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April 3, 2014

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David Smith
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Bruce Wolfe, Executive Officer
California Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, CA 94612

Re: 1997-2012 Southwest Ocean Outfall Regional Monitoring Program Summary Report

Dear Ms. Hashimoto, Mr. Smith and Mr. Wolfe:

Enclosed please find a copy of the City and County of San Francisco Public Utilities Commission Southwest Ocean Outfall (SWOO) Regional Monitoring Program summary report for the period 1997 through 2012, as required in the Oceanside Water Pollution Control Plant NPDES Permit No. CA0037681. In lieu of preparing a separate annual report for the 2012 offshore and beach water quality monitoring data, they are included in the comprehensive analysis of the sixteen-year data set.

This report explores shoreline bacteria data and relationships to San Francisco's combined sewer system and rainfall. The offshore data collected over this period provide a regional context for evaluating SWOO impacts and continue to demonstrate that conditions at the outfall and reference sites are essentially the same. Differences that did occur between outfall and references stations appear to be haphazard and transitory. None of the indicators measured (sediment quality including priority pollutants, biological community structure, bioaccumulation of priority pollutants in crab tissue) provide an indication of persistent or long-term impacts from the wastewater discharge.

Other important findings in this report include an overall increase in sediment fines (silt and clay) in the study area beginning in 2007 that corresponds to a reduction of suspended sediment loads within the San Francisco Estuary system and a contraction of the ebb-tide delta at the mouth of the Bay as documented by the U.S. Geological Survey. In addition, the fisheries section of the report presents support for our request to drop the trawling requirements from the offshore monitoring program. A summary of this request and its support have been included in the ROWD submitted with the permit renewal application.

If you have any questions regarding information contained in this report, please contact Michael Kellogg, Supervising Biologist, Oceanside WPCP, at 415.242.2218.

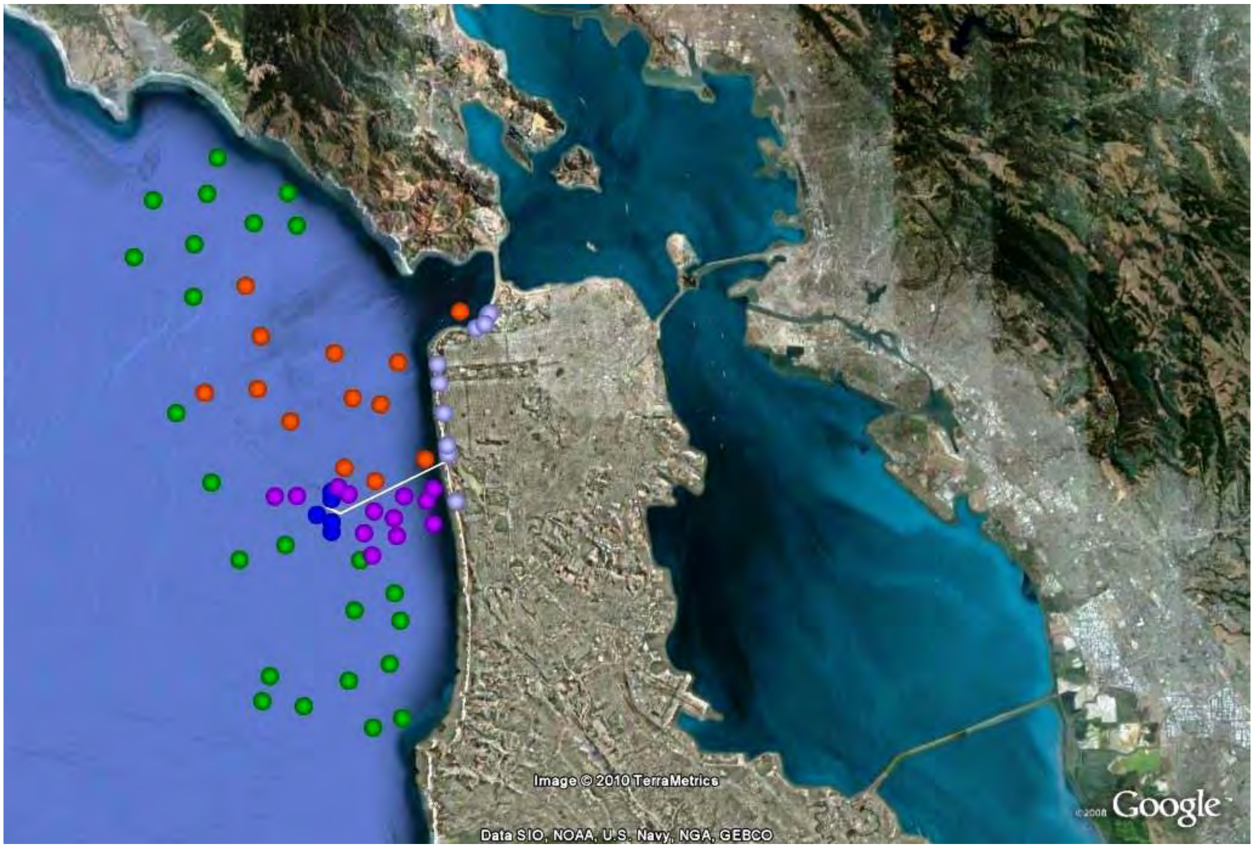
Sincerely,

Tommy T. Moala
Assistant General Manager
SFPUC Wastewater Department

cc Robyn Stuber
Derek Whitworth

Southwest Ocean Outfall
Regional Monitoring Program

Sixteen-Year Summary Report
1997 – 2012



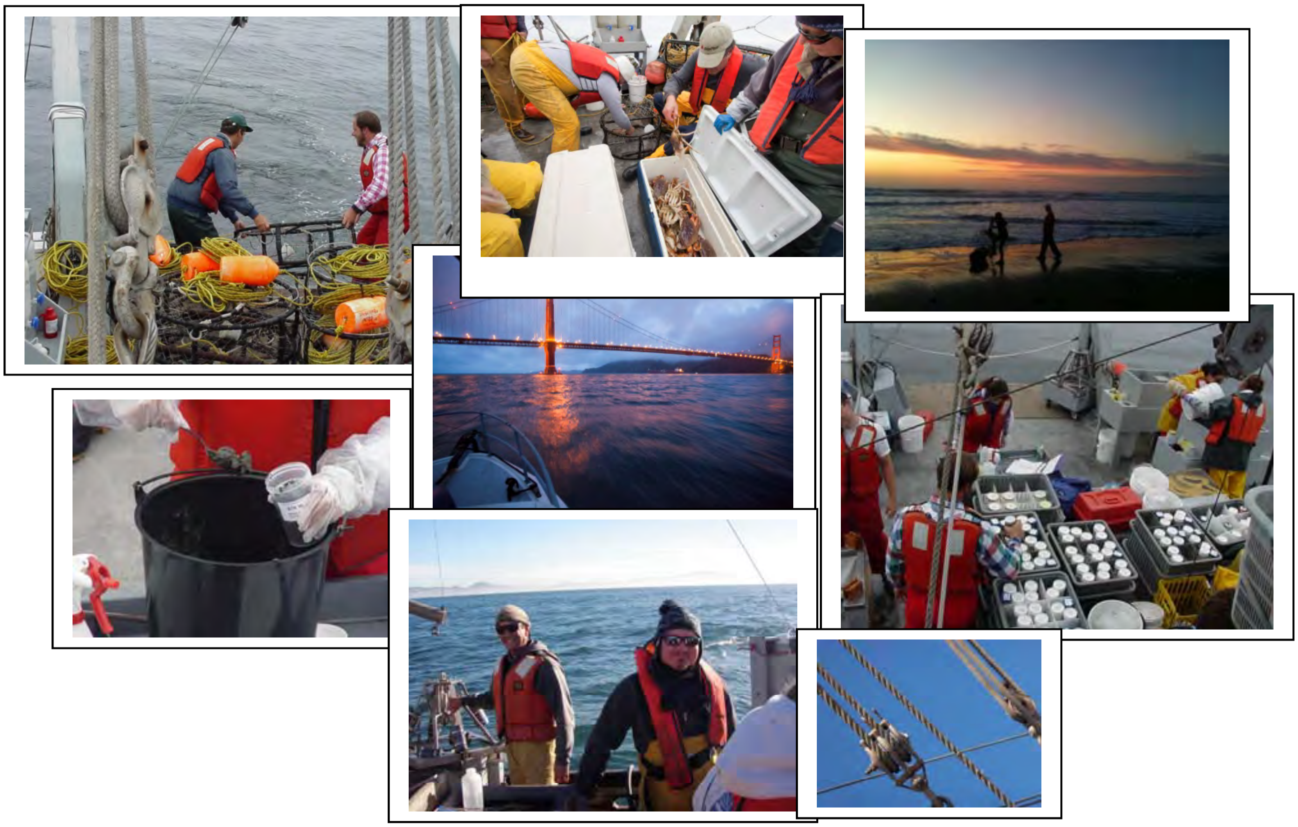
submitted to
U.S. Environmental Protection Agency, Region 9
and
San Francisco Bay Regional Water Quality Control Board

for
San Francisco Public Utilities Commission, Waste Water Enterprise
Oceanside Water Pollution Contol Plant NPDES Permit CA0037681

by
SFPUC Natural Resources and Lands Management Division
Oceanside Biology Laboratory
April 2014

SOUTHWEST OCEAN OUTFALL
REGIONAL MONITORING PROGRAM

SIXTEEN-YEAR SUMMARY REPORT
1997 – 2012



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For
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Oceanside Water Pollution Contol Plant NPDES Permit CA0037681

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San Francisco Public Utilities Commission
Natural Resources and Lands Management Division
OCEANSIDE BIOLOGY LABORATORY

April 2014

San Francisco
Water Power Sewer
Services of the San Francisco Public Utilities Commission

EXECUTIVE SUMMARY

This report summarizes and explores trends in sixteen years of environmental monitoring data collected from 1997 through 2012 as part of the Southwest Ocean Outfall Regional Monitoring Program. The monitoring is designed to detect environmental impacts related to the discharge of treated combined sewer effluent from the Oceanside Water Pollution Control Plant (WPCP) and associated Westside Wet Weather Facilities owned and operated by the City and County of San Francisco. The combined sewer system collects and treats sanitary flow, industrial effluent, and storm water. All dry weather flows (average 14 MGD) and wet weather flows up to 43 MGD receive secondary treatment. Wet weather flows above 43 MGD receive primary treatment. Flows up to 175 MGD are discharged approximately 3.75 miles offshore in the Pacific Ocean through the Southwest Ocean Outfall (SWOO) and flows in excess of 175 MGD result in combined sewer discharges into shoreline waters including some recreational beaches. All discharges to the environment have received treatment at least equivalent to wet weather primary effluent. The facilities and discharges are regulated under the National Pollution Discharge Elimination System (NPDES) provisions of the Clean Water Act through a permit jointly administered by the U.S. Environmental Protection Agency, Region IX and the State Regional Water Quality Control Board, San Francisco Bay Region. The Oceanside NPDES permit mandates extensive monitoring to assess compliance with broad goals of the Clean Water Act (maintain fishable and swimmable waters) and the California Ocean Plan (prevent degradation of beneficial uses).

Specific details of the monitoring requirements have varied over the sixteen-year period, but have always included two main components:

- The Beach Monitoring Program involves measurements of bacteria concentrations at recreational beaches and notification to the public when State standards are exceeded or when a combined sewer discharge occurs.
- The Offshore Monitoring Program involves collection and analysis of physical, chemical, and biological parameters in order to assess and compare the outfall region, where potential impacts may be expected, with reference conditions utilizing:
    1) sediment quality (physical and chemical)
    2) benthic infauna community structure
    3) demersal fish and epibenthic invertebrate community structure
    4) physical anomalies and bioaccumulation of contaminants in organism tissues

MONITORING INDICATORS

Beneficial Uses

Water contact and non-water contact recreation at San Francisco beaches is an important beneficial use by thousands of local Bay Area residents and tourists annually. Beach water quality is generally very good at Baker Beach, China Beach, and Ocean Beach on the City’s north and west shores, especially during dry weather. Bacteria concentrations (indicators of impaired water quality) that exceed State standards for water contact recreation are most frequently associated with wet weather, either because of treated combined sewer discharges or for unknown causes. Treated combined sewer discharges continue to show a strong relationship with rainfall: years with greater rainfall usually have more discharges, but the intensity of storms is the main determining factor. There has been a dramatic reduction in treated combined sewer discharges since the completion of the westside infrastructure improvements in 1997, demonstrating the efficacy of the combined sewer system controls. The long-term design goal of eight or fewer discharges per year has been met during this study. The switch from a single (total coliform) to three bacteria indicators (total coliform, *Escherichia coli*, and enterococcus) in October 2003 has resulted in an increased frequency of beach posting and, presumably, in greater protection of public health by use of these more sensitive indicators. Implementation of confirmation posting in July 2007 has resulted in fewer postings at Ocean Beach. Lobos Creek continues to be a source of bacteria at Baker Beach, which had more posted days than the other beaches. Overall, San Francisco west side beaches were available for water contact recreation 94% or more of the time during the nine years that the three indicators have been used (2003 – 2012).

Recreational Use observations were made after combined sewer discharges to assess their effect on beach use. Because discharges most often occur during winter storms associated with shorter days and unpleasant weather conditions, few beach users are affected. However, isolated discharge events that occur in early Fall or Spring potentially impact more users since recreational use increases when days are longer and the duration of storm events is typically shorter and may contribute to good surf conditions.

Sediment Quality

Sediment organic content (e.g., TOC, TVS, TKN) often increases at wastewater discharges. However, a BACIP analysis comparing samples from before and after the onset of effluent discharge from an impacted and control site demonstrates that the differences in means of those constituents at a reference station and an outfall station are not significantly different now than they were before the discharge began. The BACIP analysis did show a significant difference for sediment fines at outfall Station 01, which also often increase at wastewater discharges, however, examination of the data revealed that this is due to a reduction of sediment fines at the outfall station, not an increase. Mean sediment grain size has remained similar at the outfall compared to pre-discharge values.

Community Analyses

Benthic infauna, demersal fish, and epibenthic invertebrate communities sampled in the study area represent a general assortment of native species common in sandy offshore environments in central California. Multivariate analyses demonstrate that communities at the outfall do not differ from communities in reference areas. Rarely, one or a few introduced invertebrates common in the San Francisco Estuary have appeared in benthic samples. It is perhaps surprising that exotic species are not more common offshore given that the San Francisco Estuary is considered the most invaded aquatic ecosystem in North America.

Benthic Infauna

Reference envelope analysis shows that benthic infauna indicators (abundance, species richness, diversity, evenness) at outfall stations are the same as at reference stations. Occasional excursions from reference conditions that occurred at outfall stations were generally matched by similar excursions at reference stations in the same years. Abundance has appeared high at the outfall in some years, but a BACIP analysis comparing samples from before and after the onset of discharge from an impacted and control site demonstrates that the differences in means of infauna abundance at a reference station and an outfall station are not significantly different now than they were before the discharge began. In addition, none of the species with high abundance at outfall stations are known to be pollution tolerant or indicators of enrichment. Sporadic, occasional high abundance at stations throughout the study area appears to be due to haphazard recruitment events. Benthic infauna are currently in a high abundance cycle, particularly the polychaete worm *Spiophanes norrisi*. Total infauna abundance has been higher in the past three years than any of the previous 13 years. Cluster and ordination analyses demonstrate that, based upon abundance and species composition, benthic infauna communities at outfall and reference stations are not different. Subtle differences that do occur are of short duration.

Demersal Fish and Epibenthic Invertebrates

Under the adaptive management provisions of the NPDES permit Monitoring and Reporting Program, trawl sampling was curtailed in 2009 due to the listing of longfin smelt (*Spirinchus thaleichthys*) as a threatened species by the California Department of Fish and Wildlife. Longfin smelt were commonly caught as by-catch during SWOO monitoring program trawl sampling. In light of the information gathered through trawl sampling over two decades, we argue to drop the trawl requirement from the permit because: 1) the trawl sampling has not revealed a significant difference between outfall and reference area demersal fish and epibenthic invertebrate communities; 2) trawl sampling is not suited to finding an outfall effect; 3) the demersal fish caught are not representative of contaminant exposure to consumers of local fishes or of body burdens obtained within the Gulf of the Farallones; 4) trawl sampling results in significant mortality to demersal fish and epibenthic organisms including listed species; 5) trawl sampling destroys benthic habitat; 6) other new sources of high-quality data are available; and 7) given the absence of an outfall effect, the trawl program is expensive and burdensome to implement.

Priority Pollutant Analyses

Regulatory guidelines do not exist for pollutant concentrations in sediment or organisms for the offshore San Francisco region.

Sediment Organic Pollutants

DDT and derivative compounds (organochlorine pesticides) and PCB congeners (polychlorinated biphenyls) are infrequently detected and occur at low concentrations within the study area. PAH compounds (polycyclic aromatic hydrocarbons) are detected annually, but also at generally low concentrations. Reference envelope analysis showed that outfall Station 58 was above reference conditions for total PAHs in seven of the 16 years and near the upper tolerance interval bound in other years. Station 58 also had the highest percentage of sediment fines (silt and clay) ever measured in the study area. Reference Envelope exceedances at Station 58 have generally been matched by similar exceedances at northern reference stations that also have high percentages of silt and clay.

Sediment Inorganic Pollutants – Trace Metals

Reference envelope analysis demonstrated that sediment metals concentrations at outfall and reference stations do not differ. Within the SWOO study area, arsenic, chromium, cadmium, mercury, and nickel generally have higher concentrations than other metals measured. Some trace metals occur naturally in the environment. For example, nickel may be elevated in the region due to natural geologic sources such as serpentine soils.

Bioaccumulation – Pollutants in Tissues

Organic pollutants and trace metals were found in varying levels and tended to accumulate in higher concentrations in crab hepatopancreas tissues than in muscle tissue. Public awareness and education may be appropriate to inform people that these fatty tissues may not be suitable for consumption. None of the regressions involving sediment and tissue concentrations were significant. There appears to be a trend of decreasing PCB-levels in hepatopancreas tissue from both outfall and reference areas, but those compounds are generally detected near or below detection limits and conclusions about them should be made cautiously.

The bioaccumulated pollutants and abnormalities (e.g. tumors and lesions) found in Dungeness crab from the SWOO study area may have their source in contaminated sediments and organisms from the San Francisco Estuary. Dungeness crab utilize estuarine environments during their juvenile stages. Furthermore, they are mobile predators that can range substantially both latitudinally and along inshore-offshore gradients. Thus, the bioaccumulation results reported herein are not relevant to determining an outfall effect because the origin of body burdens cannot be determined. However, the data do provide information of potential interest to important commercial and sport fisheries and for assessing public health risk.

STUDY AREA OVERVIEW

Sixteen years of monitoring data allow some characterization of the SWOO study area. The sedimentary environment appears to be dominated by input from the Sacramento and San Joaquin River system through the San Francisco Estuary, and by reworking from tidal currents and wave action. Sediment-laden currents funnel through the Golden Gate on ebb tides and fan out, depositing sediments along the transport path. The strong tidal currents have formed an ebb tide delta of sandbars that surround the mouth of the San Francisco Estuary. Sediment at stations surrounded by these sandbars has been predominantly medium and coarse sands. The sandbars of the ebb tide delta are predominantly fine and medium sands and are well sorted. Seaward of the sand bars are areas of fine to very fine sands with the highest average percentages of silt and clay occurring in a band just seaward of the sandbars.

Each region of grain size has a distinct benthic infauna community. The community in the coarse grain sediment surrounded by the sandbars has been numerically dominated by two small, interstitial-like polychaetes, *Hesionura coineaui difficilis* and *Heteropodarke heteromorpha*, nematodes, and the bivalve *Tellina nuculoides*. The community associated with the well-sorted fine sands of the sandbars has been numerically dominated by the polychaete *Spiophanes norrisi* and characterized by a higher percentage of Crustacea than the other infauna communities. The benthic infauna community of the very fine sands characterizing the outfall and reference regions has been numerically dominated early in the study period by the polychaetes *Spiophanes berkeleyorum* and the bivalve *Tellina modesta*, but in later years by the polychaete *S. norrisi* and the bivalve *Mactromeris catilliformis*.

Smaller sediment grains provide greater relative surface area for adsorption of contaminants and organic matter, therefore areas seaward of the sandbars with higher percentages of silt and clay might be expected to have higher contaminant concentrations.

Such a pattern of grain size distribution, sediment chemistry measures of TOC, TVS, TKN, and metals concentrations, has been observed. Thus, the location of the SWOO (just seaward of a sandbar) places it in an environment where elevated measures of sediment fines, organic matter, and contaminants might be expected even in the absence of a wastewater discharge. It is important to evaluate potential discharge impacts by comparing similar environments.

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7 Physical Anomalies And Bioaccumulation

TABLES

FIGURES

FIGURES (cont.)

ACRONYMS AND ABBREVIATIONS

AAS	atomic absorption spectroscopy
AB	California State Assembly Bill
Ag	silver
Al	aluminum
ANOVA	analysis of variance
As	arsenic
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BACIP	Before-After-Control-Impact-Paired statistical test
BDL	Below Detection Limit
BND	black necrotic disease
BOD	biochemical oxygen demand
BW	body weight
BWPC	Bureau of Water Pollution Control
°C	degree Celsius
CalEPA	California Environmental Protection Agency
Cd	cadmium
CCSF	City and County of San Francisco
CDFG	California Department of Fish and Game
CDPH	California Department of Public Health
CDOI	Corrected Delta Outflow Index
CEDEN	California Environmental Data Exchange Network
CFCP	Coastal Fish Contamination Program
CFU	colony forming unit
cm	centimeter
COP	California Ocean Plan
Cr	chromium
CR	consumption rate
CSDOC	County Sanitation Districts of Orange County
CSS	Combined Sewer System
CSD	Combined Sewer Discharge
Cu	copper
cv	coefficient of variation
CVAAS	cold vapor atomic absorption spectroscopy
CWA	Clean Water Act
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
df	degrees of freedom
DHS	California Department of Health Services
DL	Detection Limit
DMA	dimethyl arsenic
DO	dissolved oxygen
DPW	San Francisco Department of Public Works
dry wt	dry weight
DW	disk width
EAP	Ecological Analysis Package

ACRONYMS AND ABBREVIATIONS (cont.)

EMAP	Environmental Monitoring Assessment Program
ERL	effects range low
ERM	effects range median
ERMq	effects range median quotient
FDR	false discovery rate
Fe	iron
g	gram
g/day	grams per day
GC/MS	gas chromatography/mass spectrometry
GF-AAS	graphite furnace atomic absorption spectroscopy
GFNMS	Gulf of the Farallones National Marine Sanctuary
GGNRA	Golden Gate National Recreation Area
H’	Shannon-Weiner Diversity Index
Hg	mercury
ICP-AES	inductively coupled plasma atomic emission spectroscopy
IRIS	Integrated Risk Information System
J’	Pielou’s Eveness Index
kg	kilogram
km	kilometer
L	liter
LACSD	Los Angeles County Sanitation Districts
LM	Lake Merced discharge structure
L/V	Lincoln/Vicente discharge structures
m	meter
m^2	square meter
MANOVA	Multivariate Analysis of Variance
MBNMS	Monterey Bay National Marine Sanctuary
MDL	method detection limit
METC	Marine Estuarine Technical Committee
mg	milligram
MgCl	magnesium chloride
MGD	million gallons per day
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
MMA	monomethyl arsenic
Mn	manganese
MPN	most probable number
MWH	MWH laboratory referenced in method/metals
n/a	not applicable or not assessed
NA	not applicable or not assessed
ND	no data or not detected
NMDS	Nin-Metric Multidimensional Scaling
NSMCSD	North San Mateo County Sanitation District

ACRONYMS AND ABBREVIATIONS (cont.)

Ni	nickel
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPGO	Northern Pacific Gyre Oscillation Index
NPS	National Park Service
NRC	National Resource Council
NRD	Natural Resources Division of the SFPUC
NRLMD	Natural Resources & Lands Management Division
NS	no sample
NWS	National Weather Service
p	probability
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCA	principal components analysis
PCB	polychlorinated biphenyl
PCR	polymerase chain reaction
PFE	pressurized fluid extraction
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PSMFC	Pacific States Marine Fisheries Commission
QA	quality assurance
QC	quality control
RfD	oral reference dose
RL	reporting limit or risk level
RMP	Regional Monitoring Program for Trace Substances
RWQCB	Regional Water Quality Control Board
SC I	Sea Cliff I
SC II	Sea Cliff II
SCAMIT	Southern California Association of Marine Invertebrate Taxonomists
SCCWRP	Southern California Coastal Water Research Project
SD	standard deviation
Se	selenium
SF	slope factor
SFDPH	San Francisco Department of Public Health
SFEI	San Francisco Estuary Institute
SFPUC	San Francisco Public Utilities Commission
SIM	selected ion monitoring
SIMPER	similarity percentage analysis
SL	standard length
sp	species (singular)
spp	species (plural)
SQG	sediment quality guidelines
SSM	single-sample maximum
SV	screening value
SVc	screening value for a carcinogen

ACRONYMS AND ABBREVIATIONS (cont.)

SVn	screening value for a non-carcinogen
SWRCB	State Water Resources Control Board
SWOO	Southwest Ocean Outfall
S-W	Shannan-Weiner Index
TKN	total Kjeldahl nitrogen
TL	total length
TOC	total organic carbon
TS	total solids
TSS	total suspended solids
TVS	total volatile solids
USDOE	United States Department of Energy
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WPCP	Water Pollution Control Plant
WQB	Water Quality Bureau
WRCC	Western Regional Climate Center
wt	weight
ZID	zone of initial dilution
Zn	zinc
α	probability of Type I error
μg	microgram
Σ	sum of
ϕ	phi (= $-\log_2$(particle diameter (mm)))

SECTION 1

INTRODUCTION

INTRODUCTION

1.1. FACILITIES AND REGULATORY AUTHORITY

The Oceanside Water Pollution Control Plant (WPCP) and Westside Wet Weather Facilities are owned and operated by the City and County of San Francisco (City), Public Utilities Commission. These facilities collect, treat, and discharge wastewater and stormwater from the City's western drainage into the Pacific Ocean through the Southwest Ocean Outfall (SWOO) approximately 3.75 miles offshore. San Francisco has a combined sewer system that collects domestic sanitary flow, industrial wastewater, and stormwater runoff in the same set of pipes and conveys these combined flows to treatment facilities. Because of the combined sewer system, flow through SWOO varies from an average of 14 MGD during dry weather to a peak of 175 MGD during wet weather. The Oceanside WPCP provides secondary treatment for all dry weather flows and wet weather flows up to 43 MGD and primary treatment for wet weather flows above 43 to 65 MGD. Flows in excess of 65 MGD receive flow-through treatment equivalent to wet weather primary effluent within the Westside Wet Weather Facilities and are discharged through SWOO along with the blended secondary and primary effluents from the Oceanside WPCP. Flows exceeding the maximum capacity of SWOO (175 MGD) also receive flow-through treatment, but are discharged at several locations along the shoreline. All discharges to the environment have received treatment. More details and a history of the facilities are presented in Appendix A.

These facilities and discharges are subject to regulation under the Clean Water Act through the National Pollution Discharge Elimination System (NPDES) program. Because the ocean outfall is located beyond the California territorial limit of 3 miles, regulatory authority is jointly administered by the U.S. Environmental Protection Agency (U.S. EPA), Region 9, and the California Regional Water Quality Control Board, San Francisco Bay Region (RWQCB). The Oceanside WPCP NPDES permit (no. CA0037681) has included extensive environmental monitoring requirements (U.S. EPA and RWQCB 1997, 2003). This report provides a summary of environmental monitoring data collected over the eight-year period from 1997 to 2004 and an analysis and discussion of time related trends.

1.2. SOUTHWEST OCEAN OUTFALL REGIONAL MONITORING PROGRAM

The monitoring program adopted a regional perspective in 1997 (Figure 1-1). Many studies had been conducted since the late 1970s to determine impacts of the design, construction, and operation of the SWOO. Pre-design studies included investigations of biota, water quality, water circulation, and plume behavior to determine the optimum placement of the SWOO, and to collect data on baseline physical, chemical, and biological conditions of the proposed discharge site. The SWOO began operation in 1986 to transport primary treated effluent from the Richmond-Sunset WPCP. Discharge of secondary treated effluent began in September 1993 when the Richmond-Sunset WPCP was replaced by the Oceanside WPCP. Offshore monitoring programs from 1986 to 1996 were conducted under various plans that compared impacted sites near the outfall to a single reference site and they are discussed in Appendix A. The most significant findings from those previous studies (BWPC 1988, 1989, 1990, 1992a, 1992b, 1993, 1994, 1995, WQB 1997a, 1997b, Niemi and Warheit 1989, Kellogg, et al. 1998) included:

- A single reference station was inadequate to fully characterize reference conditions or to determine if observed differences between stations were attributable to natural variability or actual differences.
- Seasonal variability was the predominant factor affecting differences in water quality conditions, grain size distribution,

sediment chemistry, and abundances of invertebrates and fish in the study area.

- Interpretation of potential outfall impacts was possibly confounded by the proximity of the SWOO to the mouth of the San Francisco Estuary.
- There was little detectable evidence of the effluent plume in the water column away from the ZID.

To address these issues, City biologists and U.S. EPA biologists and statisticians discussed ways to improve the study design so that possible effects from the SWOO discharge might either be detected or determined to be environmentally negligible. The monitoring program was modified in the 1997 NPDES permit, expanding the study area to include multiple reference sites. Including more reference sites increased the statistical power to detect differences between sites due to effects from the SWOO. The sampling frequency was reduced to one annual event, eliminating the effects of seasonal variability on the data. Sampling was scheduled during the fall when sediments in the study area are least disturbed and when benthic infauna are most abundant.

Seven stations (01, 02, 04, 06, 25, 28, and 31) that were monitored under previous permits remained part of the program. Initially, 40 additional offshore sample sites (stations 32-71) for sediment and benthic infauna sampling were added to the study. The new stations were

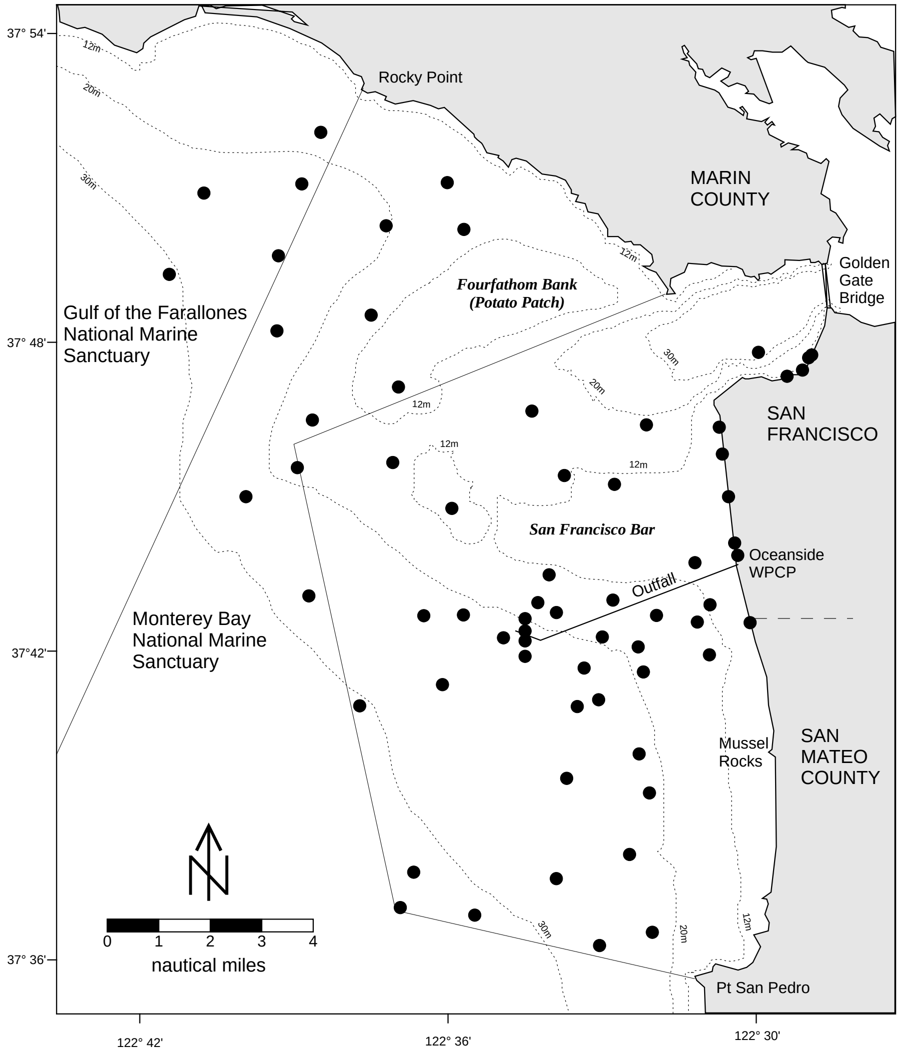
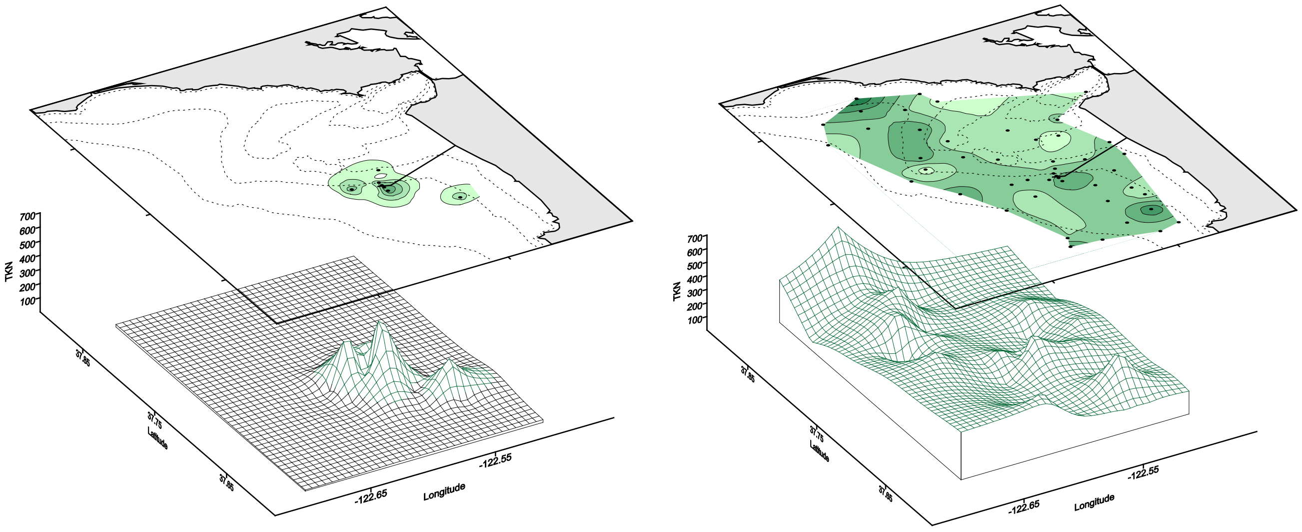


Figure 1-1
Study area with station locations

located using the U.S. EPA's Environmental Monitoring Assessment Program (EMAP) random sampling site selection process in which sample sites are randomly selected in a grid pattern within the study area (Overton, et al. 1990, White, et al. 1992). The expanded study area extends from Rocky Point in Marin County south to Point San Pedro in San Mateo County. This expansion ensured the inclusion of reference locations in similar hydrological and sedimentary environments as the SWOO. In addition, the new study area spans the mouth of the San Francisco Estuary so that the effects of outflow through the Golden Gate might be detected. Three previous summary reports covering five years (WQB 2003a), eight years (NRD 2006a), and twelve years (NRLMD 2010a) of data collected under the regional monitoring program and subsequent monitoring and analysis has confirmed that potential impacts from the SWOO discharge can only be evaluated with a regional perspective (Figure 1-2).

The Southwest Ocean Outfall Regional Monitoring Program has two main components:

1) The Beach Monitoring Program involves measurements of bacteria concentrations at recreational beaches and notification of the public when State standards are exceeded or when a combined sewer discharge occurs.
2) The Offshore Monitoring Program involves collection and analysis of physical, chemical, and biological parameters in order to assess and compare outfall (potentially impacted) and reference conditions utilizing:
    - sediment quality (physical and chemical)
    - benthic infauna community structure
    - demersal fish and epibenthic invertebrate community structure
    - physical anomalies and bioaccumulation of contaminants in organism tissues



a) old sample design

b) regional sample design

Figure 1-2a-b

1997 sediment total nitrogen (TKN) concentrations. a) shows only stations sampled under the old sample design; b) shows those stations plus the additional stations of the regional monitoring program. There is an apparent peak of sediment nitrogen at the outfall compared to the single reference station in a), but that peak blends into the "TKN landscape" in b). The San Ftrancisco Estuary watershed is a probable source of nitrogen in the study area. The figure pair illustrates the need for a regional perspective when interpreting potential SWOO impacts.

1.2.1. SETTING

The SWOO study area lies on the continental shelf within the nearshore area of the Gulf of the Farallones. The Gulf of the Farallones is bordered by Point Reyes to the north, Point San Pedro to the south and extending about 26 nautical miles west of the Golden Gate, to the Farallon Islands. The primary influences on the near shore water quality and sediment characteristics within the Gulf include the broad changes in wind and current conditions that define oceanographic seasons, tidal currents, and outflow from the San Francisco Estuary (Brown and Caldwell 1971a,b). The San Francisco Estuary has historically been a major supplier of fine sediments to the Gulf (Noble and Gelfenbaum 1988), with the magnitude of the effects depending on the season and amount of freshwater outflow from the Sacramento-San Joaquin Rivers. Freshwater outflow and sediments transported from the estuary also have the potential to transport nutrients and contaminants into the study area. The San Francisco Estuary drains 40% of the land area of California (Conomos 1979) and nearly half of the state's total runoff (SFEP 1993) including most the agricultural, industrial, and municipal wastewater inputs from that aerial extent. Outflow from the Estuary is substantial even during drought years (Kellogg, et al. 1998). Further discussion of the setting of the study area including oceanographic seasons, El Niño and La Niña events, and marine sanctuaries is presented in Appendix A.

1.2.1.1. Oceanographic Seasons

The California near shore marine climate consists of two major seasons: the California Current season during which the principal near shore current flow is southerly; and the Davidson Current season during which the principal near shore current direction is northerly.

The California Current season usually occurs between February or March and November and comprises an upwelling and an oceanic period. The upwelling period begins about February or March and extends into late summer. Persistent west and northwest winds result in upwelling of deep, cold, nutrient rich waters into the Gulf of the Farallones. Weather systems are seldom stationary and upwelling may occur sporadically during this period. In the late summer and fall (August or September to November) the northwest winds subside and upwelling ceases. The oceanic period occurs between the cessation of upwelling and the start of the Davidson Current season and is a time when both ocean surface temperatures and salinities are at maxima.

From approximately November to February or March the northward flowing Davidson Current displaces the California Current offshore. During the rainy season, low-pressure systems offshore produce south and southwest winds along the central California coast. They produce onshore currents that are blocked by the northwest trending coast and gain a northerly direction that generates the Davidson Current. Because the low pressure systems do not remain stationary, the Davidson Current does not occur at all times and the end of the Davidson Current period can be diffuse and difficult to pinpoint (Bolin and Abbot 1963, Pavlova 1966, Schwartzlose and Reid 1972).

1.2.1.2. Large Scale Oceanographic Phenomena

The intermittent oceanographic phenomena known as El Niño and La Niña have global weather consequences and may significantly impact water quality and sediment transport in the Gulf of the Farallones by altering normal seasonal climate patterns. El Niño events are characterized by warmer than normal sea-surface temperatures in the equatorial Pacific Ocean. La Niña events are characterized by colder than normal sea-surface temperatures in the equatorial Pacific Ocean. Both types of events can vary in strength and local effects are difficult to predict. Locally, El Niño winters have included both greater than normal precipitation and drought. Oceanographically, the primary local effects of wet El Niño events are intensified storms and sustained southwest winds that reduce upwelling and result in higher than normal sea surface temperatures (USGS 1999). An unusually strong El Niño event occurred during in 1997-1998 (NOAA 1999a), with over two times the normal annual rainfall recorded in San Francisco (WRCC 1999). This event was followed by a La Niña that caused unusually strong upwelling of cold, nutrient-rich waters off the northern California coast (USGS 1999). Another, particularly strong, La Niña occurred in 2007-2008 and an El Niño event occurred in 2009-2010.

The Pacific Decadal Oscillation (PDO) is a long-lived climatic pattern affecting the northern Pacific above about 20º N, with a warm (or positive) phase and a cool (or negative) phase, that are thought to alternate about every 20-30 years. The underlying mechanisms of PDO are not well understood. The PDO has been in the warm/positive phase since 1977, the effects of which are generally increased biological production in coastal waters of Alaska and inhibited production off the west coast of the contiguous United States. A regime change to the cold/negative phase may have begun in 2008.

The North Pacific Gyre Oscillation (NPGO) is a newly described pattern of climate change that significantly correlates with previously unexplained fluctuations in salinity, nutrients and chlorophyll (Di Lorenzo et al. 2008). Fluctuations in the NPGO are driven by regional and basin-scale variations in wind-driven upwelling and horizontal advection.

1.2.1.3. National Marine Sanctuaries

Three national marine sanctuaries lie partially within or adjacent to the Gulf of the Farallones. Data collected from the SWOO regional monitoring program provide important information relevant to the marine habitat management goals of these marine sanctuaries.

The SWOO is surrounded on three sides by the boundary of the Monterey Bay National Marine Sanctuary (MBNMS). An exclusion zone which extends off the north coast of San Mateo County and the City and County of San Francisco between Point Bonita and Point San Pedro was originally created to encompass the SWOO, the shipping channel providing access to and from San Francisco Bay, and the Golden Gate dredged material disposal site associated with the shipping channel (NOAA 1992). Ten stations of the SWOO Regional Monitoring Program lie within the MBNMS.

Adjacent to the northwest MBNMS boundary, the Gulf of the Farallones National Marine Sanctuary includes the Farallon Islands on the western edge of the Gulf and near shore tidal flats, rocky intertidal areas, wetlands, subtidal reefs, and coastal beaches north of San Francisco. Five stations of the SWOO Regional Monitoring Program lie within the GFNMS.

Cordell Bank National Marine Sanctuary is an offshore sanctuary near the edge of the continental shelf at the northern most end of the Farallon Ridge.

1.3. MONITORING INDICATORS

The Clean Water Act was enacted to ensure that the nation’s waters remain fishable and swimmable. The California Ocean Plan has the goal of preventing the degradation of beneficial uses of water bodies. In conformance with those mandates, the primary objectives of the SWOO Monitoring Program are 1) to evaluate near shore bacteria concentrations and inform the public when water-borne bacteria along the City’s shoreline are elevated, either from combined sewer discharges or other sources; and 2) to assess potential impacts on ecological communities in the receiving water environment from the presence of the SWOO discharge.

1.3.1. BENEFICIAL USES

(see Beach Monitoring Program, Section 3)

When the capacity of the combined sewer system is exceeded during wet weather periods, treated discharges occur onto recreational beaches that have several beneficial uses related to recreation and marine habitat. Ocean Beach, China Beach, and Baker Beach occupy the western and northern shores of the City and are part of the Golden Gate National Recreation Area. These beaches provide recreational activities for Bay Area residents and tourists throughout the year. Walking, jogging, surfing, kite surfing, stand-up paddle boarding, and fishing are the primary activities that occur along the City's beaches. Weekly sampling for bacteria (total coliform, *Escherichia coli*, and enterococcus) in the surf zone at these beaches enables the City to provide information to the public about compliance with state water contact recreation standards. The City maintains a Recreational Water Quality Hotline (1-877-SF BEACH) and a web site (http://beaches.sfwater.org) with current water quality information.

1.3.2 SEDIMENT QUALITY

(see Marine Sediments, Section 4)

Physical and chemical sediment measurements are important components of marine monitoring programs designed to assess the environmental effects of wastewater discharges around ocean outfalls (Bilyard 1987). Wastewater discharges may change the properties of bottom sediments next to outfalls, which in turn may affect the natural biological communities. Such discharges are generally high in suspended solids and organic matter and, with the addition of urban runoff and industrial discharges, may contain high levels of metals, petroleum hydrocarbons, and other toxic compounds. Most sewage-related contaminants enter the marine environment as particulate matter associated with fine suspended sediments (Parker and Lee 1981, Reed et al. 1986). In addition to potentially altering the chemistry of marine sediments, wastewater discharges may physically affect the grain size distribution of bottom sediments around the outfall by adding large inputs of fine sediment and organic matter, as well as by increasing sediment re-suspension near the discharge (Reed et al. 1986). These physical and chemical sediment changes may also affect benthic organisms.

Generally, fine-grained suspended and bottom sediment particles (silt and clay) accumulate greater concentrations of contaminants than coarser particles, especially those contaminants with low water solubility. Fine-grained particles have greater relative surface area and properties than coarser particles, allowing different physiochemical sorption and ion exchange of contaminants. A large part of the benthic community is supported by the food found in organic matter associated with fine-grained sediment particles. Sampling of the sediment surface layer provides information on the horizontal distribution of parameters such as particle size distribution and geochemical composition for the most recently deposited sediment (Mudroch and Azcue 1995).

Assessment of the solids and organic content of the sediments in the study area was determined through measurements of total solids (TS), total volatile solids (TVS), total organic carbon (TOC), and total Kjeldahl nitrogen (TKN). Maps of sediment grain size were created to determine physical impacts of the outfall and to help characterize any chemical and biological impacts of the outfall (as these effects may be greater where sediments are finer).

Bottom sediments are naturally variable, with their composition fluctuating in response to a variety of natural and anthropogenic factors (Boesch and Rosenberg 1981, Zmarzly et al. 1994). Factors affecting sediments include:

1) natural environmental conditions such as wave disturbance, currents, storms, and El Niño-La Niña events
2) ecological interactions such as feeding, burrowing and tube-building/cementing activities
3) anthropogenic disturbances such as wastewater discharges, oil spills, dredging, and construction

This study compares outfall stations with similar reference stations, as well as with historical data preceding the SWOO construction, with the goal of distinguishing SWOO-related effects from other effects.

1.3.3. COMMUNITY ANALYSES

(see Benthic Infauna, Section 5 and Demersal

Fish and Epibenthic Invertebrates, Section 6)

The structure of biological communities (species composition, abundance, diversity) can be affected by wastewater discharges. Community properties are measured for comparison of outfall and reference areas and to determine the presence of balanced indigenous populations within and beyond the zone of initial dilution.

1.3.3.1. Benthic Infauna Communities

Benthic infauna are invertebrates, most of them sedentary, that live in sediments. Infauna near wastewater outfalls can be chronically exposed to sewage-derived pollutants and organic particulates that become incorporated into the bottom sediment (Khan 1980), and abundance of benthic infauna has been shown to fluctuate in response to organic input and toxicant concentrations (Swartz et al. 1986, Stull 1995). Community measurements are important components of marine monitoring programs designed to assess the environmental effects of wastewater discharges around ocean outfalls (Bilyard 1987).

Exposure to organic particulates and pollutants may result in the biological uptake of nutrients or toxicants by infauna species (Segar and Stamman 1986, Swartz et al. 1984), which can lead to changes in community population characteristics such as abundance and diversity (Pearson and Rosenberg 1978). Some infauna species respond to organic input with enhanced growth and reproduction, since the addition of low levels of organic particulates provides an additional food source for the organisms (Word et al. 1977). Filter-feeding organisms can be negatively affected by the physical clogging of feeding mechanisms (McCave 1981). The silting over of feeding and larval recruitment grounds may also affect infauna populations. In environments with high organic input, opportunistic deposit and detritus feeders (Word 1978) that can tolerate organically enriched sediments reproduce quickly and take advantage of an environment with reduced biological competition (Pearson and Rosenberg 1978). Therefore, both species composition and diversity measures are important aspects in the evaluation of potential community impacts from an outfall (Levinton 1972, Reish 1980).

The Pearson/Rosenberg model (Pearson and Rosenberg 1978) predicts changes in benthic infauna communities subjected to organic inputs such as wastewater discharges. Under the most extreme conditions of organic input, a barren zone exists in which there is an absence of infauna. With increased distance from the input source, abundance increases reaching a maximum in the opportunist zone, which is dominated by a few extremely abundant opportunistic species. At a further distance from the input source, a transition zone exists where dominance and abundance decrease while diversity and species richness reach maximum values. Transition zone communities can be unpredictable due to seasonal recruitment of species that may cause large fluctuations in abundance and species richness. A normal community is present at some greater distance from the input source and is characterized by a decrease in abundance, species richness, and diversity compared to the transition zone. This study examines species composition, diversity measures and abundance to evaluate whether Pearson/Rosenberg-style impacts are occurring in the area of the outfall.

In addition to organic enrichment, a wastewater outfall may affect benthic infauna through the introduction of increased levels of toxic substances. Bioaccumulation of pollutants by infauna may occur by absorption across surface membranes, ingestion of sediments, diffusion across respiratory surfaces or by selective absorption by certain tissues (e.g., DDT in fatty tissues). The biological uptake of contaminants by infauna species can lead to acute and/or chronic toxicity effects. Acute effects may kill organisms in the short term; chronic effects reduce reproductive capacity and/or can affect larval development and growth and may affect populations over time (Anderson et al. 1983). Various organic pollutants and trace elements have been associated with diseases and abnormalities of benthic invertebrates as well as fishes and marine mammals that feed on them (Sinderman 1979, Malins 1982). These compounds also affect the community structure (Grassle et al. 1981, Rygg 1985) so their impact can be detected using infaunal community analysis. In addition, benthic infauna are a primary food source for demersal fishes and epibenthic invertebrates, and may play a role in the transfer and bio-magnification of toxic substances to higher trophic levels (Parsons and Takahashi 1984, Spies 1984, Malins et al. 1985a,b). This study looks for such effects both by looking for bioaccumulated pollutants and physical abnormalities in individual organisms at higher trophic levels (Section 7) and by looking for community effects (Section 6).

Benthic communities fluctuate in response to a variety of natural and anthropogenic factors (Boesch and Rosenberg 1981, Zmarzly et al. 1994), which include:

1) natural environmental conditions such as temperature, wave impact, currents, storms, and El Niño-La Niña events
2) ecological interactions such as predation, competition, feeding and burrowing activities, and seasonal cycles of reproduction and recruitment; and
3) human disturbances such as wastewater discharges, oil spills, dredging, and construction

Although univariate analyses (diversity and abundance measures) describe changes in the community structure, multivariate methods (pattern analysis) are effective in describing those changes in relationship to both anthropogenic and natural factors (Thompson et al. 2000, Zmarzly et al. 1994). This study uses both univariate and multivariate analyses.

1.3.3.2. Demersal Fish and Epibenthic Invertebrate Communities

A comprehensive evaluation of Demersal fish and epibenthic invertebrate communities within the SWOO study area was presented in the twelve-year summary report (NRLMD 2010a). No trawling has been conducted since that report due to the listing of the longfin smelt as threatened by the State of California. Section 6, Demersal Fish and Epibenthic Invertebrates of the current report presents arguments to drop the trawl requirement from the offshore monitoring program because 1) the trawling has not revealed significant differences in outfall or reference area demersal fish or epibenthic invertebrates communities; 2) the trawl sampling program is not suited to finding outfall effects; 3) the demersal fish specimens collected are not necessarily representative of contaminant exposure to consumers of local fishes or of body burdens obtained within the Gulf of the Farallones; 4) the trawl sampling results in significant and unnecessary mortality to demersal fish and epibenthic organisms including listed species; 5) the trawl sampling destroys benthic habitat; 6) other new data sources of high quality are available; and 7) given the absence of outfall effects demonstrated by the data, the trawl program is expensive and burdensome to implement.

1.3.4. PRIORITY POLLUTANT ANALYSES

(see Marine Sediments, Section 4 and Physiological Effects and Bioaccumulation, Section 7)

Regulatory guidelines do not exist for pollutant concentrations in sediment or organisms for the region offshore of San Francisco

1.3.4.1. Organic Pollutants

The deposition of organic pollutants, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides, into marine sediments is a potential source of contamination for marine invertebrates, fishes, and the organisms (including humans) who ingest them (Malins et al. 1980, 1986).

Pesticides are only slightly soluble in water and tend to concentrate in sediments where they can be ingested by marine organisms and accumulate in fatty tissues (Malins et al. 1980).

The organochlorine pesticide DDT, which has been banned in the US since 1972, can cause neurotoxic and carcinogenic effects. 4,4’ DDT and derivatives (4,4’ DDD and 4,4’ DDE) are extremely persistent in the environment, resist metabolism, have a strong affinity for lipids, and biomagnify in aquatic food webs (Gobas et al. 1993, Suedel et al. 1994).

PAHs, often derived from petroleum products, constitute most of the “oil and grease” regulated as a conventional pollutant under the Clean Water Act (Levensen and Barnard 1988). Petroleum and petroleum by-products may be composed of up to 40% PAHs, some of which are extremely carcinogenic (Malins et al. 1980, Hutzinger 1982). Once deposited in sediments, PAHs are strongly adsorbed to particulates and are generally unavailable for either de-sorption to the water column or microbial degradation, particularly when sediments are anaerobic (Wilson & Jones 1993 as cited in Law & Biscaya 1994). Anthropogenic sources of these organic pollutants include sewage outfalls, storm drains, petroleum operations, industrial discharges, shipping, and atmospheric fallout (Anderson and Gossett 1988). Asphalt sealants have recently been identified as a source of PAHs in runoff (WEF 2005). Sources of atmospheric contamination include burnt plant material from forest fires, charcoal used outdoors in food grilling, and car exhaust (SFEI 2000). In some marine environments PAHs occur naturally through seepage of oil from the ocean floor (Levensen and Barnard 1988).

PCBs are a group of over 200 organic chemicals manufactured from 1929 to 1979 and used in hydraulic fluids, lubricants, plasticizers, insulators in electrical transformers, and in carbonless copy paper; smaller quantities were also used as pesticide extenders and in inks, waxes, and other products (SFEI 2000). These pollutants were banned in 1979 because they were found to be extremely toxic in long-term exposures and can cause developmental abnormalities, disruption of the endocrine system, impairment of immune function, and cancer in organisms near the top of the marine food chain, including humans who consume fish (SFEI 2000). Although manufacture of PCBs is now banned, the runoff from PCB-contaminated streams and urban areas continues to deliver these pollutants to the environment (SFEI 2004). PCBs accumulate in the fatty tissues of marine biota, where they are resistant to biological degradation (Malins et al. 1980, Hutzinger 1982).

This study examines both sediments and organisms for levels of organic pollutants of concern.

1.3.4.2. Inorganic Pollutants – Metals

The deposition of trace metals in the marine environment is a concern because metals bioaccumulate in marine organisms and contribute to a variety of chronic health problems and developmental anomalies (Bryan 1971, McDermott et al. 1976, Sinderman 1979). Sources of trace metals include wastewater outfalls, erosion of soils and minerals, river discharge, and atmospheric fallout. Trace metals either remain in solution in the water column, or are held in suspension on the surface of fine-grained particles (Eisma and Irion 1988 as cited in Stevenson 2000). Studies indicate that some quantities of suspended material do not accumulate on the seafloor but remain in the water column and may be transported by currents that can distribute the material over long distances (Stevenson 2000). In order to affect aquatic organisms, metals must be in a form that is biologically available (Waldichuk 1985).

Many metals occur naturally depending upon the nature of the geo-chemical and rock-forming environment (Keller 1976). Sampling stations in the study area lie on the Farallon platform, which has a granitic or high-grade metamorphic basement that is exposed locally at Montara, Point Reyes, and the Farallon Islands (Cooper 1973). Granitic material naturally contains various concentrations of cadmium, chromium, copper, fluorine, iodine, lead, lithium, molybdenum, selenium, and zinc (Keller 1976). Nickel may be elevated in the region due to natural geologic sources such as serpentine soils (SFEI 1996). Mercury is still entering San Francisco Bay from the leavings of mercury mining operations in upland watersheds during the late 1800s and early 1900s (SFEI 2002). This study examines both sediments and organisms for levels of metallic contaminants of concern.

1.3.4.3 Bioaccumulation – Pollutants in Tissues

(see Physiological Effects and Bioaccumulation, Section 7)

Measures of contaminant bioaccumulation and disease (which can result from immunological breakdown) characterize the effects of pollutants on individual fish and invertebrates. There is often a link between environmental contamination by organic compounds and marine vertebrate and invertebrate health problems (including increases in epizootic lesions, epithelial and hepatic tumor growth, ‘fin rot’, mutagenesis, lowered immune response) and decreased fitness (Sinderman 1979, Malins 1982, Malins et al. 1985a,b). Contamination with metals may result in reduced reproductive potential and developmental anomalies in fishes and invertebrates (Bryan 1971, Westernhagen and Dethlefson 1975). There is also a connection between high metal concentrations and a variety of chronic health problems in fishes, including microbial diseases, skeletal anomalies due to interference with calcium metabolism, inhibited or accelerated enzyme activity due to interference with metal based enzyme systems, fin erosion, and behavioral changes (Bryan 1971, McDermott et al. 1976, Sinderman 1979). Interactive effects between metals and other contaminants frequently found in sewage effluent can increase their toxicity to marine organisms (Rhodes et al. 1985). This study analyzes levels of organic and metal contaminants in organism tissues as well as examining individual animals for abnormal characteristics that may be the result of toxic exposures.

Additionally, transfer of contaminants through the food chain has the potential to cause human health concerns when fish or invertebrates at higher trophic levels are used as food. This concern for human health in relation to bioaccumulated pollutants led to the development of water quality criteria by regulatory agencies. These guidelines are not strict water quality limitations above which human health impact may be expected; however, as the number of fish consumption studies increases, greater effort has been made to identify the level of pollutant concentrations in edible tissues to determine human health risks.

1.4. REGIONAL MONITORING PROGRAM HISTORY

1.4.1. 1997 NPDES PERMIT (1997 to 2002)

1.4.1.1. Beach Monitoring

Beach monitoring studies consisted of sampling at shoreline stations for bacteria concentrations and observational surveys of shoreline recreational use activities. Bacteria data collected for eight years prior to the issuance of the 1997 Oceanside NPDES permit included analysis for total and fecal coliform and enterococcus bacteria. A review of those data indicated the total coliform bacteria analysis was more conservative in measuring near shore bacteria contamination than the fecal coliform analysis, and timelier than the enterococcus bacteria analysis in providing results. Shoreline bacteria requirements in the 1997 NPDES permit therefore included analysis of only total coliform bacteria. One shoreline sampling site (station 21.1), at the foot of Sloat Boulevard, was added to the program in 1997 because the surfing community identified the site as an area of high use. Public notification of impaired water quality at recreational beaches was significantly enhanced during the life of this permit.

- A Recreational Beach Water Quality Hotline was established in 1998 to alert the public when water quality conditions were impaired or a combined sewer discharge had occurred. The hotline is reached by dialing 415-242-2214 (local)

or 1-877-SFBEACH (toll free).
- Beginning in 2001, recreational beach water quality status and data have been published on the internet at the SFPUC web site http://beaches.sfwater.org.

1.4.1.1.1. Recreational Use Study

In order to address concerns raised by the San Francisco Chapter of the Surfrider Foundation, the 1997 permit included a provision requiring the City to complete a comprehensive Recreational Use Study along Ocean Beach. The purpose of the study was to make an assessment of the number of water contact users along Ocean Beach and to determine the impact from combined sewer discharges on water contact recreation. The study was conducted over a two-year period from October 1998 through September 2000. Results from the study (WQB 2001b), determined that water contact and non-water contact (including surf fishing) recreational activities along Ocean Beach are extensive. Of the 154,054 people observed during the two-year study, the majority of users (83%) were involved in non-water contact recreation; and of those involved in water contact recreation, up to 25% were surfers. The number of users observed participating in water contact recreation following a combined sewer discharge event represented less than one percent of all water contact users observed during the study. The two-year investigation concluded that most discharge events occur in mid-winter and have little impact on recreational use, as little use was observed during the cold, short days of winter. Isolated combined sewer discharge events that occur in early spring have the potential to impact more users as beach use increases when days become longer and the duration of storm events are shorter, contributing to good surfing conditions.

1.4.1.2. Offshore Monitoring

The expanded offshore monitoring program implemented with the 1997 permit provided the opportunity to fully characterize the study area and to better evaluate potential SWOO impacts with a regional perspective. While the program continued to identify potential impacts from the SWOO, the new sample design incorporated appropriate reference conditions and could therefore better address confounding effects of outflow from the San Francisco Estuary. Adaptive management incorporated into the permit allowed for periodic changes to the sample design throughout the permit cycle as necessary to obtain more meaningful and useful data.

Fisheries sampling was initially conducted throughout the study area using a stratified-random design independent of the sediment and infauna stations. Fisheries sampling was later modified to include a subset of benthic stations with the goal of detecting trends and relating fish and epibenthic invertebrate community data to sediment and infauna data.

1.4.1.3. Adaptive Management during the 1997 Permit

The 1997 permit allows for dynamic implementation of the monitoring program to maximize the relevance and usefulness of the data gathered.

- Sample collection at reference station 35 was not possible during the 1998 survey, rocks prevented the grab sampler from closing completely, and no acceptable sample was collected. Several attempts to collect sediment and benthic infauna samples from alternative locations in close proximity to station 35 were also unsuccessful because of the hard substratum. A substitute site (station 72) was selected for benthic infauna and sediment sampling in lieu of sampling at station 35 to complete the 1998 survey.
- Benthic sampling attempted at station 35 in 2000 was only successful for infauna. Subsequent samples for sediment analysis were unobtainable due to the rocky bottom substratum. The substitute station 72 continued to be sampled. Trawling was also unsuccessful at station 35 because of the rocky substratum (torn

trawl net) and station 34 was adopted as a replacement trawl station.

- Sampling in Trawl Stratum C located just outside the Golden Gate was inconsistent. Extreme tidal currents, rocky bottom substrate, and highly variable depth contours, prevented the collection of successful trawls from within Stratum C in 1998. In addition, the trawl net was snagged, torn, and nearly lost on an unidentified bottom obstruction in Stratum C that year.
- The trawl sampling strategy within strata was discontinued after 1998 because of difficulty in interpreting results. Sampling for demersal fish and epibenthic invertebrates was modified to correspond directly with discrete sediment/benthic infauna sampling sites. Trawl sampling was conducted at 20 of the sediment/benthic infauna sample sites.
- Station 46 was not sampled for benthic infauna after the 1998 survey and stations 44 and 49 were not sampled after the 1999 survey. Previous survey samples consisted of very coarse grain sizes that were inappropriate to live-sieve, and the infauna communities were very different from those of the reference and outfall stations, and not comparable (WQB 1998, 1999). Sediment samples at these stations continued to be collected and analyzed. Stations 41 and 42 were discontinued after the 2001 survey because of their course sediments and stations 44, 46, and 49 were discontinued for sediment sampling at the same time.
- The City elected to conduct whole sediment toxicity testing of sediment collected from the 2000 monitoring survey. Amphipod survival, using *Eohaustorius* spp. was measured at 24 stations that were also sampled for sediment organic and inorganic pollutant analyses and benthic infauna. Along with sediment chemistry and benthic infauna community analysis, sediment toxicity completes the sediment quality triad environmental monitoring strategy (Chapman, et al. 1986). Sediment toxicity testing is used to assess possible contaminant effects not detected in sediment chemistry or benthic infauna analyses. Results of the investigation indicated no detectable toxicity to this amphipod species at any of the sample sites. Mean survival was greater than 90% at all stations with no statistically significant differences detected between test samples and controls (WQB 2001a). Subsequent sediment toxicity testing in the study area was not warranted because survival percentages in the 2000 survey were uniformly high.
- A pattern of high benthic infauna abundance at the near shore end of the outfall (e.g. station 57) led to the addition, in 2002, of seven stations (73, 74, 75, 76, 77, 78, and 79) along the length of the pipe to examine a possible reef effect from the structure itself.

1.4.1.4. Reports Submitted Under the 1997 Permit

Environmental monitoring data collected for the Southwest Ocean Outfall Regional Monitoring Program in 1997, 1998, 1999, and 2000 were compiled, analyzed, and reported to the U.S. EPA and RWQCB in annual monitoring reports (WQB 1998, 1999, 2000, 2001a). Data collected in 2001 were presented in a five-year summary report covering 1997 through 2001 (WQB 2003a). Data collected in 2002 were submitted in a data report (WQB 2003b). A recreational use study along Ocean Beach was conducted from 1998 to 2000 and reported in 2001 (WQB 2001b).

1.4.2. 2003 NPDES PERMIT (2003 to 2008)

1.4.2.1. Beach Monitoring

The following changes to the beach monitoring program occurred in the October 2003:

- The number of indicators measured increased from one (total coliform bacteria) to three (total coliform, Escherichia coli, and enterococcus bacteria).
- The frequency of routine monitoring decreased from three times per week to once per week.
- The number of stations routinely monitored was reduced from 9 to 7.
- Recreational use observations were to be made after combined sewer discharges in order to determine their effect on beach use.

These changes were deemed to bring beach monitoring in San Francisco County more in line with monitoring conducted by other counties in California.

- In July 2007 the City adopted a confirmation approach to posting beaches at certain locations as recommended by the Beach Water Quality Workgroup of the California State Water Resources Control Board.

1.4.2.2. Offshore Monitoring

The following change to the offshore monitoring component was made in the 2003 permit:

- The minimum number of trawls required for demersal fish and epibenthic invertebrate community assessments was reduced from eight to two, one from an outfall station and one from a reference station.

This change acknowledged that, based upon analyses of previous data, the mobile organisms collected by trawl net had not shown an outfall effect. In addition, even though samples were processed on board and returned to sea as quickly as possible, substantial mortality occurred that was not warranted by the information gained. By requiring minimum trawls, the presence or absence of a balanced indigenous fauna at the outfall and possible effects from the discharge can still be determined by comparison to reference conditions.

1.4.2.3. Marine Mammal Report

In order to address concerns raised by NOAA Fisheries and the U.S. Fish & Wildlife Service, the 2003 permit included a provision requiring the City to produce a report that identifies "…monitoring methodologies to determine the presence in wastewater of pathogens with the potential to affect marine mammals." A report was submitted in October 2005 in fulfillment with that requirement (Casteel 2005). A thorough literature review revealed that little or no information is available on the environmental occurrence, fate, and transport of *Toxoplasma gondii*, *Sarcocystis neurona* and marine mammal morbilliviruses. An understanding of such information would be useful in support of studies that attempt to identify and link pathogens to the occurrence of infectious disease in marine mammals. That information would also be helpful in determining possible options for pathogen control in wastewater and stormwater. New and improved procedures, such as ultrafiltration, may prove to be important advancements for marine mammal pathogen detection in water. Polymerase Chain Reaction (PCR) based detection and characterization assays are likely to play important future roles in monitoring methods for marine mammal pathogens. Techniques for protozoan parasite and morbillivirus detection should be investigated in a research effort to develop environmental methods for marine mammal pathogens in wastewater and stormwater. The objective of this process would be to develop basic protocols generated from bench-scale efforts in the laboratory. Such work would most likely involve matrix spike experiments using actual water matrices. Because there are important issues in dealing with environmental samples and in the use and interpretation of some molecular methods, development of a complete method would require an appreciable laboratory effort and collaboration by investigators in the areas of environmental and veterinary microbiology, in addition to water utility professionals (Casteel 2005).

1.4.2.4. Adaptive Management during the 2003 Permit

- The reef effect investigation began in 2002 led to the addition of benthic station 80 in 2004, located at the end of the North San Mateo County Sanitation District outfall.
- The coarse grained stations (42, 44, 46, and 49) were sampled again in 2004 for sediment and benthic infauna to confirm that the patterns established earlier still prevailed.
- Sample collection at reference station 35 remained inconsistent due to hard substratum and substitute station 72 has been sampled continuously.
- Beginning in 2006 sediment fines were reported as combined silt and clay rather than as separate silt and clay fractions due to the small percentage of fines in the study area.

1.4.2.5. Reports Submitted Under the 2003 Permit

Environmental monitoring data collected for the Southwest Ocean Outfall Regional Monitoring Program in 2003, 2005, 2006, and 2007 were compiled, analyzed, and reported to the U.S. EPA and RWQCB in annual data reports (WQB 2004; NRD 2006b; NRLMD 2007, 2008). Data collected in 2004 were presented in an eight-year summary report covering 1997 through 2004 (NRD 2006a). Data collected in 2008 were presented in a twelve-year summary report covering 1997 through 2008 (NRLMD 2010a). A report discussing techniques for detection of pathogens of concern for marine mammals was submitted in October 2005 (Casteel 2005).

1.4.3. 2009 NPDES PERMIT (2009 to present)

1.4.3.1. Beach Monitoring

The following change to the beach monitoring program occurred in October 2012:

- Recreational use observations are now made at every beach visit (sampling, posting, de-posting) instead of just after treated combined sewer discharges.

1.4.3.2. Offshore Monitoring

1.4.3.3. Adaptive Management during the 2009 Permit

- The coarse grained stations (42, 44, 46, and 49) were sampled again in 2010 for sediment and benthic infauna to confirm that the patterns established earlier still prevailed. Stations 44 and 46 have not been processed for infauna.
- Trawl sampling was curtailed due to the listing of the longfin smelt as threatened by the State of California.

1.4.3.4. Reports Submitted Under the 2009 Permit

Environmental monitoring data collected for the Southwest Ocean Outfall Regional Monitoring Program in 2009, 2010, and 2011 were compiled, analyzed, and reported to the U.S. EPA and RWQCB in annual data reports (NRLMD 2010b, 2011, 2012). Data collected in 2012 are analyzed and reported herein.

1.5. ACKNOWLEDGMENTS

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SFPUC Natural Resources and Lands Management Division
Oceanside Biology Laboratory
<u>1997-2012 Summary Report</u> – Pat Conroy Executive Editor

Michael Kellogg	Executive Summary, Introduction
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Patricia McGregor	Marine Sediments
Dot Norris	Benthic Infauna
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SFPUC Project Management

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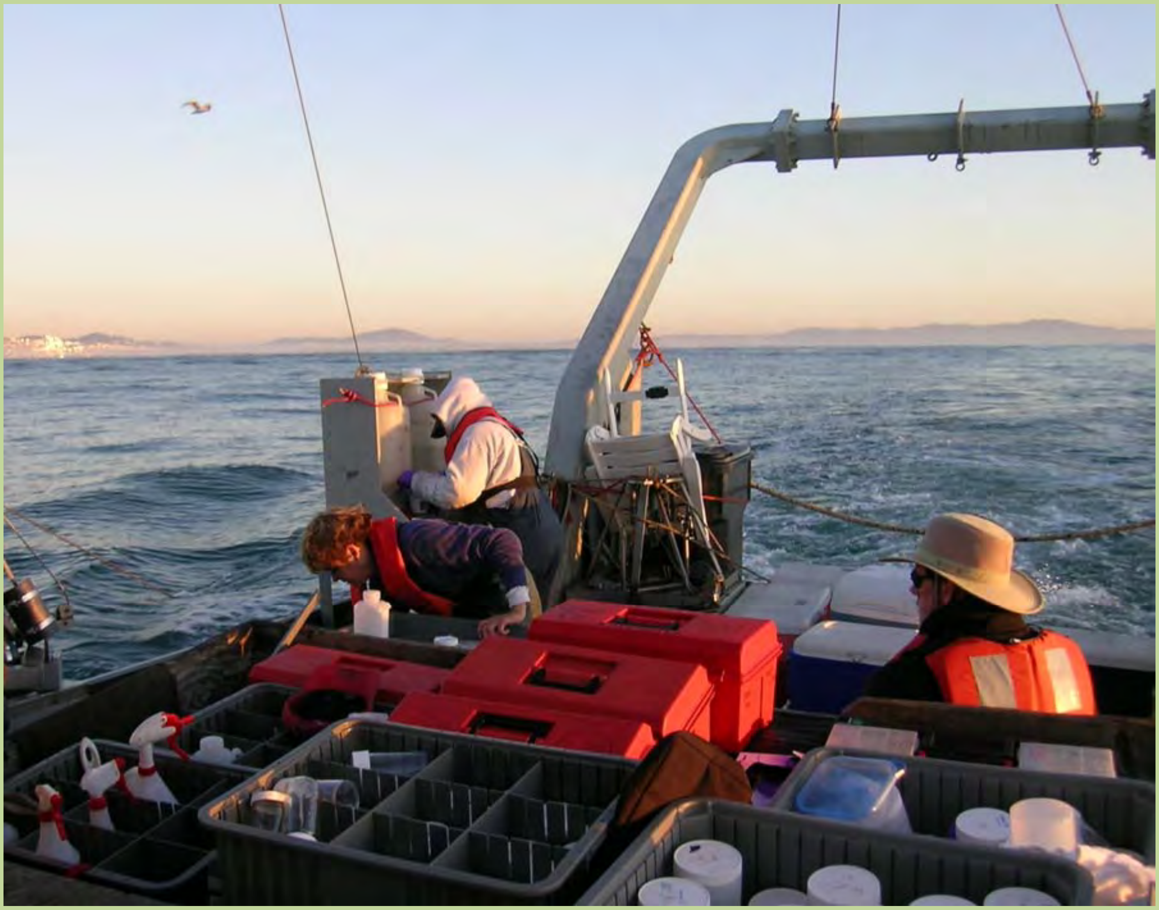
Frontier GeoSciences	Inorganic Pollutant Analysis, Seattle, WA (2000)

Cover, Title Page, and Section Dividers designed by Oceanside Biology Staff



SECTION 2

METHODS

METHODS

Specific methods for each component and methods common to multiple components of the SWOO monitoring program are discussed below.

2.1. BEACH WATER QUALITY MONITORING

2.1.1. FIELD SAMPLING

The City sampled ten shoreline stations between the Golden Gate Bridge and Mussel Rocks during the years 1997 to 2008. These stations are mapped in Figure 2-1 and detailed location information is given in Table 2-1. In general, stations were sampled three times per week from 1997 through September 2003 and once per week thereafter. Station 15E has been collected regularly since October 2002. Stations 20, 21, and 22, which were originally collected regularly, are currently collected only when combined sewer discharges occur (this has been true of station 22 since 1998 and of stations 20 and 21 since October 2003).

Water samples were collected from the surf into sterile containers, stored at or below 10°C, and was analyzed in the laboratory within six hours of collection for bacterial concentration assessment. This report includes recreational use observations taken since 2008 whenever combined sewer discharges occurred; on each day of re-sampling after the discharge (when feasible), and on the day the beach was posted and de-posted. Sample collection and transfer to the laboratory included chain of custody documentation and procedures. When bacteria levels at a site exceeded relevant standards, the site was re-sampled daily until counts were again within limits regarded as safe for recreational activities.

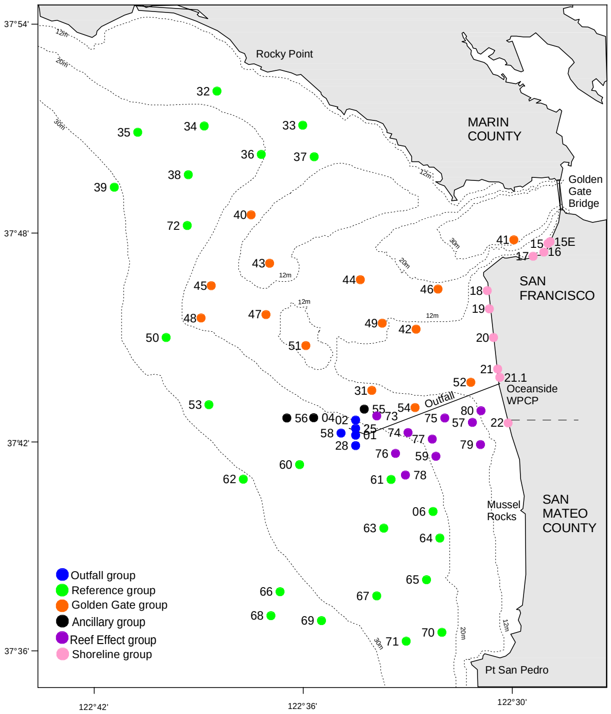


Figure 2-1
Shoreline and offshore sampling stations.

2.1.2. LABORATORY SAMPLE ANALYSIS

City and County of San Francisco personnel at the Millbrae Water Quality Bureau Laboratory analyzed water samples for total coliform, *Escherichia coli*, and enterococcus bacteria. From 1997 through September 2003, all samples were analyzed for total coliform bacteria using membrane filtration method 9222B in Standard Methods for the Examination of Water and Wastewater (Eaton et al. 2005). Sample aliquots of 1 ml and 10 ml were processed, yielding a detection limit of 10 mpn/100mL (most probable number per 100 milliliters of sample). Beginning in October 2003, total coliform and *Escherichia coli* bacteria were measured using the Colilert®-18 Quanti-Tray® (IDEXX Laboratories, Inc.) formulation of the enzyme substrate test (Clesceri et al. 2005) and enterococcus bacteria were measured using Enterolert^{tm} Quanti-Tray® methods (IDEXX Laboratories, Inc.). These marine samples were diluted for analysis, and a 10mL aliquot was used per test.

Throughout the study period, quality assurance practices as outlined in Standard Methods for the Examination of Water and Wastewater (Rice *et al*. 2012) were strictly followed, and annual State of California Environmental Laboratory Accreditation Program certification was maintained.

2.2. OCEAN FIELD SAMPLING

Annual offshore sampling was completed in the months of September or October during the Oceanic period of the California Current season (see Oceanographic Seasons 1.2.1.1). Historical studies show that the Oceanic period is the time of greatest infaunal abundance and the greatest level of settled fine sediments, which improves the chances of detecting priority organic and inorganic pollutants in the sediments. Sampling was conducted aboard the research vessel *Shana Rae*, Monterey Canyon Research Vessels, Inc., Santa Cruz, California in all years except 1998, when sampling was conducted from the R/V *White Lightning*, operated by West Coast Seaworks, Alameda, California. Stations were located in the field using a differential global positioning system. Benthic collection stations for sediment and infauna are mapped in Figure 2-1, with their exact coordinates given in Table 2-2.

2.2.1. BENTHIC MONITORING

The sampling scheme incorporated between 47 and 55 stations per year; pre-1997 data are available for five of these stations. Infauna and sediment data are available beginning in 1982 for stations 01, 02, 04, and 06; and in 1991 for station 31 (BWPC 1984, 1988-1990, 1992a,b, 1994, 1995; WQB 1997a,b). The station depths ranged from 10.5 to 36 meters for the twelve-year period. At least three grab samples were collected at each station using a 0.1 m^2 Smith-McIntyre bottom sampler. One grab sample was used for benthic infauna analysis. The

Table 2-1
Shoreline sampling stations

Beach (Station)	Latitude	Longitude	Description
Baker Beach			
15	37°47.700'	122°28.980'	At the point where Lobos Creek enters the surf (exact location varies over time as the stream meanders)
15E	37°47.754'	122°28.920'	In the surf opposite small path from upper parking lot to beach
16	37°47.460'	122°29.100'	In the surf directly opposite the Sea Cliff 2 pump station
China Beach			
17	37°47.340'	122°29.400'	Near the Sea Cliff 1 pump station
Ocean Beach			
18	37°46.350'	122°30.720'	Foot of Balboa Street
19	37°45.828'	122°30.660'	Lincoln Way overflow structure
20	37°45.000'	122°30.540'	Foot of Pacheco Street
21	37°44.100'	122°30.420'	Vicente Street overflow structure
21.1	37°43.860'	122°30.360'	Foot of Sloat Boulevard
22	37°42.552'	122°30.120'	Lake Merced overflow structure at Fort Funston

Table 2-2
Offshore sampling station coordinates

Station	Depth (meters)	Latitude	Longitude
1	26	37°42.21'	122°34.52'
2	23	37°42.63'	122°34.50'
4	25	37°42.70'	122°35.70'
6	25	37°40.00'	122°32.25'
25	25	37°42.23'	122°34.52'
28	27	37°41.90'	122°34.48'
31	14	37°43.50'	122°34.00'
32	21	37°52.08'	122°38.48'
33	19	37°51.10'	122°36.01'
34	24	37°51.08'	122°38.85'
35	28	37°50.90'	122°40.75'
36	22	37°50.26'	122°37.20'
37	17	37°50.19'	122°35.69'
38	27	37°49.68'	122°39.30'
39	31	37°49.32'	122°41.43'
40	16	37°48.53'	122°37.50'
41	17	37°47.81'	122°29.96'
42	13	37°45.24'	122°32.76'
43	12	37°47.13'	122°36.96'
44	17	37°46.66'	122°34.37'
45	20	37°46.49'	122°38.64'
46	18	37°46.40'	122°32.14'
47	16	37°45.66'	122°37.08'
48	22	37°45.56'	122°38.93'
49	14	37°45.41'	122°33.74'
50	29	37°45.00'	122°39.93'
51	13	37°44.77'	122°35.93'
52	13	37°43.72'	122°31.19'
53	30	37°43.07'	122°38.71'
54	16	37°42.99'	122°32.79'
55	19	37°42.94'	122°34.25'
56	26	37°42.69'	122°36.47'
57	16	37°42.56'	122°31.15'
58	26	37°42.26'	122°34.92'
59	22	37°41.59'	122°32.20'
60	29	37°41.35'	122°36.11'
61	26	37°40.92'	122°33.48'
62	33	37°40.94'	122°37.72'
63	28	37°39.53'	122°33.69'
64	25	37°39.24'	122°32.08'
65	27	37°38.05'	122°32.47'
66	33	37°37.70'	122°36.67'
67	29	37°37.58'	122°33.89'
68	35	37°37.02'	122°36.93'
69	33	37°36.87'	122°35.48'
70	25	37°36.54'	122°32.02 '
71	30	37°36.28'	122°33.05'
72	27	37°48.22'	122°39.33'
73	18	37°42.75'	122°33.89'
74	21	37°42.28'	122°32.99'
75	17	37°42.69'	122°31.94'
76	26	37°41.67'	122°33.35'
77	21	37°42.08'	122°32.30'
78	25	37°41.05'	122°33.07'
79	16	37°41.93'	122°30.91'
80	13	37°42.90'	122°30.90'

remaining two grab samples were homogenized and used for physical and chemical sediment analyses. Grabs samples with disturbed or unevenly distributed surfaces were discarded and resampled.

2.2.1.1. Sediment

If the sediment within the grab did not meet a minimum overall depth penetration of five centimeters the sample was discarded, and another sample was collected. From 1997 through 1999, the top two centimeters of sediment were composited for physical and chemical analyses. Starting in 2000, the top five centimeters of the grab sample were used for analyses to correspond with methods in the San Francisco Bay Regional Water Quality Control Board (RWQCB) Regional Monitoring Program for Trace Substances (RMP).

The top two or five centimeters (as described above) of each sediment grab sample were scooped into a Halar$^{®}$ coated stainless steel bucket, and homogenized using a Halar$^{®}$ coated spoon. Halar$^{®}$ is tough, smooth, and chemically inert and is used to prevent sample contamination. Unusual sediment texture and/or odor were noted if present. From this homogenized sample, five sub-samples were taken: a 200 gram sub-sample was transferred into a polyethylene container for physical and chemical analyses; a 200 gram sub-sample was transferred into a polyethylene container for inorganic analyses; a 200 gram sub-sample was transferred into a glass jar for organic analyses, and two 100 gram sub-samples were transferred into two glass amber jars for TOC and TKN analyses. All sample containers were pre-labeled and pre-cleaned. The homogenation bucket, utensils, brushes, and grab were all cleaned between stations using Alconox soap followed by four rinses, one each with sea water, 1% HCL solution, 100% methanol, and deionized water.

In all years, benthic stations were sampled for physical and chemical analyses except for organic priority pollutants; from 1997 through 2000, the number of stations sampled for organic priority pollutants gradually increased. From 2001 forward all stations were sampled for organic priority pollutants.

A field blank for each container type (glass and polyethylene), filled with ultra-purified water (milli-Q® in 1997 and 1998, NANOpure® thereafter), was opened for the duration of sampling at one outfall station per day. Field blanks serve as a control for atmospheric contamination for the inorganic and organic analyses. All samples were stored on ice, transported to the laboratory, and held at 4°C prior to processing and analysis.

2.2.1.2. Benthic Infauna

Grab samples with undisturbed surfaces and at least 7cm sediment depth were processed for benthic infauna community assessment. If the sediment within the grab did not meet a minimum overall depth penetration of seven centimeters the sample was discarded and another sample was collected. The benthic infauna sample depth criterion is based on the vertical distribution of organisms in the sediment. Generally, seven centimeters is sufficient to capture 95% of benthic infauna

Table 2-3

Analytical methods for bacteria, sediment, and tissue samples

Analysis	Method	Reference	Limits
Total Coliform, Enterococcus, and E. coli bacteria	Enzyme Substrate Coliform Test Quanti-tray method	Rice et al. 2012 9222 B	10 mpn/100 mL
Grain Size	Dry sieving; hydrometer analysis of the portion passing the #230 sieve	Plumb 1981	1 ppm
Total Solids	Dried at 103 - 105 ºC	Plumb 1981	0.1 ppm
Total Volatile Solids	Ignition at 550 ºC	Plumb 1981	0.1 ppm
Total Organic Carbon	High Temperature Combustion Method	Rice et al. 2012 5310b	2 ppm
Total Nitrogen	Total Kjeldahl nitrogen by acidification and ammonia distillation followed by titration	Rice et al. 2012 4500(C)-NH3	0.2 mg/Kg
Organic Priority Pollutants	Isotope Dilution GC/MS (EPA Method 1613)	U.S. EPA 1993 Rice et al. 2012	Appendices D-4, G-2
Inorganic Priority Pollutants	a) Digestion (EPA Method 3050b) b) ICP-MS with Collision/Reaction cell (EPA 6020) c) Cold Vapor AA (EPA 7471A)	Tetra Tech 1986a U.S. EPA 1983 and 1993c Rice et al. 2012	Appendices D-6, G-3

organisms and species inhabiting fine sands to a depth of 20 cm (U.S. EPA 1987). Acceptable samples were live-sieved through nested 1.0 mm and 0.5 mm stainless steel mesh sieves. The material retained on each sieve was washed with seawater into separate sample jars. Jars were pre-labeled inside and outside with serial number, station number, and sieve mesh size; the sampling date was added to the external label at collection time. Animals adhering to the sieves were carefully removed with forceps and added to the sample jar for that sieve size. Seawater was decanted from each sample jar through a 0.25 mm Nitex® mesh screen-lid. An isotonic solution of magnesium chloride ($MgCl_2$) was added as a relaxant for a minimum of fifteen minutes. In 2006, the relaxant was changed to $MgSO_4$, since it was found to be more effective than $MgCl_2$. The relaxant solution was then decanted through the 0.25 mm mesh screen-lid and replaced with a 10% solution of sodium borate-buffered formalin in seawater (a fixative). In 1997 and 1998, 3-4 drops of rose bengal (a protein-specific biological stain) were added to each sample jar to facilitate later sorting. This practice was discontinued in 1999 because the stain interfered with subsequent taxonomic identification of infauna. Sample jars were transported in plastic trays to the laboratory for processing.

