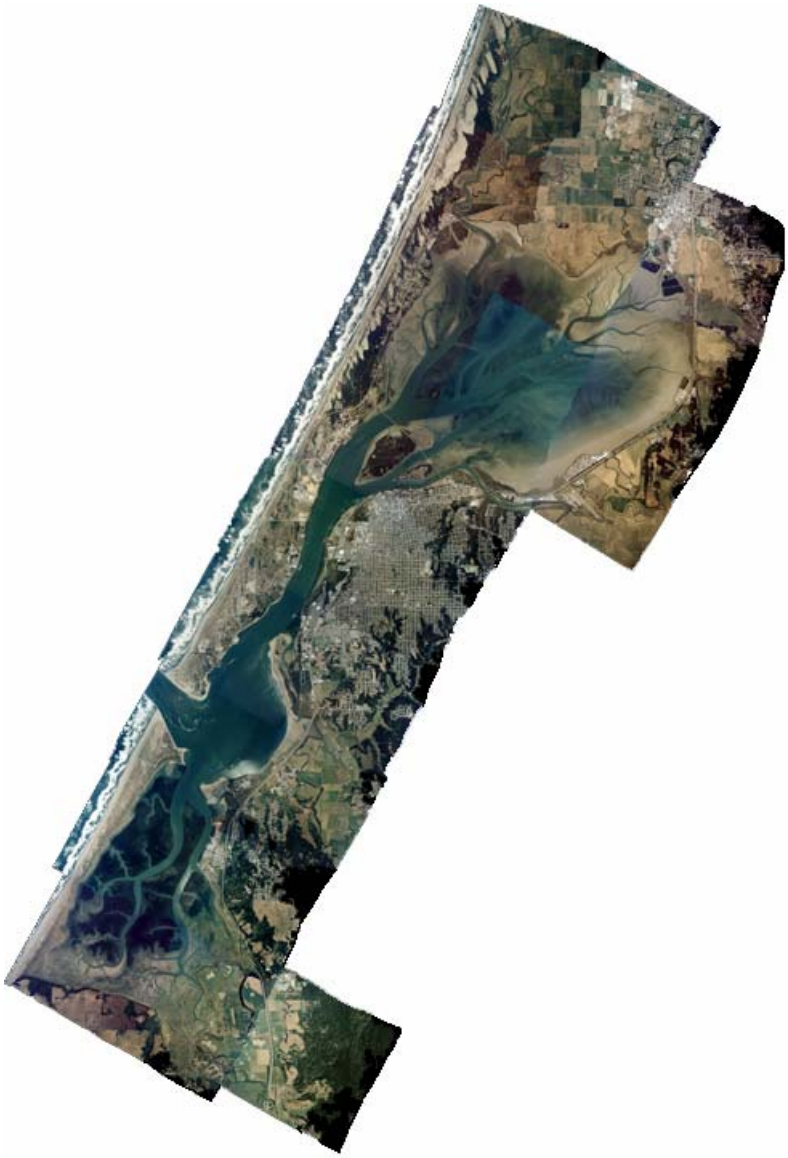
Final Comment Report

Humboldt Bay and Watershed Fecal Coliform Study



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Presented to the:

North Coast Regional Water Quality Control Board
and
Department of Health Services-Preharvest Shellfish Sanitation Unit

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Acknowledgements

Previous bacteriological studies have been performed in Humboldt Bay, however they were of limited duration, geographic area, sample locations and sample frequency. This study provides additional information about Humboldt Bay's water quality during rainfall events that may impact commercial shellfish harvesting in Humboldt Bay.

Numerous agency employees, businesses and individual volunteers are to be commended for their dedication of seeing this project through to its completion. Special thanks to those individuals willing to go forth in driving rain to collect samples and field data, transport samples to the analytical laboratories, then return to their 'normal' lives. Special thanks to the following individuals, for without them this study would not have been realized as a community endeavor.

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Acronyms and Abbreviations

DHS-PSSU - Department of Health Services Preharvest Sanitary Shellfish Unit
E. Coli – *Escherichia coli*
ELAP – Environmental Laboratory Accreditation Program
GPS – Global Positioning System
HBSTAC - Humboldt Bay Shellfish Technical Advisory Committee
mg/day Milligram per day
km – Kilometer
MPN –Most Probable Number
MTF – Multiple Tube Fermentation
NCRWQCB - North Coast Regional Water Quality Control Board
NPDES – National Pollutant Discharge Elimination System
SWRCB – State Water Resource Control Board
Area A - DHS-PSSU Classified Growing Areas
Area B –DHS-PSSU Classified Growing Areas
Area C – DHS-PSSU Classified Growing Areas

I. Executive Summary

Humboldt Bay is located on the coast of Northern California in Humboldt County, California, 270 miles north of San Francisco. Commercial aquaculture has successfully produced shellfish since the mid-1950's in Humboldt Bay. Currently four state-certified shellfish harvesters are active in the Bay tidelands. Land uses within the watershed include timber, agricultural, rural residential, urban and commercial/industrial activities.

The North Coast Regional Water Quality Control Board established a Technical Advisory Committee for Humboldt Bay as a result of the 1993 Shellfish Protection Act (SB 417). Under this Act, Regional Water Boards were required to form a technical advisory committee if a commercial shellfish growing area was determined to be threatened. Humboldt Bay met the threatened criteria, based upon the number of days each year that the Bay is closed to shellfish harvesting due to rainfall closure criteria established by Department of Health Services – Preharvest Shellfish Sanitation Unit (DHS-PSSU).

The Humboldt Bay Shellfish Technical Advisory Committee members coordinated and conducted a study to investigate tributary coliform loading characteristics and evaluate Department of Health Services closure criteria based upon impacts to the bay waters. The study was designed to (1) evaluate existing shellfish harvesting closure criteria, and (2) to determine the extent of fecal coliform concentrations contributed by Humboldt Bay tributaries, and (3) identify, where possible, those areas warranting additional investigation.

Investigation Method

This study was conducted at 51 water sampling stations between October 1999 and June 2000, over six separate events (two dry weather and four wet weather events). Of the 51 stations, 17 were located within the bay and 36 sites within the watershed. In addition to bay water sampling, five sentinel oyster stations located at select water quality monitoring stations were used to obtain shellfish tissue samples.

This resulted in over 1,000 discrete grab water and 50 shellfish tissue samples collected to develop fecal coliform and *Escherichia coli* (*E. coli*) concentration characteristics from tributary and bay waters. Dry weather samples were collected from each of the 51 stations and tissue samples from the five sentinel stations one day per event. Wet weather sampling was initiated when a precipitation in excess of 0.50" within a 24-hour period triggered a rainfall harvest closure for growing areas. Sampling occurred during the three consecutive days and Day X (the first day that DHS-PSSU routinely re-opens shellfish harvesting activities) for a total of four days sampling per wet weather event.

Fecal coliform and *E. coli* analysis was conducted using *Standard Methods for the Examination of Water and Wastewater*, Methods 9221 and 9221(F) and *Standard Methods for the Examination of Seawater and Shellfish*.

Conclusions of the Study

The study results support the following:

- Overall, current management and regulations of shellfish harvesting criteria are effective. The results of this study support existing DHS-PSSU shellfish harvesting area rainfall closure criteria for the protection of public health.

- Bay waters consistently meet NCRWQCB water quality objectives during periods when growing areas are open to harvest activities.

- Fecal coliforms contributed from tributaries have an episodic impact upon Bay waters during rainfall events. However, dispersion of storm water runoff, tidally induced circulation and mixing, and organism die-off result in bay water meeting water quality objectives within timeframes established by DHS-PSSU's closure criterion.

- Fecal coliform concentrations indicate a variety of non-point source within the watershed.

II. Introduction

This report presents investigative findings and recommendations following coliform monitoring activities conducted around and in Humboldt Bay between October 1999 and June 2000. The study was designed to (1) evaluate existing shellfish harvesting closure criteria during rainfall events, and (2) determine the extent of fecal coliform concentrations contributed by Humboldt Bay tributaries, and (3) identify, where possible, areas warranting additional investigation.

Background

In 1993, the California State Legislature passed the Shellfish Protection Act (SB 417), requiring the appropriate Regional Water Quality Control Board to form a technical advisory committee if a commercial shellfish growing area was determined to be threatened. Humboldt Bay met 30 days per year closure based on rainfall criteria.

In 1995, the Humboldt Bay Shellfish Technical Advisory Committee (HBSTAC) was formed pursuant to SB 417 requirements. The HBSTAC's goal was to develop investigation and remediation strategies to reduce pollution affecting the shellfish growing waters of Humboldt Bay by defining pollution contamination, identifying pollution sources (point and non-point), developing a literature data base, developing a strategy to identify and fill data gaps, quantifying economic impacts of shellfish harvesting closures, developing and recommending strategies to reduce pollutant loading and recommending pollution reduction strategies.

In findings released April of 1999, the HBSTAC determined a water quality study was necessary to investigate tributary coliform characteristics and evaluate Department of Health Services rainfall closure criteria to determine coliform loading impacts to the bay waters. This report summarizes the field sampling and analytical methods used to determine fecal coliform and E.*coli* concentrations from Humboldt Bay tributaries and their impact to bay water and shellfish meat tissue. In addition, the purpose of this report is to describe the preliminary evaluation of the following objectives:

1. Evaluate existing shellfish harvesting closure criteria during rainfall events;
2. Determine the extent of fecal coliform concentrations contributed by Humboldt Bay tributaries, and
3. Identify, where possible, areas warranting additional investigation.

Humboldt Bay Watershed Description

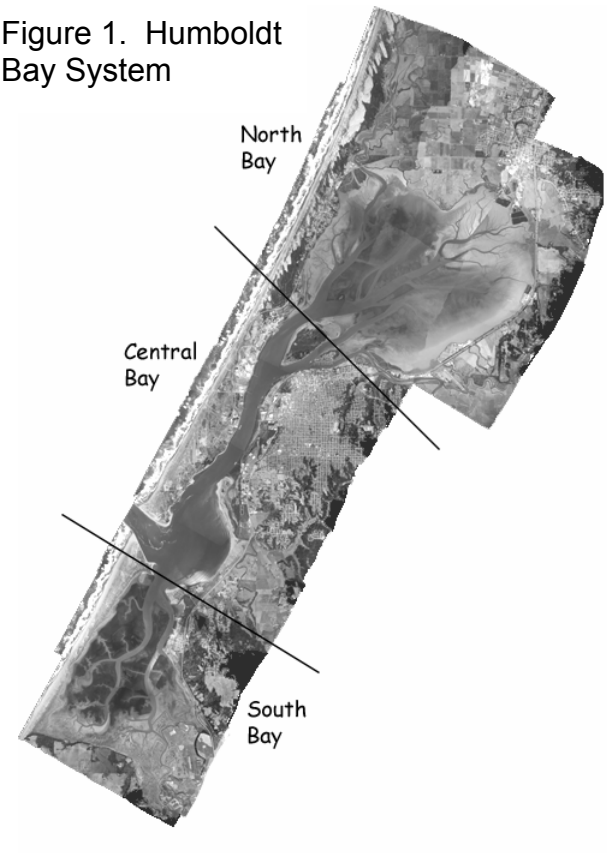
Humboldt Bay, located in Humboldt County, California is 270 miles north of San Francisco. Resembling an hour-glass in configuration, the Bay is long relative to width, 14 miles in length and ranges in width from 0.5 to 4.0 miles. Humboldt Bay has a surface area of 16,000 acres (23.4 square miles) characterized by tidal flats, channels and freshwater and salt marshes. The bay is separated from the Pacific Ocean by a sand spit, separated approximately in the center by a shipping channel and rock jetties.

The Humboldt Bay watershed encompasses approximately 213 square miles. The upper watershed is characterized by steep, forested mountainous terrain and the lower watershed includes agricultural lands and urban community activities. The region

typically experiences moderate to cool wet weather. Eighty-five percent of the mean annual precipitation of 40" falls between October and May. Previous bacterial pollution studies document that a significant portion of fecal coliform loadings are associated with rainfall-related runoff from bay tributaries.

Three sub-bays comprise the Humboldt Bay system:

Figure 1. Humboldt Bay System



North (or Arcata Bay) - North Bay is bounded on the south by the multi-span Highway 255 bridge that joins Eureka and the communities and beaches of the North Spit. Mad River Slough is a long arm of North Bay that includes one growing area (T2a). This is one of the largest sub-bays. Encompassing the entire northerly end, it is a wide, shallow bay 7.3 km wide and 6.6 km long, covering 9,400 acres. Tributaries include Mad River Slough, McDaniel's Slough (Jane's Creek), Butcher's Slough (Jolly Giant Creek), Gannon Slough (Campbell, Fickle Hill, Grotzman and Beith Creek), Jacoby Creek, Ryan, Washington and Eureka Slough. Commercial aquaculture activities are conducted within North Bay.

Central Bay (Entrance Bay) – is 3.6 km long and 2.5 km in width. Central Bay connects the North and South Bays and exchanges tidal waters through the bay inlet to the ocean. Commercial shipping is restricted to the dredged channel and docks along this section of the Bay. Commercial aquaculture facilities utilize docks on the western portion of the Central Bay for floating seed culture systems. The shoreline surrounding Entrance Bay is occupied by port facilities engaged in shipping, commercial fishing, associated commercial services and other industrial activities around the bay. Elk River is the primary tributary. City of Eureka storm drain outfalls are found along the City's waterfront.

South Bay – is located south of the South Jetty. This shallow sub-bay is 6.6 km long and 4 km wide, covering 4400 acres. The Humboldt Bay National Wildlife Refuge is located entirely within the South Bay. Commercial and recreational docks, marinas, shipyard and a fish processing plant are located in the South Bay. Salmon Creek is the primary tributary. No sampling was conducted in South Bay during this study.

Land Uses

Land uses within the surrounding watershed include agricultural (livestock and timber) activities, urban communities, industrial activities, low-density residential and protected refuge lands. Historically, agricultural activities have been an important part of the local economy. However, the number of mills and number of dairy, cattle and sheep ranching activity has declined over the past 15 years. Residential and commercial development, in general, has increased around the bay.

Agencies with land use planning jurisdiction include the cities of Arcata and Eureka, County of Humboldt and the Humboldt Bay Harbor, Recreation and Conservation District (HBHRCD). Development and land use activities within Arcata and Eureka are governed and enforced through their community General Plan and Local Coastal Plans. Development and land use activities within unincorporated lands around Humboldt Bay are implemented through the Humboldt Bay Area Plan. Land use within Humboldt Bay and to an elevation of mean higher high water (MHHW) fall within the regulatory jurisdiction of the HBHRCD.

The cities of Arcata (population 16,800) and Eureka (population 26,000) support mixed industrial, commercial, retail and residential activities. Each municipality maintains and operates a wastewater collection system and centralized wastewater treatment facility and conducts industrial pretreatment activities and storm drain educational programs. Other areas served by water and sewer services include the Greater Eureka area (Myrtle, Cutten, portions of Ridgewood, Pine, Rosewood, Humboldt Hill, Fields Landing and King Salmon) and Manila. The remainder of improved bayland parcels are served by septic systems. Table 1 summarizes tributaries and area communities by sub-basin

Table 1 Tributaries and Communities by Sub-basin

Sub-bay	Tributaries	Communities
North Bay	Mad River Slough McDaniel's Slough (Jane's Creek) Butcher's Slough (Jolly Giant Creek) Gannon Slough (Campbell, Fickle Hill, Grotzman and Beith Creeks) Jacoby Creek Ryan Slough Washington Slough Eureka Slough	Manila City of Arcata Bayside Jacoby Creek Indianola/Walker Point Greater Eureka Area (portion)
Central Bay	City of Eureka Storm drains Elk River	Eureka Woodley Island Marina Indian Island Fairhaven Samoa Greater Eureka Area (portion)
South Bay	Salmon Creek	Humboldt Hill Pine Hill Fields Landing King Salmon

Point Source Dischargers

The North Coast Regional Water Quality Control Board (NCRWQCB) administered National Pollutant Discharge Elimination System (NPDES) permits to six facilities discharging to Humboldt Bay during the study period. Three major dischargers are the wastewater treatment facilities of Arcata, Eureka and College of the Redwoods. Of the three, the City of Arcata's facility is the only major point source discharging directly to North Bay. The City of Eureka facility controls discharge releases to coincide with the ebb tide, so that disinfected effluent clears the bay mouth and discharges to the ocean. College of the Redwoods discharges into South Bay. Remaining permitted dischargers include Pacific Gas and Electric's (decommissioned) nuclear power plant cooling water discharge, Eureka Fisheries (Fields Landing – closed November 2001) and Sierra Pacific Lumber Mill (Manila).

Storm water permits exist for some industrial facilities located around Entrance Bay. All permitted facilities were in discharge or "reported" compliance during the study duration. Table 2 summarizes NPDES and Storm water monitoring permittees adjacent to Humboldt Bay in operation during the study period.

Table 2. NPDES and Storm water Permits

Sub-bay	NPDES Permittee	Storm water Permittee
North Bay	Arcata Wastewater Treatment Plant Sierra Pacific	City of Arcata Corporation Yard Cal-Trans Corporation Yard - Bracut Simpson Timber Co. –Brainard Murray Field Airport Coco-Cola Distribution Plant
Central Bay	Eureka Wastewater Treatment Plant	Phil Kadle Boat Yard Samoa Pacific Cellulose Pulp Mill Simpson Chip Export Facility & Pulp Mill Pacific Affiliates Unocal Distribution Facility Chevron Distribution Facility Hilfiker Pipe Schmidbauer Lumber
South Bay	College of the Redwoods Wastewater Treatment Plant PG&E Power Plant Eureka Fisheries (closed November 2001)	Environmental Technology Industries Humboldt Bay Forest Products

Non Point Sources Pollution

Non-point source discharge activities which may impact the Bay include surrounding watershed activities by domestic livestock, wildlife, migratory fowl, septic systems, horticultural runoff, urban runoff, marina and boating activities related to live-aboard boats, Cal-Trans and railroad maintenance related activities and rainfall related releases.

Shellfish Industry

Humboldt Bay supports the largest commercial industry for growing and harvesting activities of bivalve molluscan shellfish in California. Growing and harvesting of the Pacific oyster in Humboldt Bay was first undertaken in 1953 when 20 cases of seed

were planted on an allotment in North Bay. In 1954 an additional 100 cases of seed were planted. The success of these plantings demonstrated that Pacific oysters could be grown commercially in Humboldt Bay. Coast Oyster Company began commercial mariculture in 1955.

Commercial shellfish growing and harvesting activities are permitted only within North Bay where approximately 1,800 acres are available as certified growing areas by Dept. of Health Services – Preharvest Shellfish Sanitation Unit (DHS-PSSU).

Coast Seafoods, Inc. (formerly Coast Oyster) is the largest producer of oysters in Humboldt Bay raising Pacific Oyster (*Crassostrea gigas*) Kumamoto Oyster (*Crassostrea sikamea*) and the Manila Clam (*Tapes phillippinarum*). In addition to Coast Seafoods, North Bay Shellfish, Aqua-Rodeo Farms and Emerald Pacific Farms are engaged in growing and harvesting commercial oysters in Arcata Bay. Kuiper Mariculture/Shellfish Seed Services produces oyster and clam seed for local and worldwide distribution.

The shellfish growing and harvesting industry infused an excess of $2 million dollars during this study period into the North Coast economy through product export. On average, commercial growers plant and process over 80,000 gallons of shucked oysters and 100,000 dozen Kumamoto shellstock oysters from Humboldt Bay per year.

Historical Bacterial Data

Previous bacterial pollution studies[1] have documented that a significant portion of fecal coliform contamination of Arcata Bay is associated with rainfall-related runoff from tributaries within the Humboldt Bay watershed.

It was originally proposed that a retrospective compilation of bacteriological studies dating back to 1953, including an inventory of all previous sampling sites and corresponding water quality information for each site, and a compilation of wastewater treatment system improvements be conducted. Intern assistance was needed to perform data entry and compilation as part of the retrospective study. This study originally proposed to employ a student intern with the Sacramento office of the DHS-PSSU, however this was not completed.

Indicator Organisms

Shellfish accumulate and filter water for nutrient values, and if waters are impacted by fecal wastes, shellfish may become contaminated by many types of microorganisms and viruses, thereby potentially infecting shellfish consumers. To protect shellfish consumers, water samples are routinely examined and analyzed for total and fecal coliform indicator organisms.

Indicator organisms are used to demonstrate the presence of wastes, using the assumption that if the indicator organism is detected, pathogenic bacteria may also thrive and be uptaken from the environment. Indicator organisms are chosen because

[1] Bacteriological studies are provided in the References section.

they are typically easy to monitor, correlate with populations of pathogenic organisms and can assist in the determination of the presence or absence of human or animal fecal pollution.

Bacteriological water quality objectives applicable to Humboldt Bay and surrounding watershed include water quality and shellfish tissue using fecal coliform indicators. As an indicator, the fecal coliform group is frequently used as it is more specific to fecal contamination than the ubiquitous Total coliform group. While not a perfect indicator, the fecal coliform group is the accepted microbiological indicator group used by DHS-PSSU as the primary regulatory tool for all commercial shellfish growing areas.

E. coli is the most frequent fecal coliform type found in the intestinal tract of man and other warm blooded animals and is rarely found outside the gut except in association with excretal contamination.

Water Quality Objectives

The North Coast Water Quality Control Board defines water quality objectives for (1) shellfish growing areas and (2) watersheds in the ***North Coast Basin Plan*** (Plan)***.*** Objectives for shellfish growing waters (applied within the Bay waters) state "*the geometric mean for fecal coliform shall not exceed 14 MPN per 100 ml and that the 90th percentile value for fecal coliform shall not exceed 43 MPN per 100 ml*." This Study applied the 90th percentile value of 43 MPN in the interpretation analyses of bay water samples.

The Plan does not provide numerically defined bacteriological water quality objectives for bay tributaries and surrounding watersheds, stating "*the bacteriological quality of waters of the North Coast Region shall not be degraded beyond natural background levels*." Strictly for the purposes of this report, individual site Dry Weather coliform concentrations were used to 'define' site specific background concentrations[2]. Tributaries exhibiting coliform concentration values exceeding the applied 'background' concentration MPN can not be interpreted as being 'impacted' or 'degraded'.

Shellfish Tissue Objectives

Results of shellfish tissue analysis are not used as a monitoring or regulatory tool to evaluate shellfish growing areas; however, if samples exceed 230 MPN fecal coliform per 100 grams of meat Department of Health Services-Food and Drug Branch prohibits shipment of harvested shellstock into interstate commerce. This standard was applied for the interpretation analyses of shellfish tissue samples.

[2] Background concentrations were based upon a single sample result from each sample location. Background concentrations were estimated by using the sample concentration collected from the last Dry Weather sampling event and should not be used to infer degraded or impacted conditions.

III. Sampling and Microbiological Examination Methods

Sample Program and Locations

The sampling program was initiated October 20, 1999 and concluded June 19, 2000. Over 1,000 discrete grab water and 50 shellfish tissue samples were collected to determine representative tributary, bay water and shellfish tissue coliform concentration characteristics during dry and wet weather events. All samples were examined for fecal coliforms and *E. coli*.

Sampling was conducted over six separate sampling events (two dry weather and four rainfall events) and included 50 water sampling stations. Of the 50 stations, 34 were watershed locations and 16 were located within the bay (*Table 3 and 4*).

Table 3. Watershed Sample Locations

Arcata Loop	**Description**	***Eureka Loop***	**Description**
T1	Manila	**T13B**	48" Culvert, P Street and Waterfront, Eureka
T2c	Lanphere Rd	**T13C**	24" Culvert, L Street and Waterfront, Eureka
T4a	Jane's Creek, Samoa Blvd.	**T13D**	12" Culvert, J Street and Waterfront, Eureka
T4e	Jane's Creek, 17th St	**T13E**	54" Culvert, C Street and Waterfront, Eureka
T4I	Jane's Creek, West End	**T13F**	30" Culvert, Commercial St at Waterfront, Eureka
T5a	Jolly Giant, Butcher's Slough Bridge	**T13G**	Boat Ramp Launch, Waterfront St
T5c	Jolly Giant, Samoa Blvd.	**13H**	West 14 and Railroad
T5i	Jolly Giant, Park	**13I**	30" Del Norte and Railroad
T7	Gannon Slough, Highway 101	**T13J**	Palco Marsh
T7Ba	Beith Creek, Old Arcata Rd	**T13K**	Palco Marsh
T7Gb	Grotzman Creek/Buttermilk/Samoa	**T13N**	48" Culvert Truesdale and Christie
T7Ca	Campbell Creek Union/Sports Complex	**T13O**	36" Culvert at the west end of McCullen's St
T8	Jacoby Creek, Highway 101	**T13P**	Ditch north of the Eureka Sewage Treatment Plant
T8a	Jacoby Creek, Old Arcata Rd	**T14a**	Elk River at Highway 101
T9	Washington Slough, Highway 101	**T14A**	Swain Slough at Pine Hill Road
T10A	Fay Slough, Old Arcata Rd	**T14Aa**	Martin Slough Pine Hill Road
T11A	Freshwater Slough, Devoy Rd		
T11B	Ryan's Slough, Mrytle		

Table 4. Bay and Shellfish Tissue Sample Locations

	Bay Sites		***Tissue Samples***
T2a	NBSC float in Mad River Slough above water pipe crossing	***T2a****	*NBSC float in Mad River Slough above water pipe crossing*
21	Mad River Slough Channel west of CSC Mad River Beds		
22	Mad River Beds	***22****	*Mad River Beds*
24	CSC Bird Island Beds, Central		
31	NBSC Parcel 1 Beds	***33****	*C4A NBSC Parcel 1 Beds*
33	C4A NBSC Parcel 1 Beds		
34	Southwest end of CSC Sand Island Beds		
45	CSC Sand Island Beds	***45****	*CSC Sand Island Beds*
HD1	Harbor District Marina - Dock A		
51	C10A CSC East Bay Beds		
52	CSC East Bay Beds	***52****	*CSC East Bay Beds*
53	CSC Gunther Island Beds		
41	Arcata Ruins		
50	East Bay at CSC oyster seed floats north of east bay bed		
60/T11	Eureka Slough at RR Bridge		
11	at Sandy Point		
T3	Near Mad River Slough - 3 culvert outfalls		

For discussion purposes, the watershed results were further divided into 13 sub-basins; Manila, Mad River Slough, Jane's Creek, Jolly Giant Creek, Gannon Slough, Jacoby Creek, Washington Slough (Rocky Gulch), Faye Slough, Freshwater Creek, Elk River, North Eureka, Central Eureka, and South Eureka. Sample location coordinates were recorded by using a global positioning system (GPS) unit (Appendix V).

* Five sentinel oyster stations located at select water quality monitoring stations were used to obtain shellfish tissue samples. The sentinel stations were selected on the basis of proximity to sources of suspected fecal contamination, past history of contamination and accessibility. Sample location coordinates were recorded by GPS (Appendix V). Water quality samples were also collected at these sites.

Figure 2. Humboldt Bay and watershed fecal coliform monitoring stations.

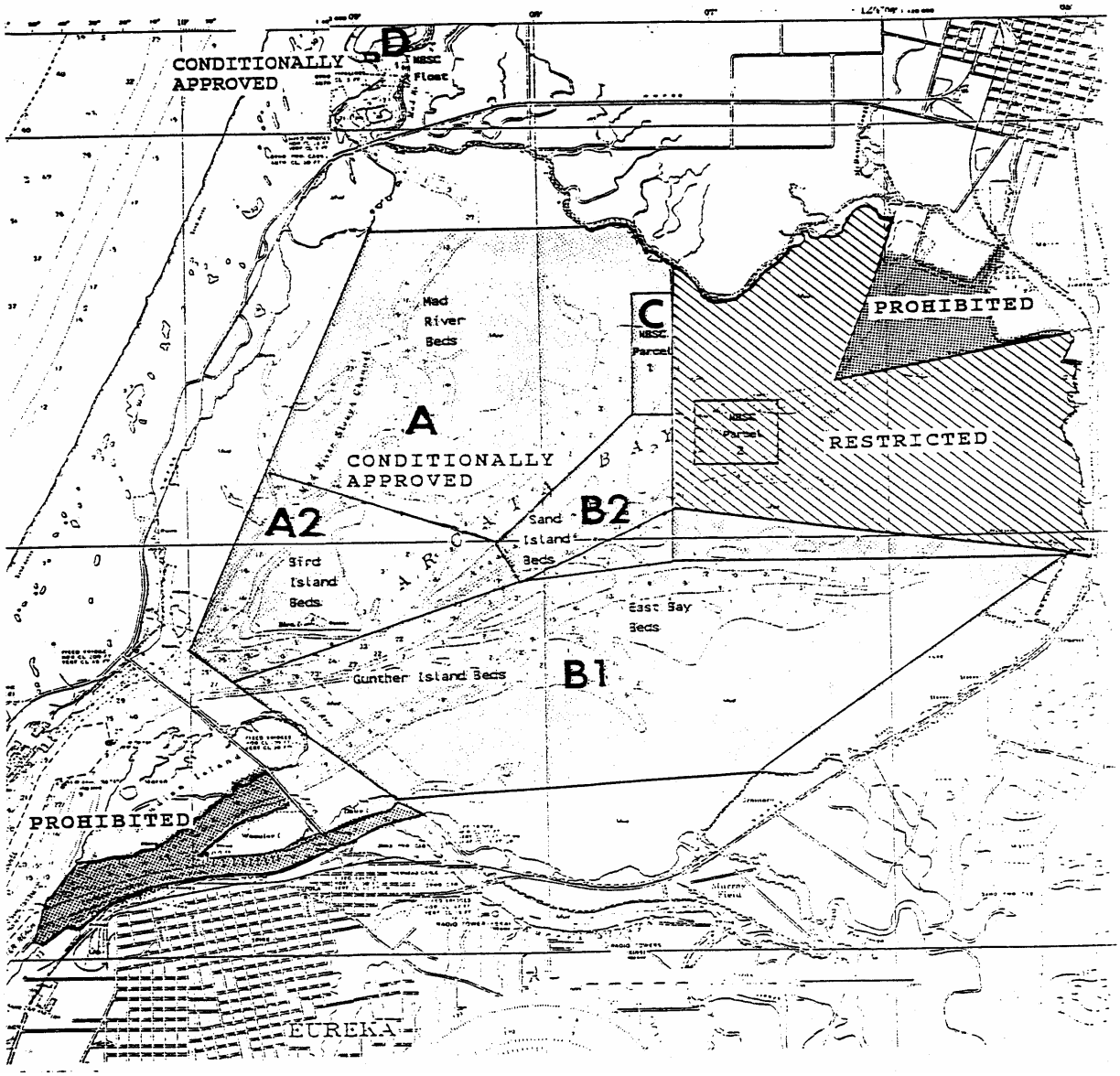


Figure 3. Humboldt Bay Shellfish Growing Areas and Classifications (Calif. Dept. Health Services 1999).

Sample Collection and Transport

Collections of water and tissue samples were conducted by three sampling teams. Collection personnel were provided route maps, trained in proper collection procedures, necessary sampling equipment (manhole hooks, etc) and storage/transportation coolers. For safety purposes, sample collection was restricted to daylight hours. Samples were collected at pre-determined sample locations along tributaries and storm drain infrastructures. Sample times coincided with an ebb tide to represent bacterial concentrations indicative of the watershed. DHS-PSSU staff monitored rainfall and contacted sampling teams after one-half inch threshold of rainfall was recorded at the National Weather Service rain gauge in Eureka, California. Except for the constraints of daylight and tide cycle, sampling teams began sample collection at the earliest opportunity following rainfall threshold exceedence.

Water samples were collected in 125 ml sterile IDEXX screw cap bottles approximately 1 foot beneath the water surface. Each sampling team collected a blank sample at the beginning of each day's sampling run as temperature control blanks to assess proper sample handling and storage. Sample bottles were labeled with the bottle number, location, date, time, water temperature, salinity and collection method. Information was logged onto a field data sheet with other notations. For *Sentinel oyster tissue* samples, whole oysters were collected and placed into a sterile plastic bag with a water proof identification tag and collection information and noted accordingly.

All water and tissue samples were placed into ice chests with frozen gel packs to ensure temperature stability within the range 4 -10 degrees Celsius during storage and transport to the laboratory. At no time did water and tissue sample collection and inoculation exceed a 24-hour holding time.

Sampling Events and Frequency

Dry weather sampling was conducted during periods when all shellfish growing areas were opened for harvesting activities and there had been no measurable rainfall for the previous 72 hours and the 10-day cumulative rainfall was less than 1 inch. Dry-weather sampling events occurred October 20, 1999 and June 19, 2000. For each event, water samples were taken from each of the 50 water quality monitoring stations, tissue samples were taken from the five sentinel stations and analyzed for fecal coliform and E.coli.

Wet Weather sampling (rainfall event) was conducted during four rainfall events from November 1999 to April 2000. To obtain samples reflecting unsaturated and saturated soil conditions, sampling activities were staggered in the fall, winter and late spring. Rainfall events were defined as a storm event with a precipitation in excess of 0.50" within a 24-hour period. This threshold coincides with that which currently triggers a rainfall harvest closure of shellfish growing area for several of the growing areas in Humboldt Bay as stipulated by the '*Management Plan for Commercial Shellfishing in Humboldt Bay'* (Calif. Dept. Health Services 1999). Each event consisted of a total of four (4) sampling days. Day 1, 2, and 3 coincided with the first, second, and third day of closure following a rainfall event. Day *X* was defined as the first day that DHS-PSSU re-opened for harvesting activities as established in the Management Plan. (Table 5)

Table 5 – Event Sampling Dates

Event	Day 1	Day 2	Day 3	Day X	Tissue 1	Tissue X
E 1	Oct 20 '99	-	-	-	Oct 20 '99	-
E 2	Nov 09 '99	Nov 10 '99	Nov 11 '99	Nov 14 '99	Nov 09 '99	Nov 14 '99
E 3	Jan 10 '00	Jan 11 '00	Jan 12 '00	Jan 25 '00	Jan 10 '00	Jan 25 '00
E 4	Feb-13 '00	Feb-14 '00	Feb-15 '00	Feb 19 '00	Feb-13 '00	Feb 19 '00
E 5	Apr 16 '00	Apr 17 '00	Apr 18 '00	Apr 21 '00	Apr 16 '00	Apr 21 '00
E 6	Jun 19 '00	-	-	-	Jun 19 '00	-

Reference Laboratories and Examination Methodology

Contracts were established for the use of three California State certified Environmental Laboratory Accredited Program (ELAP) laboratories to analyze the water and shellfish tissues: Humboldt County Department of Public Health Laboratory, North Coast Laboratory and the City of Eureka Water/Wastewater Laboratory.

Laboratories examined water samples for fecal coliform and *E. coli* using *Standard Methods for the Examination of Water and Wastewater 19th Edition, Method 9221 - Multiple Tube Fermentation (MTF) Technique for Members of the Coliform Group Method* and *Standard Method's 9221 F (Proposed)* to examine presence of *Escherichia coli* (E.coli). MTF technique results provide a statistically valid Most Probable Number (MPN) estimate of coliform density.

All samples were set up within 24 hours of sample collection. Laboratory personnel inoculated tubes with appropriate dilutions, as directed by HBSTAC. All samples were examined for presumptive total coliform phase of MTF. However, as a measure of laboratory quality control, 10% of the total coliform positive tubes received confirmation analysis.

The "*Laboratory Procedures for the Examination of Seawater and Shellfish*" 4th and 5th editions serve as the model procedure for total and fecal coliform examination of shellfish tissue sample(s) by the Humboldt County Public Health Laboratory. A total of 50 shellfish tissue samples were examined for fecal coliform and E. coli. Laboratory personnel inoculated all plates with processed shellfish tissue samples within 24 hours of tissue sample collection.

Sample Collection and Transport Quality Assurance

Sample collectors were instructed and provided written procedures for sterile sample collection, labeling procedures, use of temperature blanks, transportation containers and chain of custody protocols. Upon laboratory delivery, sample containers were inspected for leakage, volume, temperature and proper labeling. Deficiencies were reported on the chain of custody by receiving laboratory personnel.

Each laboratory provided detailed quality assurance protocols addressing chain of custody, sample acquisition, standard operating procedures, sample analysis and reporting sample results.

Quality Control Program

To provide an ongoing demonstration of sample collection integrity, field condition variability, laboratory analytical capability and reporting procedures, several quality control examinations were included in the sample design. These included an Independent Trial Run, Inter-calibration exercises, Split and Field Duplicate Sample examinations. A summary of individual quality control exercises are contained in the following appendices:

- *Appendix II – Inter-laboratory Correlation*
- *Appendix III – Split Sample*
- *Appendix IV – Field Duplicate*

IV. Fecal Coliform Results and Discussions

Screening Methods

Four screening methods were used to qualitatively review the collected data. A graphical summary of tributary, bay water and shellfish tissue samples are attached in Appendix I.

First, for watershed comparison purposes, site specific 'background concentrations' were derived using Event 6 (June 2000) fecal coliform concentration sample results for all watershed sites. Event 6 data was used with the assumption that samples collected reflected an absence of accumulated residual fecal material having been previously flushed by the season's storms. Those sites exceeding the 'background concentration' on Day X were identified as sites warranting additional investigation.

A second method identified sites indicating elevated fecal coliforms concentrations were during Dry Weather events. This provided an indication of the fecal coliforms constantly present, not related to storm water runoff.

Sites exhibiting First Flush characteristics were identified to indicate those sites that might pose a problem during early season storms. First flush depends primarily on the nature and source of the pollution, drainage hydrology, pollutant mobility and pollutant supply. The existence of first flush should not always be assumed as some pollutants may not be mobile, and soils and vegetated surfaces are not generally 'cleansed' as effectively as impervious surfaces. Generally, the first storm event of the season will contain more pollutants than subsequent storm water runoff.

