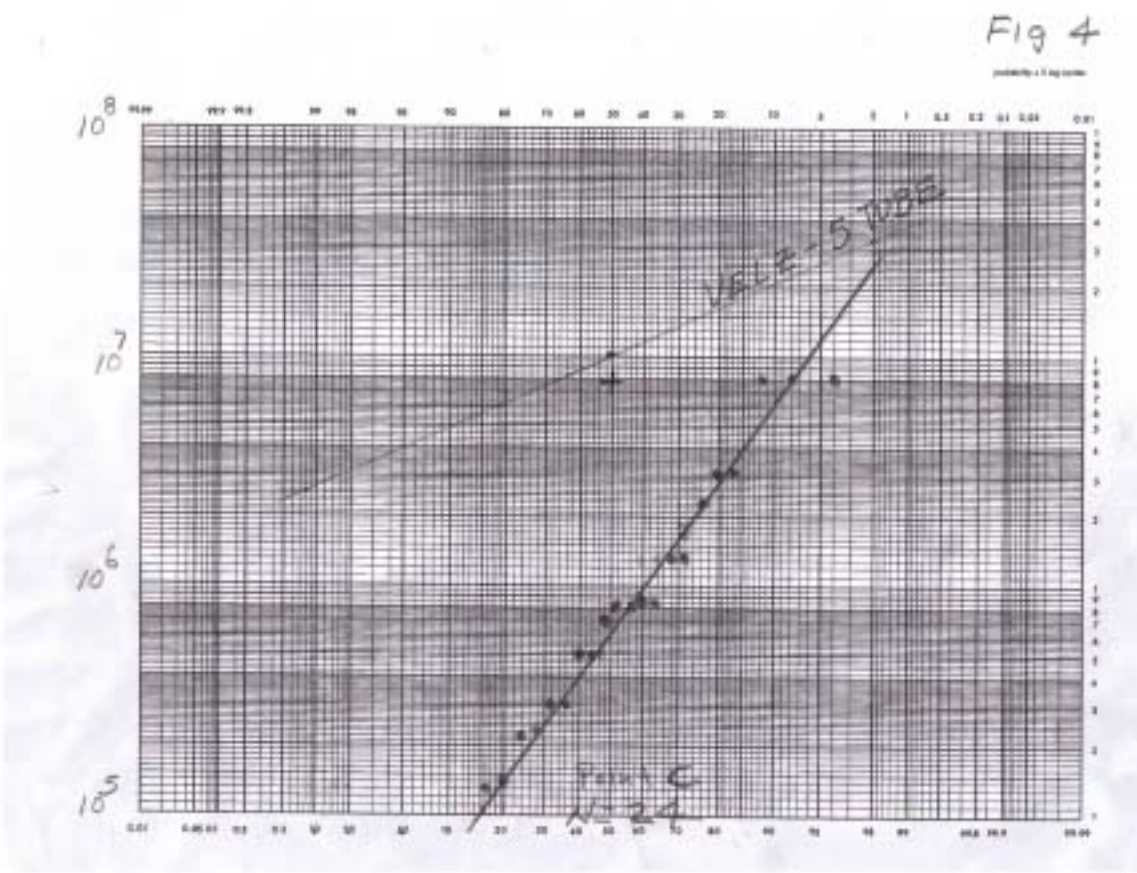


Figure A-5. Probability plot for sampling station D.

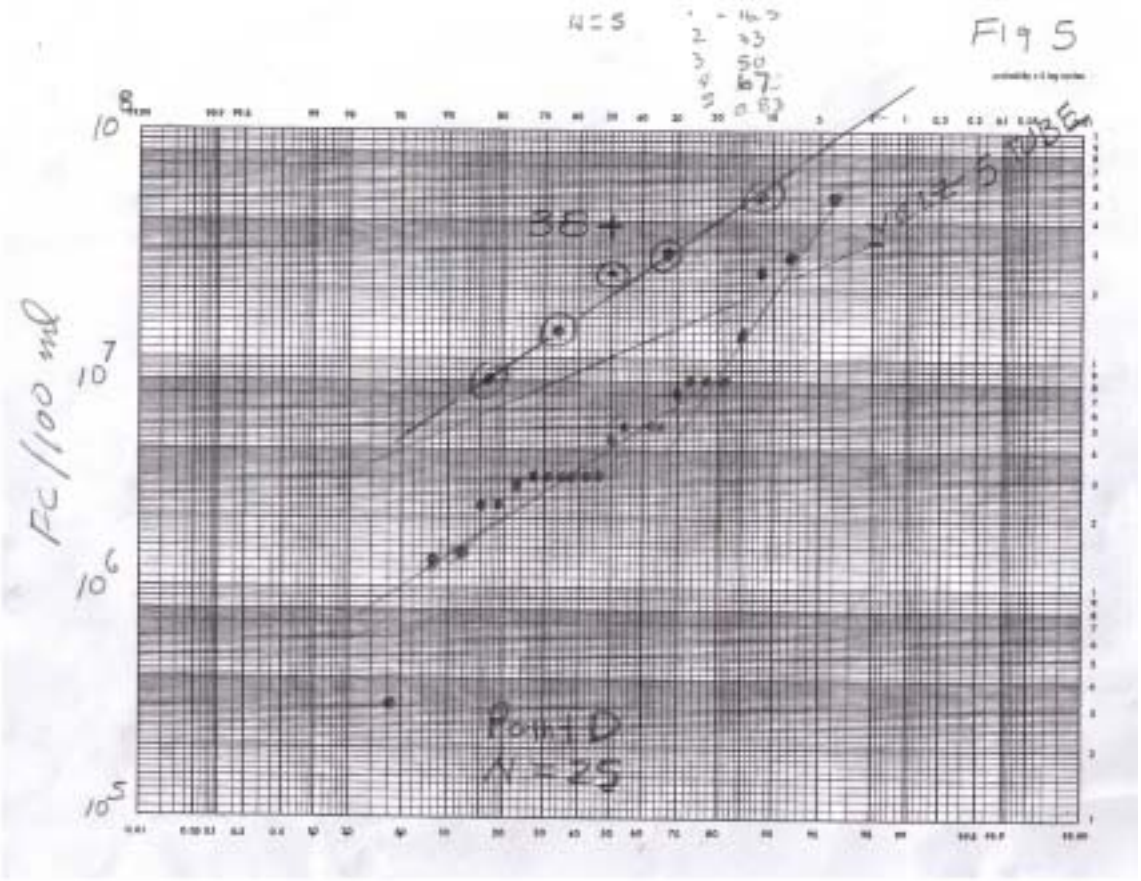


Figure A-6. Probability plot for sampling station E.