Sediments at stations 41, 42, 44, and 46 were too coarse to pass through the 0.5 mm sieve screen making them impractical to live-sieve on board. Samples collected from these stations were fixed directly in a 10% solution of sodium borate-buffered formalin in seawater in separate, labeled 5-gallon plastic buckets fitted with water-tight lids, and sieved later with tap water in the laboratory. These stations were not collected for infauna between 2000 and 2003, and 2005 to 2008 (nor was the sample collected at station 46 in 1999 processed), because the observed sediment and benthic infauna characteristics at these stations were so different from other stations in the study area that they did not provide useful data for comparison to the outfall stations. These stations were sampled again in 2004 to confirm that these differences were still present. The following stations (year) were not sampled due to inclement weather: station 35 (2005, 2006), stations 45, 48 and 49 (2006).

2.2.2. DEMERSAL FISH AND EPIBENTHIC INVERTEBRATES

Trawl sampling for the SWOO monitoring program was conducted from 1982-2008 as a means of characterizing the resident fish and epibenthic invertebrate assemblages. The number, locations, and seasonality of trawl sampling have varied throughout this time period as NPDES permit requirements have changed. From 2003-2008, permit requirements reduced fishery sampling to single trawls at one outfall station (Station 1) and one reference station (Station 6) (see NRLMD, 2010a). With notification to the U.S. EPA, trawl sampling was curtailed in 2009 due to listing of Longfin smelt (*Spirinchus thaleichthys*) as a threatened species by the California Department of Fish and Wildlife.

2.2.3. BIOACCUMULATION AND PHYSICAL ANOMALIES

Organisms used to assess bioaccumulation of organic compounds and trace metals were collected from the outfall and reference areas. Outfall specimens were generally collected from station 01 and rarely, when necessary, also from stations 02, 25, and 28. Reference specimens generally came from stations 06 and 66 (both south of the outfall), with additional collections as needed from stations 32, 35, 39, 50, 53, 62, 65, and 70. Assessment of fish tissues for bioaccumulation was discontinued beginning in 2009. Dungeness crabs (*Cancer magister*) were collected using commercial crab pots set for at least 24 hours. Male crabs were placed in labeled burlap sacks, stored live on ice, and transferred to the laboratory where they were dissected within 48 hours of collection. Female crabs were infrequently utilized, when insufficient numbers of males were collected.

From 1997-2003, only fish and macroinvertebrates collected in community analysis trawls were examined for tumors and gross physical anomalies at the time of taxonomic identification. Beginning in 2004, biologists examined all fish collected for community analysis and bioaccumulation analyses, and all of the Dungeness crab, whether collected in crab pots, or in trawls for community analysis or bioaccumulation analyses.

2.2.4. OFFSHORE STATION GROUPS

Some figures and discussion refer to Golden Gate, reference, outfall, ancillary, and reef effect station groups or regions. These groupings (Figure 2-1) allow comparisons among similar stations and are based on proximity to the outfall, depth, sediment characteristics, benthic infauna cluster analysis and diversity patterns. To assess impacts from the SWOO discharge, outfall stations must be compared to a group of reference stations that are in a similar sedimentary environment and depth. The reference station group (stations 06, 32, 33, 34, 35-39, 50, 53, and 60-72) and the outfall station group (stations 01, 02, 25, 28, and 58) are both generally characterized by well-sorted very fine sand with a variable percentage of silt and clay, and similar infauna communities. The outfall group can be distinguished from the reference group by proximity to the outfall.

The Golden Gate station group comprises those stations on or near the sand bars with predominantly fine sands (stations 31, 40, 41, 43, 45, 47, 48, 51, 52, and 54) and those stations on or inside the sand bars with predominantly medium and coarse sands (stations 42, 44, 46, and 49). Stations within the Golden Gate group are generally shallower than stations in either the reference or outfall groups, have little or no silt and clay, and have different infauna communities. Stations 04, 55, 56, 57, and 59 constitute the ancillary group. Stations 73-79 were added in 2001 to assess the potential effects of the outfall structure on the benthic community and are referred to as the reef effect stations (note that stations 57 and 59 were included in the reef effect stations in the analysis of the benthic infauna). Station 80 was added in 2004 to determine the effect of the North San Mateo County Sanitation District outfall, and for the present report it has been included with the reef effect stations. These groups were initially defined based upon benthic infauna cluster analysis and diversity patterns evident in the 1997 data set (WQB 1998). They have been slightly altered over the intervening years, and care must be taken in comparing this report with previous ones. Additional groupings of stations, identified and discussed in each section, are based upon cluster analysis and are referred to as cluster groups.

2.3. LABORATORY PROCESSING

Staff of the City and County of San Francisco, Public Utilities Commission, Natural Resources & Lands Management Division processed all samples, except for benthic infauna sample sorting (see Benthic Infauna 2.3.2), organic contaminant analysis of tissue in 1997 and 1998, and inorganic contaminant analysis of sediment in 2000 (see Priority Pollutants Analyses 2.3.5). All samples were preserved according to established protocols and analyzed within the recommended storage limits. Many of the methods used were taken from U.S. EPA guidance documents for biological monitoring programs associated with 301(h) waivers (Tetra Tech 1985 a-f; 1986 a-c).

2.3.1. SEDIMENT

After thorough mixing in the laboratory, each sediment sample was split into portions for total Kjeldahl nitrogen (TKN) analysis, total volatile solids (TVS) analysis, total organic carbon (TOC) analysis, and grain size analysis. Total solids and TVS analyses were performed within thirty days of collection. TKN samples were stored at or below -20°C until being transported to the City and County of San Francisco's process laboratory within 14 days of collection. All chemical analyses except TOC were performed on wet samples.

Grain size analysis was performed using dry sieve and hydrometer methods. In the dry sieve method, a series of sieves were stacked in order, coarsest on top, above a catch pan. Sieves sizes used were 4.75 mm, 2.0 mm, 1.0 mm, 1.5 mm, 0.25 mm, 0.125 mm, and 0.0625 mm. The entire stack was placed in a shaker apparatus. Air-dried sediment samples were placed in the top sieve and shaken for five minutes. The weight in grams of the portion of sample retained on each sieve was recorded. The fraction of sample retained in the catch pan represents the amount of silt and clay in each sample. Silt and clay fractions less than 1.0 gram were reported as a combination of silt/clay. Silt and clay fractions greater than 1.0 gram were further analyzed using the hydrometer method. The silt and clay portion of each such sample was placed in a 1L glass cylinder filled with double distilled water. A hydrometer was then placed in the cylinder and measurements of the distance the hydrometer settled over discrete time intervals were recorded. Calculations of the settlement distance and time intervals were used to determine the particle size fractions that distinguish silt from clay (beginning in 2005, silt and clay fractions were not separated using the hydrometer method). Duplicate analyses were conducted on 10% of the total number of sediment samples as a quality control check. A summary of the methods used in the physical and chemical sediment analyses is shown in Table 2-3.

2.3.2. BENTHIC INFAUNA

Samples were fixed in buffered formalin for 48 to 96 hours, then rinsed with tap water and transferred to a preservative solution of 70% ethanol. The City's benthic contractor (Susan McCormick, Georgetown, Ca) sorted the samples using a stereo dissecting microscope into five major taxonomic groups: Polychaeta, Mollusca, Crustacea, Echinodermata and Others (all other taxa). In some samples in some years, polychaetes were further sorted by family. The 0.5 mm and 1.0 mm sieve fractions for each sample were processed separately, but the results were combined for statistical analyses. Sample residues were retained and 10% of them were subjected to a sorting efficiency quality control check. If any sample showed less than 95% sorting efficiency, the samples processed by the same sorter immediately before and after it were re-sorted and evaluated. If either of those samples failed the 95% sorting efficiency check, then all samples processed by that sorter were re-sorted.

The organisms from each sample were morphologically identified to the lowest possible taxon using published taxonomic keys and literature, in-house voucher sheets and reference collection, museum collections, and materials developed by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT). Species level identifications clearly increase the precision of station comparisons (Furse et al. 1984, Rosenberg et al. 1986) and are valuable in building a regional database for future long-term comparisons (Lenat and Barbour 1994). Organisms that did not fit described species were given a provisional identification and/or were sent to specialists for identification. Species identification sheets and a reference collection of representative species developed in-house aid in identification. For quality control purposes, randomly chosen samples from each taxonomist were re-identified by a different taxonomist. Discrepancies in taxonomic identifications were reviewed and resolved by discussion and re-examination of the specimens. Misidentifications by either the original or QC taxonomist resulted in review of all specimens identified by that taxonomist as belonging to the problem taxon or closely related taxa.

2.3.3. DEMERSAL FISH AND EPIBENTHIC INVERTEBRATES

See NRLMD (2010a) for details of demersal fish and epibenthic invertebrate laboratory processing.

2.3.4. BIOACCUMULATION

Individual crabs (*Cancer magister*)were divided in half; one half was used for organic analysis and the other half for metals analyses. Generally, each of three replicates consisted of ten crabs.

Crabs were rinsed with Barnstead NANOpure® Type I ultrapure deionized water (NANOpure water) prior to dissection, and dissected using clean room conditions in Nuaire model NU-201-324, series 13, positive flow dissection hoods using techniques recommended by TetraTech (1986a). Instruments contaminated with mucus or carapace material did not contact tissue sampled for analyses. Hepatopancreas tissue and muscle tissue from the legs and claws were dissected from Dungeness crab.

Dissections for organic analyses were performed on new, kilned aluminum foil that was changed between each replicate. Stainless steel or Teflon-coated instruments used for dissections were rinsed with ultra-purified water and methanol during all dissections and between the processing of individual organisms. The dissected tissues were placed in new, pre-cleaned, glass jars (untreated in 1997 and 1998 and kilned thereafter). They were sealed, labeled, and stored at or below -20°C.

Dissections for metals analysis were performed on pre-cleaned plastic trays that were changed between each replicate. Teflon-coated or plastic forceps were used for metals dissections. Results from laboratory blanks indicate that these procedures and instruments did not contaminate the samples (Appendix G-3). Instruments used in dissections were rinsed with an Alconox□ detergent solution, rinsed with tap water and then rinsed with NANOpure water between and during dissections. Dissected tissues were placed in new polypropylene jars that were rinsed with ultra-purified water, labeled, and stored at or below -20°C.

2.3.5. PRIORITY POLLUTANT ANALYSES

2.3.5.1. Organic Analyses

All tissue samples and the sediment samples targeted for organic pollutant analyses were processed for extraction, isolation of pollutants, and final quantification of the extractable components. Tissue and sediment samples were processed and analyzed by a contract laboratory (ToxScan, Inc., Watsonville, California) in 1997 and 1998, and by City personnel in subsequent years. Sediment and tissue extracts were analyzed for polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyl (PCB) congeners, and the pesticide DDT and its analogs. PCB congeners are individual chemicals that are based on substitution of the biphenyl molecule with varying numbers of chlorine atoms. Forty-seven out of a possible 209 cogeners were measured in 1997 and forty-two were measured in 1998. a fixed set of 45 congeners was measured annually from 1999 – 2008; since 2009, a set of 52 PCB congeners has been assessed annually. These 52 cogeners were selected to closely parallel those analyzed in sediments and tissue in the RWQCB Regional Monitoring Program for Trace Substances (SFEI 1999a). All pollutants were extracted using U.S. EPA Method 3545 (Pressurized Fluid Extraction – PFE) and analyzed using a modification of U.S. EPA Method 1625, Rev. B – Semi-volatile Organic Compounds by Isotope Dilution GC/MS, (U.S. EPA 1993), using selected ion monitoring (SIM).

Reporting limits (RL) for each compound expressed in terms of dry weight and analyzed in sediment samples are presented in Appendix D-4. U.S. EPA Method 1664 was used to determine percent lipids in tissue samples, and U.S. EPA Method 160.3 for percent solids.

Detection limits for tissue samples are listed in Appendix G-2.

All of the Tetra Tech (1986b) recommended quality assurance/quality control (QA/QC) procedures were employed. Reference materials were processed and analyzed concurrently with each set of samples. Organic concentrations were measured in blanks, duplicates, and spiked samples.

2.3.5.2. Trace Metals Analyses

Tissue and sediment samples were processed and digested according to the Tetra Tech modification of U.S. EPA Method 3050 with recommended procedures for monitoring priority pollutants in marine sediments and tissues (Tetra Tech 1986a, U.S. EPA 1983 and 1993). Sediment samples were analyzed by a contract laboratory (Frontier GeoSciences, Seattle, Washington) in 2000; in other years, they were processed by the City chemistry laboratory. Samples were mechanically homogenized, and aliquots were digested under a Class-100 laboratory hood using a wet oxidation technique (perchloric/nitric acid digestion) and trace metal clean techniques.

Elemental concentrations of aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), and zinc (Zn) were measured by emission spectroscopy using inductively coupled plasma instrumentation (ICP-AES) according to U.S. EPA Method 200.7. Mercury (Hg) concentrations were determined using atomic absorption spectroscopy (AAS) with cold vapor techniques. Selenium (Se) and silver (Ag) were determined using ICP-AES for sediment samples, and for tissue samples in 1997 and 1998. Since 1999, however, hydride generation AAS (U.S. EPA Method 270.3) was used to determine selenium concentrations in tissue samples, and graphite furnace AAS (U.S. EPA Method 272.2) was used to detect silver concentrations in tissue samples. The method detection limits for sediment samples are listed in Appendix D-6. Detection limits for tissue samples are listed in Appendix G-4.

In 2006, MWH Laboratories (Monrovia, CA) assessed arsenic speciation in organism tissues – for total arsenic, As; trivalent arsenic, As(III); inorganic arsenic, As(In); monomethyl arsenic, MMA; and dimethyl arsenic, DMA; including pentavalent arsenic, As(V) determined as the difference between As(In) and As(III) – to determine contribution of organic, relatively non-toxic form of arsenic to total arsenic body burdens. Total arsenic (As) was determined using U.S. EPA Method 1638 (ICP-MS); all other forms were determined using U.S. EPA Method 1632 (AAS).

All of the Tetra Tech (1986b) recommended quality assurance/quality control (QA/QC) procedures were employed. Reference materials were processed and analyzed concurrently with each set of samples. Elemental concentrations were measured in digestion blanks, duplicates, and spiked samples.

2.4. DATA ANALYSIS

2.4.1. SUMMARY STATISTICS AND UNIVARIATE ANALYSES

2.4.1.1. Sediment

Sediment grain size data were converted to phi (ø) units where $ø = -\log_2$(diameter of the particle in millimeters) (Appendix D-1a,b). This transformation is widely used in sediment size analysis because it produces a normal distribution. Grain size data for each station were summarized to calculate skewness, kurtosis, the median, the mean, and the standard deviation of the mean (Appendix D-2). Inorganic and organic pollutant data were converted to dry weights.

2.4.1.2. Biological Community Measures

The following community measures were calculated (using Primer v6) for each benthic infauna and trawl station: abundance (number of individuals), species richness (number of species), Shannon-Weiner diversity index, Simpson's or Swartz's dominance index, and Pielou's evenness index. A detailed discussion of these indices is found in Appendix B.

Abundance of each species was measured as total count of individuals for combined 0.5 mm and 1.0 mm sieve of each 0.1 m^2 sample (Appendix E-2). Taxonomic community analyses and computations presented in this report include all taxa identified and enumerated, except that diversity analyses exclude higher or incompletely identified taxa whose inclusion would artificially inflate diversity (e.g. a few juvenile or incomplete specimens identified as *Glycinde* spp. would not be included in diversity calculations if numerous specimens of *Glycinde polygnatha* and/or *Glycinde* sp. SF1 were present at the same station). This conservative procedure can result in an underestimate of species richness, but avoids inflation that would occur by inclusion.

2.4.1.3. Bioaccumulation

Statistical analyses were generally conducted using wet weight values; dry weights were used as noted. In statistical analyses, any sample that tested below detection limits for a compound was treated as though the compound level was equal to the detection limit. This assumption simplifies calculations and yields a conservative result.

In looking for patterns of causality, statistical comparisons were made using one- or two-tailed Student's T-tests, as noted, with unequal variance, $\alpha = 0.05$. Trends and correlations were determined using linear regression with $\alpha = 0.05$. Linear regressions used the Pearson product moment correlation coefficient. Tables of t-test results show probabilities.

2.4.1.4. Mapping

Contour maps of physical grain size, phi size, sediment chemistry values and biological community measurements were plotted spatially to show patterns in the study area using Surfer for Windows 8.0 contouring and 3D surface mapping software by Golden Software, Inc. Figures 3-1, 5-6, and 5-7 were created using ArcMap for ArcGIS 10.1 by ESRI.

2.4.2. MULTIVARIATE ANALYSES

Detailed discussions of principal components analysis, principal coordinates analysis, cluster analysis, reference envelope analysis, and regression are found in Appendix B.

2.4.2.1. Ordination and Cluster Analyses

Ordination and cluster methods are used to distinguish groups of entities (such as stations) according to similarity or dissimilarity of attributes (such as community composition or grain size parameters) (Tetra Tech 1982). Ordination analysis displays the sampling stations as points in a multidimensional space. The distance between the points in the space is proportional to the dissimilarity of the attributes found at the respective stations. The different dimensions of the ordination space, called axes, define independent gradients of change in the data. The axes are ordered so that the first axis defines a maximal amount of the change; the second axis defines a maximal amount of the remaining change, and so on for subsequent axes.

Cluster analysis defines groups of stations with similar community or grain size composition. The results are displayed in a hierarchical tree-like structure called a dendrogram. Stations that cluster together are more similar to each other than they are to stations in other cluster groups.

Principal components analysis (PCA) with varimax rotation (Dillon and Goldstein 1984) is an ordination technique applied to physical grain size and metals data at all sediment stations. The resulting axes define the main independent gradients of change in the sediment data. The axis scores were used as independent variables in multiple regression analysis with infauna and trawl ordination scores.

Non-metric Multi-Dimensional Scaling (NMDS) analysis attempts to map the samples in 2 or 3 dimensional space in relation to their similarities of the Bray-Curtis index (Bray and Curtis 1957). The map is then compared to the PCA ordination of abiotic parameters such as sediment composition and chemistry to find patterns of similarity. A BEST (Biota and Environmental STepwise) test can then define the relevance of any observed pattern (Appendix B.2.2.1). All taxa, including rare species, were included in the analysis and an overall square root transformation was done on the data prior to analysis. This reduces the stress coefficient (a measure of significance) of the plots and the effect of the rarer species on the distribution of stations on the NMDS plot.

In order to produce hypotheses concerning the possible causes of the community patterns identified by the ordination and cluster analyses, further analyses were performed to correlate the community patterns with sediment chemistry, grain size, Delta outflow data (IEP 2005) and oceanographic conditions (NOAA 2005). The community gradients defined by the ordination analysis often correlate with external environmental factors, which may be suspected of causing the associated benthic community changes. The relationships between the ordination axis scores and environmental parameters were observed by the ANOSIM (analysis of similarity) method from the Primer v6 program, which compares the similarity indices of the two distributions for statistical relevance. Parameters used in the ANOSIM analyses for benthic infauna were grain size, sediment organic content (Total PAHs and TOC and TKN) and trace metals (Clark and Gorley 2006).

2.4.2.2. Reference Envelope Analysis

Reference envelope analysis involves comparing parameters at potentially impacted stations with the population of parameters at individual reference stations and avoids the pseudoreplication (Hurlbert 1984) inherent in the common approach of using analysis of variance (ANOVA) to compare indicator variable means for reference and outfall locations (Smith 1995, 1998). When comparing an indicator value for a potentially impacted station with a population of reference indicator values, it is useful to compare the indicator value to a quantile on the tail of the population distribution (Smith 1995).

For the reference population, the actual value of the quantile of interest is usually unknown, but if appropriate sample data are available one could estimate the quantile (See Appendix B, 2.4. Reference Envelope). In this report, quantiles of 0.10 (for indicators expected to decrease with impact) or 0.90 (for indicators expected to increase with impact) and $\alpha = 0.05$ were used for comparison with reference. These quantiles were subjectively chosen to balance between environmental protection (sensitivity to impacts) and avoidance of false indications of impact (Smith 1998). Using these parameters, values that exceed the tolerance interval bounds are a potential indication of impact because, 95% of the time, only 10% of the reference population would exceed them in the absence of an impact.

2.4.2.3. BACIP Analysis

The general BACIP (Before-After-Control-Impact Paired) experimental design involves sampling at predetermined “control” and “impact” areas before and after the onset of the potentially impacting activity (Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986). A change in indicator values at a potentially impacted location after the onset of the impacting activity does not necessarily indicate that an impact has occurred, since indicator values can change naturally over time. With this statistical design, it is assumed that large-scale environmental factors causing natural temporal changes in indicator values will have a similar effect in both the impact and control areas. Thus, the test for impact is a test for changes in the after-impact period that do *not* take place in both the control and impact areas. The null hypothesis of the BACIP statistical test is that the average differences between impact and control sites will be the same in the before- and after-operational periods. The details of the sampling design can vary, although all credible designs should involve multiple sampling periods both before and after the impact. As a paired test, the comparison involves a single impact and a single control location. This is because a point source impact (such as an outfall) will create gradients of change in the vicinity of the impact, and the severity of the impact at different locations on the gradient is of interest rather than the impact to the larger area.

An assumption of the BACIP test is that the differences within each group are normally distributed. When the data are positively skewed as total abundances usually are, log transformation will make these differences more normal. Using the log is equivalent to testing for the same ratio of abundances before and after impact. Student’s T test was used to evaluate the differences in the log values prior to discharge and after discharge.

The City and County of San Francisco began pre-discharge benthic infauna studies in 1982. Since that time, one outfall station (station 01) and one reference station (station 06) consistently remained part of the sampling program. A BACIP analysis of infauna abundance at these two stations was performed to provide some information on the degree to which the wastewater discharge may have affected organism abundance.

SECTION 3

BEACH WATER QUALITY MONITORING

BEACH WATER QUALITY MONITORING PROGRAM

3.1. INTRODUCTION

The San Francisco Public Utilities Commission (SFPUC) and the San Francisco Department of Public Health (SFDPH) jointly administer the beach water quality monitoring program in San Francisco. Both agencies participate in sample collection; the SFPUC Microbiology Laboratory performs bacteriological analyses. The SFPUC is responsible for public notification when water quality does not meet State standards for water contact recreation, while the SFDPH is responsible for ensuring compliance with the California Sanitation, Healthfulness and Safety of Ocean Water-Contact Sports Areas Regulations, Title 17, California Code of Regulations.

Shoreline bacteria monitoring provides a measure of water quality conditions for near shore waters. Because measuring all pathogens is impractical, bacteria indicator organisms are used with the assumption that high numbers of bacterial indicators imply the presence of fecal contamination. The beach monitoring program is designed to monitor compliance with State standards for water contact recreation along recreational beaches in San Francisco (City) and to alert the public when water quality conditions exceed those standards. In addition, the public is alerted and water quality conditions are monitored when treated combined sewer discharges occur from the City's combined sewer system at locations where water contact recreation occurs.

Bacteria concentrations are measured along Baker Beach and China Beach on the City's north shore and along Ocean Beach, which extends along the western shore south to Fort Funston (Figure 3-1). This chapter provides a summary of those measurements spanning sixteen years.

Figure 3-1

Shoreline sampling stations and combined sewer system discharge sites

3.1.1. REGULATIONS AND STANDARDS

The U.S. Environmental Protection Agency (U.S. EPA) strives through regulation to ensure that all waters of the nation are "fishable and swimmable" as required under the goals of the 1972 Clean Water Act. The California State Water Resources Control Board established water quality standards in the California Ocean Plan (SWRCB 2012) that apply to discharges into California territorial waters up to three miles from shore. Water quality objectives and standards were developed to ensure (1) the reasonable protection of beneficial uses (including water contact recreation) and (2) the prevention or detection of nuisance conditions.

The single sample maximum (SSM) standard (Table 3-1) is based on a variety of epidemiological studies from: (1) the U.S. EPA's draft "Implementation Guidance for Ambient Water Quality Criteria for Bacteria" that recommends enterococcus bacteria monitoring for marine systems (U.S. EPA 2002), (2) the U.S. EPA's "Water Quality Standards for Coastal Recreation Waters:

Using Single Sample Maximum Values in State Water Quality Standards" that addresses the appropriate use of SSM values for the presence of fecal contamination, specifically for the indicator organisms *Escherichia coli* (*E. coli*) and enterococci (U.S. EPA 2006) and (3) changes to the California Ocean Plan that provide standards for total and fecal coliform and enterococcus bacteria. The SSM standard is also in the California Department of Health Services regulations that implement Assembly Bill 411 (AB 411) for high-use public beaches with storm drains that discharge during dry weather. Although San Francisco beaches are not regulated under AB 411, use of this standard maintains consistency with other California beaches (U.S. EPA and RWQCB 1997). *Escherichia coli* and enterococcus bacteria were added to the beach monitoring program under the Oceanside Water Pollution Control Plant, Southwest Ocean Outfall, and Westside Wet Weather Facilities 2003 NPDES permit (Table 3-2).

Table 3-1
Single sample maximum criteria for the three bacteria indicators monitored

Indicator Bacteria	Single Sample Maximum Limit (per 100 mL)
Total Coliform	10,000
Fecal coliform *(E. coli)*	400
Enterococcus	104

3.1.2. SOURCES

Elevated bacteria concentrations at the shoreline may occur for a variety of reasons: naturally from soil bacteria, organic decay, marine mammals and birds, and storm or surface water runoff; or from anthropomorphic influences such as sewage, domestic pet waste, waste from boat holding tanks, ship or boat bilge-water purging, and street runoff (CDPH 2006).

Storm water runoff and street runoff are concerns the City has addressed through the development of the combined sewer system (CSS) control structures (see Introduction Section 1 and Appendix A). The CSS controls all dry weather flow including street runoff. All dry weather flow receives secondary-level treatment prior to discharge to receiving waters. Under normal wet weather conditions, all flow including storm water runoff is contained and treated prior to discharge. During intense rainstorms, treated combined sewer discharges may occur along the shoreline. The structures that store and transport wastewater and storm water are designed to allow settling of solids and to retain floatable materials, thus, shoreline discharges have received flow-through treatment equivalent to wet weather primary effluent. However, combined sewer discharges are not disinfected and may introduce waterborne pathogens into shoreline waters that could cause illness to those involved in water contact recreation. Treated combined sewer discharges that affect recreational beaches can occur from the Sea Cliff I pump station located at China Beach, the Sea Cliff II pump station located at

Table 3-2
Shoreline monitoring indicators and sampling frequency, 1997-2013

Time Period	Indicator(s) monitored			Minimum Monitoring Frequency
	Total coliform	*E. coli*	Enterococci	
June 1997 to September 2003	√			3 times per week
October 2003 to present	√	√	√	1 time per week

Baker Beach, or the Lincoln, Vicente, or Lake Merced Discharge structures located along Ocean Beach (Figure 3-1).

Lobos Creek is a contributor of bacteria on Baker Beach, but the source of bacteria in the Creek is not known. The creek is a spring brook about 0.5 mile long that is fed from an aquifer underlying the Richmond and Sunset districts and that originates as surface flow between 17th and 18th Avenues. It is densely vegetated and supports numerous wildlife species that might contribute bacteria loads. There are also about 30-35 homes that border the creek on the south (upper reach) and west (lower reach) banks. In addition, the City has two combined sewer crossings, one underground at 17th Avenue and one above ground at 22nd Avenue. Internal inspections and creek sampling above and below each crossing have indicated that they are not leaking. Extensive sampling has shown intermittent elevated bacteria levels throughout the creek, but has not identified a potential source.

3.2. PROGRAM DESCRIPTION

The NPDES permit for the Oceanside Water Pollution Control Plant, Southwest Ocean Outfall, and Westside Wet Weather Facilities requires routine shoreline monitoring, and monitoring after a treated combined sewer discharge occurs. Routine shoreline monitoring consists of ankle-depth, surf zone grab samples once per week, year-round at seven ocean shoreline stations, and combined sewer discharge monitoring consists of sampling at those locations in closest proximity to the treated discharge. In addition to shoreline bacteria monitoring, the permit requires that recreational use surveys (which tally users by full, partial or non-water contact activities) be conducted after any combined sewer discharge. The public must also be notified whenever bacteria levels exceed State standards and whenever a combined sewer discharge occurs. Bacteria water quality data, beach-posting data, and recreational use data collected from 1997 to 2011 are available in previous reports (WQB 1998, 1999, 2000, 2001a, 2003a, 2003b, 2004; NRD 2006a, 2006b; NRLMD 2007, 2008, 2010a, 2010b 2011).

Seven sites are monitored weekly (daily when counts are elevated) at Baker Beach, China Beach, and Ocean Beach (Figure 3-1). Samples are analyzed for three different bacteria indicators of impaired water quality (total coliform, *Escherichia coli*, and enterococci). Results for samples collected are not available until the following day because of the time required to culture the bacteria to obtain an estimate of their presence. Beaches are posted and the public is notified 18 to 24 hours after an elevated concentration of bacteria occurs. This is done in case the elevated bacteria concentrations persist. In order to provide as rapid a response as possible the City proactively posts (and de-posts) beaches and makes public notifications based upon preliminary bacteria counts made available before final results are confirmed. The public is better served overall by timely notifications based upon preliminary counts than by the necessary delay needed to act upon confirmed counts.

3.2.1. PUBLIC NOTIFICATION

The City has implemented several public notification methods for dissemination of shoreline bacteria information. Permanent, large, yellow signs are installed along recreational beaches to explain that beaches will be posted if water quality is impaired. These information signs are written in English, Spanish, and Chinese (Figure 3-2).

3.2.1.1. Recreational Beach Water Quality Hotline

The current status of beach water quality in San Francisco is available on the SFPUC Recreational Beach Water Quality Hotline 415-242-2214 or 1-877-SFBEACH (toll-free). The hotline is updated whenever new sample results are available. The information provided includes the date and results (posted/not posted) of the most recent samples and additional information related to combined sewer system discharges as warranted.

3.2.1.2. Internet

The current status of beach water quality in San Francisco is also available on the internet at http://beaches.sfwater.org. The site uses color-coded symbols on a map of the City to provide an at-a-glance view of water quality status. Additional information including monitoring program description, monitoring station locations, beach descriptions and photos, and data tables with recent sample results are available by clicking on the station symbols. The tables of sample results allow beach users to make an informed decision about water quality at San Francisco beaches.

NOTICE

The following sign will be posted along the shore when it is unsafe to enter the water. This may be due to high bacteria counts, especially during heavy rainfall; or infrequently at other times due to other conditions.

For current information, call the Recreational Water Quality Hotline (877) 732-3224 or the San Francisco Department of Public Health (415) 252-3945

AVISO

La siguiente señal de advertencia será instalada a lo de la playa cuando sea inseguro entrar al agua. Esto podria ser a causa del alto nivel de bacteria, especialmente durante la temporada de lluvias fuertas, y en raras ocasiones por otras condiciones.

Para información actual, llamar a la Línea de Información de la Calidad de Aguas Recreacionales (877) 732-3224 o al Departmento de Salud Pública de San Francisco (415) 252-3945.

警告

當海水不適合游泳和滑浪的時侯，沿著海岸線將會招貼警告標語。在豪雨和某些特別情況下，可能會帶來大量污水入海，這些情況都會對健康有害。

欲獲詳細資料，請電水質電話熱線(877)732-3224或三藩市公共衛生局(415)252-3945。

Figure 3-2
Permanent public notification sign located at major beach access points

3.2.1.3. E-mail

E-mail notifications are sent to affected agencies, user groups, and interested parties whenever a beach is posted or de-posted, including whenever a combined sewer discharge occurs that affects a recreational beach. The public can subscribe to e-mail notifications of beach postings (and de-postings) at http://beaches.sfwater.org.

3.2.1.4. Beach Posting

In the event of a treated CSS discharge or when routine monitoring indicates that water conditions are not suitable for water contact recreation, beach access areas are posted with an international "No Swimming" sign (Figure 3-3). The "No Swimming" signs posted along Ocean Beach, located at beach entry points and at each traffic signal light stanchion, are easily visible to passing motorists on the Great Highway. Signs at Baker Beach and China Beach are located in parking areas and at trail entrances. The sign at Fort Funston is located near the entrance of the foot path. The 'No Swimming' signs are removed and the public is notified when bacteria concentrations indicate water conditions are within State standards for water contact recreation.

Table 3-3
Discharge structures and associated shoreline stations sampled when a discharge occurs

Combined Sewer System control structures	Stations
Seacliff I (China Beach)	17
Seacliff II (Baker Beach)	15, 15E, 16
Lincoln (Ocean Beach)	18,19, 20
Vicente (Ocean Beach)	20, 21, 21.1
Lake Merced (Ft Funston)	22

3.2.1.4.1. Posting Due to a Combined Sewer Discharge

Whenever a treated CSS discharge occurs that affects Ocean Beach (including Fort Funston), China Beach, or Baker Beach the affected beaches are posted with "No Swimming" signs and samples are collected as soon as practical after a discharge occurs (Table 3-3). Beaches remain posted, recreational use surveys are conducted, and samples are collected daily until the discharge ceases and all three bacteria indicators are below State levels for water contact recreation. The SFPUC web site http://beaches.sfwater.org is flagged with a flashing symbol to indicate the discharge location(s). The flashing symbol remains active until the discharge has ceased and all affected sample locations are below SSM standards. If elevated bacteria levels persist more than three days after the last discharge, the flashing symbol is removed and the station(s) remain(s) posted.

Figure 3-3
International no swimming symbol indicating that water quality does not meet recreational water quality standards

3.2.1.4.2. Posting Due to Elevated Bacteria Counts

Because a single elevated indicator may be spurious and historical data indicate that such counts typically do not persist, a confirmation approach to posting beaches that lack sources of pollution (see Section 3.2.1.4.2.1) was adopted on July 1, 2007. For those beaches, confirmation is provided by a second elevated indicator in the same sample, an elevated indicator at a linked station (if applicable), or an elevated indicator in a repeat sample. Linked stations are hydrologically connected such that, during routine monitoring, single indicator exceedances at both stations provide the necessary confirmation for posting.

1. Station <u>not requiring confirmation</u> to post: Baker Beach at Lobos Creek (station 15) is posted with “No Swimming” signs when one or more of the bacteria indicators are above the SSM standards for water contact recreation. Once posted, the station remains posted and is re-sampled daily until all three indicators fall below SSM standards for water contact recreation.
2. Stations <u>requiring confirmation</u> to post: Ocean Beach (stations 18 and 19 are linked, station 21.1), China Beach (station 17), Baker Beach (stations 15E and 16 are each independently linked to station 15). Stations in this category are only posted with “No Swimming” signs when one or more of the following confirmation criteria are met:
    1) More than one indicator exceeds its respective SSM at a single station.
    2) One or more indicator exceeds its respective SSM at a linked station on the same date.
    3) One or more indicator exceeds its respective SSM in a repeat sample.

    If a single indicator exceeds SSM standards and confirmation criterion 1) or criterion 2) is not met, the station is re-sampled and evaluated using criterion 3). Once posted, stations remain posted and are re-sampled daily until all three indicators fall below SSM standards for water contact recreation. In contrast to routine monitoring, treated CSS discharges at these beaches are discrete events that require a separate response not involving confirmation (see Section 3.2.1.4.1).

3.2.1.4.2.1. Rationale for Confirmation before Posting

The Beach Water Quality Workgroup of the California State Water Resources Control Board charged its Monitoring and Reporting Subcommittee with: 1) evaluating the existing monitoring program mandated by State law (AB 411), 2) reviewing the latest scientific findings regarding effectiveness and reliability of that program, and 3) recommending changes to increase public health protection and public notification for those engaged in ocean water contact activities. Although the beach water quality monitoring program conducted in San Francisco by the SFPUC and SFDPH is not regulated by AB411, implementing the recommendations of the Monitoring and Reporting (M&R) Subcommittee provides optimal information delivery to the public and will also assure that San Francisco's program is consistent with other programs throughout the State, to the extent practical. The Guidance Document prepared by the M&R Subcommittee and adopted by the Beach Water Quality Workgroup recognizes three types of beaches, each with distinct water quality issues:

1) Open Coastal Beaches with tidal flushing and unimpeded swell energy, with no known sources of contamination affecting water quality and a history of good water quality.

The M&R Subcommittee recommends employing a confirmation approach to posting this type of beach when a single sample standard is exceeded. Routine beach monitoring data have shown that San Francisco's ocean beaches have a history of good water quality, with no known source of contamination, and with sufficient circulation that the confirmation approach is appropriate. A single exception is indicated below. In contrast to routine monitoring, treated CSS discharges at these beaches are discrete events that require a separate response not involving confirmation.

2) Beaches with storm drain, creek, or river discharges during the summer.

The M&R Subcommittee recommends permanent posting for beaches within this category. In San Francisco, Lobos Creek entering the sea at Baker Beach represents a known or potential source of dry weather contamination. Confirmation is not required at this site. Permanent information signs are posted at this location.

3) Beaches in an enclosed harbor, bay, or estuary.

The M&R Subcommittee recommends an approach requiring "best professional judgment" for these beaches. None of the beaches covered in this report qualify as an enclosed beach.

3.2.2. RECREATIONAL USE MONITORING

San Francisco beaches are popular recreation areas used by the local and regional community and tourists throughout the year. Surveys that document the number of people at the beach provide an indication of the users potentially impacted by combined sewer discharges.

Under the terms of the 1997 NPDES permit the City was required to complete a comprehensive Recreational Use Study along Ocean Beach. The purpose of the study was to make an assessment of the number of water contact users along Ocean Beach and to determine the impact from treated combined sewer discharges on water contact recreation. The study was conducted over a two-year period from October 1998 through September 2000. Results from the study, contained in a separate report (WQB 2001b), determined that water contact and non-water contact (including surf fishing) recreational activities along Ocean Beach are extensive. Of the 154,054 people observed during the two-year study, the majority of users (83%) were involved in non-water contact recreation; and of those involved in water contact recreation, up to 25% were surfers. The number of users observed participating in water contact recreation following a combined sewer discharge represented less than one percent of all water contact users observed during the study. The two-year investigation concluded that most combined sewer discharges events occur in mid-winter and have little impact on recreational use, as little use was observed during the cold, short days of winter. Isolated combined sewer discharge events that occur in early spring have the potential to impact more users as beach use increases when days become longer and the duration of storm events are shorter, contributing to good surfing conditions.

3.3. RESULTS AND DISCUSSION

3.3.1. BACTERIA DATA

Over 80 percent of San Francisco's rainfall occurs between November and March (Null 1995). Most of the data analyses presented here are from July 1 through June 30 in order to correspond with the rainfall year rather than the calendar year. Data in this section is presented for the full 2012-2013 rainfall season, as well as for the combined survey years of 2003 to 2013 (1997 to 2013 for CSDs).

3.3.1.1. Survey Year 2012-2013

Bacteria data from July 2012 to June 2013 are presented in Appendix C-1. Data for prior years are available in earlier reports referenced above. Bacteria sampling from July 2012 to June 2013 resulted in the collection of 468 samples from the ten locations in Figure 3-1: 215 along Ocean Beach (including Fort Funston), 54 at China Beach, and 199 along Baker Beach.

3.3.1.2. The SSM standard was exceeded in 56 samples during the year: the total coliform bacteria standard was exceeded 16 times, the E. coli standard was exceeded 31 times and the enterococcus standard was exceeded 50 times (Appendix C-2(a-e)). Thirty-nine of these samples were associated with wet weather and treated combined sewer discharge events. Of the 17 samples not associated with wet weather, 9 (53%) occurred at Baker Beach and 7 of those were at station 15 where Lobos Creek drains into the Pacific Ocean. Of the remaining eight elevated counts during dry weather, three occurred at China Beach, and five at Ocean Beach, where beach sources (such as pet waste, organic decay, etc.) or ground water were the most likely cause of the elevated counts. The majority (76%) of elevated bacteria counts (including those associated with treated CSS discharges) dropped below the level of concern for water contact recreation within 24 hours. Station 15 (Baker Beach at Lobos Creek) remained elevated for 96 hours, stations 15E (Baker Beach East) and 16 (Baker Beach West) for 72 hours and stations 18 (Ocean Beach at Balboa) and 21.1 (Ocean Beach at Sloat Boulevard) for 48 hours after CSS discharges in November 2012. Station 19 (Ocean Beach at Lincoln Way) remained elevated for 48 hours after a CSS discharge in December 2012. Elevated bacteria counts not related to treated CSS discharge include station 15E (Baker Beach East) which remained elevated for 48 hours in September 2012 and stations 16 (Baker Beach West) and 21.1 (Ocean Beach at Sloat Boulevard) for 48 hours in October 2012 (Appendix C-2(a-e) and C-6-C15)Survey Years 2003-2013

Monitoring for all three bacteria indicators (total coliform, *Escherichia coli*, and enteroccoci) began in October 2003; prior to that date only total coliform bacteria were measured (Section 3.1.1 Regulations and Standards).

The SSM standard was exceeded in 189 samples during the last 4 years (July 2009-June 2013, Appendix C-2(a-e)) since the previous Summary Report (NRD 2010a). Eighty-three of these samples (56%) were associated with wet weather or treated combined sewer discharge events. Of the 65 samples not associated with wet weather, fifty occurred at Baker Beach. These 50 elevated counts were primarily due to outflow from Lobos Creek, which drains into the Pacific Ocean. The remaining seven samples were due to unknown sources. The total number of days when there were elevated bacteria counts not associated with wet weather or a treated discharge(s) at one or more ocean beaches was eight days during the four-year period.

Venn diagrams (Chow and Rodgers 2005)

were developed to assess the degree of overlap in SSM exceedances among the three indicators (October 2003-June 2013). Enterococcus was the indicator that was most frequently exceeded followed by *E. Coli* and total coliforms at all stations (Fig 3-4 (a)). The enterococcus threshold was exceeded ten times more than *E. Coli* and total coliforms thresholds. Enterococcus alone accounted for 189 (44%) of the standards failures, all three bacteria thresholds were collectively exceeded 79 times (19%) and *E. Coli* and enterococci combined for 92 (22%). The remaining threshold exceedences comprised of *E. Coli* 16 (4%), total coliform 20 (5%), total coliform and enterococci 28 (7%) and total coliform and *E. Coli* 2 (1%) thresholds. When comparing all stations, 15 (Baker Beach at Lobos Creek) and 19 (Ocean Beach at Lincoln Way) had the highest number of exceedances (143 and 55, respectively) (Fig 3-4 (b,c)). The enterococci standard was exceeded two times as often as any other standard at station 15. Station 19 had twenty-one enterococci exceedances followed by 17 for all three bacteria thresholds. All of the exceedances at station 19, except one dry-weather enterococci and one *E. Coli* exceedance, were due to treated CSS discharges and rain.

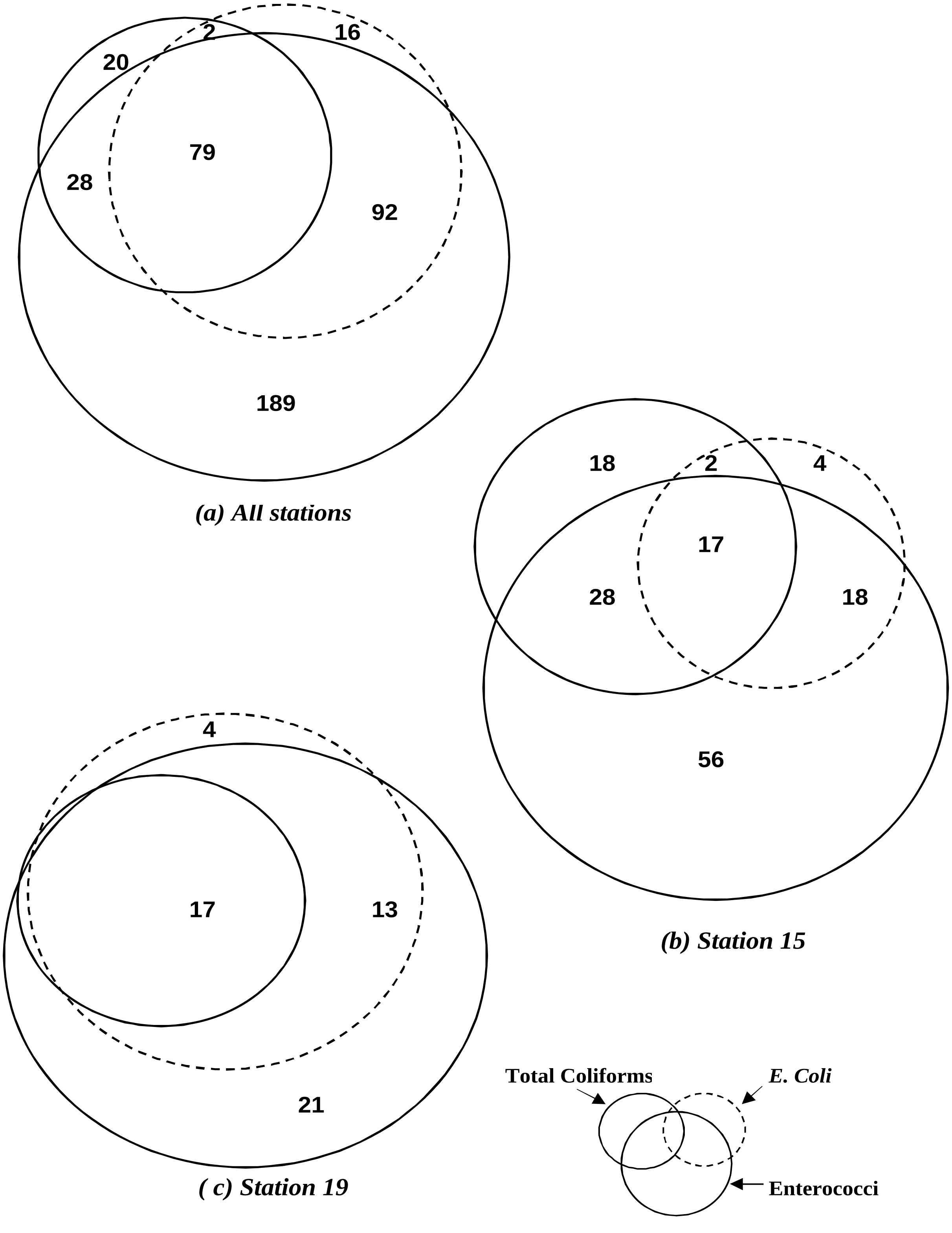
3.3.2. TREATED COMBINED SEWER DISCHARGES

During periods of heavy rainfall, combined flows may exceed the capacity of the City's CSS and treated discharges onto beaches can occur from discharge structures. A treated combined sewer discharge event is defined as a discharge from the CSS through one or more discharge structures as a result of rainfall. To be considered a discrete event discharges must be separated by six hours in time from any other discharge.

San Francisco's Combined Sewer System (CSS) is unique in coastal California. In addition to normal sanitary, commercial, and industrial wastewater flows treated by separate sewer systems, a CSS collects and treats storm water. This offers significant environmental benefit because both storm water and urban street runoff is captured and treated. All street runoff during dry weather receives full secondary treatment, most storm flows receive full secondary treatment, and all storm flow receives treatment to at least wet-weather primary effluent equivalence before being discharged through a designated outfall. During heavy rain events, treated effluent typically comprised of 94% treated storm water and 6% treated sanitary flow can discharge into coastal waters through the CSS. A system of underground storage, transport, and treatment boxes handles major rain events, minimizing the number of combined sewer system discharges. Best management practices are implemented to maximize storage and treatment and minimize shoreline discharges.

3.3.2.1. Survey Year 2012-2013

Average historic rainfall (1948-2013) is 19.99 inches for San Francisco near Oceanside (WRCC 2013). From July 2012 to June 2013 there were 55 days of recorded rainfall, totaling 19.7 inches, which is 99% of average historic rainfall (Appendix C-3). Eight discrete discharges occurred during the rainfall year. The number of Combined Sewer System discharges generally corresponds to the duration and number of rainfall events. Over 14 inches of rain (71% of total) occurred in the months of November and December; all of the discharges occurred during this same period. Six combined sewer discharge events occurred at the Lincoln, Vicente and Lake Merced discharge structures, and three at Sea Cliff I and II pump stations (Appendix C-3). December had the heaviest rainfall with 8.75 inches over 16 days. Five of the eight CSS discharges that occurred during the year took place in December. The other three events occurred in November, which had 5.98 inches on 10 days. The 2012-2013 rainy season was longer than any other in recent record, beginning in October and lasting until the end of June (the rainy season typically ends by the second week of April). No dry weather discharges occurred from any discharge



(a) All stations

(b) Station 15

(c) Station 19

Zero values are not indicated

Figure 3-4

Venn diagrams showing the number of SSM threshold exceedances for each indicator alone and in combination October 2003-June 2013. These diagrams illustrate that enterococci account for the majority of threshold exceedences at (a) All stations combined; and at the two stations with the greatest number of exceedences (b) Baker Beach at Lobos Creek; and (c) Ocean Beach at Lincoln Way.

structures in 2012-2013 (Appendix C-3).

3.3.2.2. Survey Years 1997-2013

Prior to construction of the transport and storage structures, over 80% of wet weather flows were discharged untreated at the shoreline as combined sewer overflows. Rainfall at a rate of 0.02 inches per hour regularly resulted in untreated combined sewer discharges to the City's shoreline. From November 1993 until completion of the Richmond Transport in January 1997, there were over 150 untreated combined sewer discharge events reported from the Sea Cliff II pump station that were uncontrolled and did not receive treatment. Since completion of the final CSS control structures in 1997 (Westside Transport in 1986, Lake Merced Transport in 1994 and Richmond Transport in 1997), all wet weather flows, including treated combined sewer discharges, receive the minimum equivalent of wet weather primary treatment before discharge to the receiving waters and the number of discharges has been greatly reduced (Figure 3-5). The completed CSS captures and provides treatment to 100 percent of all rainstorms. The majority of storm water flow is discharged offshore through the SWOO. Treated combined sewer discharges, which result from less than ten percent of the City's rainstorms, are composed on average of 6% sanitary flow and 94% stormwater.

There are relatively few instances of elevated or persistent high counts as a result of treated combined sewer discharges. Of the 117 discrete combined sewer discharge events that have occurred from 1997-2013, only 48 resulted in an elevated bacteria count (Table 3-4). All bacteria counts resulting from a discrete combined sewer discharge event on Baker Beach (stations 15, 15E and 16), Ocean Beach (stations 18, 19, 20, 21, 21.1 and 22) and China Beach (station 17) dropped below the level of concern for water

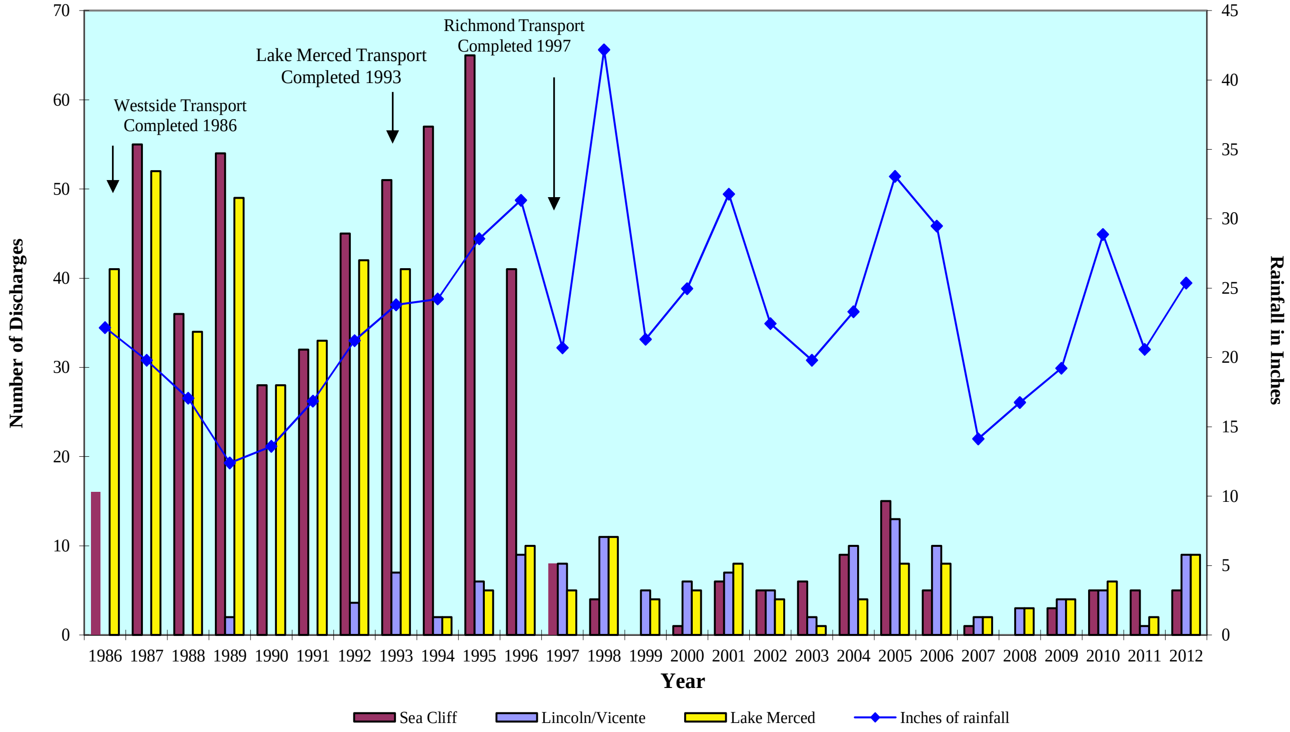


Figure 3-5

Rainfall and westside combined sewer discharges showing reduction in number of discharges with completion of infrastructure improvements in 1997. No data available for Lincoln/Vicente from 1986 to 1988; rainfall data from Golden Gate Weather Services (ggweather.com)

Table 3-4
Summary of total treated combined sewer discharges
and discharges with elevated bacteria counts
July 1997-June 2013

	Seacliff I	Seacliff II	Lincoln/ Vicente	Lake Merced	Discrete CSDs
Discharges with elevated bacteria counts	4	17	53	15	48
Total Discharges	28	67	162	83	117

Table 3-5
Summary of rainfall and related discharge events
1997-2013

		Number of treated CSD events					
Wet Weather Season (July 1 - June 30)	Rainfall (inches)	Sea Cliff I Pump Station	Sea Cliff II Pump Station	Lincoln Structure	Vicente Structure	Lake Merced Structure	Number of Discrete CSD Events*
1997-1998	41.14	2	10	13	13	10	14
1998-1999	18.86	0	0	7	7	6	7
1999-2000	23.19	1	1	6	6	5	7
2000-2001	13.76	2	2	0	0	2	3
2001-2002	24.40	1	1	6	6	6	6
2002-2003	22.25	1	7	6	6	5	9
2003-2004	18.77	2	8	4	4	4	8
2004-2005	26.20	5	8	6	7	7	12
2005-2006	31.83	3	9	9	9	11	13
2006-2007	14.76	0	2	1	1	2	3
2007-2008	18.37	0	1	4	4	4	4
2008-2009	18.29	0	1	4	4	4	4
2009-2010	25.80	6	7	3	3	4	7
2010-2011	30.06	0	4	4	4	5	7
2011-2012	17.56	2	3	2	3	3	6
2012-2013	19.70	3	3	6	6	6	8
Average (July 1997-June 2013)	22.81				Long Term Average		**7**
					Expected performance based on design		**8**

*A discrete discharge event is separated by six hours in time from any other discharge.

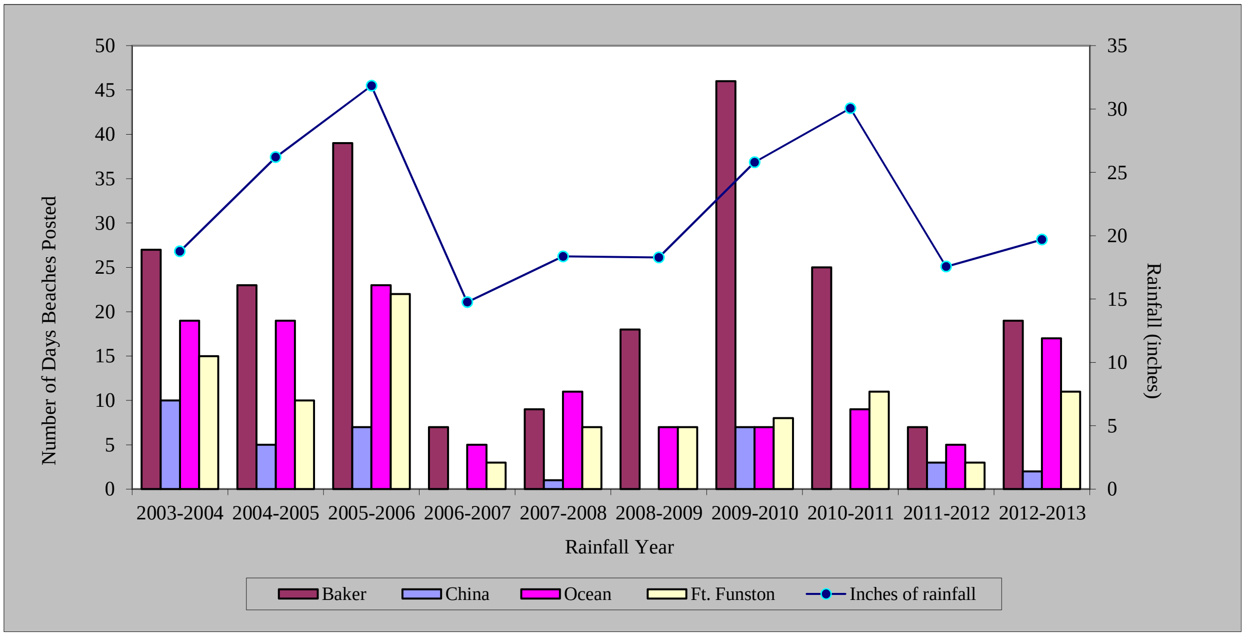


Figure 3-6
Annual rainfall and number of beach postings July 2003-June 2013

Table 3-6
Number of beach postings due to elevated bacteria counts or treated combined sewer discharges 2003-2013

Rainfall Year	Baker Beach		China Beach		Ocean Beach		Ft. Funston		Rainfall (inches)
	Elevated	Discharge	Elevated	Discharge	Elevated	Discharge	Elevated	Discharge	
2003-2004	12	15	3	7	6	13	3	12	18.77
2004-2005	9	14	0	5	4	15	0	10	26.2
2005-2006	25	14	1	6	4	19	0	22	31.83
2006-2007	3	4	0	0	2	3	0	3	14.76
2007-2008	7	2	1	0	0	11	0	7	18.37
2008-2009	16	2	0	0	0	7	0	7	18.29
2009-2010	35	11	0	7	0	7	0	8	25.8
2010-2011	20	5	0	0	0	9	0	10	30.06
2011-2012	3	4	2	1	0	5	0	3	17.56
2012-2013	11	8	0	2	1	14	0	12	19.7
average days posted/year	14	8	1	3	2	10	0	9	
Average percent of time beach available for water contact recreational use	94		99		97		98		

contact recreation within 48 hours.

A summary of rainfall and related discharge events from each structure is presented by wet weather season in Table 3-5. The wettest rainfall years were 1997-1998 (El Niño/La Niña years) with 41.14 inches of rain (207 % of normal) and a correspondingly high number of combined sewer discharges (14), 2005-2006 with 31.83 inches of rain (159% of normal) and 13 combined sewer discharges and 2010-2011 with 30.06 inches of rain (152% of normal) and seven combined sewer discharges. The 2000-

2001 rainfall season had the least rain with 13.76 inches (68% of normal) and one of the least number of combined sewer discharges (3). The 2006-2007 season also had only three combined sewer discharges with 14.76 inches (74% of normal) of rain. Notwithstanding the substantial differences in rainfall over the last 12 years, the City has met the long-term shoreline discharge system design average of eight combined sewer discharge events per year (established as the Westside design goal by the evaluation of cost/benefit analysis) since completion of the final CSS control structures in 1997. The relationship of rainfall, combined sewer discharges, and enterococci counts are presented in graphic form in Appendix C6-C15 for rainfall years 2008-2009 through 2012-2013.

3.3.3. BEACH POSTINGS AND RECREATIONAL USE MONITORING

3.3.3.1. Survey Year 2012-2013

One or more beaches were posted a total of 27 days; 17 of the posting days were due to treated combined sewer discharge events and 11 were due to elevated bacteria counts (Appendix C-4). One of the posting days was due to both a treated combined sewer discharge at Ocean Beach and elevated bacteria counts at Baker Beach at Lobos Creek. Ocean Beach (including Fort Funston) was posted for a total of 17 days, which were coincident with combined sewer discharge events. China Beach was posted for three days due to two discharge events at Seacliff I pump station. Baker Beach was posted a total of 27 days; eight days due to three discharge events at the Sea Cliff II pump station, and 11 days due to elevated counts. Of the eleven days, eight occurred at station 15 where outflow from Lobos Creek was the likely cause of the elevated counts leading to the beach postings.

Recreational use data associated with discharge events (Appendix C-5) showed a higher than average use for partial water contact (fishing) (7% vs. 3%), a lower average for water contact use (3% vs. 6%) and the same average use for non-water contact (91%) compared to those averages associated with discharge events from the extensive Ocean Beach Recreational Use Study (WQB 2001b).

3.3.3.2. Survey Years 2003-2013

The number of postings has remained fairly consistent during the last six-year period, (Fig. 3-6) with the variability in number of postings being due to the variability of rainfall and consequent discharges. The exception occurred at Baker Beach, primarily at Lobos Creek, during the 2009-2010 season. The number of beach-specific postings per rainfall year is shown on Table 3-6; postings are separated as a result of either treated combined sewer discharges or elevated bacteria counts (over the SSM). Postings due to elevated counts increased after *E. coli* and enterococci results were added to the analyses in October 2003. Postings due to elevated counts at Ocean Beach decreased after the confirmation approach was adopted in July 2007. Ocean Beach and Fort Funston were in compliance with water contact recreational use standards an average of 97% and 98% of the time during the last ten-year period; China beach 99%, and Baker Beach 94%.

3.4. SUMMARY AND CONCLUSIONS

The completion of all Westside combined sewer infrastructure improvements in 1997 has resulted in fewer combined sewer discharges and improved near shore water quality along San Francisco's ocean beaches. Beach water quality monitoring data over the past 16 years continue to verify that the City's capital improvements to the CSS are successful in treating and controlling combined sewer discharges and protecting beach water quality. Recent studies (CDPH 2006) indicate that storm water is a major source of near shore water pollution, and the City's CSS provides some level of protection for the health of recreational beach users by treating and transporting the majority of storm water runoff offshore through the SWOO.

The addition of *Escherichia coli* and enterococcus analyses in 2003, while adding to the number of postings in San Francisco, is likely more protective of public health. This is especially the case when elevated counts in dry weather are likely originating from sources other than the wastewater system.

San Francisco beaches provide activities for thousands of people throughout the year with most people visiting in the spring and fall months. The majority of beach users engage in non-water contact activities. Surveys indicated that treated combined sewer discharges in the middle of winter affect few users, since these discharges were typically associated with unpleasant weather conditions.

Sixteen years of monitoring data show that there continues to be a relationship between rainfall, elevated shoreline bacteria counts, and treated combined sewer discharges. Rainfall and combined sewer discharge events typically only cause short-term periods when bacteria concentrations exceed water contact standards.

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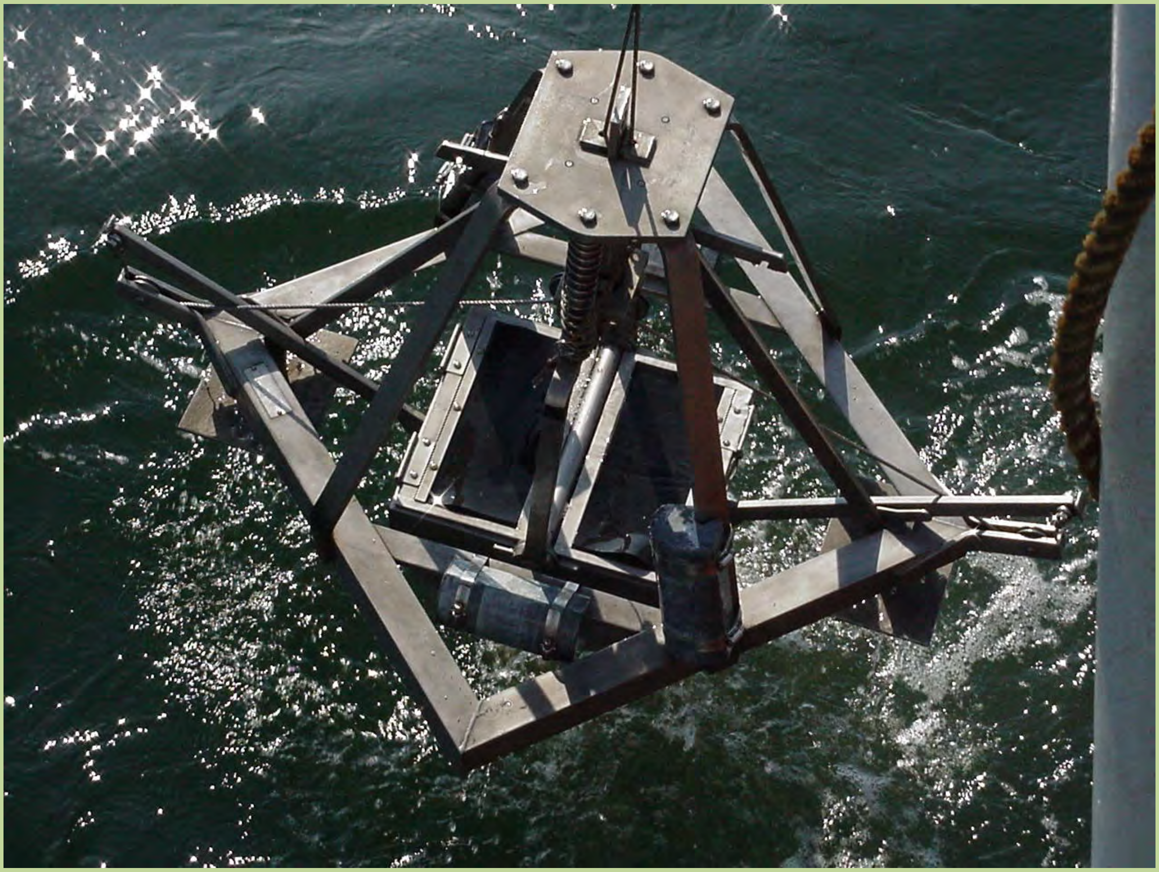


SECTION 4

MARINE SEDIMENTS

MARINE SEDIMENTS

4.1. INTRODUCTION

Sediment monitoring program is used to assess the presence, magnitude, and spatial extent of changes from the South West Ocean Outfall (SWOO) to sediment characteristics, and how they relate to or affect the surrounding environmental community in the near shore waters of the Gulf of the Farallones (Figure 4-1).

Sediment grain size, and organic, and inorganic priority pollutant levels in sediments monitored from 1997 to 2012 are discussed in this section.

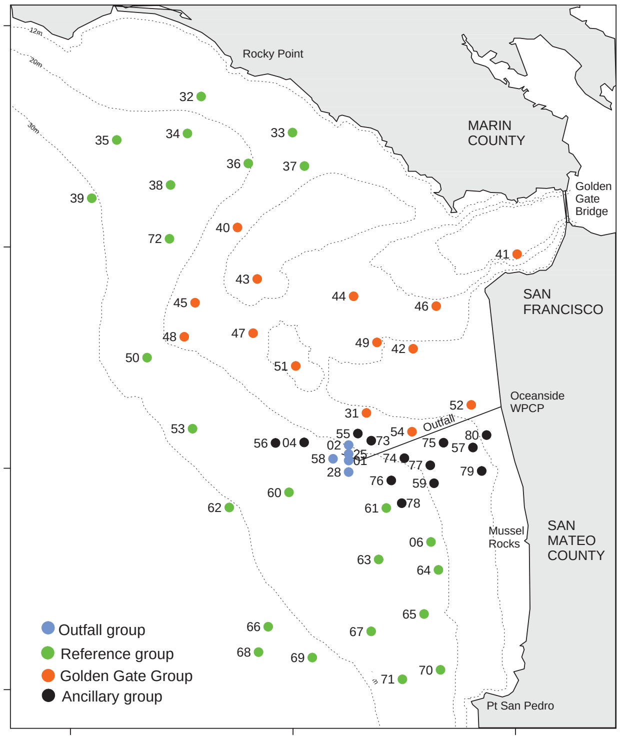


Figure 4-1
Sediment stations showing regions of the study area:outfall, reference, Golden Gate, and ancillary

4.2. RESULTS AND DISCUSSION

4.2.1. GRAIN SIZE

4.2.1.1. <u>Survey Year 2012</u>

Results of 2012 grain size analysis are presented in Appendix D-1 Grain sizes are expressed as percentages of pebble, granule, sand, and combined silt and clay. Sand is further categorized into coarse, medium, fine, and very fine grades (Table 4-1). Phi size is a numerical representation of the particle sizes in each grain size category (see Methods, 2.4.1.1 Sediment).

4.2.1.2. <u>Survey Years 1997 -2012</u>

The standard deviation (SD) of grain sizes indicates how well sorted the sediments are at each station: a high SD corresponds to a wide size distribution and indicates poorly sorted sediments, and characterizes stations with relatively high percentages of silt and clay (e.g., reference stations 36, 35, 34, 32 and outfall station 28), while a lower SD corresponds to a lower spread in size distribution and indicates well-sorted sediments, and characterizes stations with high percentages of fine sand (e.g., stations 41, 43, and 80). Figure 4-2 shows the average distribution of well-sorted (low SD) versus poorly sorted (high SD) stations from 1997 to 2012. The degree of sorting depends on sediment type; fine sands are generally well sorted, while sorting becomes progressively poorer as the percentages of silt, clay, or gravel increase (Folk and Ward 1957). Although a wide range of grain sizes are found in the study area, the low percentages of silt/clay and gravel characterize a generally well-sorted sedimentary environment. The majority of the study area is characterized by fine to very fine-grained sand (phi sizes 2 to 4).

Average grain size distribution (Figure 4-3) summarizes the patterns for each year analyzed separately (WQB 1998, 1999, 2000, 2001a,

Table 4-1
Classification of sediment grain size categories used in the study.

Description	Size (mm)	Phi size (-Log2 mm)	Comments
Gravel	> 2	≤ -1	Includes granule, pebble, and shell fragments
Coarse Sand	> 0.5 to 2	> -1 to 1	Includes very coarse sand
Medium Sand	>0.25 to 0.5	> 1 to 2	
Fine Sand	>0.125 to 0.25	> 2 to 3	
Very Fine Sand	>0.0625 to 0.125	> 3 to 4	
Silt/Clay	> 0.0039 to 0.0625	> 4	Combined Silt and Clay

2003a, 2003b, 2004: NRD 2006a, 2006b, NRLMD 2007, 2008, 2010, 2011, 2012). An area extending west from the Golden Gate Bridge and surrounded by the barrier sand bars, contained the highest average percent of coarse to medium sand. In 2004 and 2005 more than 40 large sand waves were mapped using a multibeam sonar system, in this area, and grain size measurements indicate that the bed surfaces of the sand waves are composed of primarily coarse sand and gravel (Barnard, et al., 2006). The influence of strong diurnal tides in and out

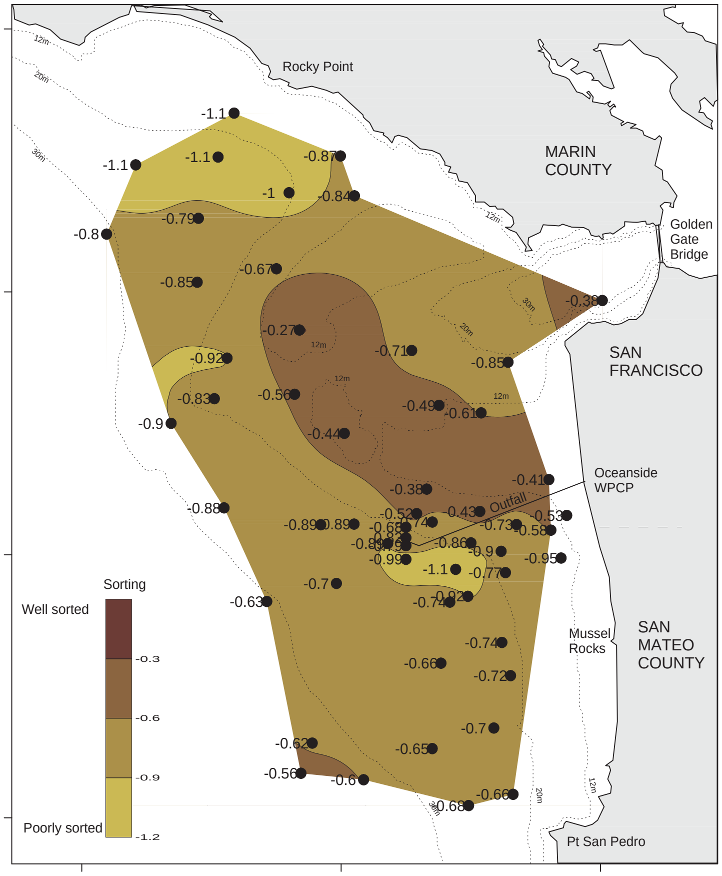


Figure 4-2
Average sediment sorting from 1997 to 2012

of San Francisco Bay and major storm events (Dean and Gardner 1995) act to rework the sediments in this area and may contribute to this pattern of coarser sand. Fine to very fine sands have been the dominant grain size fractions at most stations in the study area from 1997 to 2012 (Figure 4-3). Fine sands predominate on the sand bars. Greater percentages of very fine sands were evident seaward of the sand bars. Beginning in 2007 there has been a noticeable pattern of increasing fines (% silt/clay) at reference locations in the northern reach of the monitoring area (offshore of Rocky Point) as well as near the SWOO outfall (Figures 4-4a & b). Barnard et al. (2012) attribute the observed fining of sediments in these areas to a decrease in aerial extent of the ebb-tidal delta of the San Francisco Estuary, related to a recent (1999) step-decrease in suspended sediment concentrations observed inside San Francisco Bay. Barnard et al. (2012) also speculate that the origin of the fine sediment observed in the outer reaches of the ebb-tidal delta is either finer shelf sediment or finer bay-derived sediment.

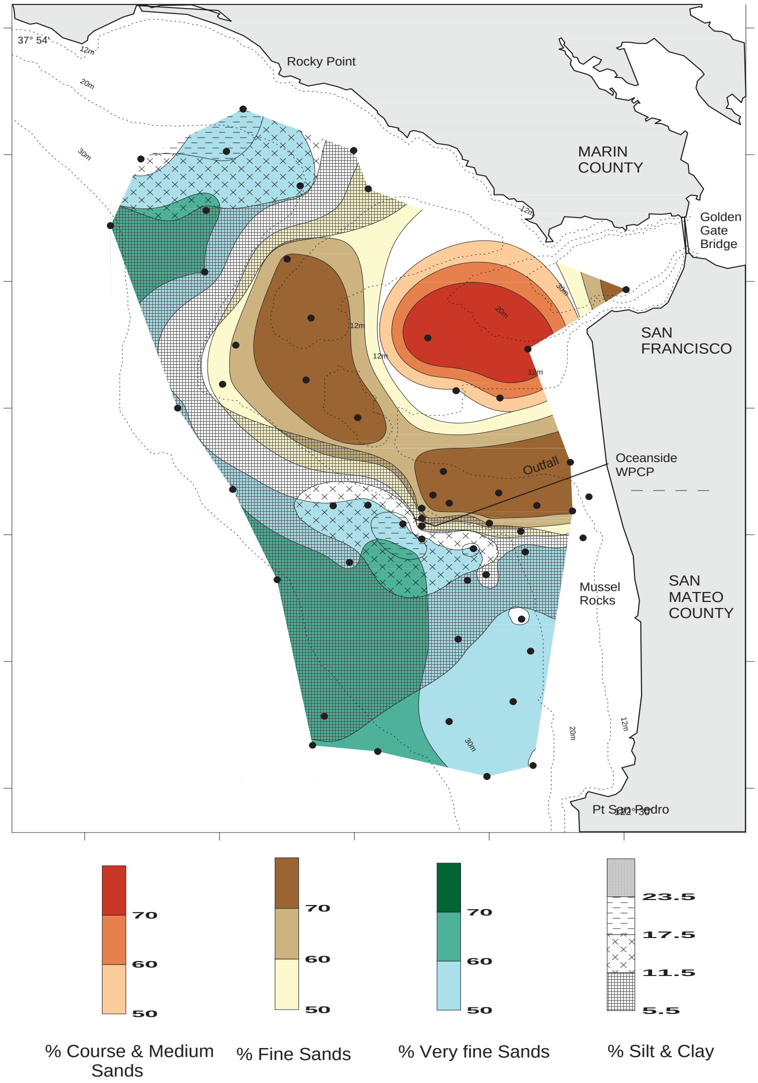


Figure 4-3
Average grain size distribution from 1997 to 2012

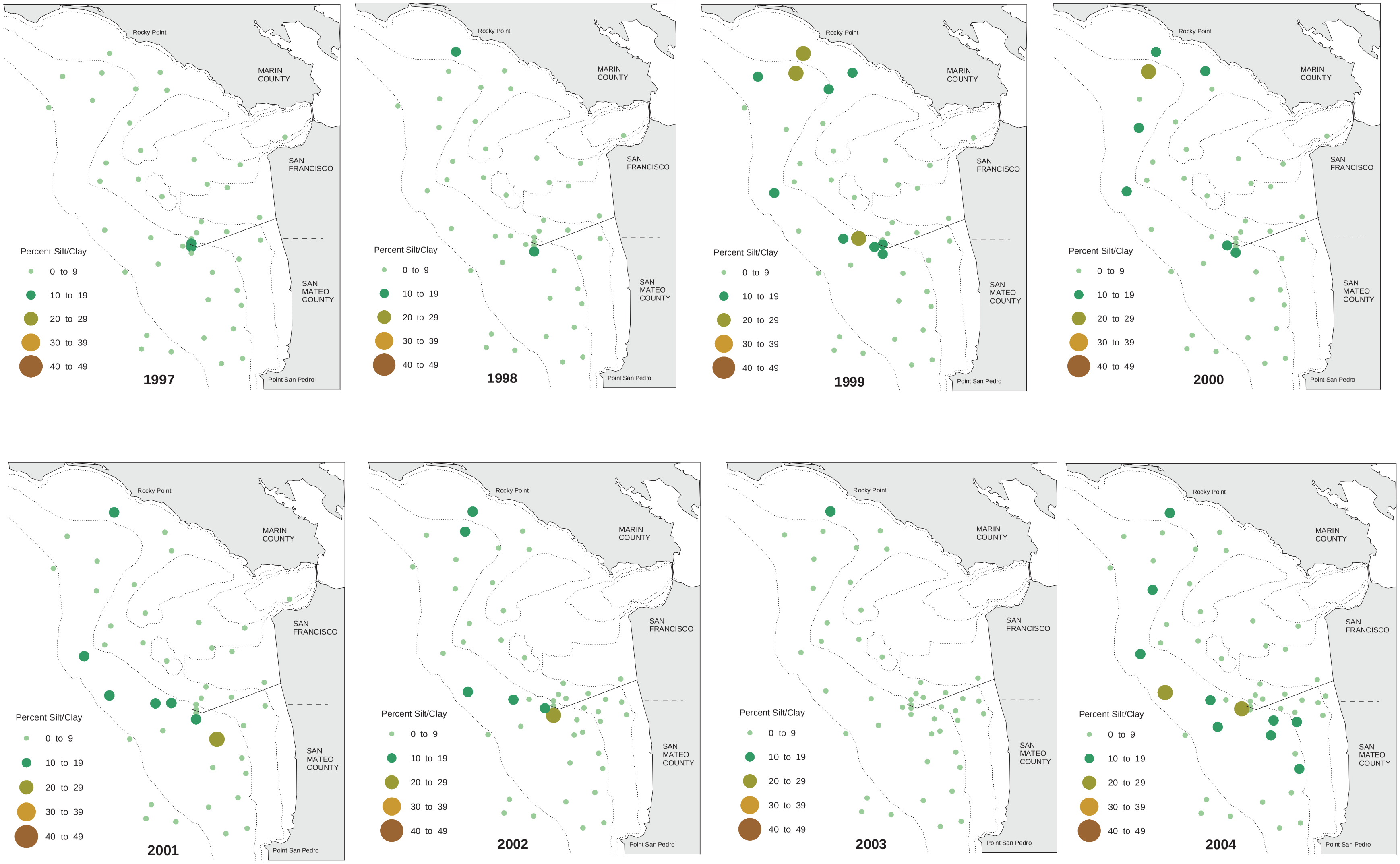


Figure 4-4a
Percent silt and clay from 1997 to 2004

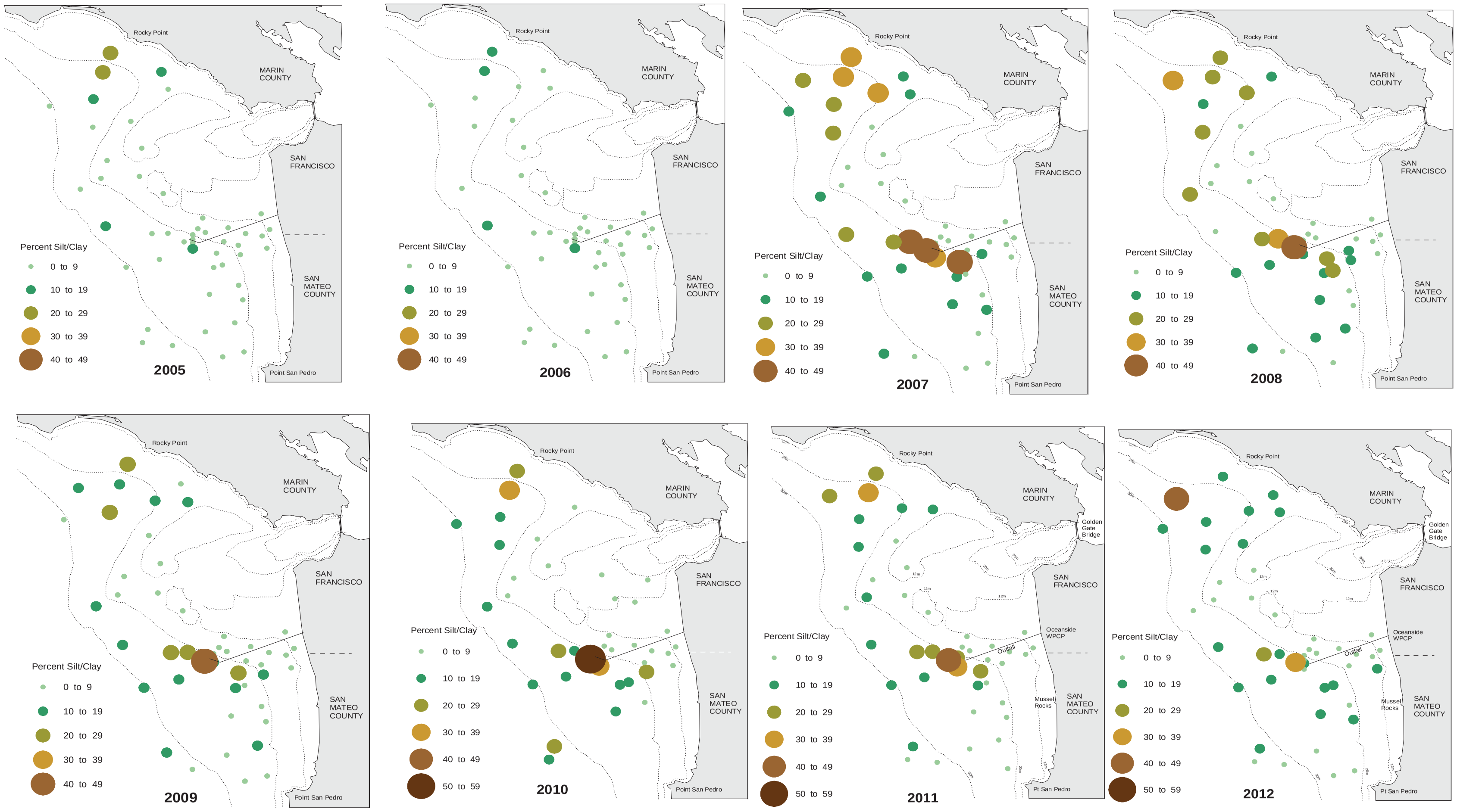


Figure 4-4b
Percent silt and clay from 2005 to 2012

4.2.1.3. Cluster Analysis

Sixteen-year cumulative cluster analyses (Figure 4-5) identified five cluster groups, using sediment physical measurements (sorting, percent silt/clay, and mean phi size) and total organic carbon (TOC). TOC is often used as a substitute for silt/clay in sediment chemistry studies. The combined analysis shows how stations changed or remained the same over time. Stations within each cluster group are more similar to each other than they are to stations in other cluster groups. Only two stations (stations 31 and 43) in the study area displayed persistent sediment characteristics over the sixteen-year study period, remaining in a single cluster group. All other stations showed some degree of variability and fell into more than one cluster group during this study period. The outfall, reference, and ancillary stations have generally clustered together.

The similar cluster patterns of the outfall stations and reference stations continue to reflect the similarity in grain size and organic carbon concentrations between these regions, validating the selection of reference stations used in the reference envelope analysis for chemical contamination (see 4.2.3). Golden Gate stations generally fell into cluster group 3, with occasional stations in cluster groups 1, 2, and 4. The ancillary station group clustered very similarly to outfall and reference stations. The majority of these stations are either near the outfall or along the SWOO pipeline.