Finally, sites with elevated levels throughout the sampling periods were identified as sites that appear to have a constant fecal coliform loading source. Elevated levels were estimated by grouping Event 6 results by basin (Arcata and Eureka sites) and calculating the median value for each basin. Sample values above the median were considered to be elevated. Based on these factors, the following discussion provides guidance on which water bodies should be examined more closely, but does not necessarily indicate a degraded or impacted condition.

Watershed Samples

As stated earlier in the report, the Water Quality Control Plan for the North Coast Region (1993) does not provide numerically defined bacteriological objectives that may be applied to the tributaries examined. Additionally, mass fecal coliform loading contributed by individual tributaries into Humboldt Bay was unable to be calculated because flow data was not collected from the sampled water bodies.

The following discussion provides guidance on which tributaries should be examined more closely, and does not necessarily infer a degraded or impacted condition.

Arcata Sites

Nineteen sites in Arcata were sampled. Fecal coliform levels during Dry Weather events were typically lower than those collected during Wet Weather events. Characteristically, fecal coliform concentrations were higher during the first Dry Weather Event (Event 1) than during the last Dry Weather event (Event 6). Fecal coliform concentrations of Dry Weather Event 1 samples ranged from 4.5 MPN (60/T11) to 16,000 MPN (T10A). Fecal coliform concentrations at eleven locations were at or below 220 MPN during Event 1. During Event 6, sample results ranged from 9.3 (60/T11) to 5, 000 MPN (T7Ca), with thirteen locations at or below 270 MPN. The median value of these sites was 230 MPN; concentrations above this are considered elevated for comparison purposes.

Fecal coliform concentrations at the ***Mad River Slough*** locations remained consistent and were minimally influenced by Wet Weather Events. Compared to the four Arcata creeks (Jane's Creek, Jolly Giant, Gannon Slough and Jacoby Creek) this basin exhibited lower fecal coliform concentrations.

Wet weather events appeared to minimally influence coliform concentrations at the ***Jane's Creek*** sample locations as there appears to be constant loading sources that warrant additional investigation. In general, Dry Weather coliform concentrations were elevated for all sample locations.

The furthest up-gradient sampling location on ***Jolly Giant Creek***, Shay Park (T5i), generally had lower coliform concentrations than down-gradient locations Samoa Blvd (T5c) and Butcher's Slough (T5a), indicating that fecal coliform loading occurs somewhere between T5i and the other sites. This creek flows through the urban areas of Arcata proper.

In comparison to other watershed sampling locations, ***Gannon Slough*** fecal coliform concentrations were higher, which could be a result of several factors. A tide gate separates T7 (Gannon Slough at Highway 101) from the other sample locations, providing dilution and attenuation in saline waters. The up-gradient locations may have lower flow and therefore, low 'flushing' is occurring, land uses range from urbanized to agricultural activities. From the Arcata Sports Complex (Campbell Creek T7Ca) to Highway 101 (Gannon Slough T7), not much elevational change or recharge occurs.

Based upon Dry Weather and Wet Weather Day X results, ***Jacoby Creek*** sample locations appear to have elevated background coliform concentrations which warrant additional investigation.

Table 6. Arcata Sites Exhibiting First Flush Effects

Location	Description
T1	Manila
T4l	Janes' Creek – West End Road
T8a	Jacoby Creek – Old Arcata Road
T9	Washington Slough – Highway 101
T11A	Freshwater Slough
T11B	Ryan's Slough

Arcata Sites Warranting Additional Investigation

Thirteen (13) sites warrant additional examination. Of these, eight sites appeared to have a constant fecal coliform loading source during Wet Weather events. Six of these sites had at least one elevated Dry Weather sample, which might indicate sporadic fecal coliform sources during early season storm events, but may not be a concern later in the Wet Weather season. One site, Jacoby Creek (T8) experienced elevated Dry Weather sample results, and was only moderately elevated during the Wet Weather sample.

Table 7. Arcata Locations Warranting Additional Investigation

Location	Site Description	Dry Event[1]	Wet Event[2]
T4e	Jane's Creek – 17th Street	**X**	**X**
T4l	Jane's Creek – West End Rd	**X**	
T5a	Jolly Giant – Butcher's Slough		**X**
T5c	Jolly Giant Creek – Samoa Blvd.	**X**	
T5i	Jolly Giant – Shay Park		**X**
T7	Gannon Slough	**X**	
T7Ba	Beith Creek	**X**	**X**
T7Gb	Grotzman Creek	**X**	**X**
T7Ca	Campbell Creek	**X**	**X**
T8	Jacoby Creek	**X**	
T9	Washington Slough	**X**	
T10A	Faye Slough	**X**	**X**
T11B	Ryan's Slough	**X**	

1. Elevated fecal coliform concentrations above the median value of 230 MPN.
2. Sites that appear to have a constant source of fecal coliform (during rainfall events)

Eureka Sites

Sixteen locations in Eureka were sample. Fecal coliform levels during Dry Weather events were typically lower than those collectd during Wet Weather events. Characteristically, fecal coliform concentrations were highter during the first Dry Weather event (Event 1) than during the last Dry Weather event (Event 6). Fecal coliform concentrations of Dry Weather Event 1 samples ranged from 20 MPN (T13C) to 16,000 (several locations). Fecal coliform concentations at six of the sites were at or below 140 MPN during Event 1. During Event 6, sample results ranged from 20 to 3,000 MPN (T13O) with eight locations at or below 80 MPN. The majority of sample locations were storm drains collecting urban related runoff and exhibited a range of coliform concentrations.

First Flush characteristics were exhibited at sampling locations in the **North Eureka** sample sites. Two locations (T13B and T13D) appear to contribute minimal fecal coliform loading following the first wet weather event. Remaining sites appear to contain constant sources of fecal coliform loading.

Sites within **Central Eureka** indicated consistent loading sources which required several rainfall events before cleansing, with the exception of T13I which remained elevated.

During rainfall events, **South Eureka** sites T13N and T13P typically returned to background levels by Day X and over all do not appear to contribute elevated coliform levels except during rainfall events. T13O exhibited elevated fecal coliform levels in comparison to other locations within this watershed.

Fecal coliform concentrations at the **Elk River** locations remained consistent and exhibited constant sources of fecal coliform loading. This sub-basin warrants additional investigation.

Table 8. Eureka Sites Exhibiting First Flush Effects

Location	Description
T13B	P Street and Waterfront
T13K	Palco Marsh
T13P	Ditch north of the Eureka Treatment Plant

Eureka Sites Warranting Additional Investigation

Sixteen sites were examined within the Eureka sub-basin. Of these, eight sites appeared to have constant fecal coliform loading sources during Wet Weather events. The following sites warrant additional investigation.

Table 9. Eureka Locations Warranting Additional Investigation

Location	Site Description	Dry Event[1]	Wet Event[2]
T13C	L Street and Waterfront	**X**	**X**
T13E	C Street and Waterfront	**X**	**X**
T13F	Commercial and Waterfront	**X**	**X**
T13G	Boat Ramp Launch, Waterfront	**X**	**X**
T13I	Del Norte and Railroad Street	**X**	
T13O	McCullens Ave.	**X**	
T13P	Ditch North of Eureka Treatment Plant	**X**	
T14a	Elk River at Highway 101	**X**	**X**

1. Elevated fecal coliform concentrations above the median value of XXX MPN.
2. Sites that appear to have a constant source of fecal coliform (during rainfall events)

Bay Sites

Twenty-three sites were sampled within Humboldt Bay. The NCRWQCB defined 90th percentile value for fecal coliform to not exceed 43 MPN per 100 ml was applied for the interpretation analyses of bay water samples.

In general, Dry Weather coliform concentrations were lower than those found during rainfall events, exceeding 43 MPN at only WQ# 31, a North Sand Island Bay site. Bay sampling stations typically experienced a bacterial concentration increase on Day 2 of each rainfall event, returning to acceptable concentrations when the sites were reopened for shellfish harvesting (Day X).

Bay sites have two orders of magnitude lower fecal coliform levels than watershed sites (ca. 100 v. 10000 MPN). Partial explanation of decreased concentrations include bay water dilution, tidal mixing, removal of bacterially laden waters with the outgoing surface freshwater and natural attenuation. It is important to note that fecal coliform levels above the regulated value were found at North and South Sand Island sites on Day X of Event 4 and in the East Bay on Day X of Events 3 and 4. Sand Island and East Bay sites are near multiple urban creek and slough systems. Urban sites in Arcata and Eureka tributaries showed the highest levels of fecal coliform during this study. Watershed runoff from Arcata watersheds flows directly towards Sand Island. Run off from Eureka has been shown to sweep over East Bay shellfish beds in salinity studies (Barnhart et.al 1992). This could partially explain the “upstream” occurrence of elevated fecal coliform levels in East Bay during rainfall events.

Note that only one Bay site showed fecal coliform concentrations greater than 10,000 MPN, North Sand Island during the Event 2, Day 1. This may result from North Bay slough runoff.

All bay sites showed considerably lower levels of fecal coliform concentrations during Event 5. This suggests that, as the rainy season progresses, bacterial loading from watershed runoff decreased over rainfall events.

Fecal coliform concentrations at all bay sites were elevated during Days 2 and 3 during wet weather events compared to Dry Event and Day 1. After Day 3, fecal coliform concentrations decreased and were below regulatory limits by the harvest opening (Day X). The delay of increased Bay fecal coliform concentrations was expected but had not been shown in previous studies. The elevated levels on Days 2 and 3 for most Bay sites reflects increased the runoff from Bay watersheds during rainfall events.

Samples collected from the **West Bay** site (WQ# 11) and **Mad River Bay** sites (WQ# 21, 22, and 24) indicated coliform concentration elevation during rainfall events, but not to the extent that other Bay sites were affected.

North Sand Island Bay sites (WQ# 31, 33, and 34) showed elevated fecal coliform levels greater than other sites monitored in the Bay. These sites had concentrations above 43 MPN on the first day of the storm events for the first three rainfall events. Site WQ# 31 was the only bay site that had a Dry Weather sample above 43 MPN. Site WQ# 33 had the highest fecal coliform concentration measured: 16,000 MPN on the first day of a rainfall event. By the last rainfall event, fecal coliform concentrations were lower, similar to the West Bay and Mad River sites.

South Sand Island Bay sites (WQ# 41 and 45) behaved similar to the North Sand Island sites, Day 1 and 2 fecal coliform levels were above 43 MPN for the first three rainfall events. By the last rainfall event, fecal coliform concentrations were similar to the West Bay, Mad River, and North Sand Island bay sites.

Fecal coliform concentrations at the **East Bay** sites (WQ# 50, 51, 52, and 53) increased on Day 2 of each rainfall event. Coliform concentrations from these sites were slightly elevated compared to those at the West Bay and Mad River Bay sites, but lower than the Sand Island sites. WQ# 50 site had the lowest fecal coliform concentrations found at any Bay site.

The **Woodley Island Harbor** site (WQ# HD1) is located outside of the certified shellfish growing areas. This site typically showed increased fecal coliform levels on Day 2 of monitoring. Fecal coliform concentrations were similar to those found at the East Bay sites.

Shellfish Tissue Analyses

A total of 50 shellfish tissue samples were examined from five sites within Humboldt Bay. The Federal Food and Drug Branch defined 230 MPN per 100 grams of meat established by the Federal Food and Drug Branch was applied for the interpretation analyses of tissue samples.

Nine of ten oyster samples collected during both dry-weather events met the market standard of 230 FC/100 mL. The one exception was from T2a (Area D) in the Mad River Slough collected October 20, 1999. This sample had an MPN of 330 FC /100mL.

In contrast, of 40 oyster samples collected during wet-weather events, 21 met the standard, and 19 exceeded the standard of 230 FC/100 g MPN. Of the samples that exceeded the standard, 17 were collected during times that the respective growing area were closed to harvest, either due to rainfall closure or seasonal closure.

The remaining two samples were collected when growing areas were open to harvest. During Event 2, Day 1 shellfish samples collected from #45 (Area B) and #33 (Area C) had an MPN of 3,500 and 640 FC/100 g, respectively. These samples were collected less than an hour before areas B and C closed to harvest under current closure rules (six hours after the 24-rainfall total exceeds 0.5 inch). Additionally, during Event 3, Day X, shellfish samples collected from stations #45 (area B2) and #52 (Area B1) had MPN values of 2,400 and 1,100 FC/100MPN, respectively. It should be noted that during the month of January, these areas are under a seasonal harvest closure to allow herring spawning. At the time that these samples were collected, area C and area B1 (represented by Station #52) were reopened to harvest approximately 12 hours previously.

FC concentrations appeared to be higher in during Event 1 compared to Event 6. Interestingly, more rainfall (0.31 inches) was recorded during the 10-day period preceding Event 6 compared to the ten-day period of Event 1 (0.01 inches). Thus, fecal coliform concentrations are not explainable in terms of rainfall. During the fall, large numbers of migratory waterfowl inhabit Humboldt Bay, and these waterfowl may be the source of the somewhat elevated levels of FC observed in the October samples.

None of the samples collected from #22 (Area A) exceeded market standards, regardless of weather. This suggests that the current rules are sufficient for area A, and that additional collection of data may support easing of rainfall rules for this area.

Data collected from #45 and #33 during Event 2 suggests a short time lag between elevated fecal coliform concentrations entering Arcata Bay may manifest as elevated fecal coliforms in oysters. These data may be evidence of a ”first flush” effect with the first significant rain of the season, and that subsequent rain events may be found to cause relatively less fecal pollution in the growing area. More data of oyster fecal coliform concentrations collected shortly after rainfall events during different segments of the rainy season are needed to assess this.

Currently, DHS-PSSU rainfall closure begins 6 hours *after* the total of the past 4 six-hour synoptic rainfall reading exceeds one-half inch as recorded by the National Weather Service in Eureka. Therefore, the current six-hour delay in the start of the closure period may warrant adjustment, if supported by further data.

V. Conclusions and Recommendations

After review of the study results, this study supports the following:

Conclusions

- Overall, current management and regulations of shellfish harvesting criteria are effective. The results of this study support existing DHS-PSSU shellfish harvest closure criteria for the protection of public health.

- Bay waters consistently meet NCRWQCB water quality objectives during periods when growing areas are open to harvest activities.

- Fecal coliforms contributed from tributaries have an episodic impact upon Bay waters during rainfall events. However, dispersion of storm water runoff, tidally induced circulation and mixing, and organism die-off result in bay water meeting water quality objectives within timeframes established by DHS-PSSU's closure criterion.

- Fecal coliform concentrations indicate a variety of non-point source within the watershed.

Recommendations

1. That future studies collect hydrographical information to determine mass fecal coliform loading by individual tributaries into Humboldt Bay.

2. Increase number of Dry Weather Sampling Events to aid in development of naturally occurring background concentration data.

3. Include sample locations in the Fairhaven and Samoa areas.

4. Reduced duration of harvest closure in the rainy season is not recommended from these study results, however comparison of Bay water and shellfish fecal coliform concentrations to total seasonal rainfall would be beneficial to examine possible refinements of the closure system.

5. None of the samples collected from #22 (Area A) exceeded the market standard. This suggests that additional data may support easing of the rainfall closure rules for this area.

6. Currently, DHS-PSSU rainfall closure begins 6 hours *after* the total of the past 4 six-hour synoptic rainfall reading exceeds one-half inch as recorded by the National Weather Service in Eureka. Therefore, the current six-hour delay in the start of the closure period may warrant adjustment, if supported by further data.

VI. References

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Appendix I

Fecal Coliform Graphical Summaries

(Figures 4 – 24)

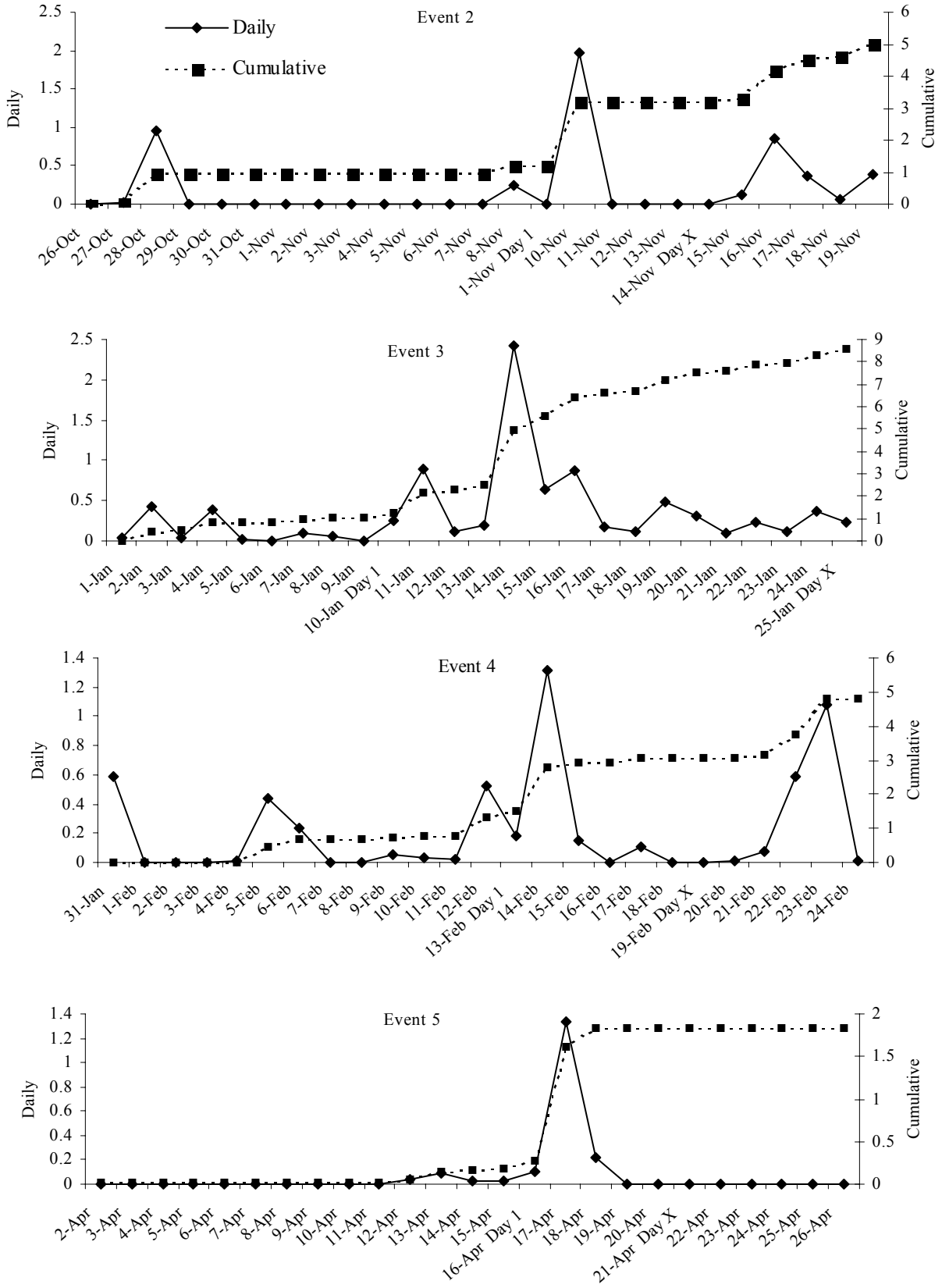
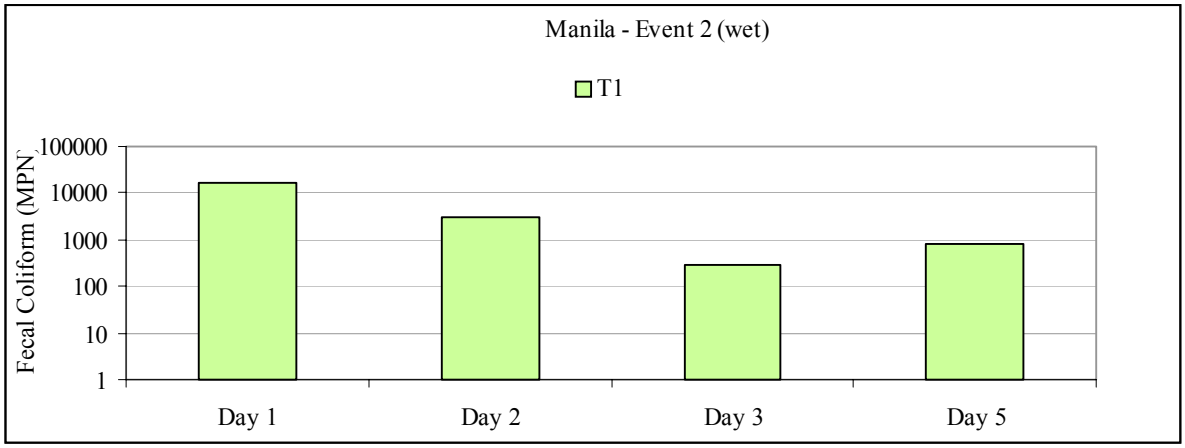
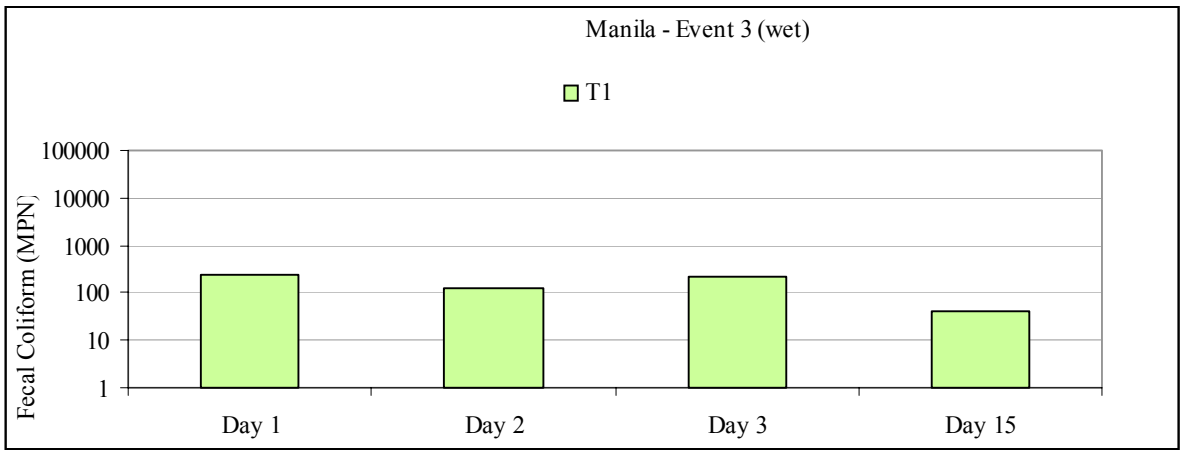
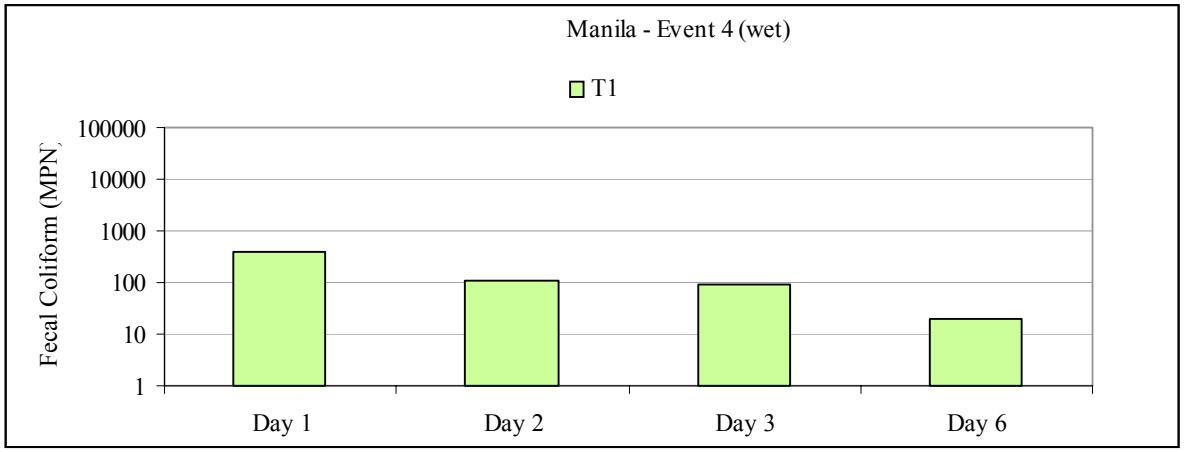
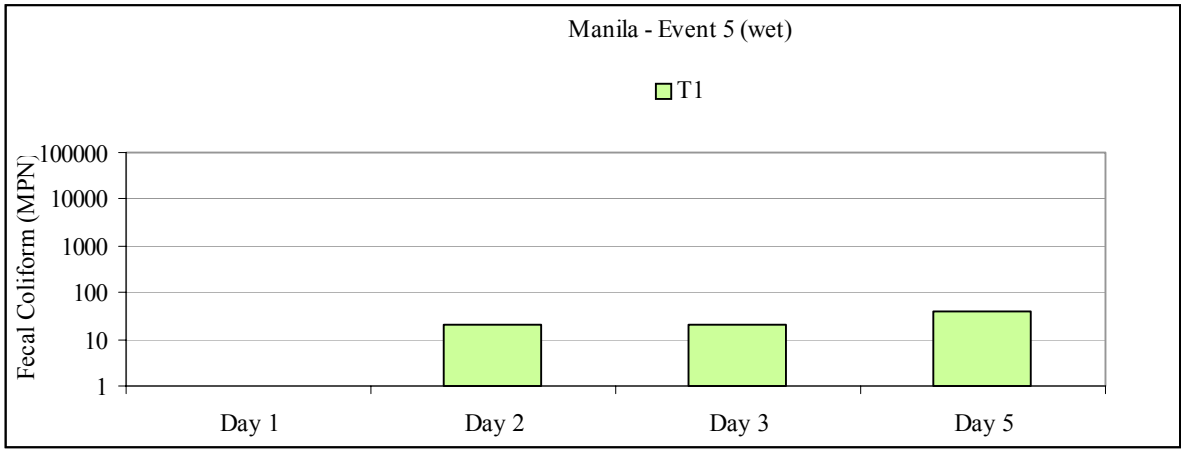


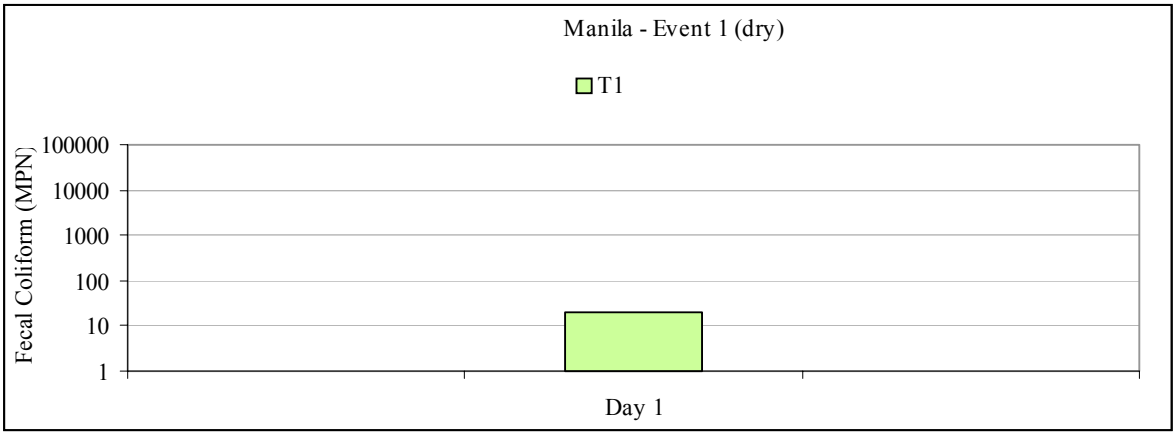
Figure 4 . Humboldt Bay daily and cumulative rainfall in inches for Events 2, 3, 4 and 5. Day 1 and Day X are in indicated. Each graph shows rainfall for a 24 day period around the sampling events.


Manila - Event 2 (wet)
T1
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Manila - Event 3 (wet)
T1
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Manila - Event 4 (wet)
T1
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Manila - Event 5 (wet)
T1
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



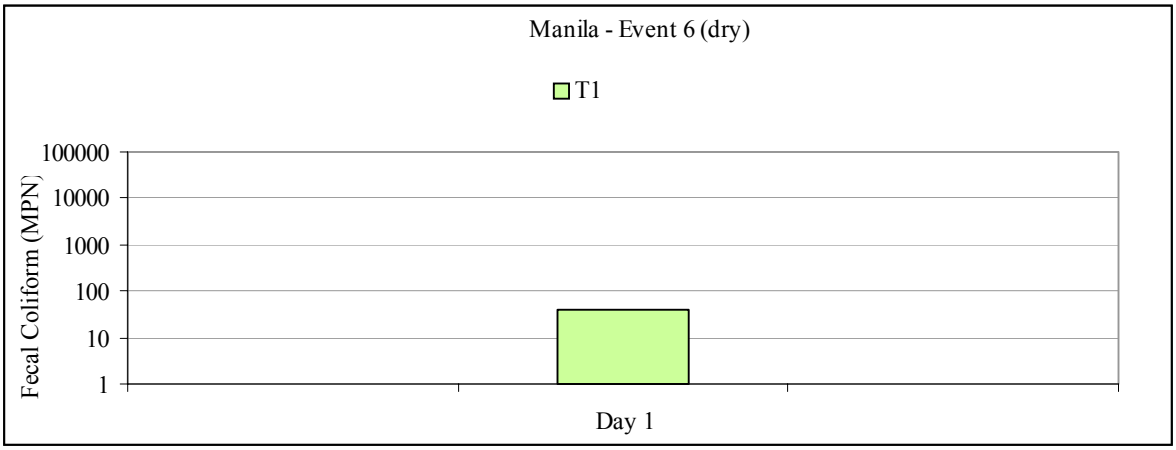
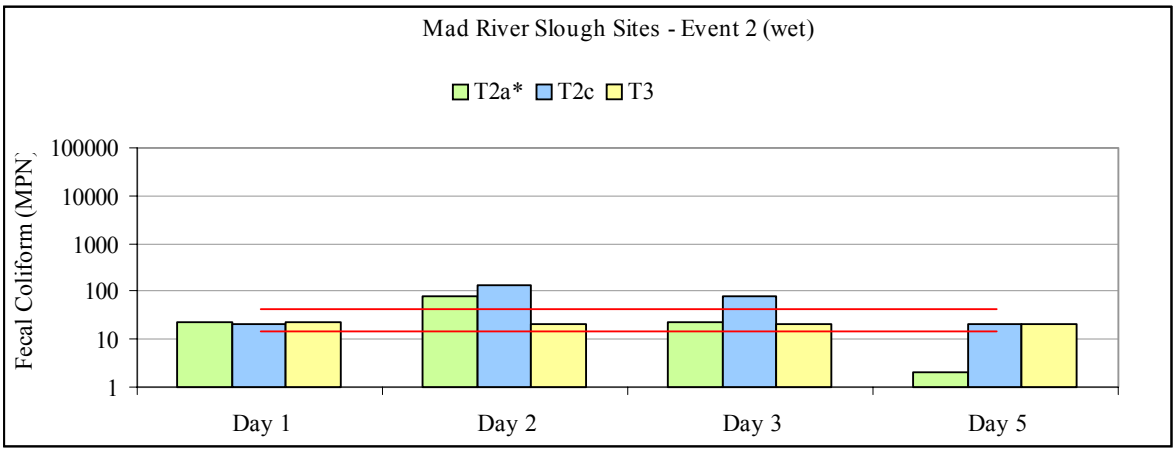
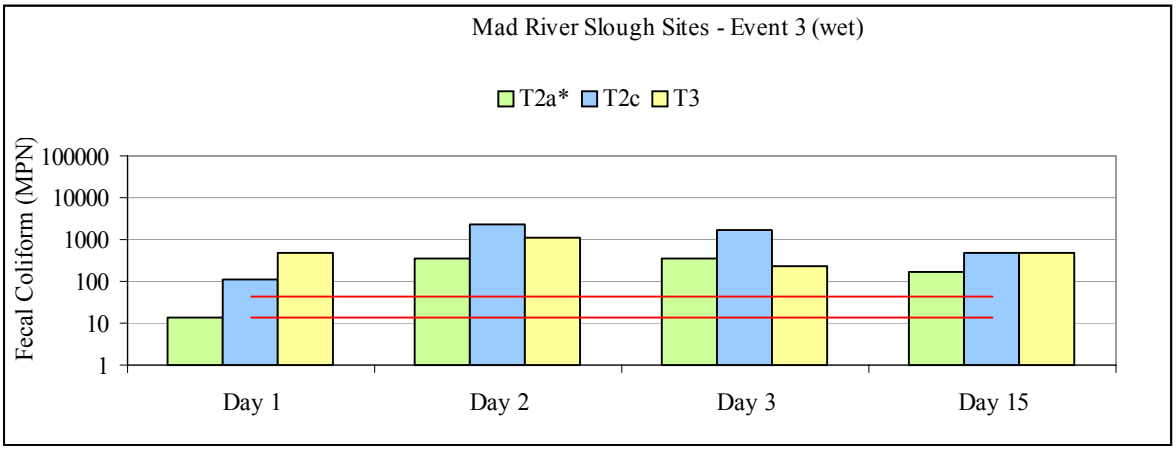
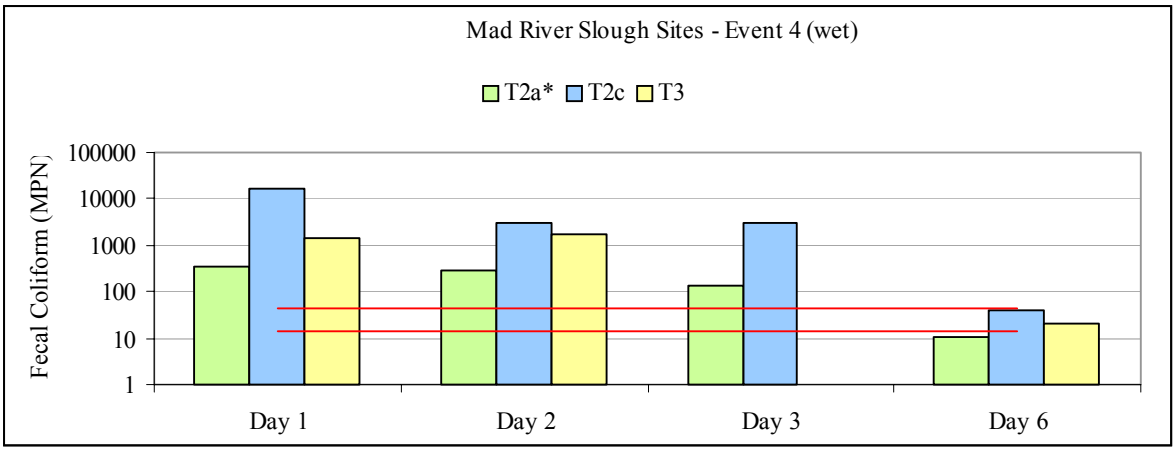


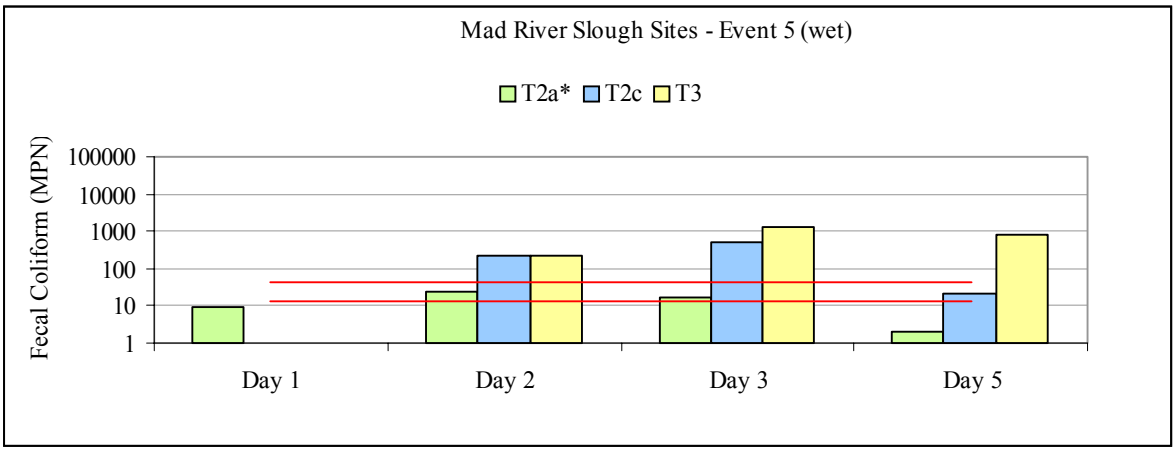
Figure 5.

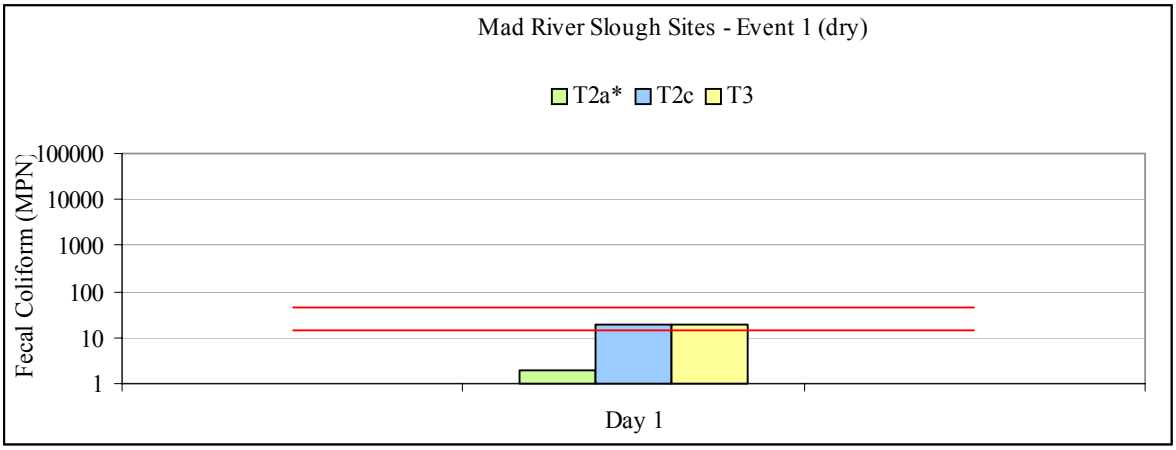
Manila - T1
Background concentration for Site T1 was 40 MPN. With the exception of Event 2, this site had low coliform levels. During the first rainfall event, Day 1 rose to 16,000 MPN decreasing to 800 MPN by Day X. This site demonstrated 'first flush' effect.