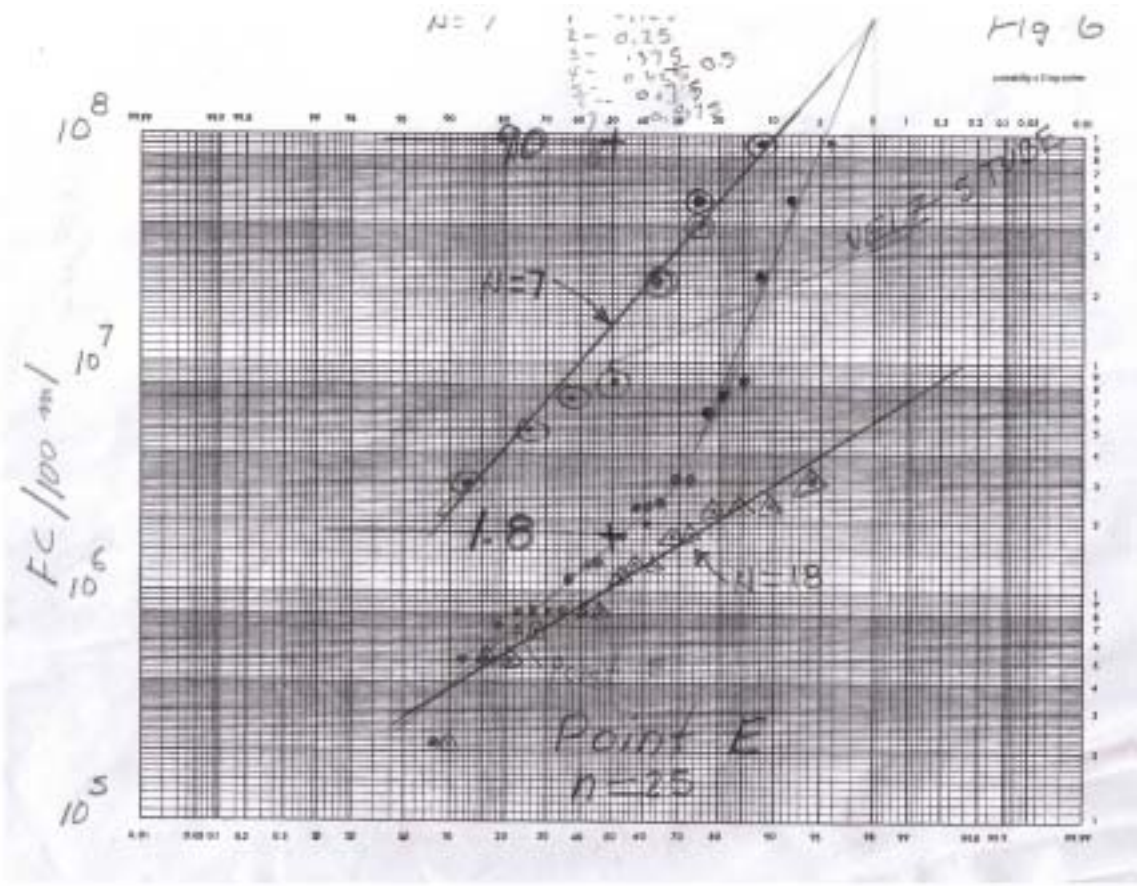
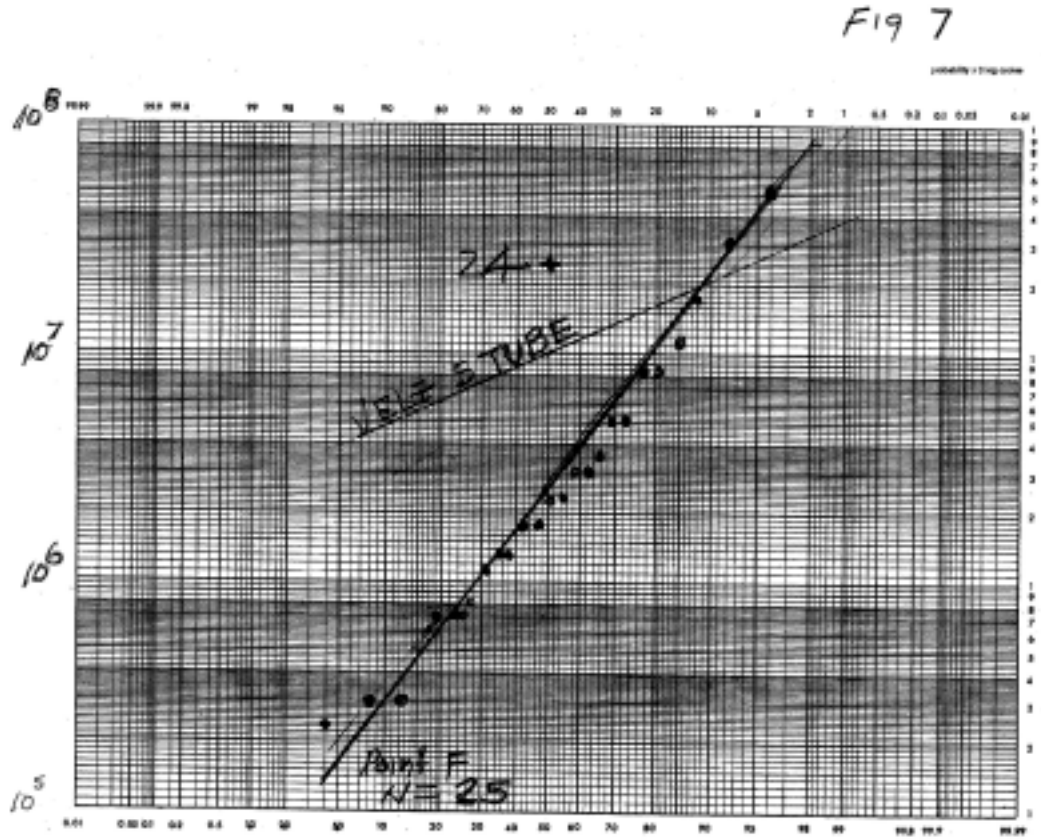


Figure A-7. Probability plot for sampling station F.



Appendix B. Evaluation of rainfall closure rule threshold for growing areas.