4.2.2. SEDIMENT CHEMISTRY

4.2.2.1. 2012 TOC, TVS, TKN

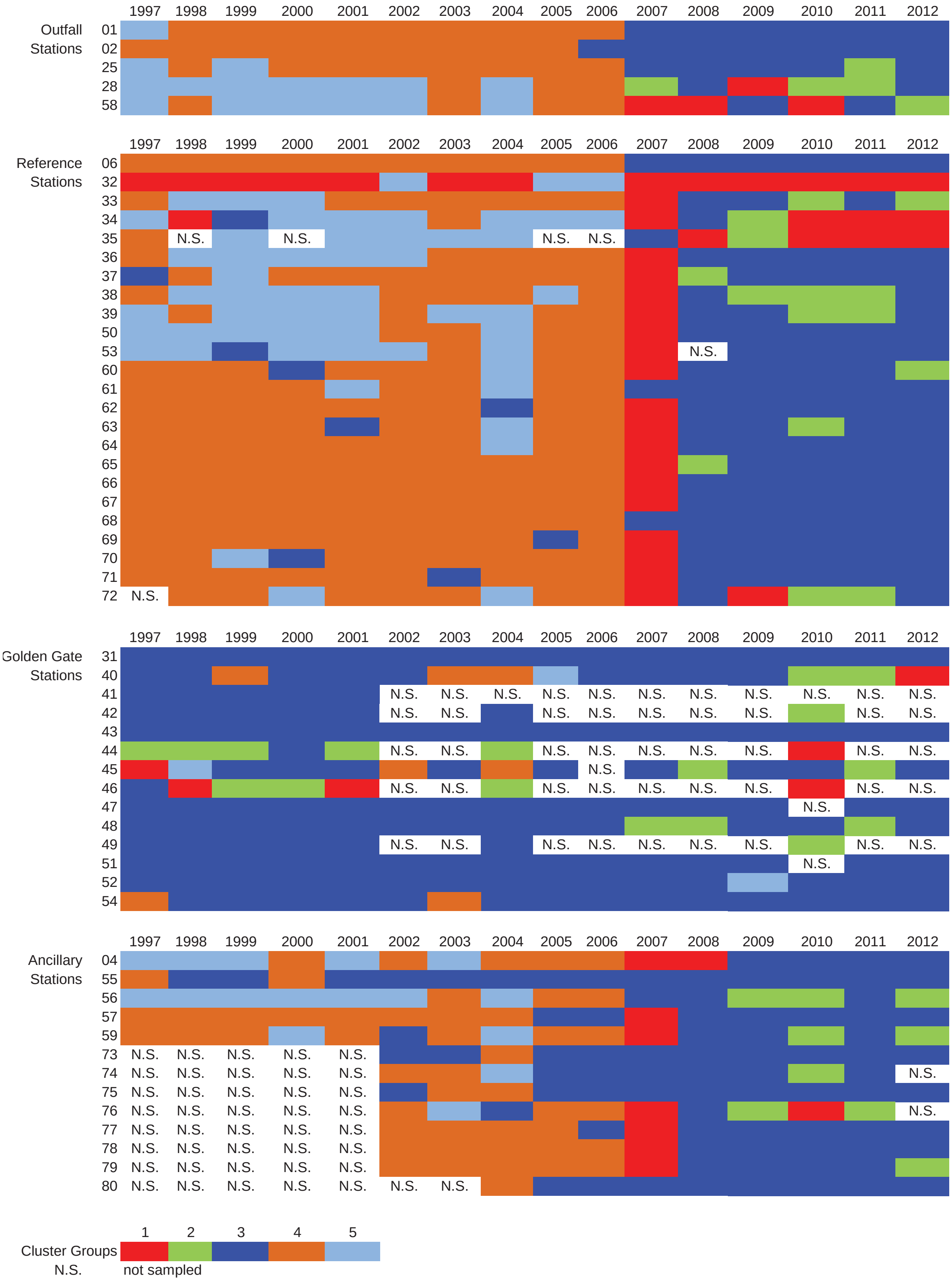
Results for 2012 sediment chemistry data are presented in Appendix D-3. TOC and Total Volatile Solids (TVS), are measures of the amount of organic material in sediments and can reflect additions or loadings from wastewater discharges. Total Kjeldahl Nitrogen (TKN) is a measure of ammonia and organic compounds, and therefore an indicator of nitrogen availability. TOC values in 2012 at outfall stations ranged from 1.31% to 2.95%; reference site values range from 1.05% to 8.72%. TVS values in 2012 at outfall stations ranged from 1.70 to 2.57; reference sites values range from 1.18 to 9.40. TKN values in 2012 at outfall stations ranged from 241 mg/Kg to 348 mg/Kg; reference site values range from 267 mg/Kg to 867 mg/Kg.

4.2.2.2. 1997-2012 TOC, TVS, TKN

Average percent TVS values from 1997 to 2012 at outfall sites ranged from1.5 to 2.4; stations in the northern reference area ranged from 2.0 to 3.5, southern reference stations range from 1.6 to 2.0 (Figure 4-6). Average TOC values at outfall sites ranged from 1.4% to 3.3% (Figure 4-7) Average TOC measurements between 1997 and 2012 were highest in the northern reference area (from 2.22% to 6.63%); station 32 had consistently high values during the sixteen year study. Average TKN values at outfall stations from 1997 through 2012 ranged from 221 mg/Kg to 342 mg/Kg (Figure 4- 8). Stations in the northern reference area had the highest TKN values. TKN averages at outfall stations were below that of northern reference stations, indicating negligible influence of the SWOO discharge on nitrogen loading in the outfall area. The Golden Gate stations, with the highest percentages of coarse and medium sand, generally had the lowest measurements of all three sediment chemistry parameters, with outliers at station 45 in 1997 which had particularly high values of TOC and TVS (WQB 1998).

4.2.2.3. Organic Pollutants

Organic waste discharged through sewage outfalls may be composed entirely of non-toxic domestic sewage or some combination of domestic and industrial/chemical waste which may include a toxic component (Swartz et al. 1984). Sewage discharged through the SWOO is predominantly domestic with minor commercial



		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Outfall Stations	01	▨	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟦	🟦	🟦	🟦	🟦	🟦
	02	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	25	▨	🟧	▨	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟦	🟦	🟦	🟦	🟩	🟦
	28	▨	▨	▨	▨	▨	▨	🟧	▨	🟧	🟧	🟩	🟦	🟥	🟩	🟩	🟦
	58	▨	🟧	▨	▨	▨	▨	🟧	▨	🟧	🟧	🟥	🟥	🟦	🟥	🟦	🟩

		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Reference Stations	06	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟦	🟦	🟦	🟦	🟦	🟦
	32	🟥	🟥	🟥	🟥	🟥	▨	🟥	🟥	▨	▨	🟥	🟥	🟥	🟥	🟥	🟥
	33	🟧	▨	▨	▨	🟧	🟧	🟧	🟧	🟧	🟧	🟥	🟦	🟦	🟩	🟦	🟩
	34	▨	🟥	🟦	▨	▨	▨	🟧	▨	▨	▨	🟥	🟦	🟩	🟥	🟥	🟥
	35	🟧	N.S.	▨	N.S.	▨	▨	▨	▨	N.S.	N.S.	🟦	🟥	🟩	🟥	🟥	🟥
	36	🟧	▨	▨	▨	▨	▨	🟧	🟧	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟦
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	38	🟧	▨	▨	▨	▨	🟧	🟧	🟧	▨	🟧	🟥	🟦	🟩	🟩	🟩	🟦
	39	▨	🟧	▨	▨	▨	🟧	▨	▨	🟧	🟧	🟥	🟦	🟦	🟩	🟩	🟦
	50	▨	▨	▨	▨	▨	🟧	🟧	▨	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟦
	53	▨	▨	🟦	▨	▨	▨	🟧	▨	🟧	🟧	🟥	N.S.	🟦	🟦	🟦	🟦
	60	🟧	🟧	🟧	🟦	🟧	🟧	🟧	▨	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟩
	61	🟧	🟧	🟧	🟧	▨	🟧	🟧	▨	🟧	🟧	🟦	🟦	🟦	🟦	🟦	🟦
	62	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟦	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟦
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	67	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟦
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	70	🟧	🟧	▨	🟦	🟧	🟧	🟧	🟧	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟦
	71	🟧	🟧	🟧	🟧	🟧	🟧	🟦	🟧	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟦
	72	N.S.	🟧	🟧	▨	🟧	🟧	🟧	▨	🟧	🟧	🟥	🟦	🟥	🟩	🟩	🟦

		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Golden Gate Stations	31	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	40	🟦	🟦	🟧	🟦	🟦	🟦	🟧	🟧	▨	🟦	🟦	🟦	🟦	🟩	🟩	🟥
	41	🟦	🟦	🟦	🟦	🟦	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	42	🟦	🟦	🟦	🟦	🟦	N.S.	N.S.	🟦	N.S.	N.S.	N.S.	N.S.	N.S.	🟩	N.S.	N.S.
	43	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	44	🟩	🟩	🟩	🟦	🟩	N.S.	N.S.	🟩	N.S.	N.S.	N.S.	N.S.	N.S.	🟥	N.S.	N.S.
	45	🟥	▨	🟦	🟦	🟦	🟧	🟦	🟧	🟦	N.S.	🟦	🟩	🟦	🟦	🟩	🟦
	46	🟦	🟥	🟩	🟩	🟥	N.S.	N.S.	🟩	N.S.	N.S.	N.S.	N.S.	N.S.	🟥	N.S.	N.S.
	47	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	N.S.	🟦	🟦
	48	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟩	🟩	🟦	🟦	🟩	🟦
	49	🟦	🟦	🟦	🟦	🟦	N.S.	N.S.	🟦	N.S.	N.S.	N.S.	N.S.	N.S.	🟩	N.S.	N.S.
	51	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	N.S.	🟦	🟦
	52	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▨	🟦	🟦	🟦
	54	🟧	🟦	🟦	🟦	🟦	🟦	🟧	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ancillary Stations	04	▨	▨	▨	🟧	▨	🟧	▨	🟧	🟧	🟧	🟥	🟥	🟦	🟦	🟦	🟦
	55	🟧	🟦	🟦	🟧	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	56	▨	▨	▨	▨	▨	▨	🟧	▨	🟧	🟧	🟦	🟦	🟩	🟩	🟦	🟩
	57	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟦	🟦	🟥	🟦	🟦	🟦	🟦	🟦
	59	🟧	🟧	🟧	▨	🟧	🟦	🟧	▨	🟧	🟧	🟥	🟦	🟦	🟩	🟦	🟩
	73	N.S.	N.S.	N.S.	N.S.	N.S.	🟦	🟦	🟧	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	74	N.S.	N.S.	N.S.	N.S.	N.S.	🟧	🟧	▨	🟦	🟦	🟦	🟦	🟦	🟩	🟦	N.S.
	75	N.S.	N.S.	N.S.	N.S.	N.S.	🟦	🟧	🟧	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	76	N.S.	N.S.	N.S.	N.S.	N.S.	🟧	▨	🟦	🟧	🟧	🟥	🟦	🟩	🟥	🟩	N.S.
	77	N.S.	N.S.	N.S.	N.S.	N.S.	🟧	🟧	🟧	🟧	🟦	🟥	🟦	🟦	🟦	🟦	🟦
	78	N.S.	N.S.	N.S.	N.S.	N.S.	🟧	🟧	🟧	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟦
	79	N.S.	N.S.	N.S.	N.S.	N.S.	🟧	🟧	🟧	🟧	🟧	🟥	🟦	🟦	🟦	🟦	🟩
	80	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	🟧	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

	1	2	3	4	5
Cluster Groups	🟥	🟩	🟦	🟧	▨
N.S.	not sampled				

Figure 4-5

Station-Cluster group matrix showing relationship of stations through time (1997 to 2012)

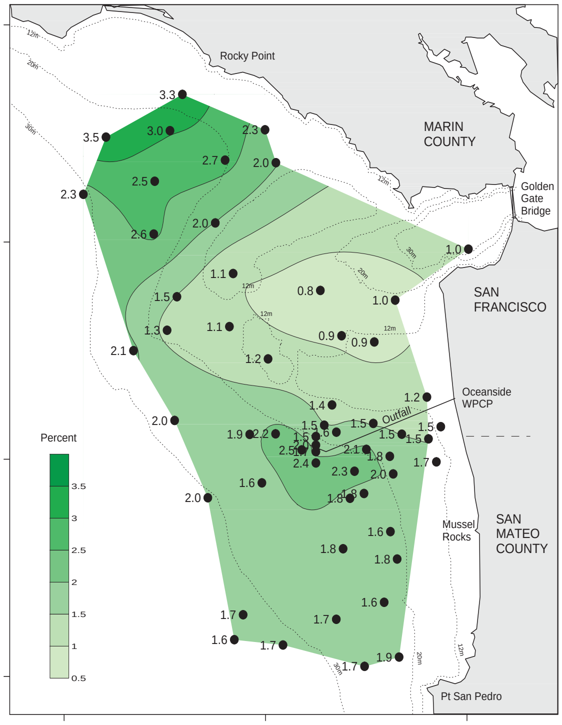
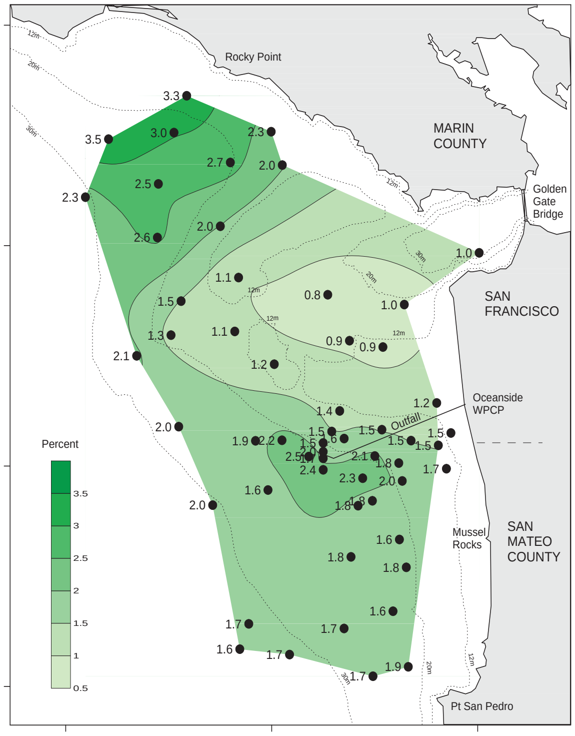


Figure 4-6
Average percent TVS from 1997 to 2012



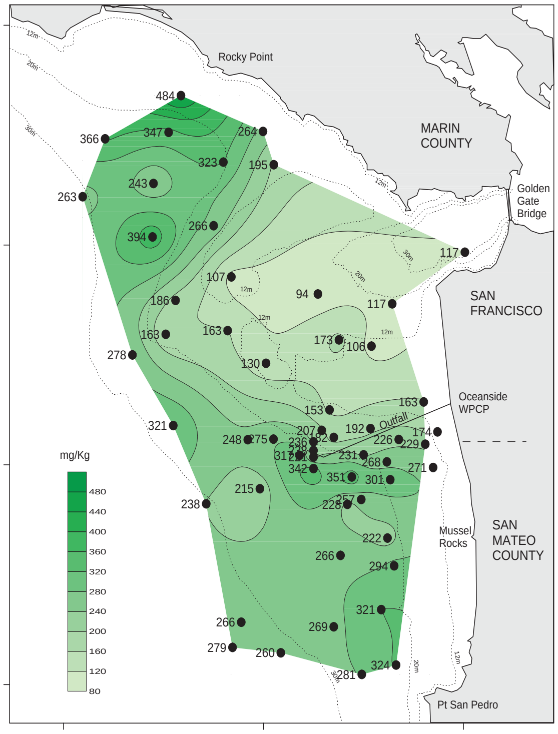


Figure 4-7
Average TOC (mg/Kg) from 1997 to 2012

Figure 4-8
Average TKN (mg/Kg) from 1997 to 2012

additions from hospitals, restaurants, and dry cleaners. Measureable amounts of organic pollutants were detected in sediments at forty-six (46) of the forty-nine (49) stations sampled in 2012 (Appendix D-4).

Final effluent samples analyses from the Oceanside WPCP over the last eleven years (2001 to 2012) have not exceeded NPDES permit limits for metals or organic compounds. Total polycyclic aromatic hydrocarbons (PAHs) from Oceanside WPCP final effluent also have not exceeded NPDES permit limits (Appendix D-5). Figures 4-9a & b shows the distribution of average concentrations of all PAH pollutants measured at each SWOO station over the sixteen-year period. PAHs were found to be a major organic component of the sediments in the vicinity of the outfall before construction began (pre-discharge) (de Lappe et. al. 1980) and the ratios of the PAH compounds indicated that their source was combustion processes (BWPC 1984). PAH concentrations within the study region appear to be transitory and have not followed percent silt/clay patterns (Figure 4-9).

Polychlorinated biphenyl (PCB) congeners and organochlorine pesticides (such as DDT) are infrequently detected and are only generally detected at low concentrations within the study area (Appendix D-4; WQB 1998, 1999, 2000, 2001a, 2003a, 2003b, 2004: NRD 2006a, b,; NRLMD 2007, 2008, 2009, 2010, 2011, 2012).

4.2.2.4. Inorganic Pollutants

Results of trace metals analysis at all stations in 2012 are shown in Appendix D-6. Analytical techniques and detection limits are listed in Appendix D-7.

Figure 4-10 shows the average concentration of metals of concern (Copper, Mercury, Nickel, and Selenium) from outfall and reference stations from 1997 to 2012. Appendix D-8 shows summary measurements of Oceanside Water Pollution Control Plant final effluent for thirteen metals. Samples were taken quarterly, then yearly, depending on permit year. All measured concentrations were within NPDES permit limits.

Both a standard analysis of variance (ANOVA), testing metal by metal, and a multivariate analysis of variance (MANOVA), testing a multivariate summary of metals variation, were performed on sediment metals concentrations to detect differences between reference and outfall stations during the study period (1997 to 2012) (Appendix D-9). Overall, the concentrations of metals at reference stations are the same as the concentrations at outfall stations ($p>0.05$). There is no discernible outfall effect in the sediment metals data.

4.2.2.5. Ordination Analysis for Sediment Chemistry

Principal component analysis (PCA) (see Methods, 2.4.2. Multivariate Analyses) of grain size parameters and sediment chemistry identified six independent gradients of change in the study area (Appendix D-10). The first four axes from the PCA analysis encompass

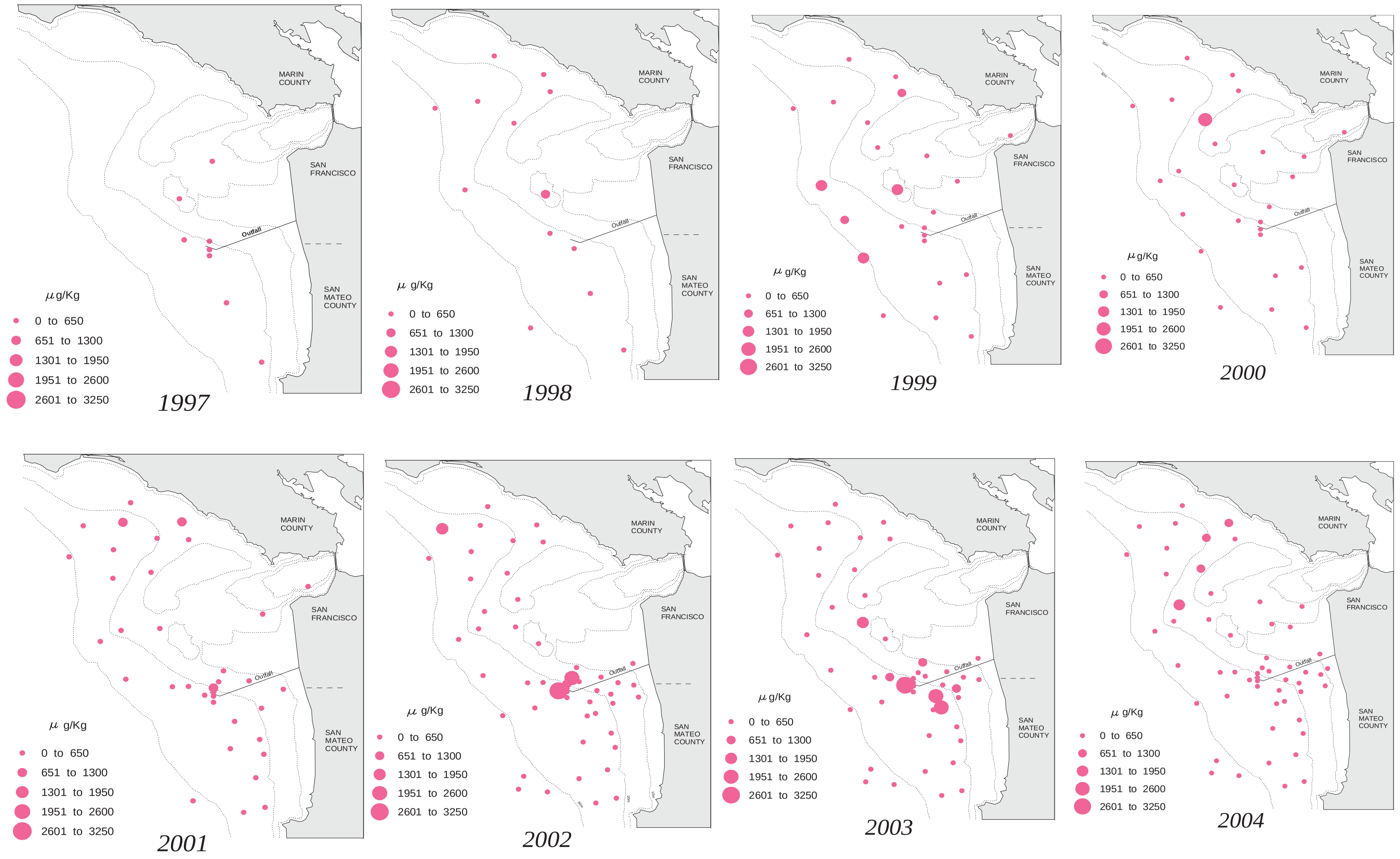


Figure 4-9a
Total PAHs (µg/Kg) measured from 1997 to 2004. The number of stations sampled increased each year.

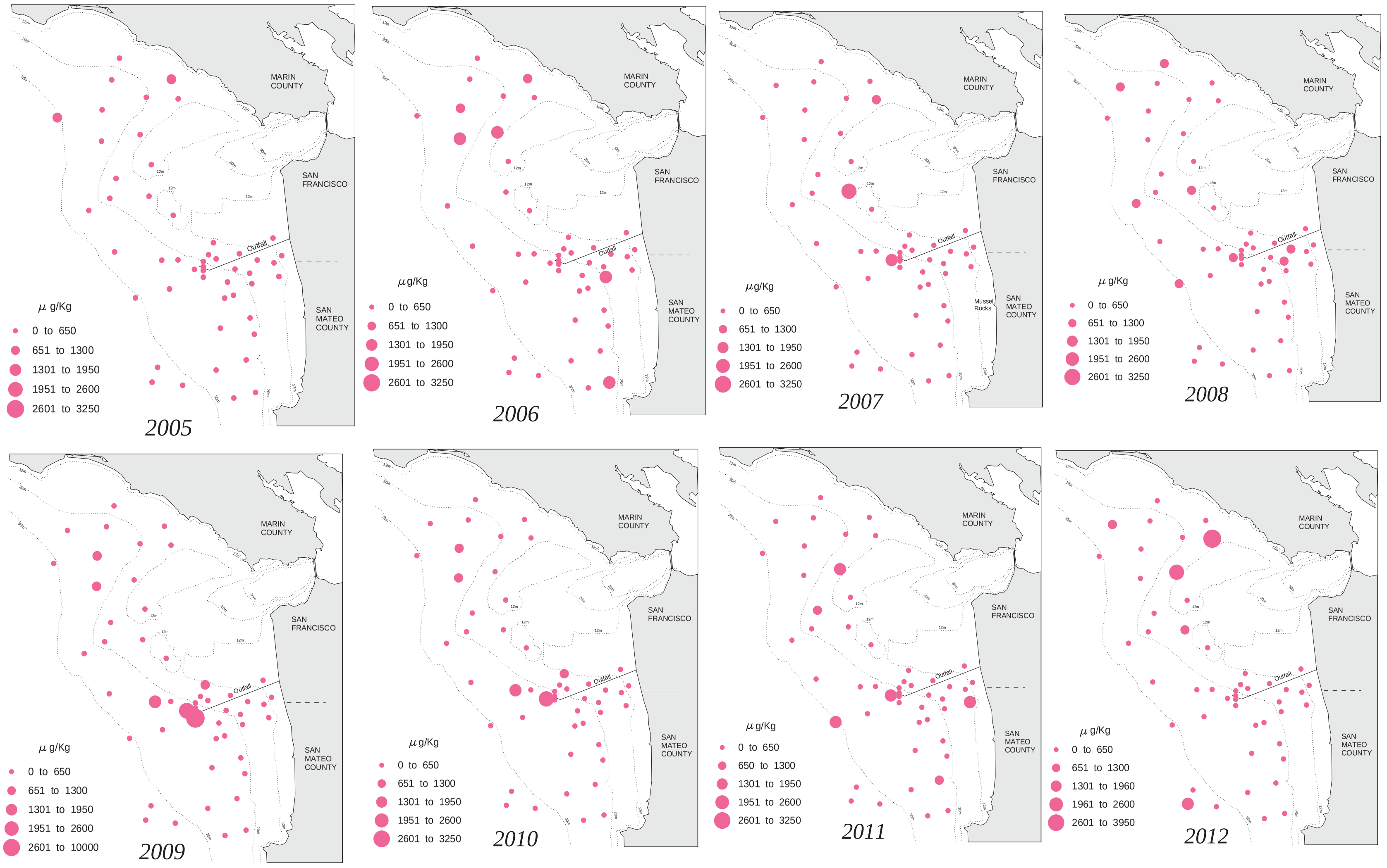


Figure 4-9b
Total PAHs (µg/Kg) measured from 2005 to 2012.

more than 87% of the variation in the data. Axis 1, accounting for 31% of the variation, combines low values of parameters associated with organic loading – silt/clay, TOC and TVS. The next three axes were all dominated by a single factor: Axis 2 (21% of the variation) by higher concentrations of metals; Axis 3 (18% of the variation) by higher concentrations of sediment nitrogen (TKN); and axis 4 (17% of the variation) by higher concentrations of organic pollutants. The remaining two axes combined explain less that 13% of the variation in the data.

4.2.3. REFERENCE ENVELOPE

Reference envelope tolerance interval bounds (see Methods 2.4.2.2 Reference Envelope Analyses) were calculated using TOC, TVS, TKN, silt/clay, metals (as the sum of their ERM quotients), and total organic pollutant from reference stations (06, 32-39, 50, 53, 60-72).

Outfall station measurements are compared to the reference station tolerance interval bounds in order to assess the potential degree of impact from the SWOO discharge (Figures 4-11a, b, & c). Analysis of measurements between 1997 to 2012 from 80 outfall samples and 384 reference samples showed that the majority of the outfall region measurements were within reference tolerance bounds, indicating that overall the SWOO discharge does not have an adverse impact on sediments in the SWOO study area. Outfall station 58 and reference station 32 have exceeded tolerance interval bounds most frequently over the last twelve years; station 58 for percent TVS in 2008, for percent silt/clay in 2004, 2007, 2009, 2010, 2011, and 2012, and for sum of organic pollutants (DDT, PAHs, and PCB’s) in the following years: 2002, 2003, 2007, 2008, 2009, 2010, and 2011. The exeedance in organic pollutants at station 58 may be due to the high silt and clay content. Reference station 32, also with high values of silt and clay, exceeded tolerance bounds for almost all parameters in multiple years except for sum of metals ERMq. Outfall station 02 exceeded the tolerance interval bound for sum of organic pollutants in 2001 and 2002 and for TKN in 2003. Outfall station 28 exceeded tolerance bounds for percent silt/clay in 2007, 2009, 2011 and 2012. Other northern reference stations, as well as a few southern reference stations, have exceeded tolerance bounds for various parameters. These stations typically have the highest percentages of silt and clay each year and often exceed or approach the upper tolerance bound for organic content.

4.2.4. BACIP ANALYSIS

The BACIP (Before-After-Control-Impact-Paired) statistical model (see Methods, 2.4.2.3 BACIP Analysis) was used to evaluate whether or not conditions have changed at the outfall since the onset of effluent discharge. Parameters used to test the relationship between an outfall and a reference station were percent silt/clay, TOC, percent TVS, and TKN. The null hypotheses for this statistical test is that the mean differences between the outfall and reference station measurements are the same in pre-discharge and discharge periods. Stations 01 (outfall) and 06 (reference) were used in this analysis because they have the longest history of continuous sampling. While there was no significant difference in relative values between pre- and post-discharge periods for TOC, percent TVS, and TKN (**t** (23) = 1.72, 1.56, 1.81 respectively, $p > 0.05$), there was a significant difference in percent silt and clay since pre-discharge at outfall station 01(**t** (23) = 2.30, $p < 0.05$); demonstrating a reduction of percent silt and clay at the outfall (Figure 4-12). This data suggests that since 1998, percent silt/clay at outfall station 01 has become more like reference station 06 post-discharge. However, there is evidence of increasing sediment fines throughout the study area (4.2.1 Grain Size section).

Figure 4-10

Average concentrations (mg/Kg) of copper, mercury, nickel, and selemium at SWOO reference and outfall stations from 1997 to 2012. These are metals of concern in San Francisco Bay (SFEI 2013).

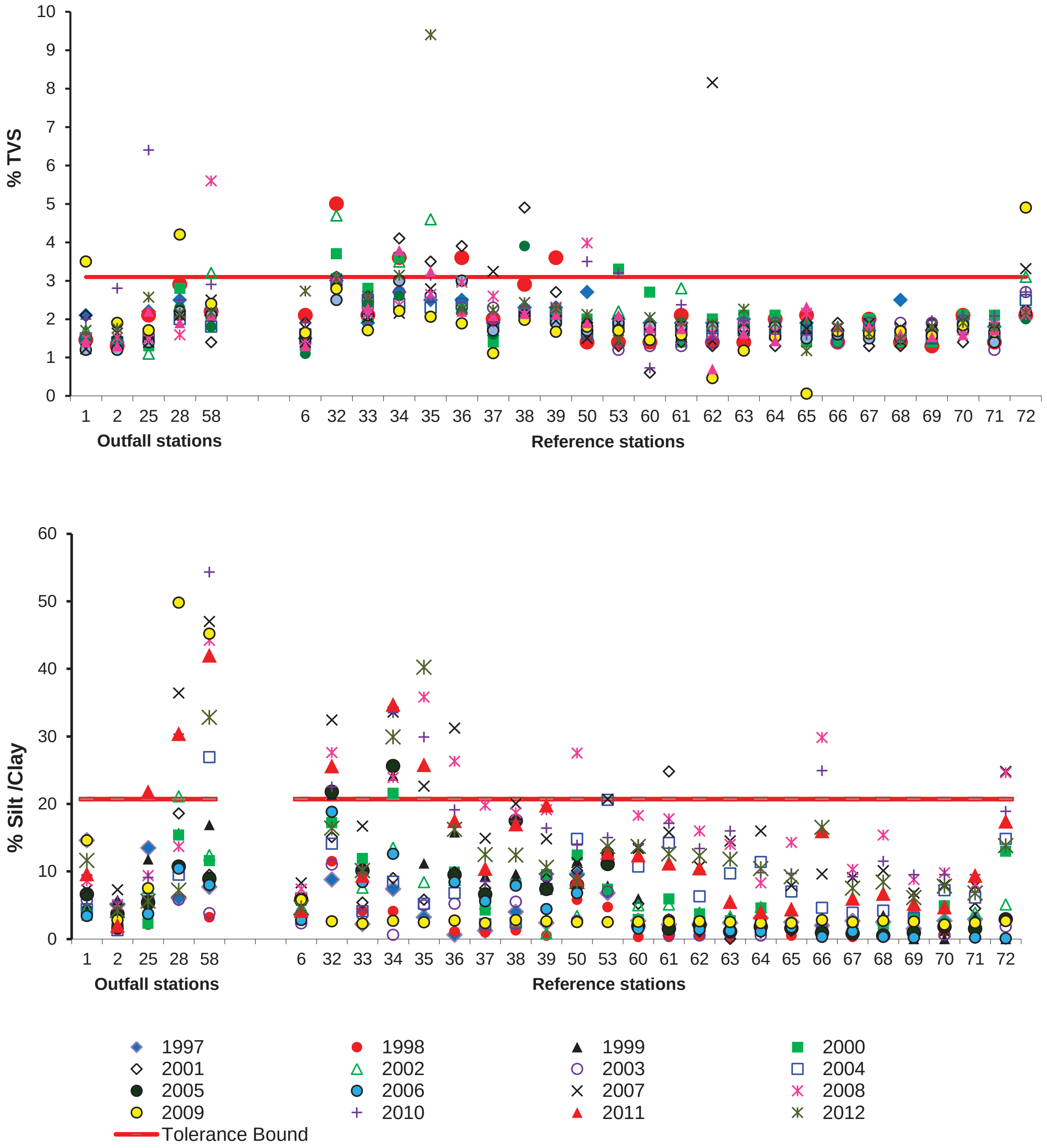


Figure 4-11a

Sediment indicators used in the reference envelope analysis and plotted with an upper tolerance interval bound P = .90 and α = .05. Only the upper interval bound is plotted since concern for these indicators would be an increase in the presence of a wastewater discharge. Tolerance interval bounds calculated from 384 reference samples.

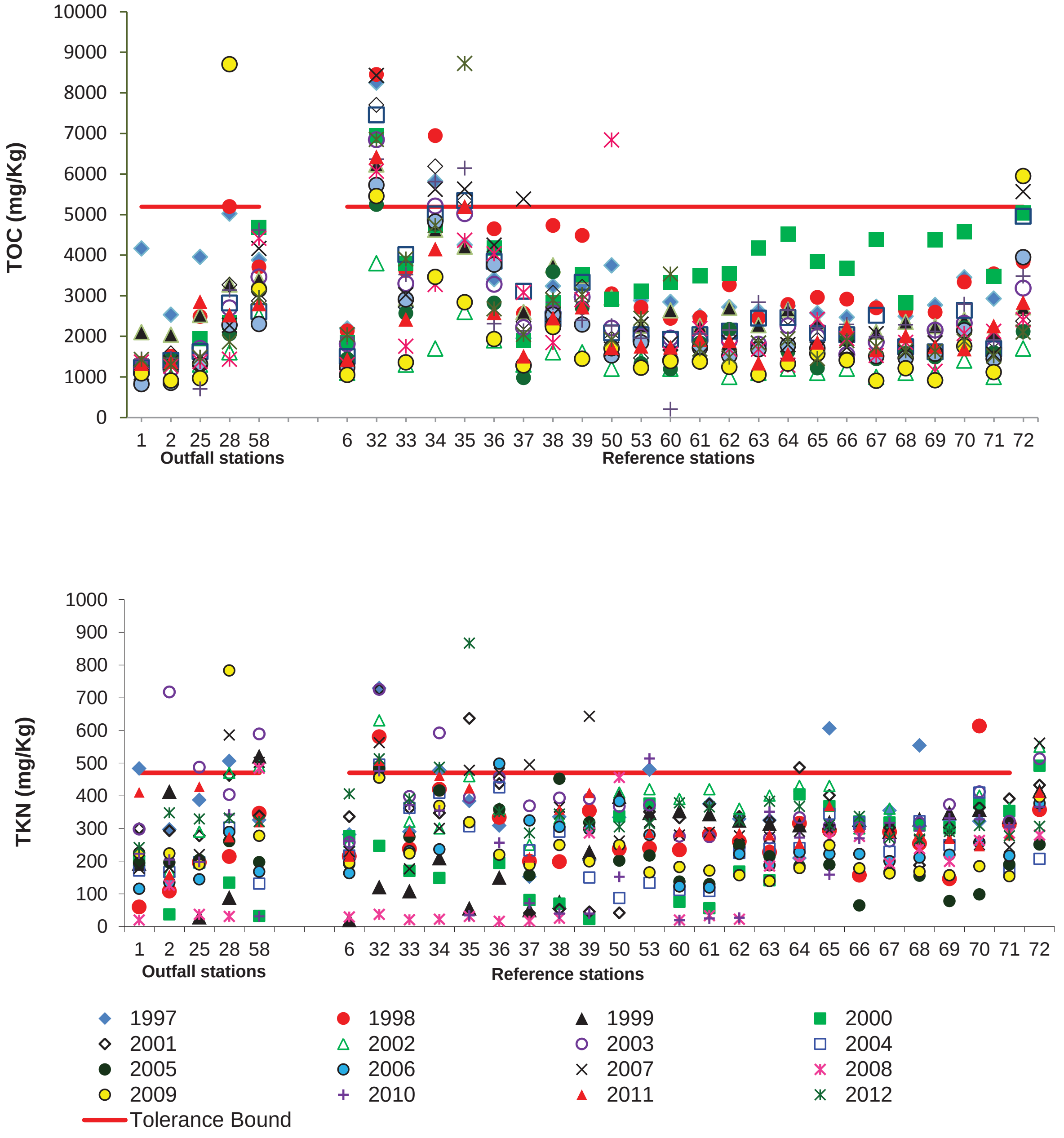


Figure 4-11b

Sediment indicators used in the reference envelope analysis and plotted with upper tolerance interval bound P = .90 and α = .05. Only the upper interval bound is plotted since concern for these indicators would be an increase in the presence of a wastewater discharge. Tolerance interval bounds calculated from 384 reference samples.

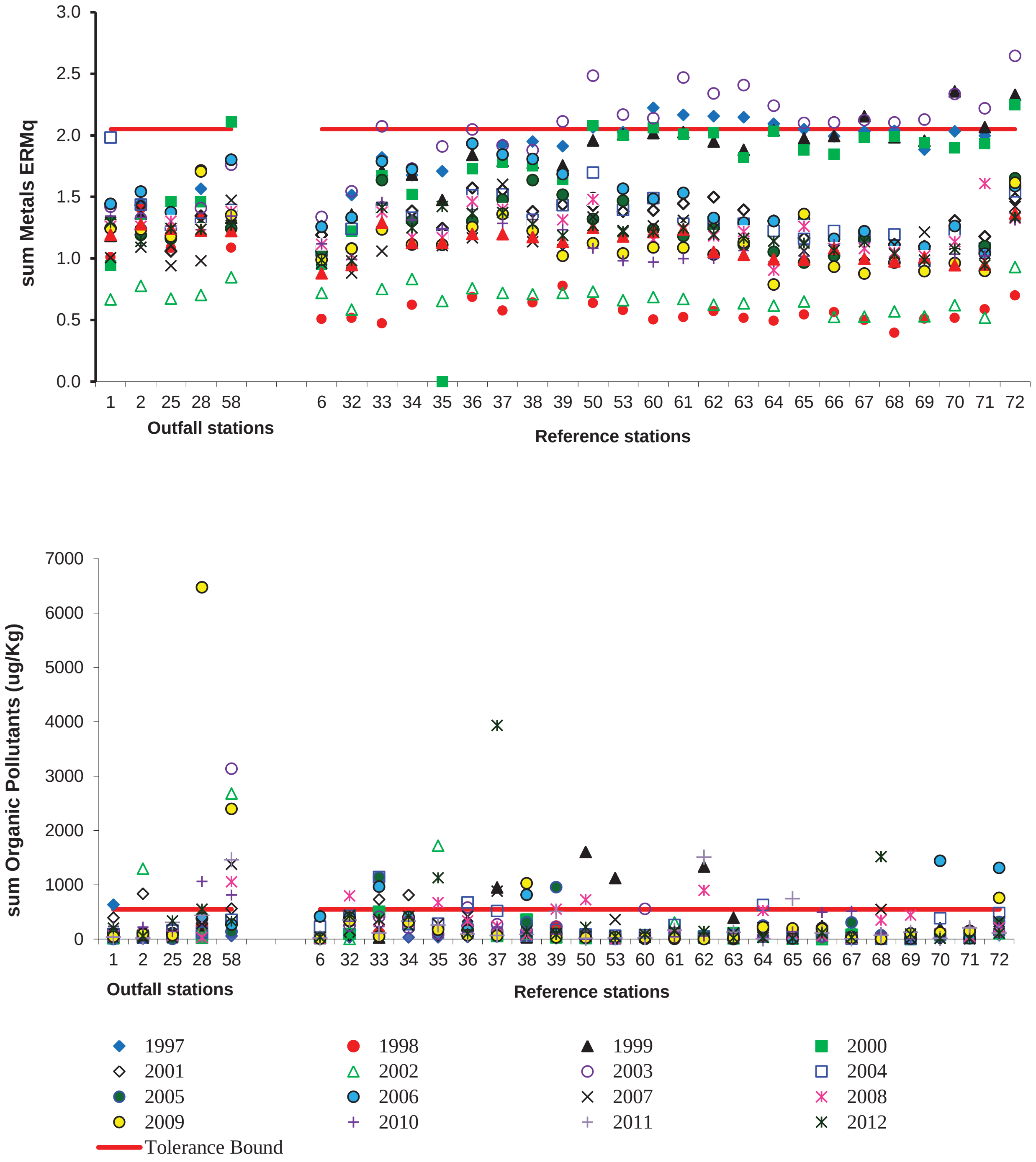


Figure 4-11c

Sediment indicators used in the reference envelope analysis and plotted with an upper tolerance interval bound P = .90 and α = .05. Only the upper interval bound is plotted since concern for these indicators would be an increase in the presence of a wastewater discharge. Tolerance interval bounds calculated from 384 reference samples.

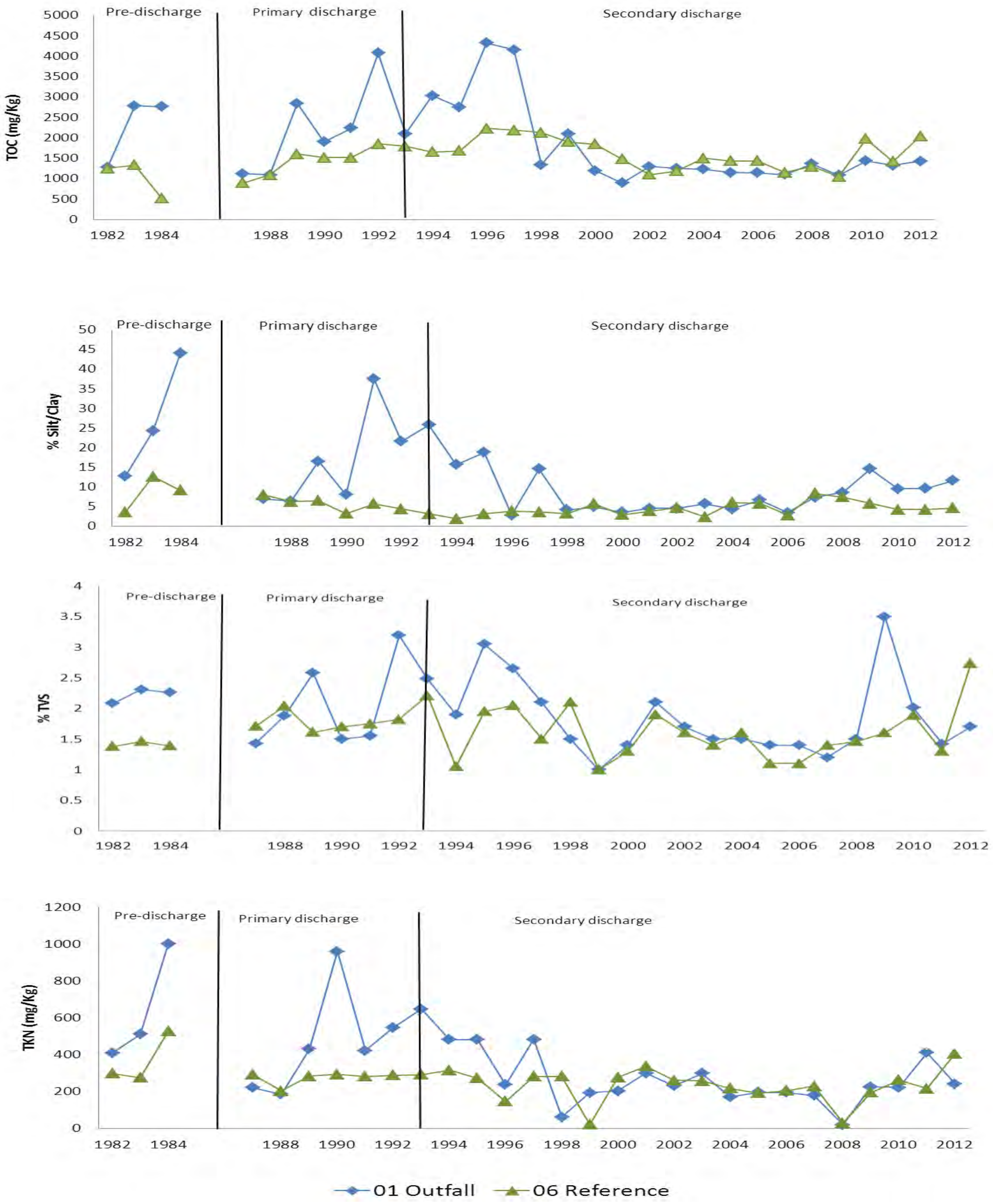


Figure 4-12
Plots of sediment fines and organic content, 1982 to 2012

4.3. SUMMARY AND CONCLUSIONS

The study area is a high-energy environment comprising primarily sandy beaches and bluffs to the south of the Golden Gate, and rocky cliffs and pocket beaches to the north. The geology is controlled by active tectonics within the San Andreas and San Gregorio Fault Zones traversing directly through the region. This area is susceptible to high energy waves, being exposed to swell from almost the entire Pacific Ocean (Barnard et al., 2013*)*.

The sedimentary environment of the SWOO study area is dominated by input from the Sacramento and San Joaquin River system through the Golden Gate, and by reworking from tidal currents and wave action. Sediment-laden currents funnel through the Golden Gate on ebb tides and fan out depositing sediments along the transport path (Carlson and McCulloch 1974, Conomos 1979). Tidal and longshore currents rework these sediments to form the barrier sandbars that surround the mouth of San Francisco Bay. The stations inside these sandbars are characterized by medium to coarse sands. Those stations that are offshore from the sandbars, and which are more or less in line with the Golden Gate Bridge and the shipping channel, had a greater percentage of medium sands than other stations at similar depths. The sandbars themselves are bathymetric highs made of fine to medium sands. Recently, an area of massive sand waves was mapped between the sand bars and the Golden Gate (Barnard, et.al, 2006). Beyond the sand bars are areas of very fine sands with the highest average percentages of silt and clay (up to 47%) just outside the sandbars, decreasing to less than 10% well beyond the sandbars.

Mean sediment particle sizes at the outfall area have not significantly changed since pre-discharge and pre-construction periods, suggesting that the SWOO outfall and effluent discharge has not affected sediment grain size distribution. Well-sorted sediments were found at stations on or near the sandbars (stations 31, 40, 41, 42, 44, 46, 43, 47, 51, 52, 54, and 57), likely as the result of reworking by waves and tidal currents. The northern reference region (stations 32, 33, 34, 35, 36, 38, and 39) had some of the most poorly sorted sediments and relatively high percentages of silt/clay in the study area.

Smaller sediment grains provide greater relative surface area for adsorption of contaminants and organic matter, therefore areas outside the barrier sandbars with finer sediments may be expected to have higher contaminant concentrations. Such a pattern of grain size distribution, measures of TOC, TVS, TKN, and metals concentrations, has been consistent throughout this study period. Consequently, the location of the SWOO (just south of a sandbar) places it in an environment where elevated measures of sediment fine grains, organic matter, and contaminants might be expected even in the absence of a wastewater discharge. It is important therefore to evaluate potential discharge impacts by comparing similar environments. The sandbar stations, and the coarse sand stations inside the sandbars, are in such a different sedimentary environment/hydrodynamic regime from stations near the outfall that the sediment characteristics from these coarse grain stations are not relevant to interpreting an outfall effect. Reference envelope analysis, using tolerance bounds defined by multiple reference station locations, of sediment measurements from outfall stations indicates that some stations exceeded tolerance bounds in four different categories with approximately the same or lower frequency as stations in the reference region. An exception is outfall stations 58 and 28 with elevated organic pollutants in multiple years.

The number of stations analyzed for organic priority pollutants was increased every year since 1997 until all stations were included by 2001. Concentrations of 18 PAHs were measured throughout the study area and have not paralleled percent silt and clay patterns. High concentrations near the outfall in some sampling years appear to be transitory. Variations in sediment organic contaminant concentrations between survey years may be a result of sediment movement over time via currents and winter storms. All stations have been sampled for trace metal analyses from 1997 to 2012. Overall, the concentrations of metals at reference stations are the same as the concentrations at outfall stations. There is no discernible outfall effect in the sediment metals data.

After sixteen years of monitoring the SWOO study area, sediment data have revealed no trends in sediment characteristics that would indicate that the discharge from the Oceanside Water Pollution Control Plant has adversely affected the surrounding environment. Increasing sediment fines in the northern reference area and around the SWOO outfall have been attributed to a consolidation of the ebb-tidal delta of the San Francisco Estuary, related to a recent step-decrease in suspended sediment concentrations observed inside San Francisco Bay (Barnard et. al., 2012). Continued analyses of wastewater effluent samples have not exceeded established water quality standards for the parameters measured. Physical measurements of sediment grain size and chemical organic and inorganic data further demonstrate that the discharge has not produced any discernable effects on the physical characteristics of sediment or resulted in contaminant accumulation in the vicinity of the outfall.

SECTION 5

BENTHIC INFUANA

BENTHIC INFAUNA

5.1. INTRODUCTION

Benthic infauna communities were monitored to evaluate effects associated with the discharge of treated wastewater effluent from the Southwest Ocean Outfall (SWOO) into nearshore waters of the Gulf of the Farallones (Figure 5-1).

Wastewater discharges characteristically change the properties of bottom sediments next to outfalls, which in turn affect the natural biological communities (*e.g.* LACSD 1981). Relationships between benthic infauna communities and sediment (Section 4.2.1) have helped in determination of the role sediments play in governing community characteristics.

Some of the analyses used only stations that were sampled every year to make the comparisons valid. These include the annual comparisons of the 20 most abundant taxa and the annual total abundance surveys. Analyses employing the entire database include the geographic distributions of community parameters, ordination, cluster and reference envelope analyses. See cluster diagram (Cluster Analysis Section 5.2.3.2) for the stations sampled each year throughout the survey period.

5.1.1. STATION GROUPS

Some figures and discussion refer to reference, outfall, Golden Gate, ancillary and reef effect groups of stations (Figure 5-1). These groupings allow comparison of similar stations and are based on geographic location, common sedimentary characteristics, and infauna community measures (Methods, Section 2.2.4). Stations in the reference (green) and outfall (blue) groups are generally characterized by well-sorted very fine sand with a variable percentage of silt and clay, and similar infauna communities. The outfall group includes those stations in closest proximity to the SWOO discharge. Stations within the Golden Gate group (orange) are generally shallower and have coarser sediments that support different infauna communities than the reference or outfall groups. Stations that compose the ancillary station group (black) are outside of the direct influence of the discharge plume but too close to be considered a suitable reference station. Reef effect stations (purple) were added to assess the potential effect of the outfall structure on the benthic communities. Station 80, which is included in the reef effect stations in this study, was added in 2004 to assess the effect of the North San Mateo County Sanitation District outfall on nearshore benthic abundance values.

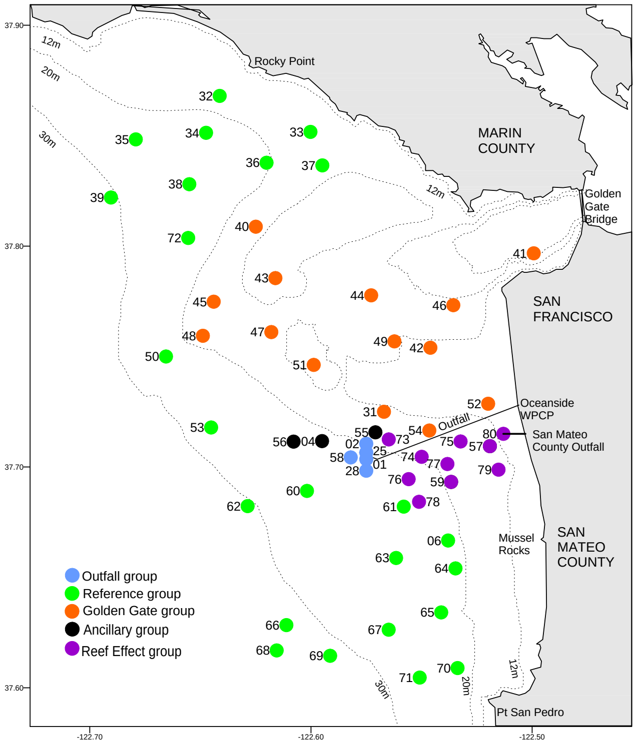


Figure 5-1

Stations sampled for infauna and station groups used in comparison analyses. Outfall stations (blue) were used to define outfall conditions that were compared to reference conditions (green). Golden Gate stations (orange) characterize conditions near the Bay outflow and reef effect stations (purple were examined to determine if there is an effect from the outfall structure. Ancillary station (black) are outside the influence of the effluent discharge.

5.2. RESULTS AND DISCUSSION

5.2.1. GENERAL CHARACTERIZATION

5.2.1.1. Survey year 2010

The processing of benthic infauna samples from stations 78 and 79 sampled in 2010 were not completed in time for inclusion in the annual data report. The infauna data for these stations are reported in Appendix E-4 and are included in the analyses of this report.

5.2.1.2 Survey year 2012

Appendix E-2 lists the raw data for 2012 and Table 5-1 displays a summary of the 20 most abundant species in the 2012 survey. A total of 149,951 specimens were collected and the polychaete worm, *Spiophanes norrisi* (formally reported as *Spiophanes bombyx*), was the most abundant taxa as it was in the previous 3 years of the survey. The mollusk, *Callianax pycna* (formally reported as *Olivella pycna*) was unique in being present in all of the samples collected in 2012.

Table 5-1

The twenty most abundant species in 2012. Abundance was dominated by polychaetes, especially Spiophanes norrisi.

Species	Taxonomic Group*	Total Abundance	Percent Total Abundance	Occurrence at 47 Stations	Percent Occurrence
Spiophanes norrisi	P	89,095	59.42	45	95.74
Photis sp.	C	10,189	6.79	44	93.62
Callianax pycna	M	6,267	4.18	47	100.00
Photis macinerneyi	C	4,776	3.19	39	82.98
Protomedeia penates	C	4,476	2.98	41	87.23
Scoletoma luti	P	3,618	2.41	45	95.74
Mediomastus spp.	P	2,393	1.60	41	87.23
Diastylopsis dawsoni	C	1,630	1.09	46	97.87
Glycinde picta	P	1,629	1.09	39	82.98
Owenia collaris	P	1,604	1.07	28	59.57
Tellina modesta	M	1,577	1.05	46	97.87
Glycinde spp.	P	1,528	1.02	42	89.36
Rhepoxynius fatigans	C	1,365	0.91	33	70.21
Ischyrocerus pelagops	C	1,351	0.90	30	63.83
Pectinaria californiensis	P	992	0.66	38	80.85
Onuphis sp. A	P	775	0.52	41	87.23
Pleurogonium sp. SF1	C	710	0.47	39	82.98
Apoprionospio pygmaea	P	619	0.41	37	78.72
Pacifoculodes barnardi	C	612	0.41	44	93.62
Magelona sacculata	P	553	0.37	36	76.60

*Taxonomic Groups: P=Polychaeta, M=Mollusca, C=Crustacea

5.2.1.3 Survey Years 1997-2012

For the study period a total of 879,666 individual organisms belonging to 628 taxa and representing 15 phyla were identified in 786 samples collected during the sixteen-year period from 1997 to 2012 (Table 5-2, Appendices E-1 and E-2, WQB 1998-2004, NRD 2006a, 2006b, NRLMD 2007-2011,).

The annelid class Polychaeta represented the greatest species richness and total abundance and contributed 41.9% of the taxa (263) and 64.1% of the total abundance (564,027 specimens) for the period (Table 5-2). Dominance of polychaete species in benthic assemblages has been documented in several studies (Reish 1983, Diener and Fuller 1995, Dorsey et al. 1995). In general, polychaete species compose over 40% of benthic infauna communities regardless of depth (Knox 1977). Mollusca were represented by 19.4% of the taxa (122) and contributed 20.1% of the total abundance (177,140 specimens). Crustacea, with 29.5% of the taxa (185), contributed 10.3% of the organisms for the period (90,468 specimens). Echinoderms

Table 5-2

Total abundance and relative contribution of major taxa from 1997 to 2012. Data includes all stations collected. Polychaetes dominate overall in species richness and abundance.

Taxon	Number of Taxa	Abundance
Polychaeta		
number	263	564,027
percentage	41.9%	64.1%
Mollusca		
number	122	177,140
percentage	19.4%	20.1%
Crustacea		
number	185	90,468
percentage	29.5%	10.3%
Echinodermata		
number	11	8,819
percentage	1.8%	1.0%
All Other Taxa		
number	47	39,212
percentage	7.5%	4.5%
TOTALS		
number	628	879,666
percentage	100.0%	100.0%

were the least abundant major group, with 1.8% of the taxa (11) and 1.0% of the organisms (8,819 specimens). All other groups combined contributed 7.5% of the taxa (47) and 4.5% of the total abundance (39,212 specimens).

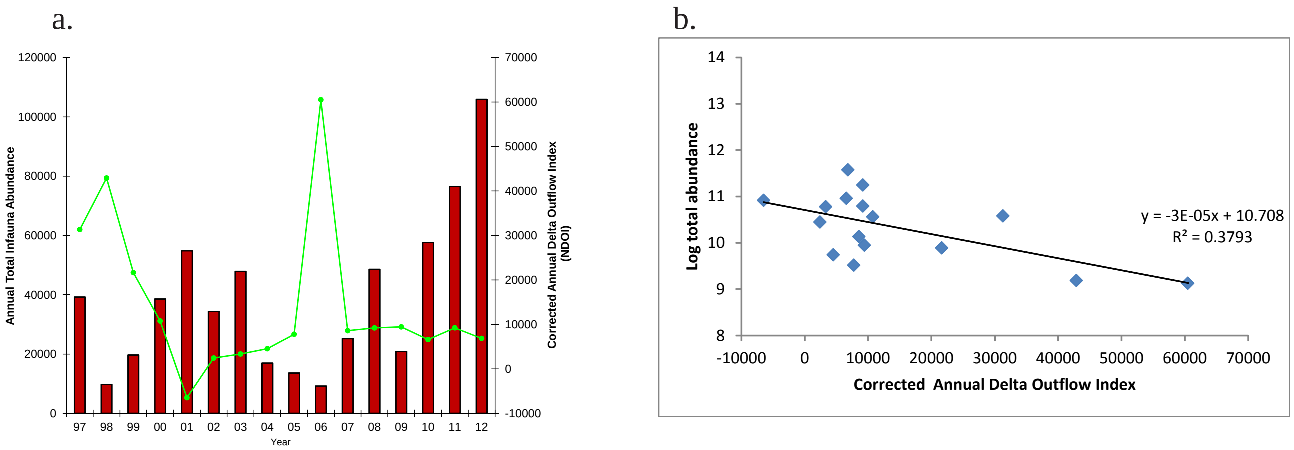
The twenty most abundant organisms in the sixteen-year period (Table 5-3) accounted for 74.6% of the total individuals at stations sampled every year. The polychaete *Spiophanes norrisi* was the most abundant species, composing 30.6% of the total number of individuals. During 2010, 2011, and 2012, this species accounted for over half of the total individuals collected. During 2007 and 2008, the most dominant taxa was a bivalve clam, *Mactromeris catilliformis*, which accounted for nearly half (47.5%) of the specimens collected in 2008. The polychaete worm taxon *Mediomastus* spp. was the third most abundant with a total percent abundance of 4.2%, and it dominated the benthic community in 2005. Another spionid polychaete, *Spiophanes berkeleyorum*, was fourth in abundance with over 11% of the specimens collected in 2000 and 2001. The bivalve, *Tellina modesta*, mostly due to high recruitment in 1997, was the fifth most abundant species. The taxa listed in Table 5-3 contributed a minium of 47% of the annual abundance for years suveyed, as well as 74.6% of the total abundance for the survey period. These organisms include 12 polychaetes, five mollusks, and three crustacea. *Spiophanes norrisi* is unusual in sustaining several years of relatively high abundance while other taxa have only one or two years of high abundance (e.g. *Tellina modesta* in 1997, *Apoprinospio pygmaea* in 1998, *Owenia collaris* in 2003, *Scoletoma luti* in 1998, *S. berkeleyorum* in 2000 and 2001, *Mactromeris catilliformis* in 2007 and 2008). The composition of this table has changed very little since the first summary report (WQB 2003a).

Table 5-3

Twenty most abundant taxa from 1997 to 2012 with cumulative, annual percent and percent total abundance for each taxon. Comparison includes only stations sampled every year. In 2010, 2011 and 2012 the polychaete worm, Spiophanes norrisi, *was dominant accounting for over half the specimens collected in those years.*

		Cumulative Abundance	Annual Percent Abundance																% Total Abundance
TAXON	Taxa*	1997-2012	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	1997-2012
Spiophanes norrisi	P	189,317	1.2	1.0	2.4	6.0	9.6	27.2	25.6	10.2	5.2	2.1	6.8	5.9	25.0	64.8	63.4	57.5	30.6
Mactromeris catilliformis	M	43,436	5.6	3.2	3.9	3.8	7.4	5.8	3.7	1.5	2.6	6.1	18.1	47.5	0.4	0.2	2.2	0.2	7.0
Mediomastus spp.	P	25,830	7.6	6.6	7.3	3.1	2.7	7.8	3.7	8.4	12.1	7.0	5.7	3.8	5.2	2.7	2.6	1.8	4.2
Spiophanes berkeleyorum	P	21,742	1.6	1.2	6.6	11.1	11.6	1.2	2.3	1.0	1.2	4.8	7.4	1.1	0.9	6.4	0.4	0.1	3.5
Tellina modesta	M	20,585	17.9	2.4	2.6	4.5	3.6	3.9	2.1	3.7	2.1	1.9	0.6	2.6	5.7	0.8	1.7	1.2	3.3
Scoletoma luti	P	20,321	8.9	12.7	3.1	0.9	2.0	1.8	1.9	6.1	4.9	7.2	2.9	2.3	6.4	2.4	3.0	2.7	3.3
Owenia collaris	P	15,425	0.3	0.2	0.2	0.7	3.1	5.3	18.2	5.0	1.9	0.0	0.0	0.1	0.2	0.0	0.1	1.3	2.5
Protomedeia penates	C	13,033	0.4	0.0	0.1	1.2	6.7	4.0	2.0	1.9	0.3	0.9	0.8	0.5	2.2	0.5	0.9	3.9	2.1
Pectinaria californiensis	P	12,683	3.6	1.3	2.8	4.3	8.2	1.1	1.1	0.7	0.5	0.8	4.4	1.2	0.1	0.4	0.6	0.8	2.1
Callianax pycna	M	12,679	0.1	0.8	0.1	1.5	2.1	1.1	2.9	0.3	0.4	0.3	0.0	0.5	4.2	1.9	4.7	2.9	2.0
Apoprionospio pygmaea	P	12,110	1.5	15.2	3.7	2.3	1.6	1.2	1.2	1.1	4.9	7.3	7.2	1.9	1.0	1.6	0.9	0.5	2.0
Onuphis sp. A	P	12,072	2.9	2.8	6.5	3.1	2.1	1.3	2.0	2.0	3.0	3.8	2.9	3.4	1.9	0.7	0.9	0.6	2.0
Photis spp.	C	11,670	0.1	0.1	0.3	0.5	1.3	0.8	1.1	0.4	0.5	0.1	0.4	0.7	1.5	0.9	1.0	7.3	1.9
Leukoma staminea	M	9,357	8.3	1.7	1.2	4.0	1.9	0.7	1.5	0.5	1.5	0.2	1.0	1.7	1.6	0.1	0.3	0.2	1.5
Kurtiella tumida	M	8,580	3.2	3.1	0.7	1.2	2.8	4.5	1.9	6.4	1.8	0.7	0.3	0.3	1.1	0.2	0.3	0.3	1.4
Magelona sacculata	P	8,041	0.6	2.8	1.6	2.6	0.7	0.5	1.1	0.9	3.8	4.1	3.7	0.5	1.3	2.2	1.2	0.4	1.3
Glycinde picta	P	7,210	0.3	0.1	0.1	0.5	1.7	1.7	0.9	1.6	0.7	0.3	0.7	2.6	1.5	0.9	1.7	0.9	1.2
Rhepoxynius fatigans	C	6,071	0.4	0.6	0.3	0.2	0.3	1.2	1.3	4.0	3.8	2.9	1.6	0.4	2.0	0.4	0.7	1.2	1.0
Maldanidae	P	5,851	4.7	1.4	3.1	1.1	0.5	1.3	2.2	1.8	1.8	1.8	0.6	0.1	0.3	0.0	0.0	0.0	0.9
Magelona hartmanae	P	5,625	0.5	1.9	1.2	3.9	0.7	0.4	0.6	0.5	1.2	1.2	1.1	0.3	2.1	1.1	0.6	0.3	0.9
Totals			69.6	59.2	47.6	56.5	70.7	72.6	77.3	57.8	54.3	53.6	66.3	77.6	64.8	88.3	87.1	84.2	74.6

* = *P = Polychaeta, M = Mollusca, C = Crustacea*



Figures 5-2a & b

Annual total abundance plotted with the corrected annual mean outflow. The relationship is significantly negative (F-ratio=8.5567, p<0.05, df=1,16). Data includes only stations sampled every year.

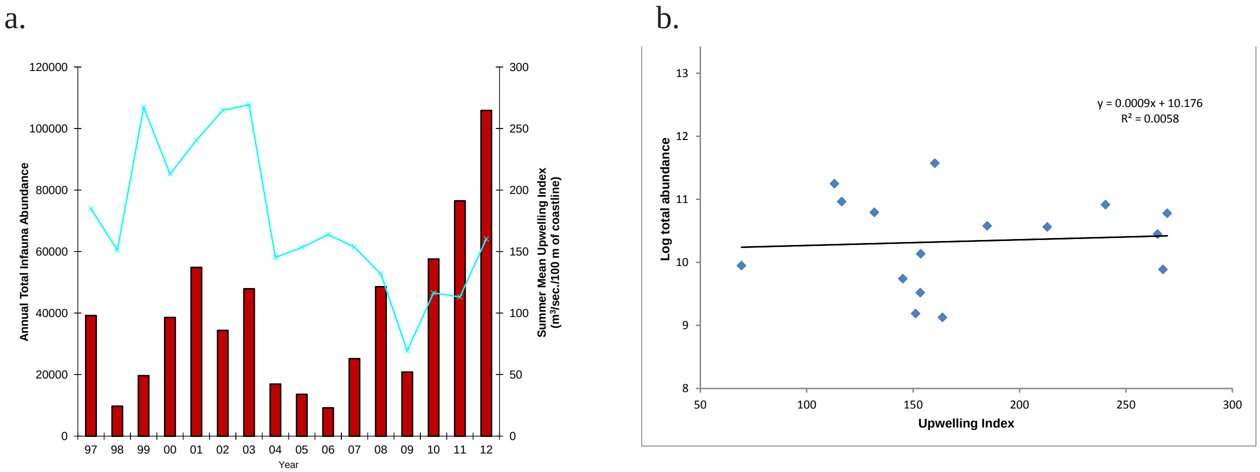


Figure 5-3a & b

Annual total abundance plotted with the mean summer upwelling index (NOAA 2014) is not significant (F-ratio=0.0816, p=0.7793, df=1,16). Data includes only stations sampled every year.

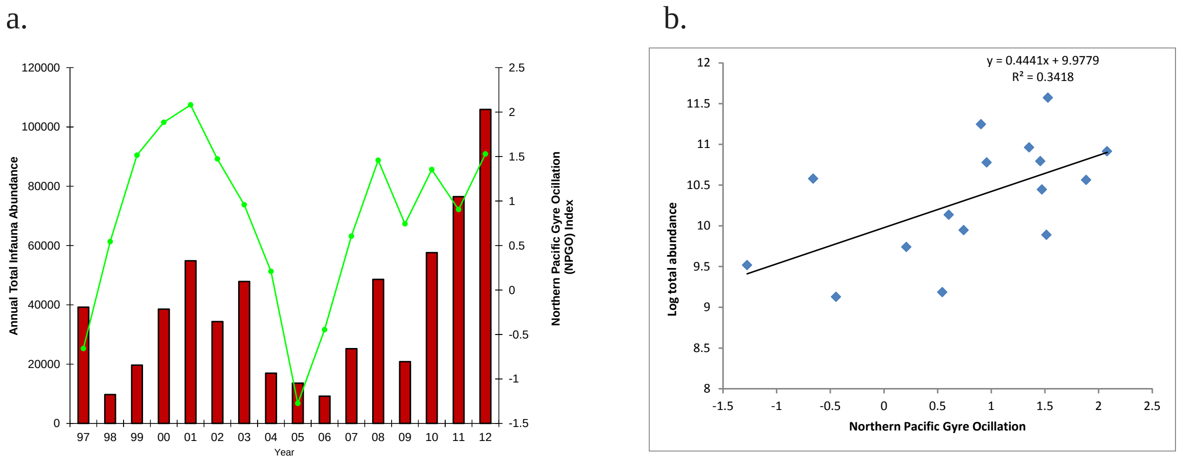


Figure 5-4a & b

Annual total abundance plotted with the North Pacific Gyre Ocillation is significant (F-ratio=7.268, p<0.05, df=1,16). Data includes only stations sampled every year.

5.2.2. COMMUNITY PARAMETERS

Community measures of abundance, species richness (number of species), Shannon-Weiner diversity (H’), and Pielou’s evenness (J’) were calculated and are shown in Figures 5-2 to 5-10. The values calculated for each station for the sixteen-year period are in Appendix E-3.

5.2.2.1. Abundance

Annual infauna abundance measured at stations collected every year varied substantially and ranged from a low of 9,187 organisms in 2006 to a high of 105,883 organisms in 2012 (Figures 5-2a, 5-3a, 5-4a). During the last 3 years of the survey period infauna abundance offshore has increased greatly mostly due to the increase in abundance of the polychaete, *Spiophanes norrisi*. Over the study period, there has been an inverse correlation between the Corrected Delta Outflow Index (http://www.water.ca.gov/dayflow/output/Output.cfm) and infauna abundance (Figure 5-2a). Figure 5-2b shows this relationship is significant (Linear regression F-ratio=8.5567, p=0.011, df=1,16), however statistical tests show that the relationship is not linear. The positive relationship between total abundance and the appearance and strength of the summer upwelling index documented in the previous summary report (NRLMD 2010a) did not persist with additional data (Figures 5-3a & b). The graphs also indicate that the infauna abundance is positively correlated with the Northern Pacific Gyre Ocillation Index (Figure 5-4a and b).

Abundance at individual stations varied annually and ranged from a low of 23 individuals at Station 41 in 1999 to a high of 13,007 individuals at Station 73 in 2012 (Figure 5-5). Overall, abundance was lower at stations in the Golden Gate group than at other stations in the study area. The greatest overall abundance was observed in 2012 at the southern reference stations (6, 60, 61, 62, 67, and 69), reef-effect stations (59, 73, 75, 77, 78), ancillary stations (4, 56) and outfall stations (01, 02, and 25).

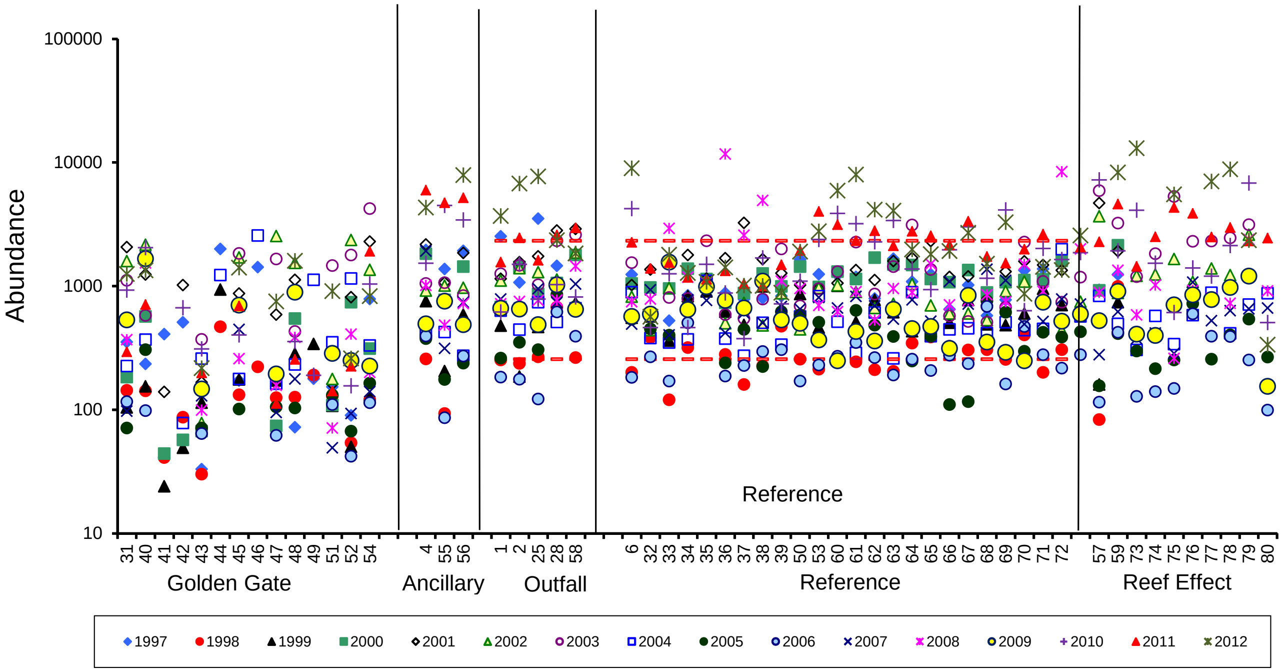


Figure 5-4

Infaunal total abundance values plotted against a logrithmic axis by station groups. Year 2012 generally had the greatest abundance values per station, especially in the southern reference, reef effect, ancillary and outfall stations. Dashed red lines indicate the upper and lower tolerance interval bounds of the reference envelope analysisand are derived from 380 reference samples.

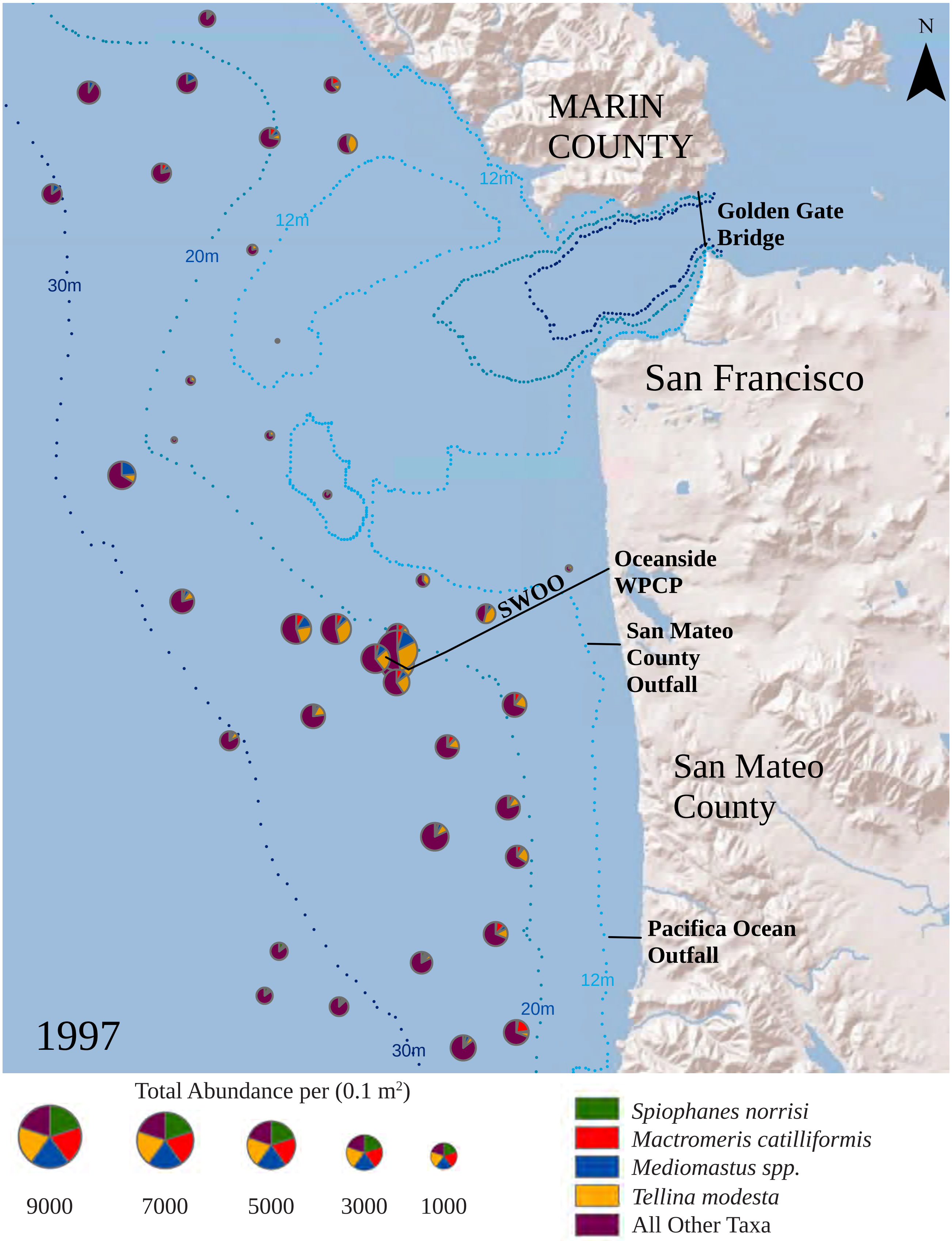


Figure 5-6a

Percent composition and total abundance for the four most abundant species from 1997.

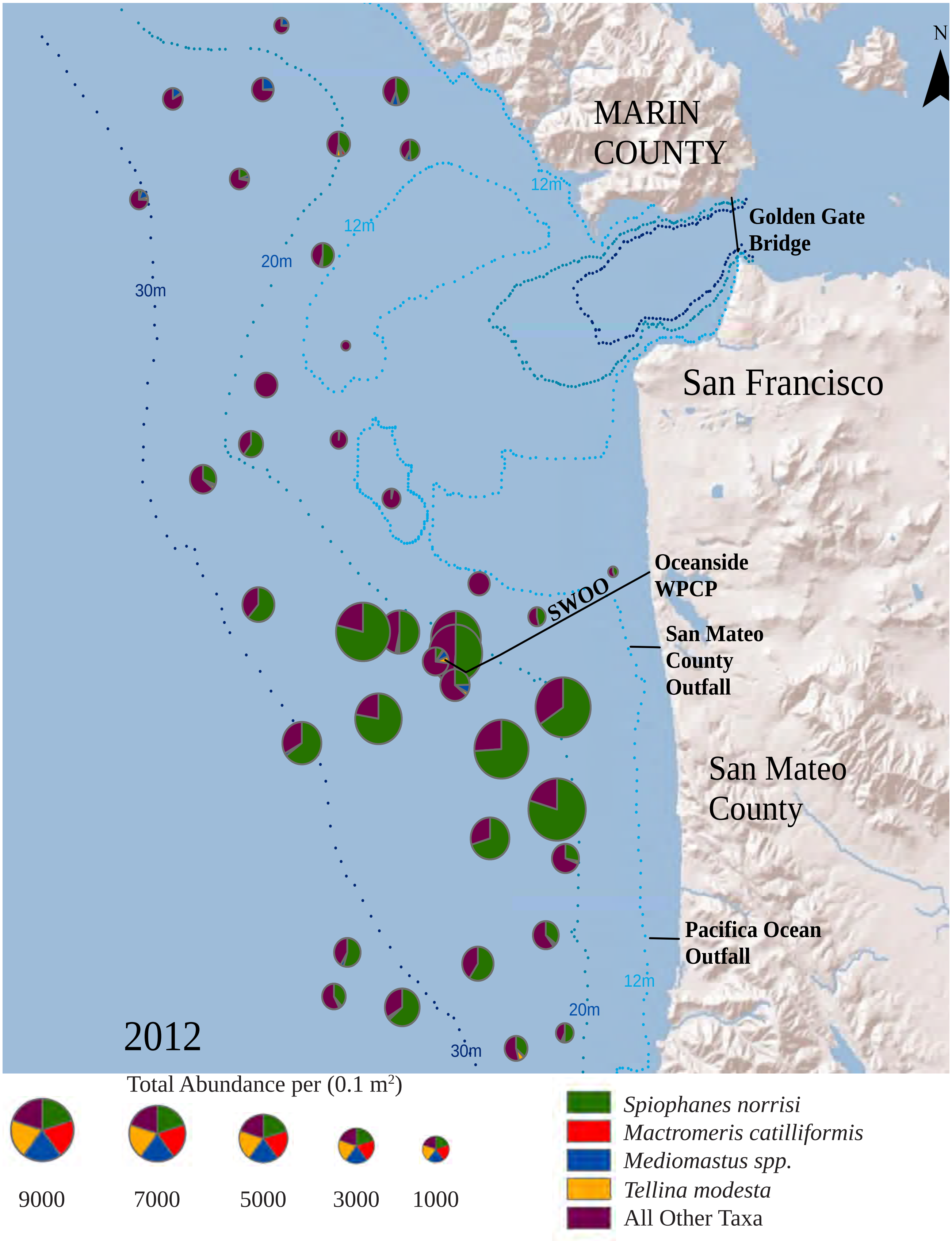


Figure 5-6b.

Percent composition and total abundance for the four most abundant species from 2012 (Does not include reef-effect stations).

This increase shows a trend of increased infaunal abundances and are largely due to the increase in the population of *Spiophanes norrisi*. This species was also responsible for the high abundances values at all of the station groups for 2010, 2011 and 2012. All of the station abundance values above 5,000 occurred during the 2003, 2008, 2010, 2011 and 2012 sampling years. In stations south of the outfall (particularly stations 59, 64 and 79), the polychaete, *Owenia collaris* was the most abundant species during 2003, with the exception of station 57, which had sustained high abundances of *Spiophanes norrisi*. In 2008, recruitment of the bivalve, *Mactromeris catilliformis* is responsible for the spikes in abundance at northern references stations 36 and 38. Until 2009 no station was dominated by a single species for more than one year. Abundance distributions for 1997 and 2012 are shown geographically in Figure 5-6a and 5-6b respectively. These maps show the major changes in the abundance and dominant species.

5.2.2.2. Diversity, Evenness, and Species Richness

The Shannon-Weiner diversity index primarily reflects both species richness and the evenness of the distribution of individuals among those species. Shannon-Weiner index values ranged from a low of 0.54 at ancillary station 55 in 2010 to a high of 3.91 at reference station 39 in 2000 (Figure 5-7). Similar to abundance values, species diversity was generally lower at Golden Gate stations in all years compared to other stations; however, low diversity values were apparent in all offshore stations (reference, outfall, reef effect and ancillary) during 2009, 2010, 2011 and 2012. The general pattern of diversity is shown in Figure 5-8. Stations with

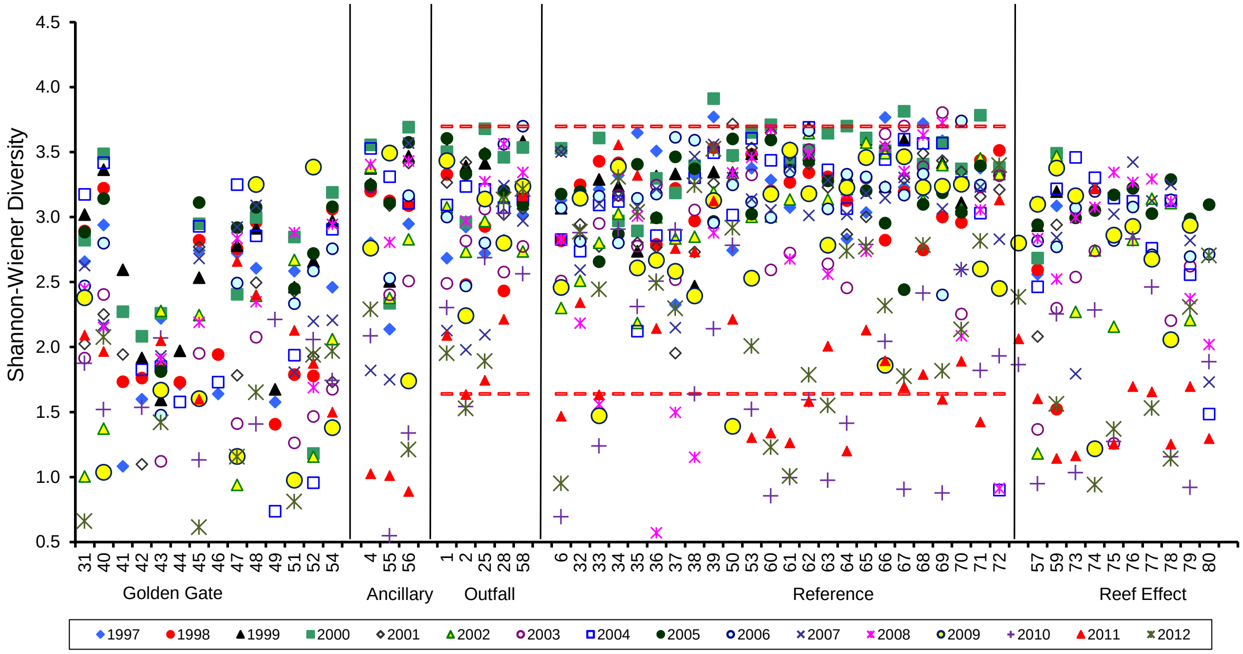


Figure 5-7

Shannon-Weiner diversity index by station group for the trend period. During the first 16 years of the survey, diversity indicies were lowest overall at the Golden Gate stations, however during 2009 through 2012 low values were seen at all stations. The offshore (ancillary, outfall, reference and reef effect) station's low values are caused by spikes in abundance of the polychaete, Spiophanes norrisi. *Dashed red lines indicate the upper and lower tolerance interval bounds of the reference envelope analysis and are derived from 380 reference samples.*

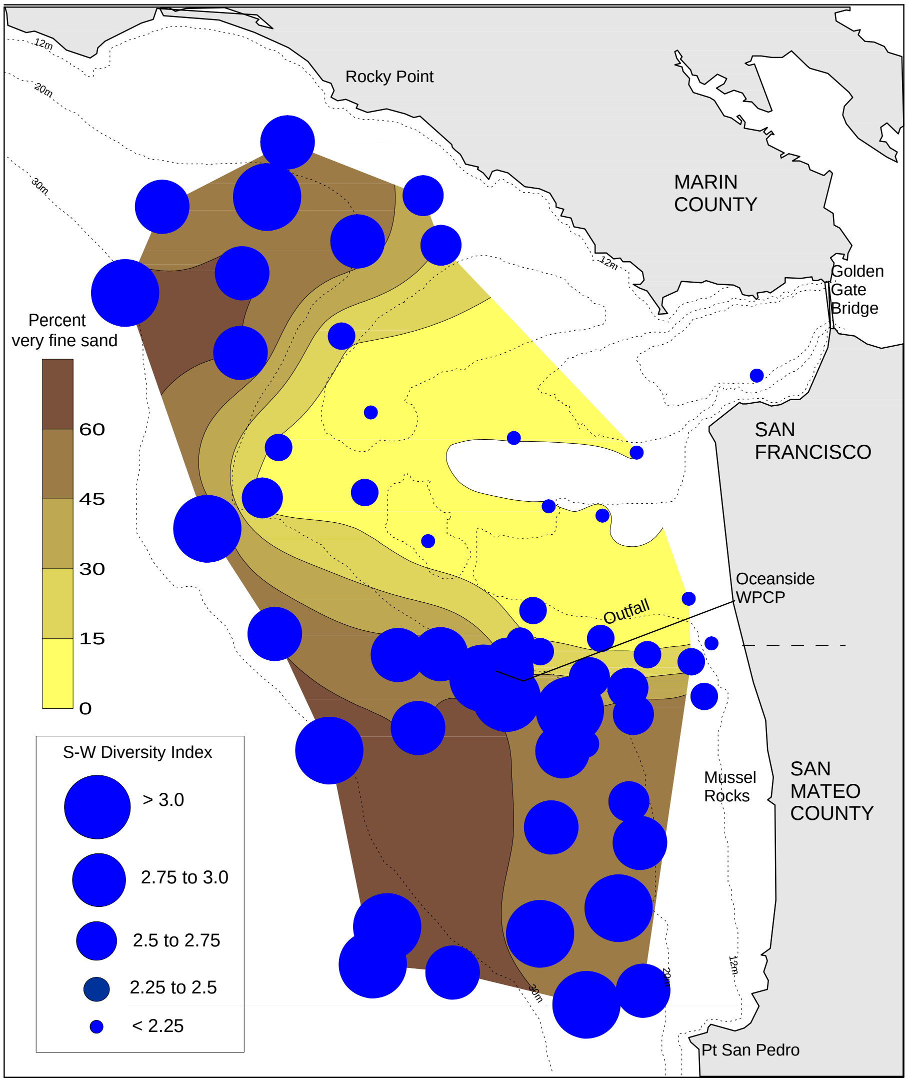


Figure 5-8
Geographic distribution of the average Shannon-Weiner Diversity index values over the trend period. Diversity distribution was not affected by relative annual abundance. Greatest diversity values were associated with very fine sands.

very fine sands usually have higher diversity values.