Mad River Slough Sites - Event 2 (wet)
T2a*
T2c
T3
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Mad River Slough Sites - Event 3 (wet)
T2a*
T2c
T3
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Mad River Slough Sites - Event 4 (wet)
T2a*
T2c
T3
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Mad River Slough Sites - Event 5 (wet)
T2a*
T2c
T3
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



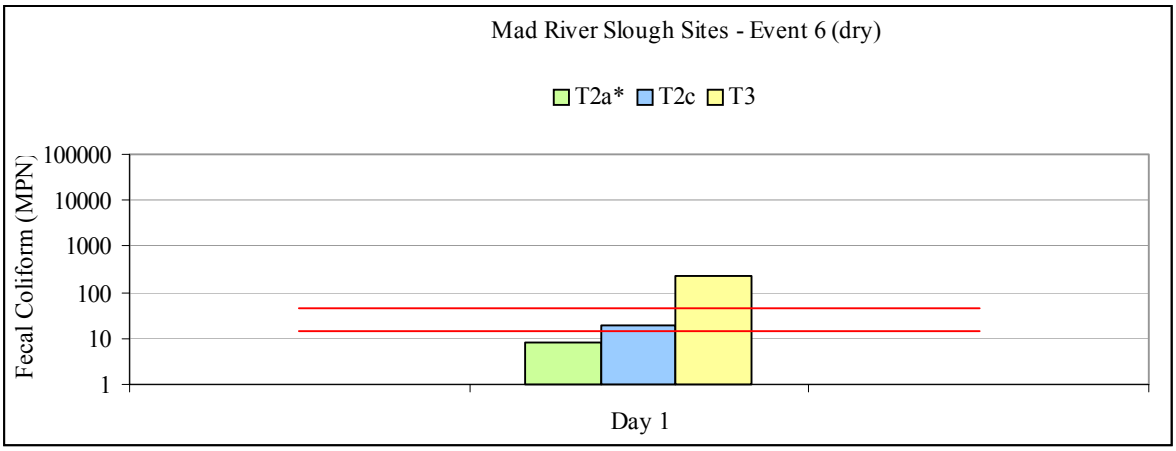
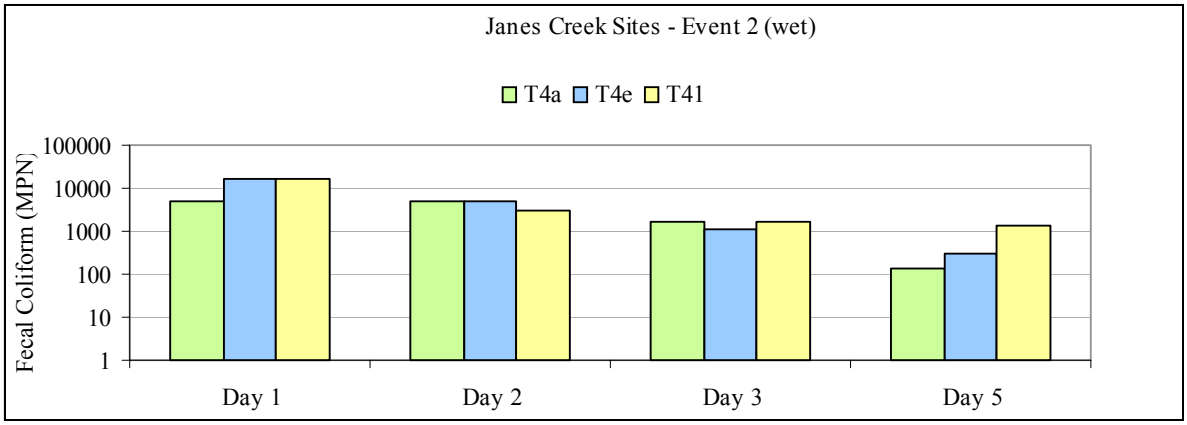


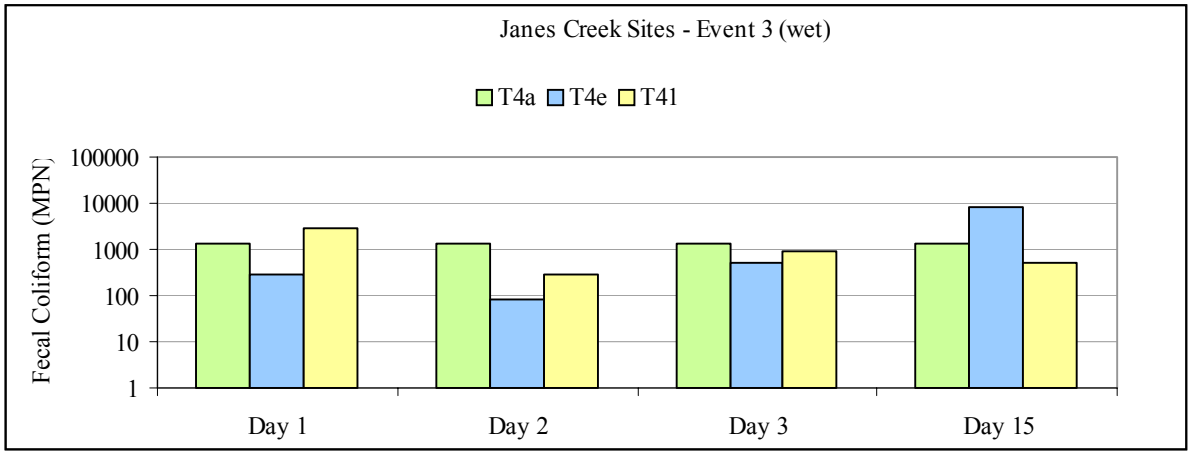
Figure 6.

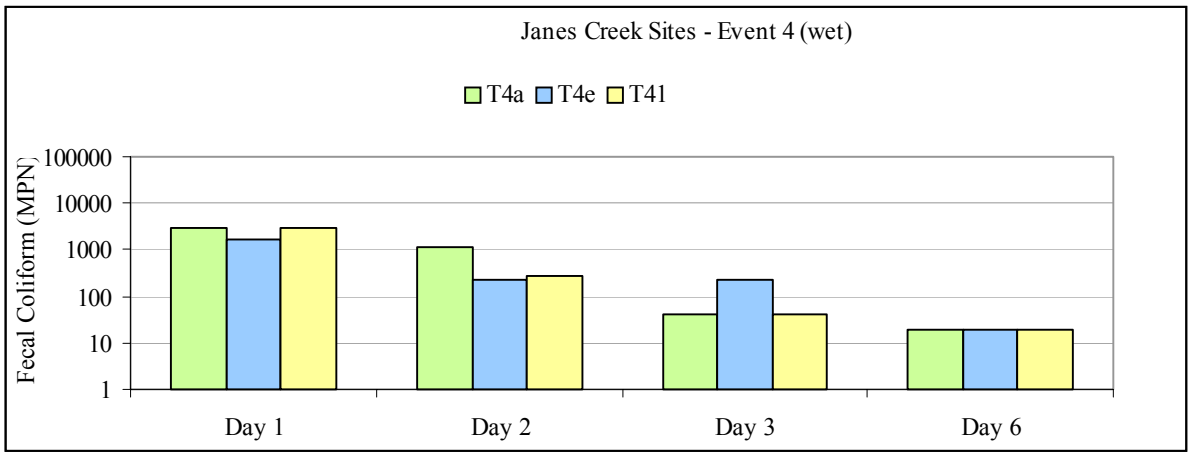
NBSC Float at Mad River Slough - T2a
Site T2a background concentration was less than 10 MPN. With the exception of Event 3, fecal coliform concentrations typically peaked on Day 2 of each rainfall event, decreasing to water quality objective levels by Day X.

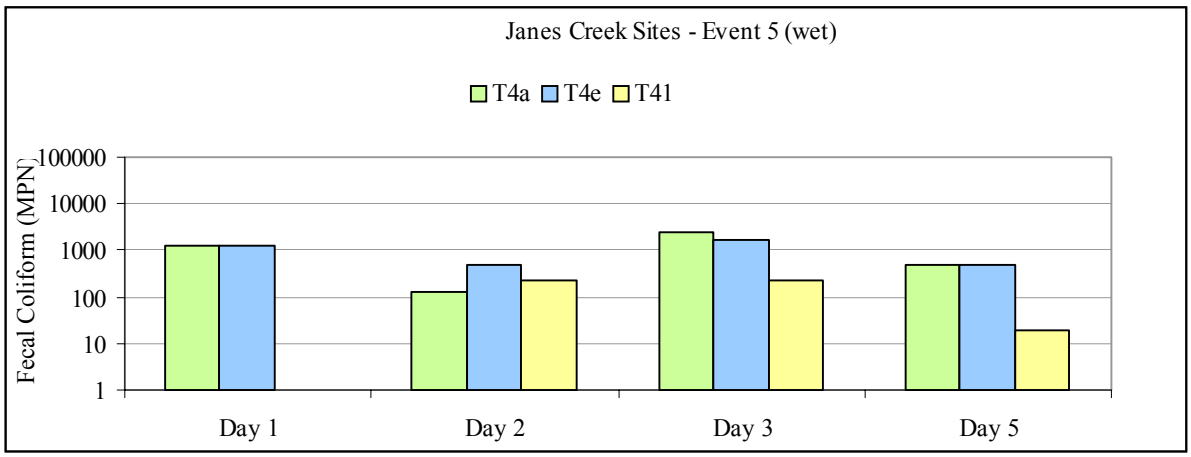
Lanphere Road - T2c
Site T2c background concentration was 20 MPN. Event 4 levels were the highest seen at this site, measuring 16,000 MPN on Day 1, decreasing to 3,000 MPN on Days 2 and 3, and 40 MPN by Day X. With the exception of Event 3, this site was at or near 20 MPN by Day X; Event 3 concentrations were 500 MPN by Day X.

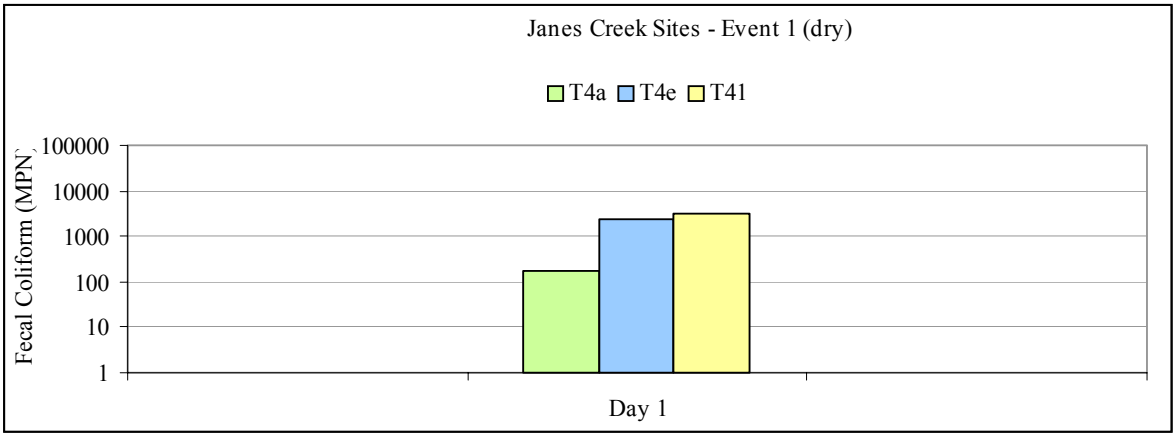
Mad River Slough Culvert - T3
Site T3 background concentration was 230 MPN. Day 1 levels seemed to increase slightly with each subsequent storm event; the highest coliform level measured at this site.
Was 1,700 MPN. Day X concentrations remained elevated from background during two of the four storm events, at 500 and 800 MPN.


Janes Creek Sites - Event 2 (wet)
T4a
T4e
T41
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Janes Creek Sites - Event 3 (wet)
T4a
T4e
T41
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Janes Creek Sites - Event 4 (wet)
T4a
T4e
T41
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Janes Creek Sites - Event 5 (wet)
T4a
T4e
T41
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



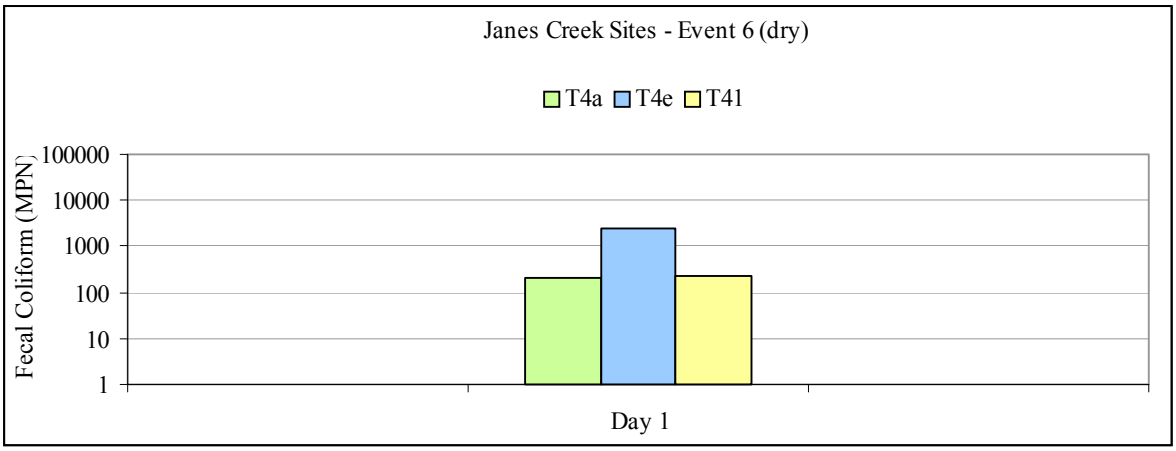
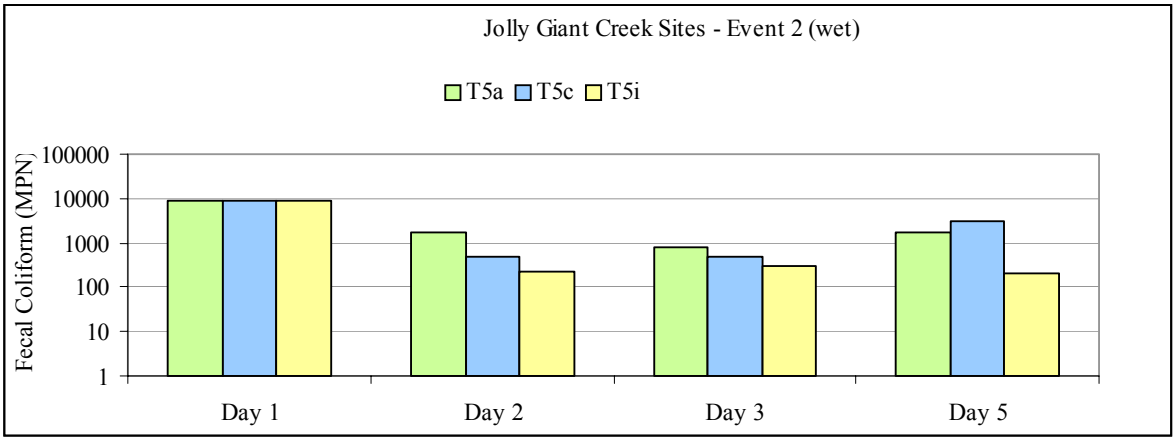


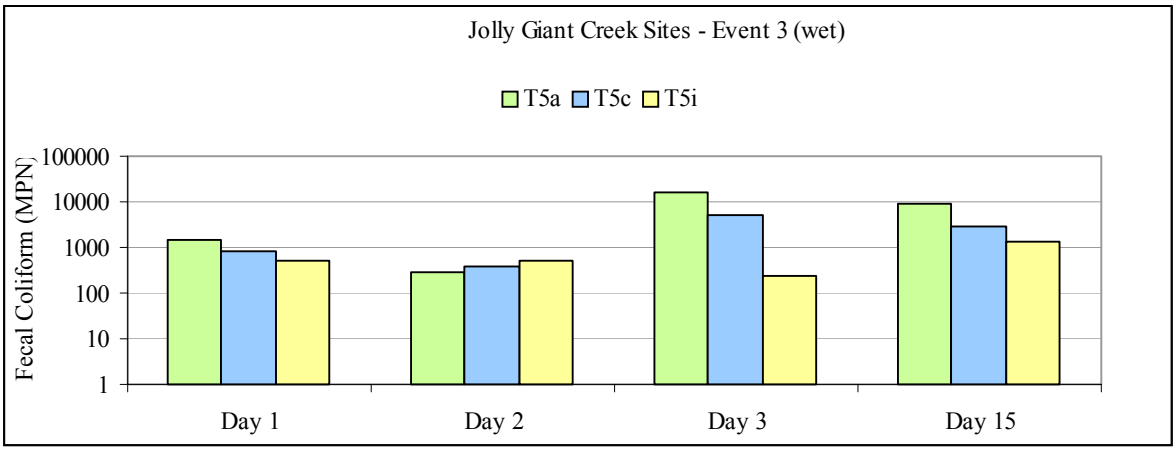
Figure 7.

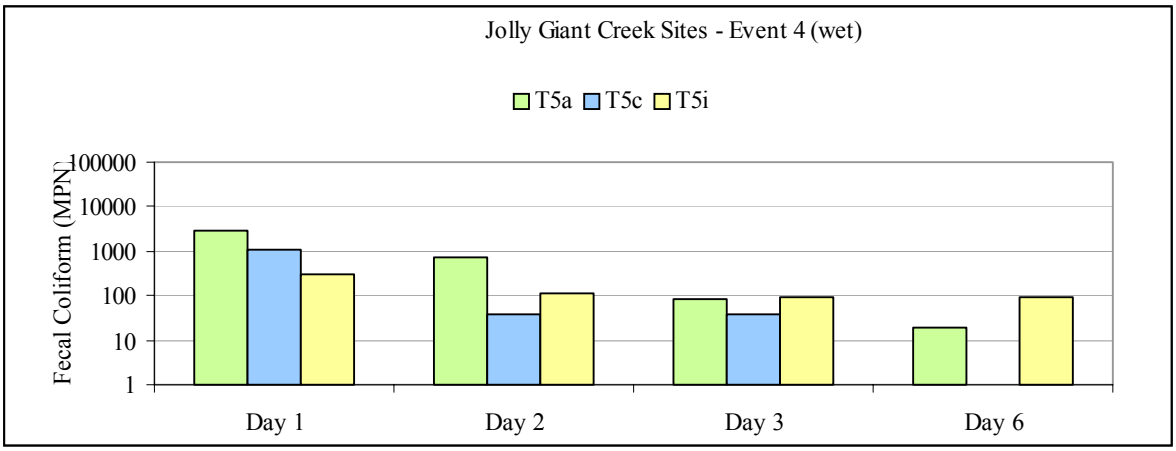
Jane's Creek, Samoa Blvd – T4a
Site T4a background concentration was 206 MPN. Four storm events, coliform levels were elevated for at least the first two days of sampling. Event 3, Day 1 levels were 1,300 MPN, remaining at this level throughout the monitoring. With the exception of Event 3, all other Day X samples were below or near the background concentrations.

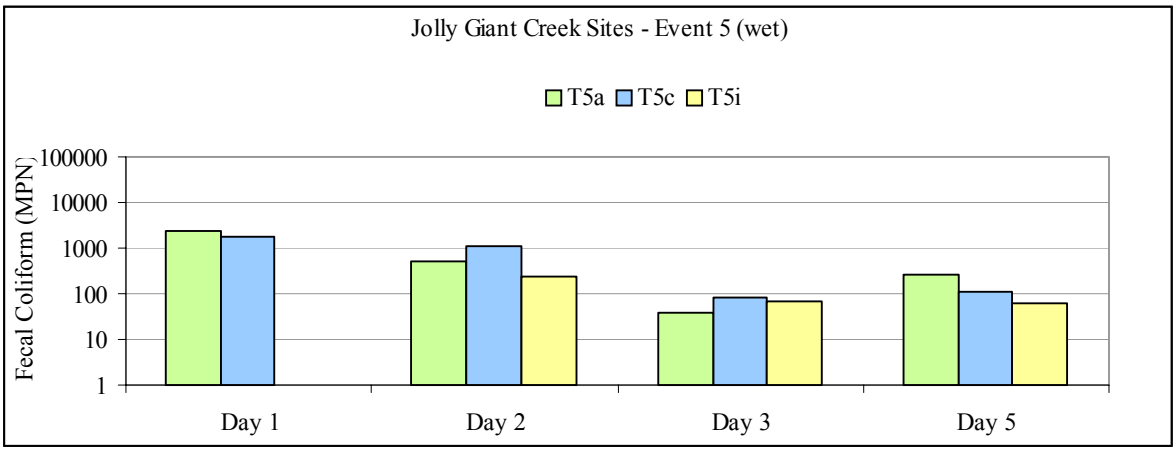
Jane's Creek, 17th Street -T4e
Site T4e background level was 2,400 MPN and was the value for both dry weather samples. This site shows variable results with levels decreasing over several days of sampling, then spiking. Day X concentrations ranged from 20 to 8,000 MPN. There might be a constant year round source of fecal coliform near this site.

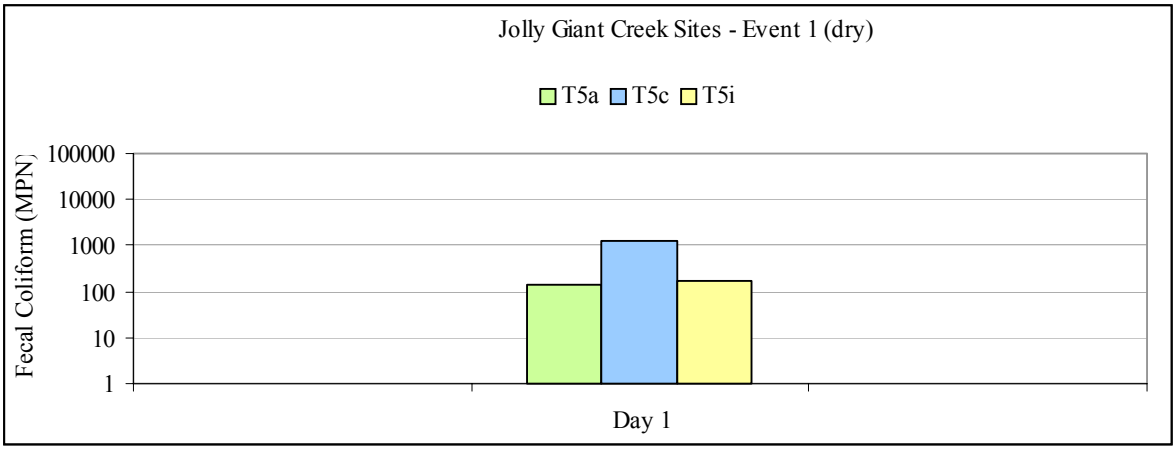
Jane's Creek, West End Road - T41
Site T4l background level was 230 MPN. This site showed higher levels during the first two storm events, with Day X concentrations elevated over the background level. There appears to be a 'first flush' effect at this site.


Jolly Giant Creek Sites - Event 2 (wet)
T5a
T5c
T5i
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Jolly Giant Creek Sites - Event 3 (wet)
T5a
T5c
T5i
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Jolly Giant Creek Sites - Event 4 (wet)
T5a
T5c
T5i
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Jolly Giant Creek Sites - Event 5 (wet)
T5a
T5c
T5i
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



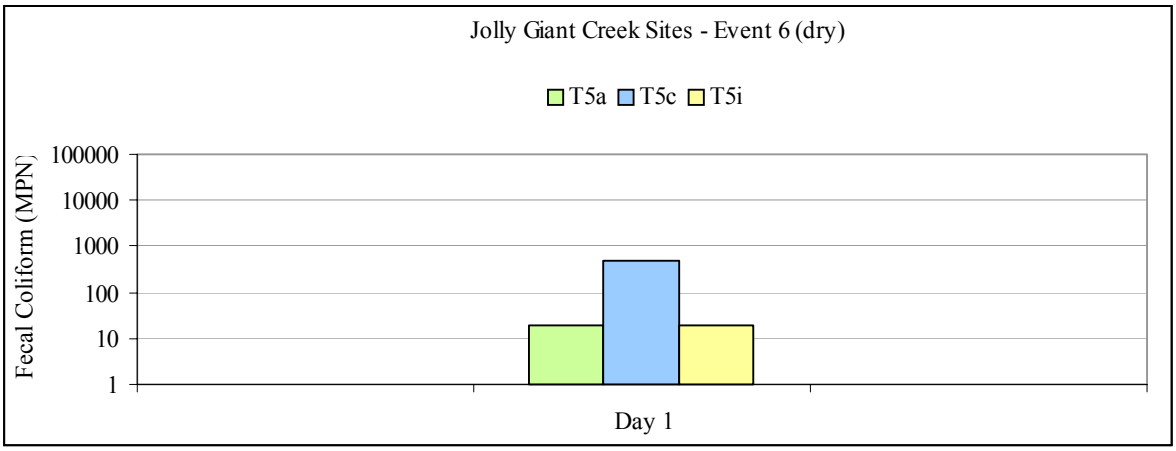
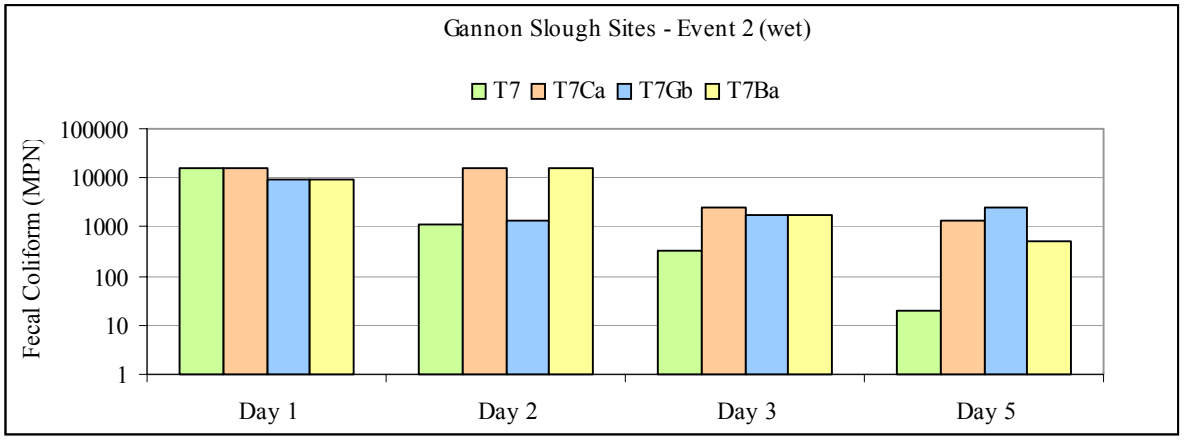


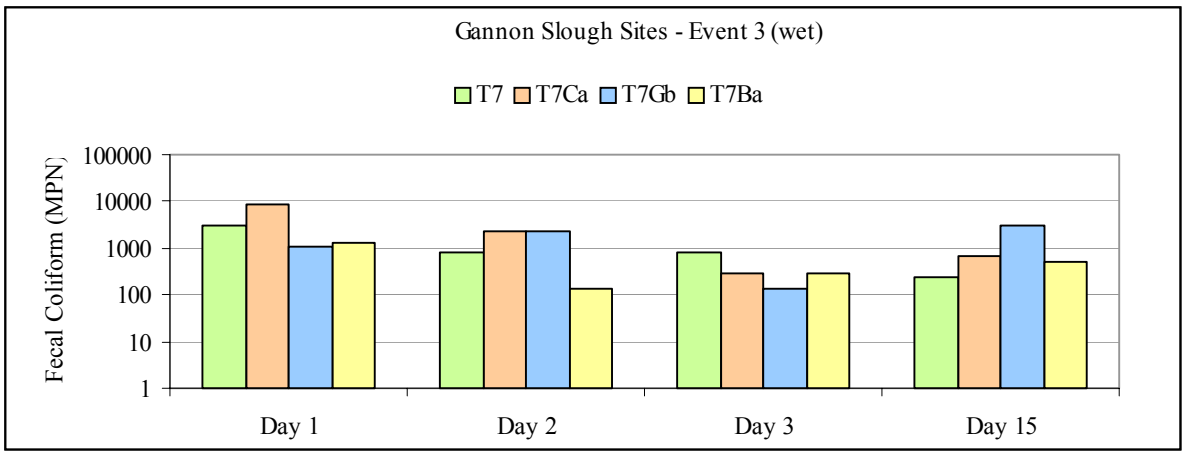
Figure 8.

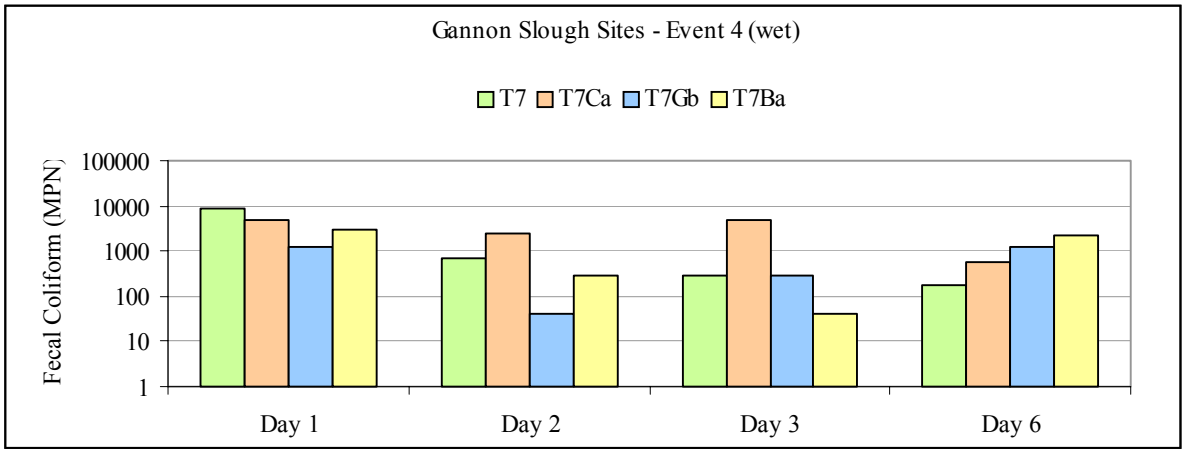
Jolly Giant, Butcher's Slough - T5a
Site T5a background level was 20 MPN. With the exception of Events 4 and 5, Day X samples never approached background levels. There was very little reduction in sample concentration during each event. During early season storm events, there appears to be a constant source of fecal coliform.

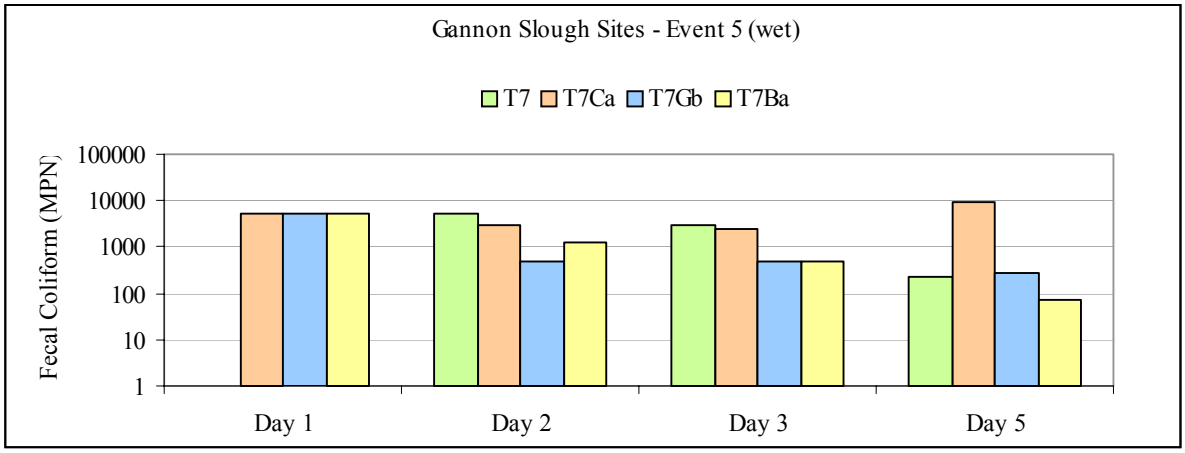
Jolly Giant, Samoa Blvd. - T5c
Site T5c background level was 500 MPN. During the first two storm events, concentrations peaked during later sampling. Event 2 values increased from 500 MPN on Day 2 and 3 of sampling to 3,000 MPN by Day X. Event 3 concentrations increased from 400 MPN on Day 2 to 5,000 MPN on Day X. This site appears to have a constant source of fecal coliform present during early season storm events.

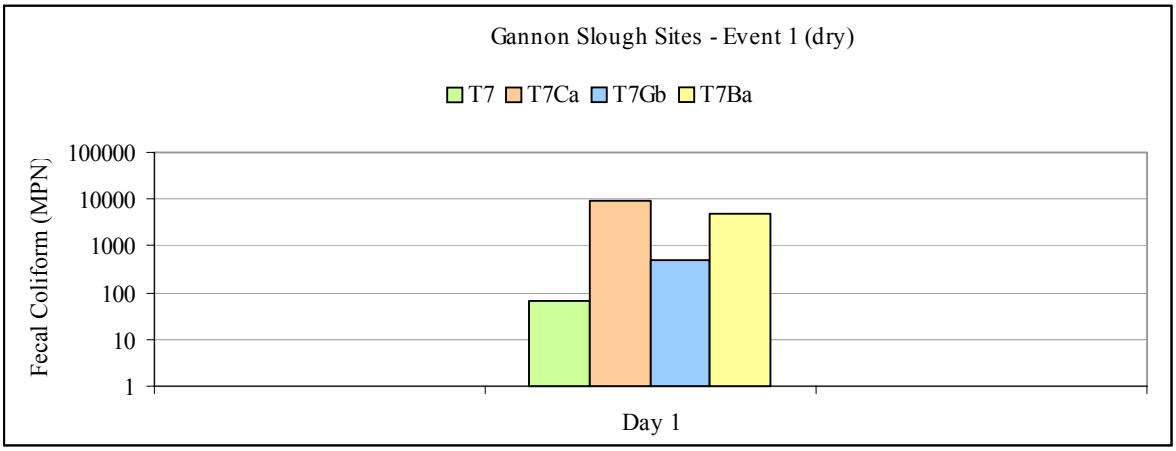
Jolly Giant, Shay Park - T5i
Site T5i background level was 20 MPN. Coliform concentrations remained constant in the 100-500 MPN range during sampling events, with the exception of Event 2, Day 1 and Event 3, Day X. The latter result appears to be from a local source of fecal coliform.


Gannon Slough Sites - Event 2 (wet)
T7
T7Ca
T7Gb
T7Ba
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Gannon Slough Sites - Event 3 (wet)
T7
T7Ca
T7Gb
T7Ba
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Gannon Slough Sites - Event 4 (wet)
T7
T7Ca
T7Gb
T7Ba
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Gannon Slough Sites - Event 5 (wet)
T7
T7Ca
T7Gb
T7Ba
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



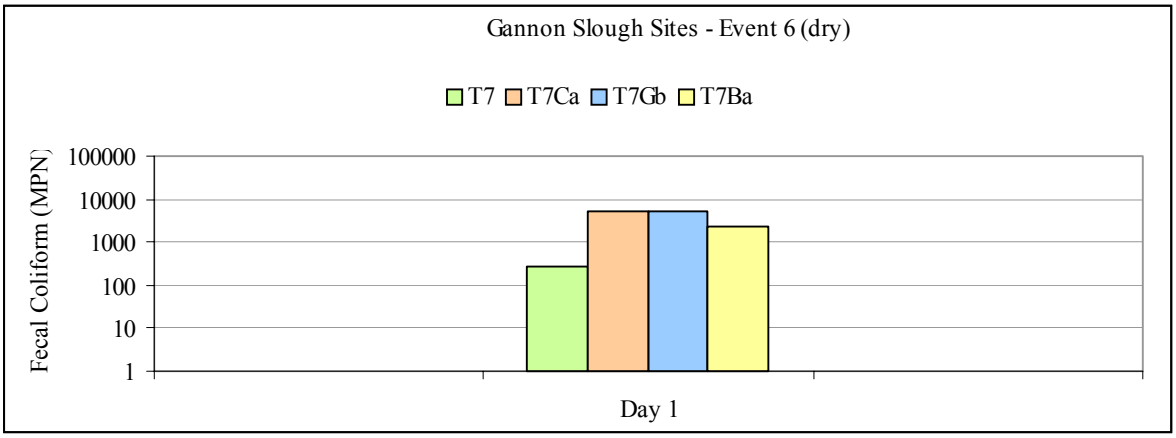


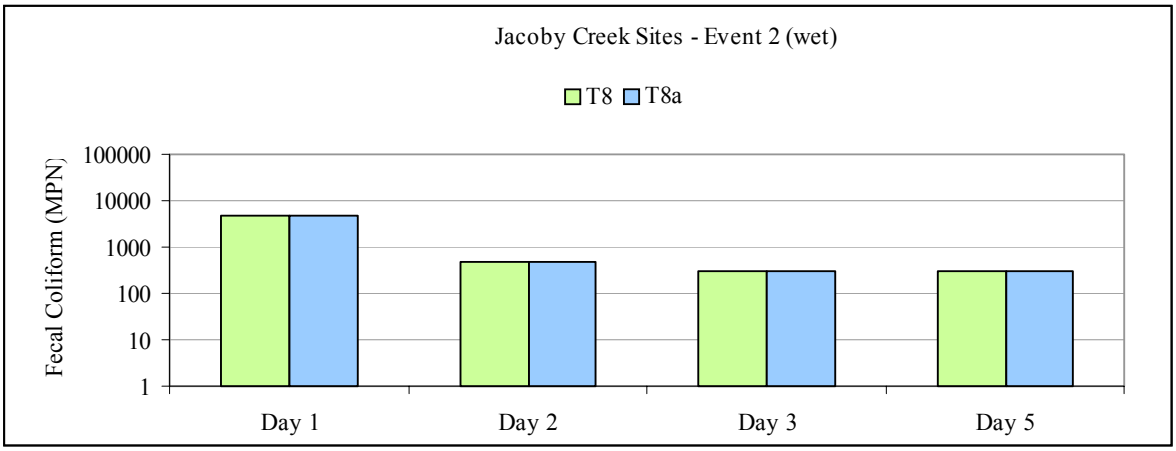
Figure 9.