I. Introduction

Coast Seafoods Company (CSC) has requested that the existing rainfall closure rules for its shellfish growing beds in North Bay be re-evaluated to assess the possibility of adjusting the rules to reduce the total number of days of closure. CSC has asserted (correspondence of April 19, 2002) that water quality data collected during the past several years has shown that water quality has improved throughout Humboldt Bay. CSC has specifically requested that CDHS evaluate the existing rainfall rules with respect to closure time onset, rainfall thresholds, and closure period lengths. CSC has further requested that CDHS consider the possibility of an *Approved* area for Humboldt Bay

A detailed evaluation of existing rainfall closure rules has not been possible before, as previous to1999 there existed too few water quality data collected from the growing waters which were adversely impacted by recent rainfall events. However, during the past four years, the Humboldt Bay Shellfish Technical Advisory Committee (HBSTAC) study, and CSC have collected a considerable number of water samples during such periods, typically during the first few days following a rainfall closure.

Although a substantial amount of data to reevaluate the 24-hour thresholds now exists, the existing data set is inadequate to evaluate (1) the current lag times, and (2) the number of days of closure[4]. Thus, the evaluation discussed in this report is limited to an attempt calibrate the primary and secondary thresholds to the recently collected water samples.

II. Methods

The existing closure rules were evaluated using recent data (fall 1999 through spring 2003) collected under adverse conditions. For the evaluation, only samples collected under what were defined as “adverse conditions” were used. Adverse conditions were defined as samples collected when the 24-hour rainfall exceeded 0.5 inch of rain within the past three days. The HBSTAC study generally showed that fecal coliform concentrations in the bay water remain elevated for about the first three days following rainfall events. The percent greater than 43 MPN and the geometric mean were

[4] For example, to evaluate the current lag time, the most straightforward approach would be to collect samples collected at hourly or bi-hourly intervals around the onset of a closure period. The information from these samples would help determine the timing of runoff pollution reaching the growing area. The number of days of closure could be assessed by the collection of multiple water and shellfish meat samples near the end of the closure period (i.e., on the third day of closure for an area with a four-day closure). These samples would be used to determine whether fecal coliform (FC) of water and shellfish return to pre-rainfall levels before the shortening of the closure periods could be justified. Samples would need to be collected during multiple rainfall events to account for environmental variability with respect to such factors as run-off volumes, rainfall intensity, and tides.

evaluated for each of 8 sampling stations under these adverse conditions.

A step-by step summary of the evaluation follows:

A. Summary of Methodology for determining rainfall thresholds:

1. The past 4 years of water quality data (the period November 1999 through April 2003) were exported from a database (Paradox) to a spreadsheet (MS Excel).

2. Only the Shellfish Growing Water (SGW) and SGW Compliance (SGWC) data was used in the evaluation (i.e., Shellfish meats and field replicates were excluded).

3. Only data collected under “adverse conditions” as defined herein with respect to rainfall was used in the evaluations. Sampling times coincided with adverse conditions when Area “D” was closed (i.e., when the 24-hour rainfall threshold exceeded 0.5 inches) and the threshold exceedance occurred within the three days preceding sample collection time. Area “D” has the most stringent rainfall closures for Humboldt Bay—it closes for 6 to 8 days whenever the 24-hour rainfall exceeds 0.5 inch. The number of resulting samples that met these criteria for the eight stations evaluated ranged between 52 and 61 (Table 1). Data where sorted in Excel with respect to closure status and fecal coliform (FC) MPN in descending order (i.e., sort for Area D closure status and then by fecal coliform in descending order). Samples representing times when the most recent rainfall threshold exceedance was exceeded more than 3 days ago was manually edited from the spreadsheet.

4. Using Excel, the percent of samples greater than 43 MPN, and the geometric mean collected under the adverse conditions was determined for each primary sampling station.

5. For each sample in which the 90th percentile criterion of 43 FC MPN is exceeded, determine the maximum 24-hour threshold that occurred in the past three days. Presently, in order to do this accurately, one must consult the monthly rainfall files that contain the 6-hr synoptic readings for Eureka reported by the National Weather Service. As presently constructed, Paradox only yields rainfall totals calculated in 24-hour increments from the time the sample set was collected, whereas CDHS currently calculates the threshold as the running ***sum*** of the past four 6-hr readings.

6. Proceeding from low to high 24-hour rainfall threshold, sequentially rank the thresholds in ascending order. When two samples taken on sequential days refer to the same threshold, rank the one that was sampled on the later day first, followed by the one sampled on the previous days. [It is assumed here that the

water quality would be more severely impacted nearer in time to the rainfall event than for samples on subsequent days].

7. For each ranked threshold, determine the percent over 43 MPN for the subset of samples that do not exceed the given rank. Continue to add ascending thresholds up to the 10 percent limit. The corresponding thresholds for the subset of samples just up to and not exceeding 10 percent limit represents an estimate of the highest threshold that will meet the NSSP criterion. As an example, suppose that for a given sampling station there were 45 samples collected under the adverse conditions described above, and 18 (40%) of them exceed the 43 MPN criterion. Suppose that the ascending 24-hour thresholds for the lowest 5 samples are as follows 0.40, 0.65, 0.95, 1.02, and 1.15. Thus, if a rainfall threshold of 1.14 inch was proposed the estimated percent > 43 equals 8.9 (4/45*100), representing the inclusion of the first three threshold ranks when a rainfall threshold of up to 1.01 inches is proposed. However, if the next threshold rank of 1.15 inch were included, (i.e., a threshold of 1.16 inch is proposed) the 10 percent criterion would be exceeded (95/45*100 = 11.1%).

8. Calculate the geometric mean of the subset of the adverse condition data up to the threshold determined in #7 above. The geometric mean of the data must not exceed the 14 MPN.

B. Determining antecedent rainfall period for secondary thresholds.

Perform a linear regression analysis of the relationship between antecedent rainfall and the log of the fecal coliform MPNs. Determine the respective correlations (as R-squared values) for each 24-hour rainfall increment (i.e., 0-24 hr., 24-48 hr., 48-72 hr., etc.) The resulting R-squared values approximate the amount of the observed variability in fecal coliform that is attributable to a given increment). The lower the R-squared value, the less influence the rainfall increment has on current growing water fecal coliform concentrations.

III. Results:

Table B-1 compares the adverse condition data with only the subset of adverse condition data represented by open periods under the proposed rainfall threshold. The thresholds column is the highest threshold for with both the percent greater than 43 MPN and the geometric mean criteria are met.

Table B-2 provides a further breakdown of the distribution of water samples with respect to rainfall thresholds. The number of adverse condition samples that exceeds the respective thresholds varies from ten (ten samples above the 1.61” threshold for station #51to 37 samples above the 0.95” threshold for station #45).

Table B-3 shows the results for an analysis of the association between antecedent rainfall and water fecal coliform concentrations for two samples stations. All of the stations showed the same general pattern of decreasing correlation as the time difference between antecedent rainfall and sample collection increased beyond two days. It appears that rainfall amounts more than 5 days previous to sample collection had relatively little affect on current water fecal coliform concentrations. Thus it seems reasonable to reduce the period over which the secondary threshold is considered from 10 days to 7 days. The seven-day figure assumes that the shellfish require approximately one to two days to depurate elevated fecal coliform concentrations acquired during a rainfall closure after the water has returned to normal.