Pielou's evenness is a measure of the degree of equality in the distribution of individuals among species. As evenness approaches 1.0, the distribution of individuals among species is more equal. Evenness values ranged from a low of 0.12 at reference station 36 in 2008 (due to recruitment spike of *Mactromeris catilliformis*), to a high 0.94 at Golden Gate station 41 in 1999(Figure 5-9). Low evenness values observed at stations 01, 02, 04, 25, 37, 55, and 73 were due to the dominance of a few species: *Mactromeris catilliformis* and *Apoprionospio pymaea* which accounted for over half of the species observed at those stations in 2007. Station 80 also had low evenness values in 2007, however it was dominated by *Spiophanes norrisi*. These 3 species were the overall dominant taxa for 2007 as shown in Table 5-3. In general, low evenness values were observed at most stations in 2009, 2010, 2011 and 2012. Low diversity and poor evenness values are due primarily to the extraordinary numeric dominance of *Spiophanes norrisi* in 2010, 2011 and 2012.

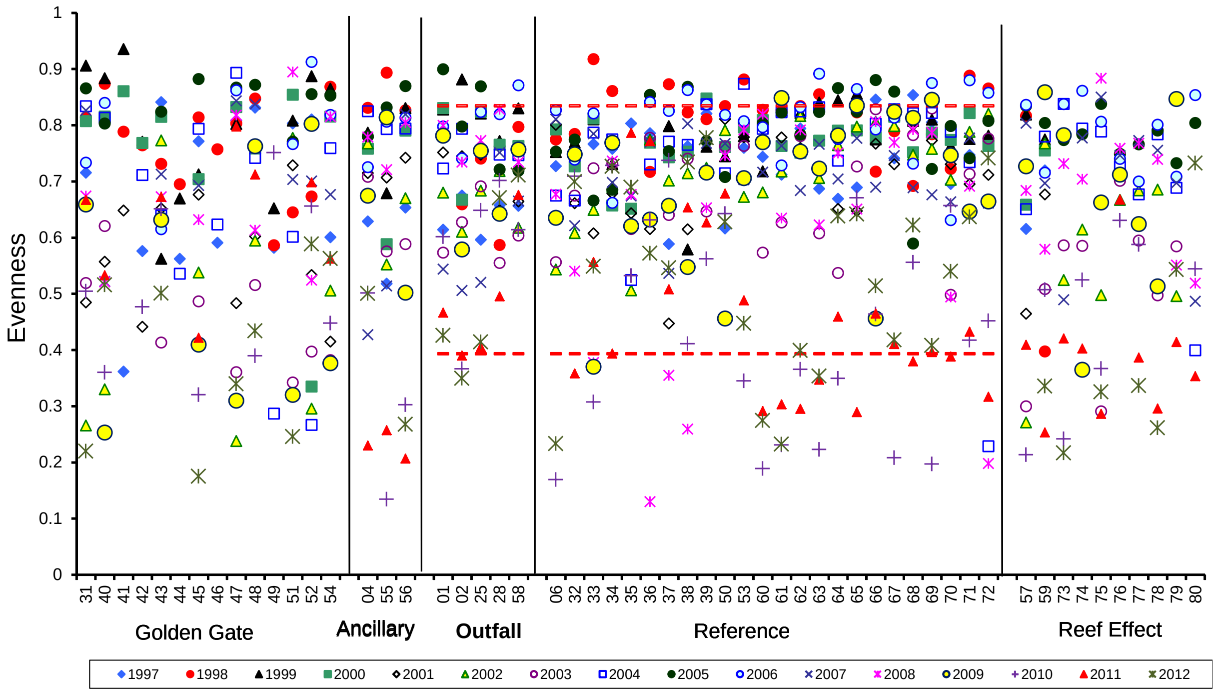


Figure 5-9

Pielou's evenness values by station group. The pattern is similar to the S-W diversity plot. Dashed red lines indicate the upper and lower tolerance interval bounds of the reference envelope analysis and are derived from 380 reference samples.

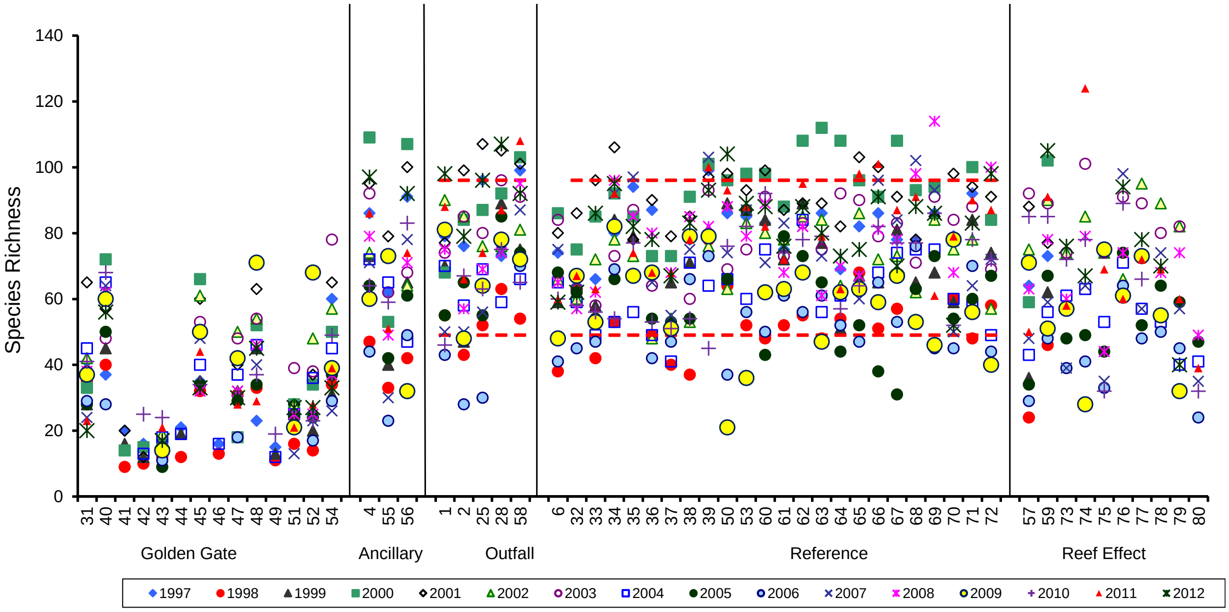


Figure 5-10

Species richness (total number of taxa per station) values for the trend period. In general, Golden Gate stations had lower species richness values. Dashed red lines indicate the upper and lower tolerance interval bounds of the reference envelope analysis and are derived from 380 reference samples.

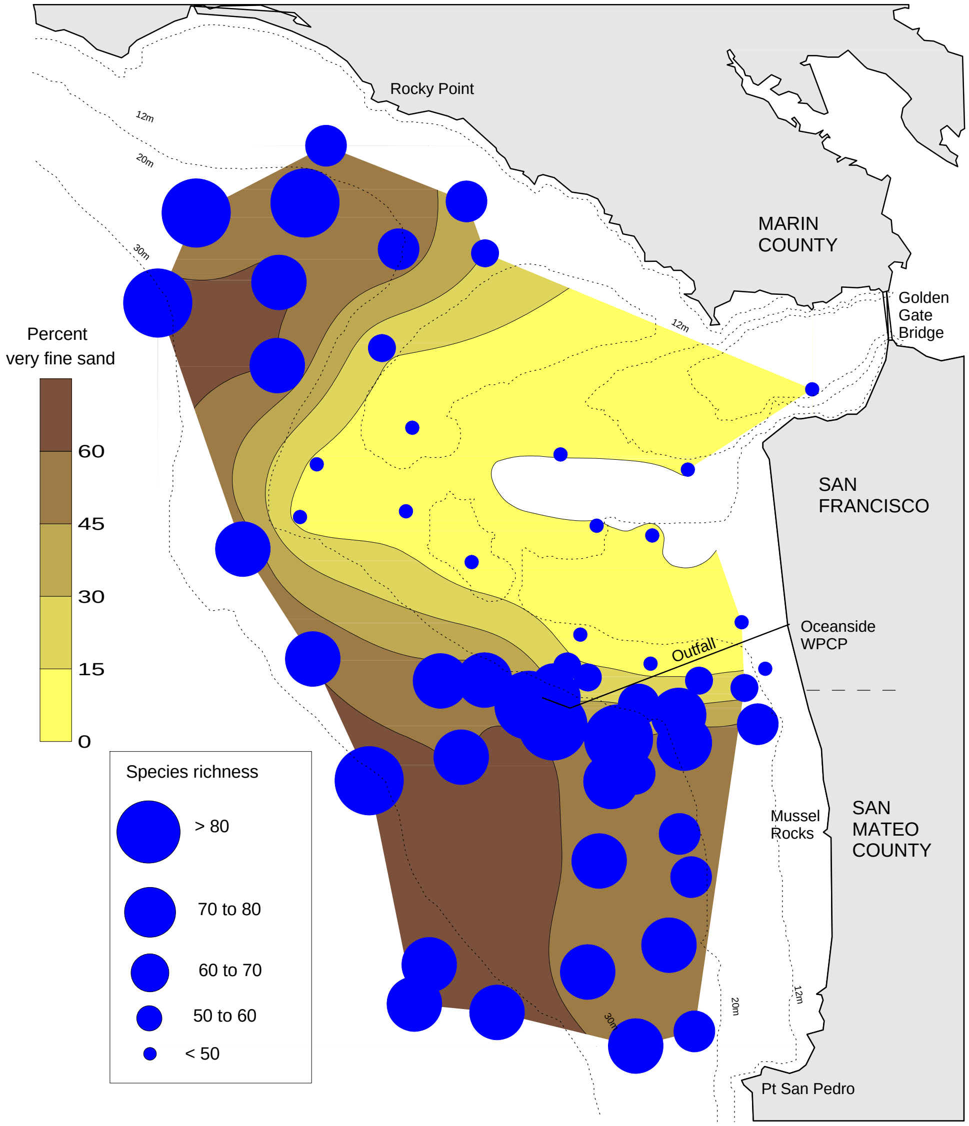


Figure 5-11

Geographic distribution of the average Species richness values over the trend period. The distribution was not affected by annual richness values with the greatest species richness values associated with very fine sands.

Species richness was variable between years and ranged from a low of 9 at Golden Gate station 41 in 1998, to a high of 124 at reef effect station 74 in 2011. As shown in Figure 5-10, the years with the overall lowest species richness are 1998 and 2006 corresponding to the years with the lowest overall abundance values. Generally, species richness values were lower at Golden Gate stations in all years. This general pattern for species richness has remained consistent each year with the fewest species collected at the Golden Gate stations, and the number of species increasing with increasing percentages of very fine sand. Species richness follows a similar geographic pattern as diversity (Figure 5-8).

5.2.3. COMMUNITY PATTERNS

5.2.3.1. Ordination Analysis

Ordination analysis can be used to assess differences in benthic invertebrate assemblage structure between outfall and reference conditions (Bernstein and Smith 1986). By examining assemblage structure at reference

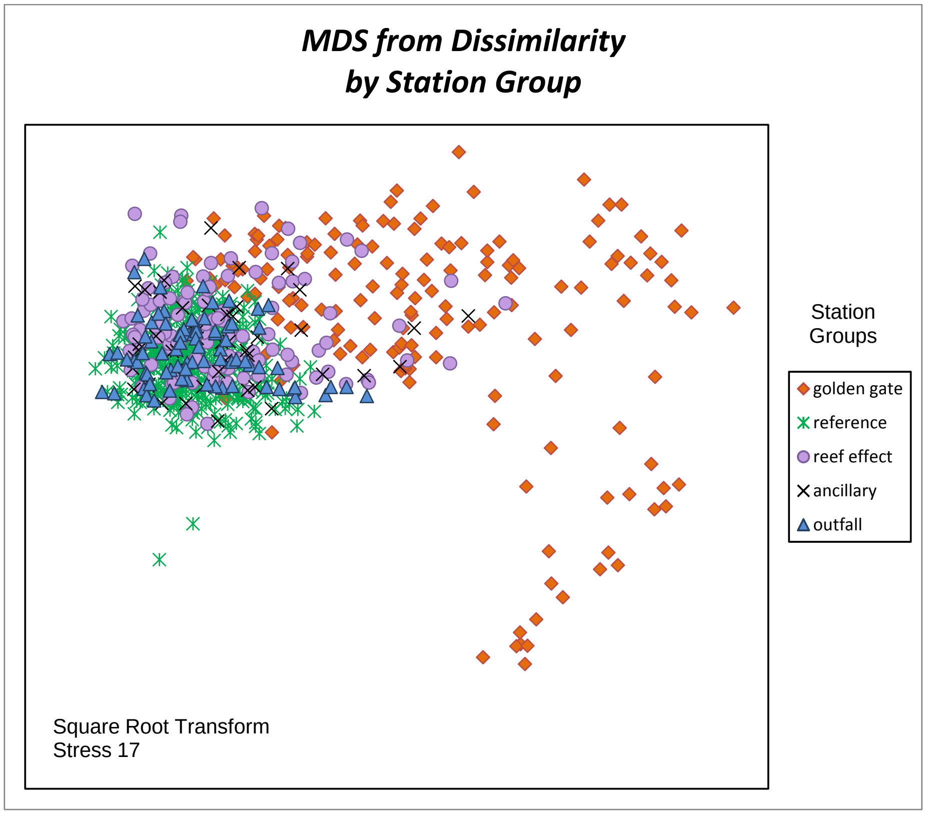


Figure 5-12
Two dimensional NMDS (non-metric multidimensional scaling) plot of the benthic infauna community. The plot shows the distribution of each station type. The plot shows that outfall stations (blue triangles) are distributed among reference (green squares) and reef effect stations (purple circles).

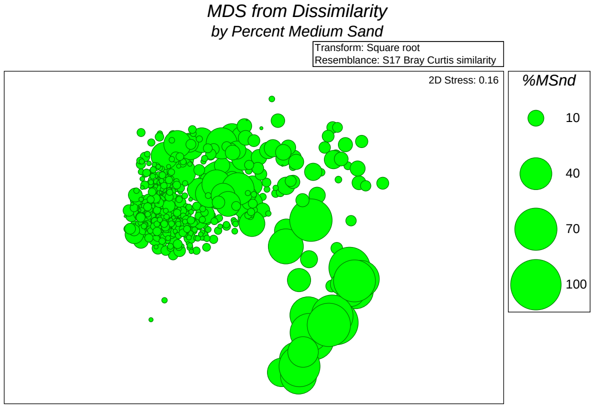


Figure 5-13
Sediment medium sand grain size data superimposed on the benthic infauna community two-dimensional NMDS plot (Figure 5-12). The medium sand distribution primarily cooresponds to the Golden Gate stations and is opposite of the very fine sand grain size plot (Figure 5-14).

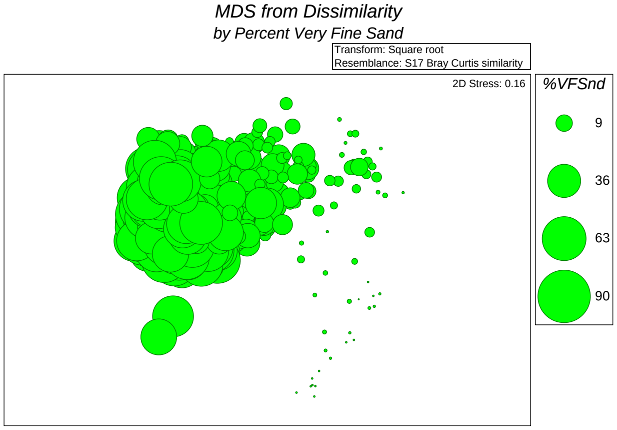


Figure 5-14
Sediment very fine sand grain size data superimposed on the benthic infauna community two-dimensional NMDS plot (Figure 5-12). The very fine sand distribution includes both reference and outfall stations and is opposite of the medium sized sand grainsize plot (Figure 5-13).

stations compared to those at outfall stations through time, a determination can be made on the departure or convergence of outfall and reference conditions (Bray and Curtis, 1957).

The ordination technique (Methods, 2.4.2. Multivariate Analyses, and Appendix B) employed non-metric multi-dimensional scaling (NMDS), which defines gradients of community similarity by utilizing a matrix of values derived from the Bray-Curtis index of dissimilarity (see Appendix B.2.1.1.). The resulting 2-dimensional plot is shown inFigure 5-12.

When the sediment grain size data are overlayed onto the biotic NMDS bubble plots, they show that the distribution of the two parameters (medium sand and very fine sand) have opposite patterns (Figure 5-13 and Figure 5-14). The horizontal axis of the NMDS plot has a very strong relationship with the very fine sand sediment component while the vertical axis has a relationship with the medium sand content.

The NMDS plot did not correspond well with any of the other abiotic parameters including sediment total PAHs, organics or metals.

5.2.3.2. Cluster Analysis

Cluster analysis (Appendix B.2.1.3) produced a hierarchical dendrogram of sample relationships that, like the ordination analysis, was based upon Bray-Curtis similarity index scores. The distance between samples on the dendrogram reflects the degree of dissimilarity in species composition and abundance. Based upon examination of the dendrogram cluster groups were chosen such that samples within a cluster group were more similar to each other than they were to samples in other cluster groups.

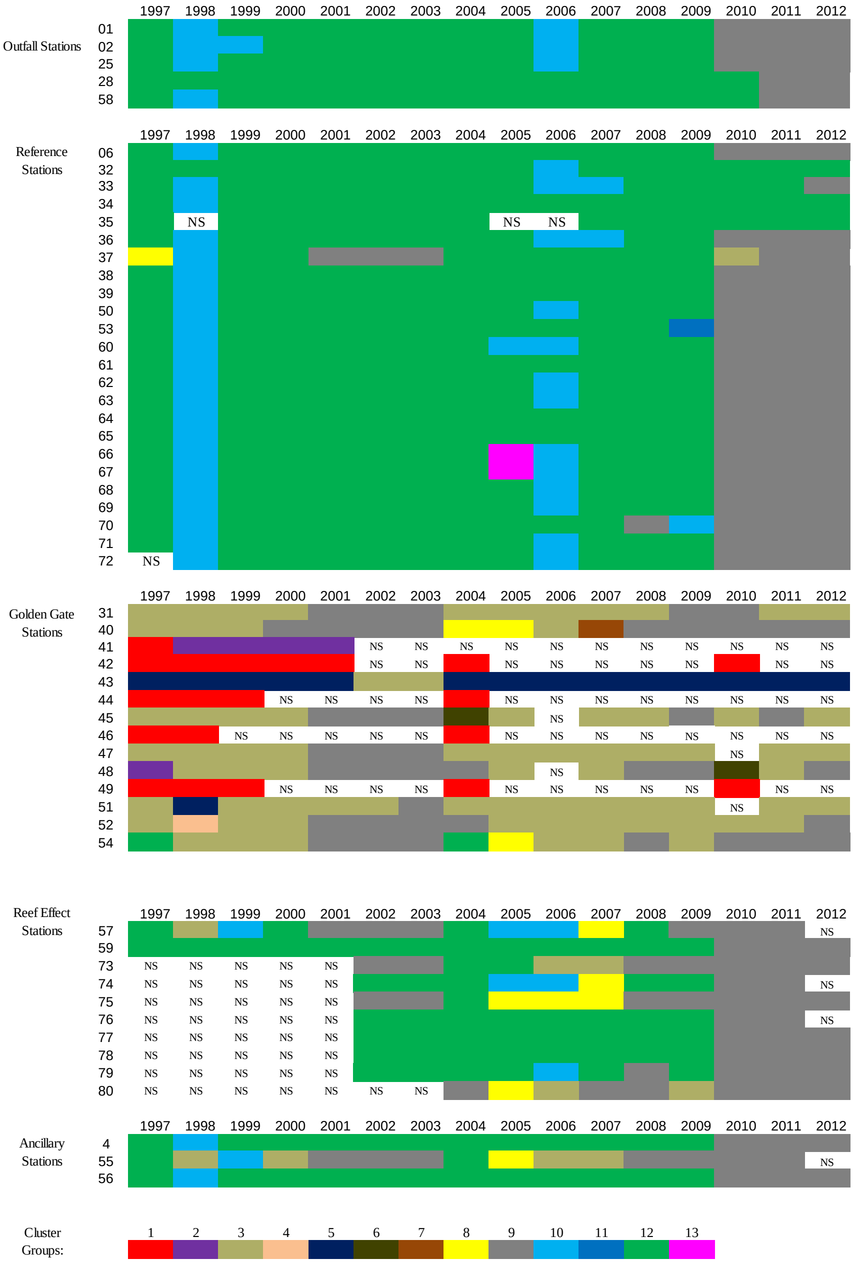
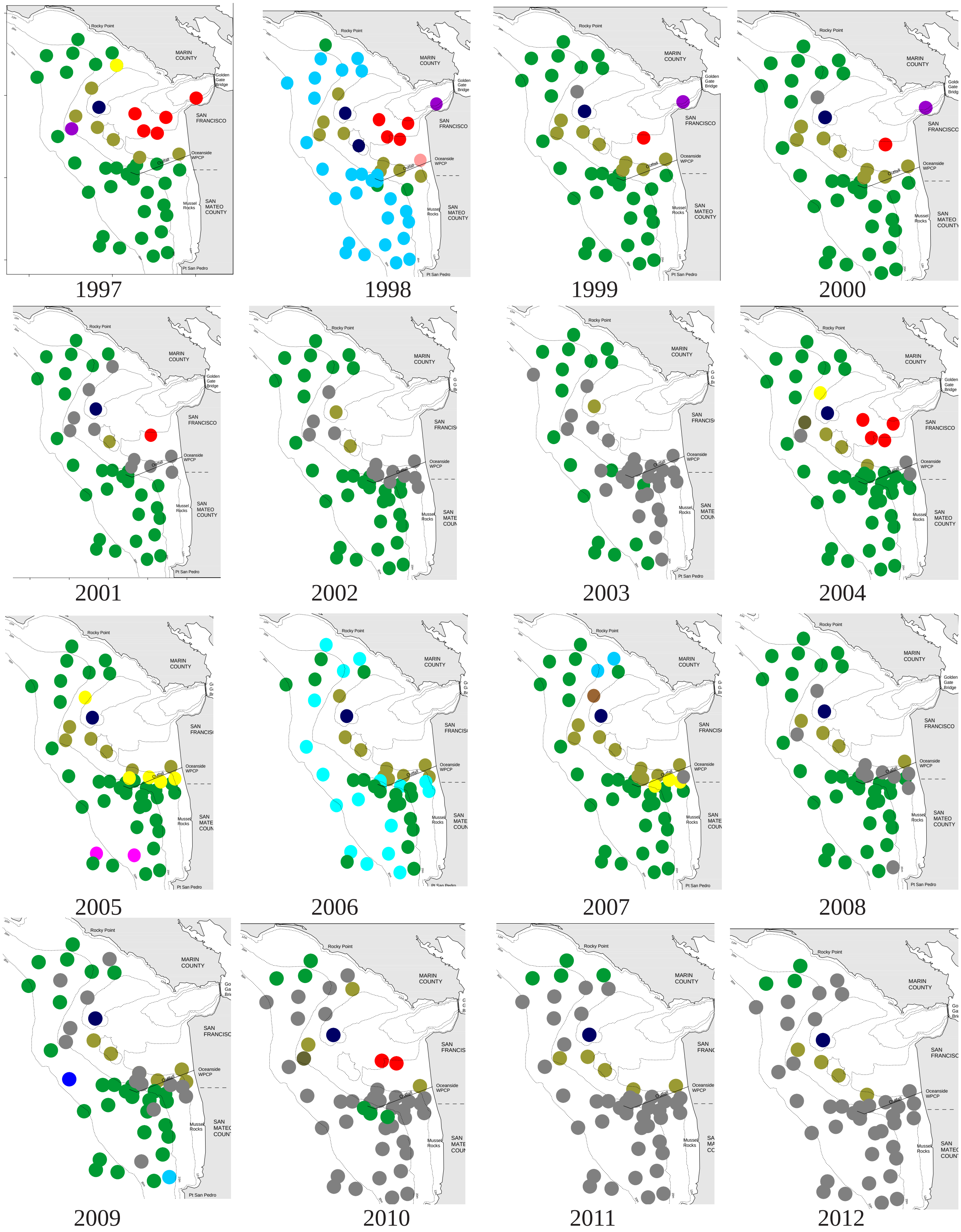


Figure 5-15

Station cluster group matrix showing the biological affinities of stations through time. Samples within a cluster group are more similar to each other biologically than they are to samples in other cluster groups.



1997 1998 1999 2000

2001 2002 2003 2004

2005 2006 2007 2008

2009 2010 2011 2012

Figure 5-16

Geographic distribution of the benthic community cluster groups 1997-2012. See figure 5-4 for cluster group color codes

Table 5-4

Taxa contributing to within group similarity for each cluster group. The taxa contributing the most to the within group similarity are highlighted in yellow.

Representative Taxa	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7		Group 8		Group 9		Group 10		Group 11		Group 12		Group 13	
	N= 20		N= 5		N= 82		N= 1		N= 15		N= 2		N= 1		N= 11		N= 174		N= 57		N= 1		N= 415		N= 2	
	wg sim = 36.2		wg sim = 34.7		wg sim = 32.5		wg sim = n/a		wg sim = 41.4		wg sim = 30.7		wg sim = n/a		wg sim = 44.7		wg sim = 45.0		wg sim = 42.3		wg sim = n/a		wg sim = 43.3		wg sim = 42.3	
	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim	Mean	Ave sim
Amaeana occidentalis	-----	-----	-----	-----	0.7	0.3	-----	-----	0.1	-----	0.5	-----	-----	-----	12.1	1.8	1.1	-----	4.5	0.7	27	n/a	13.7	0.6	-----	-----
Americhelidium shoemakeri	2.2	0.6	-----	-----	0.5	-----	28	n/a	20.3	3.9	-----	-----	1	n/a	0.2	-----	0.9	-----	0.2	-----	1	n/a	0.3	-----	-----	-----
Ampharete labrops	-----	-----	0.4	-----	0.7	-----	-----	-----	-----	-----	-----	-----	267	n/a	3.4	0.6	1.6	-----	3.9	0.6	2	n/a	4.2	0.3	-----	-----
Amphiodia spp.	0.1	-----	-----	-----	1.8	0.6	-----	-----	0.1	-----	2.5	-----	8	n/a	9.2	2.3	7.1	0.7	3.3	1.0	2	n/a	6.8	0.8	6.0	6.0
Apoprionospio pygmaea	0.1	-----	1.6	4.5	18.3	1.4	-----	-----	0.1	-----	1.0	-----	282	n/a	5.6	1.0	16.3	0.9	35.4	4.2	3	n/a	21.2	1.4	-----	-----
Astyris gausapata	-----	-----	-----	-----	-----	-----	-----	-----	0.1	-----	-----	-----	-----	-----	0.7	-----	2.6	-----	0.1	-----	69	n/a	1.8	-----	0.5	-----
Callianax pycna	0.7	-----	0.4	-----	65.2	1.6	-----	-----	1.5	-----	7.0	-----	-----	-----	0.9	-----	67.7	2.0	2.0	0.3	1	n/a	9.3	0.4	-----	-----
Capitella capitata complex	-----	-----	-----	-----	0.8	-----	1	n/a	-----	-----	-----	-----	-----	-----	-----	-----	0.0	-----	0.1	-----	-----	-----	0.0	-----	-----	-----
Diastylopsis dawsoni	-----	-----	-----	-----	2.6	0.4	-----	-----	-----	-----	142.0	7.1	1	n/a	0.1	-----	18.7	1.0	0.3	-----	2	n/a	9.0	0.4	1.0	-----
Eohaustorius spp.	-----	-----	-----	-----	9.2	2.1	2	n/a	13.6	4.7	-----	-----	12	n/a	3.8	0.8	2.9	-----	0.1	-----	-----	-----	0.1	-----	-----	-----
Gadila aberrans	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	n/a	-----	-----	0.0	-----	2.3	0.4	-----	-----	4.3	0.3	11.0	10.9
Glycera tenuis	6.9	2.9	6.4	8.3	0.6	-----	-----	-----	0.2	-----	0.5	-----	-----	-----	-----	-----	0.1	-----	0.0	-----	-----	-----	-----	-----	-----	-----
Hesionura coineaui difficilis	173.4	7.4	0.4	-----	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Heteropodarke heteromorpha	67.8	7.7	8.8	5.2	0.1	-----	-----	-----	0.2	-----	-----	-----	-----	-----	-----	-----	0.1	-----	0.1	-----	-----	-----	0.0	-----	-----	-----
Leukoma staminea	-----	-----	-----	-----	0.2	-----	1	n/a	-----	-----	-----	-----	1	n/a	2.7	-----	6.1	0.2	3.6	0.6	39	n/a	22.6	1.0	-----	-----
Mactromeris catilliformis	0.1	-----	-----	-----	6.0	-----	-----	-----	0.1	-----	4.5	-----	606	n/a	9.3	1.1	46.8	0.3	7.9	0.9	-----	-----	120.5	0.9	-----	-----
Magelona sacculata	-----	-----	-----	-----	6.3	1.5	-----	-----	1.0	-----	2.0	-----	21	n/a	5.1	1.4	18.2	1.0	10.9	2.4	8	n/a	13.1	1.1	-----	-----
Mandibulophoxus gilesi	0.2	-----	-----	-----	5.4	1.0	-----	-----	45.4	14.4	-----	-----	-----	-----	-----	-----	0.2	-----	0.0	-----	-----	-----	0.0	-----	-----	-----
Mediomastus spp.	0.3	-----	0.2	-----	1.3	0.4	2	n/a	0.3	-----	4.5	2.1	-----	-----	34.4	4.9	33.7	1.1	15.9	2.8	10	n/a	65.5	2.9	-----	-----
Nephtys caecoides	0.4	-----	1.0	2.1	6.0	3.0	-----	-----	2.1	2.9	0.5	-----	3	n/a	1.5	0.5	7.1	0.8	2.0	1.0	5	n/a	3.0	0.4	-----	-----
Onuphis sp. A	0.1	-----	0.2	-----	4.4	1.0	-----	-----	-----	-----	-----	-----	3	n/a	4.8	0.8	18.6	1.2	7.7	2.2	1	n/a	28.1	1.9	1.0	5.8
Ostracoda sp. SF2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.2	-----	0.2	-----	0.8	-----	-----	-----	1.0	-----	6.0	-----
Photis spp.	-----	-----	1.0	1.0	1.9	0.5	-----	-----	0.1	-----	9.0	4.1	35	n/a	1.5	-----	87.7	1.8	0.2	-----	1	n/a	4.5	0.4	3.0	-----
Scoletoma luti	0.2	-----	-----	-----	2.0	0.3	-----	-----	0.1	-----	6.5	-----	2	n/a	23.0	4.0	55.5	2.1	9.0	1.9	25	n/a	41.0	2.0	-----	-----
Scoloplos armiger	-----	-----	-----	-----	6.5	2.4	-----	-----	2.1	1.5	0.5	-----	-----	-----	0.5	-----	1.7	0.1	1.0	-----	-----	-----	0.8	-----	-----	-----
Spiophanes norrisi	1.1	-----	15.2	3.2	26.4	1.8	-----	-----	0.2	-----	3.5	2.5	-----	-----	3.3	-----	1518.9	11.7	5.1	1.0	2	n/a	79.2	1.6	-----	-----
Tellina modesta	0.5	-----	3.8	2.6	7.7	1.4	-----	-----	0.3	-----	4.5	2.1	21	n/a	50.1	3.6	38.4	1.9	6.3	1.9	7	n/a	47.8	1.9	-----	-----
Tellina nuculoides	69.4	6.7	0.4	-----	0.3	-----	-----	-----	11.3	0.6	-----	-----	-----	-----	0.3	-----	0.0	-----	-----	-----	-----	-----	0.0	-----	-----	-----

wg sim = within group similarity, measure how individual samples within a group are similar to each other
Ave sim = Average Similarity, amount with which each species contributes to the within group similarity
n/a = ave sim not meaningful since there is only one station within the group
mean = average abundance within the cluster group

Figure 5-15 summarizes the sample-cluster group information of the dendrogram and shows how or whether infauna communities at each station changed or remained the same over time. Figure 5-16 geographically displays the change in benthic communities over the region during the survey period. Table 5-4 shows which species were the most important in each cluster group by their percent contribution to the similarity between groups. Figures 5-17 shows actual and relative abundance and species richness of the major taxa in each of the cluster group.

The analysis resulted in seven cluster groups that primarily distinguish stations in the Golden Gate group from other stations. Groups 1, 2, 3, 4, 5, 6 and 7 are comprised almost entirely of samples from the Golden Gate station group while cluster groups 10, 11, 12 and 13 are predominantly samples from the outfall, reference, ancillary and reef effect station groups (Figure 5-15). Cluster groups 8 and 9 occurred in both the Golden Gate and offshore stations. Cluster group 10 primarily occurred during 1998 and 2006 at the reference, outfall and reef effect stations. Cluster group 12 was the overall dominant community in the region until 2010 when Cluster group 9 became pervasive offshore. This group is largely defined by high abundances of *Spiophanes norrisi* (Table 5-4) and also occupied many of the Golden Gate stations in 2001 through 2003 when that species first became abundant in the study area.

Cluster groups 10, 11, 12 and 13 were comprised primarily of samples collected from the reference, outfall, ancillary, and reef effect station groups. Samples from outfall and reference groups all have sediment of predominantly very fine sands, averaging greater than 50% very fine sand over the sixteen year period (Section 4.2.1). For the most part, outfall and reference stations had similar communities and clustered together every year, forming group 12 in all years except in 1998 and 2006 when they formed cluster group 10 and in 2010 through 2012 when cluster group 9 was dominant. Group 12 has the greatest species richness of all the groups and is characterized

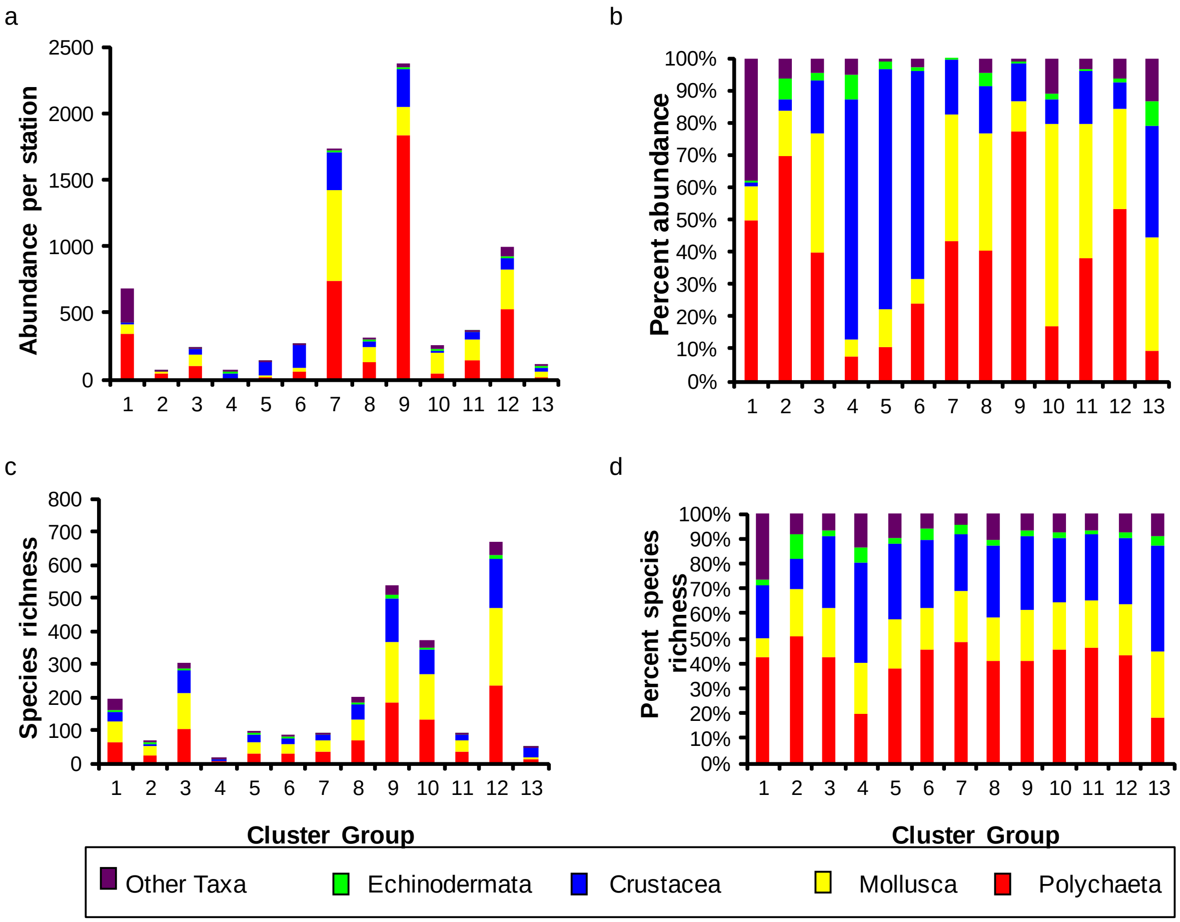


Figure 5-17

Graphical representation of abundance and species richness composition of major taxa in each cluster group (both actual amounts and percent composition

by abundant polychaete species such as *Mediomastus* spp. and *Scoletoma luti* (Figure 5-17c and Table 5-4).

Cluster group 9 generally replaced cluster group 12 offshore in 2010 through 2012 except for a few northern reference stations. The taxa identified within cluster group 9 constitute a benthic infauna community associated with very fine sand and is numerically dominated by the polychaete, *Spiophanes norrisi*.

Cluster groups 2, 3 and 5 contained samples primarily from on or near the sand bars. These stations are the shallowest in the study area and are, therefore, subject to the most wave disturbance. The sediments at these stations are predominantly well-sorted fine sand, averaging greater than 50% fine sand for the sixteen-year period (Section 4.2.1.). Cluster "groups" 4, 7 and 11 and were each composed of a single sample and were respectively dominated by a single species: the amphipod crustacean, *Americhelidium shoemakeri*, (Station 52 in 1998) a bivalve mollusk, *Mactromeris catilliformis* (Station 41 in 2007) and the gastropod mollusk, *Astrix gausapauda* (Station 53 in 2009)(Table 5-4). Of the three sandbar cluster groups, cluster group 2 had the lowest abundance, averaging 64 organisms per station (Figure 5-17a). Groups 4, 5 and 6 of the Golden Gate sandbar stations had substantial crustacean populations (Figure 5-17b, Table 5-4). The increased relative abundance of crustaceans at the sand bar stations is consistent with a pattern of zonation at a high-energy subtidal beach in Monterey Bay described by Oliver et al. (1980) where crustaceans were more abundant in the areas of greatest wave disturbance.

Cluster group 1 consisted of stations 42, 44, 46, and 49 for all years sampled and station 41 in 1997. These stations had the coarsest grain size in the study area, averaging greater than 50% coarse and medium sands (Section 4.2.1). The taxa identified with cluster group 1 constitute a distinct benthic infauna community associated with coarse and medium sands and are numerically dominated by two small, interstitial-like polychaetes, *Hesionura coineaui difficilis* and *Heteropodarke heteromorpha* and the bivalve *Tellina nuculoides* (Table 5-4).

5.2.4. REFERENCE ENVELOPE

Reference envelope analysis is a method by which indicators from potentially impacted sites (e.g. outfall stations) can be compared to a range of indicator values from reference sites (see Reference Envelope Analysis 2.4.2.3. and Appendix B 2.4.). The analysis involves computation of tolerance-interval bounds to define limits distinguishing reference from non-reference conditions (Smith 2002). Outfall station indicator values that fall outside the envelope, defined by the tolerance-interval bounds, represent a potential impact. Figures 5-4, 5-7, 5-9, and 5-10 show infauna indicators plotted with reference envelope tolerance-interval bounds for the reference and outfall station groups.

Because the Pearson/Rosenberg model predicts that abundance and diversity measures at sewage discharge sites increase and then decrease along an impact gradient, both upper and lower tolerance-interval bounds were plotted for species richness, diversity and abundance. Lower tolerance limits changed noticeably since the last trend report for diversity and evenness since reference stations were affected by the low values in 2010, 2011 and 2012.

Several outfall and reference stations fell outside reference conditions for each community measure. High abundance at outfall stations 01 and 25 in 1997, relative to reference stations, was due to recruitment by the bivalve *Tellina modesta* (WQB 1998). High abundances at some outfall stations in 2001, 2003, 2010, 2011 and 2012 were matched by high abundances at several reference stations in those years. Similarly, low abundances at outfall stations in 2006 were matched by low abundances at several reference stations in 2006. Outfall station 02 and some southern reference, ancillary and reef effect stations had diversity and evenness values that fell below the lower tolerance-interval bound in 2010, 2011 and 2012. During those years, some of the extremely low values for diversity and evenness were at reference, ancillary and reef effect stations. Species richness was outside of reference conditions at outfall stations 02 and 25 and reference stations 06, 32, 36 and 50 in 2006. The changes in the communities in 2010 to 2012 did not seem to affect the species richness. None of the outfall stations differed greatly from reference conditions each year. There has not been a persistent pattern that would indicate outfall stations have altered community measures relative to reference stationsThe reef effect stations fell outside of the reference conditions to a greater extent than the outfall stations, especially in 2002, 2003, 2006, 2007, 2009, 2010, 2011 and 2012. These deviations may be due to the effect of a region-wide recruitment of *Spiophanes norrisi* during those years in 2002, 2003, 2009, 2010, 2011 and 2012; and by various species in 2006 and 2007 (see Tables 5-3 and 5-4).

Ninetyfive percent of the time, ten percent of the reference population might exceed a tolerance-interval bound in the absence of an impact with the parameters used in this analysis (Methods Section 2.4.2 Multivariate Analyses), thus high abundance at some reference (and outfall) stations may occur naturally. The high abundances at some stations in 1997, 2000, 2001 and 2004, as indicated by the reference envelope analysis, most likely represent haphazard recruitment events as discussed previously under abundance (Section 5.2.2.1.). Sustained high abundance values in 2009, 2010, 2011 and 2012 are due to increased *Spiophanes norrisi* populations.

5.2.5. BACIP ANALYSIS

The BACIP (Before-After-Control-Impact-Paired) statistical model (BACIP Analysis 2.4.2.3.) was used to test whether the relationship between outfall and reference station abundances has changed since the onset of treated wastewater discharge from the SWOO. The null hypothesis states that the mean differences between the outfall and reference station abundances are the same in pre-discharge and discharge periods. The test assumes that natural temporal changes in abundance over time will be reflected at both outfall and reference stations, thus the mean differences in abundances in the two areas should not change. On the other hand, if the wastewater discharge causes a change in abundance, the mean differences between outfall and reference stations will change. Stations 01 (outfall) and 06 (reference) were used in the model because they have the longest history of continuous collection. The results, shown in Table 5-5 indicate that the SWOO discharge has not affected infauna abundances in the study area. Figure 5-18 shows the pattern of infauna abundance at the outfall and reference stations over time.

5.2.6. PEARSON/ROSENBERG MODEL

The Pearson/Rosenberg model (Pearson & Rosenberg 1978) predicts a pattern of change in the infaunal community in response to an organic enrichment source. At the point source, there is a zone of low faunal abundance and species richness. Further from the source is a region of high abundance comprised of mostly opportunistic species. Species richness will also increase in this zone, but reach its maximum well outside the influence of the point source.

The SWOO benthic infauna data did not show results that the Pearson/Rosenberg model would predict for an outfall with a significant impact. Although some outfall samples in some

Table 5-5
BACIP (Before and After Control Impact Paired) analysis of log10 total abundance assesses the impact of a pollution source compared to baseline data collected prior to construction of the outfall. The null hypothesis is that the differences in outfall and reference means are equal in the pre-discharge and discharge periods tested. The null hypothesis is accepted (paired t=-1.61, df=28, p=0.12).

		Pre-Discharge 1982 - 1986 n=4	Discharge 1986 - present n=26
Outfall Station	01	3.102	2.956
Reference Station	06	2.818	2.926
difference		0.284	0.029

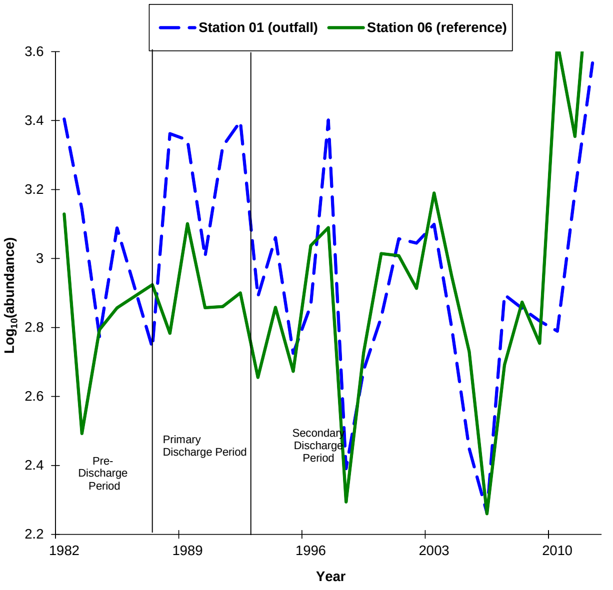


Figure 5-18
Pattern of infauna abundance (log10) at outfall (station 01) and a reference station (station 6). After the start of secondary treatment in 1993, the distribution pattern between the two stations are very similar (average difference of log10 abundance values = 0.05).

years had higher abundances than reference stations, most outfall samples were within the range for reference conditions. The high abundances at outfall stations 01 and 25 in 1997 were associated with relatively low diversity and evenness (Figure 5-5), suggestive of an opportunist zone in the model, but that situation was due to massive recruitment of the bivalve *Tellina modesta* (Table 5-2) and did not persist. Similarly, low diversity and evenness values were observed at outfall stations 01, 02 and 25, in 2010, 2011 and 2012, but, as shown in Table 5-4, these were due to large abundances of *Spiophanes norrisi*. Neither species is known to be an indicator of enrichment or other impacts typically associated with wastewater discharges. High abundances at outfall stations in 2001, 2003, 2009, 2010, 2011 and 2012 were reflected in the reference stations (Figure 5-5), suggesting that the increase in abundance was region-wide. It is possible that the SWOO data do not fit the Pearson/Rosenberg model in a classic sense. This is probably due to the relatively low volume and high quality of effluent that is discharged and the high-energy regime of the receiving water environment.

5.3. SUMMARY AND CONCLUSIONS

The multi-year trend analysis shows a distinct change in the offshore community in the last 3 to 4 years of the survey period. This change is also reflected in the sediment data (see section 4.2.1.3) and seems to be region-wide, rather than due to a particular point source.

Ordination analysis of all stations shows that sediment grain size is the most important factor in structuring of infauna communities in the study area. Ordination and Cluster analysis indicate that stations in the reference, outfall, reef effect, and ancillary station groups are very similar to one another, with similar changes in community composition from one year to another.

Cluster analysis identified several distinct benthic infauna communities. The area inside the barrier sand bars, with predominantly coarse and medium sands, has a distinct community of mostly interstitial organisms. Another community exists on or near the sand bars, which is dominated by Crustacea and by the polychaete, *Spiophanes norrisi* especially in 2002 and 2003. Composition of the communities may change from year to year depending on large scale climatic changes either within a year (as with the El Niño-La Niña years, 1997 to 1998 and periods of large Delta outflow in 1998 and 2006) or over a period of several years (as with the change to the *Spiophanes norrisi* dominated community observed from 2010 to 2012).

Reference envelope analysis shows that some outfall stations have been outside tolerance-interval bounds for some infauna community measures each year. Higher abundance values at outfall stations might be suggestive of enrichment; however similar high abundance values are found in reference stations. The species responsible for high abundance at the outfall are not known indicators of enrichment or any other impacts typically associated with wastewater discharges. A comparison of infauna abundance at an outfall and reference site spanning periods before and after effluent discharge demonstrated no statistically significant difference.

Examinations of long-term SWOO benthic infauna data (Kellogg et al 1998; NRLMD 2010a) have found that seasonality and oceanographic influences were major factors affecting the infauna community structure in the study area. This report supports the observations made by previous studies and has correlated some of these oceanographic influences with the observed patterns. The current monitoring supports the regional strategy for evaluation of point source impacts showing that the response in the benthic community near the outfall is reflective of the changes seen region-wide.

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SECTION 6

DEMERSAL FISH AND EPIBENTHIC INVERTEBRATES

DEMERSAL FISH AND EPIBENTHIC INVERTEBRATES

6.1 INTRODUCTION

The City and County of San Francisco has conducted trawl sampling in the Gulf of the Farallones over 26 years, from 1982-2008. Trawl sampling has been required in NPDES permits as a means of characterizing the resident fish and epibenthic invertebrate assemblages. NPDES permit requirements have included monitoring of these organisms to demonstrate that the community within the influence of the discharge is not degraded, and that a balanced indigenous population exists within and beyond the zone of initial dilution. Additionally, trawl sampling has been a means of collecting English sole (*Pleuronectes vetulus*) specimens in order to monitor tissue concentrations of pollutants (bioaccumulation) in demersal fish near the SWOO outfall as well as in reference areas.

The number, locations and seasonality of trawl sampling have varied over the life of the monitoring program (Appendices F-1 and F-2, Figure 6-1), however, beginning in 2003, NPDES permit requirements reduced fishery sampling to single trawls at one outfall station (Station 01) and one reference station (Station 06). These two fixed locations have been sampled consistently, with at least one trawl each fall that sampling was conducted.

Under the adaptive management provisions of the NPDES permit Monitoring and Reporting Program, and with notification to the U.S. EPA, trawl sampling was curtailed in 2009 due to the listing of longfin smelt (*Spirinchus thaleichthys*) as a threatened species by the California Department of Fish and Wildlife (CDFW). Longfin smelt were commonly caught by the SWOO monitoring program during trawl sampling as by-catch (Table 6-1).

We argue to drop the trawl sampling requirement in light of the information gathered through trawl sampling to date, using the reported results of over two decades of monitoring. A discussion of each of these reasons for permanently discontinuing the trawl program is provided below:

Table 6-1

Recorded occurrence of Osmeridae, including the threatened longfin smelt, in SWOO Regional Monitoring Program community trawls.

Year	Month	Jack Smelt	Longfin Smelt	Night Smelt	Whitebait Smelt	Osmeridae
1982	10		408	148		
1983	6		600	430		
1983	10		294	222		
1984	2	1	2			
1985	6					1
1994	3		57	43		
1994	7		1	20		
1994	9		97	49		
1995	3		1	33		
1995	9		72	28		13
1996	3		183	172		
1996	11		377		75	

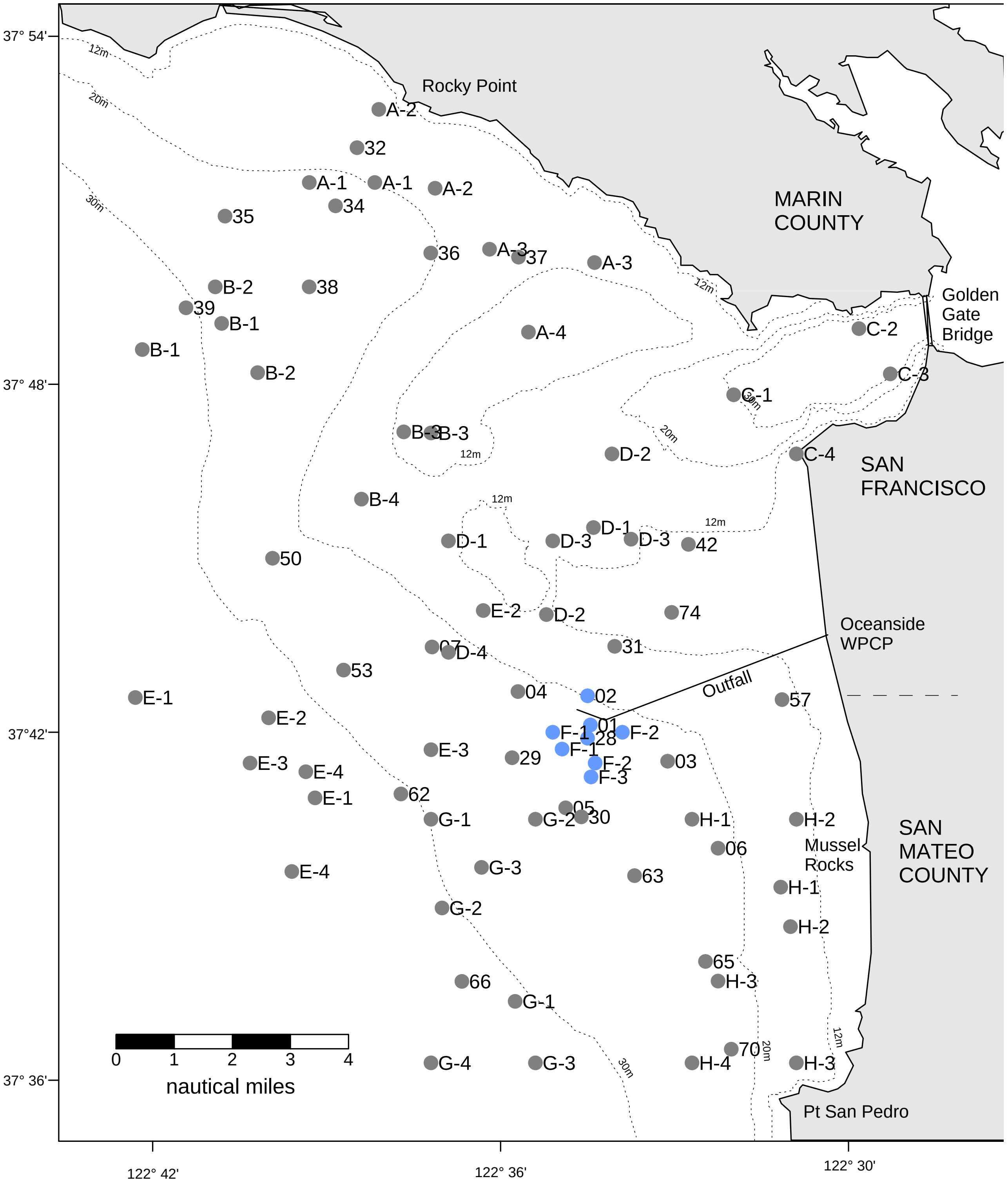

Figure 6-1
Coverage of the SWOO study area (1982-2008) by trawl samples used for community analyses. Stations in blue were used to characterize outfall conditions

1) The trawl sampling has not revealed a significant difference between outfall area and reference area demersal fish and epibenthic invertebrate communities

2) The trawl sampling program is not suited to finding an outfall effect

3) The demersal fish specimens collected are not necessarily representative of contaminant exposure to consumers of local fishes or of body burdens obtained within the Gulf of Farallones

4) The trawl sampling results in significant and unnecessary mortality to demersal fish and epibenthic organisms including listed species

5) The trawl sampling destroys benthic habitat

6) Other new sources of high-quality environmental data are available

7) Given the absence of outfall effects demonstrated by data, the trawl program is excessively costly and burdensome to implement

6.2 DISCUSSION OF REASONS TO DROP THE TRAWL REQUIREMENT

6.2.1 THE TRAWL SAMPLING HAS NOT REVEALED A SIGNIFICANT DIFFERENCE IN OUTFALL AREA OR REFERENCE AREA DEMERSAL FISH OR EPIPBENTHIC INVERTEBRATE COMMUNITIES

Twenty six years of monitoring have shown that there has been little difference between demersal fish and epibenthic invertebrate assemblages found at the outfall and in the reference areas. Measurements of community metrics (number of species, organism abundance, Shannon Weiner Diversity, and Pielou's Eveness) for demersal fish and epibenthic invertebrate assemblages show that no long-term trend of degradation has been found at the outfall station (NRLMD 2010a). Likewise, the short- and long-term trends in community metrics for assemblages of demersal fish and epibenthic invertebrates from 1982-2008 show that community metrics values tended to be similar for the outfall and reference stations, despite substantial variability over the study period (NRLMD 2010a). There has also been a great deal of similarity between organism assemblage composition between reference and outfall locations since the SWOO went into operation in 1986 (NRLMD 2010a). The similarity in results from outfall and reference stations demonstrates that changes in the biota are representative of changes in the region as a whole, rather than an outfall-related effect.

6.2.2 THE TRAWL SAMPLING PROGRAM IS NOT SUITED TO FINDING AN OUTFALL EFFECT

There has been occasionally great variability in the trawl sampling record which results in very high variances in recorded assemblage composition even between replicate trawls at the same station. Much of the variability that has been observed is attributable to chance encounters with mobile species (e.g., bay shrimp *Crangon* spp. or market squid, *Loligo opalescens*). An analysis of seven years of SWOO trawl data (Niemi & Warheit 1989) found strong temporal and spatial effects associated with all variables and concluded that it would be statistically difficult to show any discharge effect, even if one existed. They further concluded "In effect, to properly control for effects other than sewage effluent, sampling would have to occur almost year-round, an unreasonable and costly suggestion. This problem is by no means unique to the data collected in this monitoring program, and has been discussed by other authors for other areas [Richkus 1980, Seger and Stamman 1986]."

6.2.3 THE DEMERSAL FISH SPECIMENS COLLECTED ARE NOT NECESSARILY REPRESENTATIVE OF CONTAMINANT EXPOSURE TO CONSUMERS OF LOCAL FISHES OR OF POLLUTANT BODY BURDENS OBTAINED WITHIN THE GULF OF THE FARALLONES

Tissue samples have been collected from two commercially important fisheries in the San Francisco Bay Area, English sole *Pleuronectes vetulus* and Dungeness crab *Metacarcinus magister* (=*Cancer magister*). English sole were collected from trawl samples taken at Stations 06 in the reference area (and additional stations when necessary) and from Stations 01, 02, and 28 in the outfall area. Dungeness crab were collected, using crab traps, at reference Station 06 and outfall Station 01.

Bioaccumulation of pollutants was measured in fish and crab muscle tissue as well as in fish liver and crab hepatopancreas but crab tissue seems to yield higher quality data. Analysis of bioaccumulation data collected by the SWOO Regional Monitoring Program is reported in detail in Section 7 of this report, but the general trends found to date are relevant here. In general, no persistent significant differences in contaminant concentrations have been found between tissues collected from outfall stations and reference stations. No discernible trends in the concentrations of contaminants in fish or crabs from reference or outfall areas have been observed over 14 years of bioaccumulation monitoring. To date, a broader suite of pollutants have been observed in crab tissue than fish tissue in the SWOO regional monitoring record and all contaminant compounds that have generally been observed in fish tissue have been observed in crab tissue as well (NRLMD 2010a). Additionally, most pollutants that have been observed are found at higher concentrations in crab tissue than in fish tissue (NRLMD 2010a), implying that crab tissue can give a better indication of trends of environmental pollution in the monitoring region.

Contaminant concentrations found in English sole tissue by the SWOO Regional Monitoring Program are not necessarily representative of contaminant exposure to consumers of local fishes or body burdens obtained within the Gulf of the Farallones. Historically, English sole specimens gathered in the trawl samples have been relatively small (30-250 mm), and English sole of “marketable size” (greater than 279 mm) have never been caught in a SWOO Regional Monitoring Program trawl sample (Figure 6-2). Fish used for bioaccumulation tissue samples should be at least 135 mm in length, though fish greater than 200 mm in length are preferred for bioaccumulation monitoring and these are typically a very small component of the catch (Figure 6-2). In recent years the mean standard length for English sole used for bioaccumulation monitoring has been as low as 86 mm, due to difficulty in finding fish of a more suitable size. Contaminants found in the tissues of such small fish are likely to be influenced by contaminant concentrations in their nursery habitat (the San Francisco Estuary) rather than offshore regions where they migrate as they mature (Lassuy 1989, Pearson et al. 2001). A special study of the San Francisco Estuary Regional Monitoring Program for Water Quality (RMP) (Melwani et al. 2009) attempted to compare fish bioaccumulation within San Francisco Bay and the adjacent open coast by comparing data from the RMP (for San Francisco Bay) and from the South West Ocean Outfall Regional Monitoring Program (open coast). They concluded that “Lower [mercury] concentrations for this species [English sole] may be due to their small size, wide foraging range, and earlier lifestage than other species and locations included in this study. Due to their size, comparison of these data to OEHHA’s fish consumption guidelines was not appropriate.” By contrast, the Dungeness crabs that are collected for bioaccumulation analysis generally meet the criteria for commercial catch (legal sized, male). The SFPUC is not arguing to discontinue bioaccumulation monitoring of Dungeness crab.

The SFPUC was able to substitute Pacific

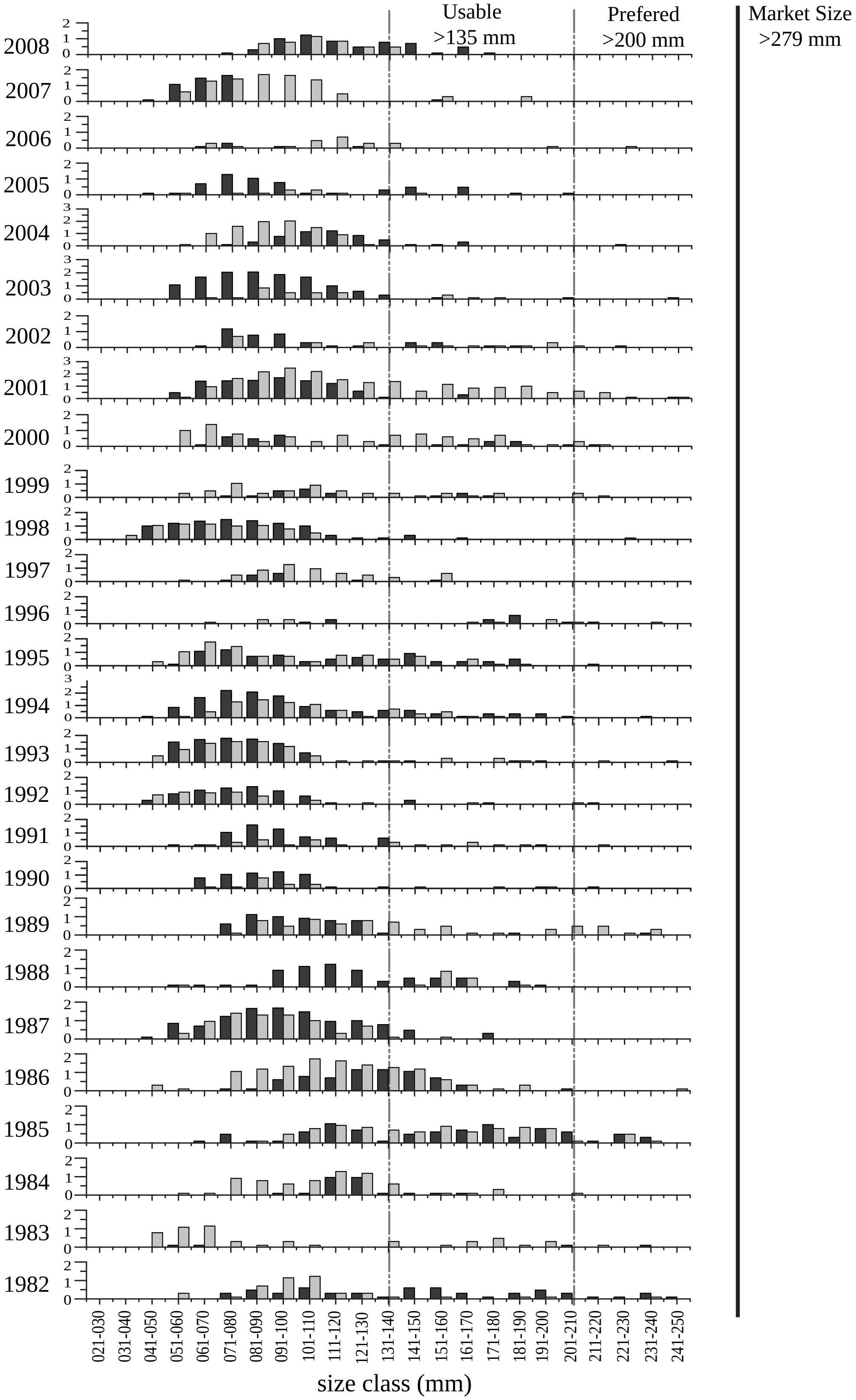

Figure 6-2

Size and log10 abundance of English sole from outfall Station 01 (grey bars) and reference Station 06 (black bars) in community trawls, 1982-2008 by station and year.

sanddab (*Citharichthys sordidus*) for English sole one year (2006) when very few English sole were present, however, no fish species in our trawl samples consistently occurs of sufficient size or abundance to be useful for bioaccumulation monitoring.

6.2.4 THE TRAWL SAMPLING RESULTS IN SIGNIFICANT AND UNNECESSARY MORTALITY TO DEMERSAL FISH AND EPIBENTHIC ORGANISMS INCLUDING LISTED SPECIES

The current mandated trawl sampling program includes one 10-minute trawl at depth at a speed of 2 knots at outfall station 01 and reference station 06 each year to assess assemblage composition. It is estimated that this activity alone resulted in approximately 3,000 fish being hauled to the surface for processing each year. While great care was taken to process quickly, salvage as many fish as possible and return them to the water alive, inevitably most did not survive the trawl. Additional trawls, 21 additional trawls in 2005 (Appendix F-1), were often conducted at each location (typically up to 30 minute duration at depth and at various speeds) in order to gather enough English sole to make the requisite tissue samples for bioaccumulation monitoring (Appendix F-1). The number of fish encountered by our net during the extra trawls conducted to collect fish tissue were not recorded, but were likely to be an order of magnitude more than those encountered (and recorded) during community trawls.

A portion of the by-catch of the SWOO Regional Monitoring Program trawl sampling was longfin smelt (*Spirinchus thaleichthys*). Because the target of the trawl monitoring were demersal fish and epibenthic invertebrates, pelagic by-catch were not always identified or enumerated. Nonetheless, capture of longfin smelt was recorded in the monitoring data in a few instances (1982-85 and 1994-96). Smelt catch has not been reported in more recent years and fish encountered in extra trawls conducted to gather English sole for bioaccumulation have not been recorded. The California Department of Fish and Wildlife listed the longfin smelt as threatened under the California Endangered Species Act (CESA) in 2009. CESA prohibits unpermitted taking of listed species and thus trawl sampling was curtailed by the SWOO Regional Monitoring Program in 2009 so that longfin smelt would not be harmed by the monitoring program.

6.2.5 TRAWL SAMPLING DESTROYS BENTHIC HABITAT

Not only are fish populations affected by the trawling, bottom habitat is also disrupted by trawling activity. Otter boards and foot chains plough into the sea bed, disrupting sediment and benthic infaunal communities through direct physical disturbance as well as by creating a turbid cloud of fine sediment. The marine science literature is replete with accounts of the lasting damaging effects of trawling (e.g., NRC 2002) and the harmful effects of trawling on benthic habitat and the structure of benthic infaunal assemblages (e.g., Engel and Kvitek 1998).

6.2.6 OTHER NEW SOURCES OF HIGH QUALITY ENVIRONMENTAL DATA ARE AVAILABLE

Since the inception of the SWOO Regional Monitoring Program other notable monitoring efforts have come on-line which provide biological data overlapping with our monitoring program.

The State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP) conducted a two-year, statewide biomonitoring screening survey of coastal fish 2009-2010, focusing on methylmercury and PCBs in fish tissue but evaluating several other contaminants as well. This study was exceptional in that it applied uniform methods to surveys of fish among 68 locations on the California coast, including ten locations in the SWOO monitoring program region and San Francisco Bay. The SWAMP Coast Survey is expected to be repeated on a 5-year interval.

With regard to monitoring demersal fish and epibenthic species populations, there are studies that monitor in regions adjacent to the area currently sampled by the SWOO Regional Monitoring Program. The California Department of Fish and Wildlife, San Francisco Bay Study intensively samples in San Francisco Bay, including Central Bay, monthly using both otter trawl and midwater trawl. The National Oceanic and Atmospheric Administration (NOAA) U. S. West Coast Groundfish Bottom Trawl Survey samples regions adjacent to the SWOO Regional Monitoring Program region twice per year (summer and fall) to monitor the demersal fish and epibenthic species populations.

6.2.7 GIVEN THE ABSENCE OF OUTFALL EFFECTS DEMONSTRATED BY THE DATA, THE TRAWL PROGRAM IS COSTLY AND BURDENSOME TO IMPLEMENT

Trawl sampling requires significant additional ship time and cost to the SWOO Regional Monitoring Program because it is not compatible with the other monitoring elements of the program. Safe use of trawling gear requires that the decks of our monitoring vessel be cleared of all other bottom sampling gear. Because trawl sampling disturbs bottom habitat, it cannot not be conducted until all sampling of bottom sediments, benthic infauna, and crab were completed. Setting and retrieving crab traps is, however, compatible with benthic sampling and those two monitoring activities are conducted concurrently. The SFPUC is not at this time advocating that crab monitoring be discontinued.

6.3 SUMMARY AND CONCLUSIONS

After reviewing 26 years of trawl sampling data we find no significant effect from the Southwest Ocean Outfall and no long-term degradation associated with the outfall. Bioaccumulation monitoring using tissue from fish caught by trawl and crab caught by traps in the reference and outfall areas have likewise not shown a significant outfall effect. Bioaccumulation monitoring has shown that crab tissue has yielded a stronger, more persistent signal of environmental pollution in the region than tissue from demersal fish species. Trawl sampling is costly to biota and environment, endangering by-catch organisms, including the longfin smelt, which is listed as a threatened species. While no monitoring program exactly duplicates the efforts of the SWOO Regional Monitoring Program in the Gulf of the Farallones, several ongoing monitoring programs do exist which provide data of a quality and context that we are not able to match. In light of these discoveries we request that the trawl sampling component be removed from the SWOO Regional Monitoring Program.

SECTION 7

BIOACCUMULATION AND PHYSICAL ANOMALIES

PHYSICAL ANOMALIES AND BIOACCUMULATION

7.1 INTRODUCTION

This section contains information on physical anomalies of individual organisms as well as organic and inorganic bioaccumulation data in the commercially important Dungeness crab *Cancer magister*. Information regarding the assessment of tissues of fish (primarily English sole *Pleuronectes vetulus* from 1997 through 2008) is in NRLMD 2010a.

Analysis of organic and inorganic compounds (trace metals) detected in organism tissues from reference and outfall areas can assist in assessing relative contamination of the study area. In addition, contamination of tissues in commercially important species may have public health implications. Comparing results from organisms collected at reference and outfall areas provides information on potential outfall effects, though caution should be used regarding those comparisons because of the mobility of these organisms.

This report references 2012 annual data and identifies trends from the 1997 through 2012 SWOO surveys (WQB 1998, 1999, 2000, 2001a, 2003a, 2003b, 2004; NRD 2006a, 2006b; NRLMD 2007, 2008, 2010a, 2010b, 2011, 2012). Comparisons of tissue pollutant levels with other agency data assist in the assessment of contaminant body burdens and human health concerns.

7.2 RESULTS AND DISCUSSION

7.2.1 PHYSICAL ANOMALIES

Dungeness crabs were examined for tumors and gross physical anomalies at the time of collection and taxonomic identification. Beginning in 2004, all Dungeness crab were more extensively assessed for physical anomalies (whether they were used for bioaccumulation analyses or not) than in previous years.

Adult Dungeness crab were examined for black necrotic disease (BND) or shell disease syndrome, a broad term describing the presence of discrete areas of melanin production, necrosis, and exoskeleton erosion on crustaceans that may be a response to disease or injury and can lead to tissue death. The presence of BND is subject to molt cycles, and may be indicative of environmental pollution or naturally occurring degradative processes in sediment (Sawyer 1982, Comely and Ansell 1989, Noga et al. 2000, Vogan et al. 1999, 2002, 2008).

7.2.1.1 Survey Year 2012

In 2012, 20% and 18% of the Dungeness crab collected in crab pots from the reference and outfall areas, respectively, had observed instances of BND (Table 7-1).

7.2.1.2 Survey Years 1997 – 2003

Frequency of BND on crabs that were collected from the reference or outfall areas, and were used for bioaccumulation analyses, varied from 0 to 12% from 1997 to 2003.

7.2.1.3 Survey Years 2004 – 2012

In 2004-2012, 7 – 36% of all the Dungeness crab collected in crab pots (and in community analysis and bioaccumulation trawls, when applicable) at both reference and outfall areas (regardless of whether they were used for analyses or not) had physical anomalies that were almost exclusively BND (Table 7-1).

The apparent increases from 1997-2003 to 2004-2012 in external physical anomalies are likely due to the more extensive external physical assessment of an increased number of organisms collected during part of the period 2004-2012 rather than an increase in the actual incidence of anomalies in fish and macroinvertebrates.

7.2.2 BIOACCUMULATION ORGANISMS

Prior to 2009, Dungeness crabs were collected by commercial crab-pot and trawl, primarily at reference station 06 and outfall station 01. Beginning in 2009, crab for bioaccumulation were collected using crab-pots, exclusively.

Within each survey year, organisms from

Table 7-1

Abundance of Dungeness crab affected by external physical anomalies, collected from SWOO Reference and Outfall areas for community composition and bioaccumulation analyses, 1997 - 2012. The last survey year to include trawl-collected crab was 2008.

	REFERENCE						OUTFALL					
Survey Year	No Anomaly Observed	Physical Anomaly Observed				Organisms Affected	No Anomaly Observed	Physical Anomaly Observed				Organisms Affected
		Deformity	Erosion	Tumor	BND*			Deformity	Erosion	Tumor	BND*	
2012	45	0	0	0	11	20%	62	0	0	0	14	18%
2011	20	0	0	0	2	9%	25	0	0	0	5	17%
2010	90	1	0	0	22	20%	70	0	0	0	35	33%
2009	37	0	0	0	12	24%	21	0	0	0	7	25%
2008	83	0	0	0	13	14%	59	0	0	0	5	8%
2007	24	0	0	0	17	10%	214	0	0	0	12	7%
2006	63	0	0	0	35	36%	91	0	0	0	19	17%
2005	67	0	0	1	25	28%	61	0	0	0	34	36%
2004	183	1	0	0	43	19%	180	0	0	0	42	19%
2003	119	0	0	0	9	7%	93	0	0	0	20	18%
2002	245	0	0	0	0	0%	76	0	0	0	1	1%
2001	131	0	0	0	3	2%	114	0	0	0	1	1%
2000	28	0	0	0	5	15%	26	0	0	0	4	13%
1999	ND	0	0	0	0	0%	ND	0	0	0	0	0%
1998	30	0	0	0	0	0%	29	0	0	0	1	2%
1997	ND	0	0	0	0	0%	ND	0	0	0	0	0%

*BND = black necrotic disease
ND = no data

both reference and outfall areas were of similar size and weight, with similar lipids content in both muscle and hepatopancreas tissues in organisms from both reference and outfall areas (Appendix G-1). Organic compounds and trace metals analyzed in tissues are listed in Appendices G-2 and G-4.

7.2.3 BIOACCUMULATIVE POLLUTANTS

7.2.3.1 Sources

The source of bioaccumulated pollutants in tissue samples may be contaminated sediments from San Francisco Bay, since Dungeness crab rely heavily on estuarine environments during their juvenile stages and, as adults, are mobile predators that can range widely along latitudinal and onshore-offshore gradients (Hankin and Warner 2001; Pauley et al 1989, PSMFC 1996).

These SWOO data address the extent of bioaccumulated contaminants in these organisms; attempts to assess contaminant origins or environmental and public-health impacts of those pollutant body burdens should be made with caution.

7.2.3.2 Organic Pollutants

Organic analyses of the tissues in this study confirm the lipid affinity of pesticides and PCBs, as evidenced by the increased number and concentrations of organic compounds detected in hepatopancreas tissue compared to muscle tissue (Table 7-2).

7.2.3.2.1 Survey Year 2012

In 2012, one organochlorine pesticide (DDE), two PAHs, and eight PCBs were found above detection limits at both reference and outfall areas; concentrations of these compounds were generally low, at levels comparable to previous years (Table 7-2).

7.2.3.2.2 Survey Years 1997 – 2012

Of the three DDTs, 18 PAHs and 53 PCB congeners assessed in tissues during the 16-year study period, one DDT (DDE), one PAH and 11 PCB congeners were detected in crab tissues in at least half of the survey years. There is only one instance of statistically significantly-elevated level of organic compounds (total PCBs) in muscle tissue of crab from the outfall area compared to the reference area in 2003 (Table 7-2). In all other years, levels of organic compounds in tissues were not statistically different between reference and outfall areas, or were statistically significantly elevated in tissues of organisms from the reference area compared to the outfall area (PAHs in muscle in 2001 and in hepatopancreas in 2003, and DDTs in muscle in 2004).

7.2.3.2.2.1 *Organochlorine pesticides (DDTs)*

Low concentrations of the DDT break-down compound 4,4'DDE were frequently detected in crab muscle tissue in all survey years (Appendix G-3), with 4,4'DDT and 4,4'DDD not detected in crab tissues since 2007.

7.2.3.2.2.2 *Polycyclic Aromatic Hydrocarbons (PAHs)*

Throughout the SWOO study in both reference and outfall areas, PAHs were detected in both tissue types at varying concentrations (Table 7-2).

7.2.3.2.2.3 *Polychlorinated biphenyls (PCBs)*

PCBs are environmental contaminants of concern due to their general resistance to metabolism and their tendency to biomagnify.

Table 7-2

Mean concentrations (ppb, wet weight) of organic pollutants detected in tissues of Dungeness crab collected from SWOO Reference and Outfall areas 1997 - 2012, and other available study data (actual concentrations may be less than value indicated when one-or-more replicates were below detection limits).

Crab Muscle

		Reference area															
CFCP		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
6	Σ DDTs	-	13	5	15	-	8	11	**10**	11	17	7	10	6	5	9	3
	Σ PAHs	22	-	-	95	**324**	494	57	20	33	4	99	11	16	19	-	2
9	Σ PCBs	-	-	-	36	-	-	2	2	4	2	2	-	-	-	-	-
		Outfall area															
CFCP		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
6	Σ DDTs	-	21	5	13	-	6	10	8	13	12	16	15	4	4	4	5
	Σ PAHs	25	-	-	69	46	281	9	18	31	10	75	5	18	19	4	4
9	Σ PCBs	-	-	-	3	-	-	**6**	-	4	2	-	2	-	-	-	-

Crab Hepatopancreas

		Reference area															
CFCP		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Σ DDTs	231	473	522	270	136	155	121	86	57	46	118	67	101	4	71	32
	Σ PAHs	18	-	-	6	22	111	**168**	7	33	4	262	10	10	66	2	-
	Σ PCBs	56	162	366	127	198	194	95	61	19	32	101	71	70	28	41	28
		Outfall area															
CFCP		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Σ DDTs	307	460	300	171	132	195	135	85	61	57	143	59	65	4	61	43
	Σ PAHs	-	48	-	9	14	86	98	39	24	5	272	8	11	52	10	-
	Σ PCBs	164	153	326	130	159	167	87	50	20	22	154	47	65	29	37	43

\- = below detection limits

Blue font = statistically significantly higher than corresponding tissue at other area; one-tailed T-test, unequal variance, $\alpha = 0.05$

CFCP - California Fish Contamination Program (RWQCB 2005, CEDEN 2010)

Organisms at the top of the food web (including humans who consume fish and shellfish) are, therefore, vulnerable to the effects of PCB exposure (U.S. EPA 1997, 1999), which can lead to toxic effects such as developmental abnormalities and growth suppression, disruption of the endocrine system, impaired immune function, and cancers (ATSDR 2000, 2010).

Levels of total PCBs in crab tissues were generally low (near detection limits, Appendix G-2), except in hepatopancreas of crab from both the reference and outfall areas (Table 7-2), as were concentrations of individual PCB-congeners (Appendix G-3).

PCBs of high concern were detected primarily in hepatopancreas of organisms from both the outfall and reference areas throughout the study years. The PCB congeners of most concern are PCB 77, PCB 126, and PCB 169, which closely mimic the potency of dioxin, one of the most toxic substances identified (SFEI 1999a, U.S. EPA 1996). PCB 126, which has the potency one-tenth that of dioxin, was detected in hepatopancreas of crab from both reference and outfall areas at levels generally near detection limits from 1999 to 2004, and not at all since 2004 (Appendix G-3).

7.2.3.2.2.4 *Trends*

None of the regressions involving sediment and tissue concentrations of these organic compounds (total DDTs, total PAHs, total PCBs) are significant (regression analysis, $\alpha = 0.05$). There appears to be a trend of decreasing PCB-levels in hepatopancreas of crabs from both reference and outfall areas over time (regression analysis, $\alpha = 0.05$), but those levels are generally detected near-or-below detection limits, and conclusions about them should be made cautiously.

7.2.3.2.2.5 *Other studies*

Comparisons of SWOO data with other local studies is limited due to differences in species composition, numbers, or organisms assessed, and the types of tissues and contaminants analyzed in each study. Body burdens of organic pollutants in Dungeness crab from the San Mateo coast assessed in the California Fish Contamination Program (CFCP) (RWQCB 2005, CEDEN 2010) are generally similar to those levels found in the SWOO study data (Table 7-2).

7.2.3.3 Inorganic Analyses – Trace Metals

7.2.3.3.1 Survey Year 2012

In 2012, there were no statistically significant differences in trace metal concentrations in tissues of organisms collected from the reference and outfall areas, and individual analyte concentrations are similar to previous years (Table 7-3).

7.2.3.3.2 Survey Years 1997 – 2012

For survey years 1997 – 2000 wet-weight data for trace metals are unavailable, making comparisons with data from subsequent years inappropriate; those dry-weight data and T-test results are in Appendix G-5.

Concentrations of trace metals analyzed 2001 – 2012 were similar, in all years for muscle and hepatopancreas of organisms from both reference and outfall areas (Table 7-3). Comparisons of metal concentrations indicated five (out of 312 comparisons) statistically significantly elevated trace-metal levels (iron, manganese, silver, nickel, and lead) in tissues of organisms from the outfall area compared to the reference area within sample years (Table 7-3), and none since 2004. Silver and zinc in muscle, and chromium in hepatopancreas, were detected at statistically higher levels in tissues of organisms from the reference area (compared to the outfall area) in 2003.

7.2.3.3.2.1 *Trends*

Metals bioaccumulation in tissues of crab from both reference and outfall areas were similar for the entire study period, with no statistically significant trends and little pattern apparent in those concentrations (regression analysis, $\alpha = 0.05$). The exception is iron, detected in decreasing concentrations in

Table 7-3

Mean concentrations (ppm, wet weight) of trace metals detected in tissues of Dungeness crab collected from SWOO Reference and Outfall areas from 2001 to 2012, and other available study data (actual concentrations may be less than values indicated when one-or-more replicates were below detection limits).

Crab Muscle													
		Reference area											
CFCP		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Silver	0.14	0.17	**0.07**	0.43	0.23	0.10	0.21	0.08	0.19	0.17	0.12	0.09
	Aluminum	1.6	1.8	4.0	1.4	3.4	3.3	68.6	7.71	1.74	-	<0.47	<3.44
11.3	Arsenic	11.5	10.5	12.4	13.7	11.3	16.8	17.7	5.8	14.7	10.9	14.0	13.0
0.14	Cadmium	-	0.02	0.02	<4.30	0.03	<0.02	0.04	0.04	0.03	0.02	<0.02	<0.01
	Chromium	0.1	-	0.02	0.18	0.34	<0.07	0.04	0.02	0.01	0.02	<0.03	<0.01
	Copper	6.8	9.9	9.2	19.1	7.3	5.4	10.5	2.9	8.2	7.4	5.2	4.8
	Iron	4.4	3.5	5.6	26.9	6.2	4.4	4.9	2.3	3.2	2.8	<0.5	2.3
0.25	Mercury	0.07	0.05	0.04	0.06	0.07	0.08	0.15	0.05	0.14	0.11	0.13	0.14
	Manganese	0.20	0.13	0.14	0.58	0.44	0.10	0.60	0.11	0.12	0.10	0.10	<0.11
	Nickel	-	0.07	0.02	<0.73	<0.05	0.08	0.06	0.02	0.03	0.04	<0.04	<0.02
	Lead	-	-	<0.02	-	0.04	0.03	<0.53	<0.01	<0.02	-	<0.02	<0.01
0.73	Selenium	0.6	0.8	0.6	1.2	0.6	0.9	0.7	0.2	0.7	0.4	0.5	0.4
	Zinc	28	29	**37**	30	27	35	37	16	42	31	35	33
		Outfall area											
CFCP		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Silver	0.17	0.15	0.05	0.15	0.26	0.11	0.25	0.10	0.18	0.17	0.13	0.08
	Aluminum	2.2	3.2	4.2	1.1	2.8	2.8	92.4	13.5	1.9	-	<6.3	<3.3
11.3	Arsenic	12.3	10.2	11.1	13.1	10.6	14.6	19.7	8.9	13.2	10.8	16.0	12.70
0.14	Cadmium	-	0.02	0.02	0.01	0.01	7.18	0.03	0.02	0.03	0.02	<0.02	<0.01
	Chromium	0.6	-	0.03	0.02	0.03	<0.05	0.06	0.02	0.01	0.02	<0.05	<0.01
	Copper	8.3	8.9	7.4	7.5	7.4	6.1	12.8	5.1	7.8	7.7	6.7	4.5
	Iron	10.3	**4.0**	5.6	3.2	4.4	4.0	4.6	3.0	3.3	3.8	<0.9	<2.6
0.25	Mercury	0.06	0.05	0.05	0.05	0.07	0.07	0.14	0.11	0.14	0.10	0.13	0.12
	Manganese	0.20	**0.17**	0.14	0.12	0.28	0.10	0.60	0.22	0.13	0.10	0.12	<0.11
	Nickel	-	0.04	0.02	0.08	0.06	0.08	0.06	0.03	0.03	0.04	<0.10	<0.02
	Lead	-	-	-	-	0.05	<0.20	0.58	<0.01	<0.01	-	<0.02	<0.01
0.73	Selenium	0.5	0.8	0.6	0.6	0.6	0.7	0.8	0.3	0.1	0.4	0.5	0.5
	Zinc	28	32	34	29	29	34	39	22	41	33	38	33
Crab Hepatopancreas													
		Reference area											
CFCP		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Silver	0.32	0.47	0.25	0.84	2.66	1.45	1.46	1.56	0.54	1.49	1.34	0.08
	Aluminum	2.3	4.4	1.6	5.0	6.6	8.2	9.1	29.3	9.1	1.33	1.64	<3.01
10.1	Arsenic	14.4	11.0	13.5	15.6	11.4	24.4	24.5	19.2	18.2	14.5	13.4	11.4
5.53	Cadmium	17.0	15.9	15.8	10.1	20.7	<18.6	19.8	25.0	20.6	12.4	18.7	0.01
	Chromium	0.10	0.07	**0.09**	0.14	0.12	0.14	0.06	0.31	0.10	0.10	0.10	0.01
	Copper	12	22	29	40	66	61	45	69	18	66	41	4
	Iron	89	83	70	54	77	87	65	86	128	63	86	2
0.19	Mercury	0.08	0.06	0.04	0.06	0.08	0.08	0.15	0.10	0.13	0.08	0.10	0.12
	Manganese	1.6	1.5	1.7	1.1	1.9	1.8	1.7	1.8	1.7	1.4	1.7	0.1
	Nickel	1.00	1.60	1.15	<1.12	4.38	5.45	1.53	1.69	1.73	1.82	1.32	0.02
	Lead	-	0.03	0.05	<0.04	0.11	0.11	<0.03	0.03	0.04	0.01	<0.05	0.01
1.36	Selenium	3.4	3.9	3.1	2.2	3.3	4.6	3.1	2.5	3.1	2.2	2.7	0.4
	Zinc	32	39	36	36	45	61	37	40	38	24	45	29
		Outfall Area											
CFCP		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Silver	0.40	0.36	**0.39**	0.94	1.76	0.92	1.55	1.17	0.78	1.87	1.38	0.08
	Aluminum	2.6	2.7	2.3	6.8	9.7	5.9	8.9	29.0	6.1	0.8	2.5	<3.02
10.1	Arsenic	14.4	11.0	13.0	12.3	9.9	14.1	28.9	23.3	17.8	13.3	14.9	11.6
5.53	Cadmium	14.3	13.7	15.0	13.5	20.9	13.1	22.1	24.6	29.9	18.6	14.7	0.01
	Chromium	0.10	0.06	0.07	0.13	0.10	0.10	0.08	0.19	0.11	0.10	<0.10	0.01
	Copper	16	16	35	39	45	45	51	97	30	82	50	4
	Iron	85	90	72	81	80	71	67	93	115	73	86	2
0.19	Mercury	0.07	0.06	0.05	0.06	0.08	0.06	0.18	0.10	0.14	0.63	0.11	0.11
	Manganese	1.6	1.6	1.6	1.7	1.6	1.4	1.7	1.9	1.9	1.1	1.8	0.1
	Nickel	0.67	1.40	0.95	**2.66**	3.39	5.39	1.18	1.53	1.96	1.96	1.51	0.02
	Lead	-	0.05	<0.02	**0.06**	0.10	0.07	-	0.06	0.04	0.03	<0.07	0.01
1.36	Selenium	3.0	3.3	2.8	3.4	3.2	3.4	2.4	3.0	3.1	2.5	2.7	0.4
	Zinc	31	36	32	45	50	42	33	42	52	33	42	30

- = below detection limits

Blue font = statistically significantly higher than in tissue at corresponding site; one-tailed T-test, unequal variance, α = 0.05

CFCP - California Fish Contamination Program (RWQCB 2005, CEDEN 2010)

hepatopancreas of crab from the outfall area. Overall, it appears that there is little evidence for substantial bioaccumulation of these trace metals in crab tissues at either the reference or the outfall areas.