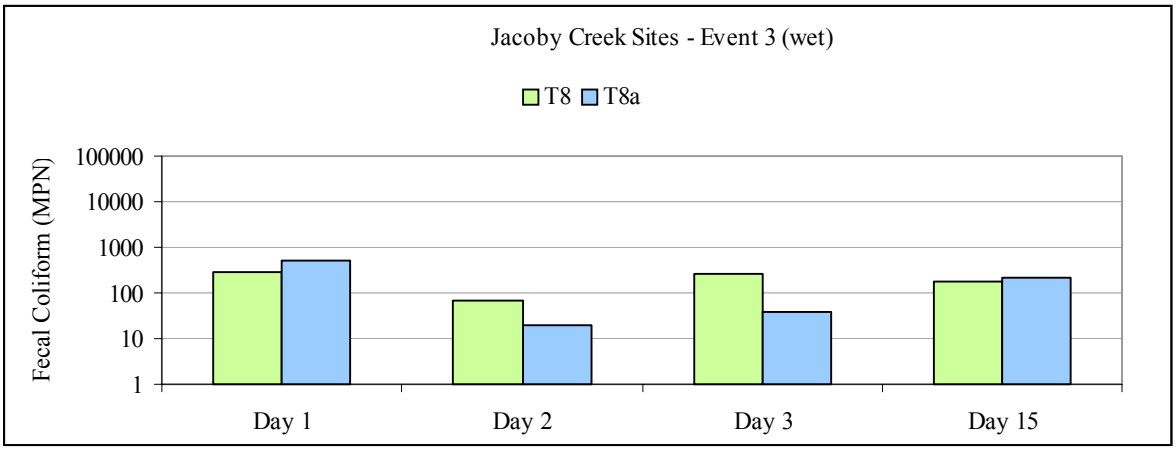
Gannon Slough, Highway 101 - T7
Site T7 background level was 270 MPN. Although coliform levels were elevated during the first three days of each storm event, concentrations returned to background concentrations by Day X.

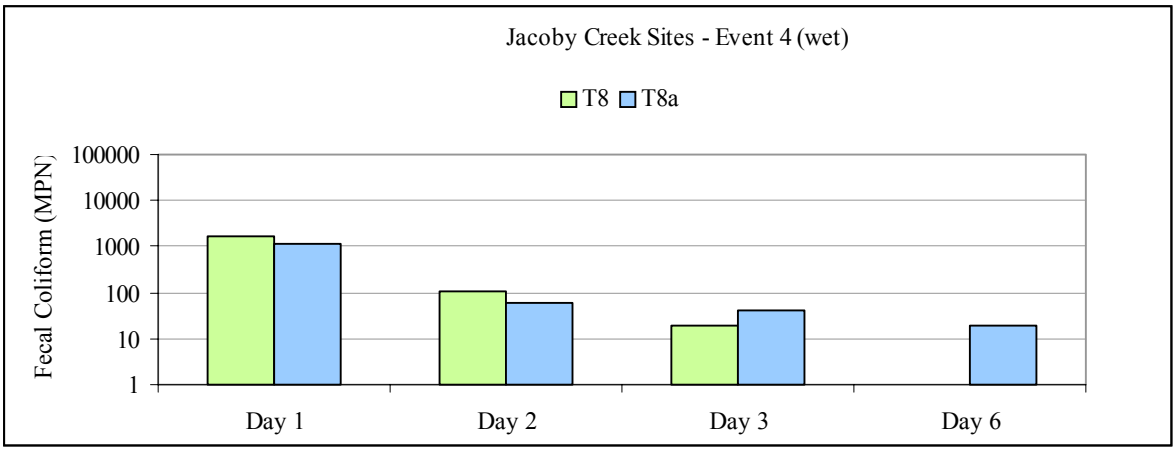
Beith Creek, Old Arcata Road – T7Ba
Site T7Ba background level was 2,400 MPN. Because the background level is high, with the exception of Event 2, Day 1, coliform concentrations were below the 2,400 MPN by Day 2. This site appears to have a constant fecal coliform loading source.

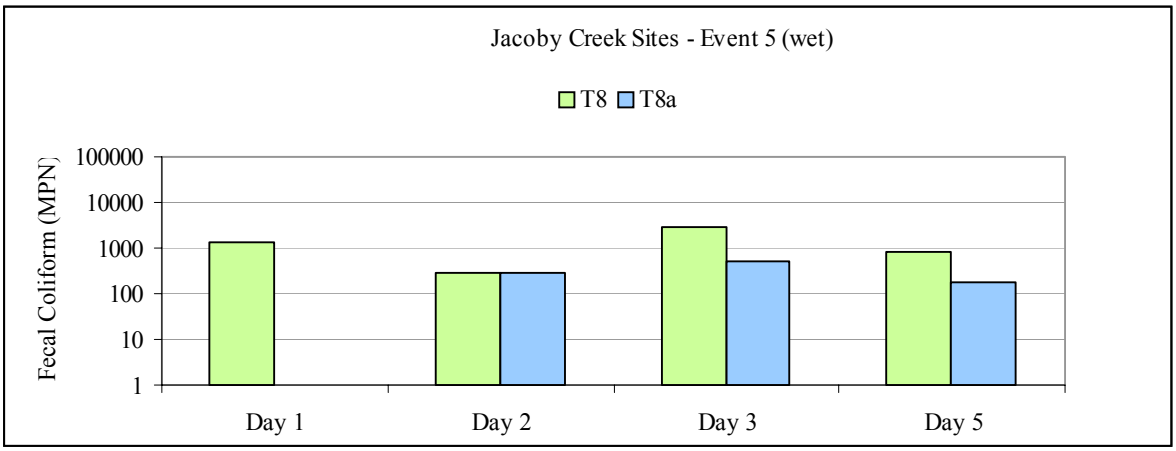
Grotzman Creek – T7Gb
Site T7Gb background level was 800 MPN. With the exception of Event 4, all Day X samples exceeded background concentrations. There appears to be a constant source of fecal coliform at this site.

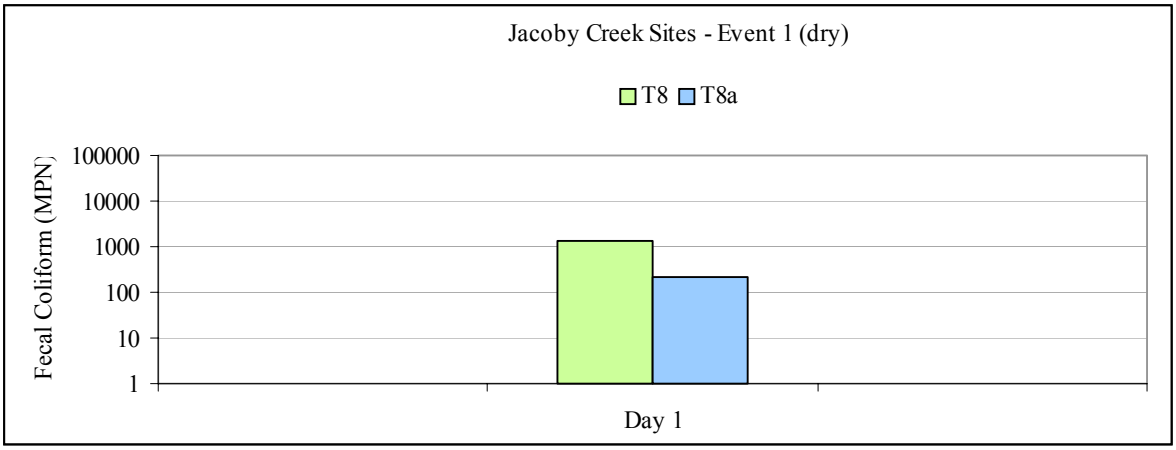
Campbell Creek – T7Ca
Site T7Ca background level was 5,000 MPN. Only eight samples collected from this site were at or below the background level during the course of this study. This site appears to have a constant source of fecal coliform at this site.


Jacoby Creek Sites - Event 2 (wet)
T8
T8a
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Jacoby Creek Sites - Event 3 (wet)
T8
T8a
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Jacoby Creek Sites - Event 4 (wet)
T8
T8a
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Jacoby Creek Sites - Event 5 (wet)
T8
T8a
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



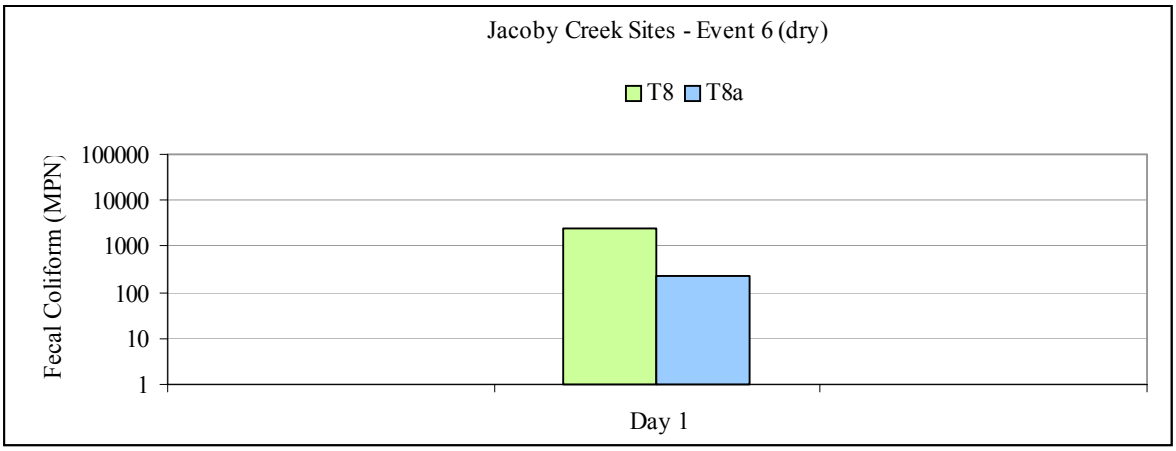
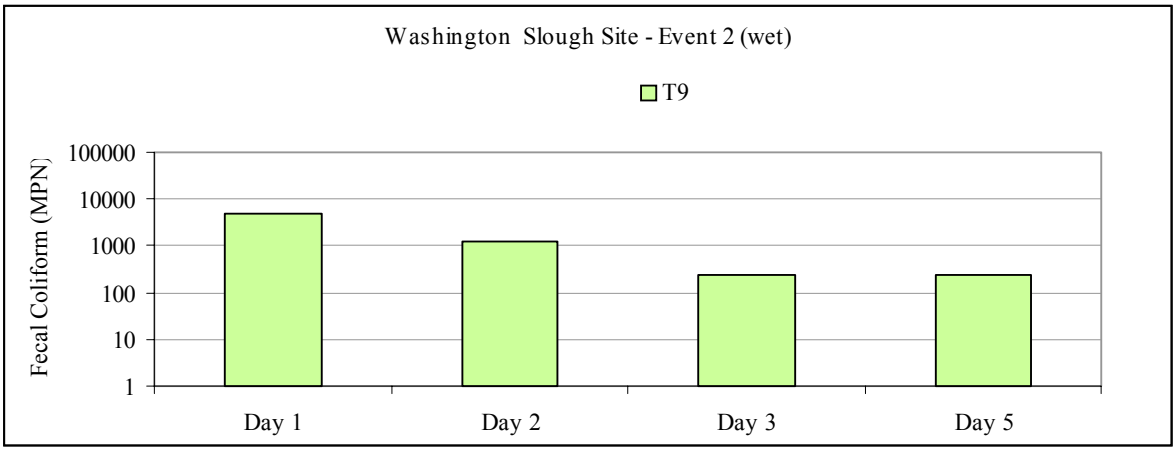
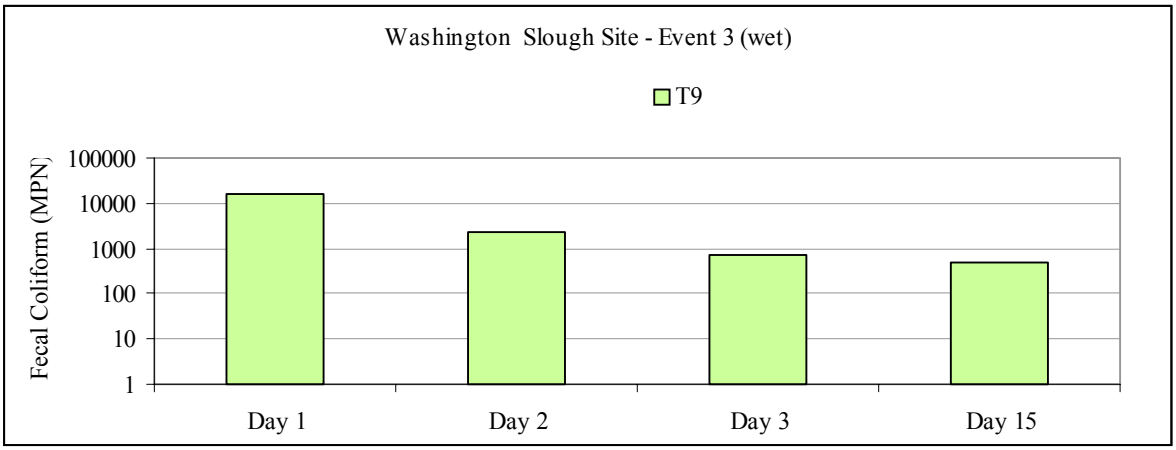


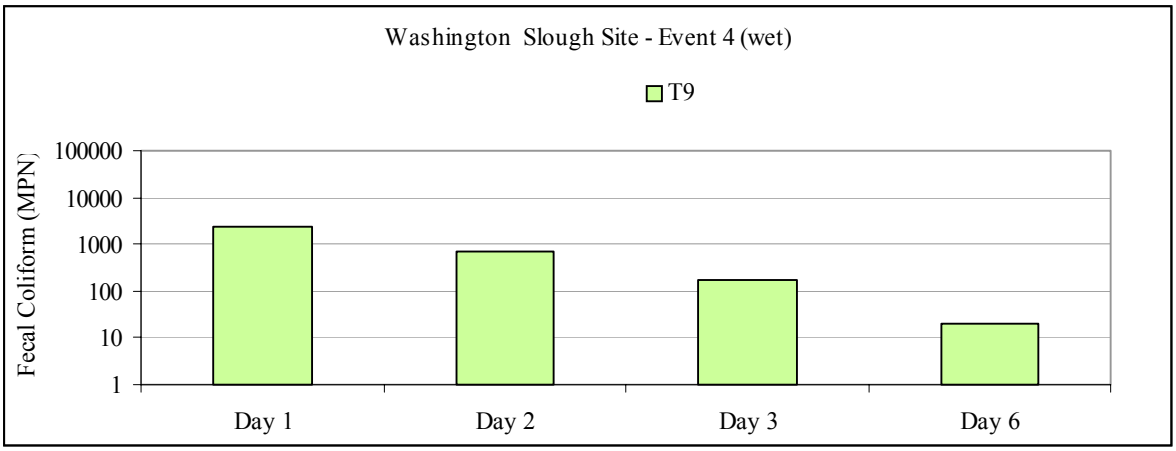
Figure 10.

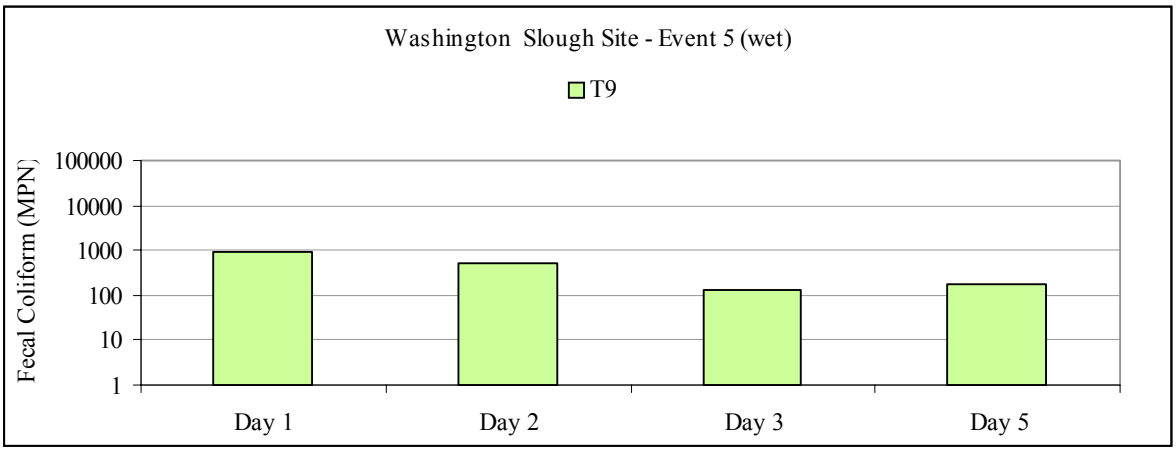
Jacoby Creek, Highway 101 - T8
Site T8 background level was 2,400 MPN. This most likely is greater than the actual background concentration as only two samples from this site exceeded 2,400 MPN during the study. In general, sample concentrations were elevated during Day 1, decreasing by Day 2 remaining at this concentration for the duration of sampling.

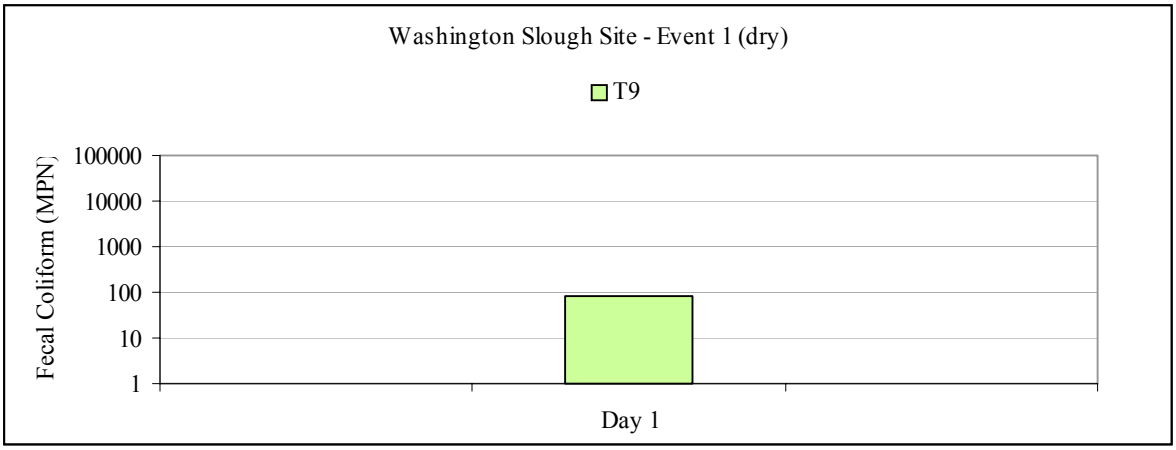
Jacoby Creek, Old Arcata Road - T8a
Site T8a background level was 230 MPN. Sample levels were elevated on Day 1, decreasing to background concentrations by Day 2, remaining at these concentrations for the duration for the sampling period. There appears to be a 'first flush' effect at this site.


Washington Slough Site - Event 2 (wet)
T9
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Washington Slough Site - Event 3 (wet)
T9
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Washington Slough Site - Event 4 (wet)
T9
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Washington Slough Site - Event 5 (wet)
T9
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



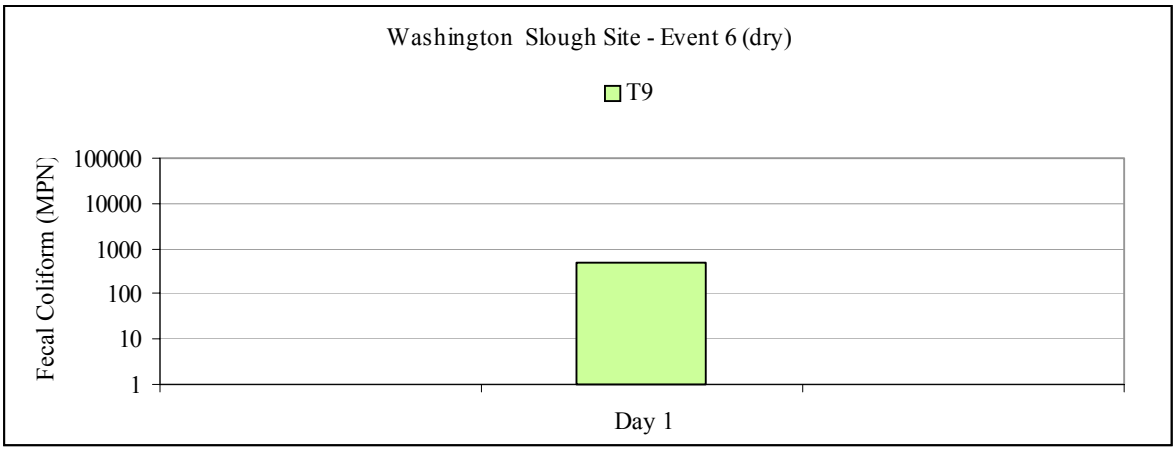
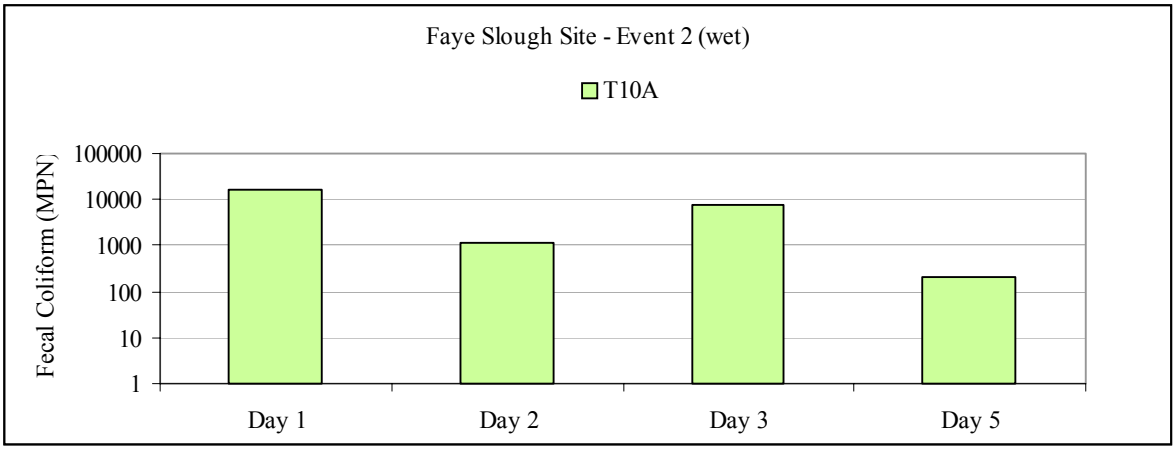
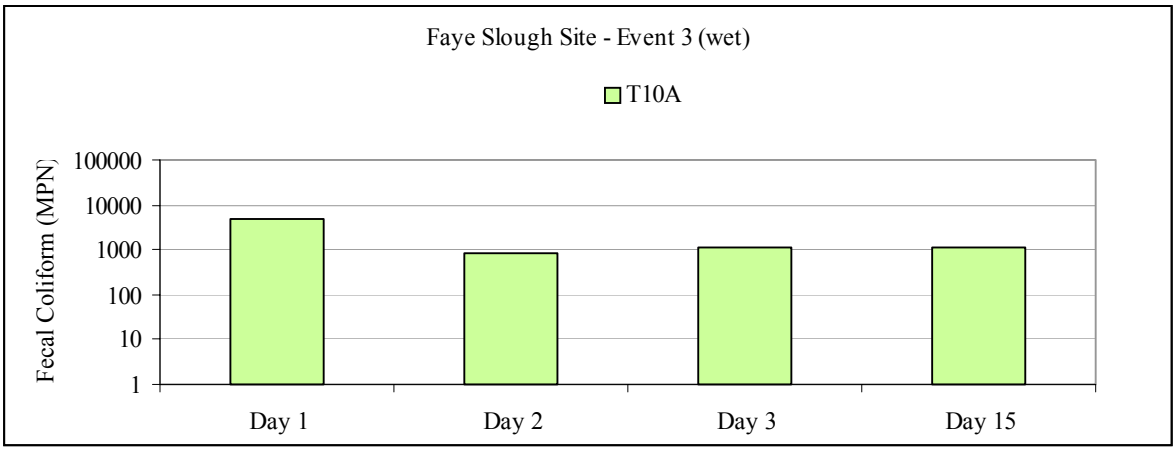
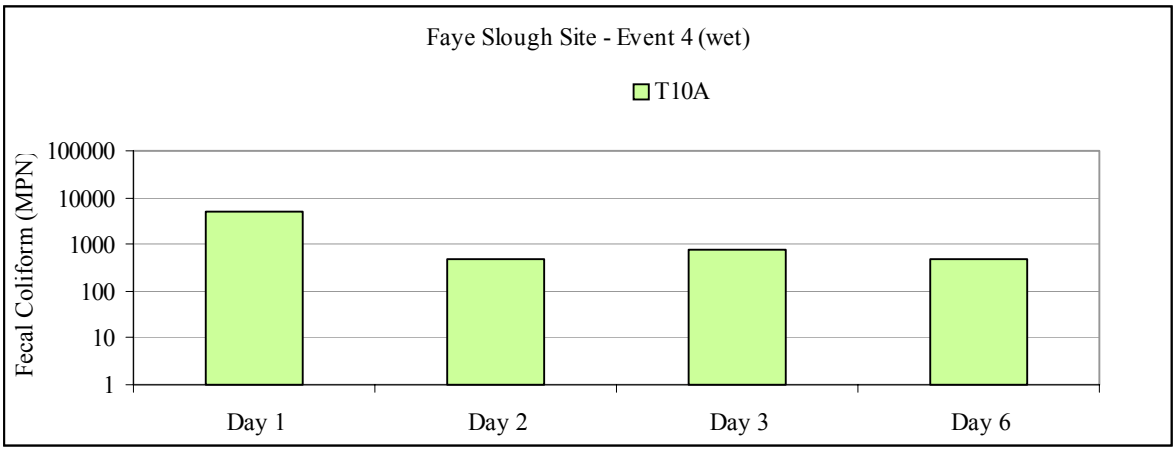


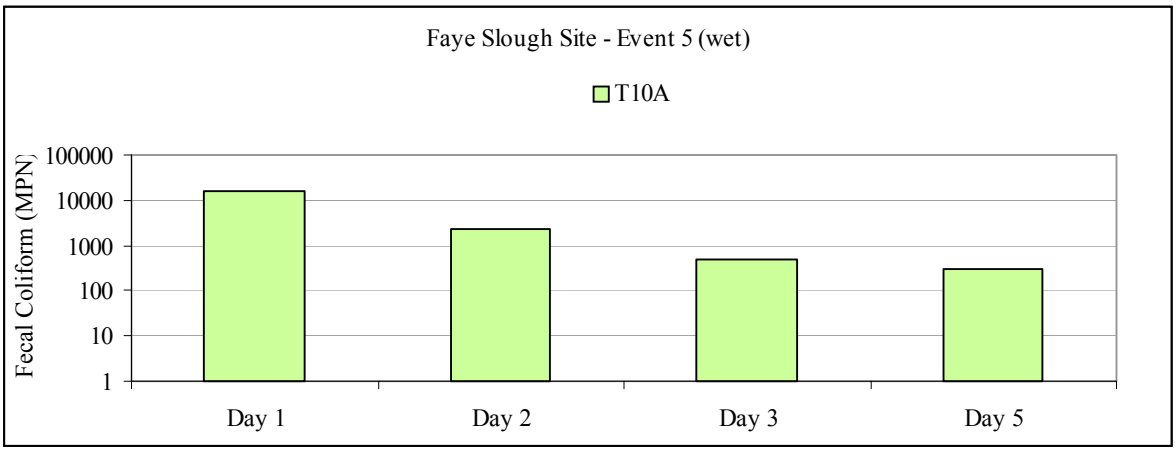
Figure 11.

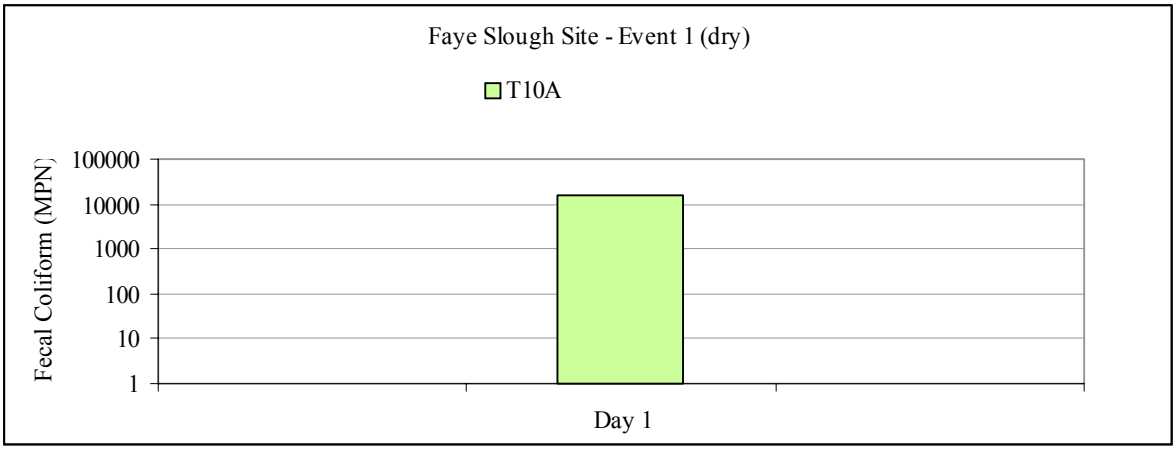
Washington Slough - T9
Site T9 background concentration was 500 MPN. Events 2 and 3 had higher Day 1 levels than subsequent storm events. In all cases, concentrations decreased below background levels by Day 3. Interestingly, the smallest Day 1 rainfall (less than one inch during Event 3) resulted in the greatest Day 1 concentration. The continued rainfall during Event 3 resulted in coliform concentrations slightly higher than during the other storm events. There appears to be a 'first flush' effect at this site.


Faye Slough Site - Event 2 (wet)
T10A
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Faye Slough Site - Event 3 (wet)
T10A
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Faye Slough Site - Event 4 (wet)
T10A
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Faye Slough Site - Event 5 (wet)
T10A
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



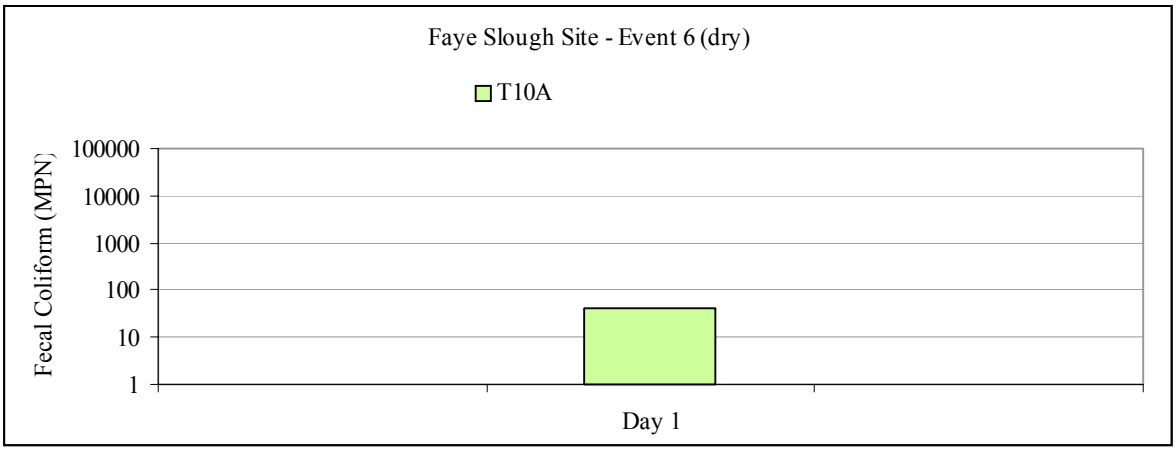
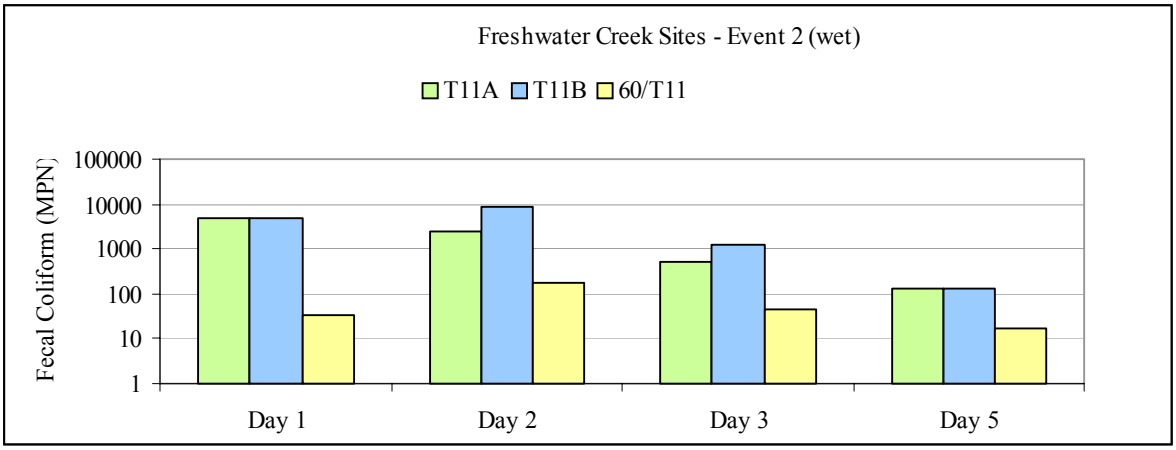
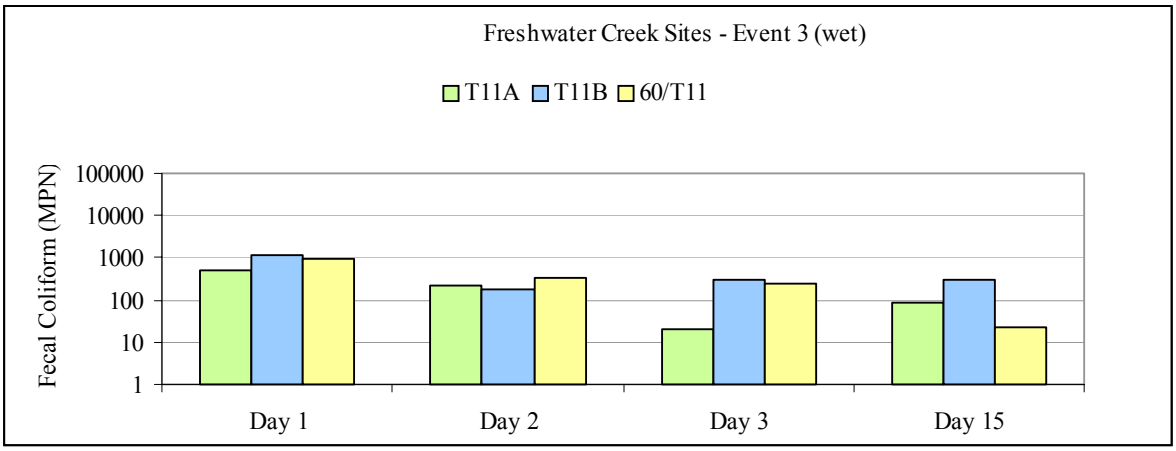
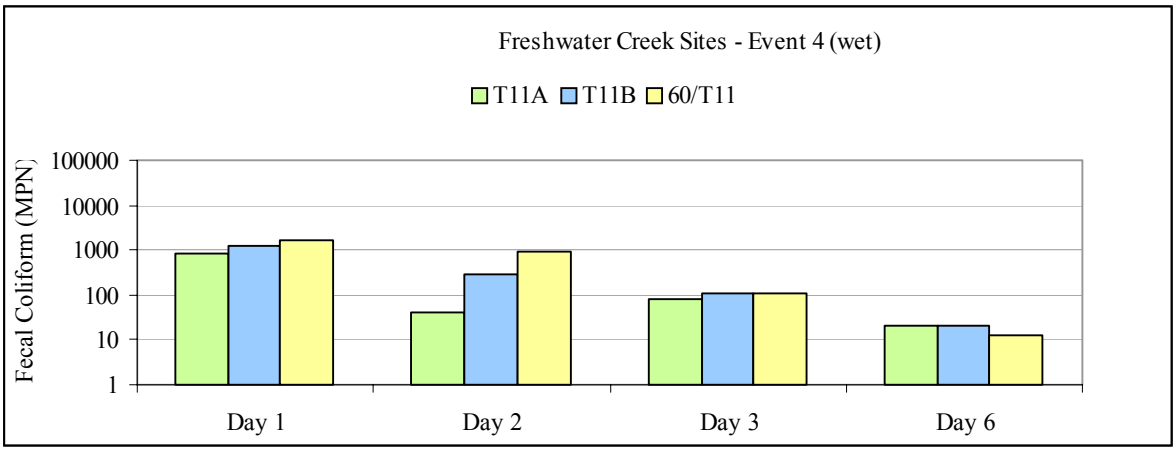


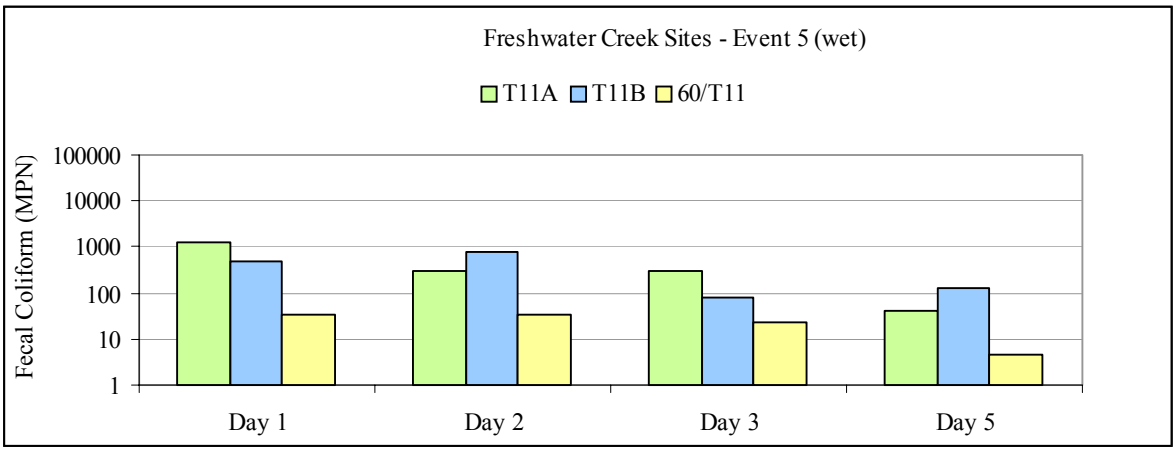
Figure 12.