The estimated maximum thresholds obtained in this analysis are all greater than existing thresholds used to mange the growing areas. Therefore, it appears that the threshold can be raised to varying degrees from the current thresholds.

IV. Recommendations:

This analysis supports raising the current threshold for at least some of CSC growing areas from the current one-half inch or 1 inch thresholds. However, due to the “fuzziness” of MPN data, there remains uncertainty of the appropriate thresholds. Therefore it would be wise to propose greater thresholds that are intermediate between existing threshold and the maximum thresholds proposed in the table. The area (north Mad River Beds) represented by station #21 probably does not warrant increasing the threshold over the current 1.0-inch threshold. The analysis supports raising the threshold for the majority of the stations, especially #22 and #51.

Table B-1. Comparison of adverse condition data and “open” data under new rainfall closure thresholds for each of CSC primary water quality stations.

Station	All adverse condition data			Rainfall rule			
	Geom. mean	% > 43	n	Maximum 24-hr threshold and no. of days (d) of closure	Geom. Mean	% > 43	n
#21	18.0	33.3 (57)	57	>1.13”	9.9	9.5	42
#22	13.3	23.1 (52)	52	>1.50”	8.5	9.1	44
#24	20.9	28.3 (53)	53	>1.19”	12.5	9.5	42
#34	19.0	33.3 (57)	57	>1.13”	13.2	9.5	42
#45	25.9	41.0 (61)	61	>0.95”	12.0	10.0	40
#51	14.6	19.6 (56)	56	>1.61”	11.3	10.0	45
#52	17.8	29.1 (55)	55	>1.21”	11.0	9.3	43
#53	24.8	32.1 (56)	56	>1.02”	13.89	4.9	41

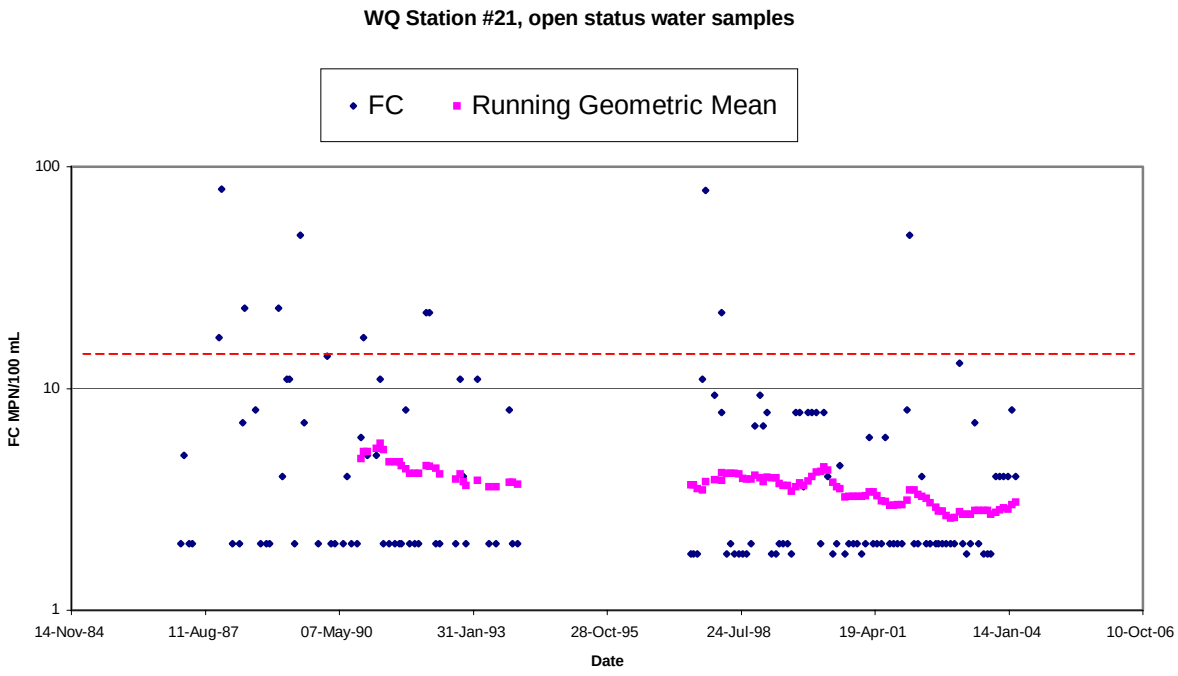
Table B-2. Distribution of samples with respect to the maximum 24-hr rainfall thresholds determined in the analysis.

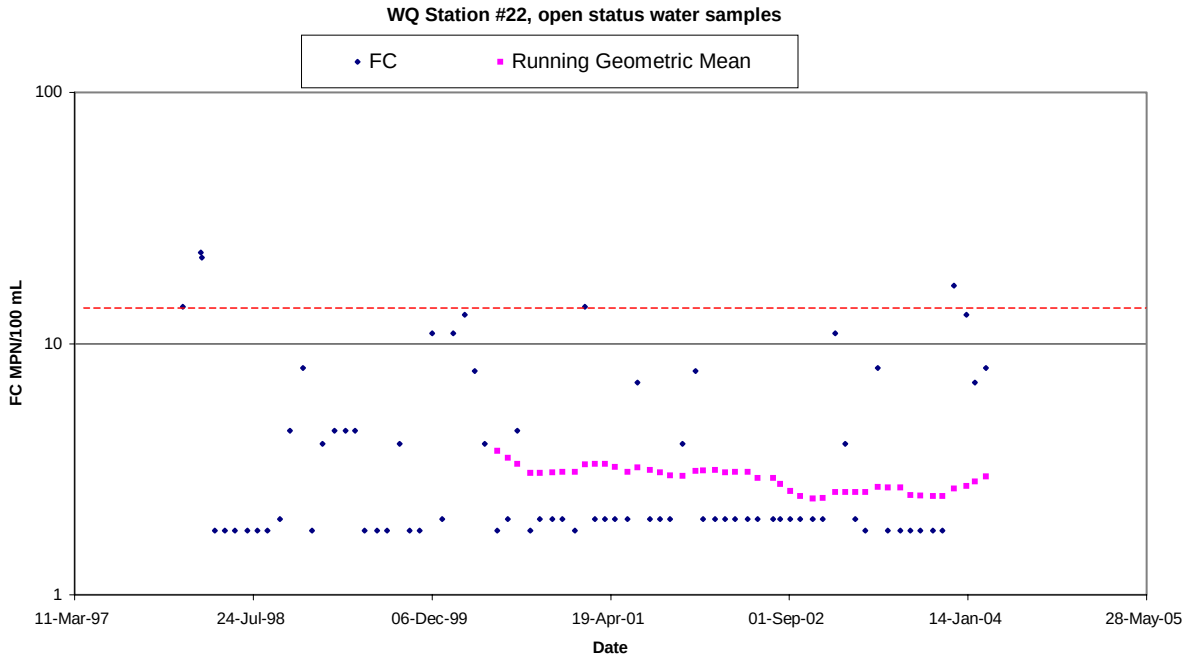
Station	Number of Adverse condition samples	Maximum rainfall threshold meeting NSSP criteria	Number of adverse condition samples below maximum threshold	Number of adverse condition samples equal to or above maximum threshold (%)
#21	57	>1.13”	30	27 (47)
#22	52	>1.50”	39	13 (19)
#24	53	>1.19”	29	24 (45)
#34	57	>1.13”	32	25 (44)
#45	61	>0.95”	24	37 (61)
#51	56	>1.61”	46	10 (18)
#52	55	>1.21”	31	22 (40)
#53	56	>1.02”	21	33 (59)