7.2.3.3.2.2 *Other studies*

Body burdens of trace metals in Dungeness crab collected from the San Mateo County coast assessed in the CFCP (RWQCB 2005, CEDEN 2010) are generally similar to those levels found in both the SWOO-study reference and outfall areas (Table 7-3).

7.3 SUMMARY AND CONCLUSIONS

Overall organism condition (based on frequency of observed anomalies) and concentrations of pollutants analyzed in tissues of organisms collected from the SWOO study area were similar between reference and outfall regions in both muscle and hepatopancreas. This similarity indicates that the SWOO discharge does not appear to affect organism body burdens of these pollutants. The bioaccumulation data demonstrate that concentrations of organic pollutants and trace metals are found in varying levels and tend to accumulate in the fatty hepatopancreas tissue, so this kind of monitoring may be important in the management of the fishery as well as for public health issues. Historically, crab hepatopancreas (crab ‘butter’) has been considered a delicacy and continues to be eaten by portions of the population; public awareness and education may be important to inform people that those tissues may not be suitable for consumption. Consequences of increased body burdens of organic pollutants (e.g. resulting in potential immunological and reproductive impairment) or trace metals (e.g. resulting in neurological damage) on the health of the organism populations are unknown at this time. Variable contaminant concentrations in tissues of organisms from reference and outfall regions, and between sampling years, may be attributable to species selection; these organisms are mobile and therefore not necessarily representative long-term residents of the locations from which they are collected. These data likely reflect the general concentration of bioaccumulated contaminants from the entire SWOO study area and this region of the California coast.

Of those pollutants detected at elevated levels, most were detected in hepatopancreas tissues. These data provide further evidence of the importance in educating the population against eating whole organisms that include organ tissues, and recommending limiting consumption to muscle tissues.

SECTION 8

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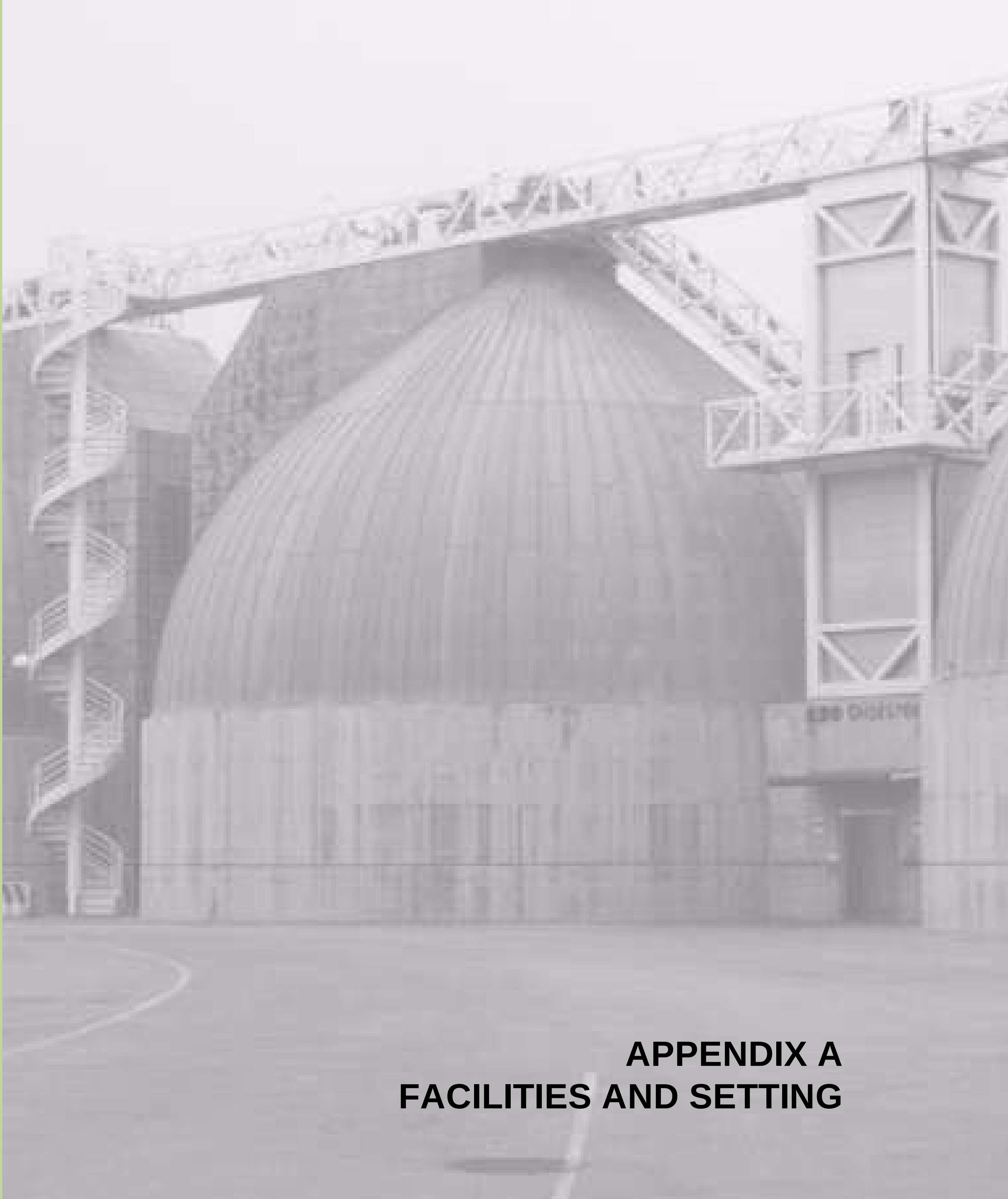

APPENDIX A
FACILITIES AND SETTING

APPENDIX A
FACILITIES, MONITORING HISTORY, AND SETTING

A.1 FACILITIES AND SYSTEM

A.1.1 COMBINED SEWER SYSTEM

The City and County of San Francisco (City) has a combined sewer system that collects domestic sanitary flow, industrial effluents, and urban stormwater runoff. Components of the system include a network of sewer pipes, catch basins and transport structures. Prior to 1982, the collected wastewater was treated at three primary treatment plants, which had a combined wet weather capacity of approximately 225 million gallons per day (MGD). The three treatment plants, shown in Figure A-1, included the Southeast Water Pollution Control Plant (WPCP) that served the central and southeastern sections of San Francisco, the North Point WPCP that served the central and northeastern sections of San Francisco, and the Richmond-Sunset WPCP that served the western section of San Francisco. When wet weather caused combined flows to exceed the hydraulic capacity of the combined system, the untreated wastewater was bypassed into San Francisco Bay or the Pacific Ocean. Untreated overflows typically occurred whenever rainfall exceeded 0.02 inches per hour, and contributed to elevated coliform bacteria levels in near shore waters that exceeded public health standards. Swimming beaches were posted throughout the winter, shell fishing was banned, and the aesthetic appeal of the shoreline and coastal areas was greatly diminished due to the presence of sewage-derived floatable materials.

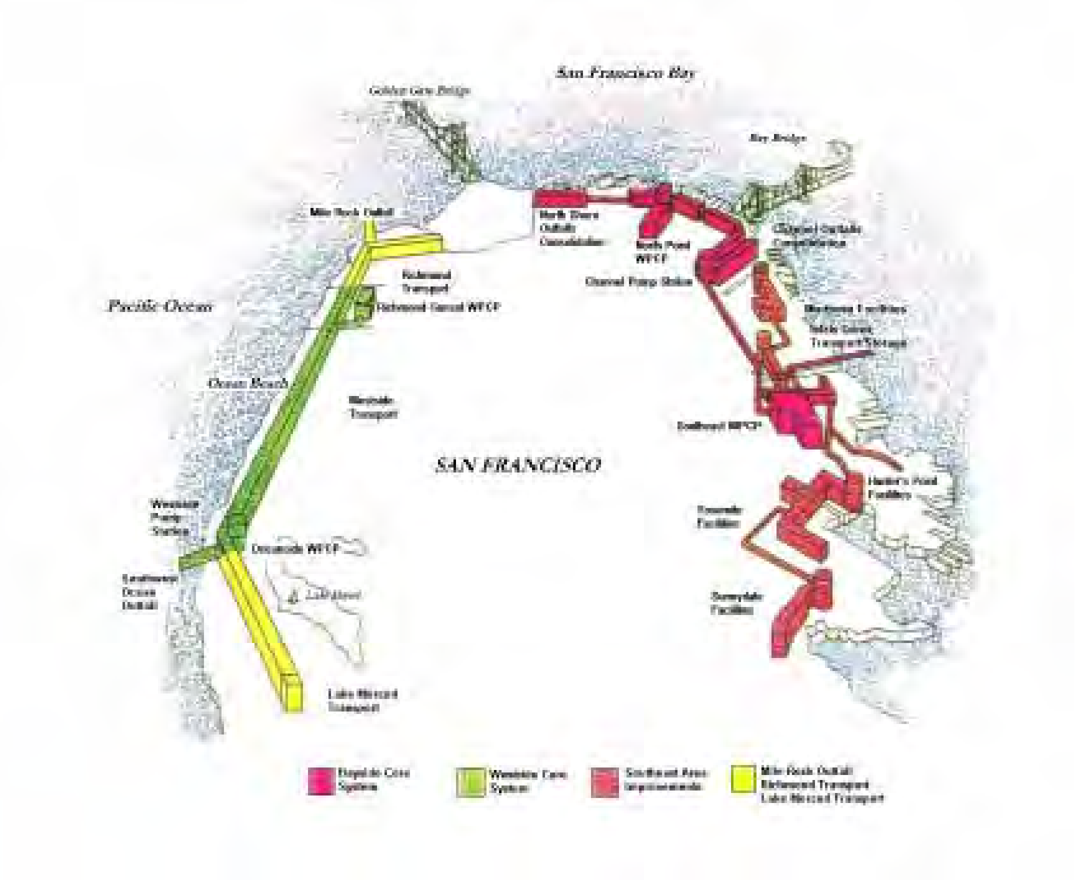

Figure A-1
Components of the San Francisco combined sewer system

In order to reduce overflows, the City prepared a Master Plan for Wastewater Management (DPW 1971). The plan was subsequently updated in 1974 to address requirements in the Federal Water Pollution Act of 1972 that wastewater treatment plants be upgraded to provide full secondary treatment. The main elements of the Wastewater Management Master Plan were (1) upgrade sewage treatment from primary to secondary, (2) construct transport/storage sewage collection systems to reduce combined sewer overflows into receiving waters, and (3) provide for the eventual discharge of all wastewater into the Pacific Ocean via an offshore outfall. A massive construction program was put in effect to meet the goals of the Master Plan.

A.1.1.1 Westside Core System

The Richmond-Sunset WPCP was built in 1939 to provide primary wastewater treatment for predominantly domestic sanitary flow and to reduce raw sewage overflows onto Ocean Beach. The Richmond-Sunset WPCP had a wet weather capacity of 40 MGD. The Westside Core System (Figure A-1) including the Westside Pump Station and the Southwest Ocean Outfall (SWOO) became operational in 1986. Effluent from the Richmond-Sunset WPCP was discharged near Lands End through the Mile Rock outfall (Figure A-1) until September 1986 when it was diverted to the SWOO.

The SWOO had the capacity to discharge both dry and wet weather flow from the Richmond-Sunset WPCP as well as wet weather flow intercepted by the Westside Transport. The Westside Transport went on line in January 1987 and provided an extra 48 million gallons of storage capacity. The Lake Merced Transport was completed in July 1993 and provided an extra 11 million gallons of storage capacity.

The Oceanside WPCP was built as a secondary treatment facility to replace the Richmond-Sunset WPCP and was completed in September 1993. The plant became operational on September 18, 1993 with primary treatment, and went to full secondary treatment on September 27, 1993. The treatment plant has a wet weather capacity of 65 MGD, of which 43 MGD receive full secondary and the remaining 22 MGD receive primary treatment that is blended with secondary flow. The final component of the system, the Richmond Transport, was completed in January 1997, with a storage capacity of 10 million gallons.

A.1.1.2 Bayside Core System

Construction of new sewage facilities in the Bayside Core System (Figure A-1), including the Southeast WPCP, the Channel and Northshore Pump Stations, and conversion of the North Point WPCP to the North Point Wet Weather Facility was completed in 1982. The Southeast WPCP was upgraded to full secondary with a wet weather capacity of 210 MGD, of which 145 MGD were provided with full secondary treatment and the remaining 65 MGD received primary treatment that was blended with secondary flow. Flow from the northeast section of San Francisco during dry weather periods is pumped from the Northshore Pump Station to the Channel Pump Station and then on to the Southeast WPCP for secondary treatment. The North Point facility was converted from a full time primary treatment plant to a wet weather facility providing primary treatment and operating only during wet weather periods. During wet weather, when the hydraulic capacity of the Southeast facilities is maximized, the North Point Wet Weather Facility can provide primary treatment for up to 150 MGD of combined storm water and wastewater.

Other Southeast area improvements included the completion of the Yosemite Facilities and the Griffith Pump Station in 1989, the Sunnydale Facilities in 1991 and the Mariposa Facilities in 1992. The Islais Creek Transport was completed in the summer of 1997. In order to address concerns regarding treated effluent discharged into Islais Creek during wet weather, improvements to the Southeast WPCP were designed and added to the Islais Creek Transport project, which extended the original estimated completion date of 1996. Islais Creek is a shallow-water, dead end channel. During wet weather periods, when the pumping capacity to the Southeast WPCP deep-water outfall to San Francisco Bay was exceeded (100 MGD), a combination of primary and secondary treated effluent was discharged into Islais Creek. Such waste discharges that receive less than 10:1 initial dilution are prohibited in California surface waters and are in violation of requirements in the San Francisco Bay Basin Plan (RWQCB 1986, 1995). Discharges to the Creek occurred approximately 600 hours per year during wet weather. Because of the infrequency of the discharge, the City requested an exception to the Basin Plan from the San Francisco Bay Regional Water Quality Control Board (RWQCB). The exception was granted contingent upon improvements to the Southeast WPCP completed in 1997, which increased the wet weather capacity from 210 MGD to 250 MGD and guaranteed any discharges into Islais Creek would undergo full secondary treatment. Further improvements to the Booster Pump Station at Islais Creek in 2001 increased the pumping capacity to the deep-water outfall from 100 MGD to 110 MGD.

A.1.1.3 Southwest Ocean Outfall (SWOO)

The SWOO is a steel reinforced concrete pipe that extends approximately 7 km (3.75 miles) west-southwest, offshore of the Oceanside WPCP terminating at an approximate depth of 24 meters (mean lower low water) in the near shore Gulf of the Farallones. The end of the outfall consists of a diffuser section approximately 900 meters in length and 3.5 meters in diameter, with risers located every 11 meters that discharge effluent (Figure A-2). Each riser is constructed with eight discharge ports that permit uniform flow to leave the diffuser and maximize dilution by the receiving water.

The hydraulic capacity of the SWOO pipeline with all risers operational is 575 MGD. Because the average daily dry weather flow through the SWOO is only 18 MGD, the circulation of saltwater through the diffusers would impede the discharge of treated effluent under normal dry weather operations if all the diffusers were open. Maintenance of the SWOO diffuser system requires manual manipulation under "hard-hat" diving conditions, making efforts to open or close the diffuser ports as needed to accommodate changes between dry and wet weather flow rates prohibitive. Therefore, a hydraulic analysis was conducted to determine optimum conditions to maintain an adequate port velocity to allow discharge through the ports during both dry and wet weather flow conditions. Results of the analysis indicated average dry weather flow is adequately dispersed to the environment with 21 of the 85 risers operational, and a maximum wet weather flow of 175 MGD can be effectively discharged offshore. Alternate risers located along the outer 460 meters of the diffuser section are active. The Southwest Ocean Outfall became operational in 1986.

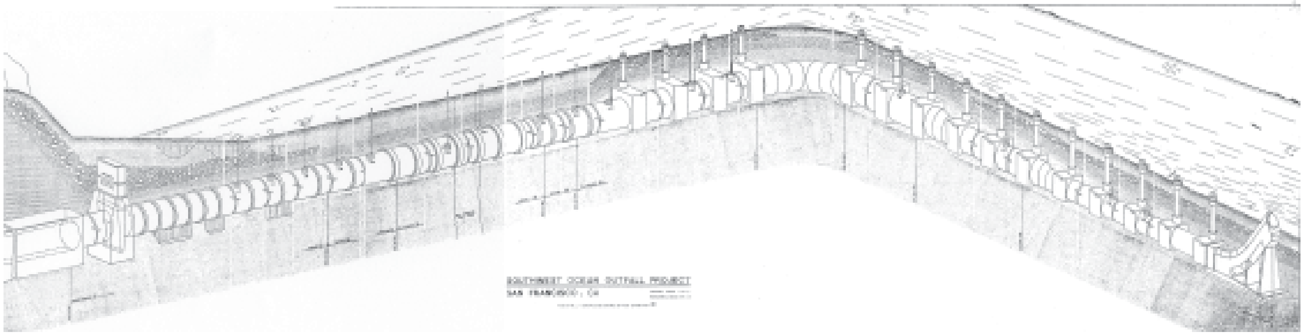

Figure A-2
Southwest ocean outfall pipeline and diffusers

A.2 MONITORING STUDIES

A.2.1 PRE-DISCHARGE STUDIES

Outfall construction was preceded by pre-design physical, chemical, and biological investigations to determine the optimum outfall location. Biological studies included an analysis of the plankton (Brown & Caldwell 1971a, 1971b), the intertidal zone (Brown & Caldwell 1973), the benthic infauna community, demersal fish and epibenthic invertebrate communities (Brown & Caldwell 1975a, 1975b), and bacterial die-off rates (CH_2M Hill and Woodward-Clyde Consultants 1978). Pre-design physical and chemical data collections were conducted from 1977 to 1978 and included oceanographic and water quality measurements, plume behavior studies and a geophysical assessment (CH_2M Hill and Woodward-Clyde Consultants 1978).

During outfall design and construction, pre-discharge oceanographic studies were conducted to further define the baseline conditions at the proposed discharge site. Seasonal sampling was conducted at permanent stations in the near shore Gulf of the Farallones (CH_2M Hill 1980). Specifications for the sampling program were developed in conjunction with the State Water Resources Control Board (SWRCB) and the Marine-Estuarine Technical Committee (METC). Phase I (June 1978 to September 1979) included a continuation of the pre-design receiving water quality program, a benthic infauna community assessment, an assessment of demersal fish and epibenthic invertebrate communities, an analysis of trace metal and organic pollutants in the water, sediments, and fauna, and a review of existing biological and chemical literature and data. Phase II (October 1979 to November 1980) was a continuation of the Phase I program and also included life history studies of four selected benthic infauna species (CH_2M Hill 1983).

In 1982, the City undertook the Pre-discharge Monitoring Program. Monitoring was conducted in the vicinity of the future discharge site following the same study design used previously by CH_2M Hill. To ensure the continuation of a comparative pre-discharge database, every effort was made to preserve procedures and methods between the two studies. This long-term pre-discharge monitoring program focused on physical and chemical water quality and sediment measurements, an assessment of benthic infauna, demersal fish, and epibenthic invertebrate communities, and an analysis of trace metal and organic pollutants in the sediment and fauna. Surveys were conducted three times per year and are summarized for the years 1982-83 and 1983-84 in monitoring program annual reports (BWPC 1984, 1985). Data from October 1984 through 1986 have not been compiled in report format.

A.2.2 POST-DISCHARGE STUDIES

In 1979 the City requested a variance from secondary treatment requirements for the Richmond-Sunset WPCP as allowed under the Clean Water Act, Section 301(h). A tentative decision, which granted the discharge of less than secondary-treated sewage to the Pacific Ocean, was issued under an Administrative Order in September of 1986 (U.S. EPA and RWQCB 1986). The order allowed for diversion of wastewater from the Richmond-Sunset WPCP to the newly constructed SWOO for discharge into the Pacific Ocean approximately 3.75 miles offshore beginning in September 1986.

A.2.2.1 Temporary Monitoring Requirements (1987 to 1989)

A revised temporary monitoring plan for the new discharge site was required in the Administrative Order (U.S. EPA 1986). The new monitoring plan was an expanded version of the pre-discharge plan and included a greater emphasis on water quality monitoring. Shoreline bacteria measurements increased to three times per week year round. The frequency of offshore water quality monitoring increased to monthly surveys. Sampling frequencies for the biological community and pollutant studies remained the same. Summaries of surveys conducted under the Administrative Order during

1987, 1988, and 1989 are presented in annual reports (BWPC 1988, 1989, 1990).

A.2.2.2 Wastefield Transport and Bacteriological Studies

In 1987 the City, jointly with CH_2M Hill and under the guidance of the U.S. EPA, conducted wastefield transport and bacteriological compliance studies to determine movement of the effluent plume (CH_2M Hill 1989). Rhodamine dye was injected into the effluent at the Westside Pump Station. Concentrations of dye were measured in the receiving water with a fluorometer. Once dye concentrations were found in the receiving water, drogues were deployed to evaluate effluent plume transport. Results from these studies determined that the minimum initial dilution of the effluent plume, calculated using dye study data was 100:1, and that the effluent plume moves in a path toward and away from San Francisco Bay, influenced by flooding and ebbing tides. These studies determined that the effluent plume never reached Seal Rocks at Point Lobos outside of the Golden Gate, nor did it move in an onshore direction toward Ocean Beach. Based upon these studies, the U.S. EPA and RWQCB determined that chlorination and subsequent de-chlorination of the effluent was unnecessary for the protection of public health. Shoreline bacteria monitoring conducted year round continues to document that the effluent plume does not reach the shoreline.

A.2.2.3 1990 NPDES Permit Monitoring Program (1990 to 1996)

The City withdrew its request for a variance from secondary treatment requirements in 1989 and began measures to design the Oceanside WPCP as a full secondary dry weather treatment facility. Based on that decision, and after reviewing results from the existing monitoring program and the wastefield and bacteriological compliance studies, the temporary monitoring plan issued under the Administrative Order was revised to a long term National Pollutant Discharge Elimination System (NPDES) monitoring program. The NPDES permit was issued in July 1990 and the receiving water monitoring program was implemented immediately.

The program was designed using a site-specific monitoring strategy to determine whether the outfall contributed to environmental impacts either through physical disturbances or pollutant loading. Stations were located to characterize the outfall zone of initial dilution (ZID), near field and far field areas around the outfall, and a reference site (Figure A-3). This traditional monitoring approach compares impact site characteristics with a reference site, and has the expectation of a gradient of impact between the ZID and the reference site.

The site-specific monitoring program under the NPDES permit differed from the temporary monitoring program implemented under the Administrative Order primarily by reduction of monitoring frequency, elimination of certain analytical parameters, and relocation of sampling stations. Water quality surveys were reduced from monthly to

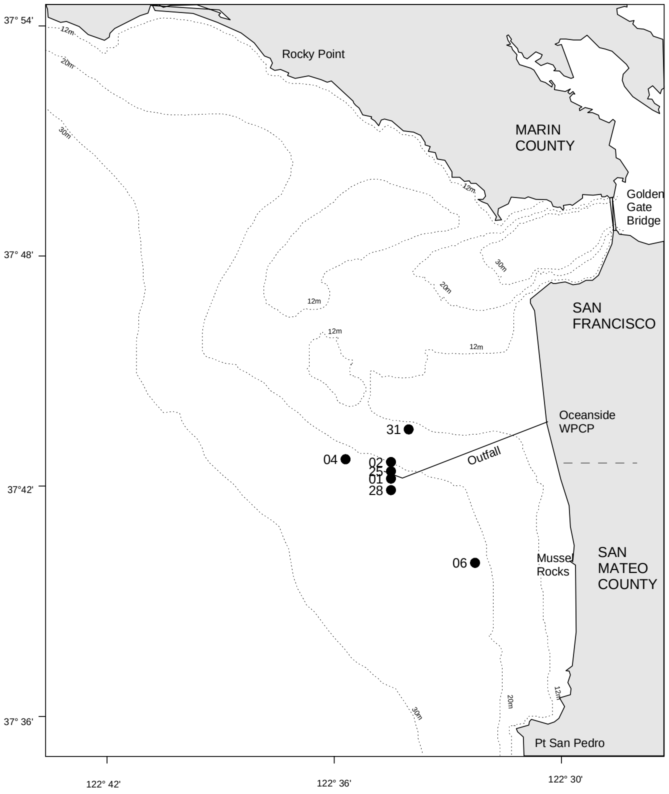

Figure A-3
Site specific monitoring program

quarterly. Demersal fish and epibenthic invertebrate studies, benthic infauna studies, and marine sediments studies were reduced from tri-annual to semiannual, and trace metal and organic contaminant studies for organisms and sediment were conducted annually. Shoreline bacteriological sampling remained unchanged. Offshore stations were relocated to be in alignment with the movement of the effluent plume as determined by the wastefield transport studies (CH_2M Hill 1989). Surveys conducted under the site-specific monitoring permit during 1990, 1991, 1992, 1993, 1994, 1995 and 1996 are summarized in annual reports (BWPC 1992a, 1992b, 1993, 1994, 1995; WQB 1997a, 1997b).

The specific components and objectives of the site-specific program included water quality studies to determine compliance with the California Ocean Plan water quality standards (SWRCB 1997), the location and extent of the wastewater plume, stratification in the water column, and onshore transport of bacteria found in the sewage effluent. Shoreline bacteria levels were monitored to warn the public about bacteria contaminated waters resulting from combined sewer overflows or other sources. Benthic monitoring included sediment studies to evaluate the spatial distribution of physical and chemical sediment characteristics, and to determine the accumulation of organic and inorganic contaminants in sediments in the vicinity of the ZID; and infauna community analyses to determine the presence or absence of a balanced indigenous population. Demersal fish and epibenthic invertebrate studies included community analyses to determine the presence or absence of a balanced indigenous assemblage of species; and bioaccumulation monitoring was conducted to determine the accumulation of organic and inorganic contaminants in the tissues of commercially important species and the potential for transfer to higher trophic levels.

Analyses of ten years of site-specific monitoring data indicated that seasonality was the predominant factor affecting differences between sites in the study area (BWPC 1988, 1989, 1990, 1992a, 1992b, 1993, 1994, 1995; WQB 1997a, 1997b). No evidence of the effluent plume in the water column was detected. Near shore bacteria monitoring provided useful public health information and indicated that no onshore transport of the effluent plume occurred. Sediment chemistry and bioaccumulation studies indicated contaminant concentrations were not unusually elevated. El Niño events contributed to between-year fluctuations in community measures (Kellogg, et al. 1998). A single reference station in the site-specific monitoring program did not provide sufficient characterization of reference conditions. With the large amount of natural variability that existed in sediment and biota, the determination of differences between stations was difficult.

A.3 SETTING

A.3.1 GULF OF THE FARALLONES

Monitoring locations in the SWOO study area lie on the continental shelf within the area known as the Gulf of the Farallones, bordered by Point Reyes on the north and Point San Pedro on the south and extending about 26 nautical miles west of the Golden Gate, to the Farallon Islands. The primary influences on the near shore water quality and sediment characteristics within the Gulf include the broad changes in wind and current conditions that define the oceanographic seasons, tidal ebb, flood, outflow from San Francisco Bay (Brown and Caldwell 1971a,b), and the complex topography of the shelf in this area (Noble and Gelfenbaum 1988). The San Francisco Estuary is a major supplier of fine sediments to the Gulf (Noble and Gelfenbaum 1988), with the magnitude of the effects depending on the season and amount of freshwater outflow from the Sacramento-San Joaquin Rivers. Sediment transport from the estuary also has the potential to transport nutrients and contaminants into the study area. The bathymetry of the continental shelf in the Gulf of the Farallones, with its broad shoaling region east of the Farallon Islands and the northern barrier formed by the Point Reyes Peninsula, may have a major effect on the along-shelf and cross-shelf flows, blocking upwelling and affecting sediment transport in the central regions of the Gulf (Noble and Gelfenbaum 1988).

A.3.2 OCEANOGRAPHIC SEASONS

The California near shore marine climate consists of two major seasons: the California Current season during which the principal near shore current flow is southerly; and the Davidson Current season during which the principal near shore current direction is northerly. The California Current season comprises an upwelling and an oceanic period (Bolin and Abbott 1963, Pavlova 1966, Schwartzlose and Reid 1972).

A.3.2.1 California Current Season

The California current season usually occurs between February or March and November and is divided into an upwelling period and an oceanic period. The current originates near the Canadian border and initially contains water characteristic of the Subarctic current and North Pacific current. As this water moves southward along the Pacific coast, the surface characteristics are modified by solar heating and by the effects of river inflow and exchange with estuaries and embayments.

A.3.2.1.1 Upwelling Period

During the upwelling period, usually beginning in February or March and extending to August or September, stationary high pressure systems offshore produce reasonably persistent north and northwest winds. Due to Coriolis force, these persistent winds along the California coast cause the surface waters to move westward (offshore). Colder, nutrient-rich waters from depth replace the westward moving surface waters. The persistence of winds determines the depth from which upwelling water is derived, as well as the duration of the upwelling. Weather systems are seldom stationary, and thus upwelling may occur sporadically during this period.

A.3.2.1.2 Oceanic Period

In the late summer and fall (August or September to November), the north and northwest winds subside and upwelling ceases. That portion of the California Current season between the cessation of upwelling and the start of the Davidson Current season is identified as the oceanic period. During the oceanic period both ocean surface temperatures and salinities are at maxima.

A.3.2.2 Davidson Current Season

From approximately November to February or March the northward flowing Davidson Current displaces the California Current offshore. During the rainy season, low-pressure systems offshore produce south and southwest winds along the central California coast. Through Coriolis force these winds produce onshore surface water movements. These onshore currents are blocked by the northwest trending coast and gain a northerly direction that generates the Davidson Current. Because the low pressure systems do not remain stationary, the Davidson Current does not occur at all times and the end of the Davidson Current period can be diffuse and difficult to pinpoint (Bolin and Abbot 1963).

A.3.3 El NIÑO AND LA NIÑA EVENTS

The intermittent oceanographic phenomena known as El Niño and La Niña have global weather consequences and may significantly impact water quality and sediment transport in the Gulf of the Farallones by altering normal seasonal climate patterns. El Niño events are characterized by warmer than normal sea-surface temperatures in the equatorial Pacific Ocean. La Niña events are characterized by colder than normal sea-surface temperatures in the equatorial Pacific Ocean. Both types of events can vary in strength and local effects are difficult to predict. Typical El Niño winters are wetter in the southwest United States from southern California eastward through Arizona, southern Nevada and Utah, New Mexico, and into Texas; but drier in the northwest including Washington, Oregon, and the mountainous portions of Idaho, western Montana, and northwest Wyoming. Northern and central California lie in a zone between these two areas and can experience either effect

(WRCC 1998). Generally, in all these regions, La Niña climate effects are approximately, but not exactly, opposite to El Niño climate effects (WRCC 1998). Locally, El Niño winters have included both greater than normal precipitation and drought. Oceanographically, the primary local effects of wet El Niño events are intensified storms and sustained southwest winds that reduce upwelling and result in higher than normal sea surface temperatures (USGS 1999). An unusually strong El Niño event occurred during in 1997-1998 (NOAA 1999a), with over two times the normal annual rainfall recorded in San Francisco (WRCC 1999). This event was followed by a La Niña that caused unusually strong upwelling of cold, nutrient-rich waters off the northern California coast (USGS 1999).

A.3.4 NATIONAL MARINE SANCTUARIES

Three national marine sanctuaries lie partially within or adjacent to the Gulf of the Farallones. Data collected from the SWOO regional monitoring program provide important information relevant to the marine habitat management goals of these marine sanctuaries.

A.3.4.1 Monterey Bay National Marine Sanctuary

The SWOO is surrounded on three sides by the boundary of the Monterey Bay National Marine Sanctuary (MBNMS) (Figure A-4), created in 1992. The Sanctuary includes the waters of Monterey Bay and the Pacific Ocean extending from southern Marin County southward to Cambria in San Luis Obispo County. The MBNMS is 348 nautical miles north to south and extends an average of 30 nautical miles offshore. An exclusion zone which extends off the north coast of San Mateo County and the City and County of San Francisco between Point Bonita and Point San Pedro was originally created to encompass the SWOO, the shipping channel providing access to and from San Francisco Bay, and the Golden Gate dredged material disposal site associated with the shipping channel (NOAA 1992). The sanctuary is managed to balance recreational and commercial uses with protection of natural resources, water quality, habitats, and its bountiful resident and migratory marine life. Major resource management issues in the sanctuary are vessel traffic and its potential impact on living resources and water quality, disposal of dredged material, land-based sources of water pollution, direct and indirect fishing impacts, and impacts of non-native, invasive species (NOAA 1992, 1999a). Ten stations of the SWOO Regional Monitoring Program lie within the MBNMS.

A.3.4.2 Gulf of the Farallones National Marine Sanctuary

Adjacent to the northwest MBNMS boundary, the Gulf of the Farallones National Marine Sanctuary (GFNMS) (Figure A-5), designated in 1981, encompasses 948 square nautical miles including the Farallon Islands on the western edge of the Gulf and near shore tidal flats, rocky intertidal areas, wetlands, subtidal reefs, and coastal beaches north and west of San Francisco. Southeast Farallon Island, 26 nautical miles west of the Golden Gate Bridge in the south central part of the sanctuary, is a national wildlife refuge, with resting and breeding sites for marine mammals and seabirds which benefit from the nutrient-rich waters in the area. The sanctuary has thousands of seals and sea

Figure A-4
Monterey Bay National Marine Sanctuary
(NOAA 1999a)

lions, and is home to the largest concentration of breeding seabirds in the contiguous United States. The resources are protected by managing human activities that may damage habitat and species, supporting restoration projects to revitalize disturbed areas, and conducting monitoring programs to assess changes from natural and human disturbance. Major resource management issues in the sanctuary are oil spills, sewage, toxic chemicals, petroleum products, pesticides, and urban runoff that threaten sanctuary waters (NOAA 1999b). Five stations of the SWOO Regional Monitoring Program lie within the GFNMS.

A.3.4.3 Cordell Bank National Marine Sanctuary

Cordell Bank National Marine Sanctuary (Figure A-6) is an offshore sanctuary about 43 nautical miles northwest of the Golden Gate Bridge. Near the edge of the continental shelf, Cordell Bank rises from the sea floor as the northern most expression of the Farallon Ridge. The water is about 200 feet deep over most of the bank. Along a few of its ridges and pinnacles, this submerged island rises to within 120 feet of the ocean surface. Upwelling of nutrient rich ocean waters and the bank's topography create one of the most biologically productive areas on the West Coast. Cordell Bank was designated a marine sanctuary in 1989 in recognition of the significant value of this marine habitat. The sanctuary covers 397 square nautical miles of Pacific Ocean including and surrounding Cordell Bank. Algae, fish, and invertebrates proliferate, and the site is a lush feeding ground for many marine mammals and seabirds. Endangered humpback whales, Dall's porpoises, albatross, shearwaters, and countless other marine species flourish in this rich marine environment (NOAA 1999c).

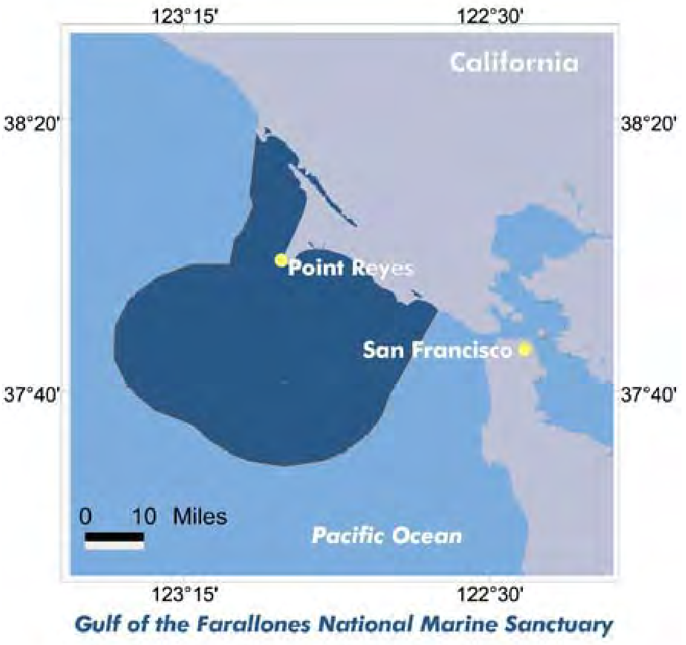

Figure A-5
Gulf of the Farallones National Marine Sanctuary (NOAA 1999b)

Figure A-6
Cordell Bank National Marine Sanctuary (NOAA 1999c)

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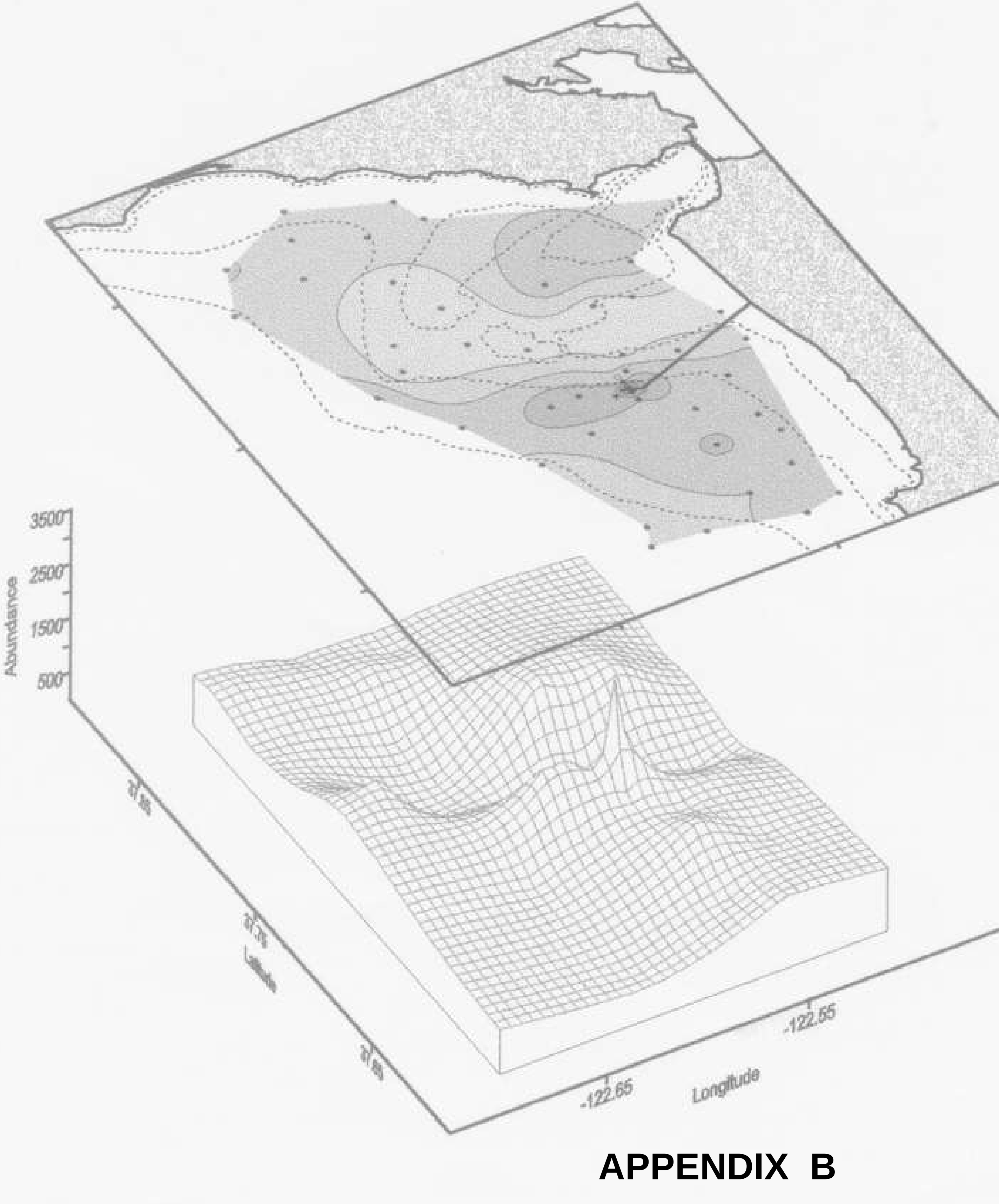

APPENDIX B

STATISTICS METHODS

APPENDIX B
STATISTICAL METHODS

by

Michael L. Johnson, Dorothy Norris and Robert W. Smith[1]

B.1. SUMMARIZATION OF SEDIMENT GRAIN SIZE DATA

Using the fractions of sediment in the different measured size classes, the standard sediment-size distribution parameters of mean, standard deviation, skewness, and kurtosis are computed for each sediment sample (Folk and Ward 1957). The sediment-size intervals are expressed in phi (ϕ) units, which are computed as $-\log_2(\mathit{size\ in\ mm})$. Higher values in phi units indicate finer sediments.

The mean of the sediment size distribution is a measure of the overall sediment size. The standard deviation (SD) is a measure of the sorting of the sediment. A sediment sample with a relatively large SD contains a wide range of sediment sizes, and is poorly sorted. Thus, the SD and the degree of sorting are inversely proportional. Skewness is a measure of the asymmetry of the sediment-size distribution. Sediment distributions with positive skewness have an elongated tail toward the finer sizes (higher phi intervals), and distributions with negative skewness have an elongated tail toward the coarser sediments. Kurtosis is a measure of the peakedness of the sediment distribution in relation to the tails distribution. A sediment sample with a relatively larger proportion of sediment in the middle of the distribution (compared to the tails) has a higher value of kurtosis.

The sediment grain size summary statistics and percentages in the individual grain size categories were used in a Principal Components Analysis to understand the patterns of variation in grain size in the sediment data. Correlations between the summary statistics and the percentages in the phi categories were performed as part of the PCA. The mean phi value was positively correlated with phi values between 3 and 4 and significantly negatively correlated with phi values between 0 to 1 and 1 to 2 indicating the prevalence of small grained sediments across the majority of the sample sites.

There are two rules of thumb for retaining eigenvalues and their corresponding eigenvectors in a PCA. The first rule is to retain all values with eigenvalues greater than 1.0 as this is the value at which their explanatory power exceeds the explanatory value of an individual variable. The second rule involves using a skree plot; plotting the value of the eigenvalue from largest to smallest and determining the location where the values “level off”, i.e., the percent of the variation in the dataset that is explained by the axes does not vary substantially and is at some arbitrarily low value.

Nine of the 13 eigenvalues had values larger than 1.0 and the skree plot suggested that all 9 eigenvalues provided some explanatory value in the analyses. However, the first four axes accounted for approximately a 50% greater amount of the variance than the next 5 axes. Overall, the amount of variation explained by the first four axes was 60.8% compared to the 92.7% explained by the 9 eigenvalues. Interestingly, there was no one major principal axis that explained a majority of the variation in the data set. This suggests that there is significant variation across the monitoring locations in their grain size characteristics.

B.2. COMMUNITY PATTERN AND CORRELATIONAL ANALYSES

Multivariate techniques are first used to elucidate community patterns in the biological data. Subsequently, correlation analyses are performed to assist in forming hypotheses as to possible environmental causes of these community patterns. This approach is detailed in Smith et al. (1988) and Clarke and Warwick (2001).

B.2.1. DEFINING COMMUNITY PATTERNS

B.2.1.1. Spatial Patterns of Biological Communities

The spatial patterns of the biotic communities in the survey area are explored with ordination and cluster analysis. Ordination and cluster methods are used to distinguish groups of entities (e.g. stations) according to similarity or dissimilarity of attributes (e.g. species) (Tetra Tech 1982). The Bray-Curtis index of dissimilarity (Bray and Curtis 1957) is used to compute a similarity matrix between all possible station pairs. The Bray-Curtis similarity index is based on the abundance and distribution of species within and between samples and ranges from 0.0, with complete similarity, to 1.0, with complete dissimilarity

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[1] Deceased 2005.

between stations. The index is calculated as:

$$S_{jk} = 100\left[1 - \frac{\sum_i | X_j - X_k |}{\sum_i (X_j + X_k)}\right]$$

where X_{ij} is the abundance of species *i* at station *j*, and X_{ik} is the abundance of species *i* at station *k*. The species abundances are transformed by a square root prior to computation of S_{jk}. In some cases, dissimilarity indices are calculated to find differences in communities using the following formula: $D_{jk} = 100-(S_{jk}*100)$.

B.2.1.2. Ordination Analysis

Non-metric Multi-Dimensional Scaling (NMDS) analysis using Bray-Curtis similarity values described above was used for the benthic and trawl data (Clarke and Gorley 2006). NMDS does not use axes, but constructs a configuration of samples in a specified number of dimensions based on rank similarities (or dissimilarities). Individual abiotic variables can be tested against the distribution of biotic data as described below in Section B.2.1.3.1.

B.2.1.3. Cluster Analysis

Cluster analysis defines groups of stations with similar species composition and abundance. The results are displayed in a hierarchical tree-like structure called a dendrogram. On the dendrogram, two groups are first defined, and within these groups subgroups are defined. Subsequently, subgroups within the subgroups are defined. This process is continued until all stations are a separate subgroup. The hierarchical nature of the dendrogram allows the analyst to choose groups of stations that represent a scale of relevant community differences.

Cluster analysis is also used to define groups of species that tend to have similar distributional patterns among stations.

B.2.1.3.1. SIMPER program

The composition of the cluster groups of samples was explored using similarity percentage analysis (SIMPER; Clarke 1993, Clarke and Gorley 2006). SIMPER, a module of the Primer v6 software, identifies species that account for the Bray-Curtis dissimilarities observed within and between groups of samples. The SIMPER routine computes mean Bray-Curtis similarity values found within user-defined groups of samples as well as between-groups dissimilarity. The SIMPER routine also ascribes the relative contribution of each species to within-group similarity, and between-groups dissimilarity, as well as reporting the average abundance and variability of each species within each group.

B.2.2. CORRELATIONS BETWEEN BIOLOGICAL COMMUNITY PATTERNS AND ENVIRONMENTAL PATTERNS

To evaluate possible causes of community patterns, as defined by the ordination and cluster analyses, further analyses correlating community patterns with sediment chemistry and size measurements are performed.

B.2.3. COMMUNITY PARAMETERS

The conceptual model of Pearson and Rosenberg (1978) predicts patterns of change for certain community parameters in response to organic enrichment. The following community parameters are computed for comparison with the model predictions.

Community parameters of total abundance and three diversity indices are computed. The Shannon-Weiner diversity index (H') is computed as

$$H' = -\sum_{i=1}^{s} p_i \cdot \ln(p_i)$$

where p_i is the proportion of species *i* in the sample, s is the number of species, and ln is the natural logarithm (Pielou 1969). Shannon and Weaver (1949) devised this formula to represent the amount of information present per symbol of a code composed of s discrete symbols whose individual probabilities are p_i. In an ecological context, H' measures the diversity per individual in a multi-species community, and is a measure of the uncertainty associated with knowing the species of a randomly drawn individual from the community. This uncertainty is greater when there are more species present and when individuals are distributed more evenly among the species. Thus, H' is sensitive to both the richness and the evenness components of diversity.

An index of evenness (J') diversity is computed as

$$J' = \frac{H'}{\ln(s)}$$

When individuals are completely evenly distributed among the species, H' is equal to ln(s). Thus, the ratio J' indicates how close the community is to this maximum evenness value, with a J' value of 1 representing perfect evenness.

B.2.4. REFERENCE ENVELOPE

To investigate whether the outfall has caused a change in any community metric for either the benthic infauna or the demersal fish, several metrics were calculated for each biological endpoint. The comparisons of interest were each community measure from stations near the outfall with the same community measure from the reference stations. Traditional inferential statistics would apply a test such as an analysis of variance to these data but an alternative approach is to calculate tolerance envelope values for the reference stations and determine if there were systematic exceedances of the outfall stations relative to the tolerance envelope values (Smith 1995, 2001).

The analysis assumes that the reference sites are a random sample from all possible reference locations. Any metric calculated from this sample represents the distribution of values of that metric calculated from the entire population. The comparison of interest is the metric from the sample collected from the outfall population with the distribution of values from the reference sites.

The specific comparison of interest is the percentiles in the outer extremes of the reference distribution. If the value of the metric from an outfall site exceeds an extreme percentile of the reference distribution, for example the 90th percentile, it is likely that the outfall has affected the metric at the outfall sample location, i.e., it is unlikely that the value of the metric from the outfall site is from the same distribution as the reference sites.

The tolerance interval bounds are confidence intervals for a percentile of the reference distribution. In this case, the null hypothesis is that the outfall and the reference samples are collected from the same population, i.e. the outfall sites are no different from the reference sites with respect to the measured parameters. The alternative hypothesis is that the outfall sites are different from the reference sites with respect to the measured parameters. The difference could be a result of either the outfall sites having a much larger value of the parameter of interest (greater than the 90th percentile) relative to the reference sites, or the outfall sites having a much smaller value of the parameter of interest (less than the 10th percentile) relative to the reference sites.

To complete the analyses, it is necessary to determine the percentile of interest P, i.e. the percentile value of the distribution that is considered to be an extreme value. Values too near the mean, e.g. the 60th percentile, increase the risk of concluding that the outfall has caused an affect on the metrics at the outfall sites. Values distant from the mean, e.g. the 99th percentile, increase the risk that any real effect of the outfall on the fauna would be missed. The 90th percentile was selected as the upper extreme value and the 10th percentile was selected as the lower extreme value. These percentiles were subjectively chosen to balance between environmental protection (sensitivity to impacts) and avoidance of false indications of impact (Smith 1998). It is also necessary to assign a value α, for the confidence estimate. In this analysis, α was selected as 0.05 which provides a 95% confidence interval for the percentile. The tolerance interval is the confidence interval calculated for the percentile of interest. In this analysis, a 95% tolerance interval was calculated for the 90th percentile and the 10th percentile of the reference distribution.

The tolerance interval is calculated differently depending on whether the reference sample is normally distributed or not. If the reference sample is not normally distributed, the data could be transformed to bring them into normality, or a non-parametric method used for the calculation. To facilitate interpretation of the data, the data were not transformed and the non-parametric method for calculating the tolerance envelope was used. A second assumption of the analysis is that the samples are independent. Samples collected yearly at the same location may not be independent. Autocorrelation analyses were used to determine if the samples from consecutive years were similar. The autocorrelation analysis calculates a correlation coefficient between values of any metric of each year and the following year (lag of one year), for each year and two years later (lag of two years), for each year and three years later (lag of three years), etc. If there are 20 years of data, the one year lag correlation value is calculated from the 19 consecutive year pairs, the two year lag correlation is calculated from the 18 two-year pairs, etc.

The data were checked for normality using the

Shapiro-Wilk W test statistic. The Shapiro-Wilk test is one of the most commonly used statistics to test the null hypothesis that the sample data are taken from a normally distributed population. It is not a definitive test and there exist additional tests for normality. However, the Shapiro-Wilk test is generally considered to be one of the best tests for small to medium sized samples.

Fish data (1982-2008) were analyzed by autocorrelation analysis to determine if there were any significant correlations between adjacent years. A significant correlation would indicate a lack of independence in the fish fauna across years. None of the variables had any significant autocorrelations at any time lag indicating independence across years in the samples of the fish fauna. Also, there was no indication of any significant periodicity in the data that could violate the assumptions of independence of samples.

All data were analyzed for normality. For those data that were determined to be normal, the 90% upper and lower tolerance envelope values were generated using the method described in Hahn and Meeker (1991). Briefly, for normally distributed data, the two sided tolerance interval bound was generated using the formula

$$b = \bar{x} \pm g_{(1-\alpha/2;, p; n)}s$$

Where *b* are the upper and lower tolerance bounds, x is the mean, *s* is the standard deviation of the sample, *p* is the percentile of interest, *g* is the constant appropriate for the value of α/2 or α and selected confidence interval of the percentile which is calculated as 100(1- *α/2*) (or (100 – *α*). The value of *α/2* is appropriate for the case where both the upper and lower tolerance envelope values are desired and the probability of an exceedance, in either direction, is set at the level *α*. For this analysis, the confidence intervals were selected to be 90%. For normally distributed samples, values of *k* were taken from Table A.11b in Hahn and Meeker (1991).

For variables that were not normally distributed, non-parametric tolerance envelope values were calculated according to the method described in Chapter 5 of Hahn and Meeker (1991). Briefly, the values are ordered from smallest to largest and the number of extreme observations from each end of the distribution are found in Table A.16 of Hahn and Meeker (1991) that enclose 90% of the population at an *α* of 0.05. The number of values is matched to the numeric value in the sequence of numbers and those values become the upper and lower tolerance values.

B.3. BIOACCUMULATION

Three analyses were performed: 1) determine if there are trends in the concentrations of metals in fish and crab tissues at the reference and outfall sites over time, 2) determine if there are differences in the concentrations of each metal from individual tissues between reference and outfall sites, and 3) determine if there are trends in the concentrations of metals in tissues at the reference and outfall sites (bioaccumulation of metals) over time.

The first analysis was performed using a linear regression of concentration against time. The slope of the regression line provides a measure of trend, and the significance of the regression slope indicates whether the trend is statistically significant. The null hypothesis for the regression slope analysis is that the slope is equal to 0 (H_0: $b_1 = 0$), and the alternative hypothesis is that the slope is unequal to 0 (H_A: b_1 <>0). The residuals of all regressions were examined to determine if the assumption of linearity was reasonable, or alternatively, if the residuals indicated that a nonlinear model would be a better fit. In no instances were the residuals suggestive of a nonlinear fit indicating a linear regression was an adequate model for the data.

The second analysis was performed using either a one-tailed paired t-test with unequal variances or a Mann-Whitney U test for differences in the median concentration. Prior to performing each of these analyses, all data were checked for normality using a variety of test statistics. If any of the test statistics indicated that the data were normally distributed, the t-test was used. If any of the test statistics indicated the data were non-normal, the Mann-Whitney test was performed to determine if there were differences in concentration between reference and outfall sites.

The third analysis was performed using a linear regression of concentration in the tissue against concentration in the sediment. Again, the slope of the regression line provides a measure of trend and the significance of the regression slope indicates whether the trend is statistically significant. The null hypothesis is that there is no relationship between the concentration in the tissue and the concentration in the sediment (H_0: $b_1 = 0$), and the alternative is that there is a significant relationship between sediment and tissue concentration (H_A: b_1 <>0). As in the first analysis, the alternative is a two-tailed test which means the tissue concentration could be either lesser or greater than the sediment concentration of any metal, i.e. as the concentration of the metal in the sediment increases, the concentration of the metal in the tissue could either increase or decrease. A slope of 1.0 indicates that the concentration of metal in the tissue and sediment increase at the same rate. A slope different from 1.0 indicates that the rate of increase in the tissue concentration is either higher or lower than the increase in the concentration of the metal in the sediment.

In all of these analyses, the large number of metals, organisms, and tissues, results in an equally large number of tests performed. In this case, there is a danger of inflating the Type I error rate when evaluating the hypotheses. When performing 100 tests for differences in the concentration of metals between two locations (e.g. reference and outfall) using an α = 0.05 indicates that there is a 5% chance that one will incorrectly reject the null hypothesis of no differences between sites and accept the alternative hypothesis that the sites differ in the concentration of the metals when no difference exists. In the second analysis, 52 tests (either one-tailed t-tests or Mann-Whitney U tests) were performed to determine if the concentration of metals differed between the reference and outfall sites. In this case, with α = 0.05, 2.6 (3) tests would be expected to falsely reject the null hypothesis. There are two general methods to correct this problem that are commonly used in statistical analyses: Bonferroni corrections, or the use of False Discovery Rate techniques. The Bonferroni corrections involve dividing the α value by the number of tests either at the beginning of the evaluation, or sequentially during the evaluation of the hypotheses. In the case of the second analysis above, the α = 0.05 value would be divided by either 104 at the beginning of the analysis making α = 0.00048 the p value necessary for a statistically significant difference in each individual test (Bonferroni correction), or divided sequentially by the number of significant tests (sequential Bonferroni). Consequently, for the first significance test, the value of α = 0.05 (p value) is used. For the second significance test, α = 0.025 (p value) is necessary to reject the null hypothesis, for the third significance test α = 0.0125 is necessary to reject the null hypothesis, and so on.

Both the Bonferroni and sequential Bonferroni corrections are generally considered too conservative and result in very few statistically significant differences. The alternative is to use recently developed False Discovery Rate (FDR) corrections. These techniques were developed in response to performing thousands of significance tests on data from molecular analyses and generally do not perform well when the number of tests is small. Fortunately, there was only one statistically significant difference in concentration between the reference and outfall sites (mercury in fish muscle, see below). A correction for the number of tests was not necessary in this analysis although it should be noted that given the large number of significance tests performed, there is the possibility that the significant difference in concentration of mercury in fish muscle does not exist. However, the formal analysis did not correct for the number of tests performed. The same caveat is true for the first and third analyses which also involved a large number of significance tests (tests of the slope of the regression line being equal to 0). There were a larger number of significant tests but neither the overly conservative Bonferroni corrections nor the FDR corrections for extremely large numbers of tests were applied. In these cases, the statistical test results should be viewed in the context of the biological and chemical mechanisms involved in the deposition and bioaccumulation of these metals.

B.4. BACIP ANALYSIS

The general BACIP (Before-After-Control-Impact Paired) experimental design involves sampling at predetermined “control” and “impact” areas before and after the onset of the potentially impacting activity (Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986). A change in indicator values at a potentially impacted location after the onset of the impacting activity does not necessarily indicate that an impact has occurred, since indicator values can change naturally over time. With this statistical design, it is assumed that large-scale environmental factors causing natural temporal changes in indicator values will have a similar effect in both the impact and control areas. Thus, the test for impact is a test for changes in the after-impact period that do *not* take place in both the control and impact areas. The null hypothesis of the BACIP statistical test is that the average differences between impact and control sites will be the same in the before- and after-operational periods. The details of the sampling design can vary, although all credible designs should involve multiple sampling periods both before and after the impact. As a paired test, the comparison involves a single impact and a single control location. This is because a point source impact (such as an outfall) will create gradients of change in the vicinity of the impact, and the severity of the impact at different locations on the gradient is of interest rather than the impact to the larger area.

An assumption of the BACIP test is that the differences within each group are normally distributed. When the data are positively skewed as total abundances usually are, log transformation will make these differences more normal. Using the log is equivalent to testing for the same ratio of abundances before and after impact. Student's T test was used to evaluate the differences in the log values prior to discharge and after discharge.

The City and County of San Francisco began pre-discharge benthic infauna studies in 1982. Since that time, one outfall station (station 01) and one reference station (station 06) consistently remained part of the sampling program. A BACIP analysis of infauna abundance at these two stations was performed to provide some information on the degree to which the wastewater discharge may have affected organism abundance.

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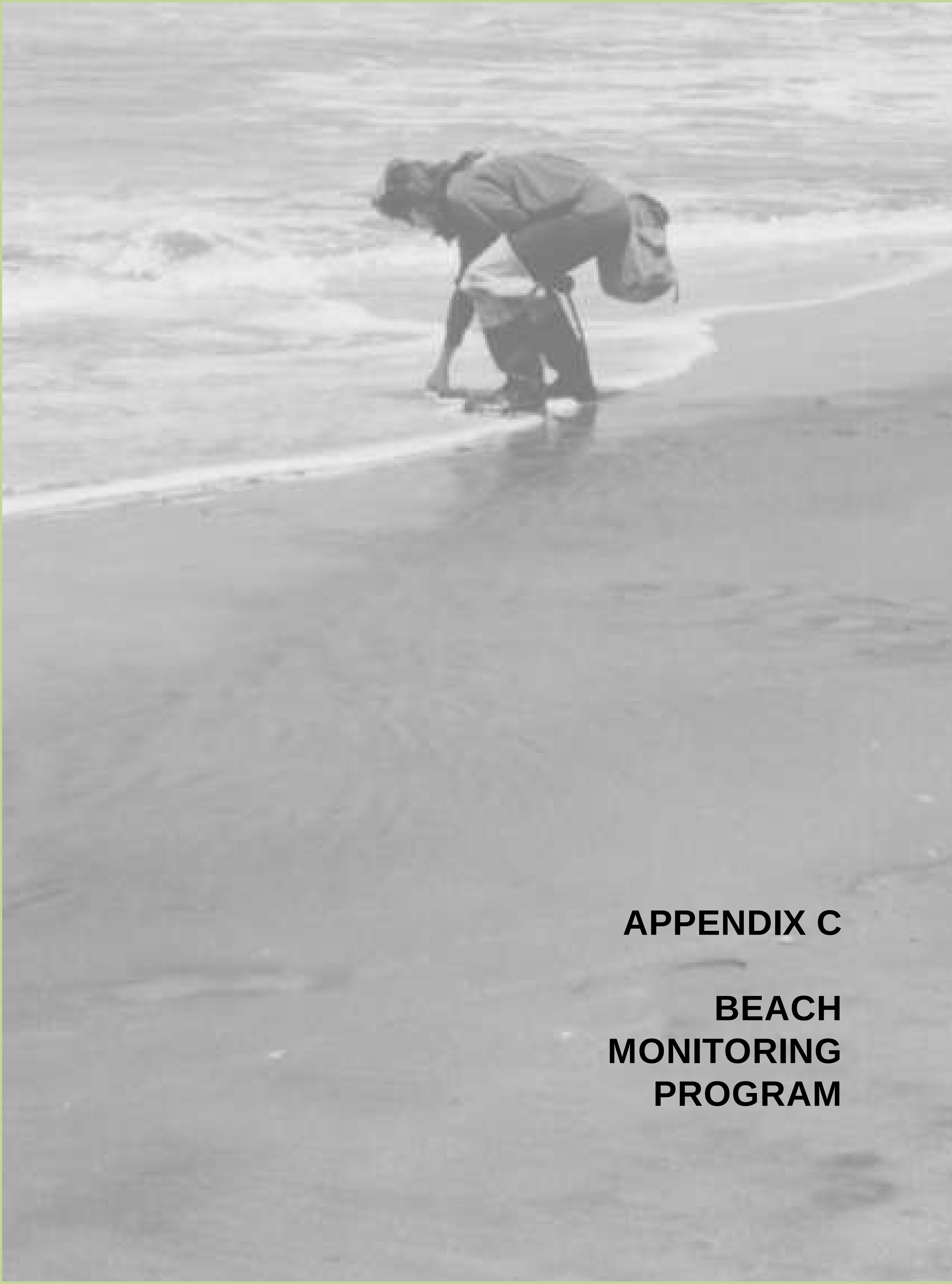


APPENDIX C

BEACH MONITORING PROGRAM

APPENDIX C
Beach Monitoring Program
1997 - 2013

APPENDIX C
Beach Monitoring Program
1997 - 2013

Appendix C-1a

Total coliform bacteria (MPN/100 mL) at shoreline stations

July 2012 - December 2012

	Shoreline Station									
	15	**15E**	**16**	**17**	**18**	**19**	**20**	**21**	**21.1**	**22**
2-Jul-12	73	31	31	31	< 10	10			< 10	
9-Jul-12	637	41	20	20	< 10	20			1333	
10-Jul-12									< 10	
16-Jul-12	8164	20	20	73	< 10	31			20	
17-Jul-12	1112	107								
23-Jul-12	794	75	< 10	20	41	< 10			10	
30-Jul-12	2310	10	< 10	20	< 10	10			31	
6-Aug-12	< 10	457	41	< 10	10	< 10			10	
13-Aug-12	620	52	160	30	< 10	< 10			10	
20-Aug-12	3448	20	52	10	20	20			10	
27-Aug-12	1616	< 10	63	41	< 10	< 10			< 10	
4-Sep-12	435	3076	41	20	< 10	< 10			< 10	
5-Sep-12	1968	10								
7-Sep-12	**19863**	175								
8-Sep-12	6488	265								
10-Sep-12	9804	20	20	10	< 10	20			< 10	
17-Sep-12	3169	63	20	10	31	< 10			< 10	
24-Sep-12	571	183	285	20	20	10			10	
25-Sep-12	31	134	20							
1-Oct-12	1182	10	85	148	31	10			20	
9-Oct-12	703	< 10	41	10	< 10	< 10			< 10	
15-Oct-12	520	134	**12033**	328	345	41			771	
16-Oct-12	1259	41	1187		10				122	
17-Oct-12			3654						10	
22-Oct-12	3441	620	108	175	789	563			393	
23-Oct-12					63					
29-Oct-12	**10462**	< 10	31	< 10	31	< 10			10	
30-Oct-12	20	< 10								
5-Nov-12	9804	20	10	< 10	31	10			< 10	
13-Nov-12	10	2909	41	74	< 10	97			10	
19-Nov-12	2603	121	41	31	52	20			20	
21-Nov-12					**> 24196**	4611	345	**> 24196**	2359	6131
22-Nov-12					203	85		109		988
23-Nov-12					63					
24-Nov-12					52					
25-Nov-12					41					
26-Nov-12	20	41	< 10	20	10	< 10			20	
28-Nov-12	5172	262	216	41						
29-Nov-12	4352	148	3255		121					
30-Nov-12	1722	1376	3255		6131	**> 24196**	3255	**> 24196**	2755	591
1-Dec-12	**> 24196**	275	282		520	323	318	529	404	
2-Dec-12	4884	4352	5475	4884	**> 24196**		1483	**> 24196**	**24196**	1529
3-Dec-12	404	201	216	175	121	2247		384	97	
5-Dec-12					**> 24196**	**> 24196**	2247	7701	613	**> 24196**
6-Dec-12					74	3873		288		504
7-Dec-12						171				
10-Dec-12	2809	10	85	31	41	1565			10	
17-Dec-12	4352	121	512	75	41	85			31	
22-Dec-12	**> 24196**	31	10							
23-Dec-12	5172	298								
24-Dec-12					86	1376	97	269	75	98
25-Dec-12						160				
26-Dec-12	**19863**	373	480	908	637	798	839	991	638	4884
27-Dec-12	235	246				179				201

BOLD = > 10,000 MPN/100mL

Appendix C-1b

Total coliform bacteria (MPN/100 mL) at shoreline stations

January 2013 - June 2013

	Shoreline Station									
	15	**15E**	**16**	**17**	**18**	**19**	**20**	**21**	**21.1**	**22**
2-Jan-13	538	< 10	52	31	< 10	10		< 10		
7-Jan-13	2400	74	31	31	120	199		373		
14-Jan-13	657	< 10	< 10	< 10	10	20		< 10		
22-Jan-13	8164	10	31	10	< 10	< 10		< 10		
28-Jan-13	5475	20	10	10	< 10	< 10		10		
4-Feb-13	1246	63	< 10	< 10	< 10	10		< 10		
11-Feb-13	74	121	31	31	52	52		< 10		
19-Feb-13	246	144	< 10	20	20	20		< 10		
25-Feb-13	1354	10	20	20	10	< 10		< 10		
4-Mar-13	683	10	10	10	31	< 10		63		
11-Mar-13	5172	85	62	20	< 10	< 10		30		
18-Mar-13	173	< 10	20	10	10	10		< 10		
25-Mar-13	98	31	171	< 10	< 10	10		< 10		
1-Apr-13	6131	110	41	52	< 10	20		146		
2-Apr-13	583	41								
8-Apr-13	3654	31	10	10	10	< 10		< 10		
15-Apr-13	4611	< 10	52	10	< 10	41		< 10		
22-Apr-13	1935	< 10	10		10	< 10		< 10		
23-Apr-13				< 10						
29-Apr-13	1201	20	< 10	< 10	< 10	31		< 10		
6-May-13	5794	41	< 10	< 10	< 10	< 10		< 10		
13-May-13	315	97	52	< 10	10	< 10		< 10		
20-May-13	4884	20	< 10	10	< 10	10		< 10		
28-May-13	1664	41	10	< 10	10	10		10		
29-May-13	2187	30								
3-Jun-13	97	31	41	< 10	< 10	< 10		< 10		
10-Jun-13	3255	743	30	10	< 10	< 10		41		
17-Jun-13	3076	97	< 10	10	10	< 10		< 10		
24-Jun-13	1281	52	31	20	20	< 10		< 10		

BOLD = > 10,000 MPN/100mL

Appendix C-1c

Escherichia Coli (MPN/100 mL) at shoreline stations

July 2012 - December 2012

	Shoreline Station									
	15	**15E**	**16**	**17**	**18**	**19**	**20**	**21**	**21.1**	**22**
2-Jul-12	41	10	< 10	< 10	< 10	< 10			< 10	
9-Jul-12	< 10	< 10	20	< 10	< 10	< 10			**538**	
10-Jul-12									< 10	
16-Jul-12	**738**	10	10	31	< 10	31			< 10	
17-Jul-12	41	< 10								
23-Jul-12	20	< 10	< 10	10	31	< 10			10	
30-Jul-12	20	< 10	< 10	< 10	< 10	< 10			20	
6-Aug-12	< 10	31	< 10	< 10	< 10	< 10			10	
13-Aug-12	30	52	20	< 10	< 10	< 10			< 10	
20-Aug-12	10	< 10	10	< 10	10	20			10	
27-Aug-12	< 10	< 10	10	< 10	< 10	< 10			< 10	
4-Sep-12	10	< 10	< 10	10	< 10	< 10			< 10	
5-Sep-12	31	< 10								
7-Sep-12	**4352**	41								
8-Sep-12	63	10								
10-Sep-12	63	< 10	10	< 10	< 10	< 10			< 10	
17-Sep-12	10	10	< 10	< 10	< 10	< 10			< 10	
24-Sep-12	52	75	108	< 10	10	10			< 10	
25-Sep-12	10	< 10	10							
1-Oct-12	30	10	< 10	110	< 10	< 10			10	
9-Oct-12	< 10	< 10	< 10	< 10	< 10	< 10			< 10	
15-Oct-12	250	86	148	195	213	10			**520**	
16-Oct-12	31	20	**1187**		< 10				63	
17-Oct-12			< 10						< 10	
22-Oct-12	75	30	31	10	**538**	31			20	
23-Oct-12					< 10					
29-Oct-12	10	< 10	< 10	< 10	< 10	< 10			10	
30-Oct-12	< 10	< 10								
5-Nov-12	52	< 10	< 10	< 10	< 10	< 10			< 10	
13-Nov-12	< 10	134	20	31	10	30			< 10	
19-Nov-12	10	31	< 10	< 10	10	10			< 10	
21-Nov-12					**> 24196**	**586**	75	**2098**	203	**464**
22-Nov-12					20	10		30		20
23-Nov-12					20					
24-Nov-12					20					
25-Nov-12					10					
26-Nov-12	< 10	41	< 10	< 10	< 10	< 10			10	
28-Nov-12	175	41	98	< 10						
29-Nov-12	298	86	**727**		10					
30-Nov-12	**521**	345	**1153**		**2282**	**24196**	**1210**	**> 24196**	**583**	160
1-Dec-12	97	109	20		134	20	20	85	31	
2-Dec-12	**990**	**988**	**886**	**1396**	**4106**		383	**6867**	**4884**	216
3-Dec-12	173	10	10	31	30	132		< 10	< 10	
5-Dec-12					**4106**	**24196**	379	**703**	41	**3448**
6-Dec-12					< 10	**565**		63		52
7-Dec-12						52				
10-Dec-12	< 10	< 10	31	10	10	161			10	
17-Dec-12	41	< 10	20	< 10	10	< 10			< 10	
22-Dec-12	72	< 10	< 10							
23-Dec-12	< 10	< 10								
24-Dec-12					52	282	10	63	20	20
25-Dec-12						10				
26-Dec-12	201	63	41	191	134	185	75	175	85	**563**
27-Dec-12	20	< 10				30				< 10

BOLD = > 400 MPN/100mL

Appendix C-1d

Escherichia coli (MPN/100 mL) at shoreline stations

January 2013 to June 2013

Shoreline Station

	15	15E	16	17	18	19	20	21	21.1	22
2-Jan-13	< 10	< 10	< 10	10	< 10	10			< 10	
7-Jan-13	31	10	10	10	30	85			120	
14-Jan-13	20	< 10	< 10	< 10	< 10	< 10			< 10	
22-Jan-13	86	< 10	< 10	< 10	< 10	< 10			< 10	
28-Jan-13	< 10	< 10	< 10	< 10	< 10	< 10			< 10	
4-Feb-13	10	< 10	< 10	< 10	< 10	< 10			< 10	
11-Feb-13	10	10	< 10	< 10	31	< 10			< 10	
19-Feb-13	< 10	10	< 10	< 10	10	20			< 10	
25-Feb-13	20	< 10	< 10	10	< 10	< 10			< 10	
4-Mar-13	< 10	< 10	< 10	10	20	< 10			< 10	
11-Mar-13	52	10	10	10	< 10	< 10			30	
18-Mar-13	< 10	< 10	10	< 10	< 10	< 10			< 10	
25-Mar-13	10	31	132	< 10	< 10	< 10			< 10	
1-Apr-13	146	< 10	< 10	< 10	< 10	10			< 10	
2-Apr-13	< 10	10								
8-Apr-13	41	< 10	< 10	10	< 10	< 10			< 10	
15-Apr-13	41	< 10	< 10	< 10	< 10	< 10			< 10	
22-Apr-13	10	< 10	< 10		10	< 10			10	
23-Apr-13				< 10						
29-Apr-13	< 10	< 10	< 10	< 10	< 10	20			< 10	
6-May-13	20	< 10	< 10	< 10	< 10	< 10			< 10	
13-May-13	< 10	< 10	52	< 10	< 10	< 10			< 10	
20-May-13	20	< 10	< 10	< 10	< 10	< 10			< 10	
28-May-13	122	10	< 10	< 10	10	< 10			< 10	
29-May-13	20	< 10								
3-Jun-13	< 10	< 10	< 10	< 10	< 10	< 10			< 10	
10-Jun-13	31	31	10	10	< 10	< 10			10	
17-Jun-13	41	10	< 10	< 10	< 10	< 10			< 10	
24-Jun-13	< 10	10	10	10	10	< 10			< 10	

#

BOLD = > 400 MPN/100 ml

Appendix C-1e

Enterococcus (MPN/100 mL) at shoreline stations

July 2012 - December 2012

Shoreline Station

	15	**15E**	**16**	**17**	**18**	**19**	**20**	**21**	**21.1**	**22**
2-Jul-12	86	< 10	< 10	10	< 10	< 10			< 10	
9-Jul-12	< 10	< 10	< 10	< 10	< 10	< 10			74	
10-Jul-12									< 10	
16-Jul-12	**146**	< 10	< 10	20	< 10	20			10	
17-Jul-12	20	< 10								
23-Jul-12	< 10	< 10	10	< 10	< 10	< 10			< 10	
30-Jul-12	10	< 10	< 10	< 10	< 10	10			< 10	
6-Aug-12	< 10	< 10	< 10	< 10	< 10	< 10			20	
13-Aug-12	10	< 10	< 10	< 10	10	< 10			< 10	
20-Aug-12	97	10	< 10	< 10	< 10	< 10			< 10	
27-Aug-12	20	< 10	< 10	< 10	< 10	< 10			< 10	
4-Sep-12	98	**223**	< 10	< 10	< 10	< 10			< 10	
5-Sep-12	20	**199**								
7-Sep-12	**2851**	10								
8-Sep-12	41	10								
10-Sep-12	96	< 10	< 10	< 10	< 10	< 10			< 10	
17-Sep-12	20	< 10	< 10	20	< 10	< 10			< 10	
24-Sep-12	**146**	75	**441**	30	< 10	< 10			62	
25-Sep-12	10	20	< 10							
1-Oct-12	10	< 10	< 10	10	< 10	< 10			< 10	
9-Oct-12	10	< 10	< 10	< 10	< 10	< 10			< 10	
15-Oct-12	**134**	20	98	74	**262**	31			86	
16-Oct-12	< 10	30	**121**		< 10				**134**	
17-Oct-12			< 10						31	
22-Oct-12	41	< 10	10	20	20	41			20	
23-Oct-12					< 10					
29-Oct-12	41	10	20	20	< 10	20			< 10	
30-Oct-12	< 10	10								
5-Nov-12	41	< 10	< 10	10	< 10	< 10			< 10	
13-Nov-12	< 10	10	< 10	41	20	75			< 10	
19-Nov-12	10	10	10	< 10	10	10			< 10	
21-Nov-12					**345**	**259**	20	**512**	63	**323**
22-Nov-12					< 10	31		31		20
23-Nov-12					< 10					
24-Nov-12					10					
25-Nov-12					10					
26-Nov-12	< 10	10	< 10	10	< 10	< 10			< 10	
28-Nov-12	**173**	20	10	20						
29-Nov-12	**441**	**109**	**3873**		74					
30-Nov-12	**1396**	**1019**	**4106**		**723**	**> 24196**	**884**	**12997**	**369**	**120**
1-Dec-12	**275**	**331**	**173**		**464**	63	63	41	**350**	
2-Dec-12	**213**	**228**	**146**	**393**	**908**		85	**1050**	**1553**	86
3-Dec-12	10	10	10	20	< 10	31		< 10	< 10	
5-Dec-12					**556**	**6867**	96	**155**	63	**2143**
6-Dec-12					10	**110**		< 10		10
7-Dec-12						31				
10-Dec-12	41	< 10	20	< 10	< 10	10			< 10	
17-Dec-12	52	< 10	10	< 10	10	< 10			< 10	
22-Dec-12	**160**	31	74							
23-Dec-12	30	10								
24-Dec-12					< 10	**135**	10	< 10	< 10	< 10
25-Dec-12						< 10				
26-Dec-12	85	41	31	20	10	**106**	63	63	98	**110**
27-Dec-12	< 10	< 10				20				< 10

BOLD = > 104 MPN/100mL

Appendix C-1f

Enterococcus (MPN/100 mL) at shoreline stations

January 2013 to June 2013

Shoreline Station

	15	**15E**	**16**	**17**	**18**	**19**	**20**	**21**	**21.1**	**22**
2-Jan-13	< 10	< 10	< 10	41	10	< 10			< 10	
7-Jan-13	20	< 10	10	< 10	10	< 10			31	
14-Jan-13	20	< 10	< 10	< 10	< 10	< 10			< 10	
22-Jan-13	10	10	< 10	< 10	10	< 10			< 10	
28-Jan-13	< 10	< 10	< 10	< 10	< 10	< 10			< 10	
4-Feb-13	20	20	< 10	< 10	< 10	< 10			< 10	
11-Feb-13	74	41	20	< 10	< 10	< 10			< 10	
19-Feb-13	< 10	< 10	< 10	< 10	< 10	< 10			< 10	
25-Feb-13	95	< 10	< 10	< 10	< 10	< 10			< 10	
4-Mar-13	10	< 10	< 10	< 10	< 10	< 10			< 10	
11-Mar-13	75	20	< 10	< 10	< 10	< 10			41	
18-Mar-13	< 10	< 10	< 10	< 10	10	< 10			< 10	
25-Mar-13	63	< 10	52	< 10	10	< 10			< 10	
1-Apr-13	**185**	10	< 10	10	< 10	< 10			10	
2-Apr-13	10	< 10								
8-Apr-13	74	< 10	< 10	< 10	< 10	10			< 10	
15-Apr-13	63	< 10	< 10	< 10	10	< 10			< 10	
22-Apr-13	< 10	10	< 10		< 10	< 10			< 10	
23-Apr-13				20						
29-Apr-13	10	< 10	< 10	10	< 10	< 10			< 10	
6-May-13	41	< 10	< 10	< 10	< 10	< 10			< 10	
13-May-13	< 10	< 10	< 10	< 10	< 10	< 10			< 10	
20-May-13	31	< 10	< 10	< 10	< 10	< 10			< 10	
28-May-13	**173**	< 10	< 10	20	10	< 10			< 10	
29-May-13	10	< 10								
3-Jun-13	< 10	10	< 10	< 10	< 10	< 10			< 10	
10-Jun-13	41	10	< 10	< 10	< 10	10			< 10	
17-Jun-13	74	20	< 10	< 10	< 10	< 10			< 10	
24-Jun-13	30	< 10	< 10	< 10	< 10	< 10			< 10	

BOLD = > 104 MPN/100 ml

APPENDIX C-2a

Bacteria counts greater than single sample maximum limit
July 2008 - June 2009

Sample Date	Station	Total Coliform Count > 10,000 MPN/100mL	*E. coli* Count > 400 MPN/100mL	Enterococcus Count > 104 MPN/100mL	Follow-up sample date	Total Coliform Count	*E. coli* Count	Enterococcus Count
29-Jul-08	15	5794	86	**185**	30-Jul-08	4106	86	86
6-Aug-08	15	**>24196**	**441**	97	7-Aug-08	2098	10	<10
12-Aug-08	15	9804	52	**199**	13-Aug-08	9208	20	73
20-Aug-08	15	**24196**	**504**	**638**	21-Aug-08	**12033**	75	74
					22-Aug-08	63	41	20
26-Aug-08	15	**>24196**	**487**	**462**	27-Aug-08	201	10	85
27-Aug-08	15E	**14136**	**583**	**959**	28-Aug-08	10	<10	10
1-Oct-08	15	**17329**	**473**	**884**	2-Oct-08	**17329**	**295**	**173**
					3-Oct-08	**12033**	110	51
					4-Oct-08	256	<10	<10
1-Oct-08	15E	256	199	**203**	2-Oct-08	189	86	63
1-Oct-08	16	269	85	**142**	2-Oct-08	97	31	<10
15-Oct-08	16	7701	107	**298**	16-Oct-08	10	<10	<10
29-Oct-08	15	**>24196**	**910**	**670**	30-Oct-08	4106	228	52
2-Nov-08	19	1872	262	**187**	3-Nov-08	120	<10	<10
12-Nov-08	19	3076	**613**	52	13-Nov-08	10	10	10
18-Nov-08	15	**11199**	279	**131**	19-Nov-08	1989	73	63
18-Nov-08	18	<10	<10	**199**	19-Nov-08	20	10	<10
25-Nov-08	17	546	323	**109**	26-Nov-08	272	171	40
13-Jan-09	15	2481	226	**108**	15-Jan-09	20	<10	<10
4-Feb-09	18	932	63	**243**	5-Feb-09	10	<10	10
15-Feb-09	16	98	10	**213**	16-Feb-09	146	10	10
16-Feb-09	18	3654	**884**	**243**	17-Feb-09	231	41	<10
16-Feb-09	19	**12033**	**2489**	**637**	17-Feb-09	3448	377	98
16-Feb-09	20	2359	**733**	**148**	17-Feb-09	275	31	10
16-Feb-09	21	3076	**845**	**230**	17-Feb-09	637	41	31
16-Feb-09	21.1	3255	**882**	**185**	17-Feb-09	187	<10	10
16-Feb-09	22	**17329**	**2481**	**2603**	17-Feb-09	**12033**	**1664**	**1860**
					18-Feb-09	20	<10	<10
5-Mar-09	21.1	3873	**613**	**121**	6-Mar-09	74	20	31
15-Apr-09	15E	1872	84	**132**	16-Apr-09	10	<10	<10
27-May-09	15	**14136**	**727**	**985**	28-May-09	4884	41	62

APPENDIX C-2b

Bacteria counts greater than single sample maximum limit

July 2009 - June 2010

Sample Date	Station	Total Coliform Count > 10,000 MPN/100mL	*E. coli* Count > 400 MPN/100mL	Enterococcus Count > 104 MPN/100mL	Follow-up sample date	Total Coliform Count	*E. coli* Count	Enterococcus Count
8-Jul-09	15	880	201	**121**	10-Jul-09	3076	10	**132**
					11-Jul-09	988	<10	**393**
					12-Jul-09	327	<10	<10
14-Jul-09	15	**>24196**	**441**	**631**	15-Jul-09	8164	74	**183**
					16-Jul-09	**12997**	97	**1336**
					17-Jul-09	2851	52	72
11-Aug-09	15	**>24196**	279	**544**	12-Aug-09	**15531**	75	**122**
					13-Aug-09	**17329**	259	**909**
					14-Aug-09	**17329**	233	**294**
					15-Aug-09	1017	10	52
19-Aug-09	15	**24196**	373	**135**	20-Aug-09	98	<10	<10
8-Sep-09	15	**12033**	369	**246**	9-Sep-09	**>24196**	185	86
					10-Sep-09	959	<10	20
22-Sep-09	15	**>24196**	**780**	**886**	23-Sep-09	862	10	<10
30-Sep-09	15	**10462**	158	158	1-Oct-09	**24196**	158	**161**
					2-Oct-09	**>24196**	426	**292**
					3-Oct-09	**3873**	**3448**	**175**
					4-Oct-09	377	10	52
3-Oct-09	15E	74	41	**108**	4-Oct-09	31	20	<10
13-Oct-09	15	**12997**	355	**359**	14-Oct-09	**4611**	**631**	**336**
					15-Oct-09	246	97	52
13-Oct-09	16	2382	75	**305**	14-Oct-09	906	122	52
13-Oct-09	18	**>24196**	**>24196**	**6867**	14-Oct-09	364	10	41
13-Oct-09	19	**>24196**	**>24196**	**>24196**	14-Oct-09	4611	**496**	86
					15-Oct-09	213	74	20
13-Oct-09	20	**>24196**	**14136**	**4611**	14-Oct-09	156	20	52
13-Oct-09	21	**>24196**	**>24196**	**>24196**	14-Oct-09	487	98	52
13-Oct-09	21.1	**>24196**	**>24196**	**2142**	14-Oct-09	281	52	52
14-Oct-09	15E	1860	**576**	**624**	15-Oct-09	259	52	10
20-Oct-09	15	6867	**471**	**301**	21-Oct-09	**24196**	**512**	**408**
					22-Oct-09	**>24196**	**1607**	**1145**
					23-Oct-09	**>24196**	108	**171**
					24-Oct-09	**15531**	31	85
					25-Oct-09	**4884**	**546**	75
					26-Oct-09	8164	41	52
22-Oct-09	15E	**>24196**	**909**	**>24196**	23-Oct-09	538	52	63
3-Nov-09	15	7270	98	**121**	4-Nov-09	63	31	<10
4-Nov-09	15E	5172	98	**108**	6-Nov-09	10	<10	<10
10-Nov-09	15	**24196**	110	**187**	11-Nov-09	**14136**	<10	75
					12-Nov-09	372	20	<10
17-Nov-09	15E	457	301	**216**	18-Nov-09	241	145	**373**
					19-Nov-09	20	10	<10
6-Jan-10	15	**12997**	20	52	7-Jan-10	**>24196**	373	**1043**
					8-Jan-10	**15531**	20	52
					9-Jan-10	1396	<10	<10
12-Jan-10	16	3873	63	**309**	13-Jan-10	173	10	97
12-Jan-10	19	776	213	**496**	13-Jan-10	31	10	86
12-Jan-10	21.1	216	<10	**420**	13-Jan-10	52	10	<10
18-Jan-10	15	1145	146	**364**	19-Jan-10	960	246	98

APPENDIX C-2b (cont.)