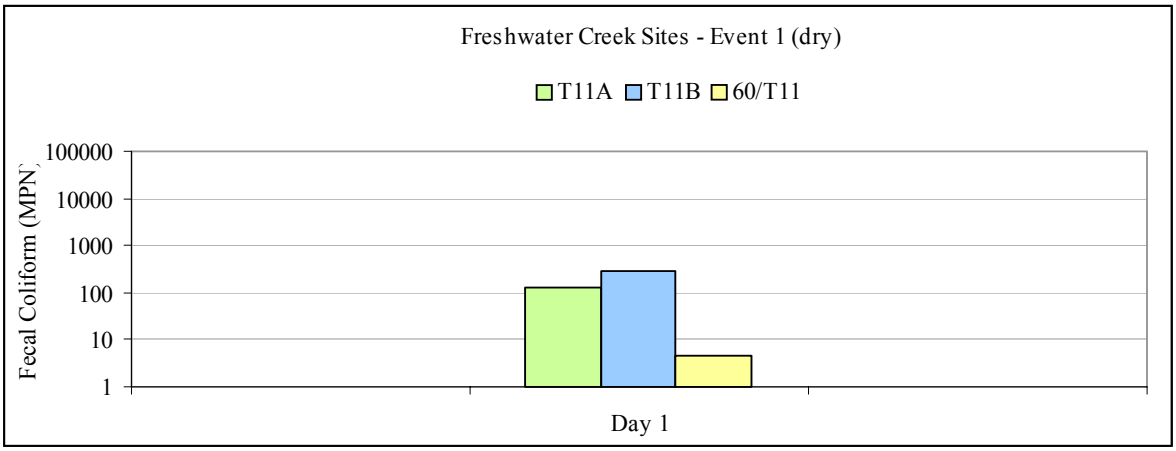
Faye Slough - T10A
Site T10A background concentrations was 40 MPN. All samples remained above this background level, including the first dry season sample. Day 1 sample concentrations from all four storm events were elevated, ranging from 5,000 to 17,000 MPN. These levels decreased by Day 2, remaining at this level for the duration of sampling. There appears to be a constant source of fecal coliform near this site, with elevated concentrations found during early season storms.


Freshwater Creek Sites - Event 2 (wet)
T11A
T11B
60/T11
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Freshwater Creek Sites - Event 3 (wet)
T11A
T11B
60/T11
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Freshwater Creek Sites - Event 4 (wet)
T11A
T11B
60/T11
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Freshwater Creek Sites - Event 5 (wet)
T11A
T11B
60/T11
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



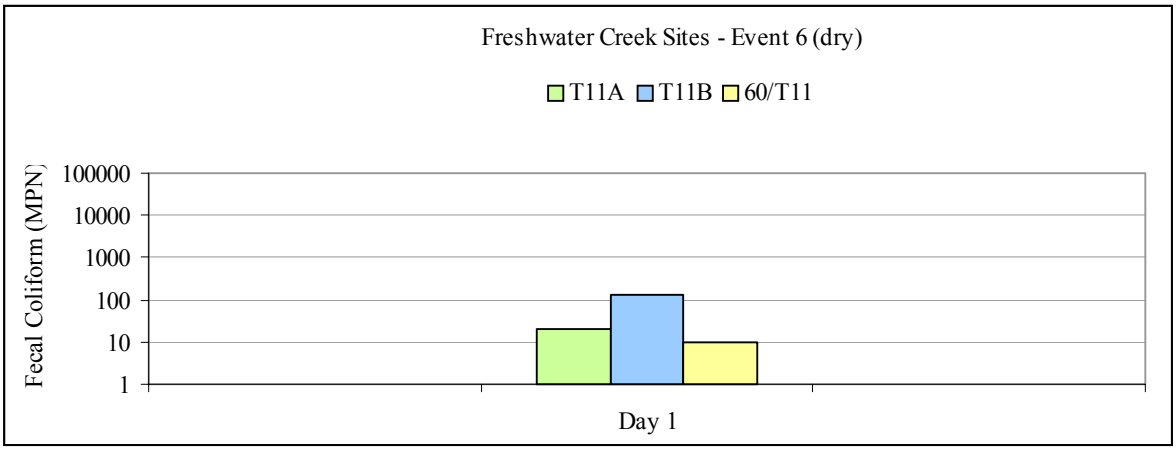
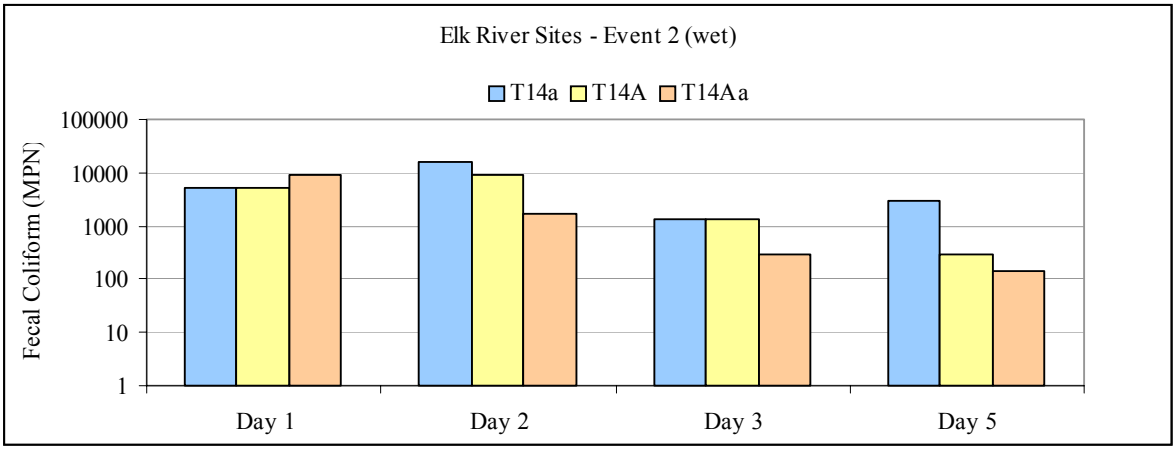


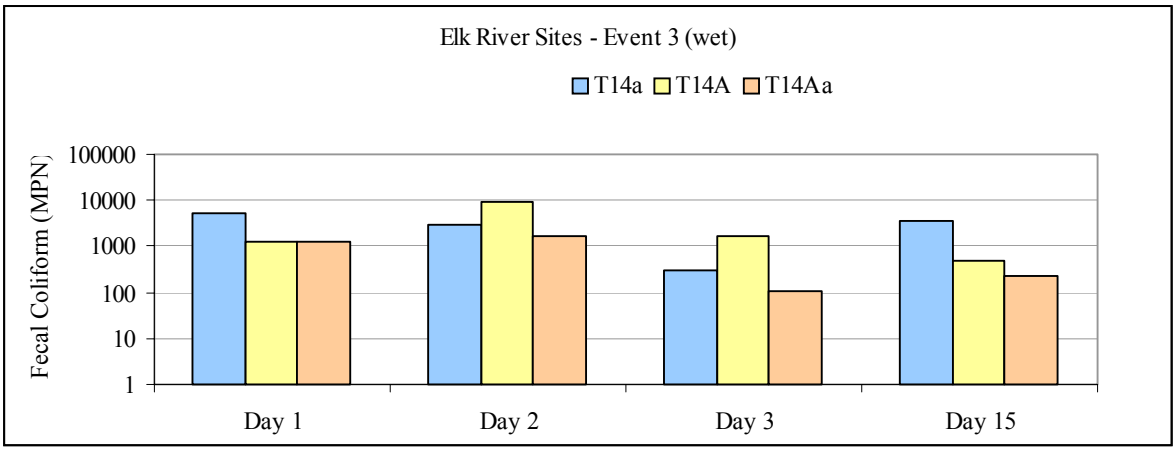
Figure 13.

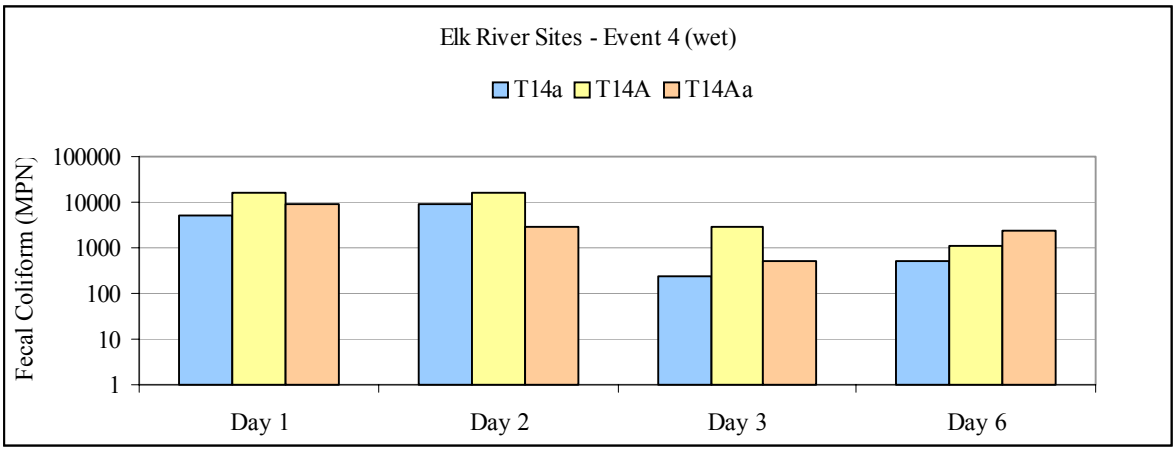
Freshwater Slough - T11A
Site T11A background level was 20 MPN. Event 2, Day 1 sample was the highest level found at this site, 5,000 MPN. Subsequent Day 1 sample levels were lower. All Day X samples were near the background level. There is a 'first flush' effect' observed at this site.

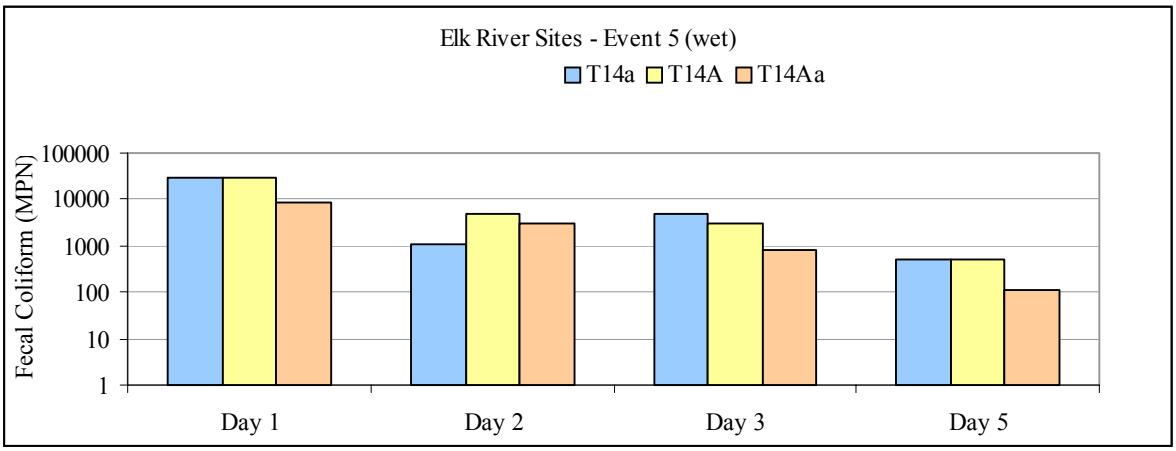
Ryan Slough - T11B
Site T11B background level was 130 MPN. With the exception of Event 3, Day X samples were at or below this background concentration. Event 2 indicated elevated levels, remaining elevated throughout the first three days of sampling. There is a 'first flush' effect at this site.

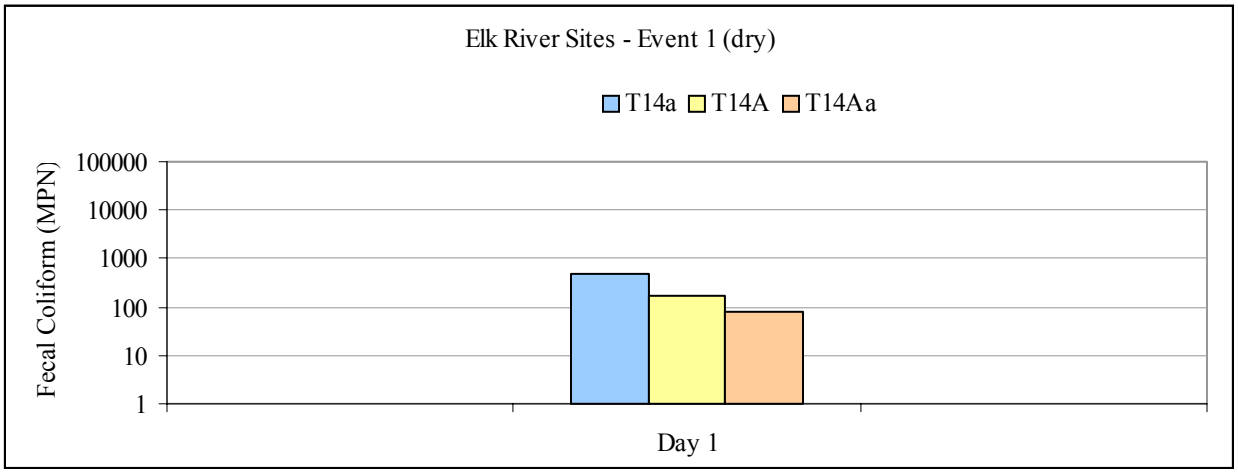
Eureka Slough at Railroad Bridge - 60/T11
Site 60/T11 background level was 9.3 MPN. During all storm events, levels were elevated above the background level during the first three days of sampling. By Day X, levels ranged from 4.5 to 22 MPN, near the background level.


Elk River Sites - Event 2 (wet)
T14a
T14A
T14Aa
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Elk River Sites - Event 3 (wet)
T14a
T14A
T14Aa
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Elk River Sites - Event 4 (wet)
T14a
T14A
T14Aa
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Elk River Sites - Event 5 (wet)
T14a
T14A
T14Aa
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



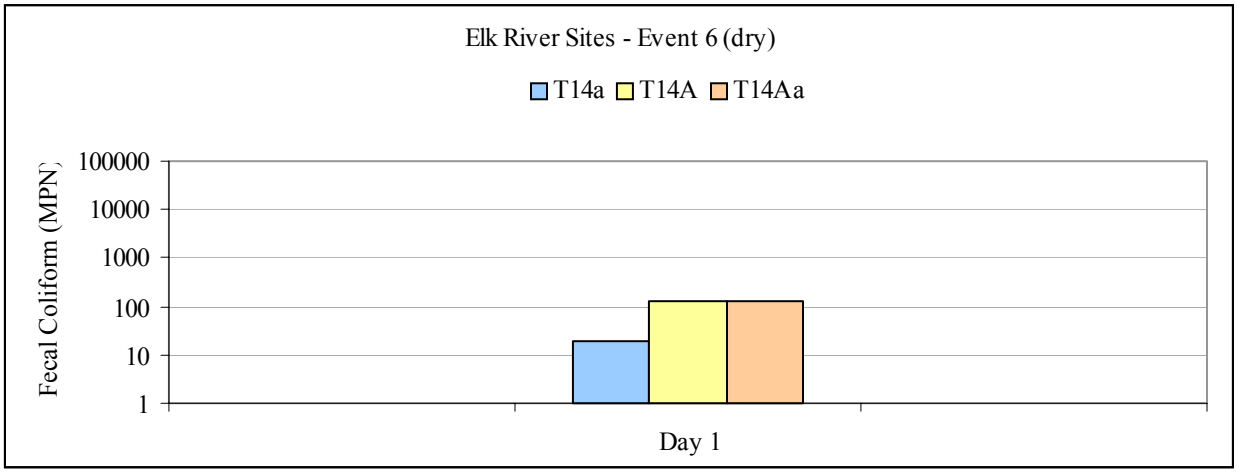
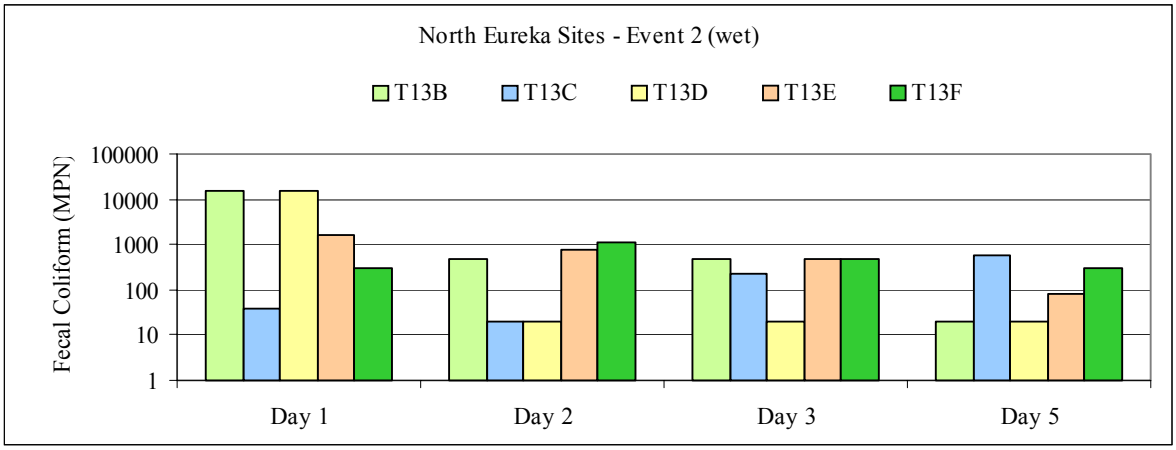


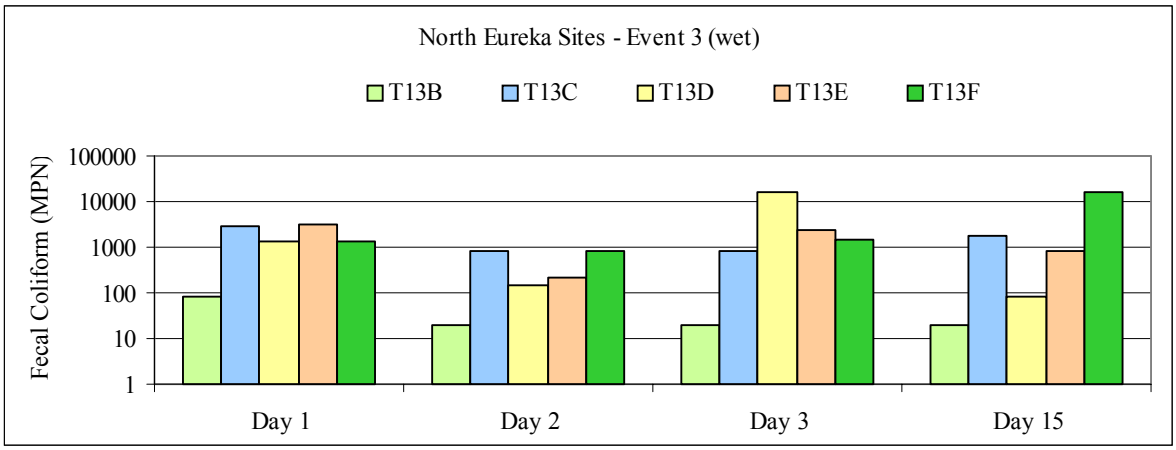
Figure 14.

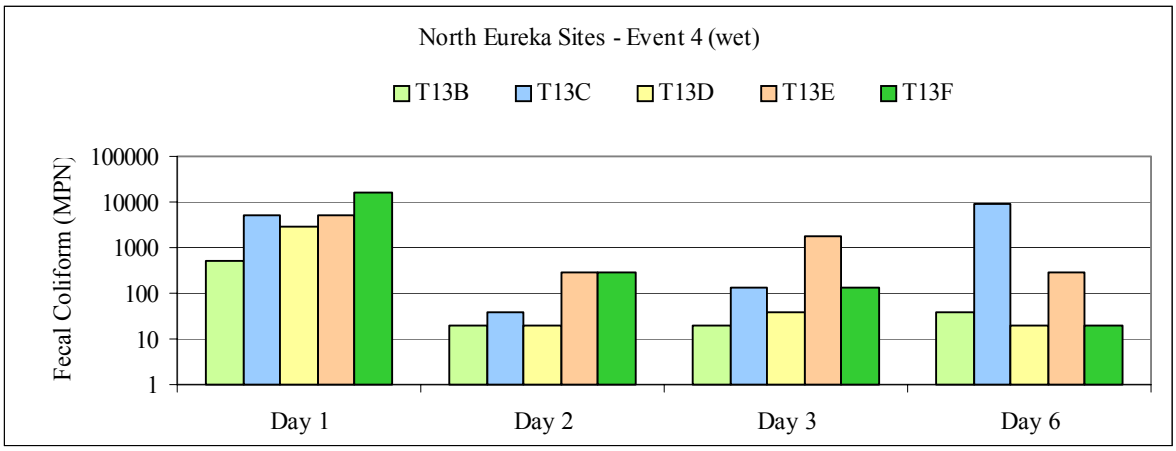
Elk River at 101 Bridge - T14a
Site T14a background level was 20 MPN. However, it appears that the wet season background level is higher, closer to 500 MPN. This site had consistently elevated coliform concentrations with very little change from Day 1 to Day X during the first three storm events. There appears to be a constant source of fecal coliform present during the wet season.

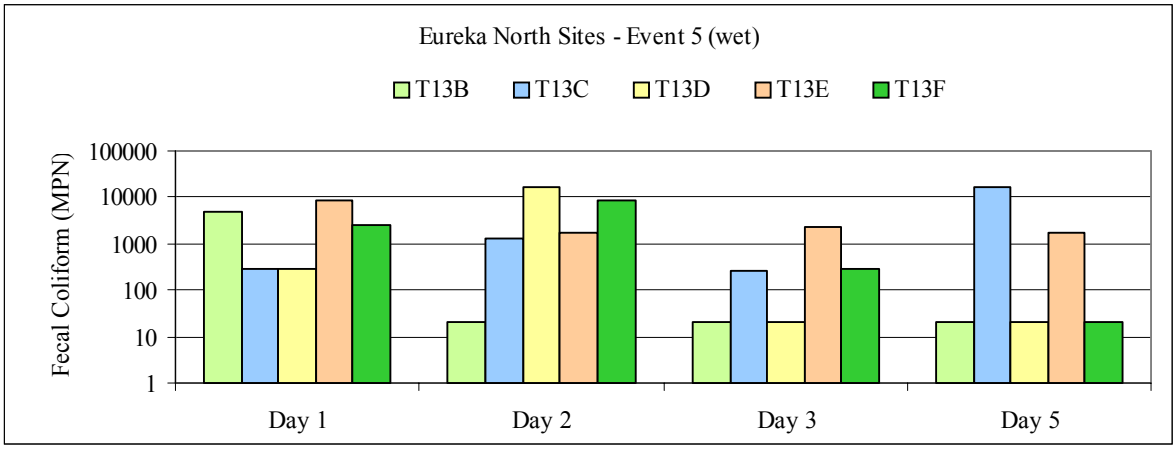
Swain Slough at Pine Hill Road - T14A
Site T14A background level was 130 MPN. During Events 2 and 3, coliform concentrations were similar, with minimal changes observed for the first three days of sampling. Event 4 showed significantly higher concentrations than previous events. Day X samples remained elevated above the background concentration but were lower than found during earlier sampling. This location appears to have a constant loading source. In three of the four storm events, concentrations increased following Day 1 sampling. Another observation is that Day 1 concentrations increased over the course of the sample events.

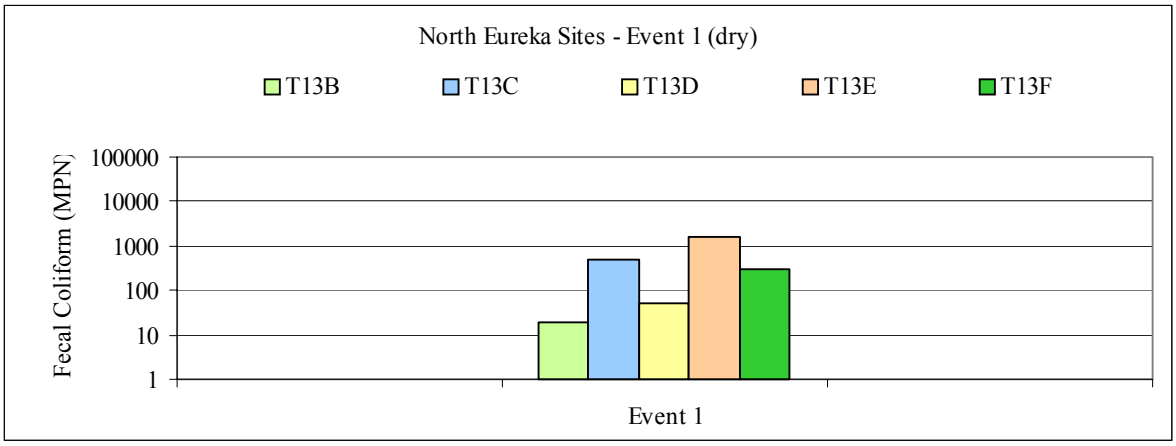
Martin Slough at Pine Hill Road - T14Aa
Site T1Aa background level was 130 MPN. All Day 1 concentrations were consistently elevated, remaining high in Day 2 samples. Day X samples were still somewhat elevated; only during Event 5 was the sample below the background level. There appears to be a constant loading source present near this site.


North Eureka Sites - Event 2 (wet)
T13B
T13C
T13D
T13E
T13F
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


North Eureka Sites - Event 3 (wet)
T13B
T13C
T13D
T13E
T13F
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


North Eureka Sites - Event 4 (wet)
T13B
T13C
T13D
T13E
T13F
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Eureka North Sites - Event 5 (wet)
T13B
T13C
T13D
T13E
T13F
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



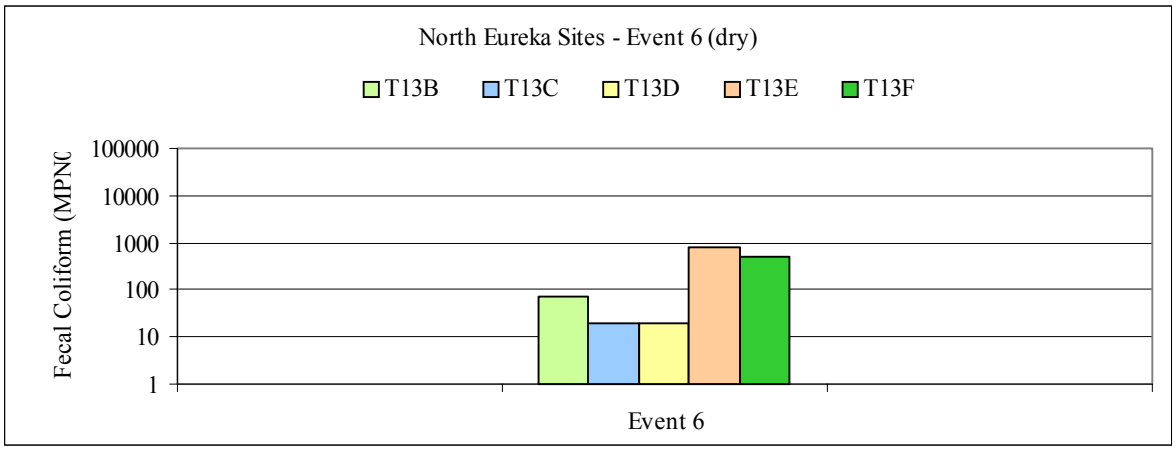


Figure 15.

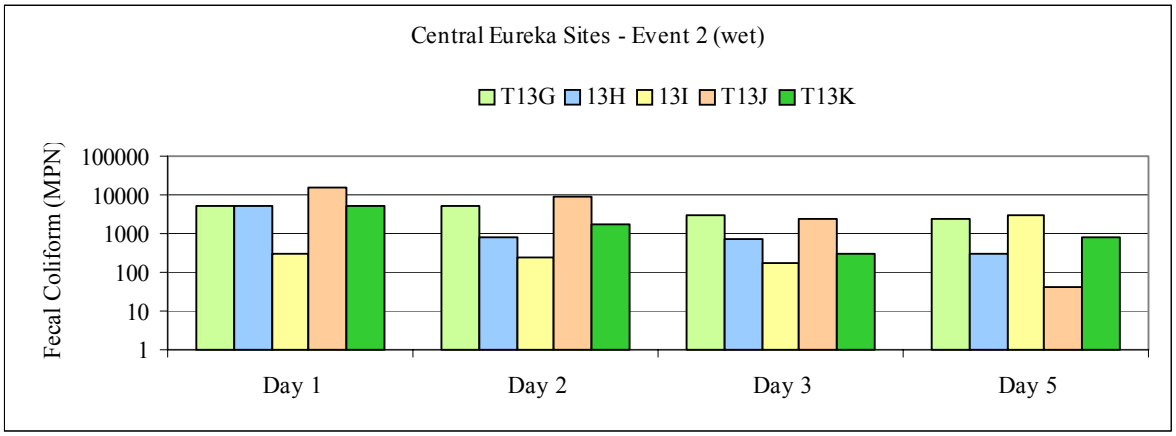
P Street and Waterfront- Site T13B (48" culvert, P St. and Waterfront)
Site T13B background level was 20 MPN. During Event 2, Day 1 results were 16,000 MPN, decreasing to 20 MPN by Day X. During other rainfall events, Day 1 samples remained lower, meeting background concentrations by Day X. There appears to be a definite 'first flush' effect at this site. Overall, this location does not appear to contribute high coliform concentrations beyond the first rainfall event.

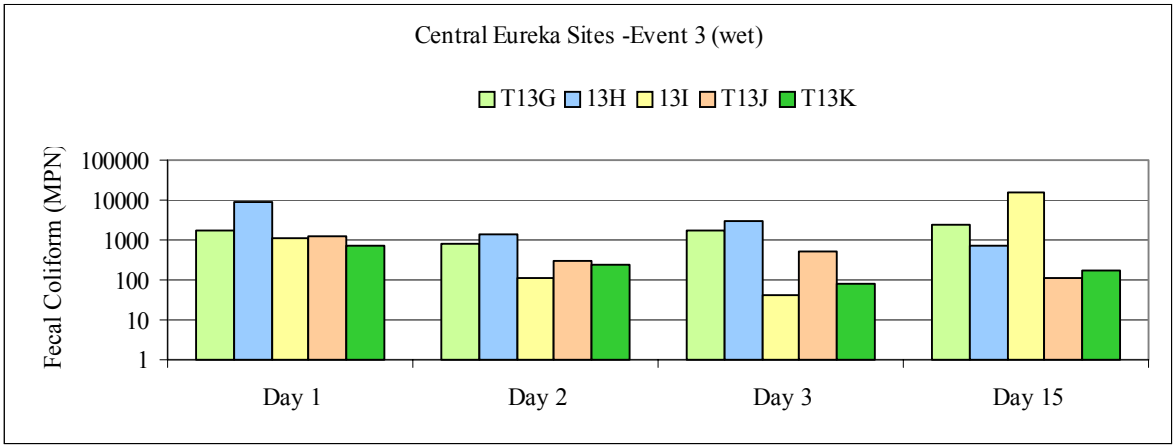
L Street and Waterfront- T13C (24" culvert, L St and Waterfront).
Site T13 C background level was 20 MPN. The background concentrations were exceeded during all storm events. Event 2 concentrations were lower than other rainfall events. Coliform characteristics indicate higher concentrations by Day X than Day 1. This site appears to contain a high and constant source of fecal coliform during rainfall.

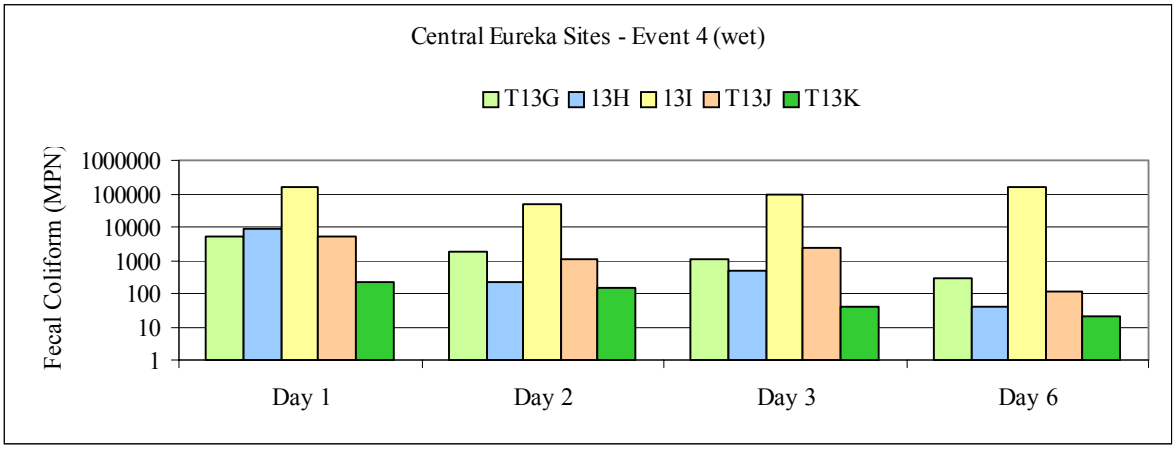
J Street and Waterfront - T13D (12" culvert, J St and Waterfront)
Site T13D background concentration was 20 MPN. During Events 2 and 4, Day 1 samples were elevated, but returned to background concentrations by Day 2 of each event, remaining low throughout the sampling. In all cases, coliform concentrations returned to background levels by Day X.

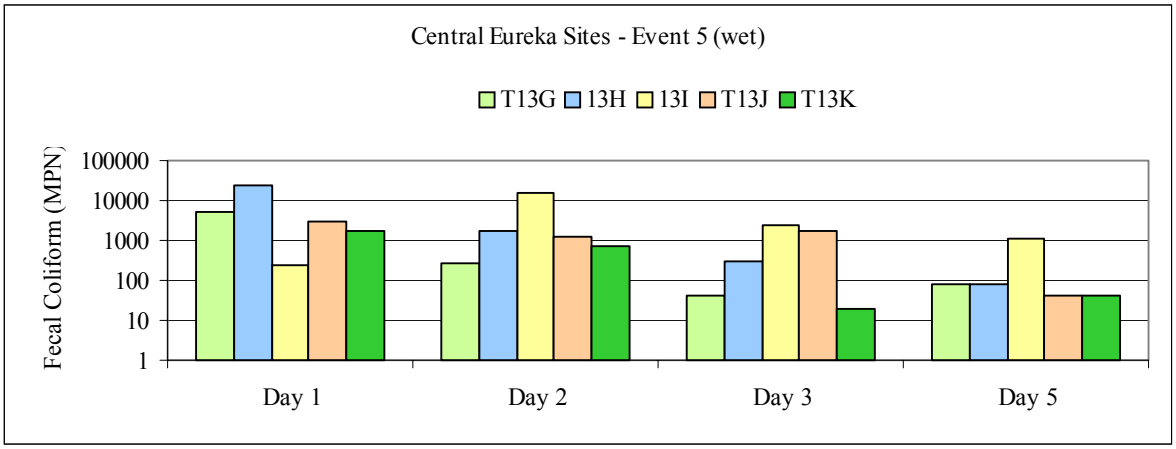
C Street and Waterfront - T13E (54" culvert, C St and Waterfront).
Site T13E background level was 800 MPN. Day X concentrations decreased to or below the background level in three of the four storm events (note: Event 2, Day X decreased to 80 MPN). During the final rainfall event, concentrations remained elevated and constant throughout the sampling with a Day X fecal coliform level of 2,400 MPN. This suggests that some constant source of fecal coliform was present near this site during the last rainfall event.