Table B-3. R-squared values determined with linear regression for various antecedent rainfall increments.

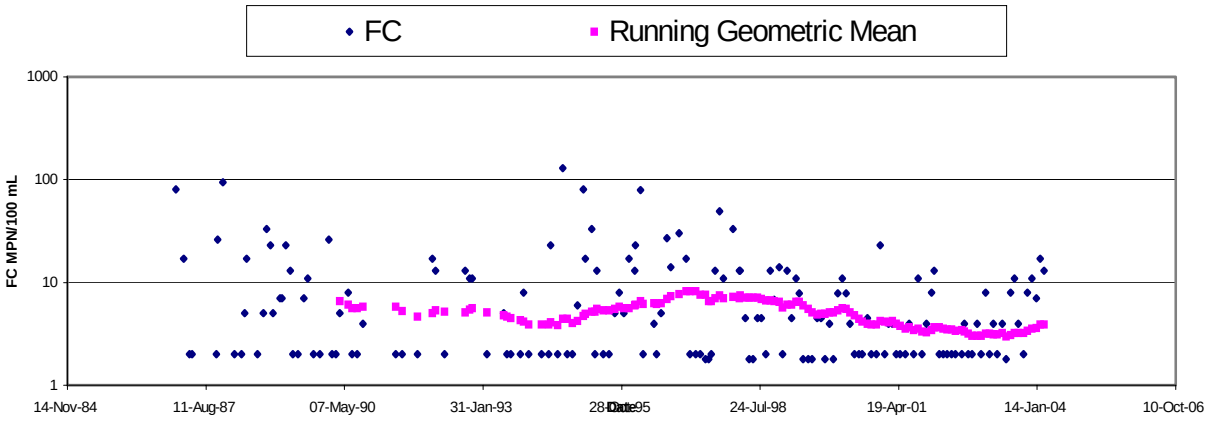
Station	1-day	2-day	3-day	4-day	5-day	6- day	1-5 day	6-10-day	10-day
#21	0.191	0.267	0.206	0.161	0.056	0.026	0.509	0.122	0.529
#52	0.138	0.298	0.235	0.069	0.006	0.046	0.416	0.069	0.379

Figure B-1. Trends in Fecal Coliform Data from Primary Water Quality Stations in Humboldt Bay.