Bacteria counts greater than single sample maximum limit

July 2009 - June 2010

Sample Date	Station	Total Coliform Count > 10,000 MPN/100mL	*E. coli* Count > 400 MPN/100mL	Enterococcus Count > 104 MPN/100mL	Follow-up sample date	Total Coliform Count	*E. coli* Count	Enterococcus Count
18-Jan-10	15E	563	120	**216**	19-Jan-10	650	134	52
18-Jan-10	16	1414	183	**538**	19-Jan-10	613	98	52
18-Jan-10	17	**11199**	**1515**	**450**	19-Jan-10	1050	226	**144**
					20-Jan-10	359	73	30
18-Jan-10	18	7270	**583**	**327**	19-Jan-10	1333	**767**	**402**
					20-Jan-10	379	63	**122**
					21-Jan-10	122	41	41
18-Jan-10		8164	**933**	**450**	19-Jan-10	6867	**2909**	**759**
					20-Jan-10	670	41	**110**
					21-Jan-10	213	52	41
18-Jan-10	21	789	134	**122**	19-Jan-10	712	75	**145**
					20-Jan-10	379	41	**121**
					21-Jan-10	132	<10	10
19-Jan-10	21.1	908	201	**256**	20-Jan-10	960	75	**262**
					21-Jan-10	97	20	20
26-Feb-10	15	2481	135	**109**	27-Feb-10	4106	119	**228**
					28-Feb-10	98	10	20
26-Feb-10	17	563	305	**216**	27-Feb-10	2224	10	10
9-Mar-10	19	<10	<10	**253**	10-Mar-10	10	10	<10
20-Apr-10	19	880	<10	**292**	21-Apr-10	63	20	20
20-Apr-10	21.1	529	<10	**1439**	21-Apr-10	30	<10	<10
18-May-10	15	5172	86	**132**	19-May-10	776	52	20
26-May-10	15	7270	63	**301**	27-May-10	**>24196**	96	**488**
					28-May-10	2909	<10	31
29-Jun-10	15	7701	**432**	**1223**	30-Jun-10	2755	31	31

APPENDIX C-2c

Bacteria counts greater than single sample maximum limit

July 2010 - June 2011

Sample Date	Station	Total Coliform Count > 10,000 MPN/100mL	*E. coli* Count > 400 MPN/100mL	Enterococcus Count > 104 MPN/100mL	Follow-up sample date	Total Coliform Count	*E. coli* Count	Enterococcus Count
3-Aug-10	15	**14136**	10	41	4-Aug-10	959	63	30
17-Aug-10	16	7270	63	**135**	18-Aug-10	<10	<10	<10
14-Sep-10	15E	8664	121	**336**	15-Sep-10	683	63	52
15-Sep-10	15	**12997**	**2359**	**2755**	16-Sep-10	**>24196**	185	**265**
					17-Sep-10	9804	256	**292**
					18-Sep-10	5475	**1106**	**836**
					19-Sep-10	**17329**	301	**435**
					20-Sep-10	417	<10	31
28-Sep-10	15	8664	108	**275**	29-Sep-10	5475	98	**173**
					30-Sep-10	**17329**	279	**645**
					1-Oct-10	**17329**	121	**450**
					2-Oct-10	**12033**	52	96
					3-Oct-10	1989	148	**226**
					4-Oct-10	**>24196**	**605**	**228**
					5-Oct-10	98	20	31
3-Oct-10	15E	120	63	**420**	4-Oct-10	86	<10	<10
20-Oct-10	15	2187	75	**122**	21-Oct-10	10	<10	63
20-Oct-10	15E	52	31	**132**	21-Oct-10	41	10	20
8-Nov-10	21.1	158	132	**317**	9-Nov-10	156	52	<10
17-Nov-10	15	**12997**	75	20	18-Nov-10	9208	10	<10
22-Nov-10	17	203	52	**389**	23-Nov-10	20	<10	10
19-Dec-10	18	**11199**	**2382**	**717**	20-Dec-10	8164	**4352**	**4106**
					21-Dec-10	75	<10	31
19-Dec-10	19	4106	**703**	**441**	20-Dec-10	771	135	**148**
					21-Dec-10	855	63	10
19-Dec-10	20	521	135	**285**	20-Dec-10	891	74	**161**
					21-Dec-10	74	<10	<10
19-Dec-10	21	479	189	**191**	20-Dec-10	884	197	**393**
					21-Dec-10	52	20	10
19-Dec-10	21.1	650	161	**231**	20-Dec-10	448	75	**158**
					21-Dec-10	75	20	10
19-Dec-10	22	833	203	**175**	20-Dec-10	495	31	74
20-Dec-10	15	1450	**833**	**839**	21-Dec-10	389	52	**144**
					22-Dec-10	404	20	<10
20-Dec-10	15E	3654	**3255**	**209**	21-Dec-10	199	20	52
20-Dec-10	16	1989	**1334**	**1250**	21-Dec-10	41	10	20
20-Dec-10	17	548	122	**109**	21-Dec-10	134	31	10
29-Dec-10	19	3873	**565**	**146**	30-Dec-10	**12033**	**743**	**144**
					31-Dec-10	259	20	20
29-Dec-10	21	**17329**	**1565**	**512**	30-Dec-10	146	10	<10
18-Jan-11	15	2046	359	**441**	19-Jan-11	134	10	10
18-Jan-11	15E	529	355	**256**	19-Jan-11	10	<10	<10
18-Jan-11	16	2359	**663**	**1187**	19-Jan-11	41	10	10
18-Mar-11	15	6488	309	**173**	19-Mar-11	960	10	20
19-Mar-11	22	1670	275	**231**	20-Mar-11	9208	**860**	**605**
					21-Mar-11	109	<10	10
22-Jun-11	15	**>24196**	63	52	23-Jun-11	960	<10	<10

Appendix C-2d

Bacteria counts greater than single sample maximum limit and follow-up samples

July 2011 - June 2012

Sample Date	Station	Total Coliform Count > 10,000 MPN/100mL	*E. coli* Count > 400 MPN/100mL	Enterococcus Count > 104 MPN/100mL	Follow-up sample date	Total Coliform Count	*E. coli* Count	Enterococcus Count
12-Sep-11	15	5794	327	**1076**	13-Sep-11	4884	31	41
5-Oct-11	15	**>24196**	62	**146**	6-Oct-11	644	31	10
11-Oct-11	17	789	**432**	**110**	12-Oct-11	3255	**1374**	**602**
					13-Oct-11	41	<10	<10
24-Oct-11	15	683	97	**171**	25-Oct-11	2909	10	74
24-Oct-11	21.1	134	74	**119**	25-Oct-11	10	<10	10
21-Jan-12	22	586	331	**231**	22-Jan-12	1334	63	85
22-Jan-12	18	185	41	**187**	23-Jan-12	122	10	41
22-Jan-12	19	670	131	**145**	23-Jan-12	109	<10	41
23-Apr-12	18	836	**573**	41	24-Apr-12	<10	<10	<10
25-Jun-12	15	**11199**	20	52	26-Jun-12	960	<10	97
25-Jun-12	15E	281	<10	**496**	26-Jun-12	62	<10	<10

Appendix C-2e

Bacteria counts greater than single sample maximum limit and follow-up samples
July 2012 - June 2013

Sample Date	Station	Total Coliform Count > 10,000 MPN/100mL	*E. coli* Count > 400 MPN/100mL	Enterococcus Count > 104 MPN/100mL	Follow-up sample date(s)	Total Coliform Count	*E. coli* Count	Enterococcus Count
9-Jul-12	21.1	1333	**538**	74	10-Jul-12	<10	<10	<10
16-Jul-12	15	8164	**738**	**146**	17-Jul-12	1112	41	20
4-Sep-12	15E	3076	<10	**223**	5-Sep-12	10	<10	**199**
					7-Sep-12	175	41	10
7-Sep-12	15	**19863**	**4352**	**2851**	8-Sep-12	6488	63	41
24-Sep-12	15	571	52	**146**	25-Sep-12	31	10	10
24-Sep-12	16	285	108	**441**	25-Sep-12	20	10	<10
15-Oct-12	15	520	250	**134**	16-Oct-12	1259	31	<10
15-Oct-12	16	**12033**	148	98	16-Oct-12	1187	**1187**	**121**
					17-Oct-12	3654	<10	<10
15-Oct-12	18	345	213	**262**	16-Oct-12	10	<10	<10
15-Oct-12	21.1	771	**520**	86	16-Oct-12	122	63	**134**
					17-Oct-12	10	<10	31
22-Oct-12	18	789	**538**	20	23-Oct-12	63	<10	<10
29-Oct-12	15	**10462**	10	41	30-Oct-12	20	<10	<10
21-Nov-12	18	**>24196**	**>24196**	**345**	22-Nov-12	203	20	<10
21-Nov-12	19	4611	**586**	**259**	22-Nov-12	85	10	31
21-Nov-12	21	**>24196**	**2098**	**512**	22-Nov-12	109	30	31
21-Nov-12	22	6131	**464**	**323**	22-Nov-12	988	20	20
28-Nov-12	15	5172	175	**173**	29-Nov-12	4352	298	**441**
					30-Nov-12	1722	**521**	**1396**
					1-Dec-12	**>24196**	97	**275**
					2-Dec-12	4884	**990**	**213**
					3-Dec-12	404	173	10
29-Nov-12	15E	148	86	**109**	30-Nov-12	1376	345	**1019**
					1-Dec-12	275	109	**331**
					2-Dec-12	4352	**988**	**228**
					3-Dec-12	201	10	10
29-Nov-12	16	3255	**727**	**3873**	30-Nov-12	3255	**1153**	**4106**
					1-Dec-12	282	20	**173**
					2-Dec-12	5475	**886**	**146**
					3-Dec-12	216	10	10
30-Nov-12	18	6131	**2282**	**723**	1-Dec-12	520	134	**464**
					2-Dec-12	**>24196**	**4106**	**908**
					3-Dec-12	121	30	<10
30-Nov-12	19	**>24196**	**24196**	**>24196**	1-Dec-12	323	20	63
30-Nov-12	20	3255	**1210**	**884**	1-Dec-12	318	20	63
30-Nov-12	21	**>24196**	**>24196**	**12997**	1-Dec-12	529	85	41
30-Nov-12	21.1	2755	**583**	**369**	1-Dec-12	404	31	**350**
					2-Dec-12	**24196**	**4884**	**1553**
					3-Dec-12	97	<10	<10
30-Nov-12	22	591	160	**120**	2-Dec-12	1529	216	86
2-Dec-12	17	4884	**1396**	**393**	3-Dec-12	175	31	20
2-Dec-12	21	**>24196**	**6867**	**1050**	3-Dec-12	384	<10	<10
5-Dec-12	18	**>24196**	**4106**	**556**	6-Dec-12	74	<10	10
5-Dec-12	19	**>24196**	**24196**	**6867**	6-Dec-12	3873	**565**	**110**
					7-Dec-12	171	52	31
5-Dec-12	21	7701	**703**	**155**	6-Dec-12	288	63	<10

Appendix C-2e (cont.)

Bacteria counts greater than single sample maximum limit and follow-up samples

July 2012 - June 2013

Sample Date	Station	Total Coliform Count > 10,000 MPN/100mL	*E. coli* Count > 400 MPN/100mL	Enterococcus Count > 104 MPN/100mL	Follow-up sample date(s)	Total Coliform Count	*E. coli* Count	Enterococcus Count
5-Dec-12	22	**>24196**	**3448**	**2143**	6-Dec-12	504	52	10
22-Dec-12	15	**>24196**	72	**160**	23-Dec-12	5172	<10	30
24-Dec-12	19	1376	282	**135**	25-Dec-12	160	10	<10
26-Dec-12	15	**19863**	201	85	27-Dec-12	235	20	<10
26-Dec-12	19	798	185	**106**	27-Dec-12	179	30	20
26-Dec-12	22	4884	**563**	**110**	27-Dec-12	201	<10	<10
1-Apr-13	15	6131	146	**185**	2-Apr-13	583	<10	10
28-May-13	15	1664	122	**173**	29-May-13	2187	20	10

Appendix C-3

Summary of treated Combined Sewer Discharges (CSD)
and rainfall July 2012 - June 2013

Month	Day	CSD Location and Duration Times					Number of Treated Discharge Events	Inches of Rain	Number of Rain Days	Monthly Rain Total (inches)
		Sea Cliff I	Sea Cliff II	Lincoln	Vicente	Lake Merced				
October	21							0.04		
	22							0.76		
	23							0.17		
	24							0.41		
	25							0.05		
	31							0.16	6	1.59
November	1							0.3		
	8							0.11		
	9							0.01		
	16							0.69		
	17							0.84		
	20							0.54		
	21			**4 hr 40 min**	**4 hr 31 min**	**3 hr 44 min**	**1**	0.54		
	28	**6 min**	**18 min**				**1**	0.82		
	29							0.22		
	30			**9 hr 5 min**	**9 hr**	**8 hr 53 min**	**1**	1.91	10	5.98
December	1							1.24		
	2	**7 min**	**31 min**	*****	**2 hr 30 min**	**2 hr 19 min**	**1**	1.16		
	5			*****	**1 hr 20 min**	**48 min**	**1**	1.15		
	11							0.03		
	12							0.06		
	14							0.03		
	15							0.12		
	16							0.08		
	17							0.24		
	21							0.24		
	22	**3 min**	**15 min**				**1**	0.89		
	23			*****	**1 hr 6 min**	**1 hr 41 min**	**1**	1.48		
	25			*****	**2hr 46 min**	**1hr 11 min**	**1**	1.18		
	26							0.24		
	28							0.42		
	29							0.19	16	8.75
January	5							0.32		
	6							0.01		
	23							0.23	3	0.56
February	7							0.31		
	8							0.26		
	19							0.29	3	0.86
March	5							0.15		
	6							0.06		
	7							0.08		
	19							0.06		
	20							0.06		
	28							0.01		
	30							0.26		
	31							0.16	8	0.84
April	1							0.4		
	4							0.43		
	7							0.02	3	0.85
May	27							0.03		
	28							0.01	2	0.04
June	23							0.02		
	24							0.03		
	25							0.16		
	26							0.02	4	0.23
Total number of treated CSDs July 2012 - June 2013		**3**	**3**	**6**	**6**	**6**	**8**	**Total in. of rain 19.7**	**Total rain days 55**	

* No data from the Lincoln structure due to lack of telemetry for this event.

Appendix C-4

Beach posting dates

July 2012 - June 2013

	Baker Beach			**China Beach**	**Ocean Beach**					**Ft. Funston**
	Station									
Date	15	15A	16	17	18	19	20	21	21.1	22
7/17/12	🟧									
9/6/12		🟧								
9/7/12		🟧								
9/8/12	🟧									
9/25/12	🟧		🟧							
10/16/12	🟧		🟧							
10/17/12			🟧						🟧	
10/30/12	🟧									
11/21/12					🟦	🟦	🟦	🟦	🟦	🟦
11/22/12					🟦	🟦		🟦		🟦
11/23/12					*					
11/24/12					*					
11/28/12	🟦	🟦	🟦	🟦						
11/29/12	🟦	🟦	🟦							
11/30/12	🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦
12/1/12	🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦
12/2/12	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
12/3/12	🟦	🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦
12/5/12					🟦	🟦	🟦	🟦	🟦	🟦
12/6/12					🟦	🟦		🟦		🟦
12/7/12						🟦				
12/22/12	🟦	🟦	🟦							
12/23/12	🟦				🟦	🟦	🟦	🟦	🟦	🟦
12/24/12					🟦	🟦	🟦	🟦	🟦	🟦
12/25/12						🟦				
12/26/12					🟦	🟦	🟦	🟦	🟦	🟦
12/27/12	🟧					🟦				🟦
4/2/13	🟧									
5/29/13	🟧									

🟧	Beach posted due to elevated bacteria count
🟦	Beach posted due to Treated Combined Sewer Discharge event
*	Bacteria not elevated: beach posted as a precaution due to sewage spill

Appendix C-5

Number of Users Engaged in Water Contact Recreation After a Treated Combined Sewer Discharge July 2012 - June 2013.
Multiple observations on the same date indicates different people posting, deposting, or sampling.

Discharge			Recreational Use Observations					
						Water Contact Number of Users		
Date and Structure	Duration	End Time	Date and Activity	Station	Time	Full	Partial	Non
11/21/2012			11/21/2012	18	0540	0	0	0
Lincoln	4 hr 40 min	0601	Posting	19	0600	0	0	0
Vicente	4 hr 31 min	0532		20	0620	0	0	0
Lake Merced	3 hr 44 min	0038		20	0625	0	0	0
				21	0630	0	0	0
				21.1	0645	0	0	0
				22	0655	0	0	0
			11/22/2012	20	1159	0	6	50
			De-Posting	21.1	1210	0	12	60
11/28/2012			11/28/2012	15	1351	0	0	1
Sea Cliff I	6 min	1040	Sampling	15E	1357	0	0	2
Sea Cliff II	18 min	1055		16	1347	0	0	1
				17	1415	4	0	0
			11/28/2012	15	1440	0	0	5
			Posting	15E	1445	0	0	3
				16	1450	0	0	2
				17	1430	8	0	5
11/30/2012			11/30/2012	18	0820	0	0	2
Lincoln	9 hr 5 min	1305	Sampling	19	0725	0	0	1
Vicente	9 hr	1251		20	1005	0	0	1
Lake Merced	8 hr 53 min	1259		21	0940	0	0	0
			11/30/2012	18	1040	0	0	2
			Posting	19	1025	0	0	0
				20	1015	0	0	1
				20	1020	0	0	0
				21	1010	0	0	0
				21.1	1004	0	0	2
				22	0940	0	0	1
12/2/2012			12/2/2012	15	1245	0	0	3
Sea Cliff I	7 min	0803	Posting	15E	1250	0	0	3
Sea Cliff II	31 min	0829		16	1300	0	0	4
Lincoln	*	*		17	1240	0	0	6
Vicente	2 hr 30 min	1047						
Lake Merced	2 hr 19 min	1031	12/2/1012	18	1130	NR	NR	NR
			Sampling	20	1540	NR	NR	NR
				21	1550	NR	NR	NR
				21.1	1120	NR	NR	NR
				22	1610	NR	NR	NR
12/5/2012			12/5/2012	18	0815	0	0	5
Lincoln	*	*	Posting	19	0810	0	0	5
Vicente	1 hr 20 min	0831		20	0845	1	0	5
Lake Merced	48 min	0749		20	0855	0	0	2
				21	0827	0	0	0
				21.1	0820	0	0	0
				22	0755	0	0	0
			12/5/2012	18	1235	0	0	8
			Sampling	19	1259	0	0	3
				20	1315	0	0	4
				21	1328	0	0	1
				21.1	1215	1	0	0
				22	1130	0	0	0
			12/6/2012	20	1530	0	0	7
			De-Posting	21.1	0910	0	0	3
			12/7/2012	18	0845	0	0	5
			De-Posting	21	0850	0	0	2
				22	0840	0	0	0

* No data from the Lincoln structure due to lack of telemetry for this event.
NR = not recorded

Appendix C-5 (cont.)

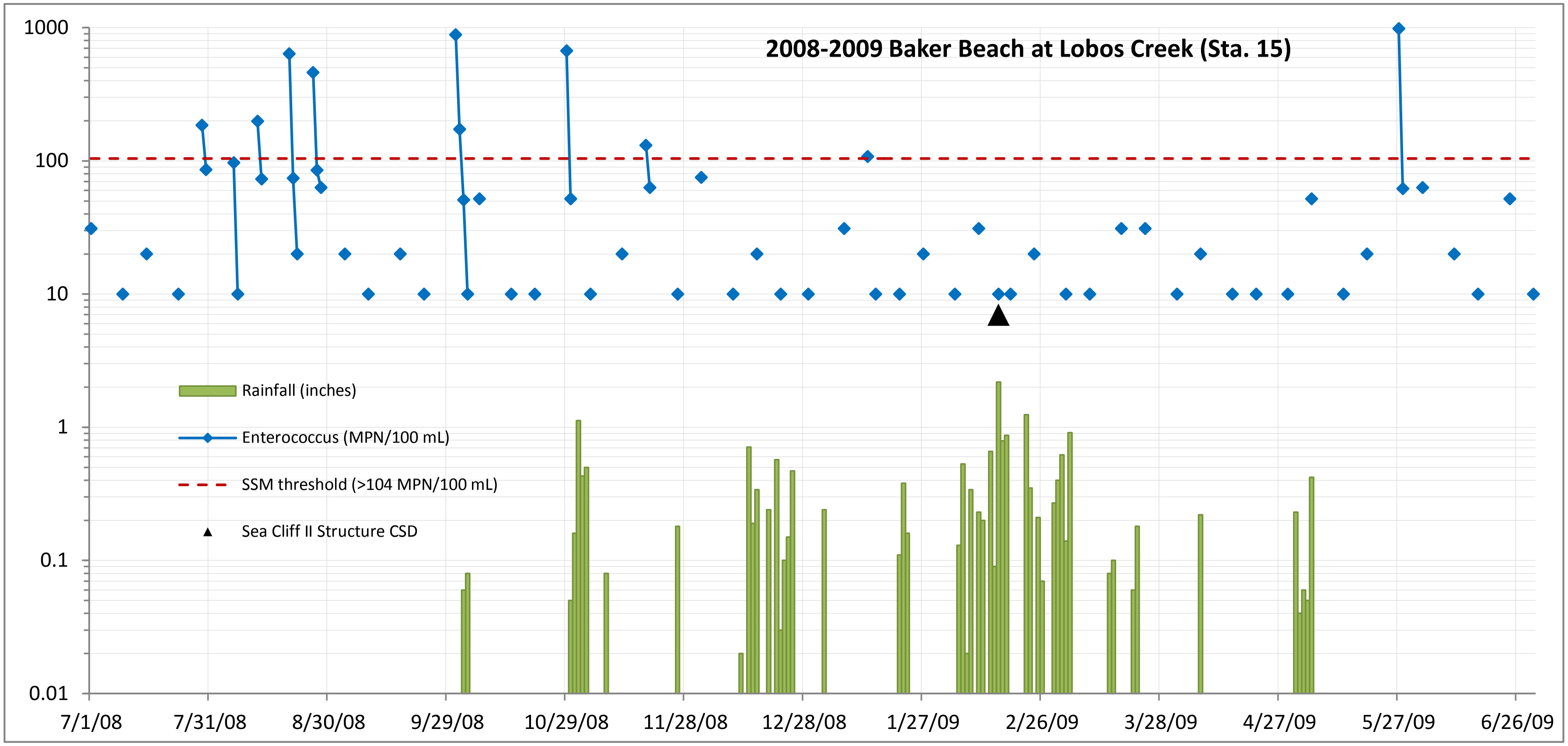
Number of Users Engaged in Water Contact Recreation After a Treated Combined Sewer Discharge July 2012 - June 2013.
Multiple observations on the same date indicates different people posting, deposting, or sampling.

Discharge			**Recreational Use Observations**					
						Water Contact Number of Users		
Date and Structure	**Duration**	**End Time**	**Date and Activity**	**Station**	**Time**	**Full**	**Partial**	**Non**
12/22/2012			12/22/2012	15	0820	0	0	2
Sea Cliff II	15 min	0355	Sampling/Posting	15E	0820	0	0	3
				16	0820	0	0	2
			12/24/2012	15	1147	0	0	55
			De-Posting	15E	1145	2	0	18
				16	1147	0	0	10
12/23/2012			12/24/2012	18	0855	0	0	10
Lincoln	*	*	Posting	19	0930	0	0	11
Vicente	1 hr 6 min	1710		20	1005	0	0	4
Lake Merced	1 hr 41 min	1706		21	1000	0	0	3
				21.1	0950	0	0	3
				22	0830	0	0	0
			12/25/2012	18	0930	3	0	7
			De-Posting	20	0945	0	0	7
				21	0950	0	0	5
				21.1	1000	6	0	5
				22	0900	0	0	0
12/25/2012			12/26/2012	18	0900	0	0	5
Lincoln	*	*	Posting	19	0915	0	0	2
Vicente	2 hr 46 min	2009		20	0920	0	0	0
Lake Merced	1 hr 11 min	1826		21	0925	0	0	2
				21.1	0930	0	0	0
				22	0835	0	0	0
			12/26/2012	18	0910	0	0	2
			Sampling	19	0918	0	0	5
				20	0928	0	0	3
				21	0940	0	0	4
				21.1	0947	0	0	1
			12/27/2012	18	1025	0	1	15
			De-Posting	20	1012	0	0	0
				21	1010	0	2	2
				21.1	1200	0	1	5
			12/28/2012	19	0915	0	5	0
			De-Posting	22	0830	0	0	0

* No data from the Lincoln structure due to lack of telemetry for this event.
NR = not recorded

Appendix C-6a

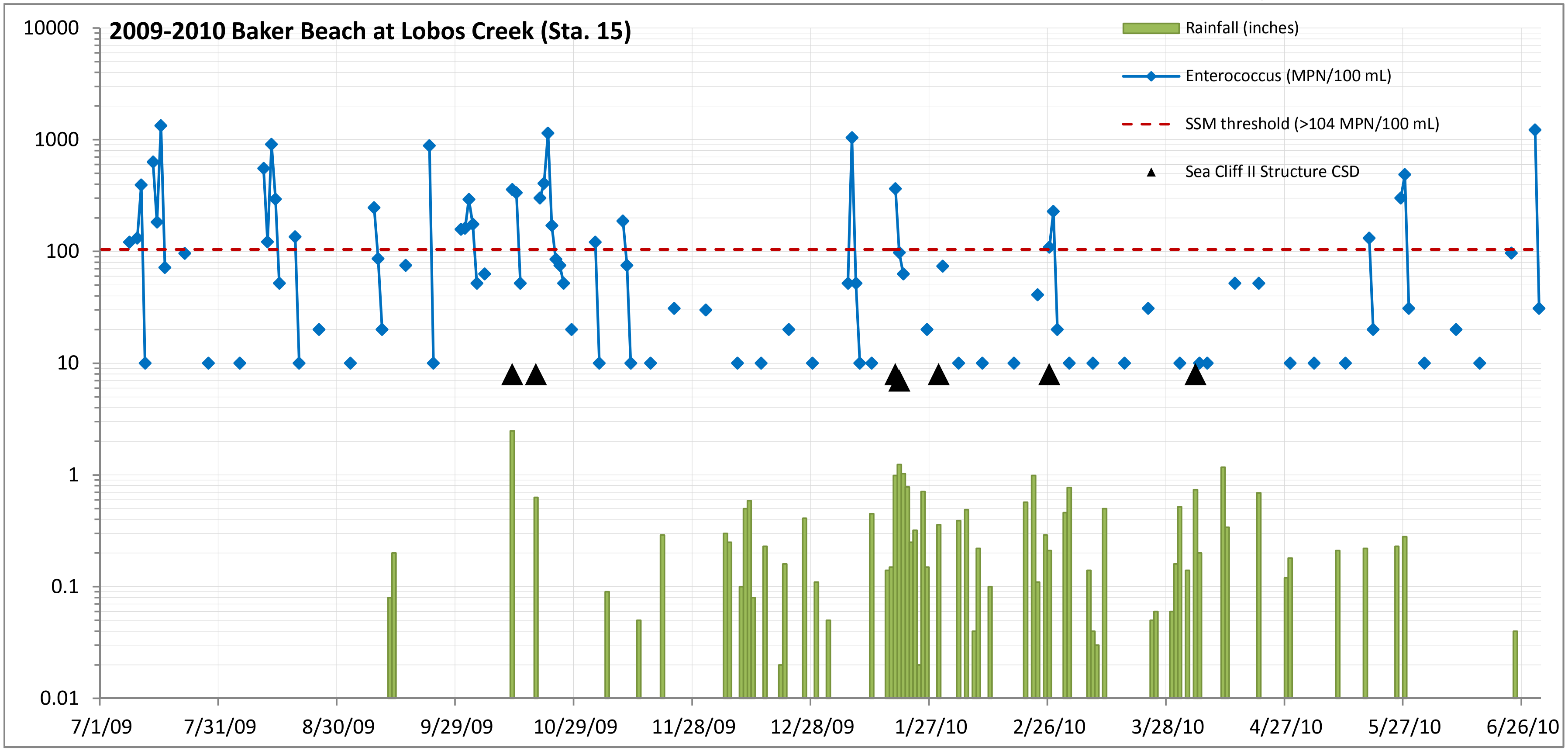
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-6b

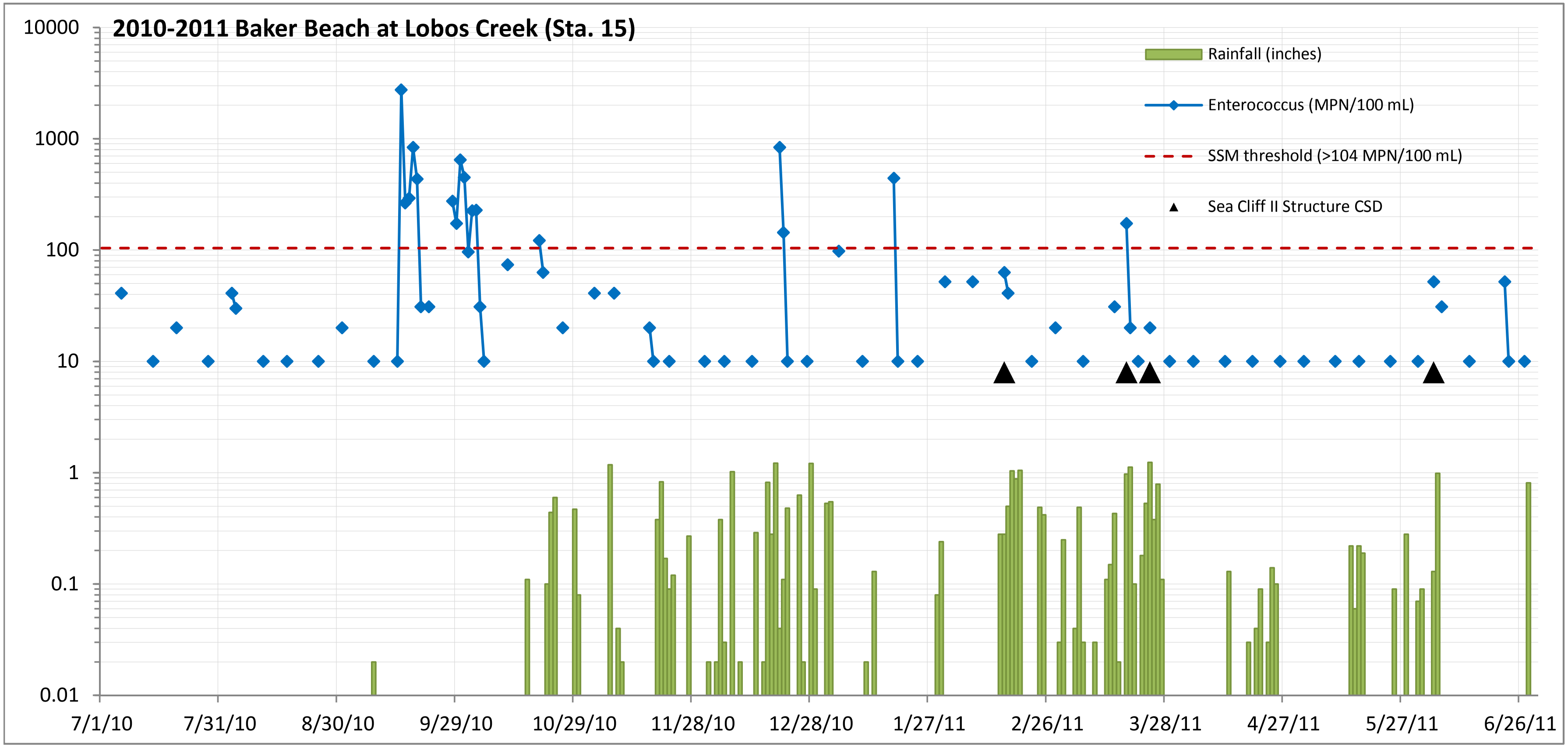
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-6c

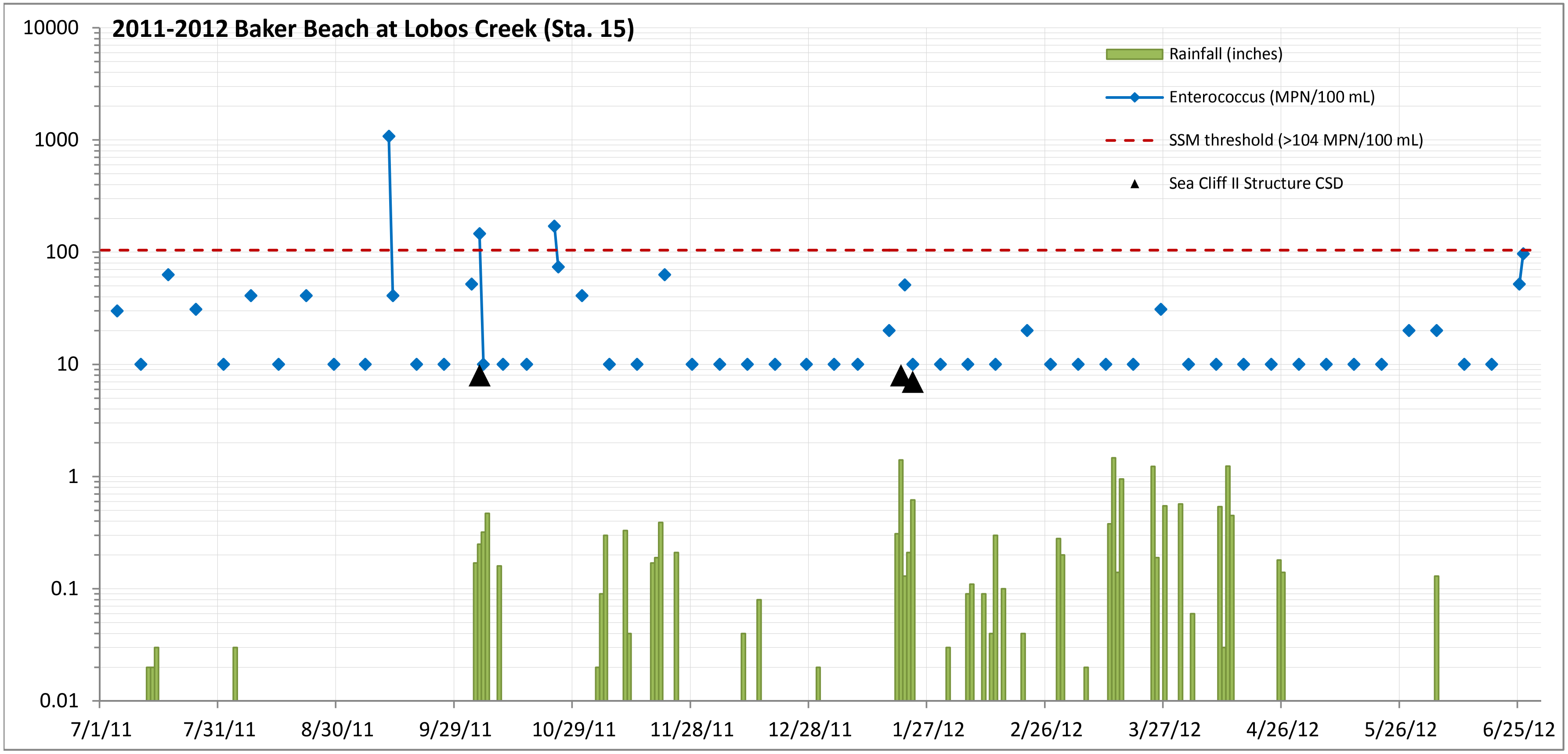
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-6d

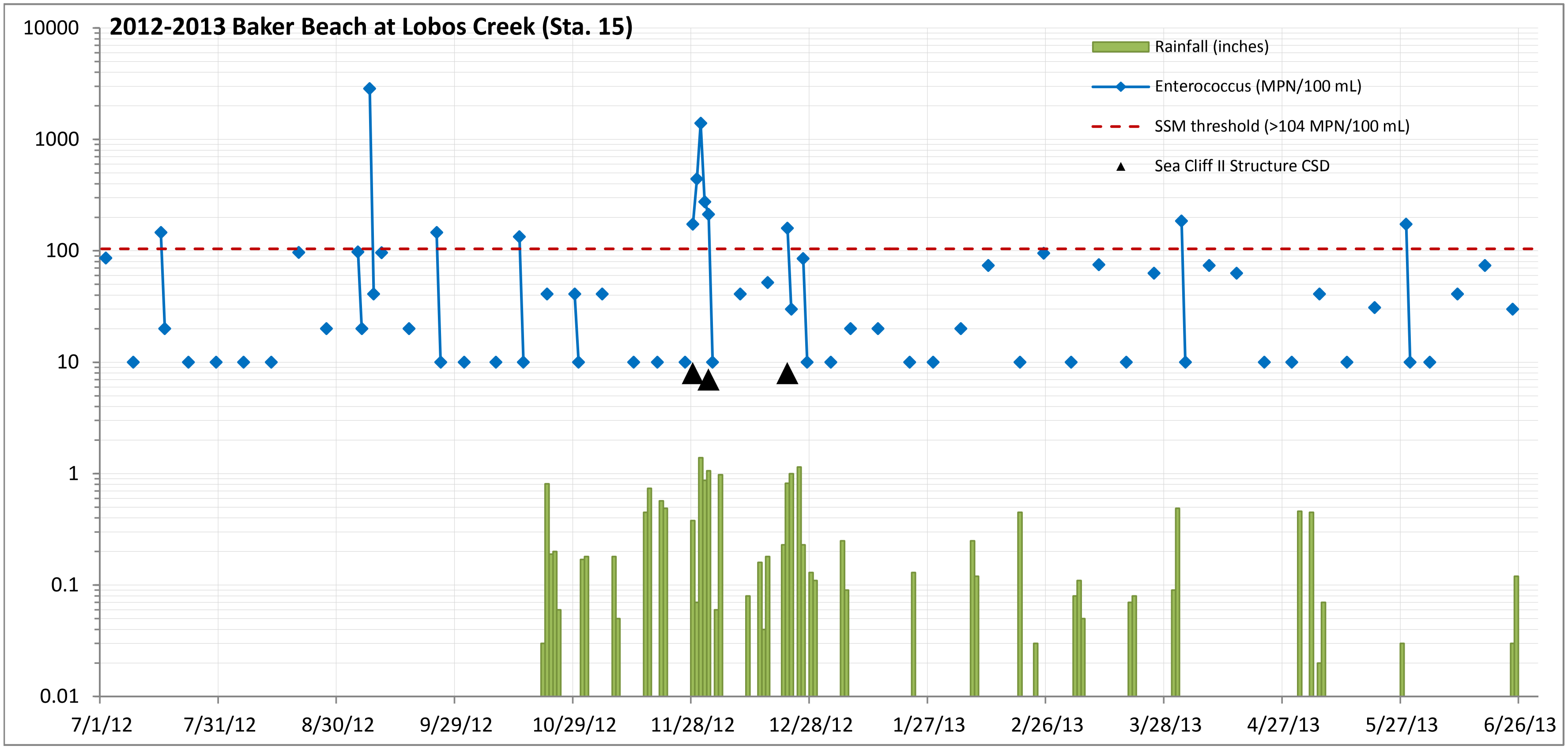
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-6e

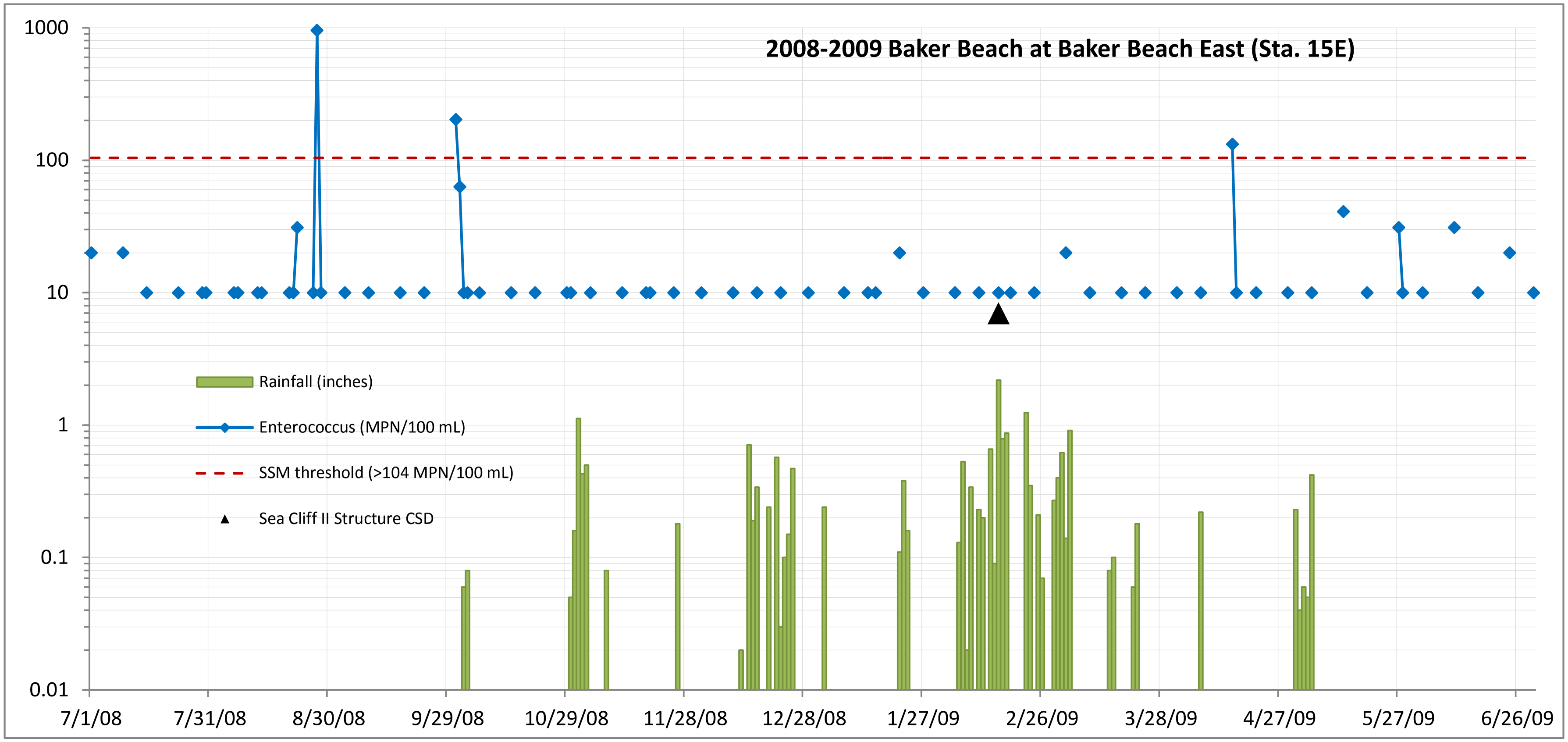
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-7a

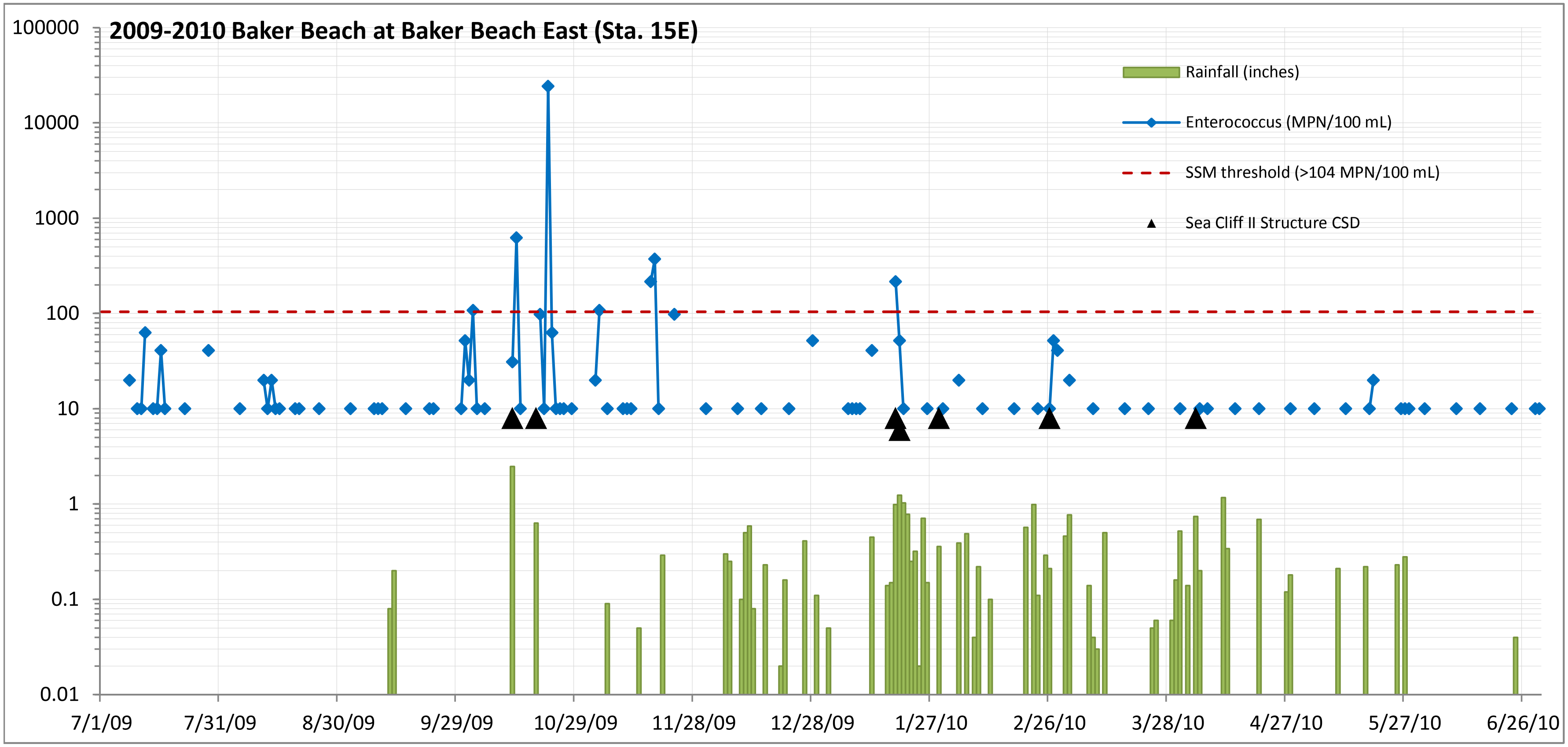
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15E from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-7b

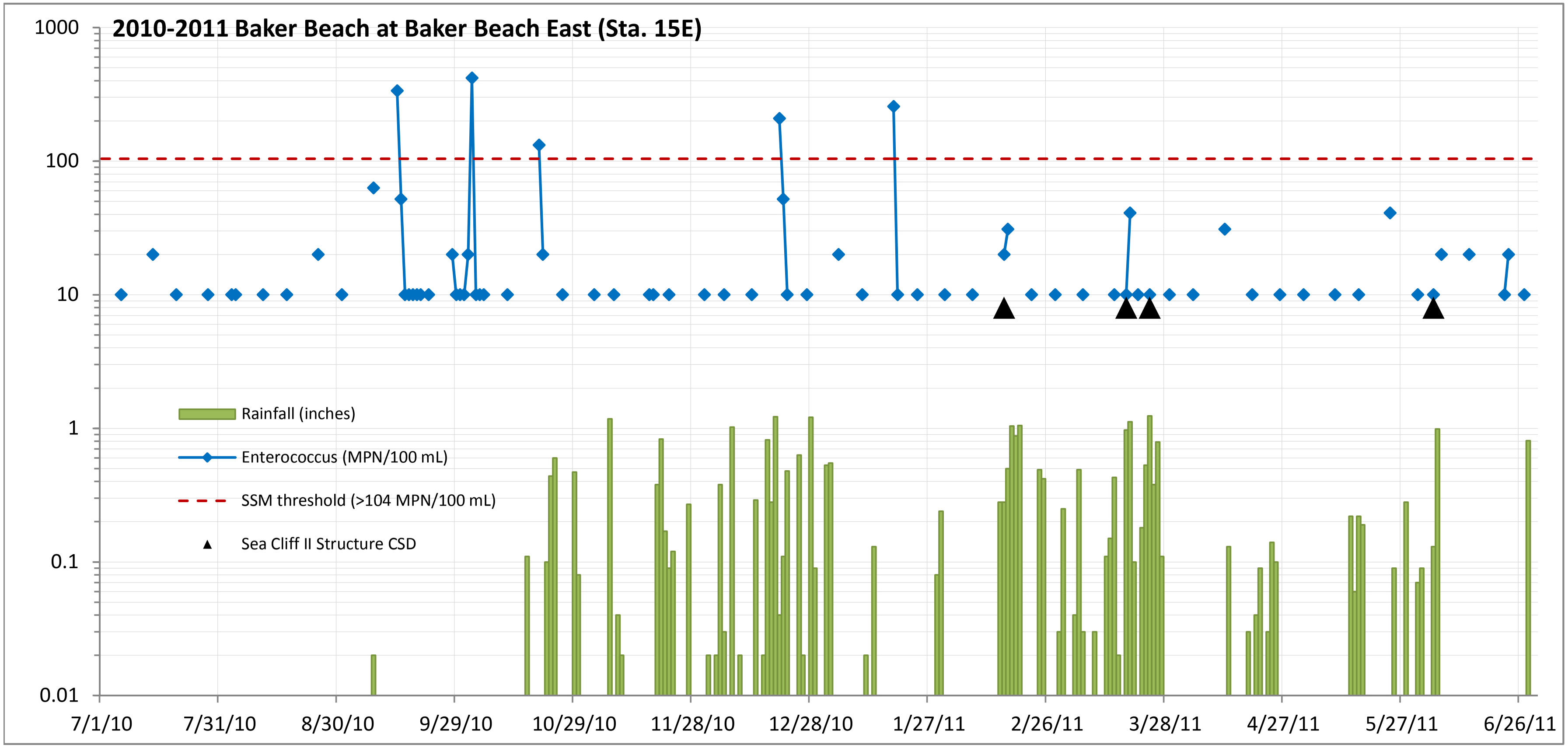
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15E from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-7c

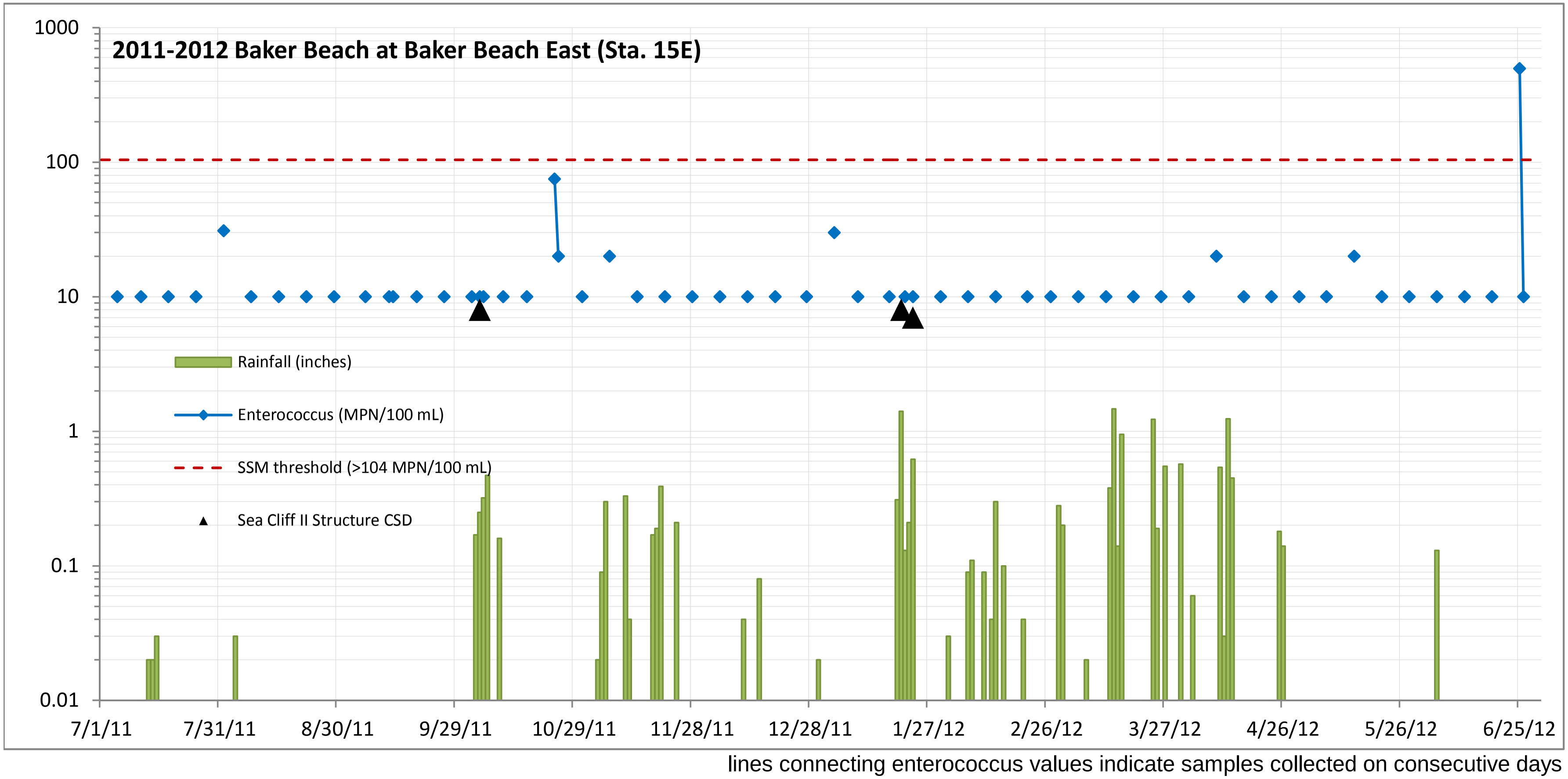
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15E from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

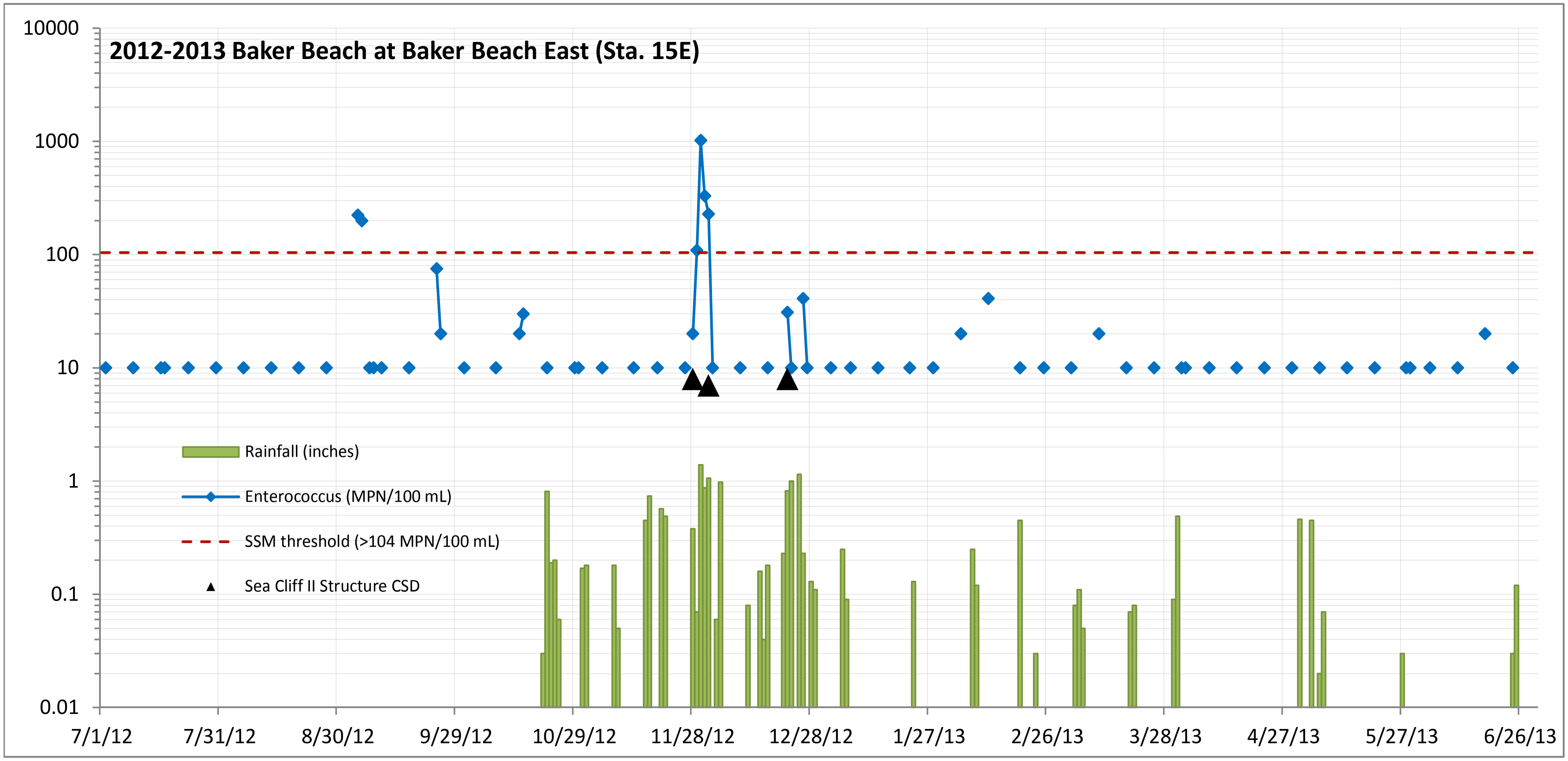
Appendix C-7d

Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15E from July 1,2011-June 30,2012



Appendix C-7e

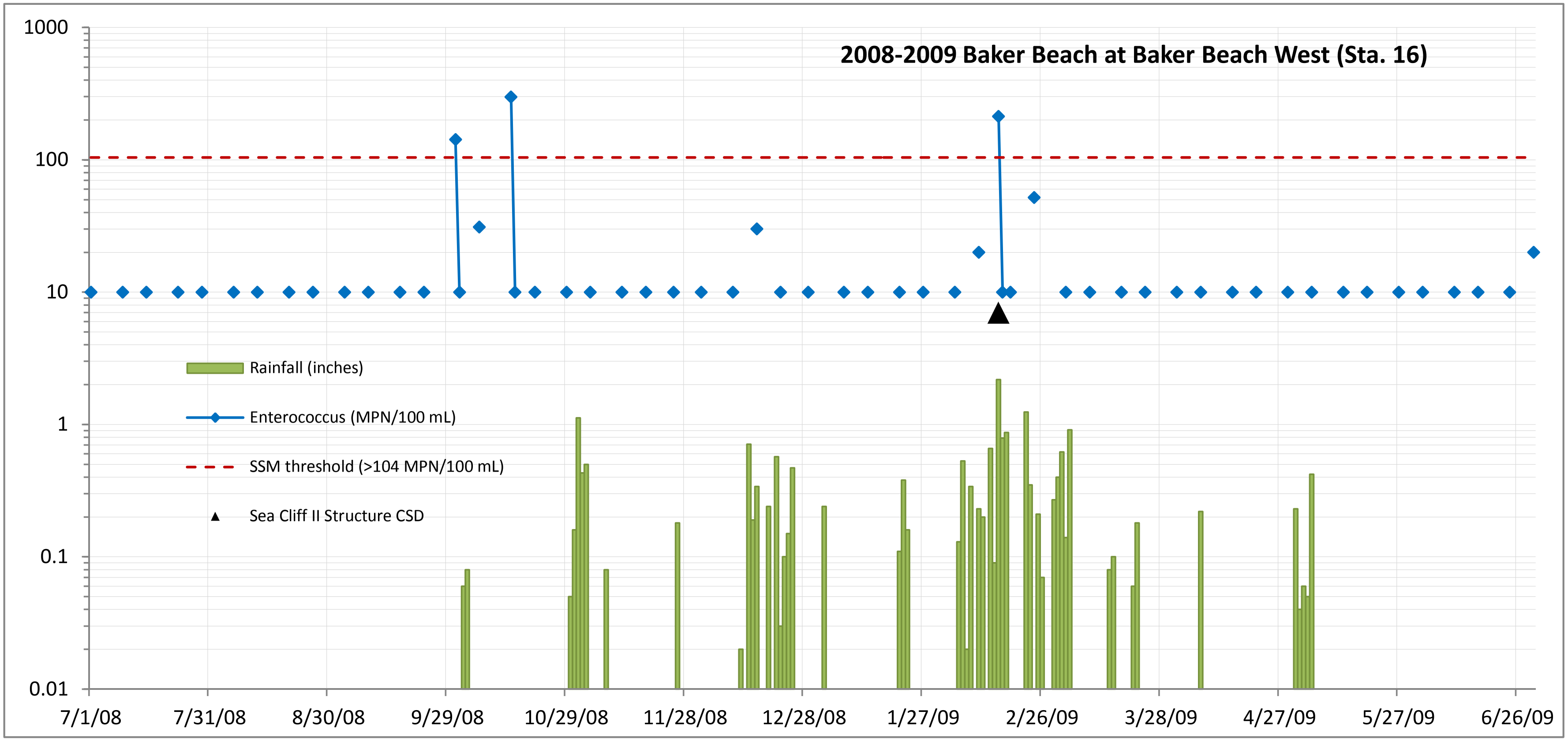
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 15E from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-8a

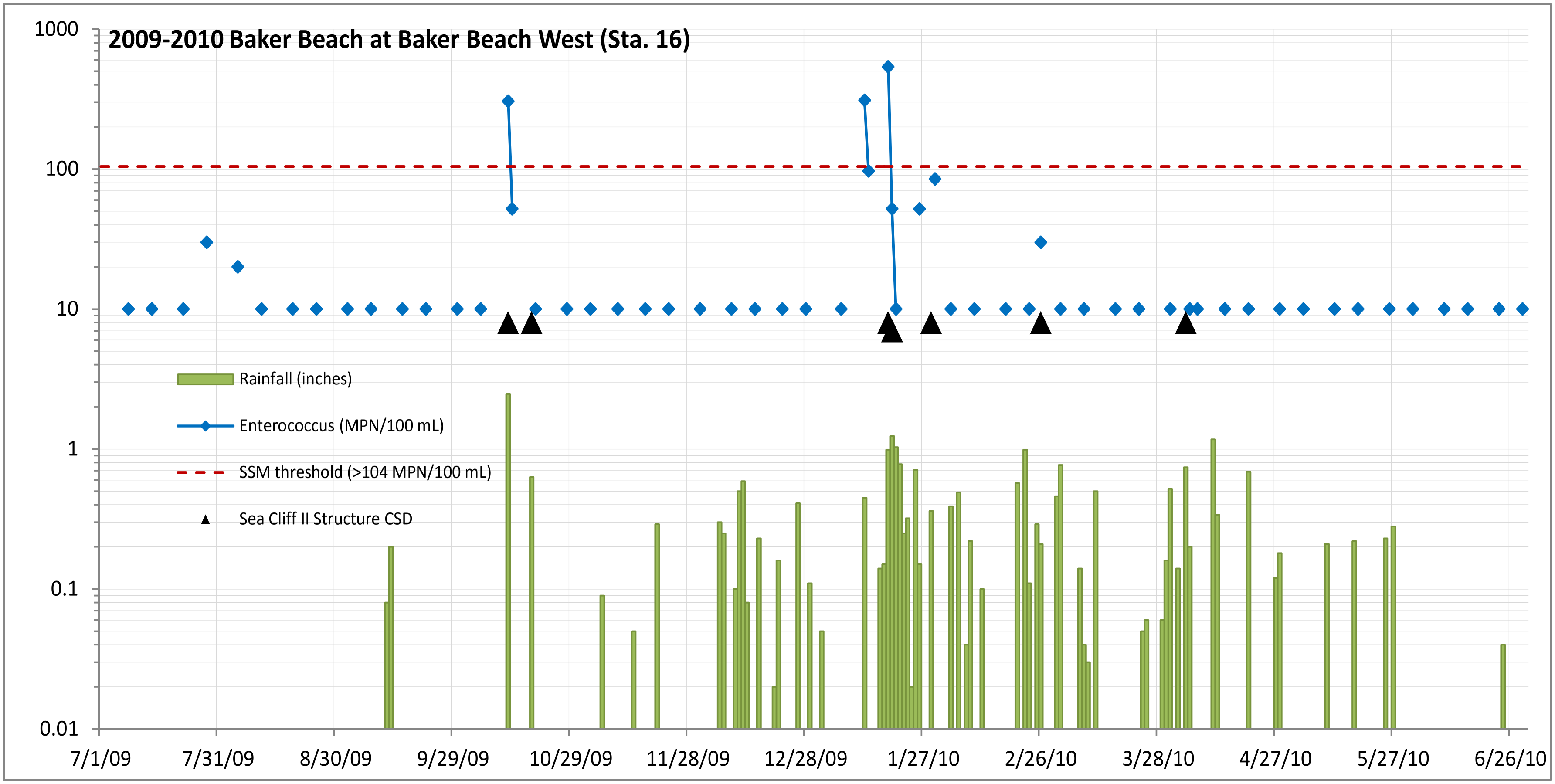
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 16 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-8b

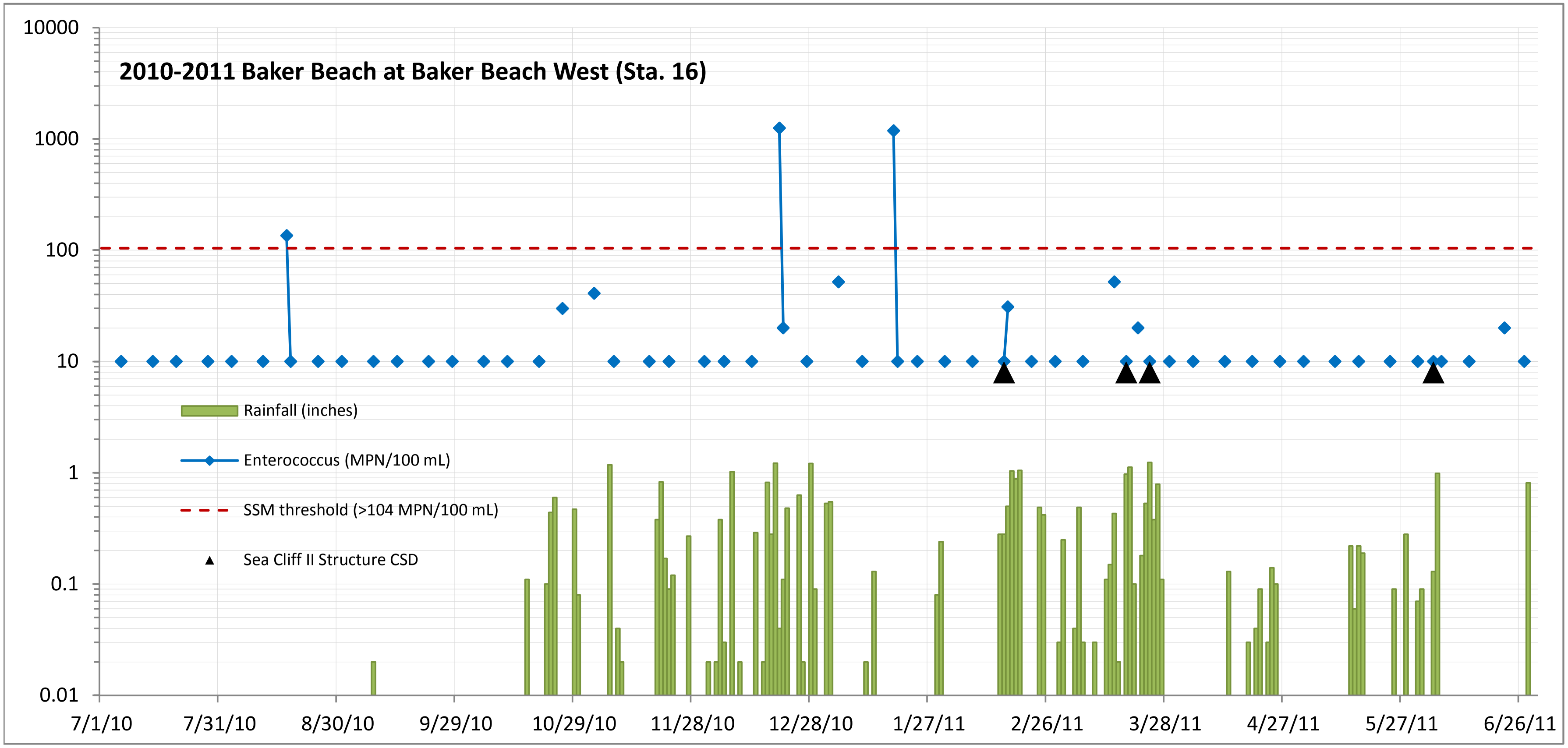
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 16 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-8c

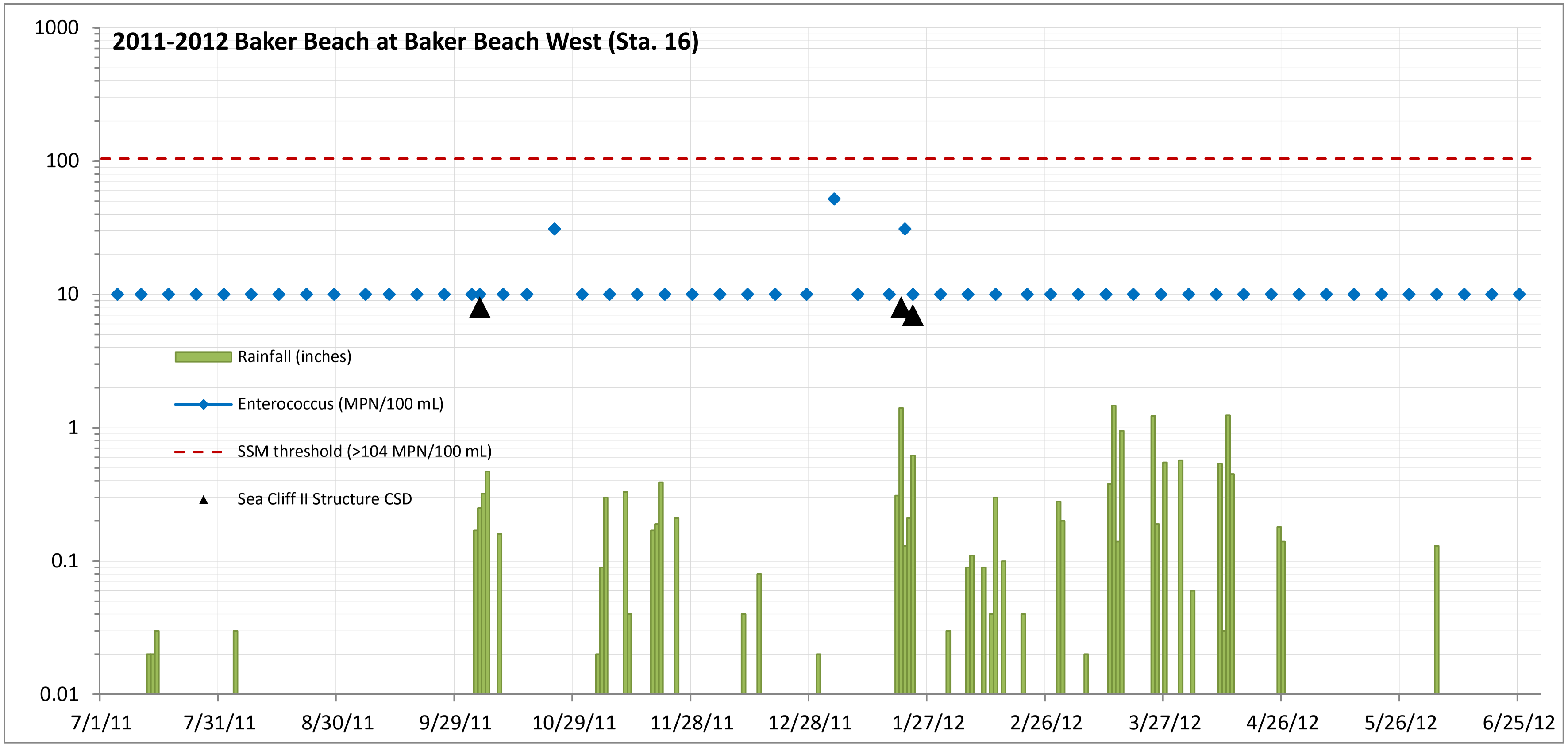
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 16 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-8d

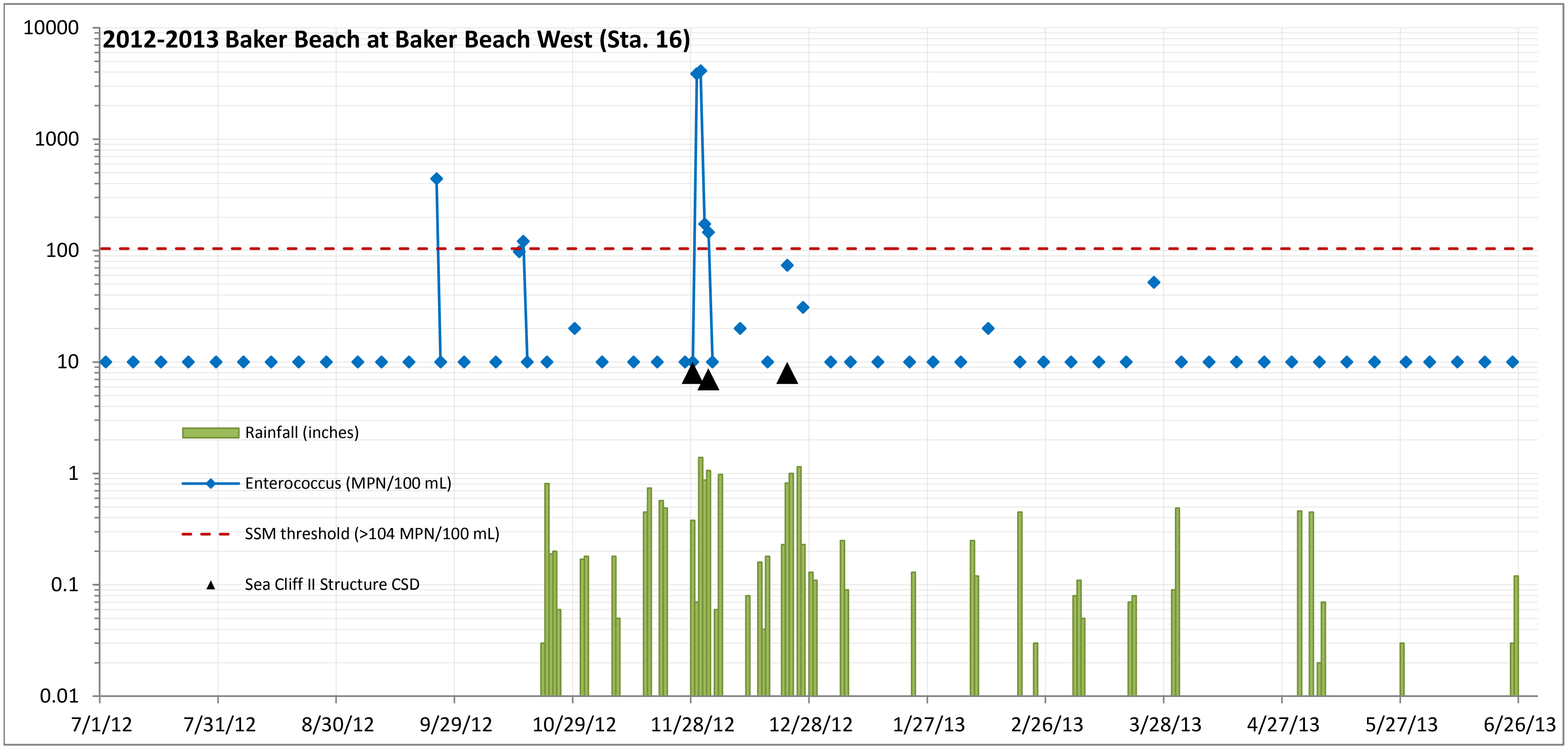
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 16 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-8e

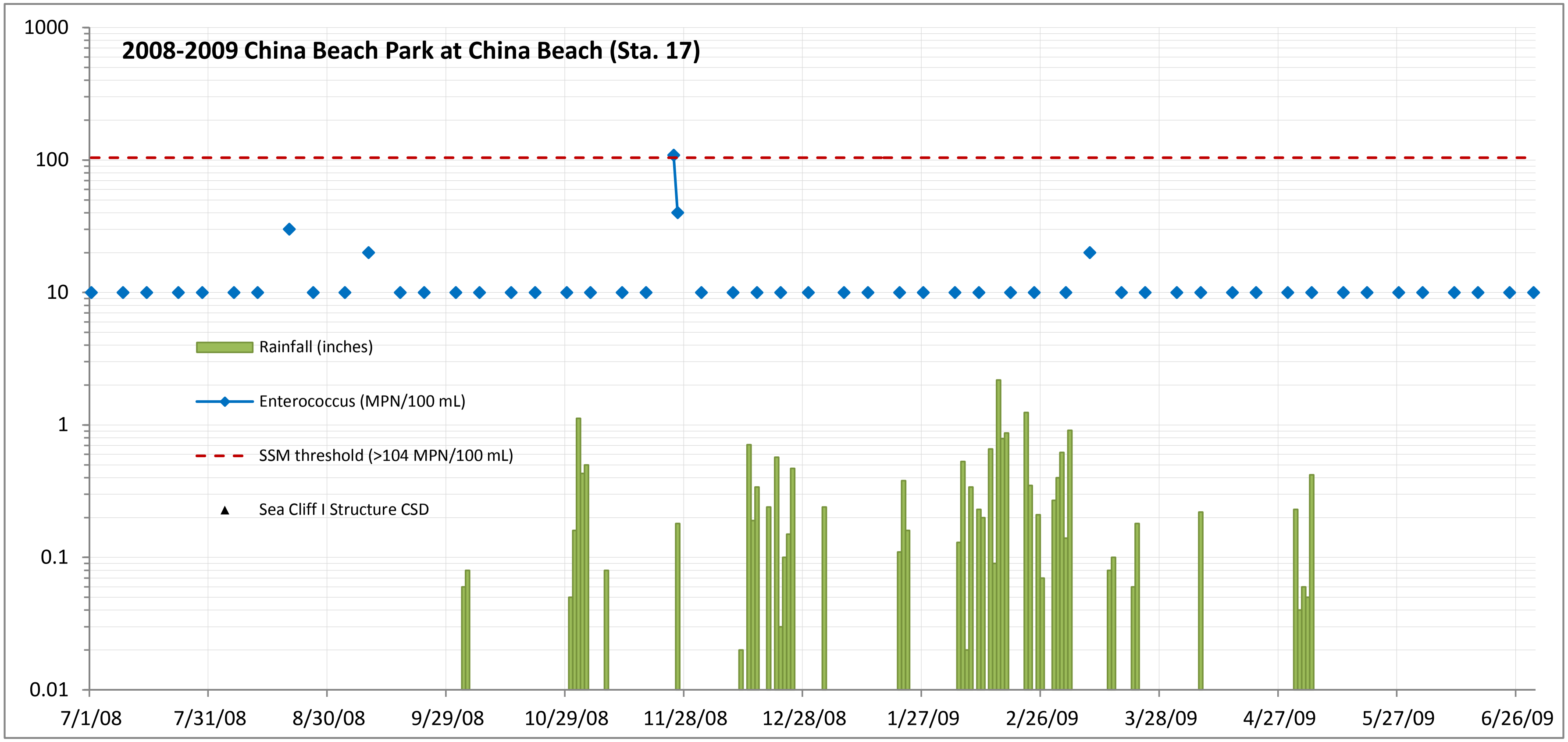
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Baker Beach Station 16 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-9a

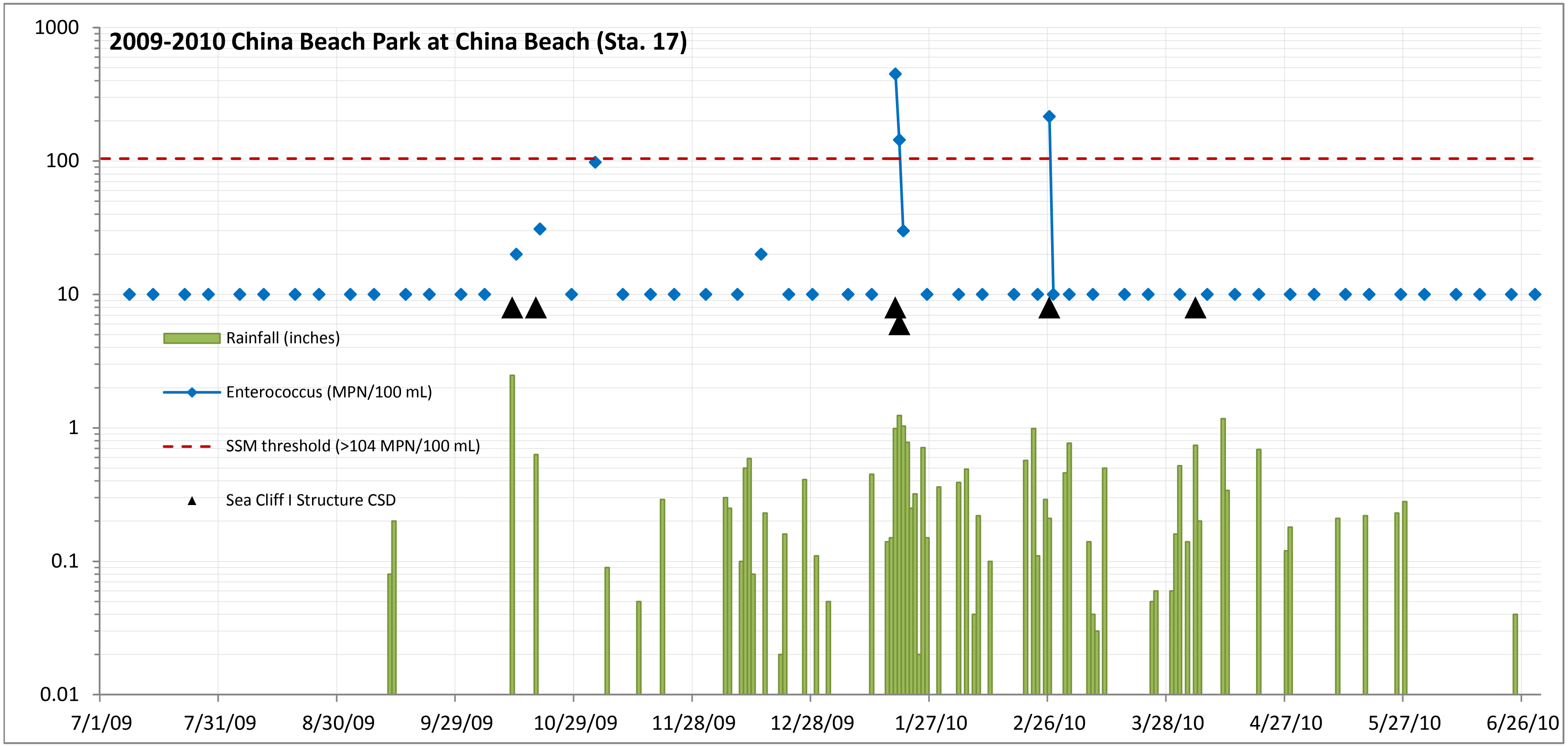
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at China Beach Station 17 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-9b