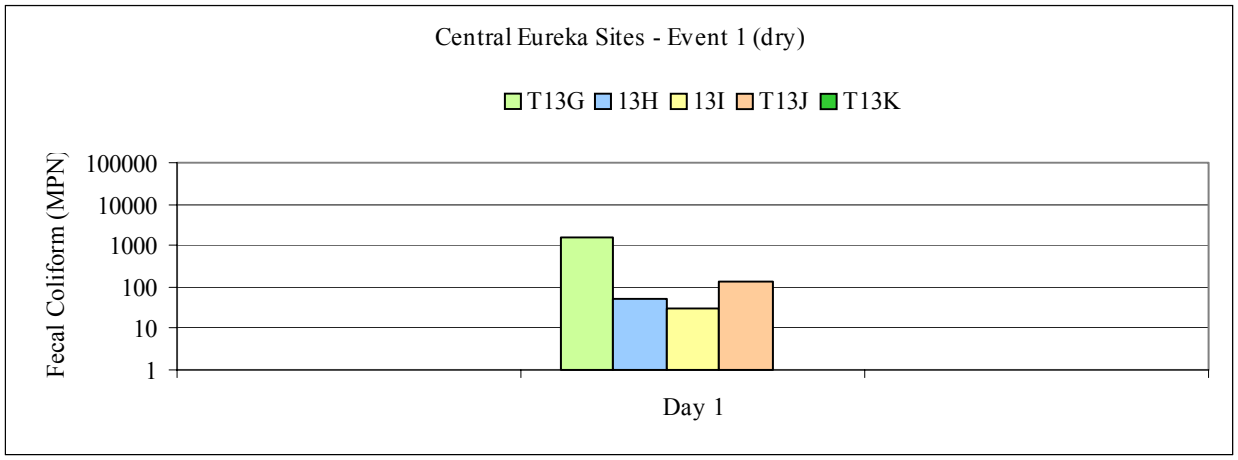
Commercial Street and Waterfront - T13F (30" culvert, Commercial St and Waterfront)
Site T13F background level was 500 MPN. While Day 1 concentrations were elevated, Day X concentrations returned to background levels in three of four Events. During Event 3, fecal coliform concentrations remained constant and elevated through Day 3, peaking at 16,000 MPN on Day X. This suggests that some constant source of fecal coliform was present at this site during Event 3.


Central Eureka Sites - Event 2 (wet)
T13G
13H
13I
T13J
T13K
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Central Eureka Sites -Event 3 (wet)
T13G
13H
13I
T13J
T13K
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Central Eureka Sites - Event 4 (wet)
T13G
13H
13I
T13J
T13K
Fecal Coliform (MPN)
1000000
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Central Eureka Sites - Event 5 (wet)
T13G
13H
13I
T13J
T13K
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



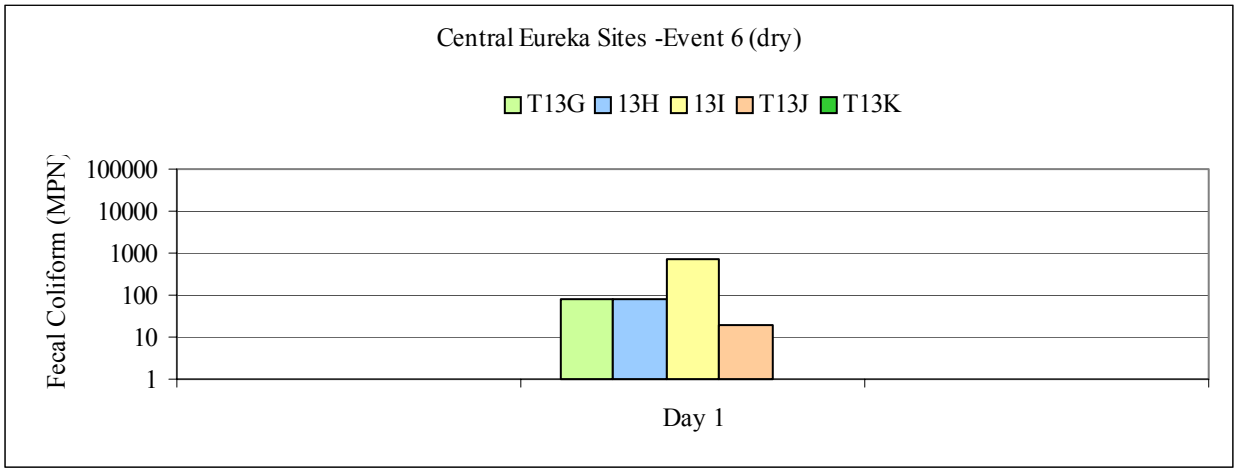


Figure 16.

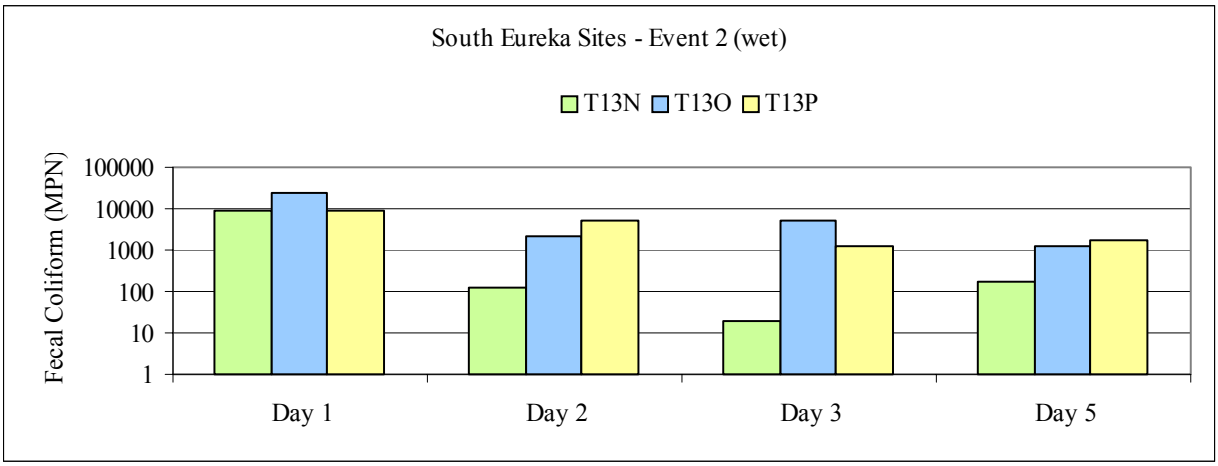
Boat Ramp Launch, Waterfront- T13G (Boat ramp launch): T13G background level was 80 MPN. During Events 2 and 3, coliform concentrations remained consistent, indicated little or no change from Day 1 to Day X. Day X levels during these events were above the background level; Event 3, Day X sample was 16,000 MPN. During Event 4, concentrations were similar to the previous two events, decreasing by Day X. Event 5 had very low fecal coliform concentrations compared to the previous three events. This site appears to have a constant source of fecal coliform nearby during rainfall. Additionally, because the dry weather samples were variable (1,600 and 80 MPN) this source might be present periodically during dry weather.

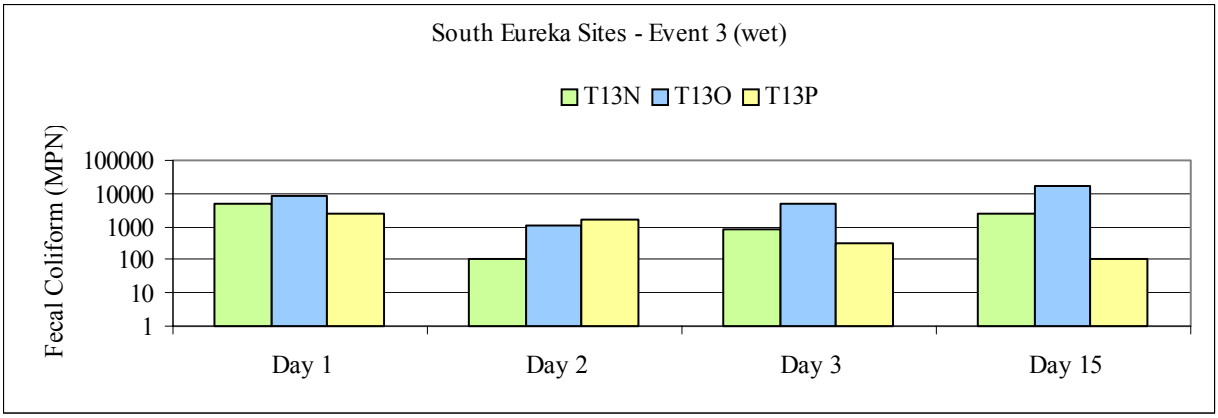
West 14 and Railroad- T13H (West 14 and Railroad): T13H background concentration was 80 MPN. During Events 2 and 3, concentrations remained elevated throughout sampling. Day X samples from the last two rainfall events were at or below the background level. Event 5, Day 1 sample was 23,000 MPN, decreasing to background concentrations by Day X. This site does not seem to contribute a large concentration of coliform except during rainfall events.

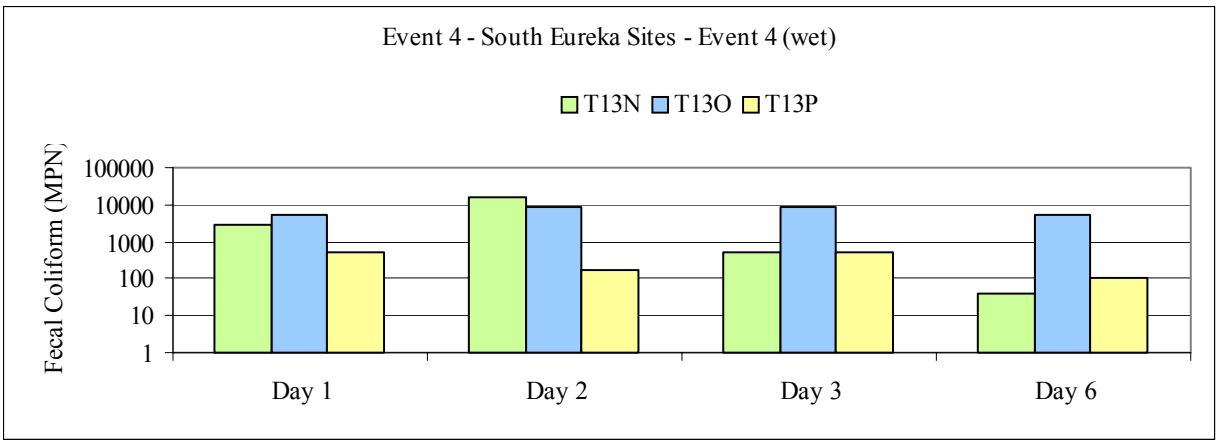
Del Norte and Railroad- T13I (30" Del Norte and Railroad): T13I dry weather samples were variable 30 and 700 MPN. In general, coliform concentrations increased or remained constant from Day 1 to Day X. This site indicated significant coliform concentrations and indicated the potential of a constant source of coliform nearby.

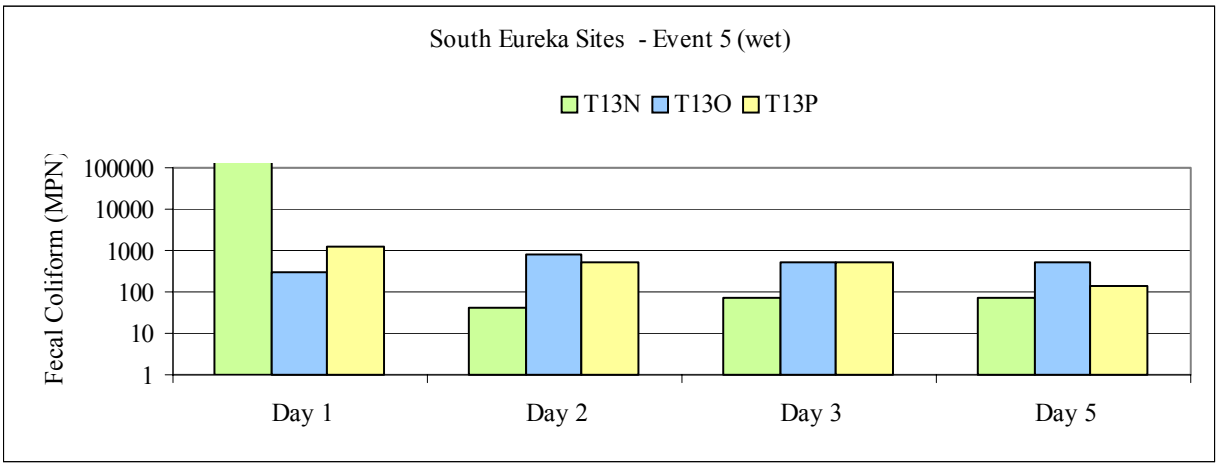
Palco Marsh- T13J (Palco Marsh): T13J background level was between 20 and 140 MPN. Coliform concentrations were elevated from Day 1 through Day 3, decreasing to background levels by Day X. This site does not appear to contribute a large concentration of coliform except during rainfall events.

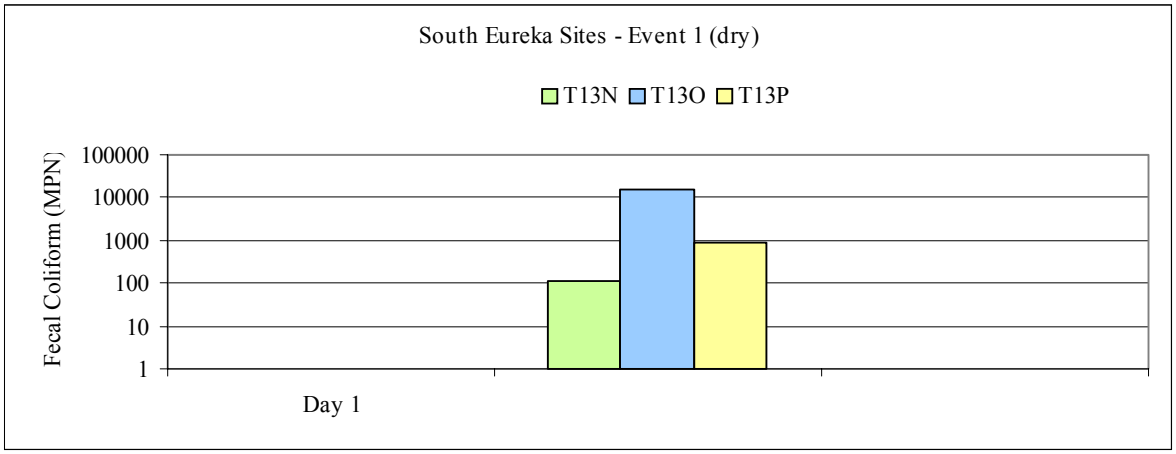
Palco Marsh - T13K: T13K dry weather samples were unattainable due to lack of flow. This location demonstrates flush effect. Coliform from Event 2 were higher than Event 3, which was higher than Event 4. It appears that a background fecal coliform concentration might be 40 MPN for this site. After the initial flush, this site does not appear to contribute high concentrations of fecal coliform.


South Eureka Sites - Event 2 (wet)
T13N
T13O
T13P
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


South Eureka Sites - Event 3 (wet)
T13N
T13O
T13P
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Event 4 - South Eureka Sites - Event 4 (wet)
T13N
T13O
T13P
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


South Eureka Sites - Event 5 (wet)
T13N
T13O
T13P
Fecal Coliform (MPN)
100000
10000
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



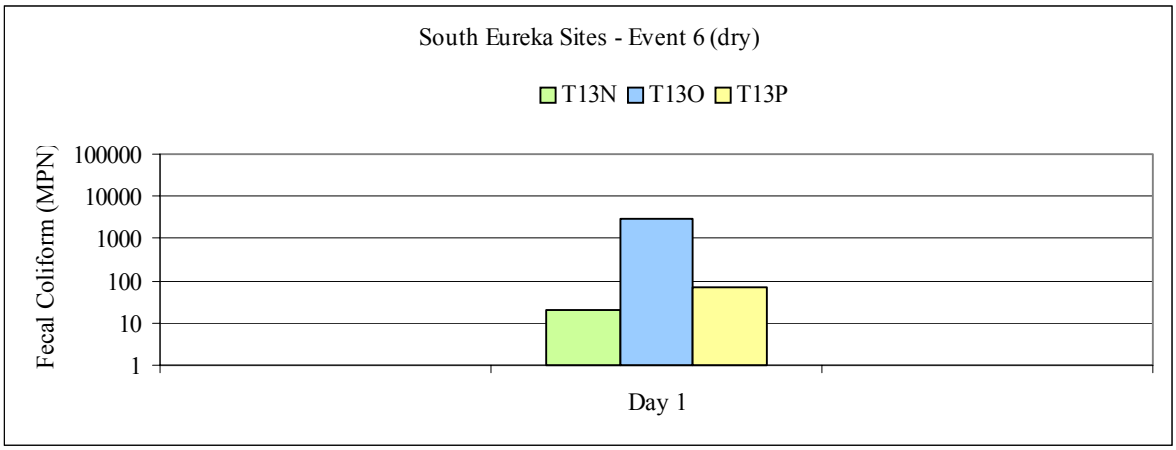
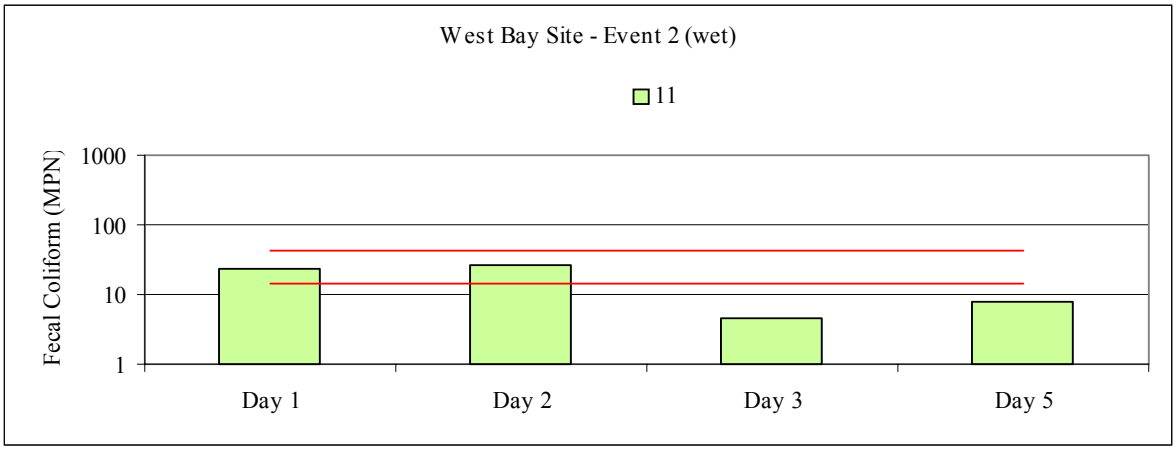


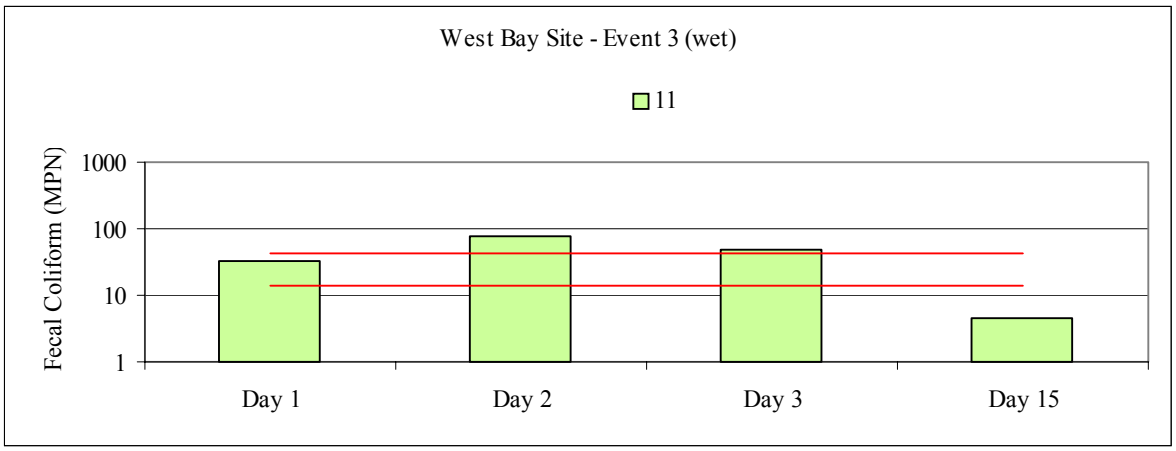
Figure 17.

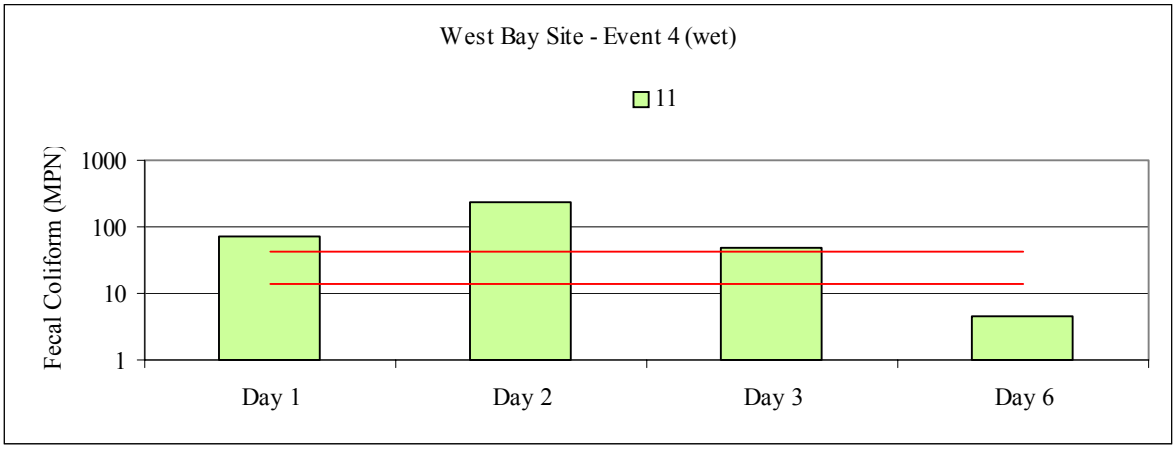
Truesdale and Christie-T13N.
T13N background concentration was 20 MPN. There were several unexpected spikes observed at this site. A possible explanation is the introduction of a localized coliform loading source. In all but one event concentrations returned to background levels by Day X. Even though the results of this site were variable, it does not appear that this site contributes high fecal coliform concentrations.

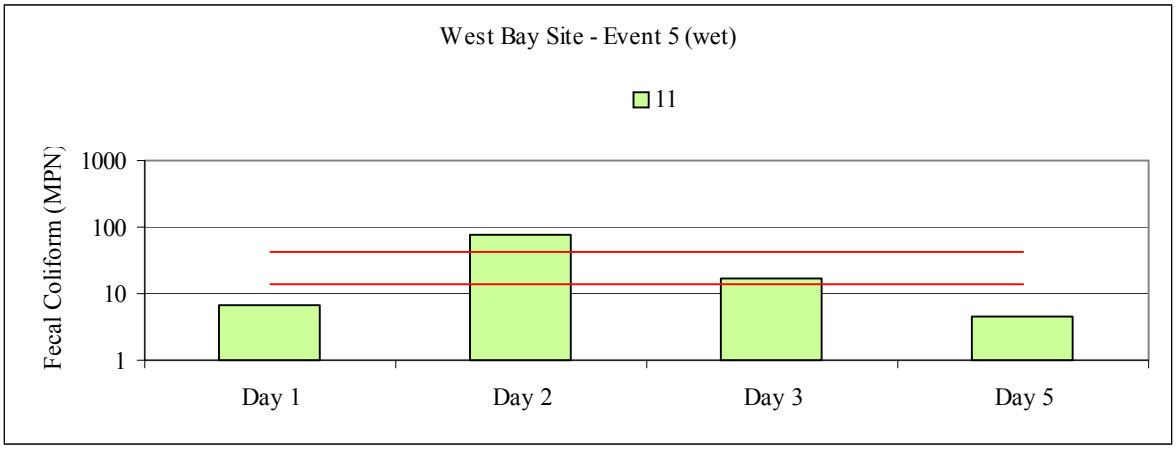
McCullens Ave. - T13O (36" culvert west end of McCullen's St.)
T13O background concentration was 3,000 MPN. Day 1 coliform concentrations ranged from 300 to 24,000 MPN. During Event 2, coliform concentrations decreased from 24,000 to 1,300 MPN by Day X. This site indicates a significant background coliform concentrations compared to other locations in this watershed, and seems to contribute a fairly large coliform concentration, at least during early to mid season storms.

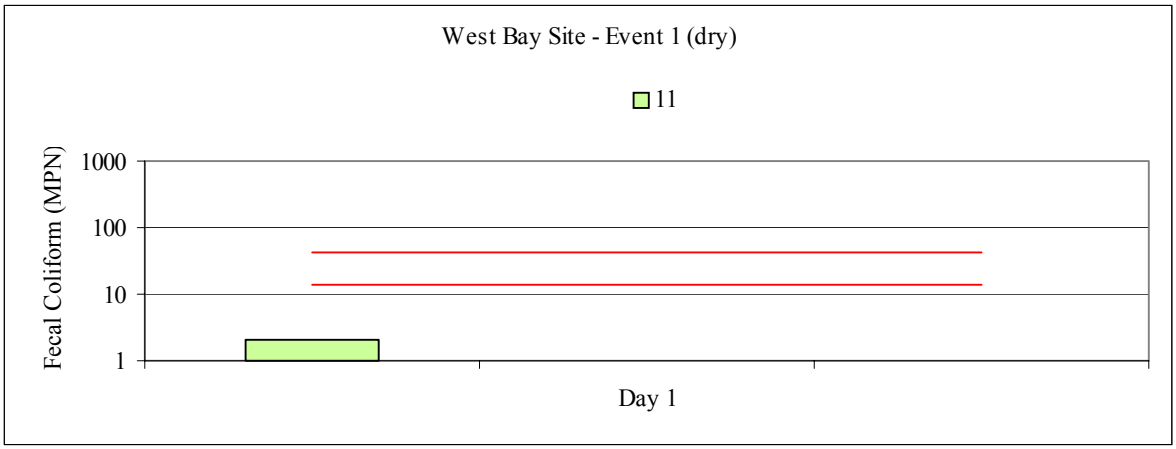
T13P - (ditch north of sewage treatment plant)
T13P background concentration was 70 MPN. This site demonstrated first flush effect. In general, coliform concentrations were highest during the first storm event, decreasing with subsequent storm events. With the exception of Event 2, Day X concentrations were only slightly elevated from background levels. Except during rainfall, this site does not seem to contribute high concentrations of fecal coliform.


West Bay Site - Event 2 (wet)
11
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


West Bay Site - Event 3 (wet)
11
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


West Bay Site - Event 4 (wet)
11
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


West Bay Site - Event 5 (wet)
11
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



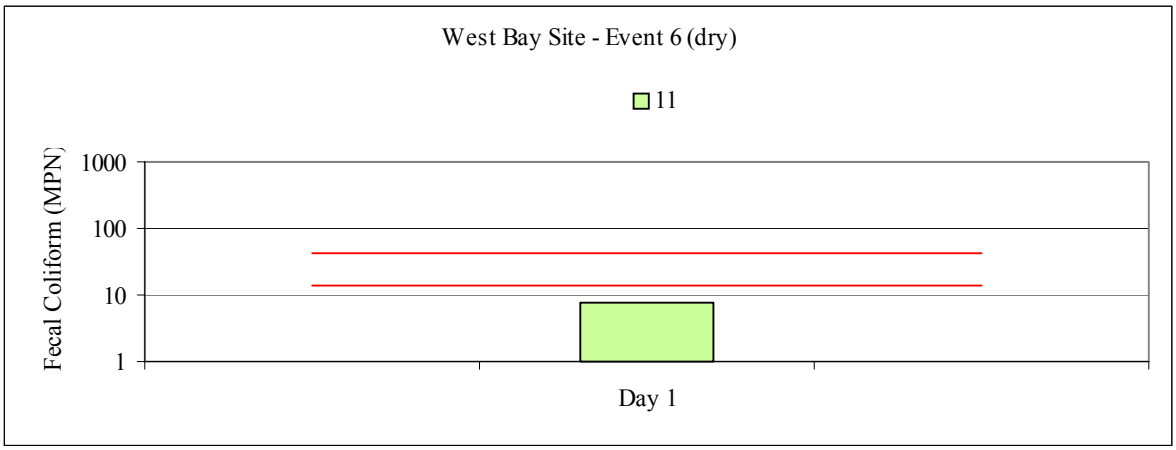
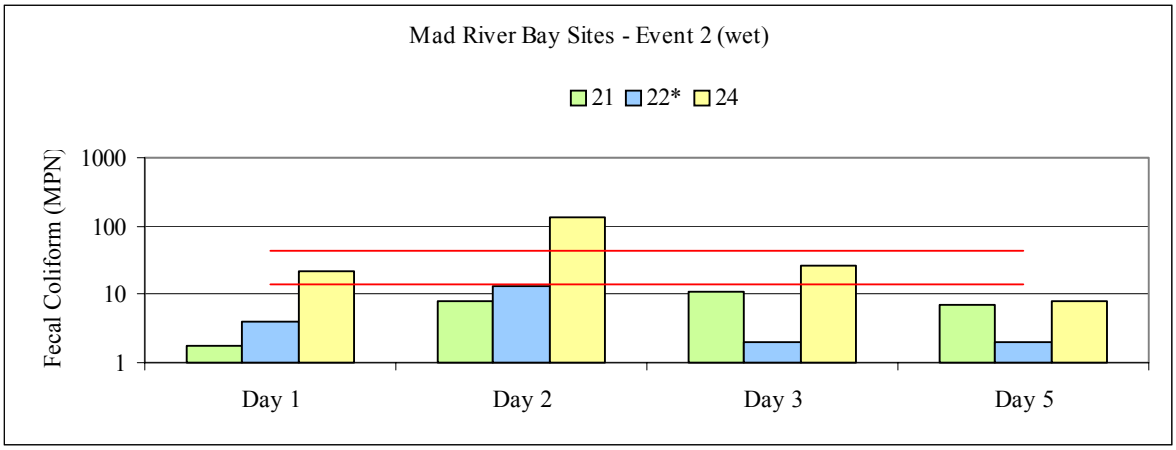
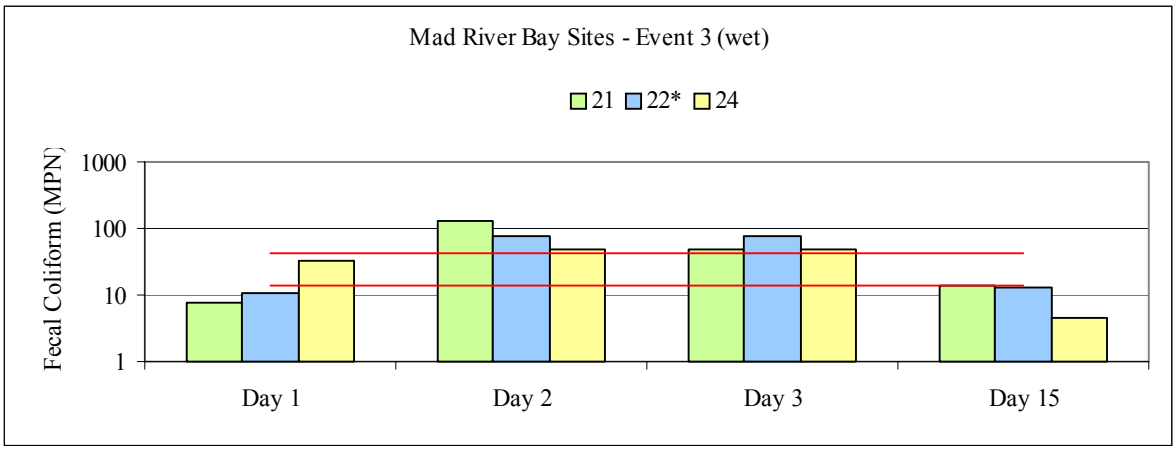
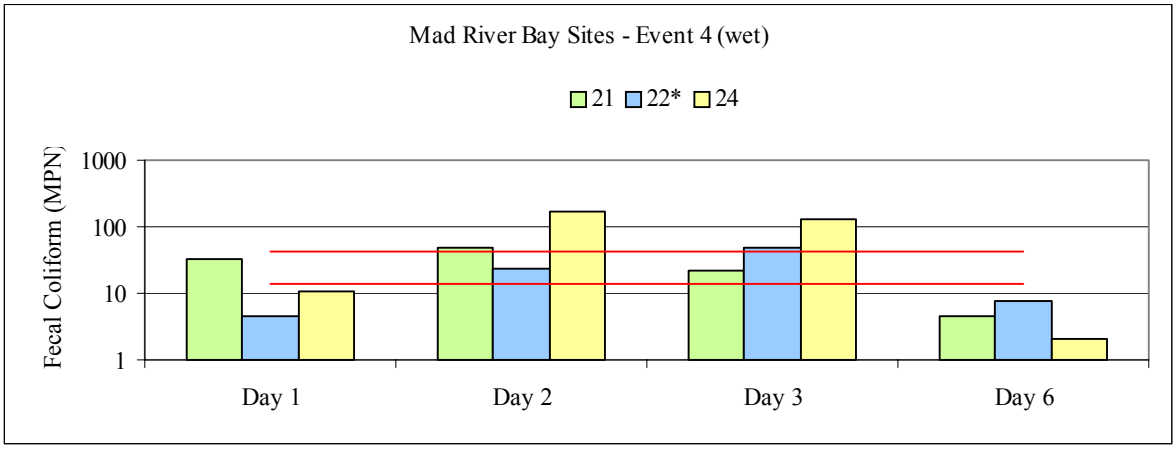


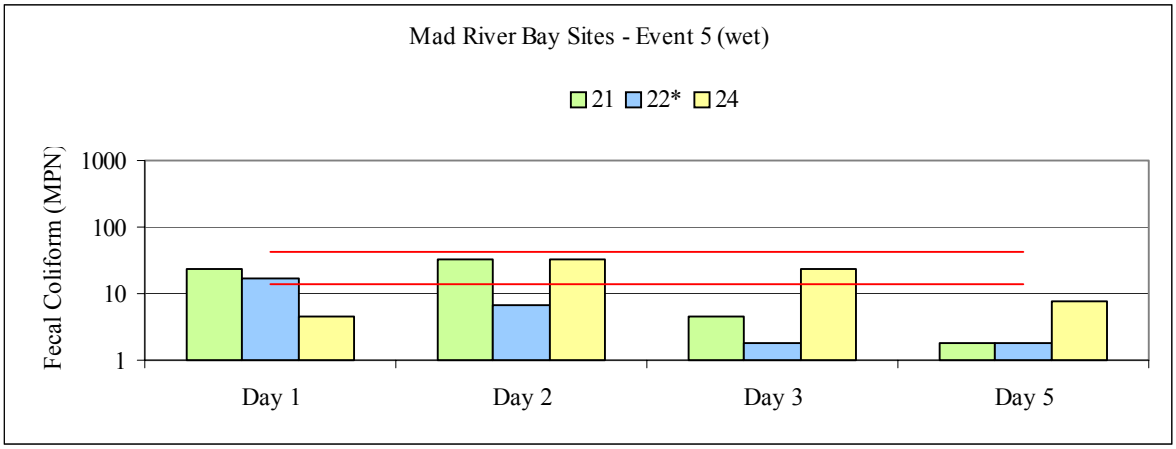
Figure 18.

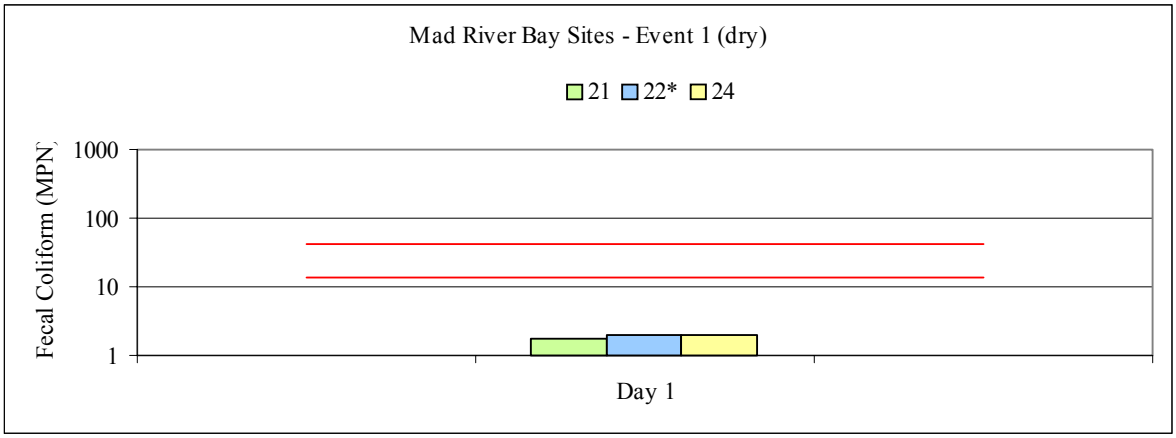
WQ# 11: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (2 and 7.8 MPN). Coliform concentrations increased during rainfall events and in each case returned to water quality objectives by Day X. Event 4, Day 2 had the single-highest coliform concentration of 240 MPN, decreasing to 49 MPN on Day 3 and 4.5 MPN by Day X.