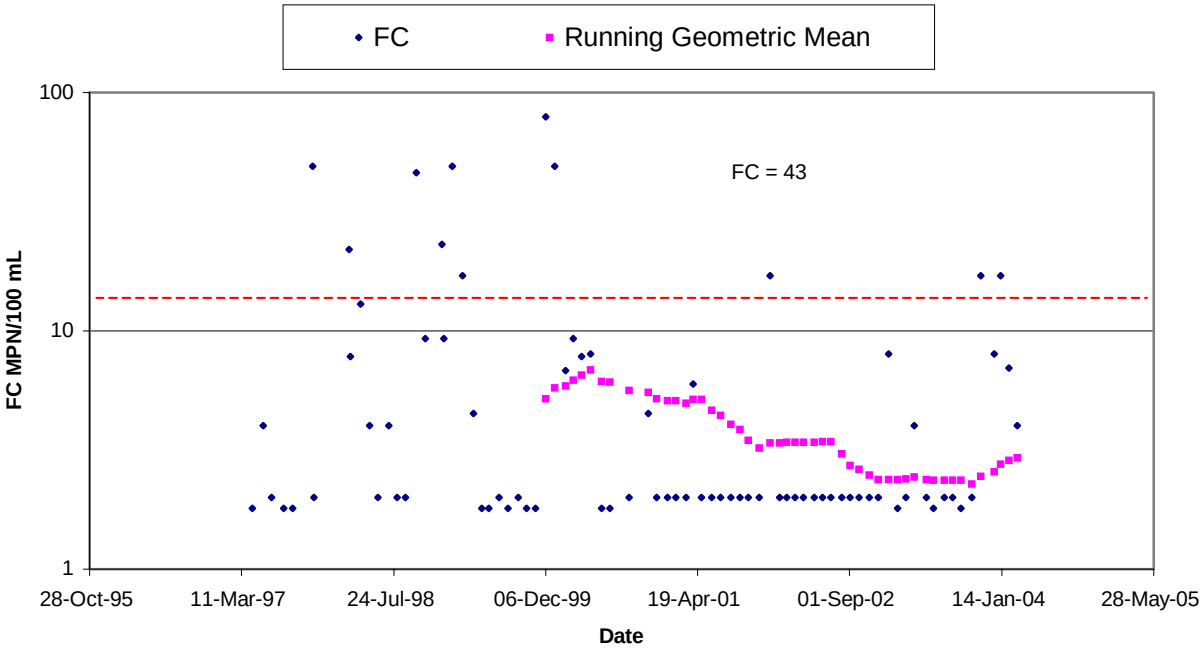


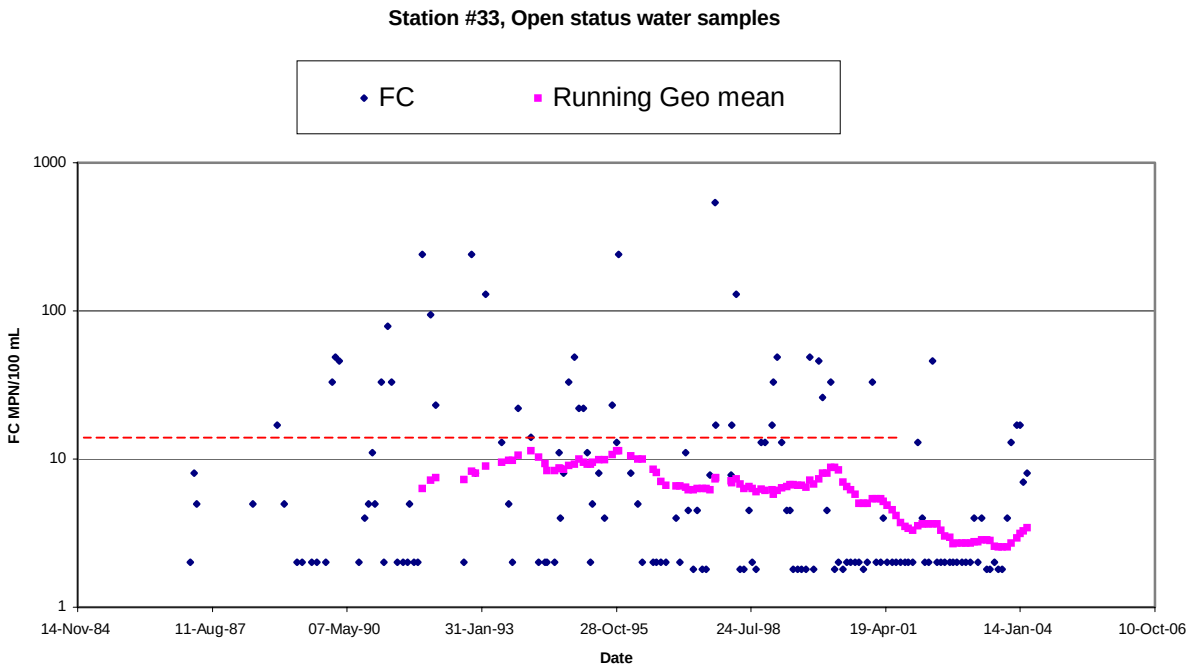


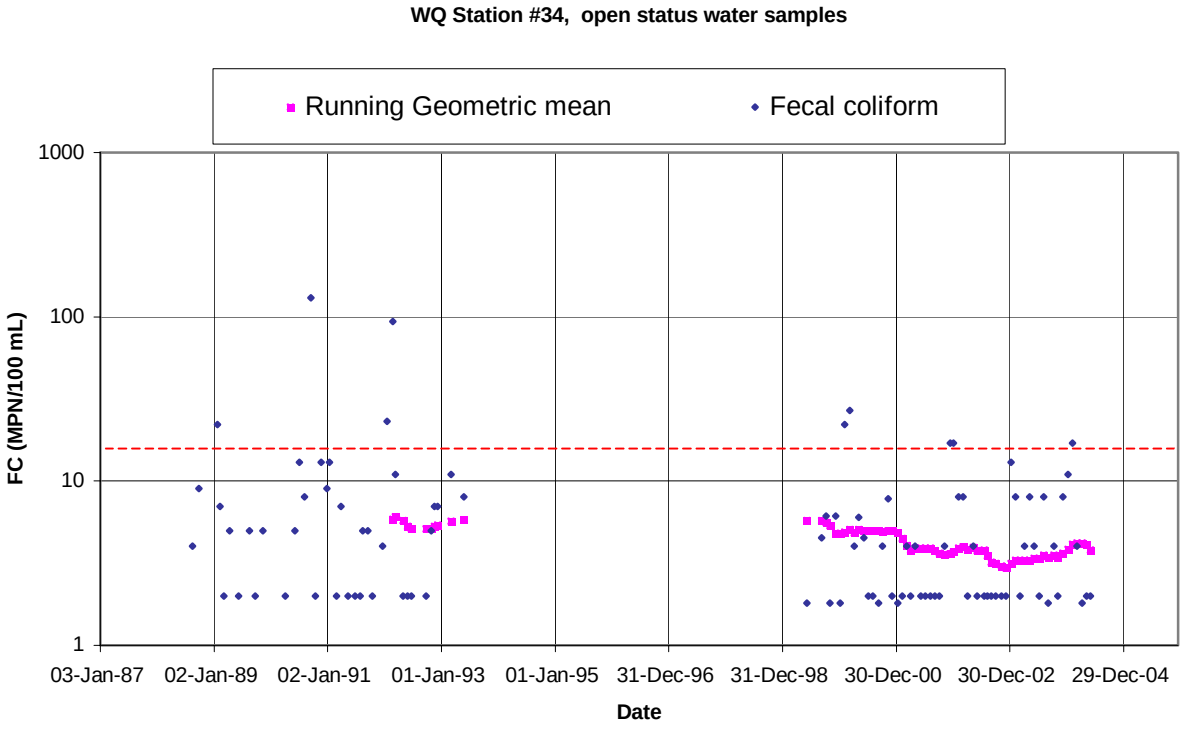
Station #24, open status water samples

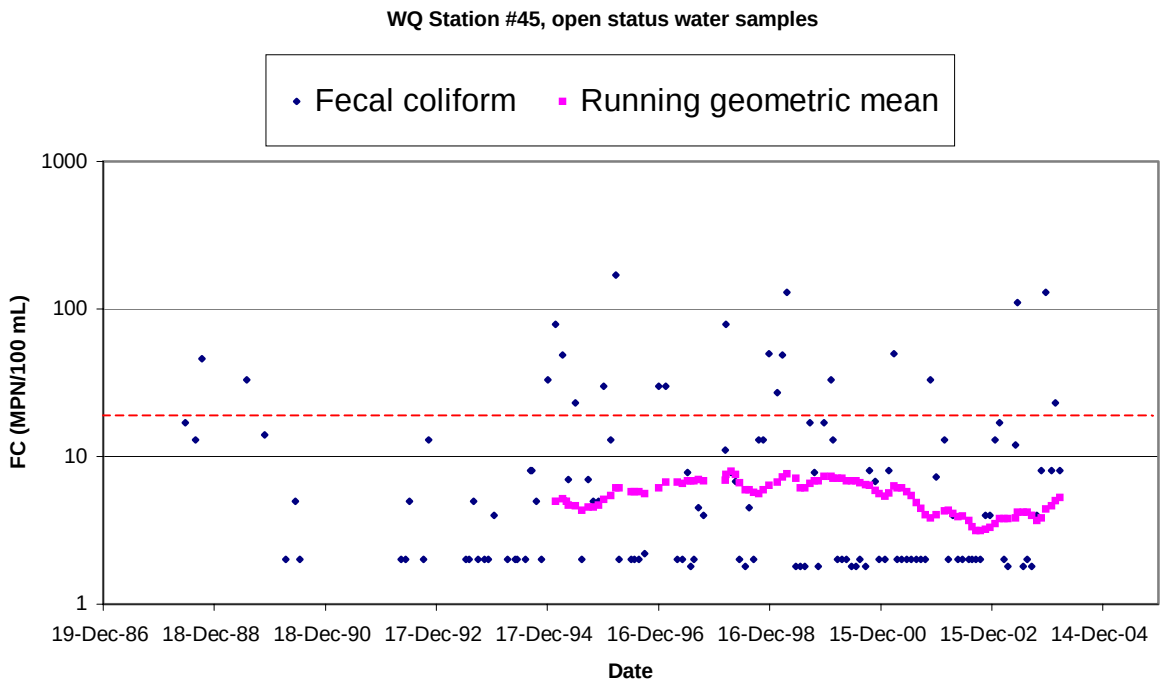


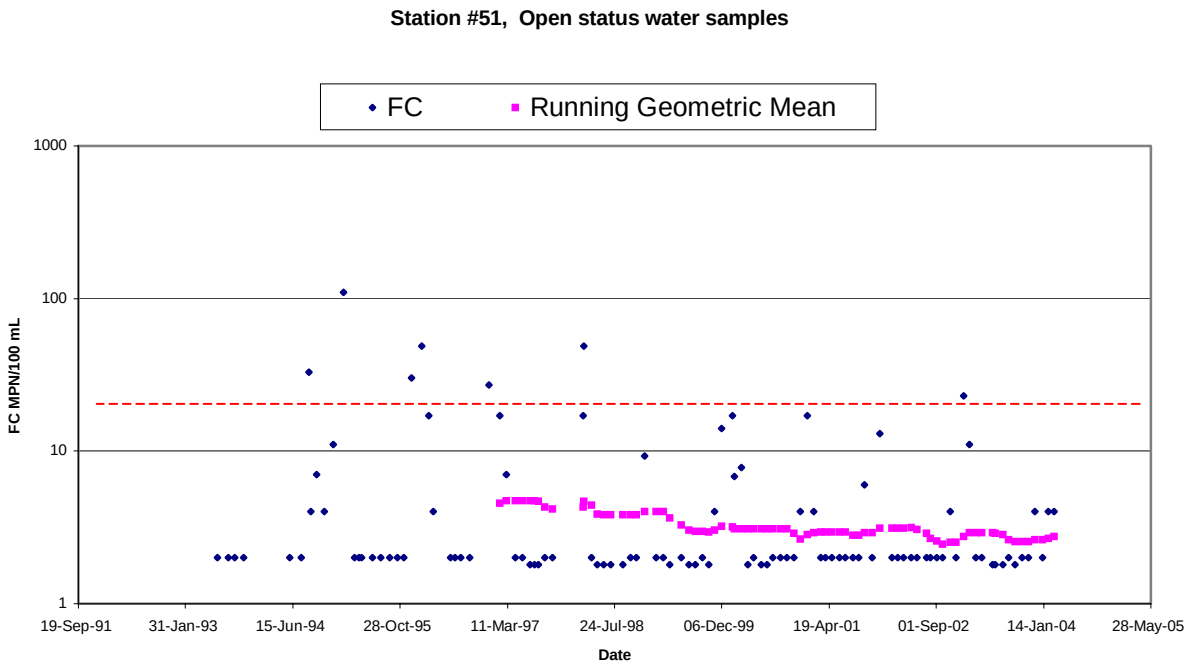
Station #31, open status water samples

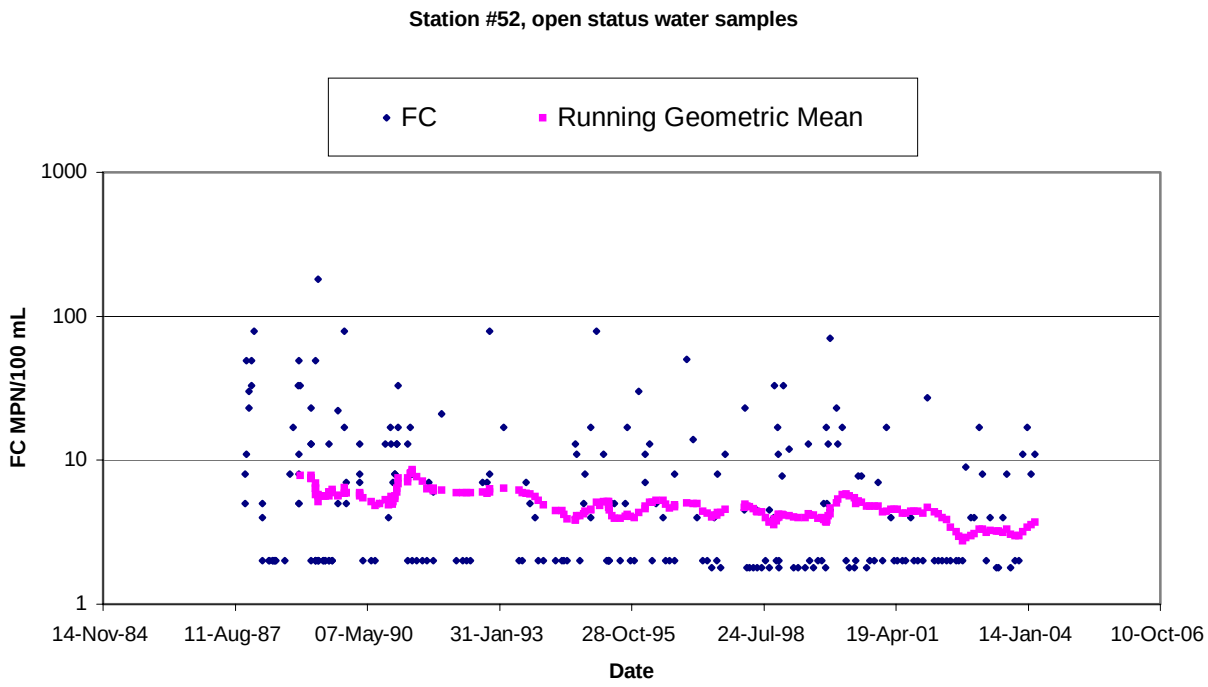


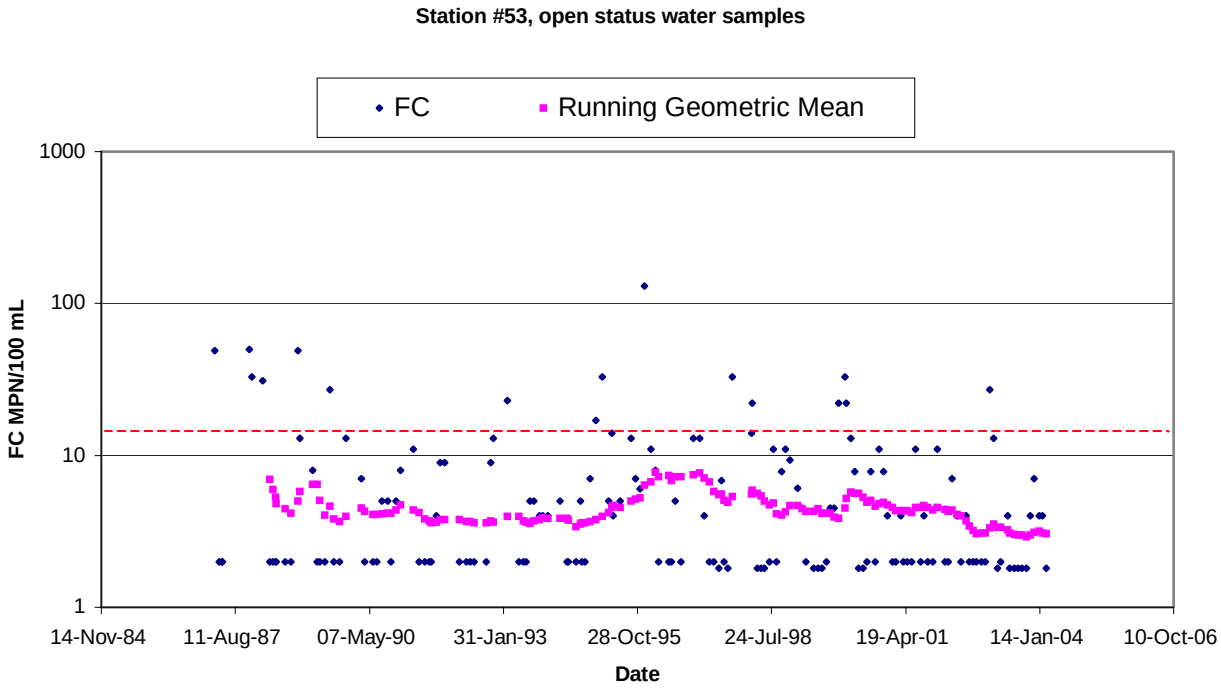

Station #33, Open status water samples
FC
Running Geo mean
1000
100
10
1
FC MPN/100 mL
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
Date

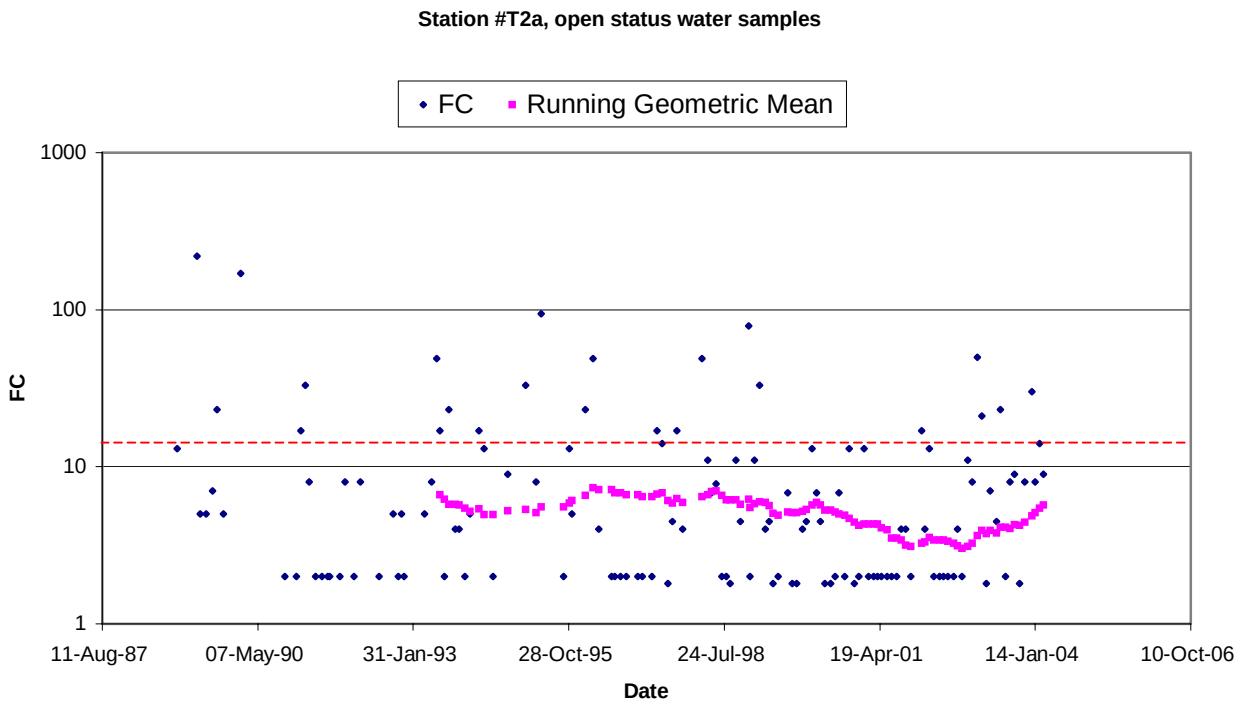