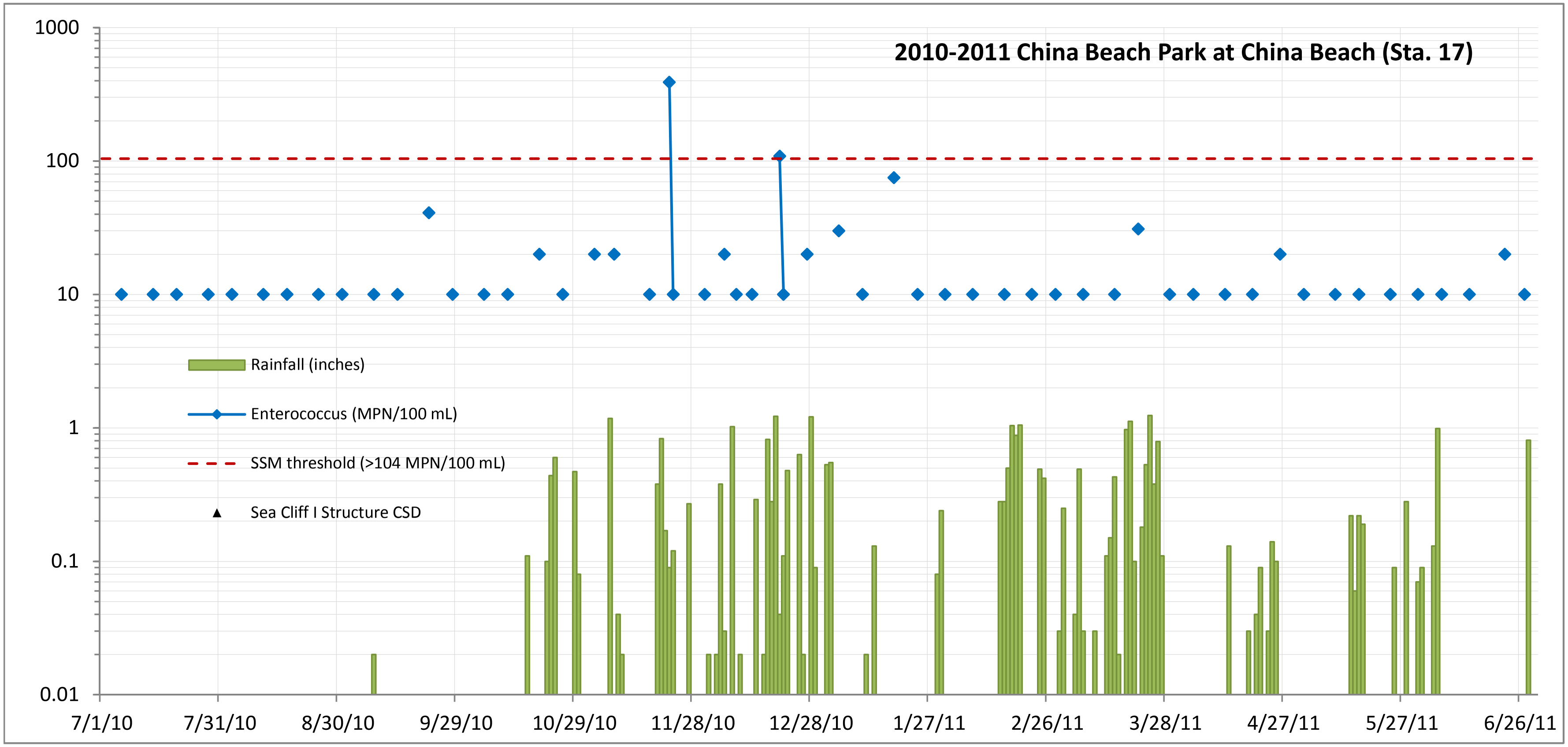
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at China Beach Station 17 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-9c

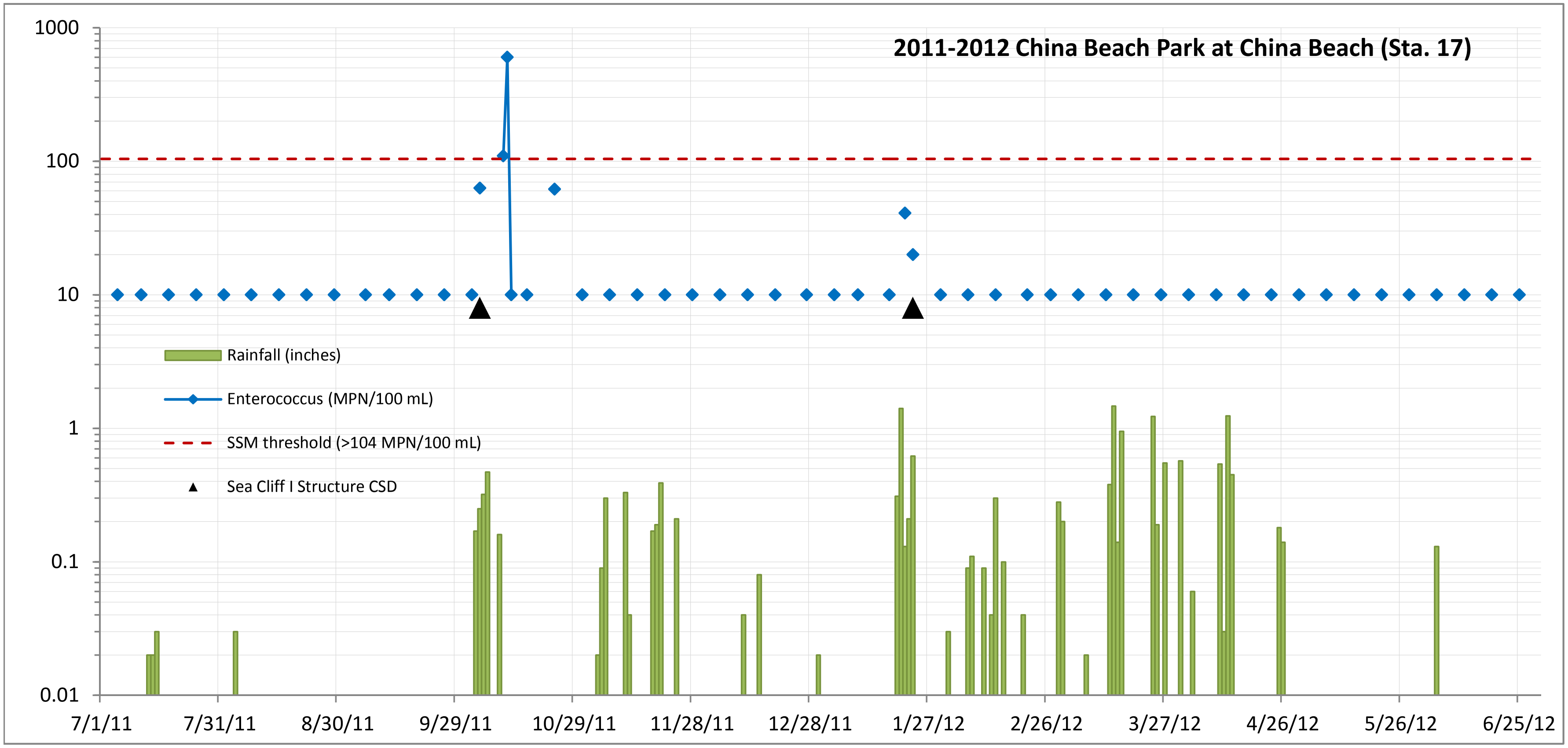
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at China Beach Station 17 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-9d

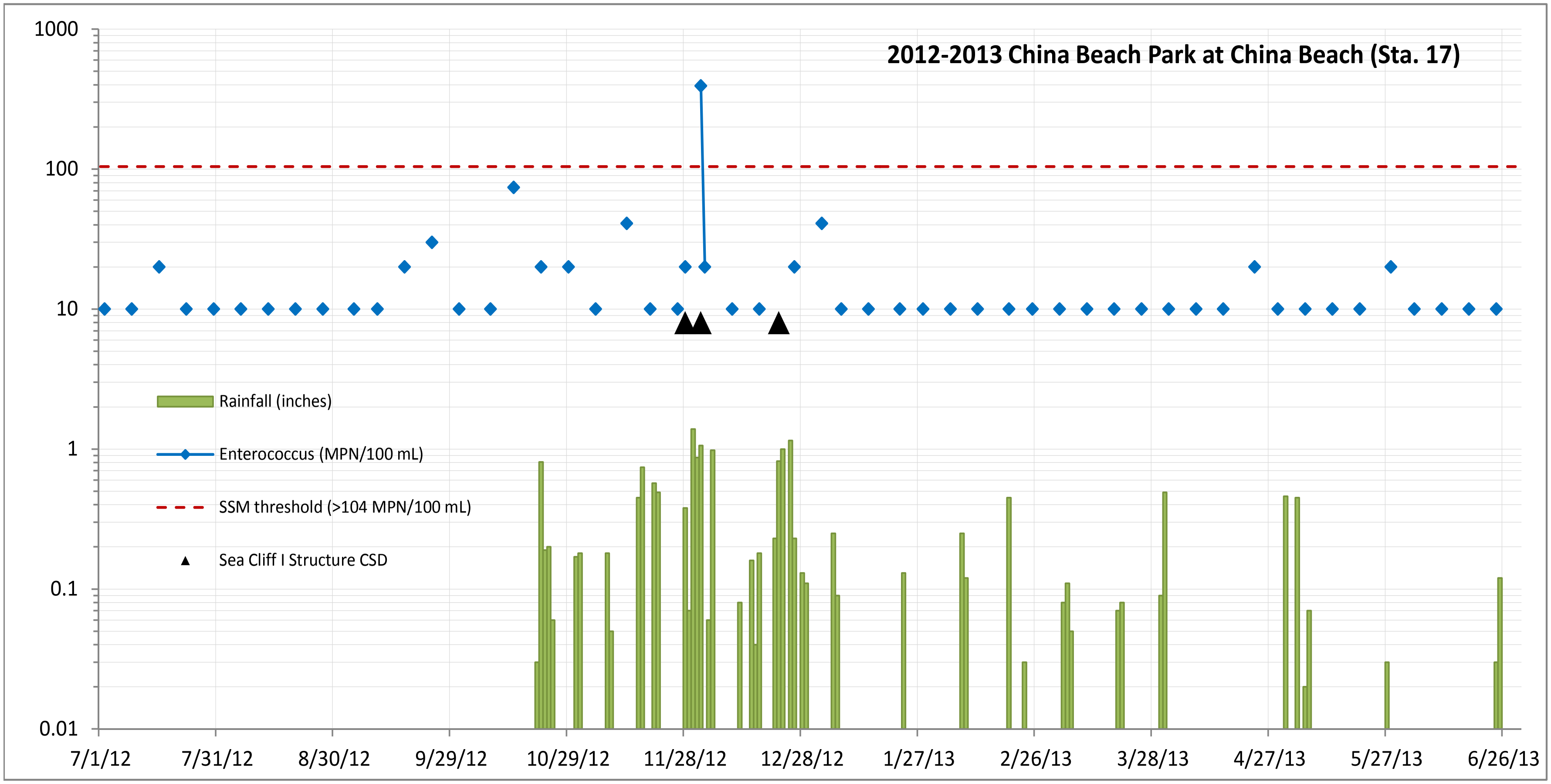
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at China Beach Station 17 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-9e

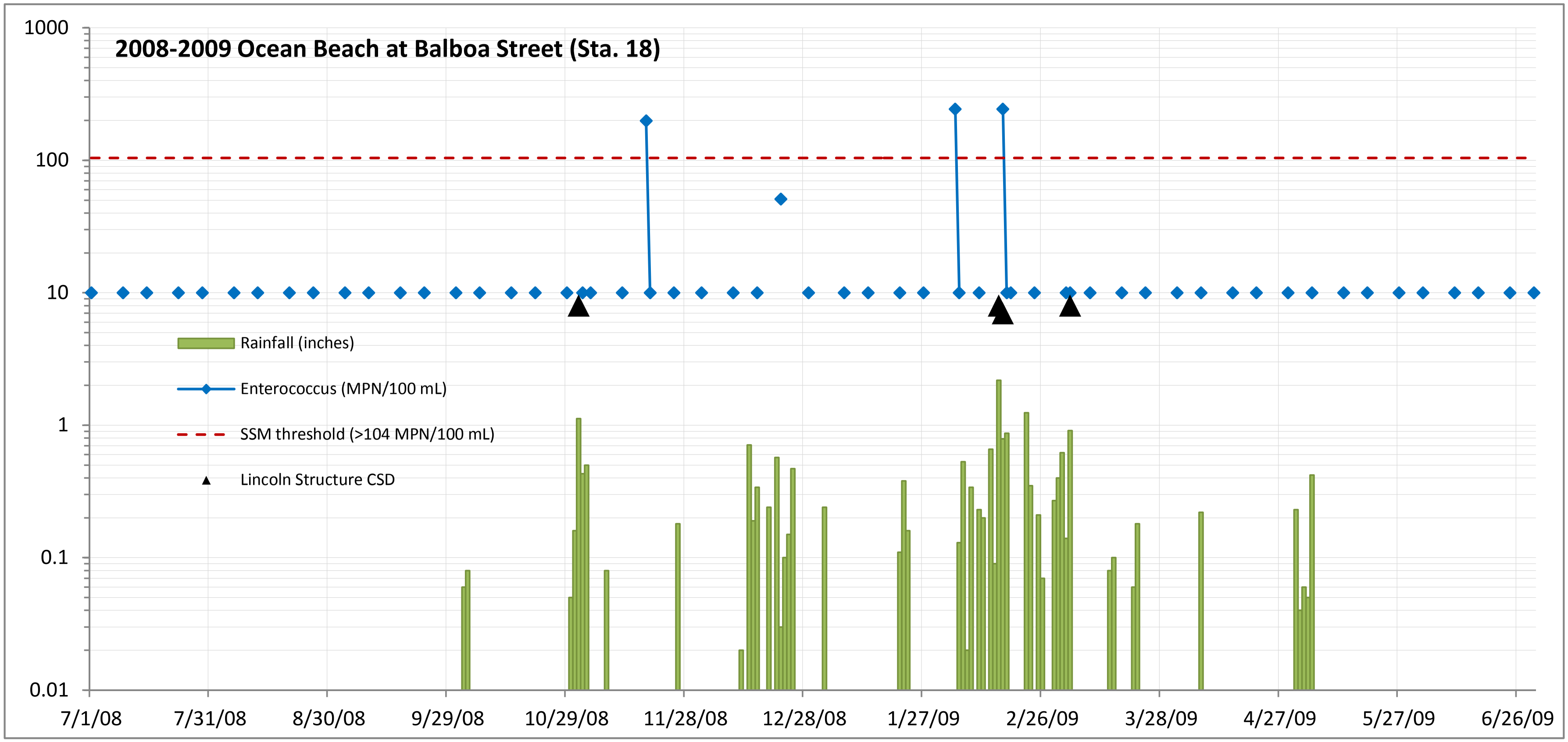
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at China Beach Station 17 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-10a

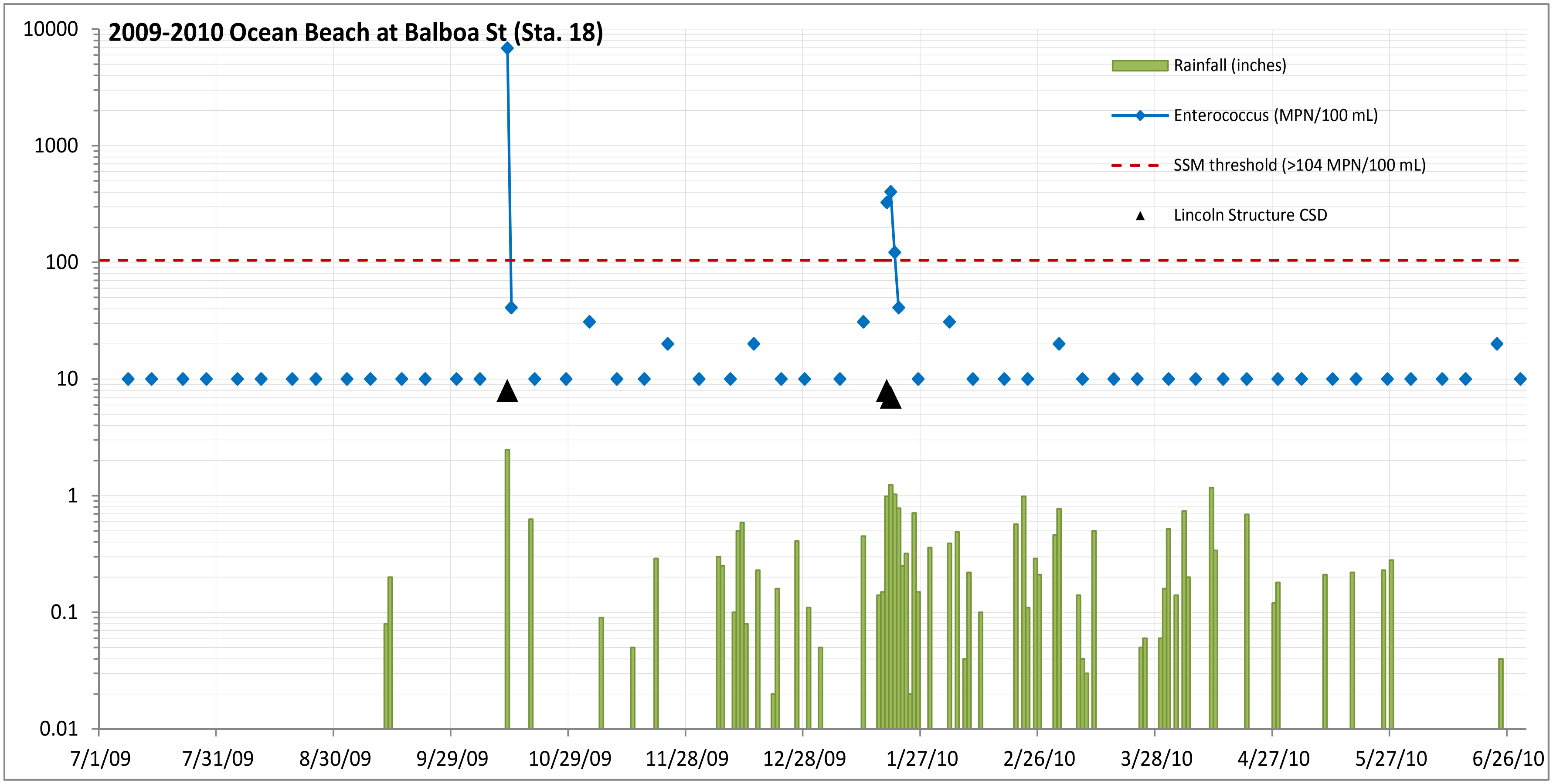
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 18 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-10b

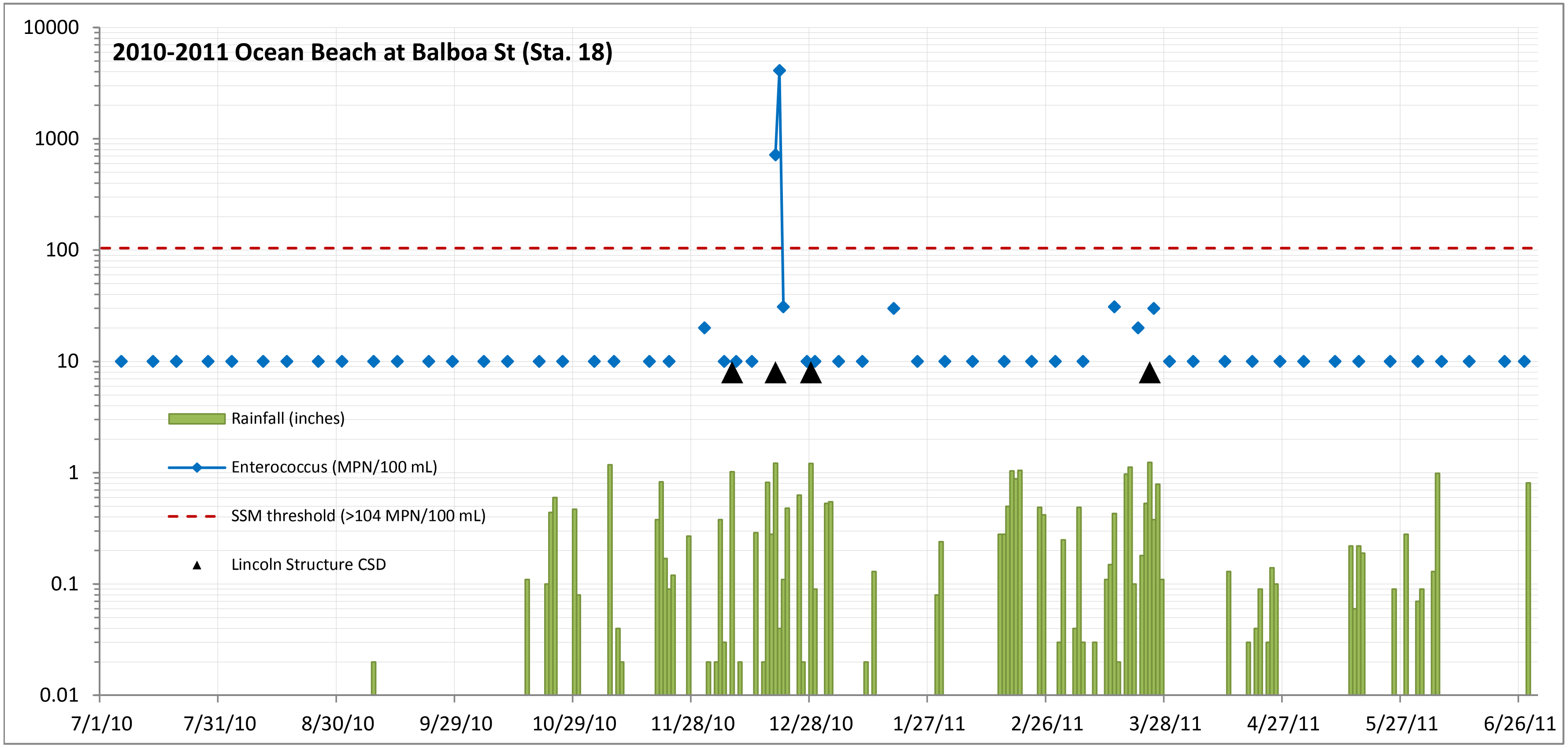
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 18 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-10c

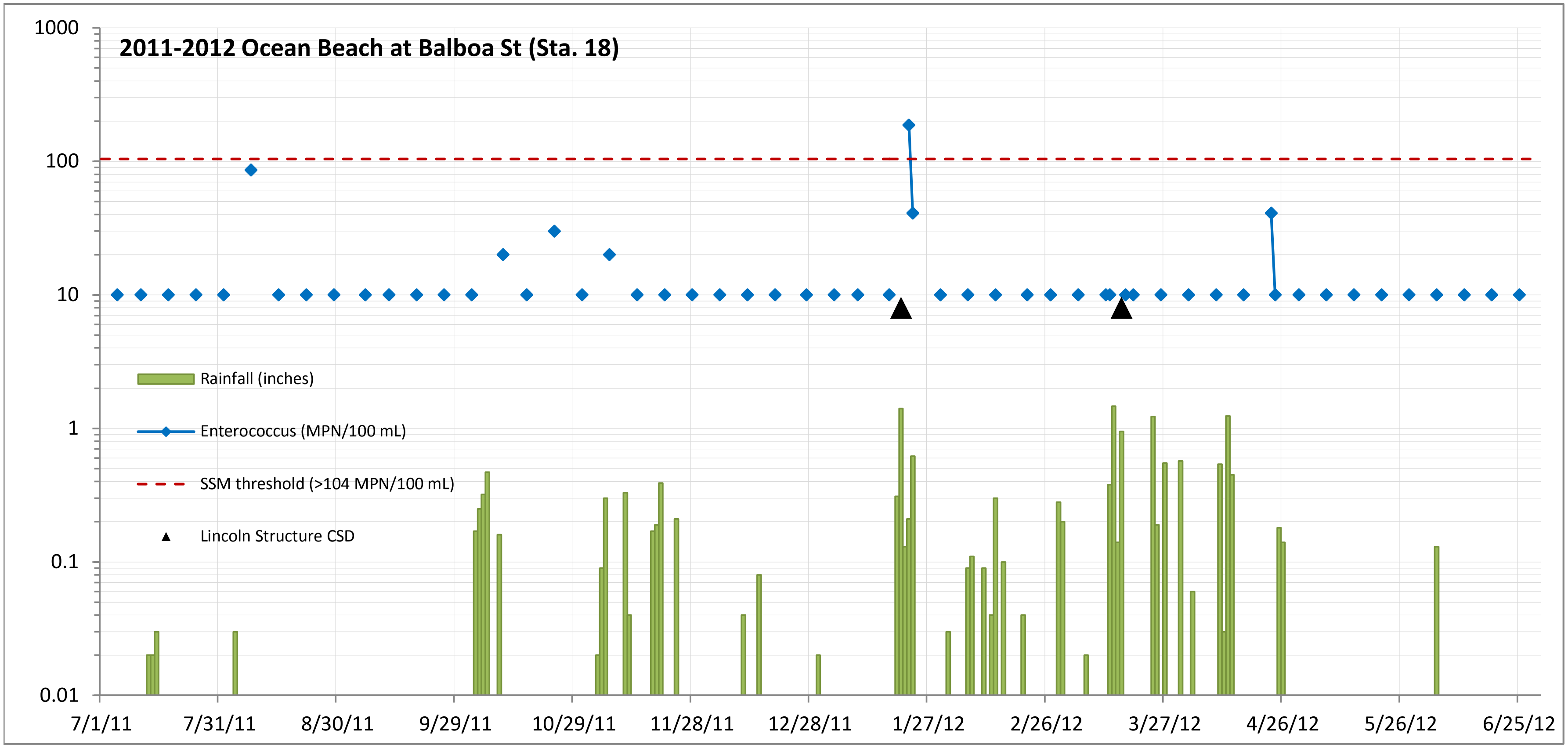
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 18 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-10d

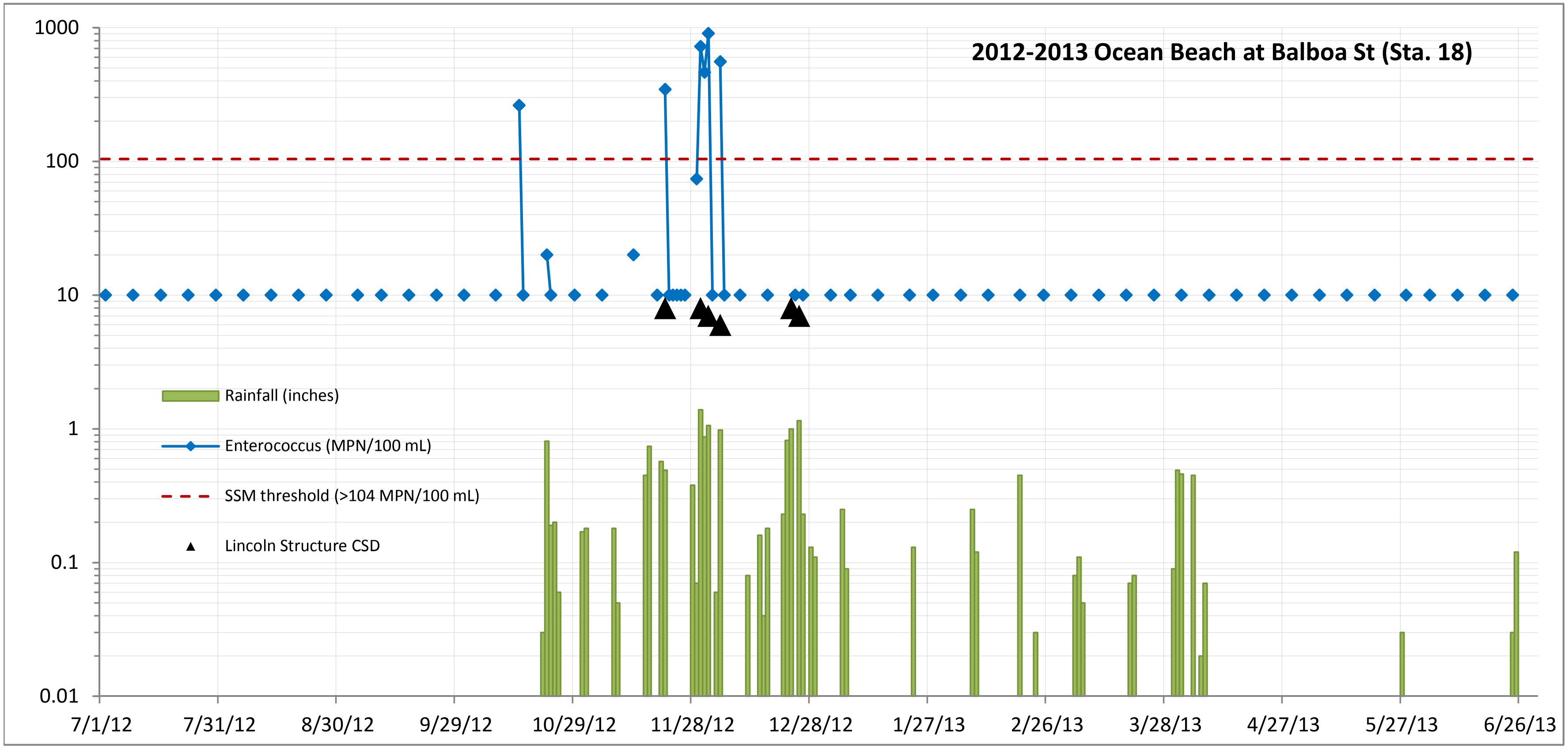
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 18 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-10e

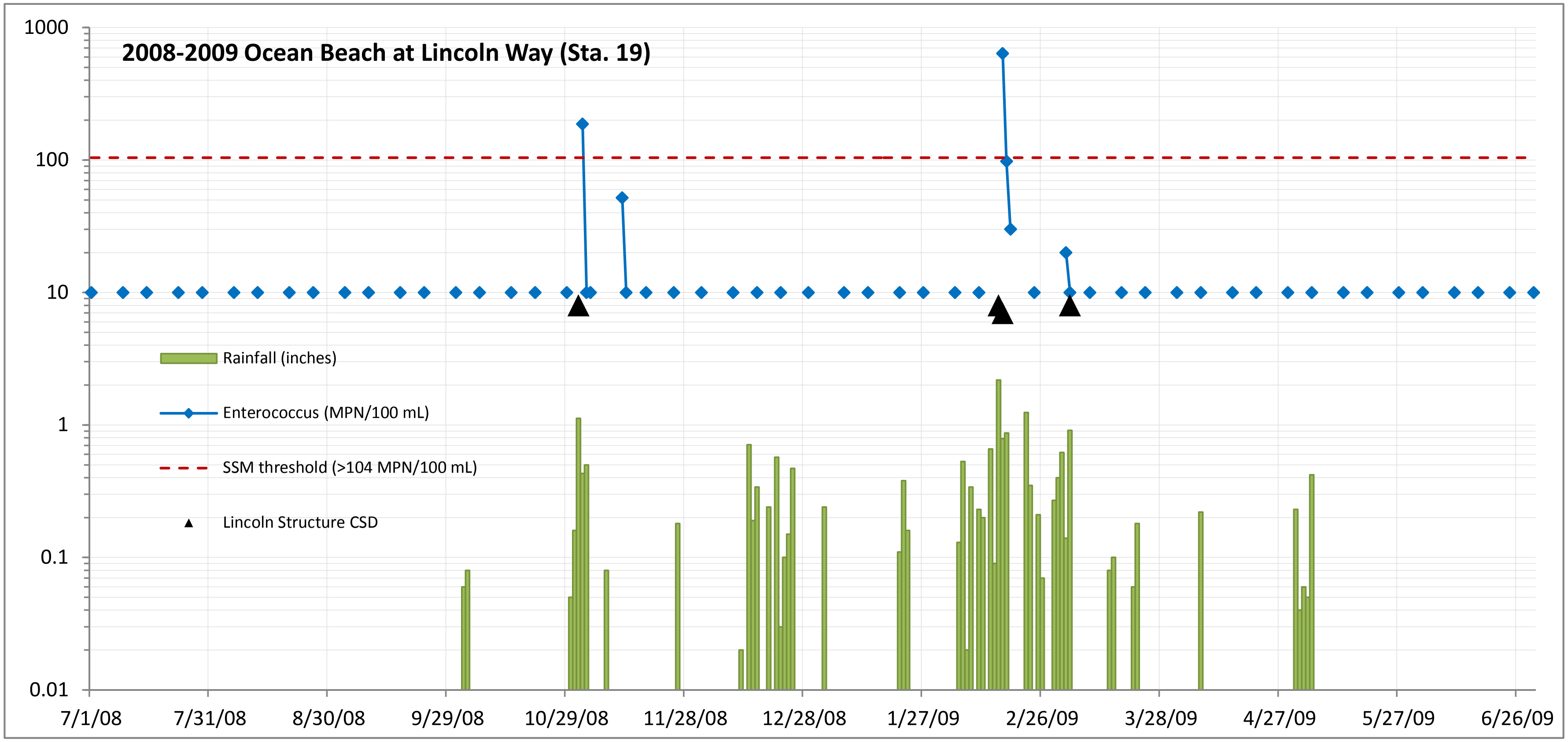
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 18 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-11a

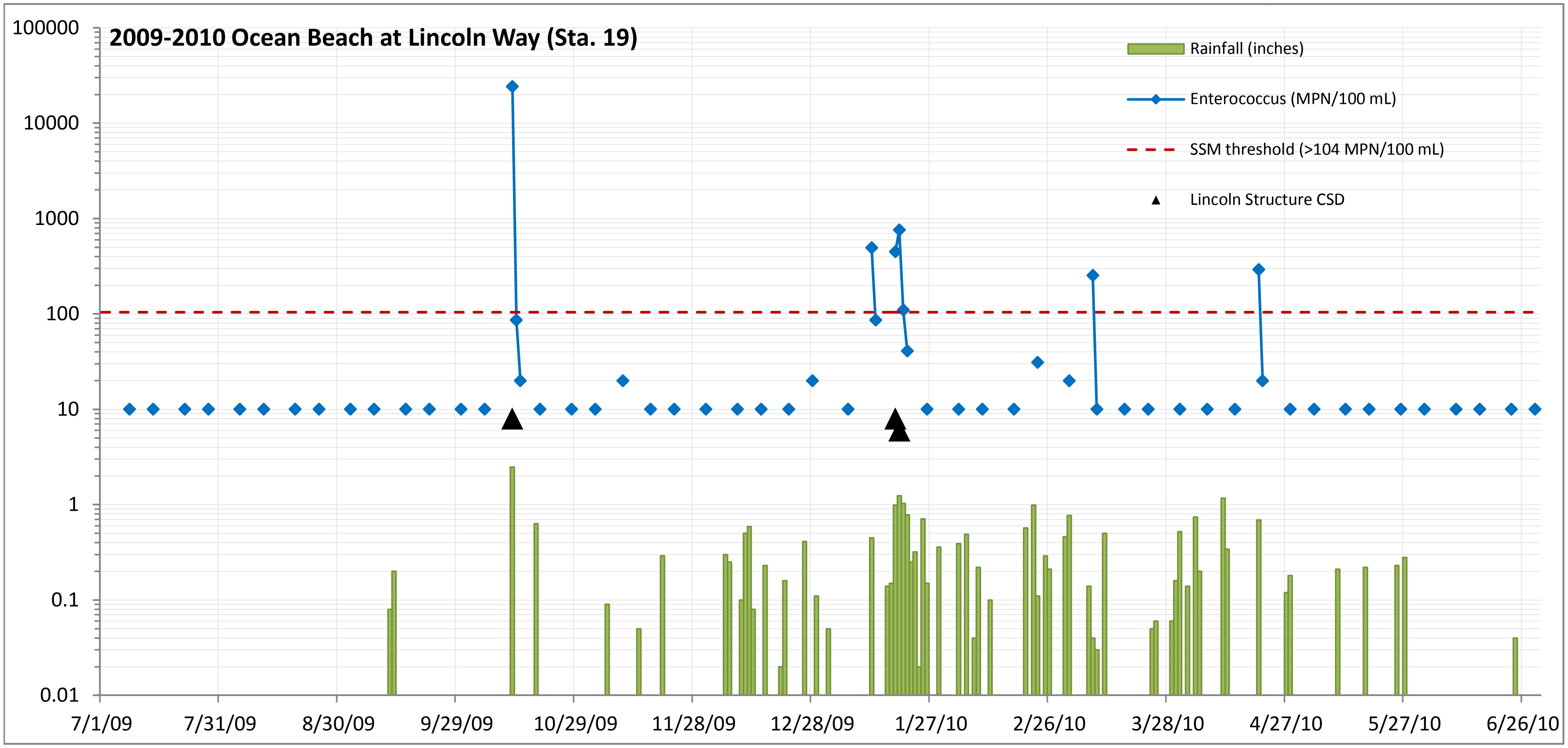
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 19 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-11b

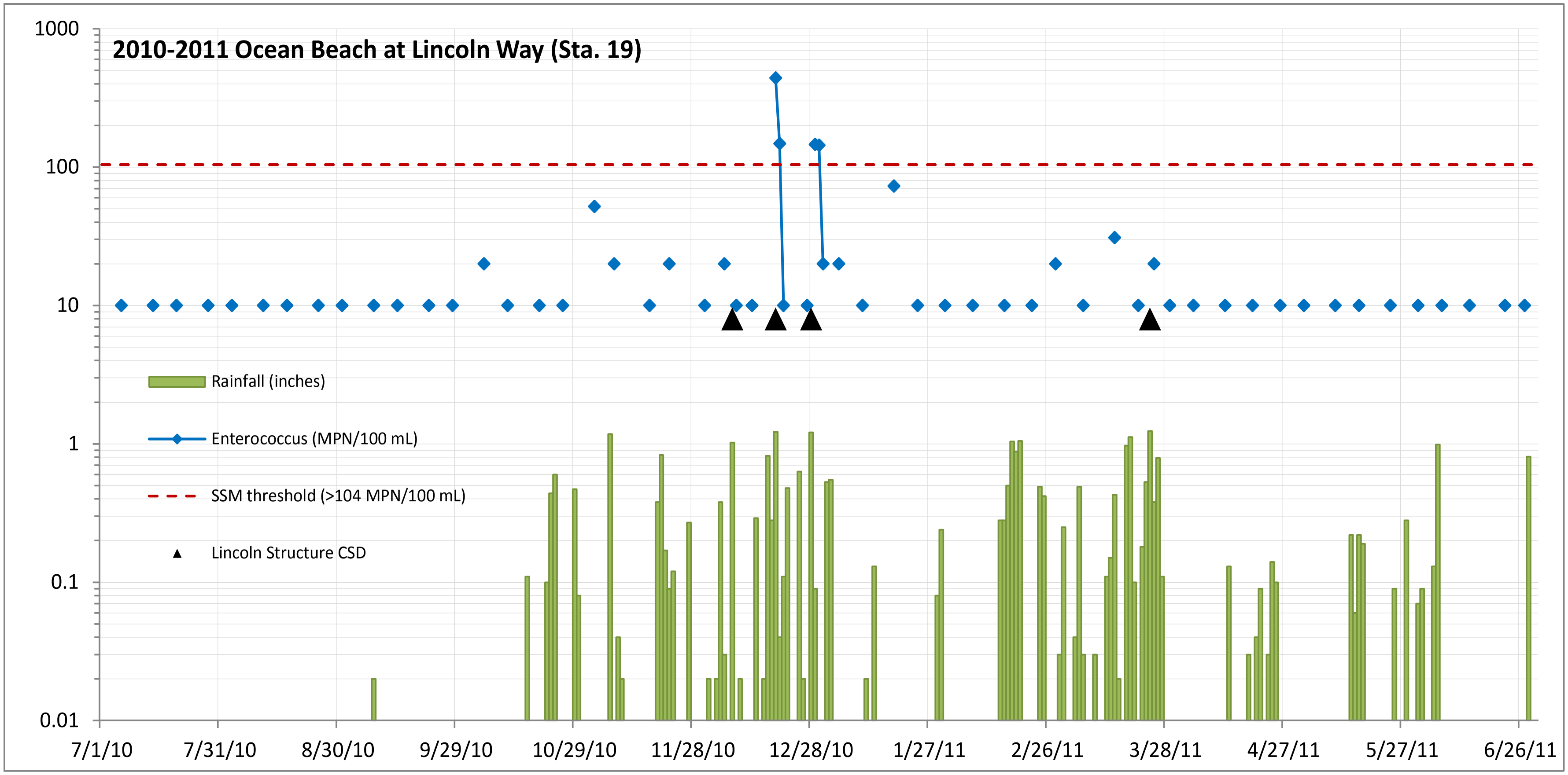
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 19 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-11c

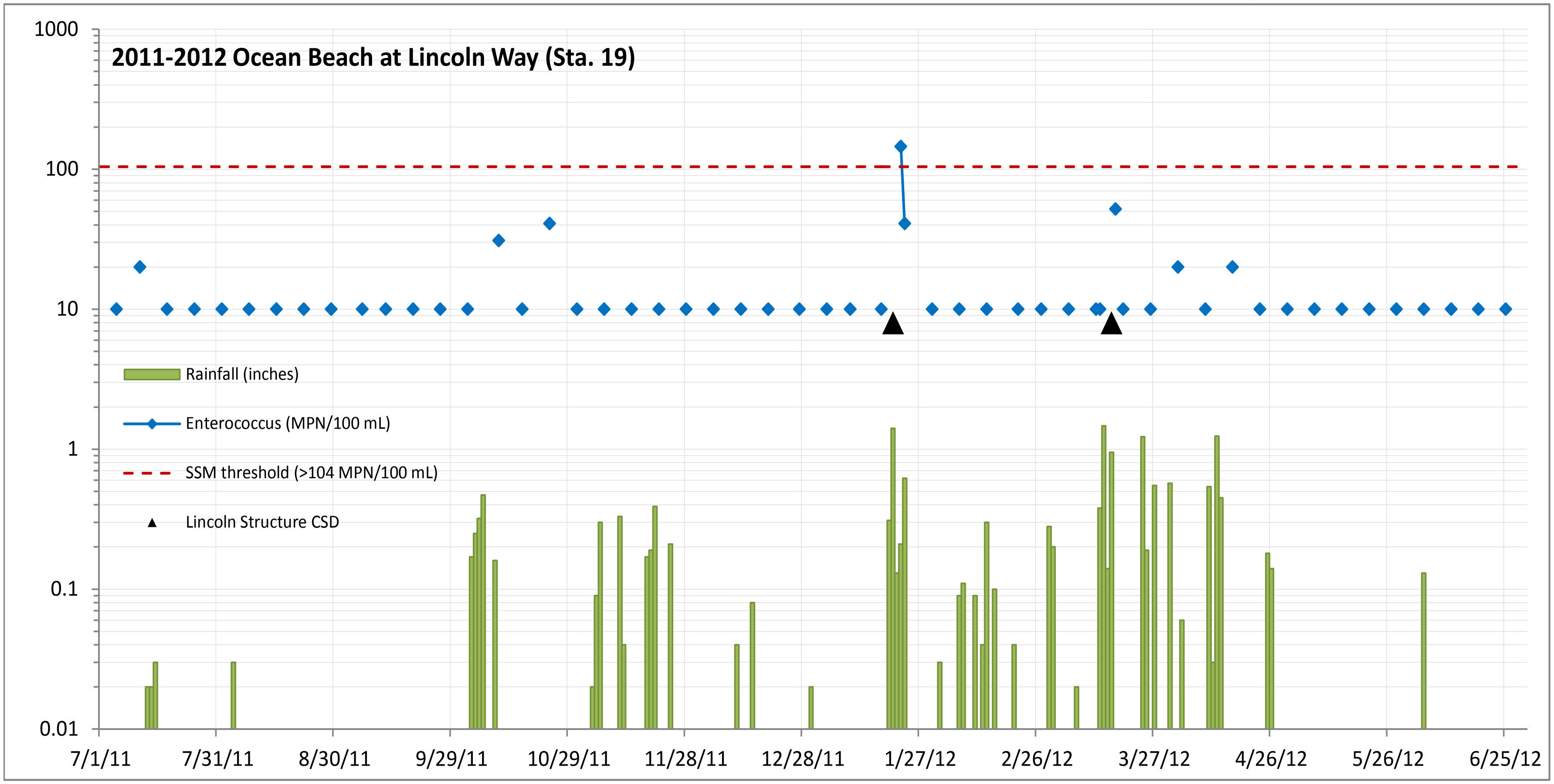
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 19 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-11d

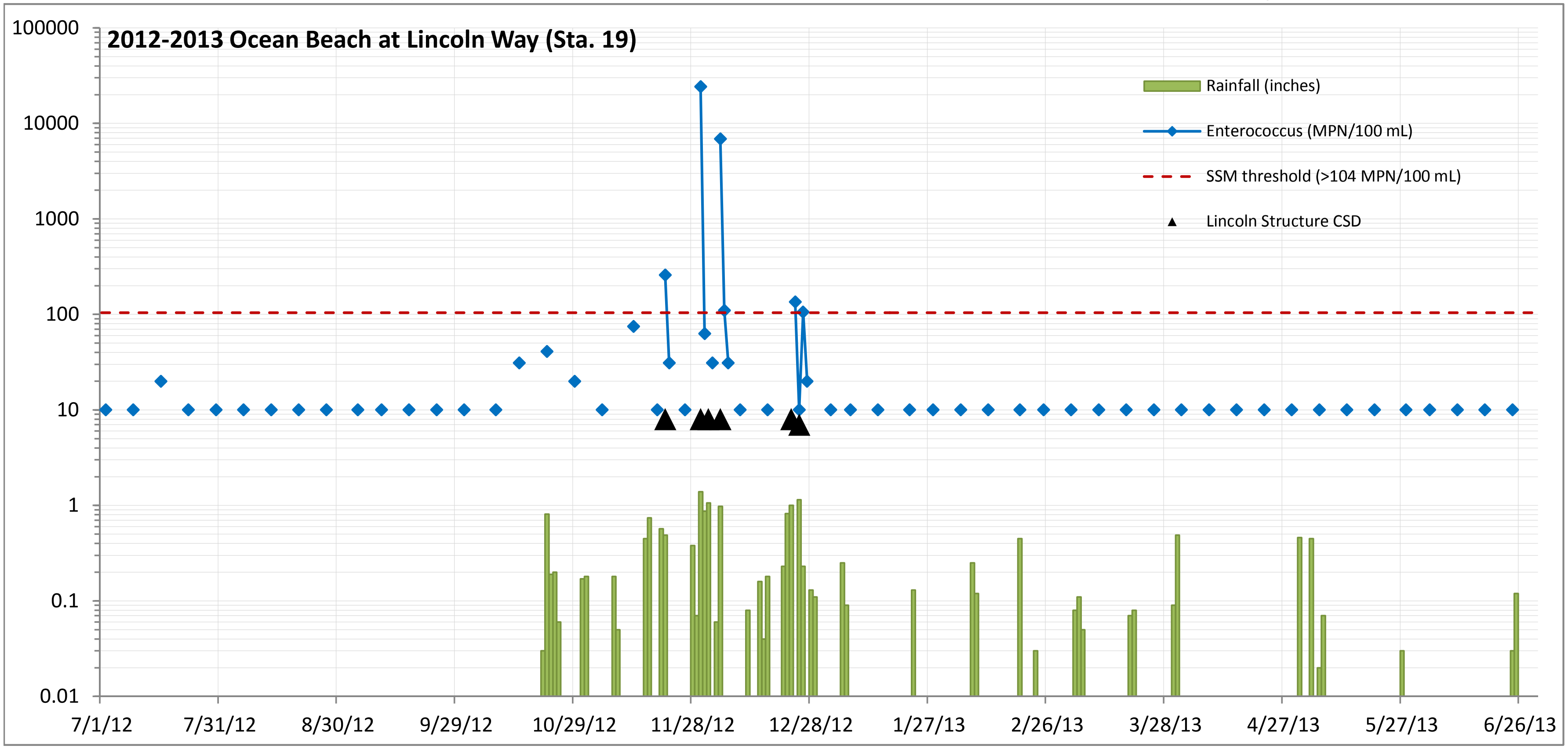
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 19 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-11e

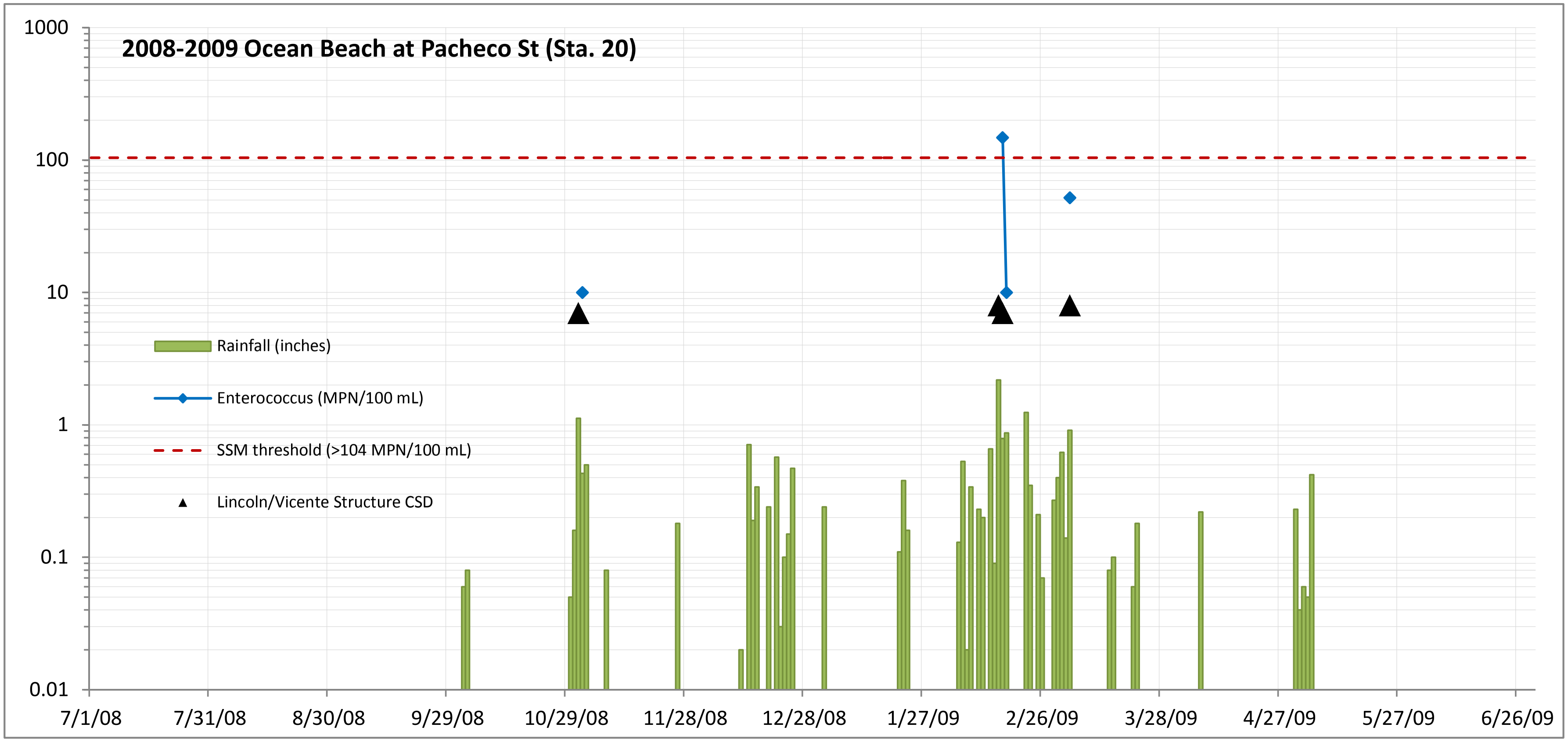
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 19 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-12a

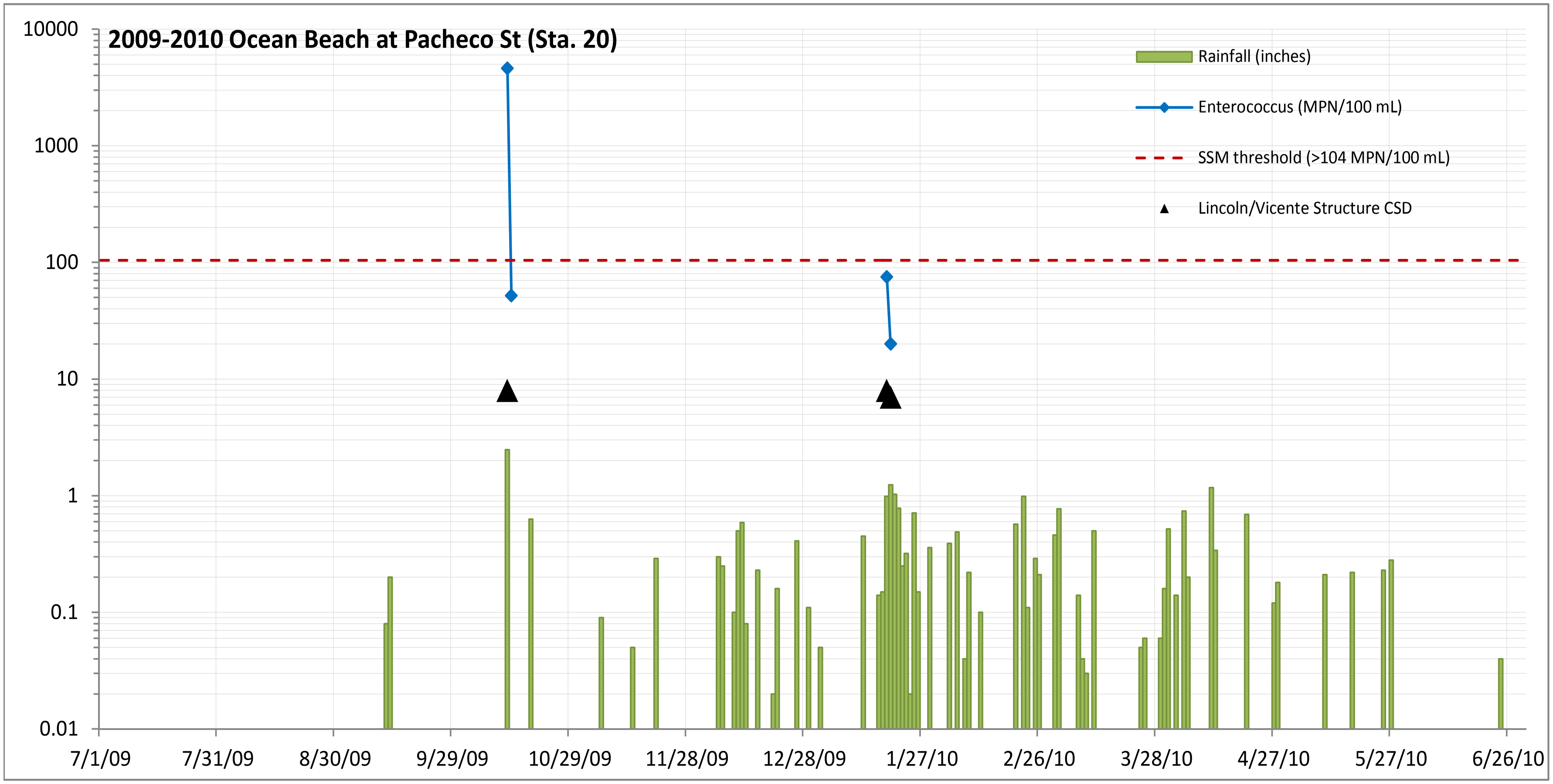
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 20 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-12b

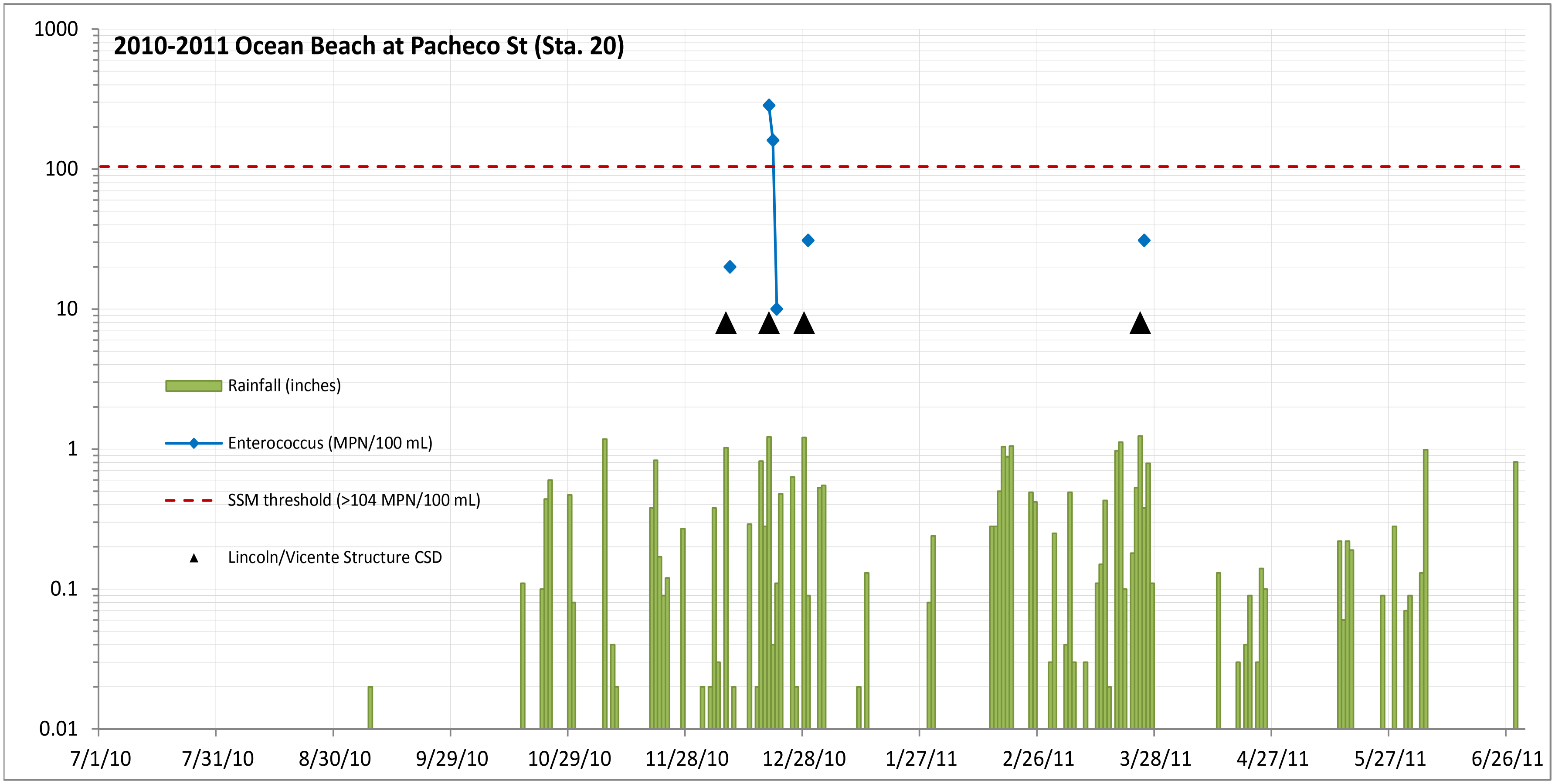
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 20 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-12c

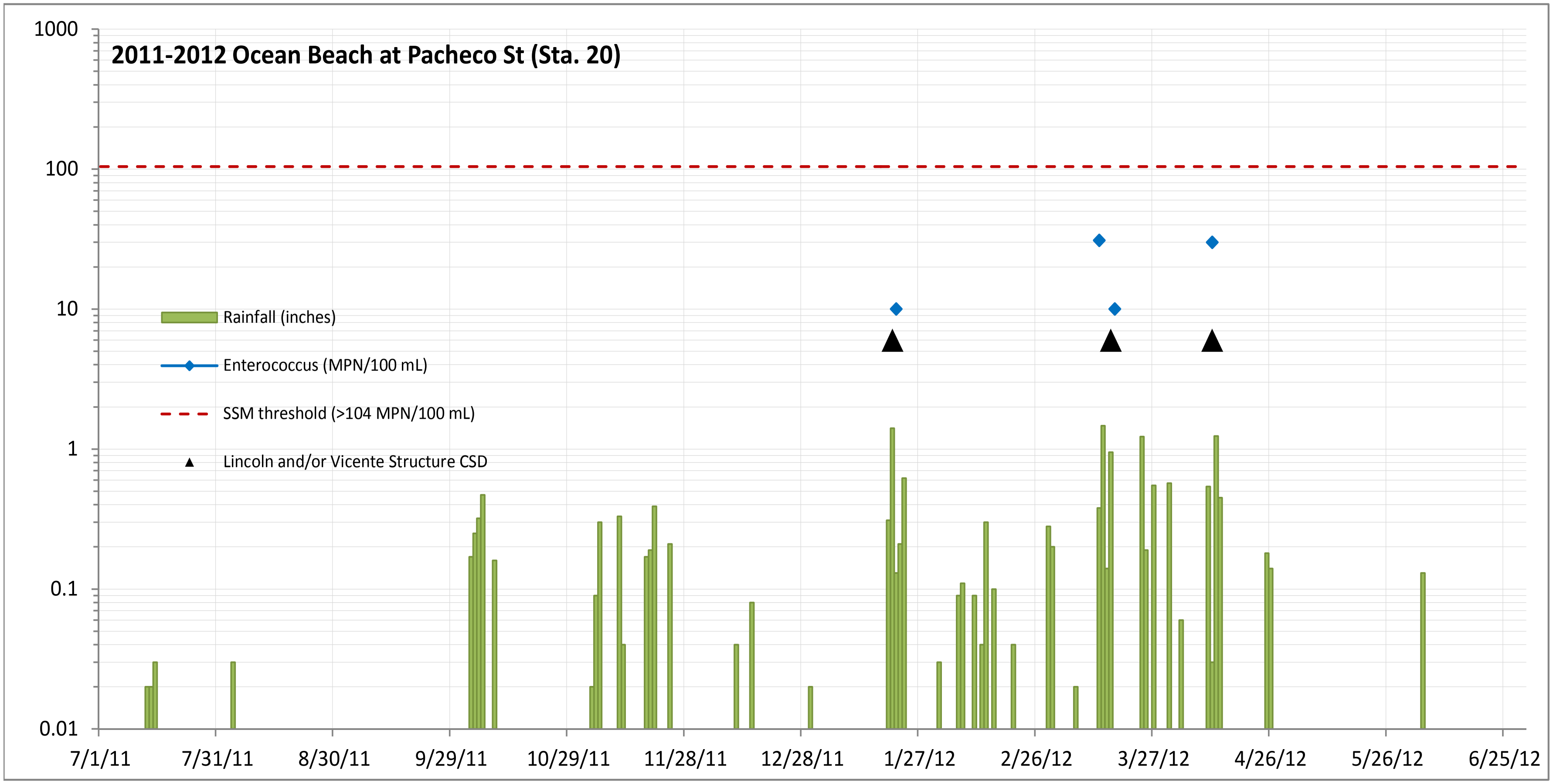
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 20 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-12d

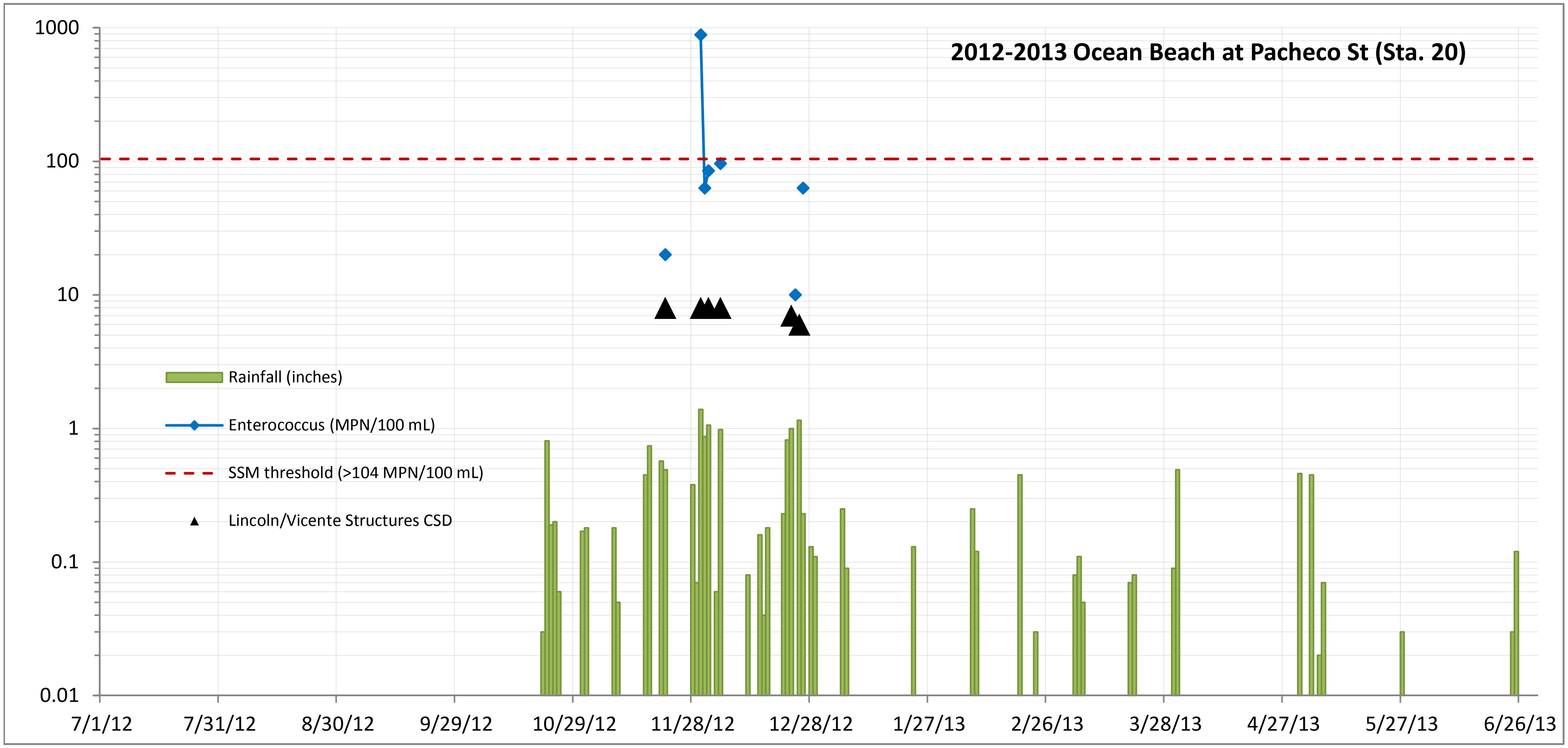
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 20 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-12e

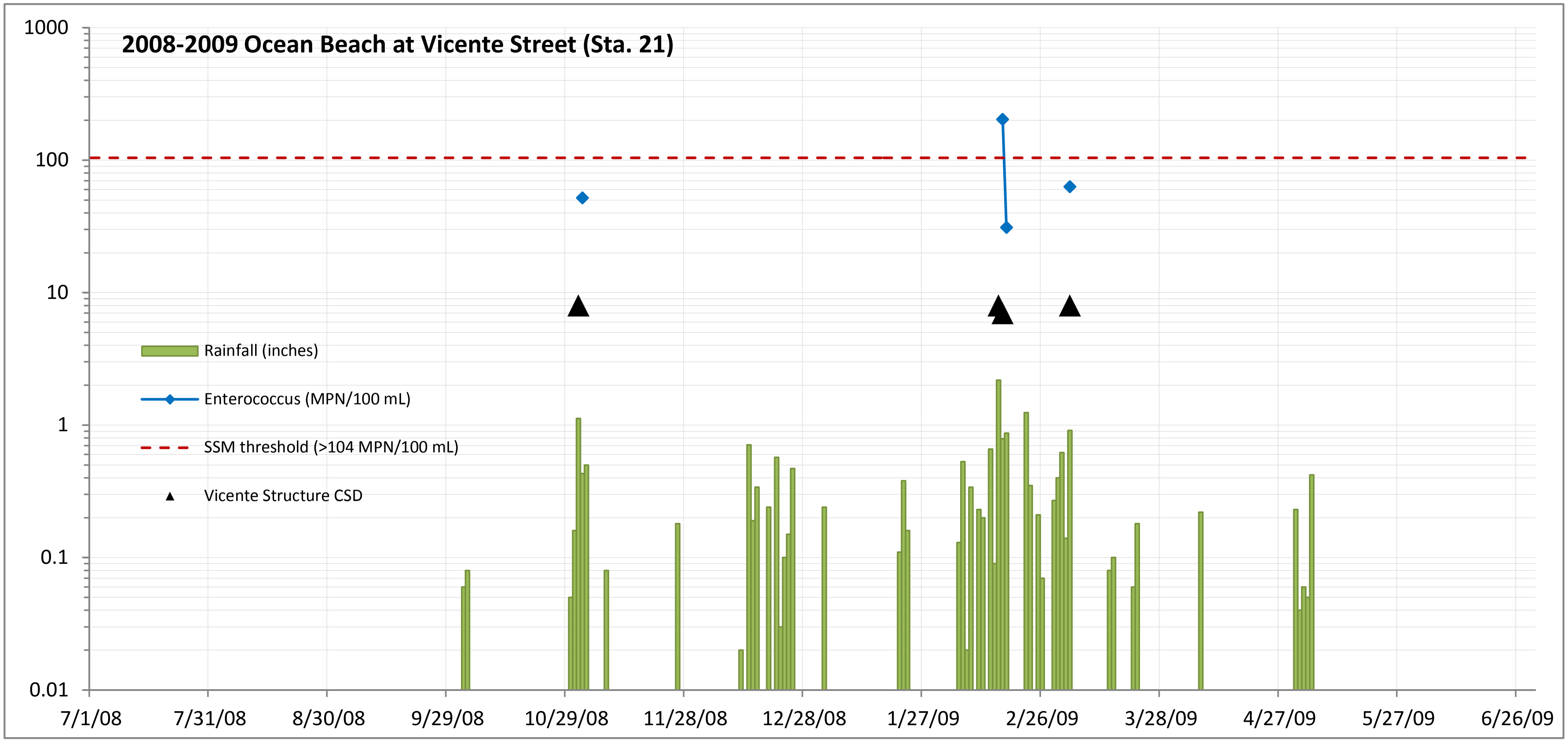
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 20 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-13a

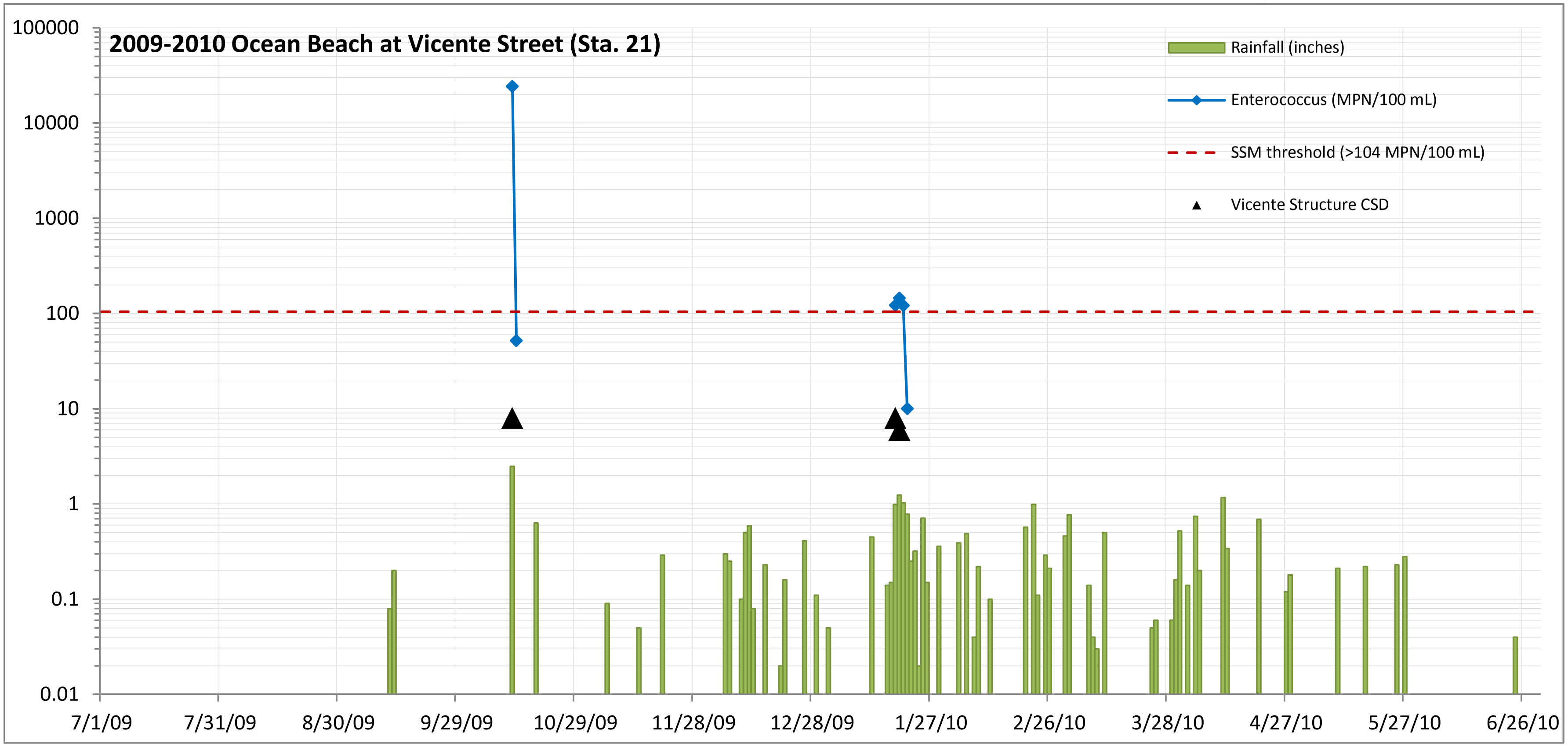
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-13b

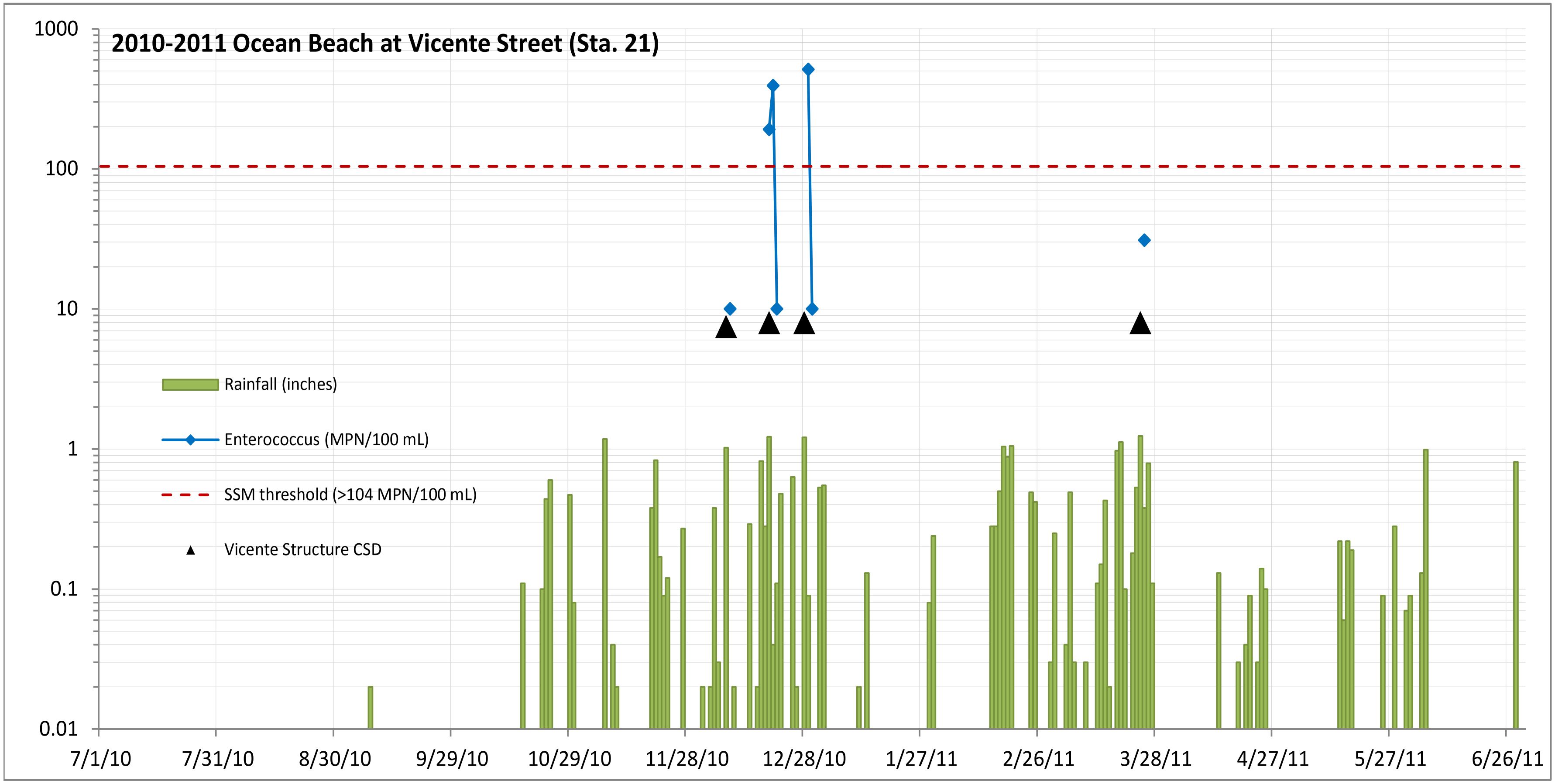
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-13c

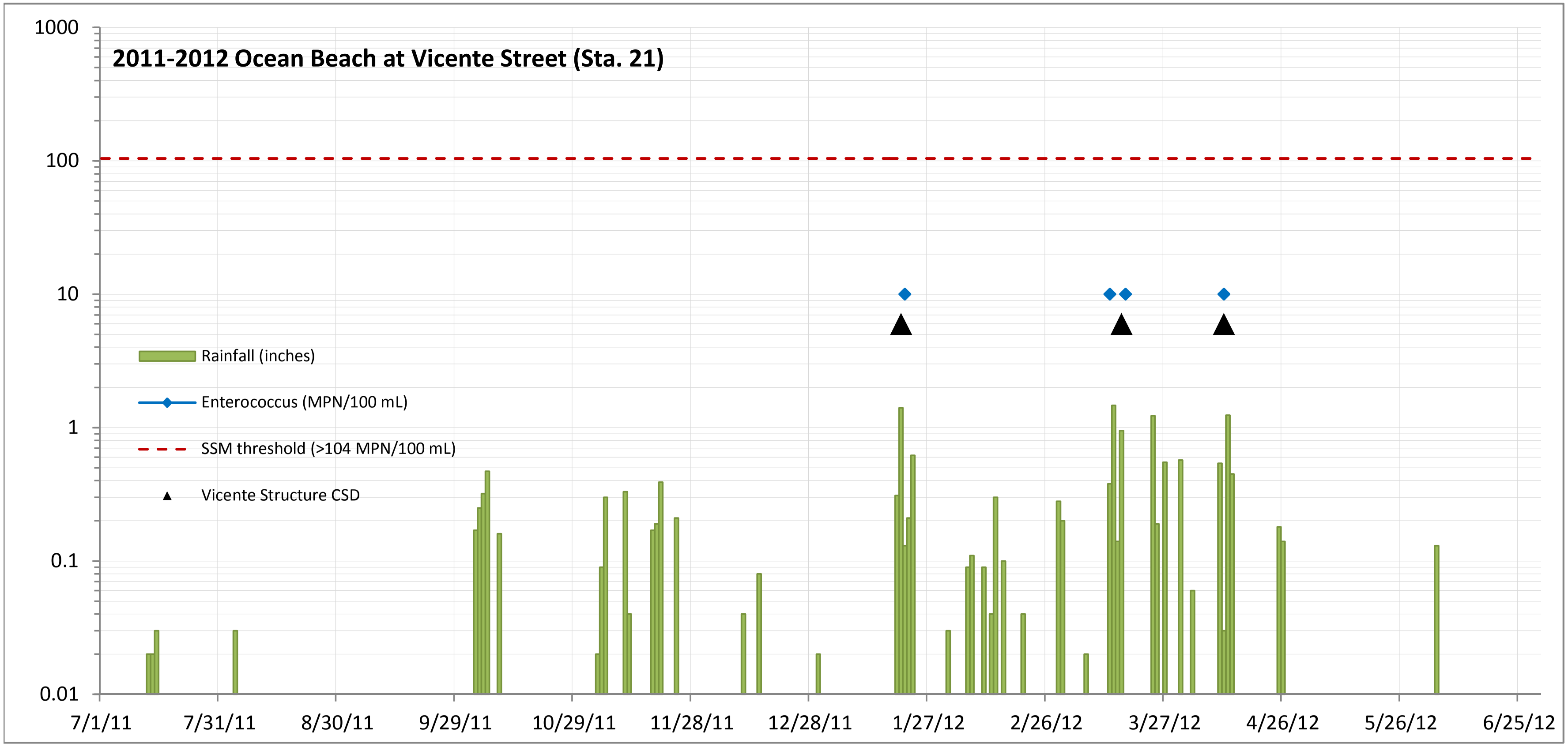
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-13d

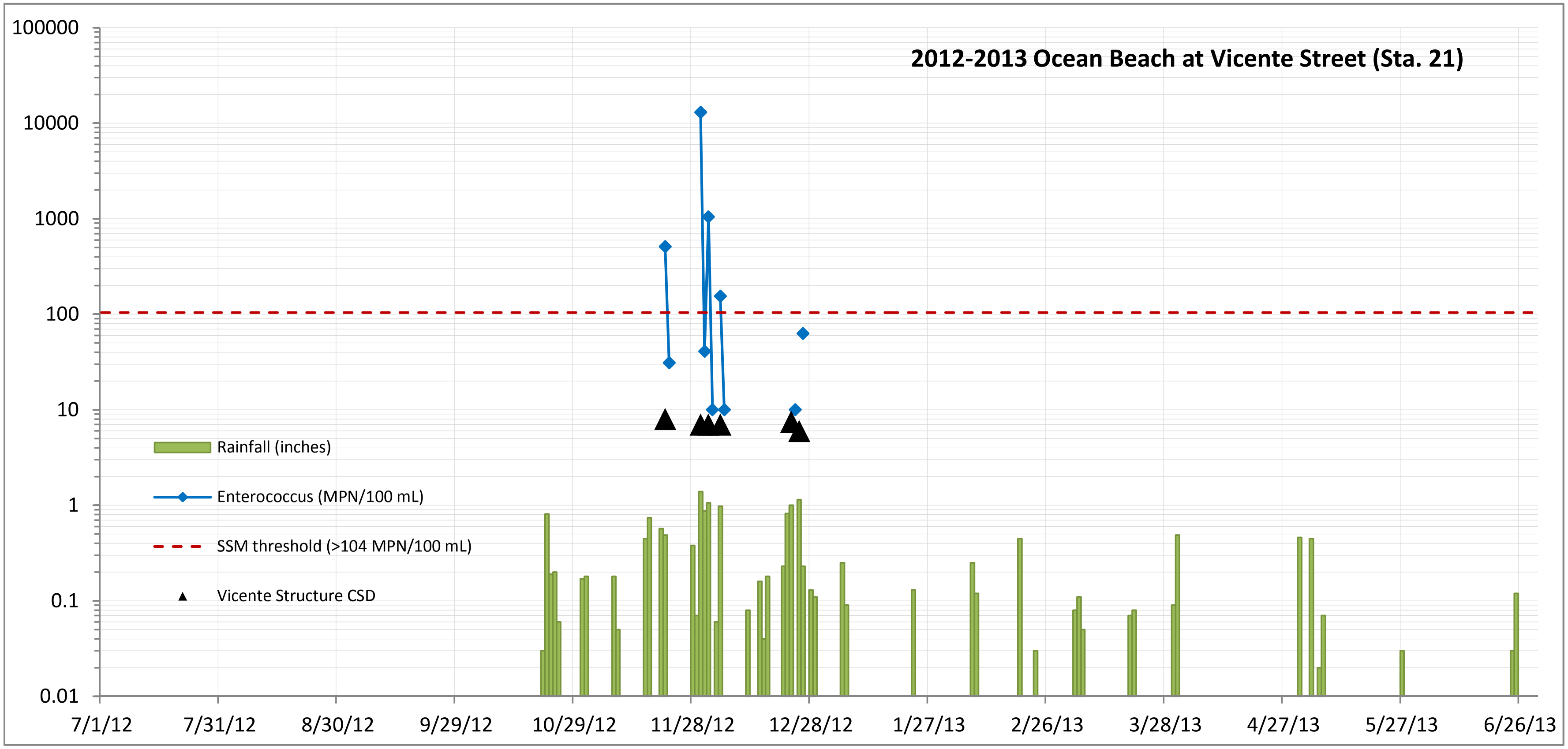
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-13e

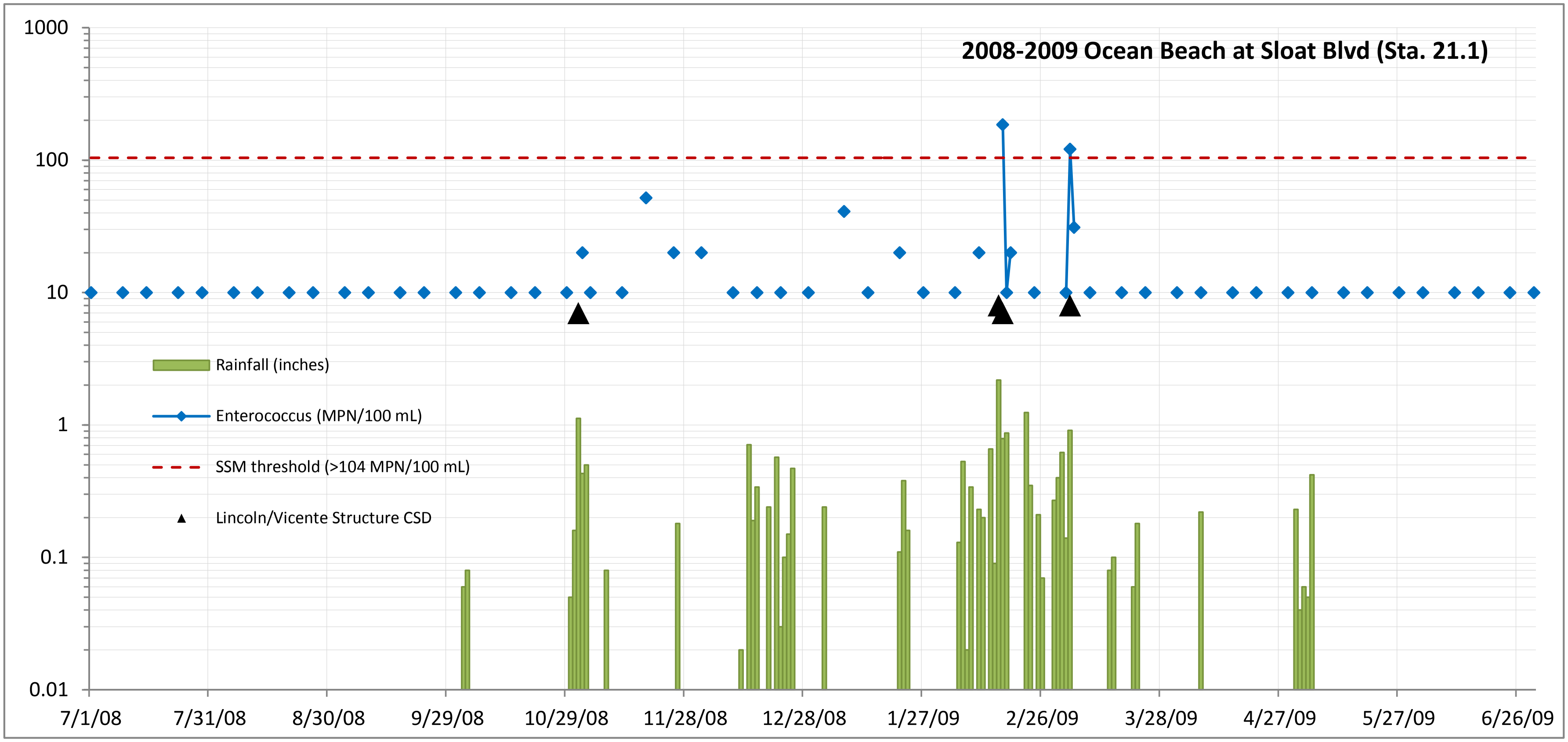
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-14a