Mad River Bay Sites - Event 2 (wet)
21
22*
24
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Mad River Bay Sites - Event 3 (wet)
21
22*
24
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Mad River Bay Sites - Event 4 (wet)
21
22*
24
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Mad River Bay Sites - Event 5 (wet)
21
22*
24
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



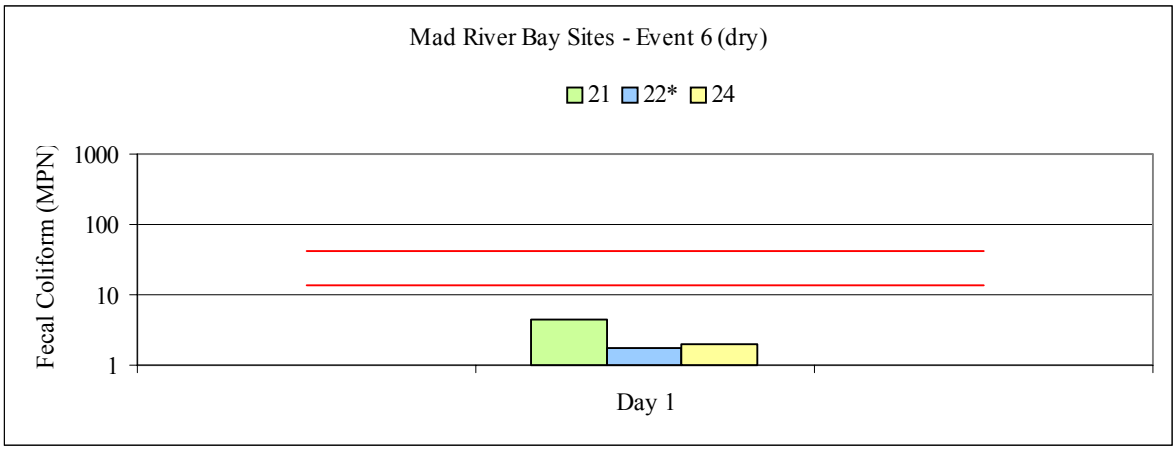
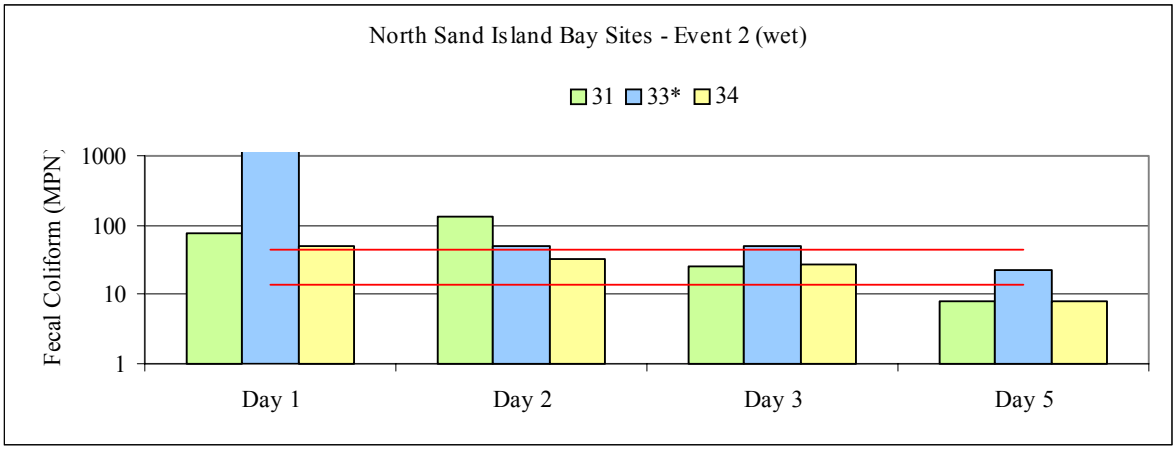


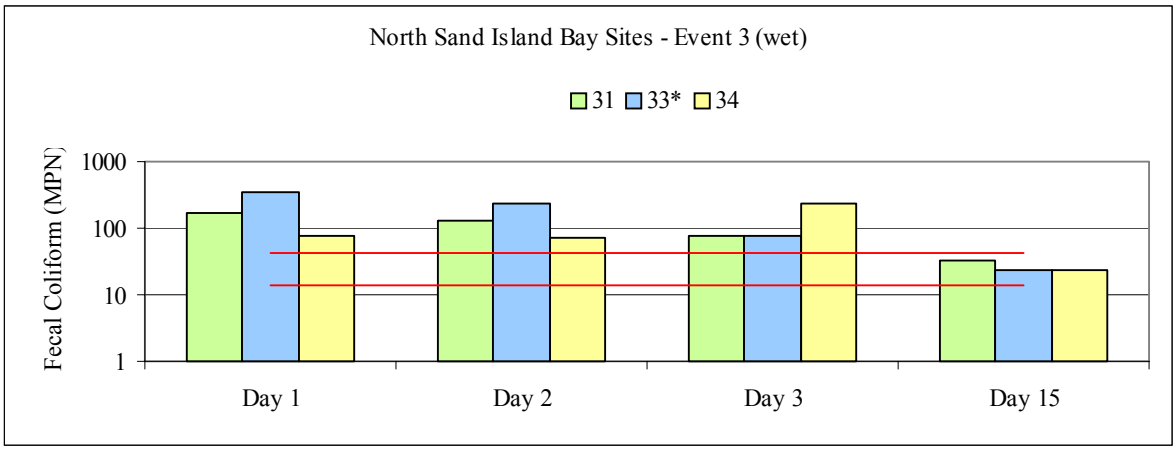
Figure 19.

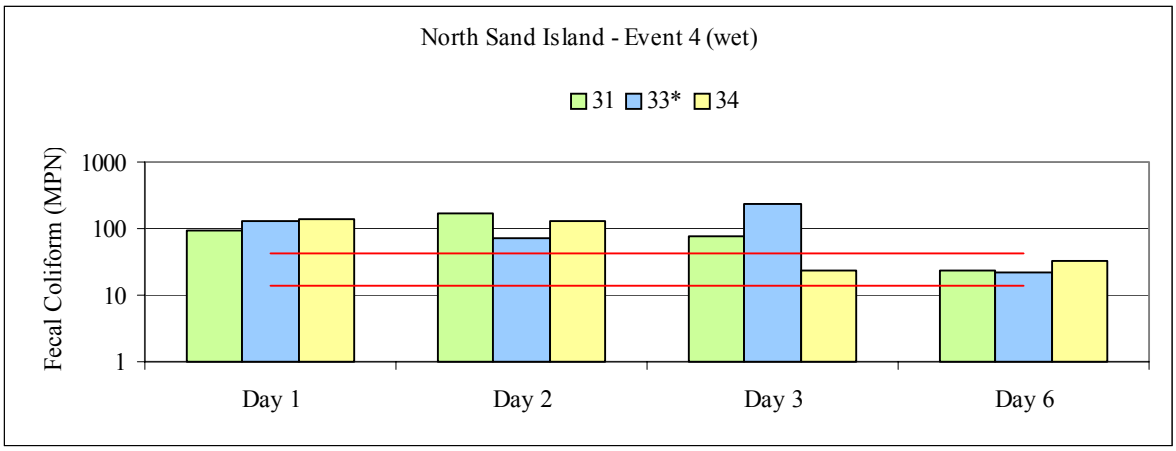
WQ# 21: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (2 and 3 MPN). Coliform concentrations increased during rainfall events and in each case returned to water quality objectives by Day X. Event 3, Day 2 had the single-highest coliform concentration of 130 MPN, decreasing to 49 MPN on Day 3 and 14 MPN by Day X.

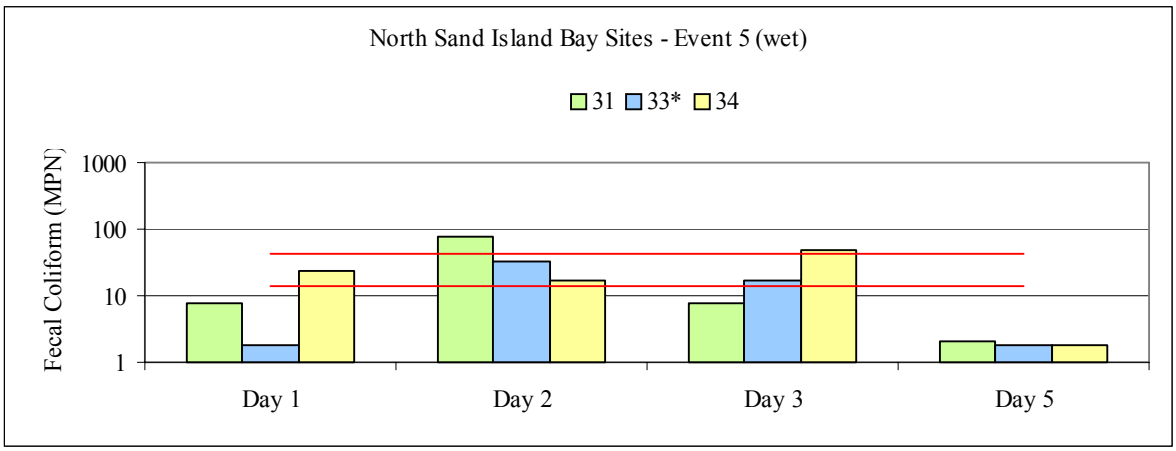
WQ# 22: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (2 MPN). Coliform concentrations increased during rainfall events and in each case returned to water quality objectives by Day X. Event 3, Day 2 and 3 had highest coliform concentrations of 79 MPN, decreasing to 13 MPN on Day X.

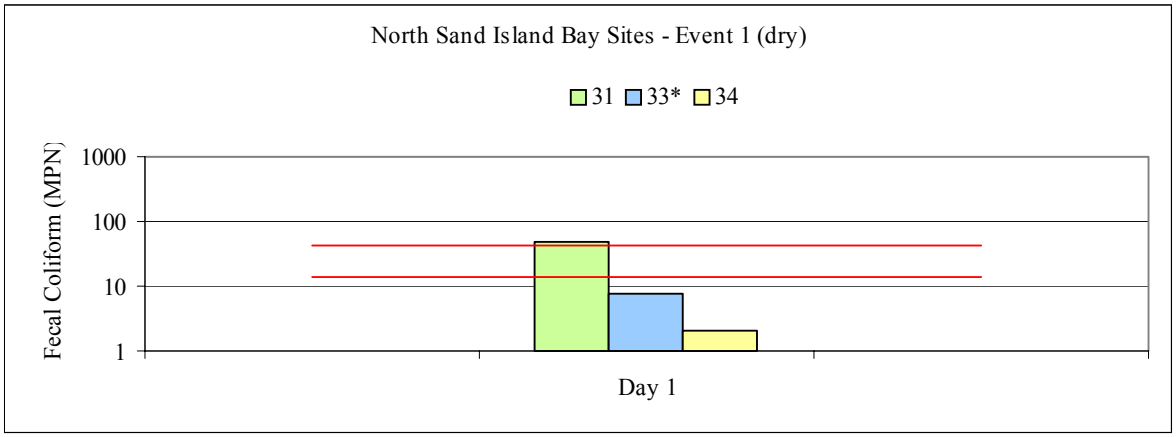
WQ# 24: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (2 MPN). Coliform concentrations increased during rainfall events and in each case returned to water quality objectives by Day X. Event 4, Day 2 and 3 had highest coliform concentrations of 170 and 130 respectively, decreasing to 2 MPN by Day X.


North Sand Island Bay Sites - Event 2 (wet)
31
33*
34
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


North Sand Island Bay Sites - Event 3 (wet)
31
33*
34
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


North Sand Island - Event 4 (wet)
31
33*
34
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


North Sand Island Bay Sites - Event 5 (wet)
31
33*
34
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



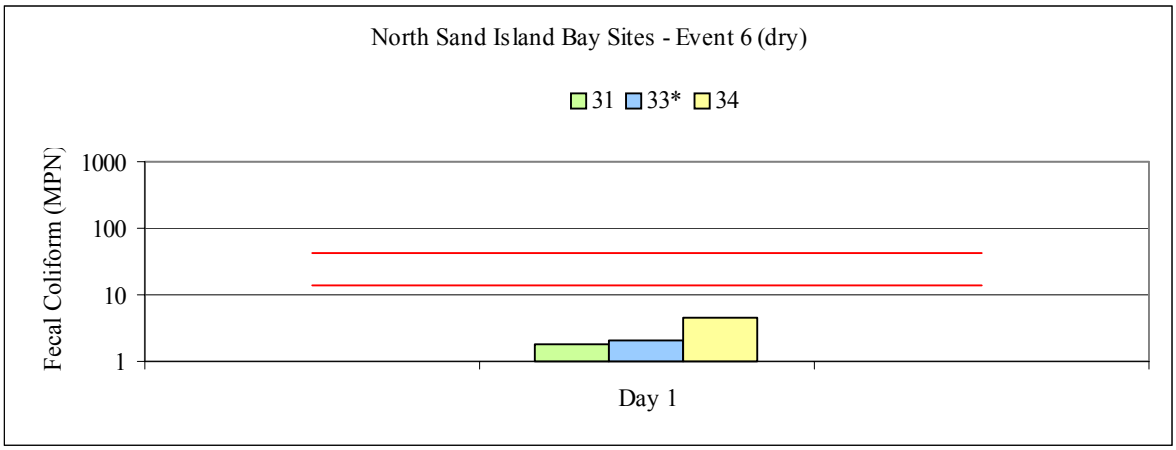
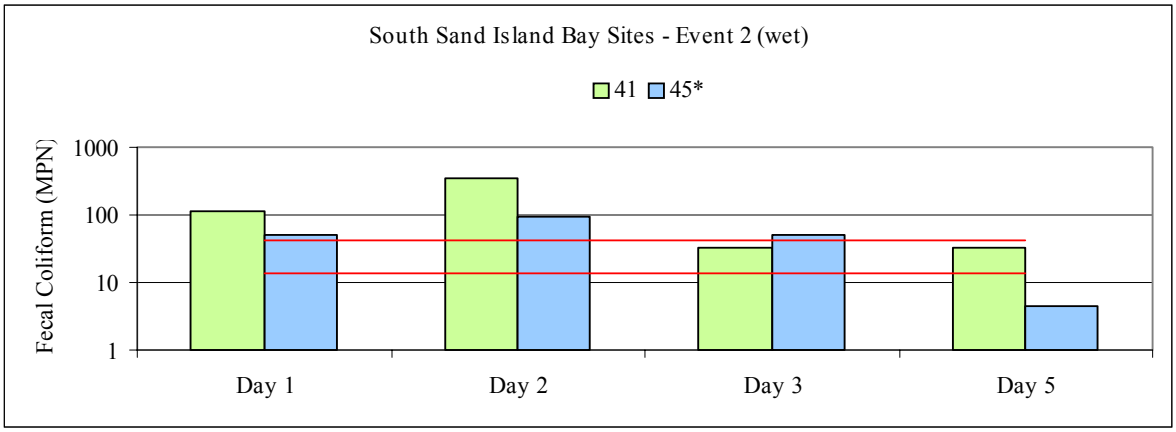


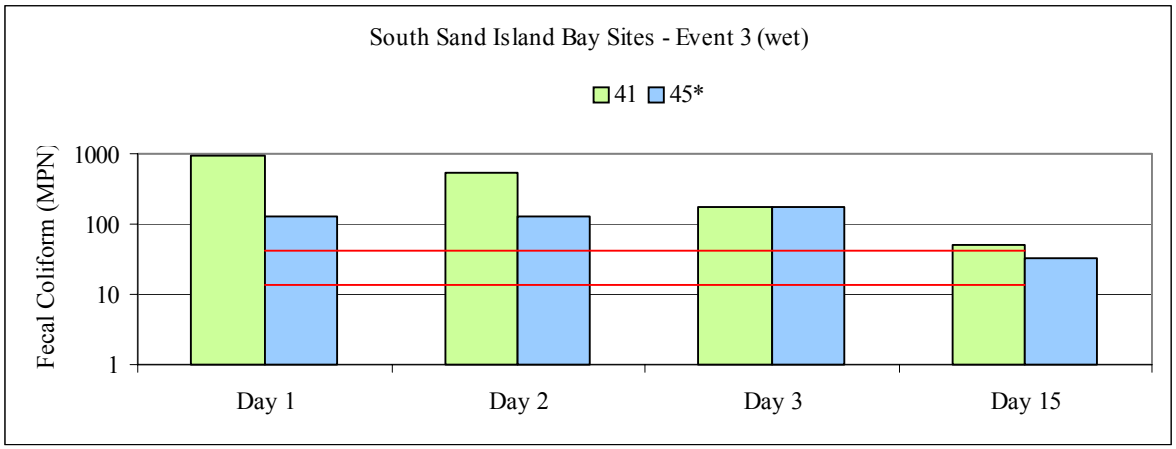
Figure 20.

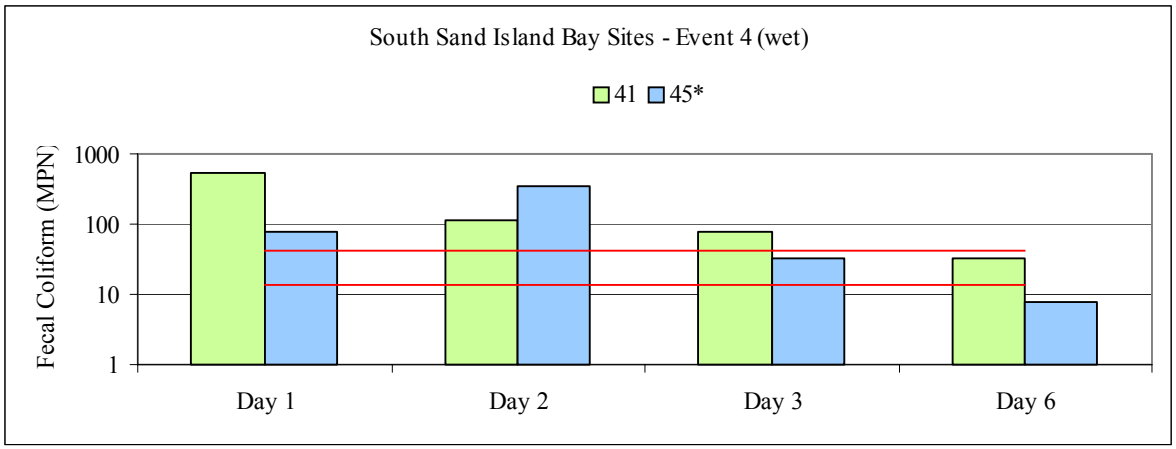
WQ# 31: Based on Dry Event coliform concentrations, the background level exceeded the 43 MPN water quality objective (49 MPN) during the first dry weather-sampling event and was 1.8 MPN during the second dry weather-sampling event. This site exhibited 'first flush' characteristics with increased coliform concentrations on Day 1,2 and 3, and in each case, returned to water quality objectives by Day X. Day 2 of each event typically had the highest concentrations.

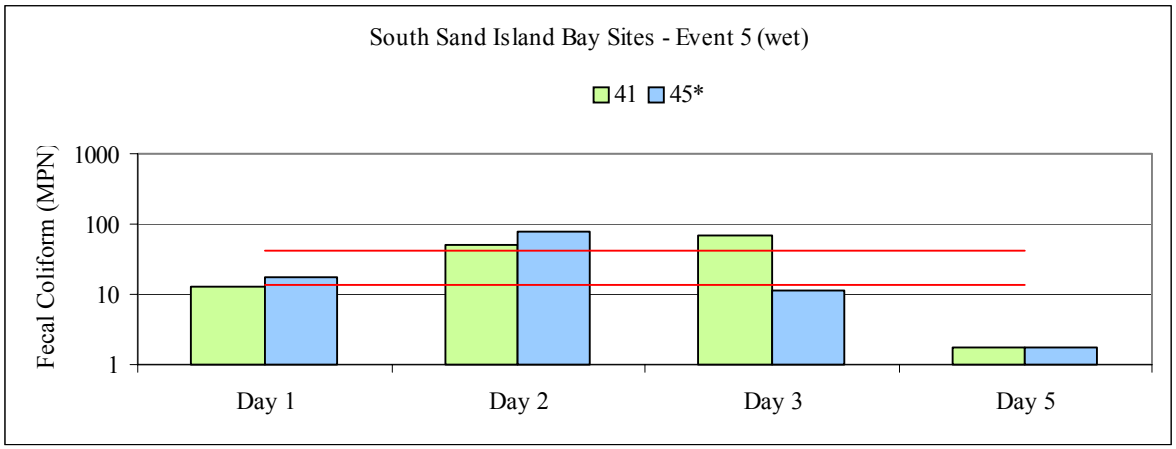
WQ# 33: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (7.8 and 2 MPN). This site exhibited 'first flush' characteristics with increased coliform concentrations on Day 1,2 and 3, and in each case, returned to water quality objectives by Day X. Event 3, Day 1 had the single highest coliform concentration at 350 MPN, returning to 23 MPN by Day X.

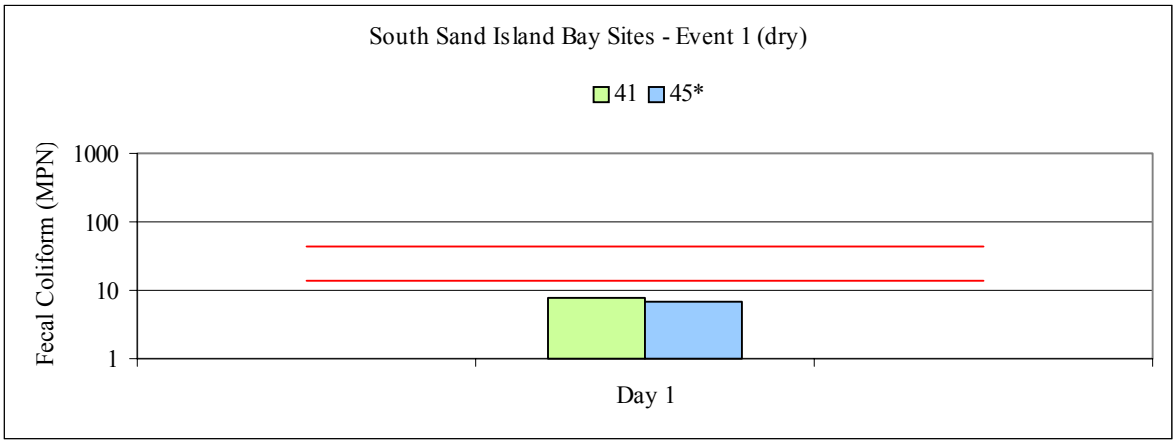
WQ# 34: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (7.8 and 2 MPN). This site exhibited 'first flush' characteristics with increased coliform concentrations on Day 1,2 and 3, and in each case, returned to water quality objectives by Day X. Event 3, Day 1 had the single highest coliform concentration at 350 MPN, returning to 23 MPN by Day X.


South Sand Island Bay Sites - Event 2 (wet)
41
45*
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


South Sand Island Bay Sites - Event 3 (wet)
41
45*
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


South Sand Island Bay Sites - Event 4 (wet)
41
45*
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


South Sand Island Bay Sites - Event 5 (wet)
41
45*
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



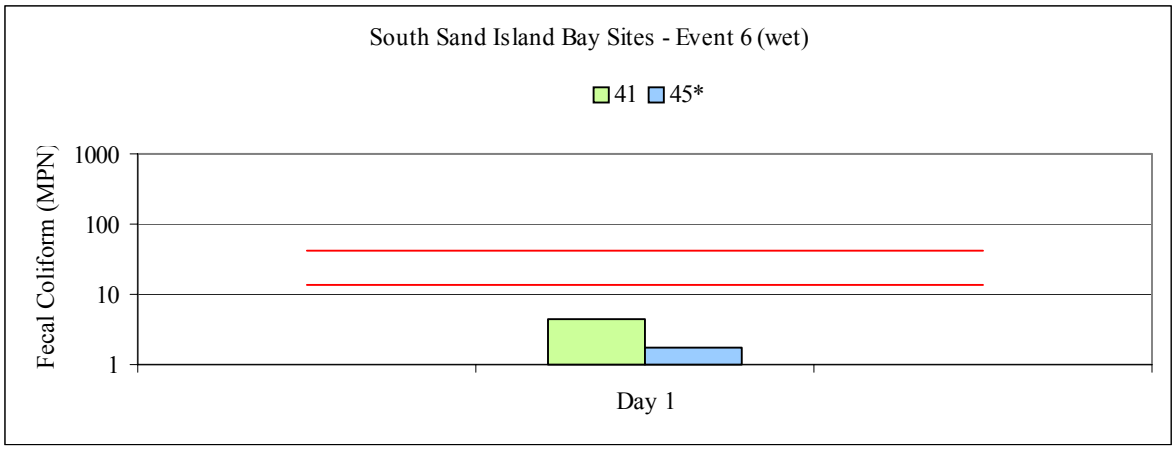
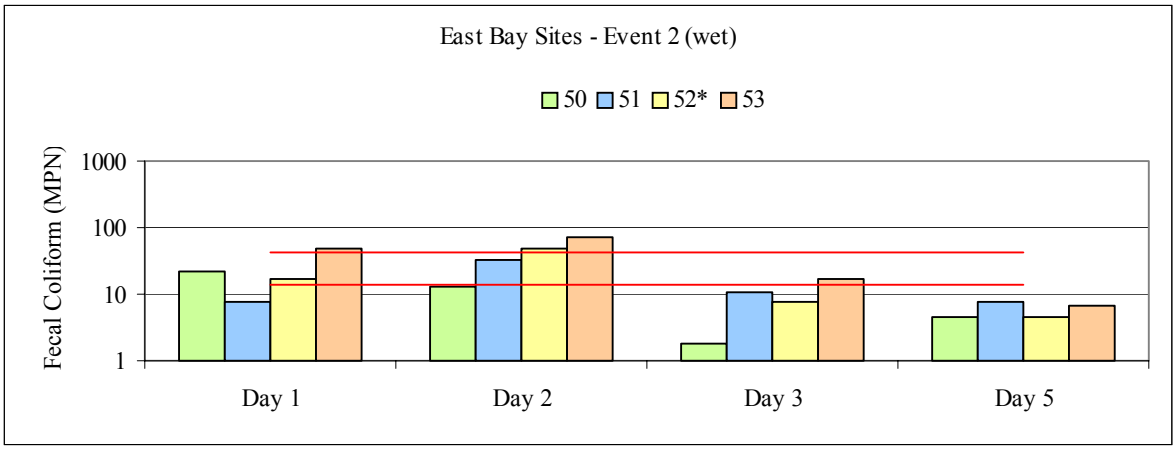
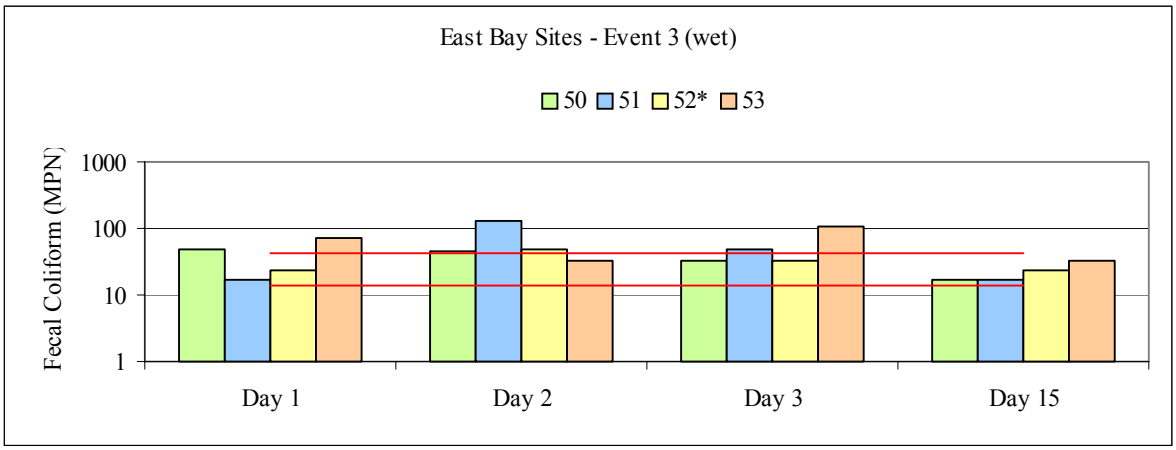


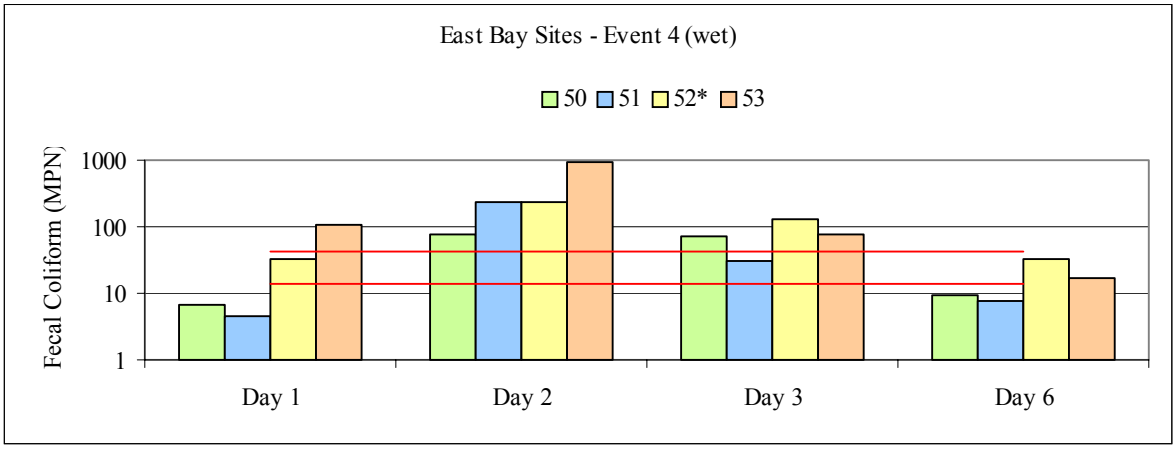
Figure 21.

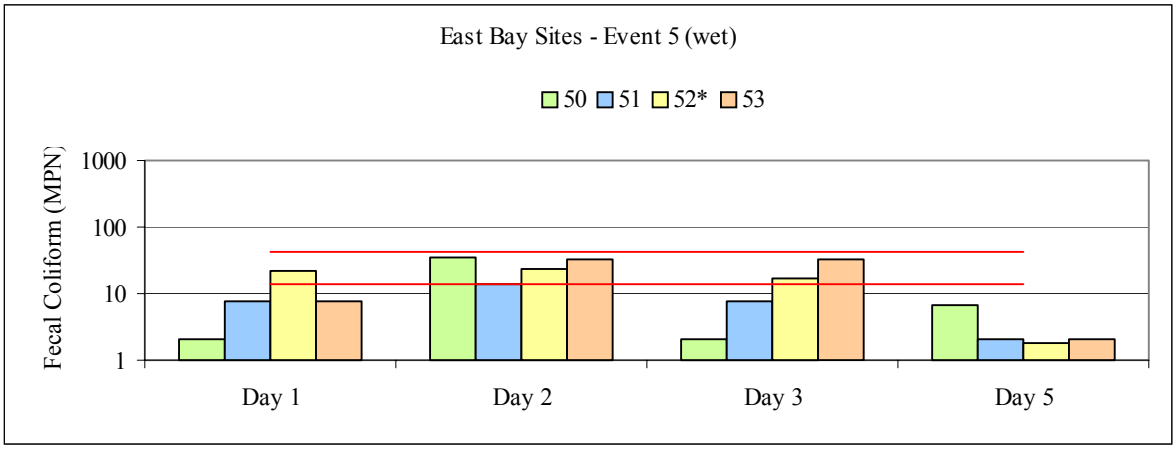
WQ# 41: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (8 and 5 MPN). This site exhibited 'first flush' characteristics with increased coliform concentrations on Day 1,2 and 3, and with the exception of Event 3, returned to water quality objectives by Day X. Event 3, Day 1 had the single highest coliform concentration at 920 MPN, returning to 49 MPN by Day X. *This site may warrant additional investigation.*

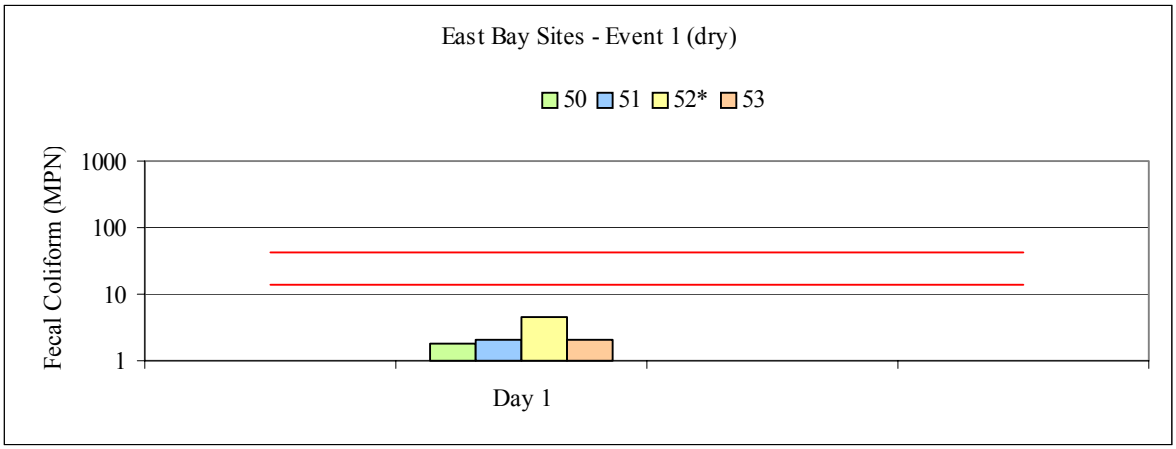
WQ# 45: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (7 and 2 MPN). This site exhibited 'first flush' characteristics with increased coliform concentrations on Day 1,2 and 3, decreasing to water quality objectives by Day X. Event 4, Day 2 had the single highest coliform concentration at 290 MPN, returning to 8 MPN by Day X.