WQ Station #34, open status water samples
Running Geometric mean
Fecal coliform
1000
100
10
1
FC (MPN/100 mL)
03-Jan-87
02-Jan-89
02-Jan-91
01-Jan-93
01-Jan-95
31-Dec-96
31-Dec-98
30-Dec-00
30-Dec-02
29-Dec-04
Date


WQ Station #45, open status water samples
Fecal coliform
Running geometric mean
1000
100
10
1
FC (MPN/100 mL)
19-Dec-86
18-Dec-88
18-Dec-90
17-Dec-92
17-Dec-94
16-Dec-96
16-Dec-98
15-Dec-00
15-Dec-02
14-Dec-04
Date


Station #51, Open status water samples
FC
Running Geometric Mean
1000
100
10
1
FC MPN/100 mL
19-Sep-91
31-Jan-93
15-Jun-94
28-Oct-95
11-Mar-97
24-Jul-98
06-Dec-99
19-Apr-01
01-Sep-02
14-Jan-04
28-May-05
Date


Station #52, open status water samples
FC
Running Geometric Mean
1000
100
10
1
FC MPN/100 mL
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
Date


Station #53, open status water samples
FC
Running Geometric Mean
1000
100
10
1
FC MPN/100 mL
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
Date


Station #T2a, open status water samples
FC
Running Geometric Mean
1000
100
10
1
FC
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
Date