East Bay Sites - Event 2 (wet)
50
51
52*
53
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


East Bay Sites - Event 3 (wet)
50
51
52*
53
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


East Bay Sites - Event 4 (wet)
50
51
52*
53
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


East Bay Sites - Event 5 (wet)
50
51
52*
53
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



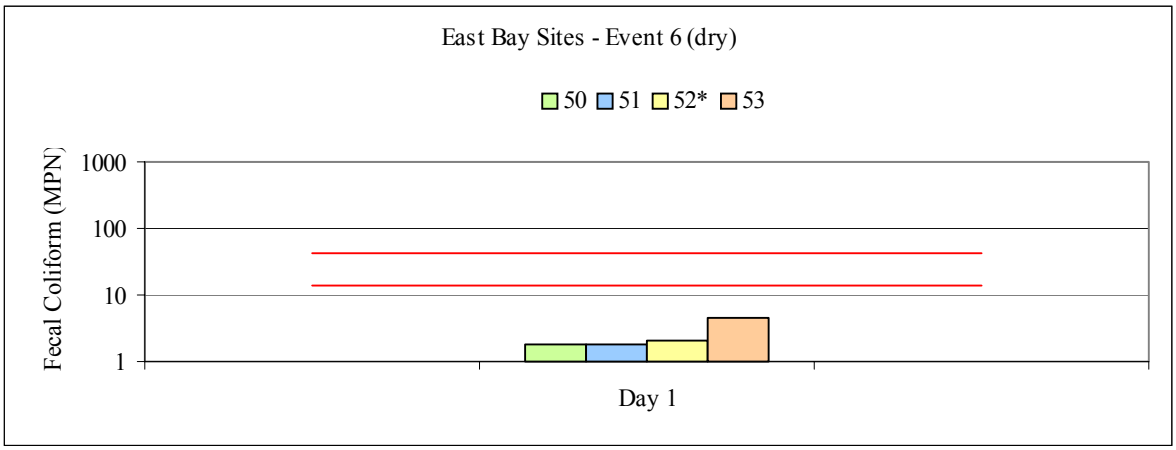
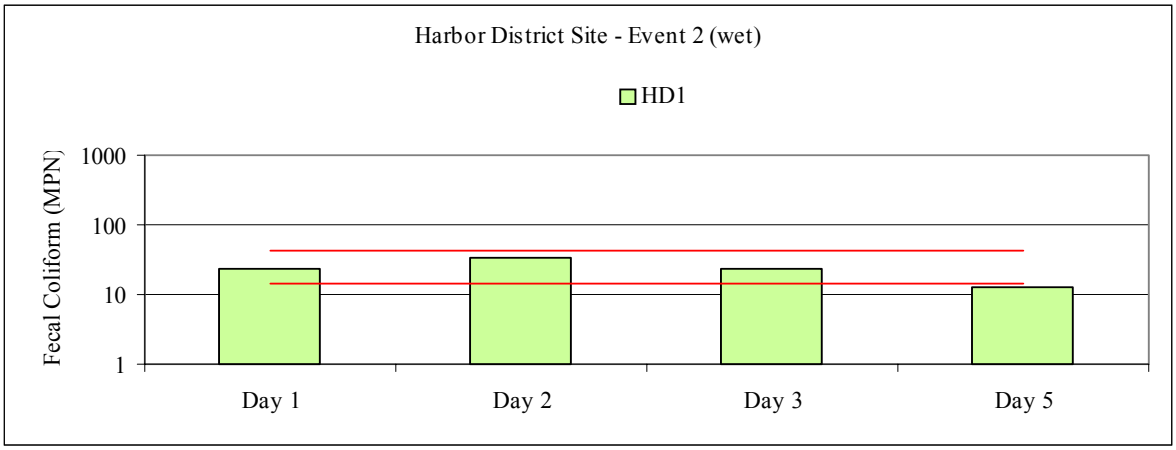
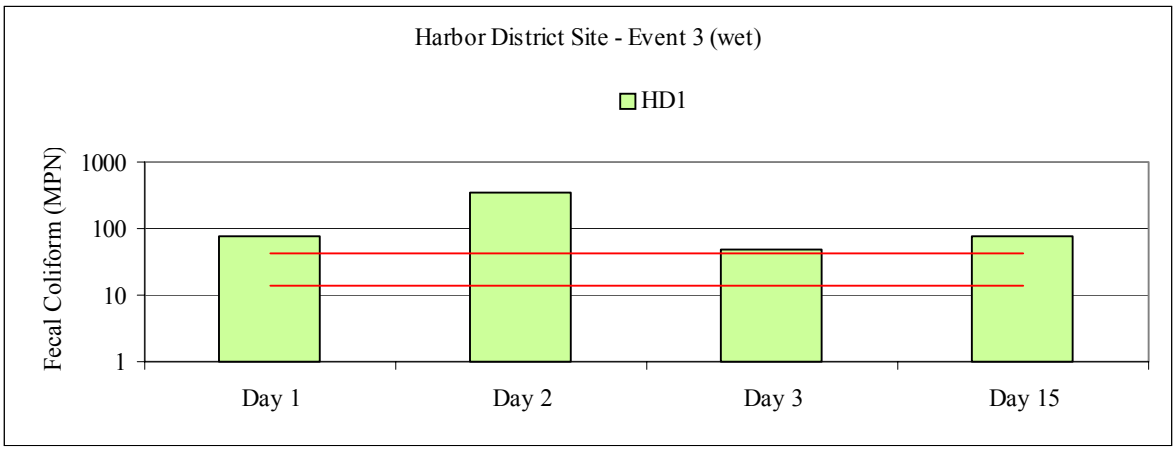
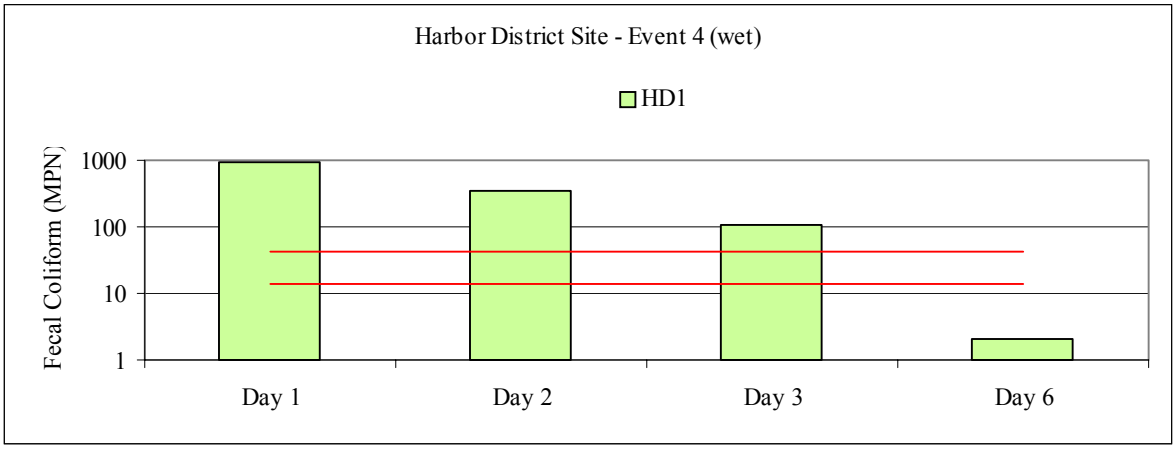


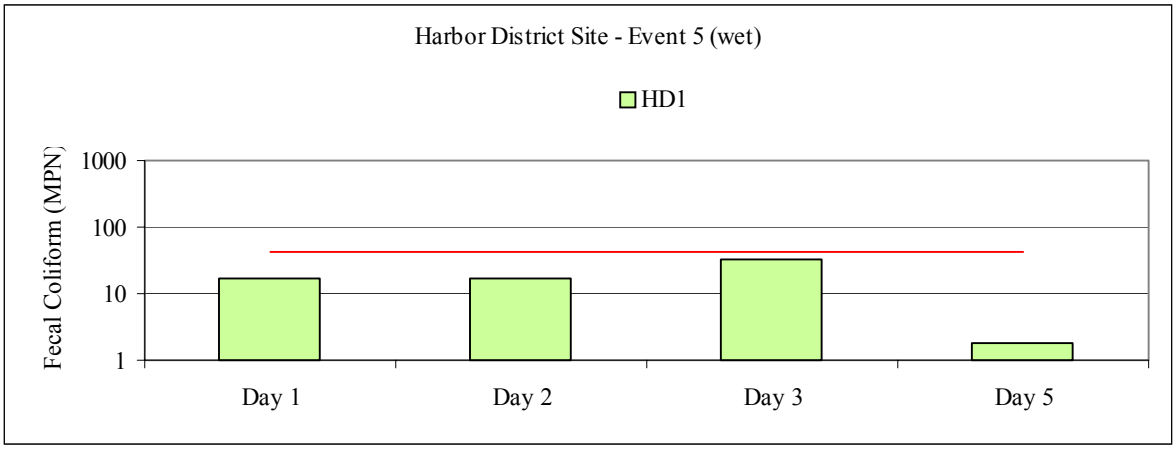
Figure 22.

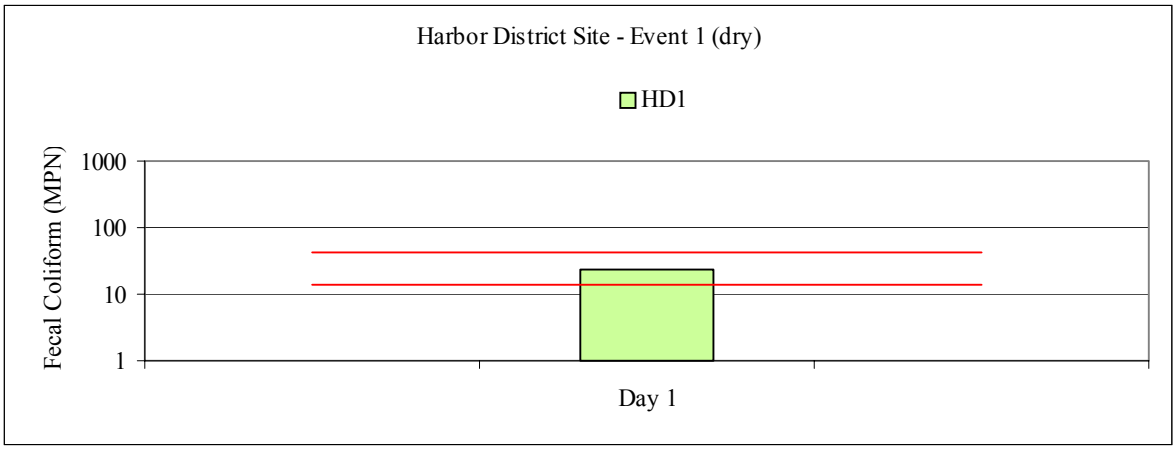
WQ# 50: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (1.8 MPN). This site exhibited 'first flush' characteristics with coliform concentrations peaking on Day 2 of each event, decreasing to water quality objectives by Day X. Event 4, Day 2 had the single highest coliform concentration at 79 MPN, returning to 9.3 MPN by Day X.
WQ# 51: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (2 MPN). This site exhibited 'first flush' characteristics with coliform concentrations peaking on Day 2 of each event, decreasing to water quality objectives by Day X. Event 4, Day 2 had the single highest coliform concentration at 240 MPN, returning to 8 MPN by Day X.
WQ# 52: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (5 and 2 MPN). This site exhibited 'first flush' characteristics with coliform concentrations peaking on Day 2 of each event, decreasing to water quality objectives by Day X. Event 4, Day 2 had the single highest coliform concentration at 240 MPN, returning to 33 MPN by Day X.
WQ# 53: Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (2 and 5 MPN). This site exhibited 'first flush' characteristics with coliform concentrations typically peaking on Day 2 of each event, decreasing to water quality objectives by Day X. Event 4, Day 2 had the single highest coliform concentration at 920 MPN, returning to 33 MPN by Day X.


Harbor District Site - Event 2 (wet)
HD1
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5


Harbor District Site - Event 3 (wet)
HD1
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 15


Harbor District Site - Event 4 (wet)
HD1
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 6


Harbor District Site - Event 5 (wet)
HD1
Fecal Coliform (MPN)
1000
100
10
1
Day 1
Day 2
Day 3
Day 5



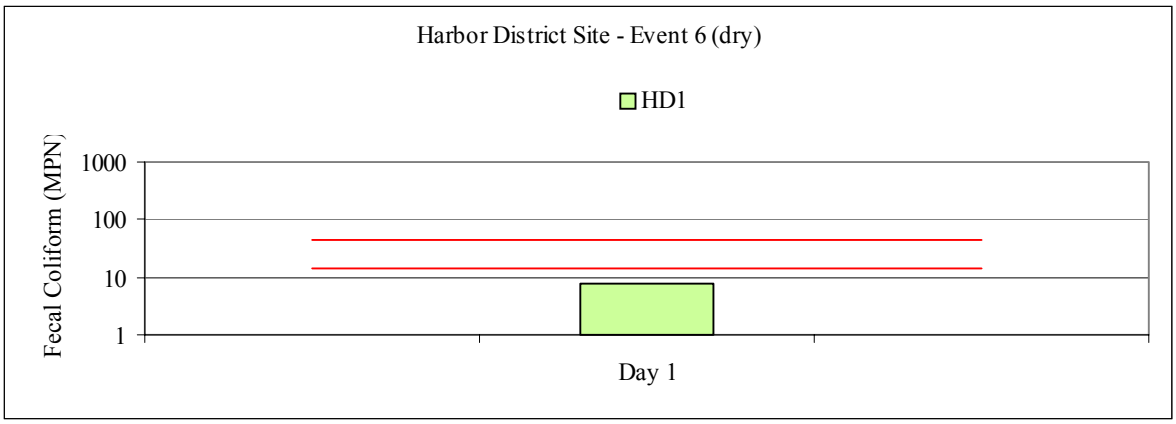
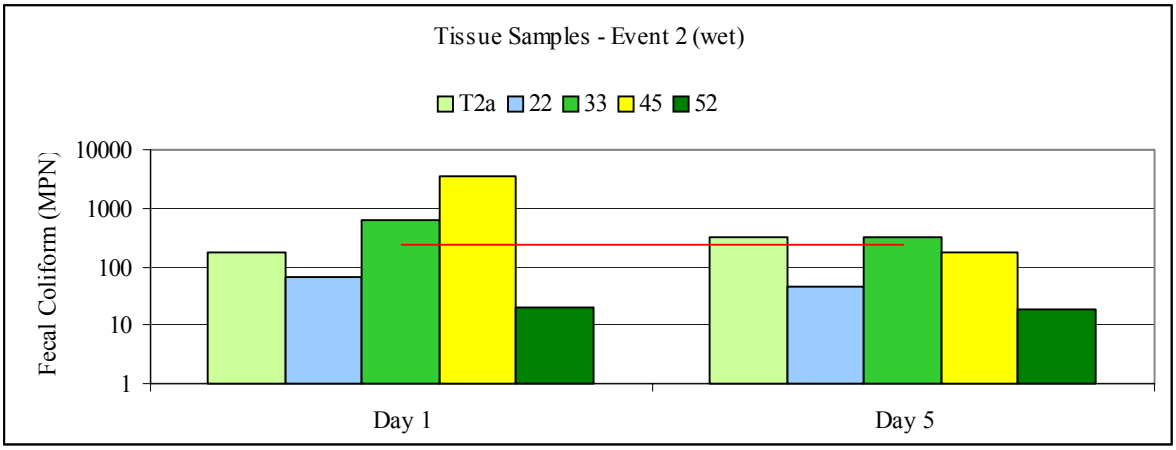
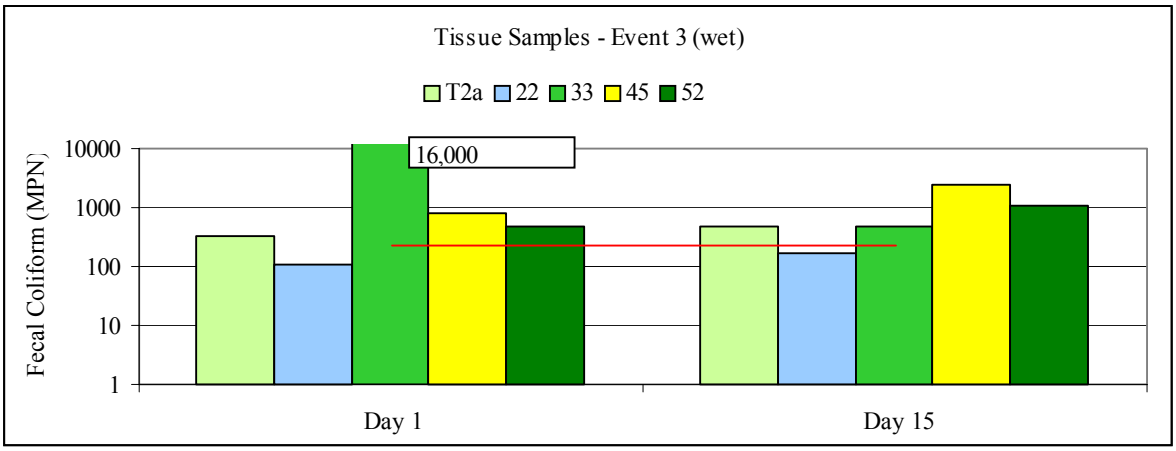
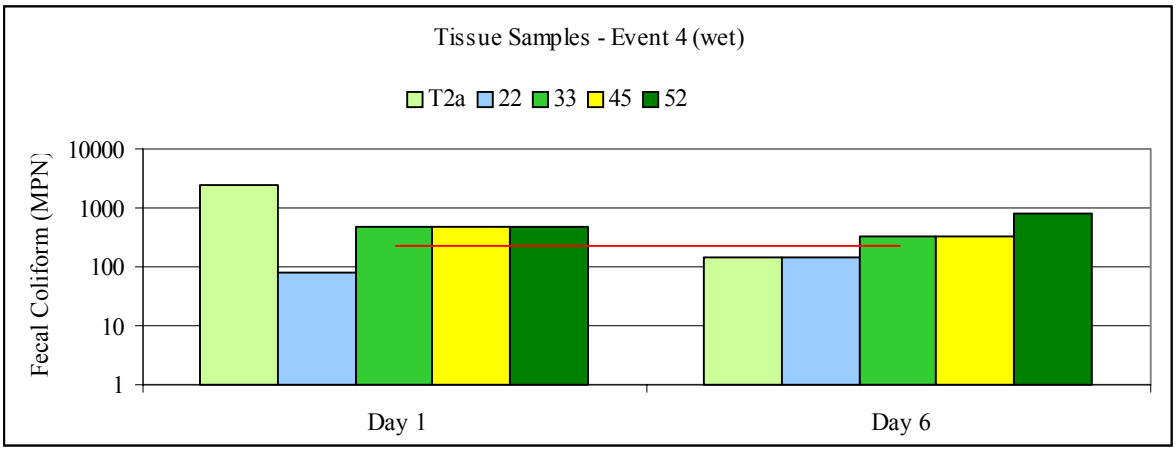


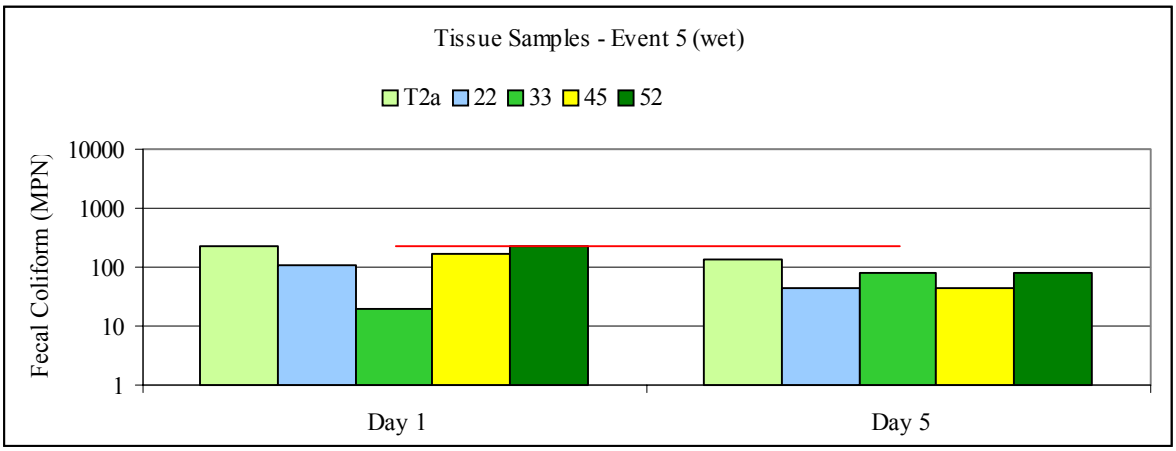
Figure 23.

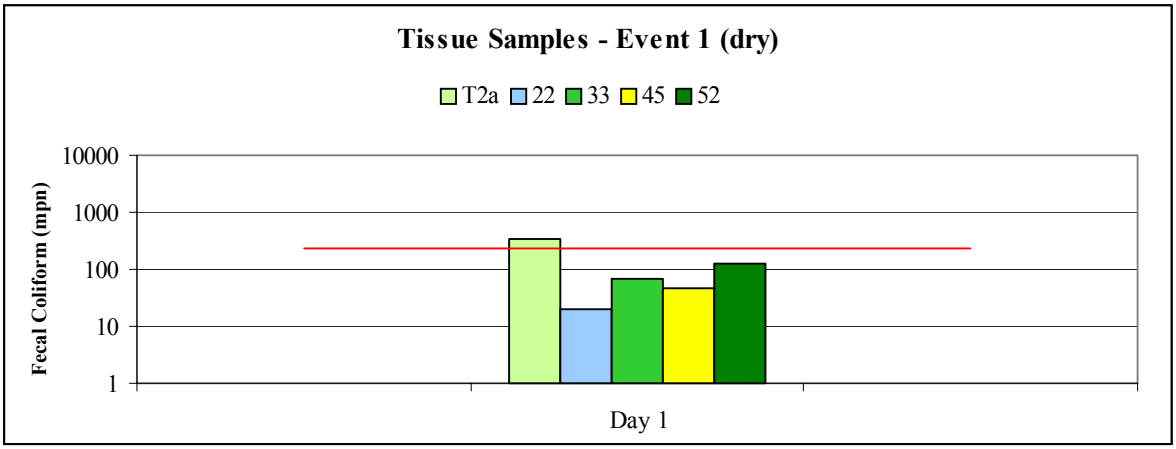
WQ# HD1: (This site, Woodley Island Harbor District Boat area, is located outside of certified growing areas)
Based on Dry Event coliform concentrations, the background level met the 43 MPN water quality objective (23 and 7.8 MPN). During Events 2 and 5, this site did not exceed water quality objectives. Coliform concentrations peaked during Event 3, Day 2 (350 MPN), decreasing to 79 on Day X. Event 4, Day 1 (920 MPN) decreased to 2 MPN by Day X. With the exception of Event 3, Day X met water quality objectives.


Tissue Samples - Event 2 (wet)
T2a
22
33
45
52
Fecal Coliform (MPN)
10000
1000
100
10
1
Day 1
Day 5


Tissue Samples - Event 3 (wet)
T2a
22
33
45
52
16,000
Fecal Coliform (MPN)
10000
1000
100
10
1
Day 1
Day 15


Tissue Samples - Event 4 (wet)
T2a
22
33
45
52
Fecal Coliform (MPN)
10000
1000
100
10
1
Day 1
Day 6


Tissue Samples - Event 5 (wet)
T2a
22
33
45
52
Fecal Coliform (MPN)
10000
1000
100
10
1
Day 1
Day 5



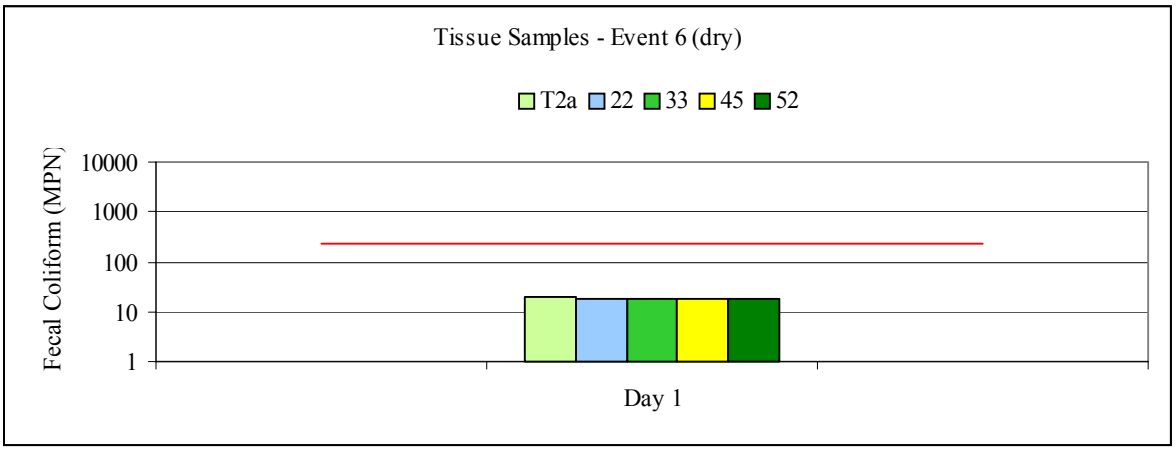


Figure 24.

Shellfish tissue samples taken during Dry Weather events indicate fecal coliform concentrations significantly lower than the 230 MPN objective. Tissue samples were taken at Day 1 and Day X intervals during each event. In comparison to Dry Weather samples, coliform concentrations increased during rainfall events and generally returned to acceptable levels by Day X. Increased fecal coliform concentrations could be explained by the continual bacterial loading in the watershed and a result of decreased organism metabolic rate during the winter months.

Appendix II – Reference Laboratory Quality Control Exercises

Three analytical laboratories were necessary to process the samples collected to complete this study. To verify handling protocols, analytical and reporting procedures, an Independent Trial Run was conducted prior to study commencement to correlate MPN results among the three laboratories. During the study, two ELEP Performance Evaluation (PE) controlled inter-calibration exercises were conducted; each using three concentrations of the bacterial indicator, to substantiate values reported by the laboratories during the course of the study.

Independent Trial Run

Four water samples were collected from four sites, selected to ensure that a range of bacterial concentrations for analyses. Three replicate samples were collected from each site, with each lab receiving one of the replicates. Sample sites included secondary water quality monitoring sites located in the restricted growing area of North Bay (WQS 41 and 44), Jane's Creek at West End Road (T4l) and a sample collected from within the Arcata Wastewater Treatment Plant, Oxidation Pond 2 effluent (T33).

Actual values were not measured for low end and high end samples; these values are expressed as "less than" and "greater than", respectively. Because we do not have values for all analytical results, statistical analyses cannot be conducted. Low values ranged from <2 MPN to 2 MPN, medium values ranged from 30 MPN to 50 MPN, and high values ranged from 900 MPN to >1600 MPN (Table 10). Results from this sampling generally show good agreement among laboratories, with the only questionable results occurring with high values.

Table 10 - Independent Trial Run Results

	Sept. 14, 1999	**Fecal coliform**	***E. coli***
	North Coast Laboratory		
WQS 41	Restricted Grow Area, North Bay	2	<2
44	Restricted Grow Area, North Bay	2	<2
T33	City of Arcata - Ox Pond 2 Effluent	>1600	>1600
T41	Jane's Creek – West End Road	50	30
	Humboldt Co. Public Health		
WQS 41	Restricted Grow Area, North Bay	4	2
44	Restricted Grow Area, North Bay	2	2
T33	City of Arcata - Ox Pond 2 Effluent	>1600	>1600
T41	Jane's Creek – West End Road	23	23

	City of Eureka Laboratory		
WQS 41	Restricted Grow Area, North Bay	<2	<2
44	Restricted Grow Area, North Bay	<2	<2
T33	City of Arcata - Ox Pond 2 Effluent	900	900
T41	Jane's Creek – West End Road	30	30

Inter-Calibration Exercise
In the first exercise, Dept. of Health Services Environmental Laboratory Accreditation Program (ELAP) provided water samples were prepared by seeding 24 hour-old stock cultures of *Escherichia coli* or *Streptococcus faecalis* into large sterile containers of NYSDH-1 transport medium. Transport media was prepared prior to the day of the experiment and sterilized. Bacteria was added to the transport media and mixed for twenty minutes on a magnetic mixer prior to dispensing the first sample. Targeted seeding densities were 100, 1,000 and 10,000 bacteria/100 ml.

Findings in the *Evaluated Report for Microbiology Performance Evaluation Study 99.04* reported that the laboratories reported values met the acceptable limits.

In the second exercise, *E. coli* was added to both fresh and bay waters as well as to the transport media. Steps were taken to ensure that fresh and bay waters were as free from bacterial contamination as possible using sources that served as control sampling areas during the study.

Samples were ready by 0800, packed in ice and distributed to the participating laboratories to begin their analyses by 1300 hours the same day. Each laboratory used its own standard operating procedures. If a laboratory used more than one method during the actual study, they were asked to repeat the two exercises using all methods. Three to five replicates for each indicator at each density were requested.

Table 11. Example of Inter-calibration Sheet

Laboratory	*ELAP Certification*	*ELAP PE No. 99.04*	*Performance Eval Result*
City of Eureka			
North Coast Laboratories			
Humboldt County Public Health Laboratory			

Appendix III - Split Samples

To ensure that the three laboratories analyses were comparable during the study, split samples were collected from pre-selected sites on the second day of each wet weather sampling event for a total of four times during the study.

Samples were collected from a one foot depth, using a sterile one liter sample container. The sample was capped, agitated, then aliquoted into three IDEXX sample containers. A single sample was delivered to each laboratory for analysis and reporting. The samplers labeled and submitted the samples using a unique sample identification number. The collector noted the sample source and identification number on the field sheet for later correlation. Each laboratory analyzed their sample for fecal coliform and *E. coli*.

The mean of the fecal coliform data is 1769.17, with a median value of 265.0 The mean of the *E. coli* data is 1738.33, with a median value of 230.0 (Table 1). In comparing just these values alone, it is clear that these data are not normally distributed. Since the data are not normally distributed, the best type of analyses are non-parametric tests. Two non-parametric tests were used for data analyses: the Friedman rank sum test and the Kruskal-Wallis test.

The Friedman rank sum test considers each lab according to the samples that were run by that laboratory. There were two statistical tests run for each lab, one for fecal coliform data, and one for *E. coli* data. The p-values obtained from the statistical tests were 0.93 and 1.0 for fecal coliform data and *E. coli* data, respectively (Table 2). This test shows that there are no differences between the laboratories, based on the results of their fecal coliform and *E. coli* analyses. The data was then graphed to obtain a visual verification of the results of the Friedman test (Figures 1 - 4). These graphs show that there is a high amount of variability within the last event, but the variability is from the event and not the laboratory results.

The Kruskal-Wallis rank and sum test was performed to verify that the three laboratories were giving comparable results. This analysis focuses on one dependant variable at a time. There were a total of four tests performed:

1. the laboratory compared to fecal data;
2. the laboratory compared to *E. coli* data ;
3. events compared to fecal data; and
4. events compared to *E. coli* data.

Table presents the summary data for these four tests. The analyses of the events are the only tests with significant p-values, meaning that there is no difference in the laboratory results, but the variability seen in Figures 1 – 4 definitely come from the events in which the sampling took place. Because there are very few data points, a 90% level of confidence is sufficient. With more data, it is very likely that the events would become even more significant.

Appendix IV - Field Duplicate Samples

To monitor field condition variability, each laboratory received a field duplicate sample representing 10% of the total samples collected. During each day of sampling, five sites were randomly selected for duplicate sampling. Two (2) discrete samples were collected in sterile IDEXX containers, capped and labeled. One sample was labeled with routine sample information, the other was submitted to the laboratory as a blind sample and included an independent identification number. Collector noted on the field sheet the source and identification number for later correlation.

These data were not normally distributed, even when logarithmically transformed. Two parametric tests (t-test and one-way ANOVA) and one non-parametric statistical test (Wilcoxin Signed Rank Test) were used to look at the paired data points. The results of the statistical analyses (Appendix 1) showed that there was no significant difference between replicate samples, with p-values well above the 0.05 limit.

APPENDIX V

Table 12. Location Global Positioning System Coordinates and Collection Methods

Location #	Site Name	GPS Y Coordinate = 40.	GPS X Coordinate – 124.	Description
T1	Manila	.85217	.15860	Alongside a small creek at the northwest side of Manila Park; Area is marshy, overgrown and surrounded by rural residential. Minimal flow during dry periods.
T2c	Lanphere Rd	.89821	.13477	Samples taken from middle of bridge over Mad River Slough. Surrounding area is rural farm/pasture/grazing lands.
T3	Three Culvert	.86501	.14577	Samples taken from top of first culvert nearest Samoa Blvd. (Hwy 255). Culvert drains runoff from Arcata Bottom land.
T4a	Jane's Creek, Samoa Blvd.	.86805	.10086	Sample taken from the south side of Hwy 255 bridge. Creek flows through agricultural and residential lands. This site is closest to mouth of creek prior to entering the Bay. Upstream residential properties 500 yards north.
T4e	Jane's Creek, 17th St	.87732	.09159	Sample taken from the south side of culvert. Farmhouse and barn with livestock on the north side.
T4l	Jane's Creek, West End	.89225	.07923	Sample taken down stream from fork in creek on east side of road beneath Hwy 101 overpass. Dairy operation on west side of road and industrial complex(es) to the northeast.
T5a	Jolly Giant, Butcher's Slough Bridge	.85660	.08958	Sample taken from on the north side of the bridge in the middle over the slough. Creek flows through urban residential and industrial areas. This site is closest to mouth of creek prior to entering the Bay.
T5c	Jolly Giant, Samoa Blvd.	.86539	.08785	Sample taken on north side of culvert near V&N Burger Bar.
T5i	Jolly Giant, Park	.87896	.08842	Sample taken near footbridge located about 30 yards from handicapped parking area in Shay Park near retired railroad tracks.
T7	Gannon Slough, Highway 101	.84669	.08051	Sample taken from middle of west side of railroad bridge. Gannon Slough drains several Arcata, and Sunnybrae small creeks. Surrounding area is agricultural lands.
T7Ba	Beith Creek, Old Arcata Rd	.85582	.07020	Sample taken 40' from culvert on south bank of creek.
T7Gb	Grotzman Creek/Buttermilk/Samoa	.85686	.07118	Sample taken from footbridge approximately 50 yards, west of parking area of Meadowbrook housing complex.
T7Ca	Campbell Creek Union/Sports Complex	.86619	.08080	Sample taken just downstream of concrete gate/valve at the far end of softball left field. Site is northwest approximately 100 yards from Sports complex parking area. Creek influenced by residential runoff.

T8	Jacoby Creek, Highway 101	.84343	.08051	Sample taken from middle of railroad bridge west of Hwy 101 overpass. This site is at mouth of creek where it enters the Bay. Creek is influenced by both residential and agricultural/timber sources.
T8a	Jacoby Creek, Old Arcata Rd	.83801	.06884	Sample taken from middle of north side of bridge over road. Area subject to flooding.
T9	Washington Slough, Highway 101	.83133	.08094	Sample taken from west side of culvert. A floodgate regulates flow into the Bay. Site just north of Bracut Industrial area, slough drains mostly rural residential, light industrial and agricultural/timber lands
T10A	Fay Slough, Old Arcata Rd	.80792	.08672	Sample taken from footbridge accessed through private residence on west side of highway. Area influenced by rural residential, light industrial and agricultural lands. Minimal flow during dry periods.
T11A	Freshwater Slough, Devoy Rd	.78740	.10818	Sample taken from middle of bridge from the west side. Area influenced by rural residential, agricultural and timber activities.
T11B	Ryan's Slough, Mrytle	.78516	.11899	Sample taken from east side of slough, Accessed by trail from north-west corner of parking area/turnout. Parking area is approximately 100 yards east of bridge crossing slough. Slough influenced by rural residential, agricultural and timber activities.
T13B	48" Culvert, P Street and Waterfront, Eureka	.80611	.15912	Sample taken from first manhole on bike lane going south from boat ramp under bridge. Manhole is next to storm drain in curb and “No Parking” sign. Used a string line w/ cup attached above weight.
T13C	24" Culvert, L Street and Waterfront, Eureka	.80606	.15908	Sample taken from manhole in sidewalk just north of the entrance to Adorni Center, north of cross walk. Used a string line w/ a cup attached above a weight.
T13D	12" Culvert, J Street and Waterfront, Eureka	.80609	.16131	Sample taken from grate in middle of parking lot directly in front of CDFG boat dock at foot of J Street. Pulled grate up and collected sample by hand.
T13E	54" Culvert, C Street and Waterfront, Eureka	.80500	.16884	Sample taken from manhole marked storm drain on west side of intersection. Used a string line w/ a cup attached above a weight.
T13F	30" Culvert, Commercial St at Waterfront, Eureka	.80416	.17309	Sample taken from manhole in center of intersection. Used a string line w/ a cup attached above a weight.

T13G	Boat Ramp Launch, Waterfront St	.80203	.17716	Sample taken over fence from concrete ditch on east side of waterfront drive directly across from the Wharfinger building. Used a string line to collect sample.
T13H	West 14 and Railroad	.79438	.18264	Sample taken from mis-marked manhole in center of intersection. Manhole is marked sanitary sewer but is actually storm drain. Used string line to collect sample.
T13I	30" Del Norte and Railroad	.79091	.18389	Sample taken from manhole in center of intersection. There is a restrictor under the manhole. Used a sting line to collect sample.
T13J	Palco Marsh	.78803	.18506	Sample was taken from center or middle concrete drain/floodgate of the northern marsh. Collected sample by hand from the top of the drain floodgate.
T13K	Palco Marsh	.78282	.18888	Sample was collected from the steel pipe culvert draining the marsh at the back of the Bayshore Mall. Pipe is marked as a storm drain. Collected sample by hand from the marsh side of the pipe.
T13N	48" Culvert Truesdale and Christie	.77647	.19296	Sample was taken from manhole directly in front of Corder Realty. Manhole is mis-marked sanitary sewer. Used a string line to collect sample.
T13O	36" Culvert at the west end of McCullen's St	.77444	.19069	Sample was taken from unmarked manhole with large squares and asphalt stuck to it in middle of road just prior to entering the Broadway Trailer Court. Manhole has restrictor under it. Used a string line to collect sample.
T13P	Ditch north of the Eureka Sewage Treatment Plant	.76820	.19489	Sample was taken from drainage ditch directly before the ditch runs through the culvert to the road entering the Eureka Sewage Treatment Plant. Sample was collected by hand.
T14a	Elk River at Highway 101	.75617	.18955	Sample was taken from the Highway 101 bridge south of the Elk River overpass. Used a string line to collect sample from bridge.
T14A	Swain Slough at Pine Hill Road	.75271	.18155	Sample was taken from the bridge that goes over Swain Slough on Pine Hill Rd. A sting line was used to collect the sample from the bridge.
T14Aa	Martin Slough Pine Hill Road	.75263	.18125	Sample was taken on the up streamside of the tide gates before Martin Slough runs into Swain Slough. A string line was use to collect the samples from atop the culverts that lead to the tide gates.

T2a*	NBSC float in Mad River Slough above water pipe crossing	.87140	.14811	Sample was taken from Primary Water quality site next to North Bay Shellfish's work raft in Mad River Slough above the highway 255 bridge crosses Mad River Slough. Certified growing area D.
21	Mad River Slough Channel west of CSC Mad River Beds	.84983	.14082	Sample was taken from Primary Water quality site located on the west side of the large slough that runs into Mad River Slough next to oyster bed MR 1-2. Certified growing area A1
22*	Mad River Beds	.84284	.13987	Sample was taken from Primary Water quality site located approximately 60 yards East of oyster bed MR 2. Certified growing area A1
24	CSC Bird Island Beds, Central	.82619	.16214	Sample taken from Primary Water quality site located on the South West tip of Bird Island next to the Cable crossing marker. Certified growing area A2.
31	NBSC Parcel 1 Beds	.84697	.12249	Sample taken from primary water quality site located on parcel 1 next to Emerald Coast Seafoods culture area. Certified growing area C.
33*	C4A NBSC Parcel 1 Beds	.84453	.12380	Sample taken from primary water quality site located on parcel 1 next to North Bay Shellfish's culture area, south of WQ 31. Certified growing area C.
34	Southwest end of CSC Sand Island Beds	.82761	.14548	Sample taken from primary water quality site located on the southwest tip of Sand Island. Certified growing area A2.
45*	CSC Sand Island Beds	.83420	.13215	Sample taken from primary water quality site located next to oyster bed SI 3-1. Certified growing area B2.
HD1	Harbor District Marina – Dock A	.80701	.16602	Sample taken from southwest end of Dock A at the Woodley Island Marina. Not in a growing area.
51	C10A CSC East Bay Beds	.82447	.11955	Sample taken from primary water quality site located in the northeast end of East Bay next to oyster bed EB 7-2. Certified growing area B1.
52*	CSC East Bay Beds	.82201	.13364	Sample taken from primary water quality site located in small slough that runs next to oyster bed EB 6-1 and into East Bay. Certified growing area B1.
53	CSC Gunther Island Beds	.82050	.14635	Sample taken from primary water quality site located next to oyster bed GI 1 in East Bay but on Gunther Island. Certified growing area B1.