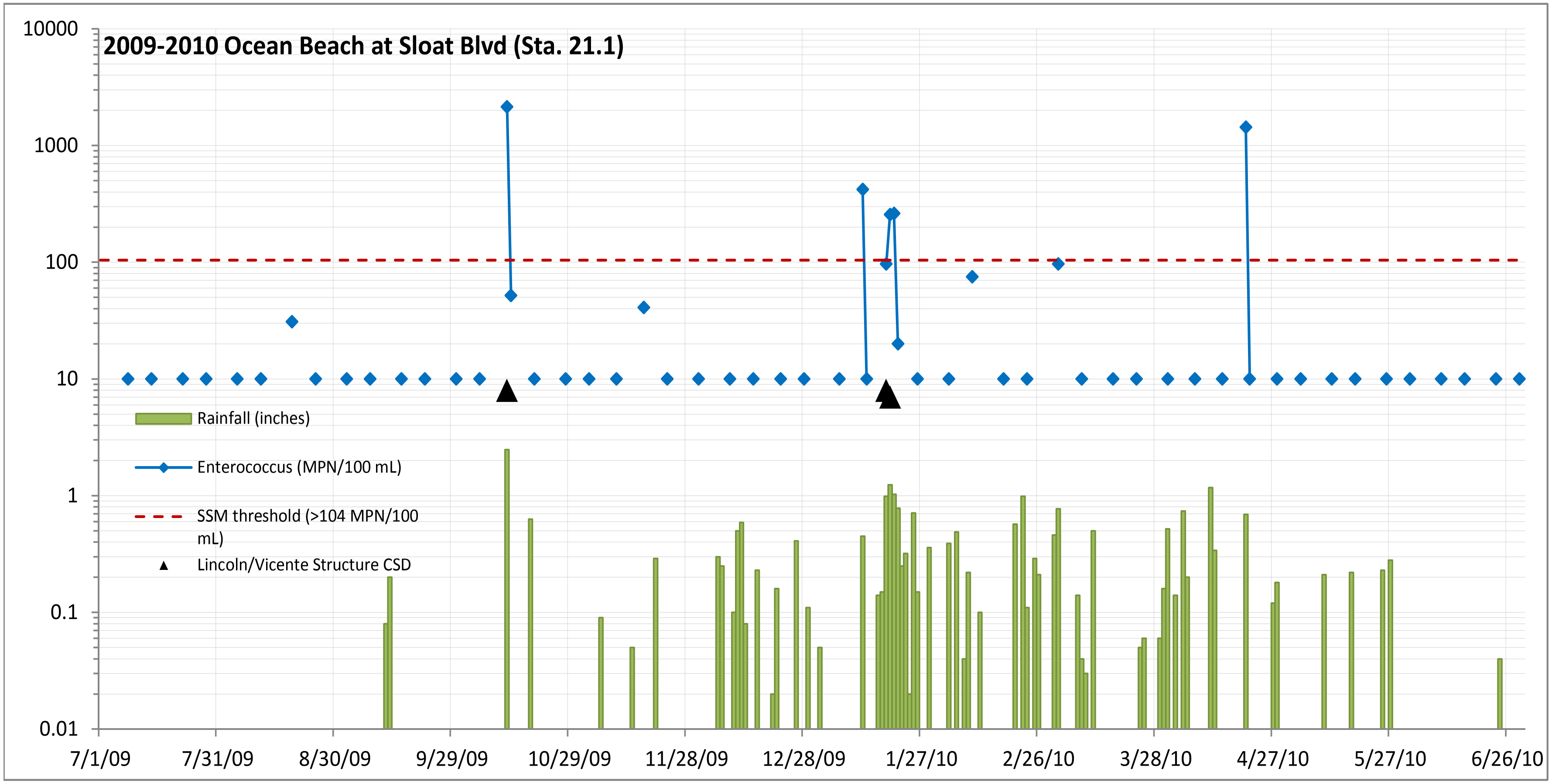
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21.1 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-14b

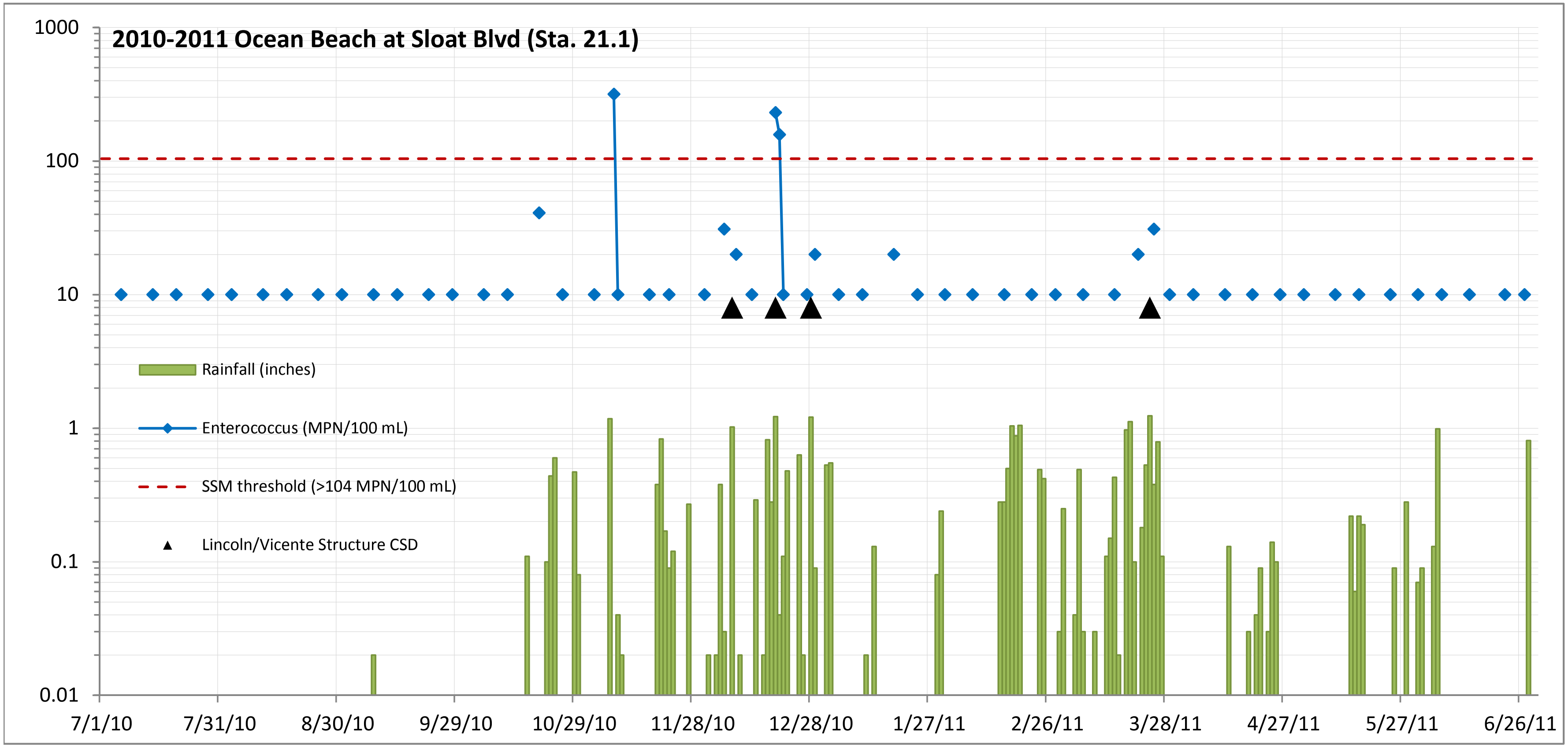
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21.1 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-14c

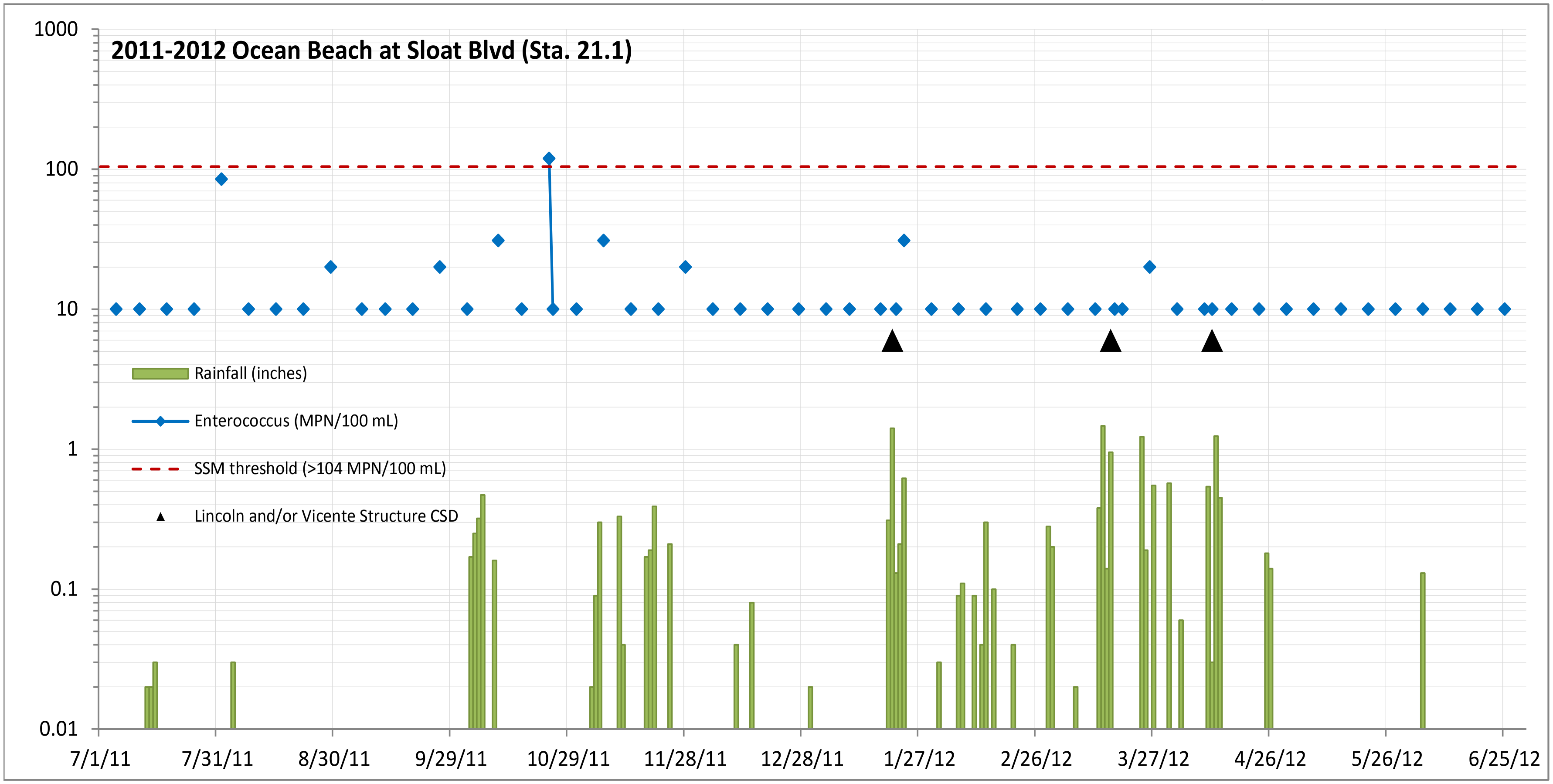
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21.1 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-14d

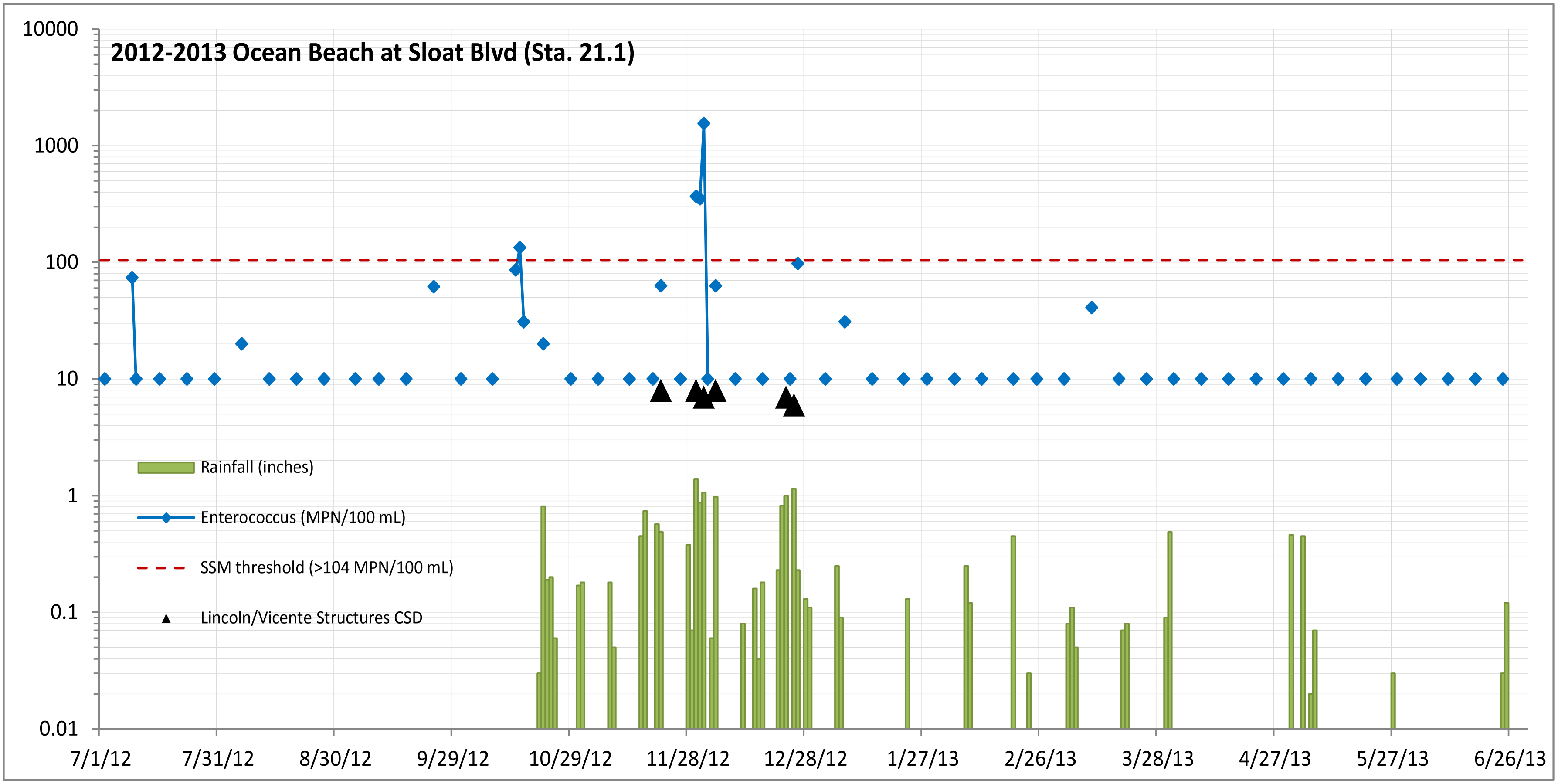
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21.1 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-14e

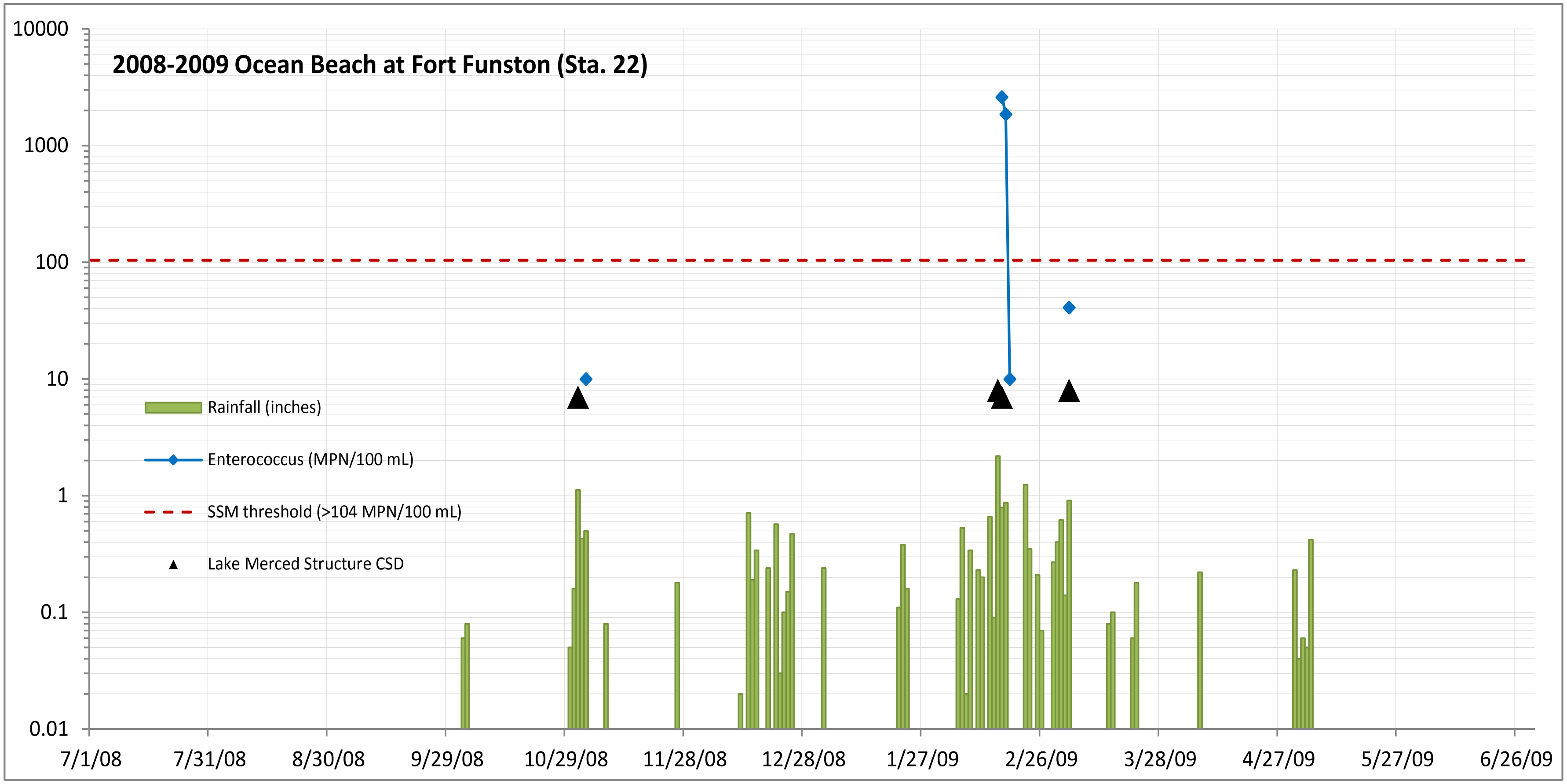
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 21.1 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-15a

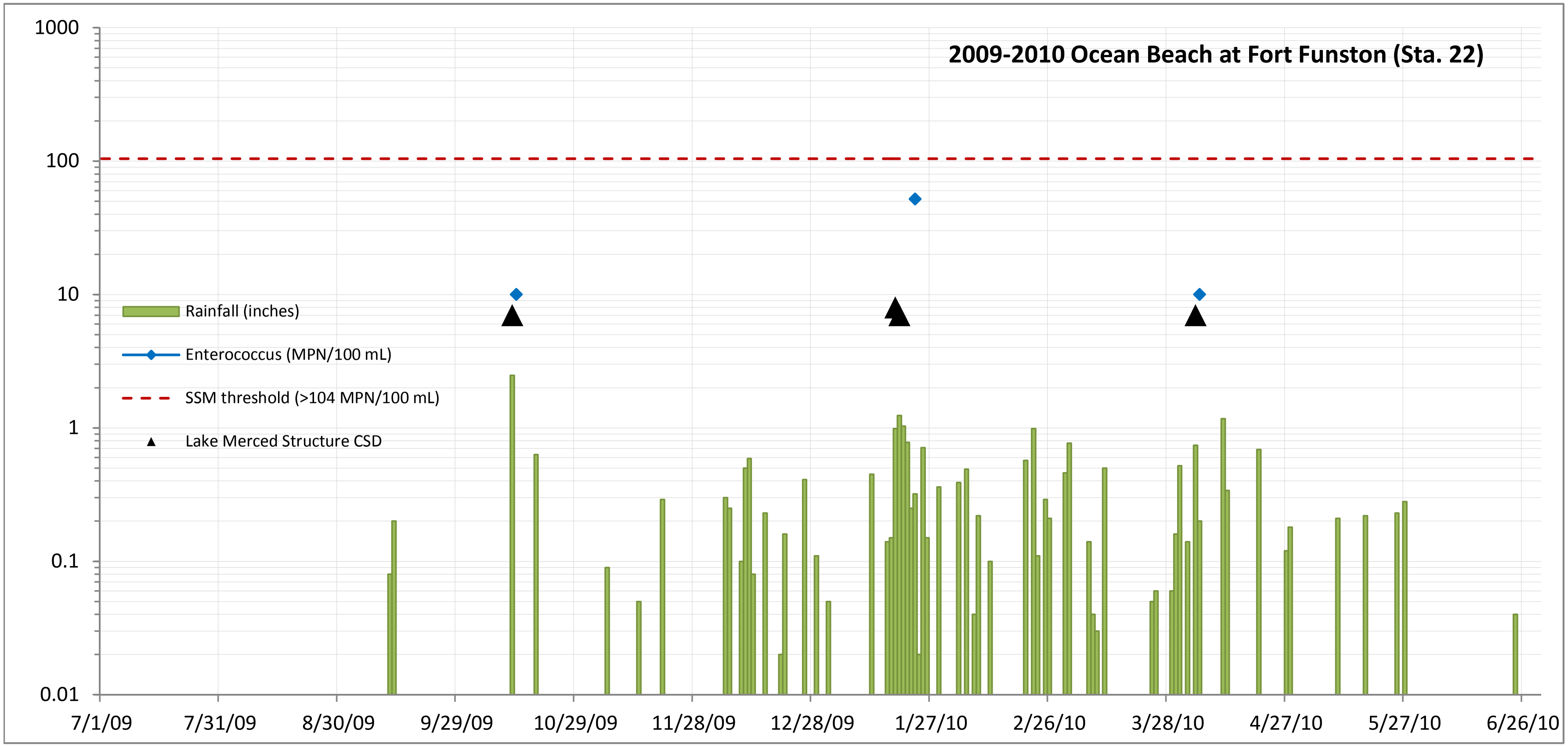
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 22 from July 1,2008-June 30,2009



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-15b

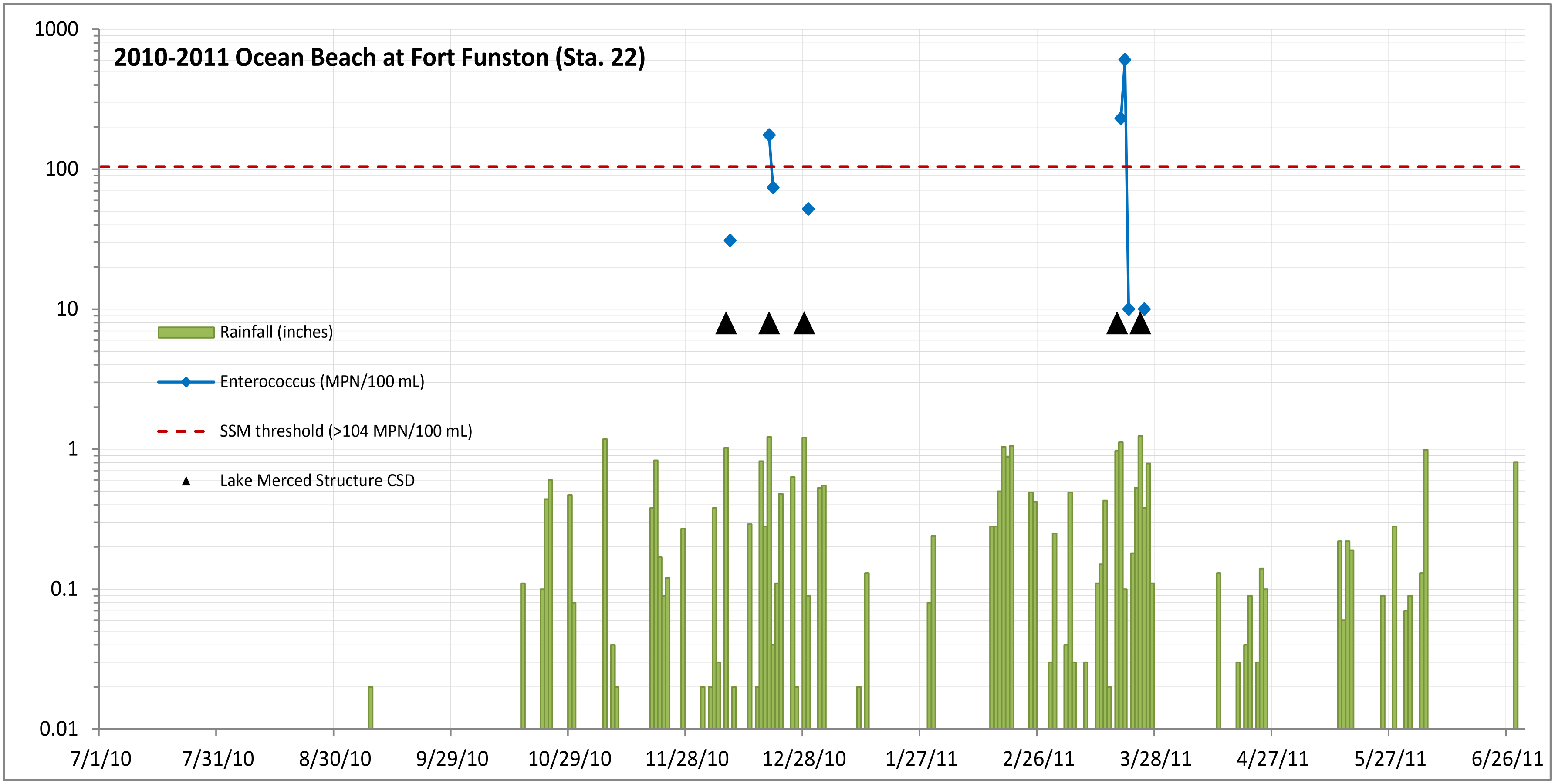
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 22 from July 1,2009-June 30,2010



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-15c

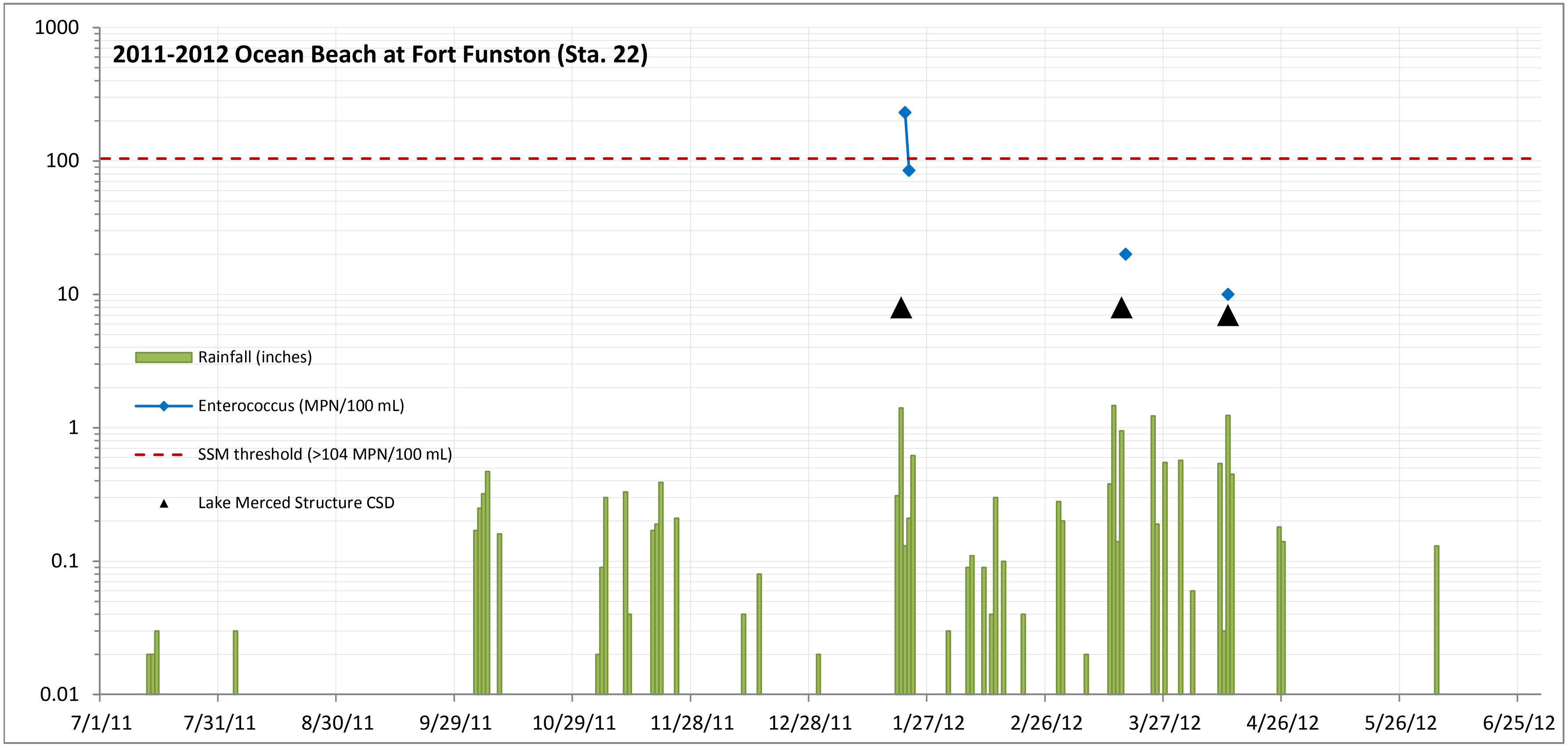
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 22 from July 1,2010-June 30,2011



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-15d

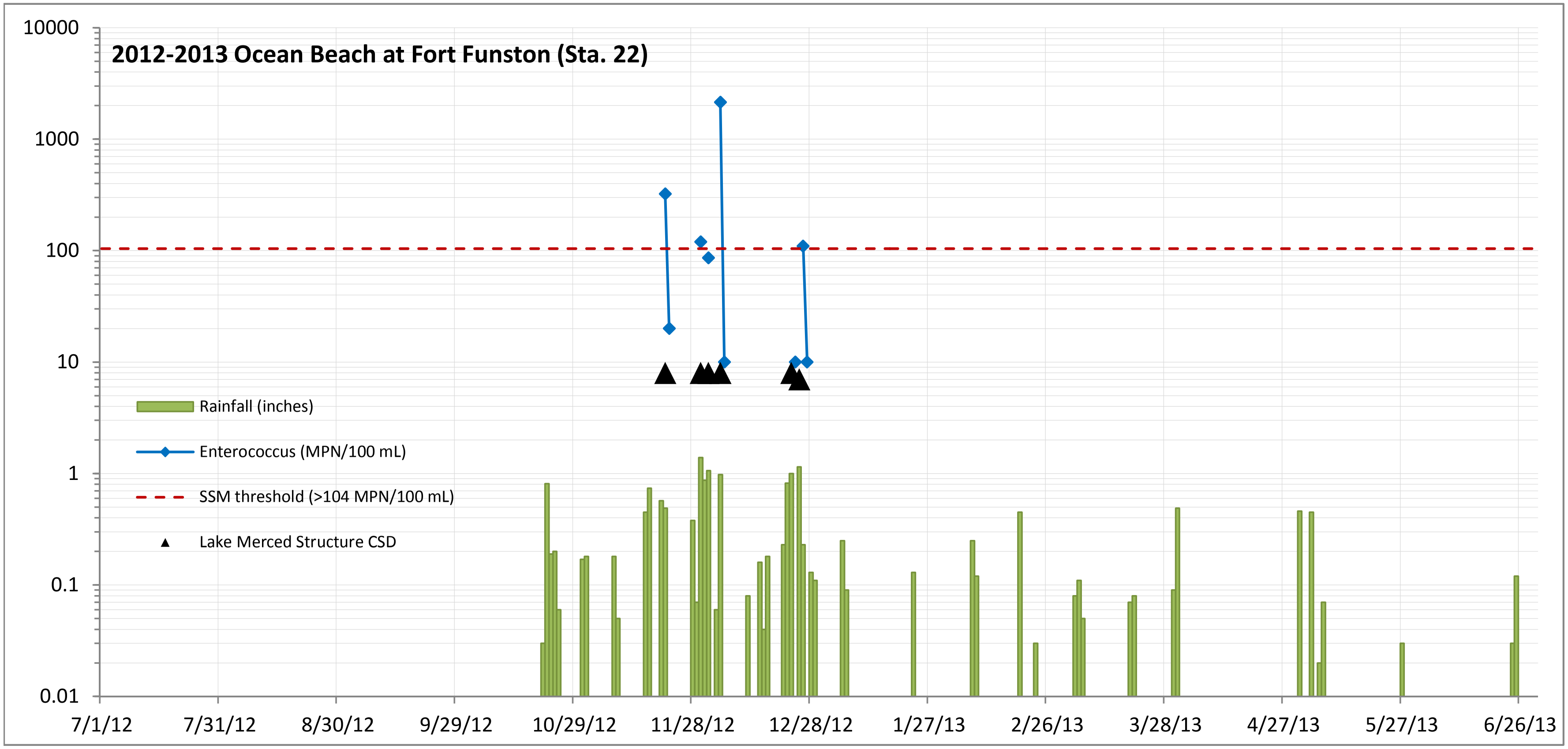
Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 22 from July 1,2011-June 30,2012



lines connecting enterococcus values indicate samples collected on consecutive days

Appendix C-15e

Enterococcus values, rainfall, and Combined Sewer Discharges (CSDs) at Ocean Beach Station 22 from July 1,2012-June 30,2013



lines connecting enterococcus values indicate samples collected on consecutive days

APPENDIX D

MARINE SEDIMENTS

APPENDIX D
MARINE SEDIMENTS
1997 to 2012

Appendix D-1

Sediment grain size percentage

September 2012

Station	Percent Pebble (Gravel) Phi <-2 to -2	Percent Granual (Gravel) Phi >-2 to -1	Percent Very Coarse Sand Phi -1 to 0	Percent Coarse Sand Phi 0 to 1	Percent Medium Sand Phi 1 to 2	Percent Fine Sand Phi 2 to 3	Percent Very Fine Sand Phi 3 to 4	Percent Silt/Clay Phi 4 to > 8	Mean Phi
1	0	0	0	0.1	1.7	52.3	34.3	11.6	2.2
2	0	0	0	1.6	3.6	79.4	11.2	4.2	1.8
4	0	0	0	0.2	2	31.9	50.7	15.2	2.4
6	0	0	0.1	0.9	2.1	45.2	47.1	4.6	2.3
25	0	0	0.1	0.3	3.4	56.3	34.3	5.6	2.1
28	0	0	0	0.1	0.8	18.5	73.4	7.2	2.5
31	0	0	0	0.1	1.3	93.5	4.9	0.2	1.8
32	0	0	0	0.8	6.5	44.6	31.7	16.4	2.4
33	0	0	0	1.5	4.9	38.7	44.8	10.1	2.4
34	0	0	0	1.7	5.2	10.7	52.5	29.9	2.8
35	0	0.8	5.2	7.9	7.6	8.5	29.8	40.2	2.4
36	0	0	0	0.2	2.1	18.8	62.7	16.2	2.7
37	0	0	0	0.7	3.6	50.7	32.5	12.5	2.2
38	0	0	0	0.1	2.3	12.8	72.4	12.4	2.7
39	0	0	0	0.2	1.5	15.8	71.9	10.6	2.5
40	0	0.3	1.7	5.9	8.2	44.1	26.5	13.3	1.9
43	0	0	0	0.1	3.9	94.3	1.6	0.1	1.7
45	0	0	0	0.6	24.4	60.5	11.6	2.9	1.5
47	0	0	0.1	1	14.7	68	14.8	1.4	1.9
48	0	0	0	1.6	29.1	55	10	4.3	1.5
50	0	0	0	0.2	2.5	25.4	63.4	8.5	2.5
51	0	0	0	0.6	8.6	86.1	4.6	0.1	1.7
52	0	0	0	0.2	5.6	90.3	3.8	0.1	1.7
53	0	0	0	0.1	1.1	21.3	63.8	13.7	2.5
54	0	0	0	0.3	1.4	87.2	10.7	0.4	1.8
55	0	0	0	0.7	3.4	76.2	16.4	3.3	2.0
56	0	0	0	0.2	1.4	17.2	54.5	26.7	2.8
57	0	0	0	0.7	2.2	68.2	25.2	3.7	2.1
58	0	0	0	0.1	1.5	20.8	44.8	32.8	2.8
59	0	0	0	0.3	1.8	16.7	61.6	19.6	2.7
60	0	0	0	0.2	0.9	21.1	64.1	13.7	2.5
61	0	0	0	0.3	1.1	25.4	60.6	12.6	2.5
62	0	0	0	0.1	0.7	14.7	72.2	12.3	2.7
63	0	0	0	0.1	0.8	20.7	66.6	11.8	2.5
64	0	0	0	0.1	1.1	22	66.4	10.4	2.5
65	0	0	0	0.1	1.2	34.7	54.8	9.2	2.4
66	0	0	0	0.1	0.8	13.6	69	16.5	2.1
67	0	0	0	0.1	0.8	28.5	63.1	7.5	2.4
68	0	0	0	0.2	1.2	13.8	76.4	8.4	2.7
69	0	0	0	0.2	0.9	21	71.8	6.1	2.9
70	0	0	0	0.1	1.2	36.8	54.1	7.8	2.4
71	0	0	0	0.1	0.6	26.5	66	6.8	2.5
72	0	0	0	0.2	2.2	17.2	66.6	13.8	2.5
73	0	0	0	0.8	2.6	76.4	17.7	2.5	2.0
75	0	0	0	1.4	2.9	72.2	19.1	4.4	2.0
77	0	0	0	0.4	2.3	54.6	36.4	6.3	2.1
78	0	0	0	0.4	1.3	27.7	60.6	10	2.5
79	0	0	0	0.2	1.8	20.8	62.4	14.8	2.5
80	0	1.1	0	1.6	8.6	77.6	11.8	0.4	1.8

Appendix D-2

Sediment grain size summary statistics

September 2012

Station	Mean Phi	Standard Deviation	Skewness	Kurtosis
1	2.2	0.665	0.553	0.854
2	1.8	0.41	0.094	2.561
4	2.4	0.665	-0.207	0.897
6	2.3	0.533	-0.353	0.587
25	2.1	0.616	0.553	0.815
28	2.5	0.564	-0.300	2.316
31	1.8	0.239	0.249	1.47
32	2.4	0.93	0.412	1.061
33	2.4	0.764	-0.278	1.084
34	2.8	0.915	-0.131	1.253
35	2.4	1.548	-0.478	1.046
36	2.7	0.747	-0.036	2.211
37	2.2	0.679	0.549	0.852
38	2.7	0.454	-0.017	2.464
39	2.5	0.577	-0.271	2.404
40	1.9	1.099	0.019	1.411
43	1.7	0.164	0.000	0.738
45	1.5	0.645	-0.240	1.042
47	1.9	0.586	0.244	2.472
48	1.5	0.675	-0.212	0.99
50	2.5	0.62	-0.281	0.951
51	1.7	0.289	-0.288	1.737
52	1.7	0.257	-0.264	1.56
53	2.5	0.62	-0.257	2.20
54	1.8	0.29	0.293	1.781
55	2.0	0.474	0.572	1.785
56	2.8	0.789	0.000	0.968
57	2.1	0.51	0.553	0.668
58	2.8	0.827	-0.027	0.876
59	2.7	0.758	-0.008	2.184
60	2.5	0.618	-0.257	2.210
61	2.5	0.633	-0.251	0.980
62	2.7	0.448	-0.008	2.408
63	2.5	0.606	-0.264	2.258
64	2.5	0.608	-0.271	2.234
65	2.4	0.634	-0.225	0.878
66	2.9	0.582	0.240	2.350
67	2.4	0.607	-0.276	0.914
68	2.7	0.429	-0.029	2.448
69	2.5	0.568	-0.319	2.214
70	2.4	0.626	-0.224	0.855
71	2.5	0.593	-0.293	0.93
72	2.5	0.61	-0.266	2.316
73	2.0	0.471	0.570	1.76
75	2.0	0.501	0.572	1.737
77	2.1	0.623	0.545	0.822
78	2.5	0.628	-0.257	0.939
79	2.5	0.629	-0.257	2.185
80	1.8	0.429	-0.004	2.64

Appendix D-3

Sediment chemical analyses

September 2012

Station	Percent Total Volatile Solids	Percent Total Solids	Total Organic Carbon (mg/Kg)	Organic Carbon Percent	Total Kjeldalh Nitrogen (mg/Kg)
1	1.70	78.8	1427	1.43	241
2	1.76	80.5	1309	1.31	348
4	2.67	70.3	1938	1.94	368
6	2.73	71.8	2040	2.04	406
25	2.57	68.1	1481	1.48	329
28	2.15	66.3	1861	1.86	331
31	1.65	79.0	1019	1.02	182
32	3.05	69.0	6849	6.85	513
33	2.60	65.9	3906	3.91	391
34	3.14	61.8	4732	4.73	487
35	9.40	52.9	8719	8.72	867
36	2.26	67.6	2674	2.67	351
37	2.24	72.9	2043	2.04	286
38	2.43	68.5	2898	2.90	344
39	2.27	70.3	3026	3.03	308
40	3.79	64.0	7186	7.19	548
43	1.15	78.2	701	0.70	116
45	1.32	82.3	1206	1.21	167
47	1.67	74.3	856	0.86	215
48	1.68	74.1	2338	2.34	244
50	2.12	70.7	1920	1.92	305
51	1.18	80.1	522	0.52	112
52	1.23	79.0	635	0.64	124
53	2.21	68.2	2440	2.44	315
54	1.46	74.0	1054	1.05	197
55	1.81	70.5	2443	2.44	349
56	2.59	65.1	3261	3.26	404
57	1.98	67.8	2653	2.65	338
58	2.17	69.3	2953	2.95	321
59	2.10	71.1	3894	3.89	416
60	2.04	71.0	3530	3.53	378
61	1.92	71.8	1687	1.69	366
62	1.87	66.4	1485	1.49	324
63	2.26	67.7	1829	1.83	383
64	1.88	73.3	1935	1.94	367
65	1.18	69.7	1451	1.45	310
66	1.78	71.1	1893	1.89	337
67	1.62	76.0	1739	1.74	271
68	1.48	71.0	1639	1.64	267
69	1.81	67.8	1625	1.63	291
70	1.91	74.4	1882	1.88	309
71	1.79	69.6	1512	1.51	277
72	2.17	69.1	2103	2.10	306
73	1.77	69.3	1526	1.53	311
75	1.90	71.5	2710	2.71	480
77	1.94	71.9	2376	2.38	314
78	2.06	66.9	2181	2.18	405
79	2.12	70.3	4374	4.37	374
80	1.52	76.8	722	0.72	130

Appendix D-4

Organic pollutants in sediment (µg/Kg, dry weight) September 2012

		PCB	Station					
Organic Pollutants	RL*	Congener #	1	2	4	6	25	28
4,4'-DDE	1		ND	ND	ND	ND	ND	ND
4,4'-DDD	1		ND	ND	ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND	ND	ND
naphthalene	1		1.7	1.7	2.4	1.6	1.6	1.5
acenaphthylene	1		ND	ND	ND	ND	ND	1.9
acenaphthene	1		ND	ND	2.7	ND	6.0	ND
fluorene	1		ND	ND	ND	ND	ND	4.4
phenanthrene	1		18.1	3.6	18.6	1.5	40.5	49.8
anthracene	1		6.9	ND	4.3	ND	5.5	34.2
Fluoranthene	1		28.1	8.0	34.5	2.4	59.2	78.5
Pyrene	1		33.8	9.6	40.3	3.3	66.9	98.0
Benz[a]anthracene	1		10.4	2.8	10.6	ND	13.7	40.0
Chrysene	1		11.8	3.5	10.6	2.0	15.7	43.2
Benzo[b]fluoranthene	1		11.8	4.2	19.1	4.1	16.4	25.8
Benzo[k]fluoranthene	1		10.4	2.8	14.2	2.7	14.4	27.7
Benzo[e]pyrene	1		11.1	3.5	17.0	3.4	14.4	24.5
Perylene	1		8.3	4.2	15.6	3.4	11.6	18.1
Benzo[a]pyrene	1		17.3	4.2	24.1	3.4	25.3	45.2
Indeno[1,2,3-cd]pyrene	1		13.8	4.2	23.4	4.7	19.8	27.7
dibenz[a,h]anthracene	1		2.1	ND	2.8	ND	2.1	3.9
benzo[ghi]perylene	1		14.5	4.9	24.8	4.7	20.5	27.1
2,4'-Dichlorobiphenyl	1	PCB 008	ND	ND	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	ND	ND	ND	ND	ND	ND
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND	ND	ND
Sum of organics			200.0	56.8	265.0	37.3	333.6	551.6

*RL = Reporting Limit
ND = Not Detected

Appendix B-4 (cont.)

Organic pollutants in sediment (μg/Kg, dry weight) September 2012

		PCB				Station			
Organic Pollutants	RL*	Congener #	31	32	33	34	35	36	37
4,4'-DDE	1		ND	2.2	ND	ND	ND	ND	ND
4,4'-DDD	1		ND	3.0	ND	ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND	ND	ND	ND
naphthalene	1		ND	2.5	2.4	2.3	5.4	ND	17.5
acenaphthylene	1		ND	ND	ND	2.1	5.1	ND	20.9
acenaphthene	1		2.2	ND	ND	ND	4.1	ND	19.0
fluorene	1		1.6	ND	ND	2.6	4.9	ND	44.6
phenanthrene	1		22.6	9.1	22.4	28.3	73.9	3.9	486.6
anthracene	1		10.4	3.0	4.3	11.0	22.0	ND	248.3
Fluoranthene	1		35.4	31.2	52.1	52.0	149.8	8.0	596.6
Pyrene	1		42.5	41.0	64.4	65.2	184.7	10.7	720.9
Benz[a]anthracene	1		23.6	15.0	12.9	19.2	59.4	3.2	238.1
Chrysene	1		24.7	16.5	18.7	24.7	61.9	3.8	270.4
Benzo[b]fluoranthene	1		21.3	31.5	25.1	23.4	63.6	8.3	155.8
Benzo[k]fluoranthene	1		20.7	26.2	17.9	22.0	56.0	7.6	167.1
Benzo[e]pyrene	1		20.1	30.0	23.0	22.7	61.9	7.6	148.6
Perylene	1		7.5	110.8	25.8	33.7	70.4	14.0	78.2
Benzo[a]pyrene	1		32.8	34.4	33.7	35.7	104.3	10.8	302.0
Indeno[1,2,3-cd]pyrene	1		16.7	30.7	26.5	30.9	90.7	10.8	196.4
dibenz[a,h]anthracene	1		2.9	3.7	2.2	4.1	11.0	ND	28.6
benzo[ghi]perylene	1		15.5	37.4	33.0	38.5	100.1	14.0	194.0
2,4'-Dichlorobipheny	1	PCB 008	ND	ND	ND	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	ND	ND	ND	ND	ND	ND	**ND**
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND	ND	ND	ND
Sum of organics			300.5	428.4	364.5	418.5	1129.2	102.9	3933.6

*RL = Reporting Limi
ND = Not Detected

Appendix B-4 (cont.)

Organic pollutants in sediment (μg/Kg, dry weight) September 2012

			Station						
Organic Pollutants	RL*	PCB Congener #	38	39	40	43	45	47	48
4,4'-DDE	1		ND	ND	ND	ND	ND	ND	ND
4,4'-DDD	1		ND	ND	ND	ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND	ND	ND	ND
naphthalene	1		ND	ND	8.4	ND	ND	3.15	1.4
acenaphthylene	1		ND	ND	14.7	ND	ND	3.15	ND
acenaphthene	1		ND	ND	16.0	ND	ND	ND	ND
fluorene	1		ND	ND	38.0	ND	ND	ND	ND
phenanthrene	1		4.2	3.9	345.9	ND	5.9	70.01	10.3
anthracene	1		4.7	ND	113.0	ND	ND	10.72	4.8
Fluoranthene	1		12.5	8.6	359.4	ND	12.0	198.05	19.0
Pyrene	1		16.6	10.6	402.9	ND	15.3	241.57	23.9
Benz[a]anthracene	1		6.0	3.1	140.9	ND	4.2	40.37	7.8
Chrysene	1		9.4	3.8	152.0	ND	4.8	44.15	8.4
Benzo[b]fluoranthene	1		10.1	6.3	83.7	ND	4.8	54.24	9.0
Benzo[k]fluoranthene	1		8.7	6.3	91.0	ND	5.3	40.37	7.8
Benzo[e]pyrene	1		9.4	5.7	74.1	ND	4.8	52.98	8.4
Perylene	1		12.1	9.4	44.0	ND	3.2	27.75	7.2
Benzo[a]pyrene	1		14.7	8.2	153.4	ND	7.4	87.67	13.8
Indeno[1,2,3-cd]pyrene	1		14.1	8.2	97.6	ND	6.4	80.73	12.0
dibenz[a,h]anthracene	1		ND	ND	15.4	ND	ND	5.68	ND
benzo[ghi]perylene	1		16.8	9.4	93.2	ND	6.9	89.56	13.2
2,4'-Dichlorobipheny	1	PCB 008	ND	ND	ND	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	ND	ND	ND	ND	ND	ND	ND
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND	ND	ND	ND
Sum of organics			139.1	83.4	2243.8	0.0	80.8	1050.2	147.4

*RL = Reporting Limit
ND = Not Detected

Appendix D-4 (cont.)

Organic pollutatns in sediemtn (μg/Kg, dry weight) September 2012

Organic Pollutants	RL*	PCB Congener #	50	51	52	53	54	55	56
4,4'-DDE	1		ND	ND	ND	ND	ND	ND	ND
4,4'-DDD	1		ND	ND	ND	ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND	ND	ND	ND
naphthalene	1		3.6	ND	ND	ND	ND	ND	1.52
acenaphthylene	1		ND	ND	ND	ND	ND	ND	1.90
acenaphthene	1		9.3	ND	ND	ND	ND	ND	2.4
fluorene	1		2.5	ND	ND	ND	ND	ND	4.3
phenanthrene	1		26.3	ND	ND	5.6	1.3	16.65	45.1
anthracene	1		4.0	ND	ND	ND	ND	6.12	15.2
Fluoranthene	1		30.6	ND	ND	6.5	4.5	34.02	42.2
Pyrene	1		36.1	ND	ND	8.0	5.2	32.92	51.8
Benz[a]anthracene	1		9.4	ND	ND	3.4	ND	15.3	18.4
Chrysene	1		8.7	ND	ND	3.4	1.8	15.9	22.8
Benzo[b]fluoranthene	1		10.7	ND	ND	3.4	1.8	8.0	12.0
Benzo[k]fluoranthene	1		9.4	ND	ND	2.7	1.8	10.4	13.3
Benzo[e]pyrene	1		10.1	ND	ND	2.7	ND	6.7	11.4
Perylene	1		8.1	ND	ND	3.4	ND	4.3	7.6
Benzo[a]pyrene	1		16.8	ND	ND	4.8	1.8	12.9	20.9
Indeno[1,2,3-cd]pyrene	1		15.4	ND	ND	4.1	1.8	8.6	15.8
dibenz[a,h]anthracene	1		2.0	ND	ND	ND	ND	1.8	2.5
benzo[ghi]perylene	1		17.4	ND	ND	4.8	2.4	8.0	17.1
2,4'-Dichlorobipheny	1	PCB 008	ND	ND	ND	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	**ND**	ND	ND	ND	ND	ND	ND
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND	ND	ND	ND
Sum of organics			220.4	0.0	0.0	52.7	22.1	181.5	306.2

*RL = Reporting Limi
ND = Not Detected

Appendix B-4 (cont.)

Organic pollutants in sediment (µg/Kg, dry weight) September 2012

Organic Pollutants	RL*	PCB Congener #	57	58	59	60	61	62
4,4'-DDE	1		ND	ND	ND	ND	ND	ND
4,4'-DDD	1		ND	ND	ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND	ND	ND
naphthalene	1		ND	1.5	ND	ND	ND	ND
acenaphthylene	1		ND	3.8	1.9	ND	ND	ND
acenaphthene	1		ND	ND	ND	ND	ND	ND
fluorene	1		ND	1.8	ND	ND	ND	ND
phenanthrene	1		5.1	37.9	38.7	2.0	14.6	14.4
anthracene	1		ND	4.4	7.7	ND	7.9	1.9
Fluoranthene	1		8.4	53.9	93.7	16.3	25.4	27.7
Pyrene	1		9.8	60.9	112.5	20.9	30.9	31.0
Benz[a]anthracene	1		2.5	12.6	20.6	3.8	11.9	6.8
Chrysene	1		3.1	12.0	23.8	4.5	9.9	6.8
Benzo[b]fluoranthene	1		4.9	17.0	29.0	6.4	7.3	8.7
Benzo[k]fluoranthene	1		3.7	14.5	20.6	4.5	7.9	7.5
Benzo[e]pyrene	1		4.3	16.4	27.7	5.7	5.9	7.5
Perylene	1		2.5	11.3	13.5	3.8	4.0	3.7
Benzo[a]pyrene	1		7.4	26.4	37.3	7.6	10.5	8.7
Indeno[1,2,3-cd]pyrene	1		8.7	25.8	40.5	8.3	6.6	9.9
dibenz[a,h]anthracene	1		ND	2.5	3.2	ND	ND	ND
benzo[ghi]perylene	1		9.9	28.3	42.5	8.9	6.6	9.3
2,4'-Dichlorobipheny	1	PCB 008	ND	ND	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	ND	ND	ND	ND	ND	ND
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND	ND	ND
Sum of organics			70.3	330.8	513.2	92.7	149.4	144.0

*RL = Reporting Limit
ND = Not Detected

Appendix D-4 (cont.)

Organic pollutants in sediment (µg/Kg, dry weight) September 2012

Organic Pollutants	RL*	PCB Congener #	Station 63	64	65	66	67	68
4,4'-DDE	1		ND	ND	ND	ND	ND	ND
4,4'-DDD	1		ND	ND	ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND	ND	ND
naphthalene	1		ND	ND	ND	ND	ND	4.6
acenaphthylene	1		ND	ND	ND	ND	ND	5.6
acenaphthene	1		ND	ND	ND	ND	2.3	1.7
fluorene	1		ND	ND	ND	ND	ND	23.4
phenanthrene	1		2.0	1.9	1.3	1.9	3.1	243.8
anthracene	1		ND	ND	ND	ND	ND	112.6
Fluoranthene	1		2.3	3.4	2.2	13.0	4.5	216.9
Pyrene	1		3.0	4.1	2.9	19.1	5.2	293.7
Benz[a]anthracene	1		ND	1.8	ND	6.0	2.4	138.6
Chrysene	1		ND	1.8	ND	6.6	3.0	167.0
Benzo[b]fluoranthene	1		2.5	2.4	ND	9.6	1.8	42.7
Benzo[k]fluoranthene	1		1.9	1.8	ND	6.6	1.8	60.6
Benzo[e]pyrene	1		1.9	1.8	ND	9.0	1.8	38.4
Perylene	1		2.5	2.4	1.8	4.8	ND	14.2
Benzo[a]pyrene	1		1.9	1.8	ND	12.6	1.8	82.9
Indeno[1,2,3-cd]pyrene	1		3.1	2.4	1.8	13.2	1.8	33.4
dibenz[a,h]anthracene	1		ND	ND	ND	ND	ND	11.8
benzo[ghi]perylene	1		3.1	3.0	1.8	14.4	1.8	24.7
2,4'-Dichlorobipheny	1	PCB 008	ND	ND	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	ND	ND	ND	ND	ND	ND
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND	ND	ND
Sum of PAHs			24.1	29.0	11.8	116.7	31.2	1516.5

*RL = Reporting Limi
ND = Not Detected

Appendix D-4 (cont.)

Organic pollutants in sediment (μg/Kg, dry weight) September 2012

Organic Pollutants	RL*	PCB Congener #	69	70	71	72	73	75
4,4'-DDE	1		ND	ND	ND	ND	ND	ND
4,4'-DDD	1		ND	ND	ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND	ND	ND
naphthalene	1		ND	ND	ND	ND	ND	0.6
acenaphthylene	1		ND	ND	ND	ND	ND	ND
acenaphthene	1		ND	ND	ND	ND	2.6	ND
fluorene	1		ND	ND	ND	ND	ND	ND
phenanthrene	1		4.8	2.8	ND	10.0	1.0	5.2
anthracene	1		ND	ND	ND	2.5	ND	ND
Fluoranthene	1		14.9	2.4	ND	12.1	1.6	18.7
Pyrene	1		17.3	2.6	1.7	14.7	2.2	23.1
Benz[a]anthracene	1		3.5	ND	ND	4.3	ND	5.6
Chrysene	1		5.2	ND	ND	4.9	ND	5.6
Benzo[b]fluoranthene	1		6.4	2.0	ND	7.4	1.3	7.3
Benzo[k]fluoranthene	1		4.7	ND	ND	7.4	ND	6.4
Benzo[e]pyrene	1		6.4	ND	ND	6.8	1.3	7.3
Perylene	1		2.9	2.0	1.9	9.3	1.3	3.4
Benzo[a]pyrene	1		7.6	ND	ND	9.9	1.3	9.0
Indeno[1,2,3-cd]pyrene	1		9.9	ND	ND	10.5	1.8	11.6
dibenz[a,h]anthracene	1		ND	ND	ND	ND	ND	ND
benzo[ghi]perylene	1		9.9	2.0	1.9	11.8	2.2	12.9
2,4'-Dichlorobipheny	1	PCB 008	ND	ND	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	ND	ND	ND	ND	ND	ND
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND	ND	ND
Sum of organics			93.4	13.9	5.5	111.7	16.8	116.7

*RL = Reporting Limit
ND = Not Detected

Appendix D-4

Organic pollutants in sediment (µg/Kg, dry weight) September 2012

		PCB	Station			
Organic Pollutants	RL*	Congener #	77	78	79	80
4,4'-DDE	1		ND	ND	ND	ND
4,4'-DDD	1		ND	ND	ND	ND
4,4'-DDT	1		ND	ND	ND	ND
naphthalene	1		ND	ND	1.6	ND
acenaphthylene	1		ND	ND	2.3	ND
acenaphthene	1		ND	ND	ND	ND
fluorene	1		ND	ND	1.3	ND
phenanthrene	1		5.5	2.2	32.8	ND
anthracene	1		1.4	ND	26.1	ND
Fluoranthene	1		19.7	5.4	81.5	ND
Pyrene	1		24.3	7.2	107.3	ND
Benz[a]anthracene	1		5.9	1.7	41.1	ND
Chrysene	1		5.9	2.2	40.6	ND
Benzo[b]fluoranthene	1		7.7	3.0	21.9	ND
Benzo[k]fluoranthene	1		6.8	2.2	28.0	ND
Benzo[e]pyrene	1		7.7	2.6	20.5	ND
Perylene	1		3.6	2.6	10.7	ND
Benzo[a]pyrene	1		9.5	3.0	41.6	ND
Indeno[1,2,3-cd]pyrene	1		12.2	3.9	27.1	ND
dibenz[a,h]anthracene	1		1.4	ND	5.1	ND
benzo[ghi]perylene	1		13.5	4.3	24.7	ND
2,4'-Dichlorobipheny	1	PCB 008	ND	ND	ND	ND
2,2',5-Trichlorobiphenyl	1	PCB 018	ND	ND	ND	ND
2,4,4'-Trichlorobiphenyl	1	PCB 028	ND	ND	ND	ND
2,2',5,5'-Tetrachlorobipheny	1	PCB 052	ND	ND	ND	ND
2,2',3,5'-Tetrachlorobipheny	1	PCB 044	ND	ND	ND	ND
2,3',4,4'-Tetrachlorobipheny	1	PCB 066	ND	ND	ND	ND
2,2',4,5,5'-Pentachlorobipheny	1	PCB 101	ND	ND	ND	ND
3,4,4',5-Tetrachlorobiphenyl	1	PCB 081	ND	ND	ND	ND
3,3',4,4'-Tetrachlorobipheny	1	PCB 077	ND	ND	ND	ND
2',3,4,4',5-Pentachlorobipheny	1	PCB 123	ND	ND	ND	ND
2,3',4,4',5-Pentachlorobipheny	1	PCB 118	ND	ND	ND	ND
2,2',4,4',5,5'-Hexachlorobipheny	1	PCB 153	ND	ND	ND	ND
3,3',4,5,5'-Pentachlorobipheny	1	PCB 127	ND	ND	ND	ND
2,3,3',4,4'-Pentachlorbipheny	1	PCB 105	ND	ND	ND	ND
2,2',3,4,4',5-Hexachlorobipheny	1	PCB 137	ND	ND	ND	ND
3,3',4,4',5-Pentachlorobipheny	1	PCB 126	ND	ND	ND	ND
2,2',3,4',5,5',6-Heptachlorobipheny	1	PCB 187	ND	ND	ND	ND
2,2',3,3',4,4'-Hexachlorobipheny	1	PCB 128	ND	ND	ND	ND
2,3,3',4,4',5'-Hexachlorobipheny	1	PCB 157	ND	ND	ND	ND
2,2',3,4,4',5,5'-Heptachlorobipheny	1	PCB 180	ND	ND	ND	ND
2,2',3,3',4,4',5-Heptachlorobipheny	1	PCB 170	ND	ND	ND	ND
2,3,3',4,4',5,5'-Heptachlorobipheny	1	PCB 189	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Octachlorobipheny	1	PCB 195	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	1	PCB 206	ND	ND	ND	ND
Decachlorobipheny	1	PCB 209	ND	ND	ND	ND
2,4',5-Trichlorobiphenyl	1	PCB 31	ND	ND	ND	ND
2',3,4-Trichlorobiphenyl	1	PCB 33	ND	ND	ND	ND
2,2',4,5-Tetrachlorobiphenyl	1	PCB 49	ND	ND	ND	ND
2,4,4',5-Tetrachlorobiphenyl	1	PCB 74	ND	ND	ND	ND
2,3',4',5-Tetrachlorobipheny	1	PCB 70	ND	ND	ND	ND
2,2',3,5',6-Pentachlorobipheny	1	PCB 95	ND	ND	ND	ND
2,3,3',4'-Tetrachlorobipheny	1	PCB 56	ND	ND	ND	ND
2,3,4,4'-Tetrachlorobiphenyl	1	PCB 60	ND	ND	ND	ND
2,2',4,4',5-Pentachlorobipheny	1	PCB 99	ND	ND	ND	ND
2,2',3',4,5-Pentachlorobipheny	1	PCB 97	ND	ND	ND	ND
2,2',3,4,5'-Pentachlorobipheny	1	PCB 87	ND	ND	ND	ND
2,3,3',4',6-Pentachlorobipheny	1	PCB 110	ND	ND	ND	ND
2,3,4,4',5-Pentachlorobipheny	1	PCB 114	ND	ND	ND	ND
2,2',3,5,5',6-Hexachlorobipheny	1	PCB 151	ND	ND	ND	ND
2,2',3,4',5',6-Hexachlorobipheny	1	PCB 149	ND	ND	ND	ND
2,2',3,3',4,6'-Hexachlorobipheny	1	PCB 132	ND	ND	ND	ND
2,2',3,4,5,5'-Hexachlorobipheny	1	PCB 141	ND	ND	ND	ND
2,3,3',4,4',6-Hexachlorobipheny	1	PCB 158	ND	ND	ND	ND
2,2',3,4,4',5',6-Heptachlorobipheny	1	PCB 183	ND	ND	ND	ND
2,3',4,4',5,5'-Hexachlorobipheny	1	PCB 167	ND	ND	ND	ND
2,2',3,3',4,5,6'-Heptachlorobipheny	1	PCB 174	ND	ND	ND	ND
2,2',3,3',4',5,6-Heptachlorobipheny	1	PCB 177	ND	ND	ND	ND
2,3,3',4,4',5-Hexachlorobipheny	1	PCB 156	ND	ND	ND	ND
3,3',4,4',5,5'-Hexachlorobipheny	1	PCB 169	ND	ND	ND	ND
2,2',3,3',4,5,5',6'-Octachlorobipheny	1	PCB 201	ND	ND	ND	ND
2,2',3,4,4',5,5',6-Octachlorobipheny	1	PCB 203	ND	ND	ND	ND
2,2',3,3',4,4',5,5'-Octachlorobipheny	1	PCB 194	ND	ND	ND	ND
Sum of organics			124.8	40.4	514.5	0.0

*RL = Reporting Limit
ND = Not Detected

Appendix D-5

Oceanside Water Pollution Control Plant Polycyclic Aromatic Hydrocarbons (PAHs) on Final Effluent

2001 (µg/L)		Value	MDL
Acenaphthene	<	0.03	0.03
Acenaphthylene	<	0.14	0.14
Anthracene	<	0.01	0.01
Benzo[a]anthracene	<	0.01	0.01
Benzo[a]pyrene	<	0.01	0.01
Benzo[b]fluoranthene	<	0.01	0.01
Benzo[ghi]perylene	<	0.01	0.01
Benzo[k]fluoranthene	<	0.01	0.01
Chrysene	<	0.02	0.02
Dibenzo-[a,h]-anthracene	<	0.01	0.01
Fuoranthene	<	0.04	0.04
Fluorene	<	0.02	0.02
Indeno[1,2,3-cd]pyrene	<	0.02	0.02
Naphthalene	<	0.06	0.06
Phenanthrene	<	0.06	0.06
Pyrene	<	0.03	0.03
Total PAH's		**0.49**	

2002 (µg/L)		Value	MDL
Acenaphthene	<	2.24	2.24
Acenaphthylene	<	2.34	2.34
Anthracene	<	2.18	2.18
Benzo[a]anthracene	<	2.02	2.02
Benzo[a]pyrene	<	2.8	2.8
Benzo[b]fluoranthene	<	2.22	2.22
Benzo[ghi]perylene	<	3.3	3.3
Benzo[k]fluoranthene	<	2.28	2.28
Chrysene	<	2.02	2.02
Dibenzo-[a,h]-anthracene	<	2.82	2.82
Fuoranthene	<	2.08	2.08
Fluorene	<	2.42	2.42
Indeno[1,2,3-cd]pyrene	<	2.7	2.7
Naphthalene	<	1.86	1.86
Phenanthrene	<	2.24	2.24
Pyrene	<	1.94	1.94
Total PAH's		**37.46**	

2003 (µg/L)		Value		MDL
Acenaphthene	<	0.376		0.376
Acenaphthylene		0.2425	DNQ	0.2425
Anthracene	<	0.033		0.033
Benzo[a]anthracene	<	0.066		0.066
Benzo[a]pyrene	<	0.068		0.068
Benzo[b]fluoranthene	<	0.068		0.068
Benzo[ghi]perylene	<	0.072		0.072
Benzo[k]fluoranthene	<	0.131		0.131
Chrysene	<	0.094		0.094
Dibenzo-[a,h]-anthracene	<	0.065		0.094
Fuoranthene	<	0.189		0.189
Fluorene	<	0.097		0.097
Indeno[1,2,3-cd]pyrene	<	0.095		0.095
Naphthalene	<	0.277		0.277
Phenanthrene	<	0.096		0.096
Pyrene(DNQ)	<	0.183		0.183
Total PAH's		**2.15**		

2004 (µg/L)		Value	MDL
Acenaphthene	<	0.44	0.44
Acenaphthylene	<	0.28	0.28
Anthracene	<	0.04	0.04
Benzo[a]anthracene	<	0.08	0.08
Benzo[a]pyrene	<	0.08	0.08
Benzo[b]fluoranthene	<	0.08	0.08
Benzo[ghi]perylene	<	0.08	0.08
Benzo[k]fluoranthene	<	0.12	0.12
Chrysene	<	0.12	0.12
Dibenzo-[a,h]-anthracene	<	0.08	0.08
Fuoranthene	<	0.24	0.24
Fluorene	<	0.12	0.12
Indeno[1,2,3-cd]pyrene	<	0.12	0.12
Naphthalene	<	0.32	0.32
Phenanthrene	<	0.12	0.12
Pyrene	<	0.24	0.24
Total PAH's		**2.56**	

2005 (µg/L)		Value	MDL
Acenaphthene	<	0.33	0.33
Acenaphthylene	<	0.21	0.21
Anthracene	<	0.03	0.03
Benzo[a]anthracene	<	0.06	0.06
Benzo[a]pyrene	<	0.06	0.06
Benzo[b]fluoranthene	<	0.06	0.06
Benzo[ghi]perylene	<	0.06	0.06
Benzo[k]fluoranthene	<	0.09	0.09
Chrysene	<	0.09	0.09
Dibenzo-[a,h]-anthracene	<	0.06	0.06
Fuoranthene	<	0.18	0.18
Fluorene	<	0.09	0.09
Indeno[1,2,3-cd]pyrene	<	0.09	0.09
Naphthalene	<	0.24	0.24
Phenanthrene	<	0.09	0.09
Pyrene	<	0.18	0.18
Total PAH's		**1.92**	

2006 (µg/L)		Value	MDL
Acenaphthene	<	0.44	0.44
Acenaphthylene		0.20	0.07
Anthracene	<	0.04	0.04
Benzo[a]anthracene	<	0.08	0.08
Benzo[a]pyrene	<	0.08	0.08
Benzo[b]fluoranthene	<	0.08	0.08
Benzo[ghi]perylene	<	0.08	0.08
Benzo[k]fluoranthene	<	0.12	0.12
Chrysene	<	0.12	0.12
Dibenzo-[a,h]-anthracene	<	0.06	0.06
Fuoranthene	<	0.24	0.06
Fluorene	<	0.12	0.12
Indeno[1,2,3-cd]pyrene	<	0.12	0.12
Naphthalene	<	0.32	0.32
Phenanthrene	<	0.12	0.12
Pyrene	<	0.24	0.24
Total PAH's		**2.46**	

DNQ = detected but not quantified

Appendix D-5 (cont.)

Oceanside Water Pollution Control Plant Polycyclic Aromatic Hydrocarbons (PAHs) on Final Effluent

2007 (µg/L)		Value		MDL
Acenaphthene	<	0.356		0.356
Acenaphthylene	<	0.162		0.162
Anthracene	<	0.033		0.033
Benzo[a]anthracene		0.002	DNQ	0.002
Benzo[a]pyrene		0.002	DNQ	0.002
Benzo[b]fluoranthene	<	0.074		0.01
Benzo[ghi]perylene		0.005	DNQ	0.004
Benzo[k]fluoranthene		0.003	DNQ	0.002
Chrysene		0.003	DNQ	0.002
Dibenzo-[a,h]-anthracene		0.002	DNQ	0.001
Fuoranthene	<	0.174		0.174
Fluorene	<	0.092		0.092
Indeno[1,2,3-cd]pyrene	<	0.086		0.086
Naphthalene		0.039	DNQ	0.101
Phenanthrene	<	0.102		0.055
Pyrene		0.015	DNQ	0.012
Total PAH's		**1.15**		

2008 (µg/L)		Value		MDL
Acenaphthene	<	0.132		0.0132
Acenaphthylene	<	0.176		0.176
Anthracene		0.002	DNQ	0.0015
Benzo[a]anthracene	<	0.008		0.008
Benzo[a]pyrene	<	0.008		0.008
Benzo[b]fluoranthene	<	0.008		0.008
Benzo[ghi]perylene	<	0.008		0.008
Benzo[k]fluoranthene	<	0.004		0.004
Chrysene	<	0.008		0.008
Dibenzo-[a,h]-anthracene	<	0.004		0.004
Fuoranthene	<	0.048		0.048
Fluorene	<	0.044		0.044
Indeno[1,2,3-cd]pyrene	<	0.032		0.032
Naphthalene	<	0.099		0.099
Phenanthrene	<	0.044		0.044
Pyrene	<	0.024		0.024
Total PAH's		**0.649**		

2009 (µg/L)		Value		MDL
Acenaphthene	<	0.0674		0.0674
Acenaphthylene	<	0.1924		0.01924
Anthracene		0.006		0.0009
Benzo[a]anthracene		0.0136	DNQ	0.0008
Benzo[a]pyrene		0.0151	DNQ	0.0034
Benzo[b]fluoranthene		0.0151	DNQ	0.0017
Benzo[ghi]perylene		0.006	DNQ	0.002
Benzo[k]fluoranthene		0.0151	DNQ	0.002
Chrysene		0.0072	DNQ	0.001
Dibenzo-[a,h]-anthracene		0.032	DNQ	0.001
Fuoranthene		0.0176	DNQ	0.0092
Fluorene	<	0..0134		0.0134
Indeno[1,2,3-cd]pyrene		0.0143	DNQ	0.0032
Naphthalene		0.0727	DNQ	0.0545
Phenanthrene		0.4711	DNQ	0.169
Pyrene		0.0398	DNQ	0.0182
Total PAH's		**0.9854**		

2010 (µg/L)		Value		MDL
Acenaphthene	<	0.018		0.018
Acenaphthylene	<	0.051		0.051
Anthracene		0.001	DNQ	0.001
Benzo[a]anthracene		0.003	DNQ	0.0005
Benzo[a]pyrene	<	0.002		0.002
Benzo[b]fluoranthene		0.004	DNQ	0.002
Benzo[ghi]perylene	<	0.002		0.002
Benzo[k]fluoranthene	<	0.007		0.007
Chrysene		0.002	DNQ	0.001
Dibenzo-[a,h]-anthracene	<	0.001		0.001
Fuoranthene	<	0.016		0.016
Fluorene		0.005	DNQ	0.003
Indeno[1,2,3-cd]pyrene	<	0.002		0.002
Naphthalene		0.061	DNQ	0.017
Phenanthrene		0.004	DNQ	0.002
Pyrene		0.006	DNQ	0.005
Total PAH's		0.186		

2011 (µg/L)		Value		MDL
Acenaphthene	<	0.018		0.018
Acenaphthylene	<	0.051		0.051
Anthracene	<	0.001		0.001
Benzo[a]anthracene	<	0.0005		0.0005
Benzo[a]pyrene	<	0.002		0.002
Benzo[b]fluoranthene	<	0.002		0.002
Benzo[ghi]perylene	<	0.002		0.002
Benzo[k]fluoranthene	<	0.007		0.007
Chrysene	<	0.001		0.001
Dibenzo-[a,h]-anthracene	<	0.001		0.001
Fuoranthene	<	0.016		0.016
Fluorene	<	0.003		0.003
Indeno[1,2,3-cd]pyrene	<	0.002		0.002
Naphthalene		0.027	DNQ	0.017
Phenanthrene	<	0.002		0.002
Pyrene	<	0.005		0.005
Total PAH's		**0.14**		

2012 (µg/L)		Value		MDL
Acenaphthene	<	0.61		0.61
Acenaphthylene	<	0.74		0.74
Anthracene	<	0.41		0.41
Benzo[a]anthracene	<	0.28		0.28
Benzo[a]pyrene	<	0.32		0.32
Benzo[b]fluoranthene	<	0.31		0.31
Benzo[ghi]perylene	<	0.62		0.62
Benzo[k]fluoranthene	<	0.31		0.31
Chrysene	<	0.31		0.31
Dibenzo-[a,h]-anthracene	<	0.73		0.73
Fuoranthene	<	0.54		0.54
Fluorene	<	0.71		0.71
Indeno[1,2,3-cd]pyrene	<	0.67		0.67
Naphthalene	<	0.48		0.48
Phenanthrene	<	0.48		0.48
Pyrene	<	0.4		0.4
Total PAH's		**7.92**		

DNQ = detected but not quatified

Appendix D-6

Elemental concentrations in sediments (mg/Kg, dry weight) September 2012

	Metals												
	Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Manganese	Nickel	Lead	Zinc	Mercury	Selenium	Silver
Background Concentrations:													
Baywide ranges (Total)[2,3]	NV	NV	NV	110-170	20-55	NV	NV	70-100	20-40	60-70	NV	NV	NV
Baywide ranges (NearTotal)[2,3]	NV	NV	NV	70-121	20-41	NV	NV	50-100	10-20	50-100	0.05-0.05	NV	NV
MDL	15.45	0.08	0.04	0.06	0.19	86.91	0.48	0.08	0.050	0.58	0.01	0.03	0.003
Stations													
1	10785	4.9	0.0716	43.5	5.2	20348	178	41.2	5.3	39.8	0.1099	0.4273	0.015
2	9928	3.9	0.064	49.6	4.4	20910	191	40.4	4.7	37.6	0.019	0.4317	0.017
4	11943	5.3	0.1129	46.0	6.4	21101	183	42.1	6.3	43.5	0.0499	0.4785	0.017
6	9254	3.8	0.0795	43.1	2.8	17354	144	33.8	3.8	32.1	0.0311	0.4577	0.008
25	11023	4.8	0.072	46.0	4.8	20943	183	42.5	9.3	45.7	0.0309	0.4488	0.015
28	11465	4.9	0.0979	45.4	5.4	20895	174	41.4	5.9	42.1	0.0553	0.4664	0.014
31	8900	4.3	0.0392	47.2	2.7	20163	251	41.1	5.0	35.4	0.0119	0.4901	0.004
32	8944	6.6	0.262	35.7	4.1	20255	123	28.0	6.6	40.6	0.0475	0.4627	0.033
33	13066	4.8	0.0962	49.3	7.2	23827	198	45.9	6.9	46.9	0.0945	0.4646	0.021
34	12098	5.6	0.1769	44.7	6.8	21999	167	39.1	6.9	44.8	0.0687	0.4358	0.03
35	14496	6.7	0.2412	52.4	10.2	24759	180	45.5	8.8	54.1	0.0393	0.4832	0.049
36	12859	5.0	0.1156	48.9	6.7	23826	192	46.4	7.8	47.4	0.0506	0.4612	0.018
37	12241	5.1	0.0601	50.2	6.8	22446	213	46.9	6.9	46.6	0.0516	0.4609	0.021
38	12441	4.6	0.0881	47.7	6.0	22894	180	42.5	6.5	43.6	0.0622	0.4537	0.02
39	11642	4.2	0.0762	48.5	4.2	23333	171	41.7	5.1	42.5	0.024	0.4929	0.014
40	14983	6.0	0.127	59.4	13.4	27324	263	52.7	9.9	58.3	0.0954	0.4909	0.055
43	9035	4.5	0.0405	47.8	5.3	18257	201	38.3	4.7	31.5	0.0218	0.0745	0.015
45	9113	6.1	0.0413	52.7	6.2	21190	205	36.0	5.7	32.0	0.0258	0.0397	0.013
47	10819	5.0	0.0506	97.0	8.7	38055	304	44.7	7.3	46.3	0.0234	0.0513	0.015
48	9021	5.2	0.0407	42.8	6.6	17643	190	36.0	5.5	30.8	0.0223	0.0568	0.018
50	13297	4.5	0.044	52.0	8.2	21998	184	43.7	5.7	41.6	0.0341	0.0983	0.021
51	9105	4.5	0.0423	55.7	5.2	18831	235	37.5	5.0	31.5	0.0316	0.0317	0.007
52	9628	4.9	0.043	47.1	5.4	18371	243	38.8	5.0	32.6	0.0095	0.0322	0.007
53	12478	4.5	0.0517	52.8	7.7	21211	187	42.3	5.5	40.0	0.0161	0.101	0.045
54	11763	4.3	0.0421	47.7	7.1	20016	174	39.9	5.0	38.5	0.1458	0.0882	0.009
55	11846	4.4	0.0465	61.6	8.0	23545	220	45.9	5.0	40.4	0.0145	0.0463	0.01
56	13659	5.1	0.0812	51.3	9.0	21797	186	44.3	6.4	42.8	0.0355	0.1448	0.017
57	11941	4.7	0.072	50.7	7.4	20887	191	45.5	5.3	39.8	0.0167	0.0879	0.017
58	12991	5.1	0.0564	50.9	9.1	21284	186	43.3	6.0	42.5	0.0323	0.0895	0.018
59	12769	5.1	0.0423	50.2	7.8	20714	171	41.5	5.5	39.9	0.0209	0.1041	0.013
60	12008	4.1	0.0467	49.4	7.3	20489	174	40.7	4.8	38.7	0.0586	0.1137	0.012
61	12839	4.9	0.0429	51.3	7.4	20270	175	41.1	5.2	38.8	0.0634	0.1198	0.007
62	12374	3.7	0.0438	53.6	6.9	20585	176	39.7	4.6	37.9	0.0577	0.117	0.011
63	12277	4.4	0.0414	48.3	7.0	19451	165	39.6	4.4	37.3	0.0409	0.114	0.006
64	11552	4.7	0.0645	49.8	6.4	19285	159	38.3	4.2	35.8	0.041	0.1286	0.007
65	11405	5.2	0.0617	48.2	6.3	19527	161	38.4	4.0	35.8	0.0277	0.1077	0.006
66	11658	4.2	0.0758	48.8	6.0	18769	160	35.7	4.1	35.6	0.0308	0.1341	0.008
67	11796	4.4	0.0628	51.6	6.2	19267	171	38.6	3.8	36.3	0.0345	0.1069	0.004
68	11317	3.4	0.0743	48.4	5.9	18175	155	36.0	3.7	35.7	0.0185	0.115	0.003
69	10413	3.6	0.0573	46.4	5.5	17245	154	33.5	3.5	33.4	0.0248	0.1205	0.003
70	10792	5.4	0.0405	41.9	6.2	18612	154	32.1	4.0	34.6	0.0934	0.1037	0.003
71	10373	4.3	0.0738	43.4	5.3	16970	143	32.2	3.5	32.7	0.0142	0.0955	0.003
72	12808	6.1	0.0566	52.6	9.3	22101	186	43.8	6.3	43.6	0.0528	0.1219	0.026
73	11477	4.3	0.046	60.0	7.4	22423	209	45.3	4.3	39.7	0.0231	0.0928	0.009
75	11935	4.5	0.0412	53.9	7.8	21596	201	46.4	5.0	40.8	0.0314	0.0873	0.008
77	11262	4.6	0.0669	60.9	7.5	21436	184	42.4	4.5	39.3	0.0463	0.0872	0.006
78	11587	4.7	0.0715	49.7	7.0	19695	168	40.3	4.8	37.7	0.0326	0.1147	0.003
79	11878	5.4	0.111	51.7	8.1	19362	167	42.0	4.8	38.4	0.0313	0.1158	0.007
80	9804	4.1	0.0407	50.3	5.9	20479	195	39.7	4.4	35.2	0.0196	0.0451	0.003

NV = No Value available

[2] Hornberger, et al. 1999 as cited by SFEI 1999

[3] Pereira, et al. 1999 as cited by SFEI 1999

Appendix D-7

Analytical techniques and detection limits for sediment metals analysis (mg/Kg, dry weight)

September 2012

Element		Method	Method Detection Limit (MDL)
Aluminum	Al	ICP-AES	9.46
Arsenic	As	ICP-AES	0.10
Cadmium	Cd	ICP-AES	0.02
Chromium	Cr	ICP-AES	0.04
Copper	Cu	ICP-AES	0.06
Iron	Fe	ICP-AES	7.15
Lead	Pb	ICP-AES	0.01
Manganese	Mn	ICP-AES	0.02
Mercury	Hg	CVAAS	0.02
Nickel	Ni	ICP-AES	0.10
Selenium	Se	HGAAS	0.04
Silver	Ag	FAAS	0.01
Zinc	Zn	ICP-AES	0.32

ICP-AES = inductively coupled plasma atomic emission spectroscopy
CVAAS = cold vapor atomic absorption spectroscopy
GF-AAS = graphite furnace atomic absorption spectroscopy
FAAS = flame atomic absorption spectroscopy
HGAAS = hydride generation atomic absorption spectroscopy

Appendix D-8
Oceanside Water Pollution Control Plant
Metals (mg/Kg) from final effluent
2001 to 2012

Metal (mg/Kg)		2001	2001 MDL	2002	2002 MDL	2003		2003 MDL
Silver, Ag		0.95	1.5	9.77	2.81	3.54	DNQ	1.21
Arsenic, As		5.91	5.7	10.82	6.91	12.28	DNQ	5.76
Cadmium, Cd	<	0.33	0.4	1.52	0.67	0.58	DNQ	0.33
Chromium, Cr	<	1.31	0.6	12.18	4.87	10.98	DNQ	3.05
Copper, Cu		32.24	14.7	219.61	4.16	17.00	DNQ	0.59
Mercury, Hg	<	0.02	0.001	0.31	0.01	0.21		0.01
Nickel, Ni		6.57	2.1	35.28	6.97	18.65	DNQ	4.48
Lead, Pb		4.80	4.3	28.36	7.91	13.57	DNQ	8.90
Zinc, Zn		119.85	22.2	760.19	9.38	483.27		8.04

Metal (mg/Kg)	2004		2004 MDL	2005		2005 MDL	2006		2006 MDL
Silver, Ag	3.71	DNQ	1.41	1.75	DNQ	0.45	1.42	DNQ	0.34
Arsenic, As	17.55	DNQ	8.06	8.79	DNQ	3.71	8.45	DNQ	5.12
Cadmium, Cd	1.42	DNQ	0.67	1.37	DNQ	0.40	0.33	DNQ	0.12
Chromium, Cr	7.28	DNQ	1.83	8.20	DNQ	2.27	6.30	DNQ	1.90
Copper, Cu	222.34	DNQ	3.56	14.71	DNQ	3.52	182.87		41.93
Mercury, Hg	0.28		0.01	0.16		0.01	0.16		0.01
Nickel, Ni	26.16	DNQ	6.48	38.55	DNQ	3.79	33.04	DNQ	2.41
Lead, Pb	19.82	DNQ	6.92	14.02	DNQ	7.43	19.00	DNQ	5.95
Zinc, Zn	527.73		8.04	437.06		6.30	410.60		5.47

DNQ = Detected but not quantified

Appendix D-8 (cont.)

Oceanside Water Pollution Control Plant

Metals (mg/Kg) from final effluent

2001 to 2012 (cont.)

Metal (mg/Kg)	2007		2007 MDL	2008		2008 MDL	2009		2009 MDL
Silver, Ag	8.2	DNQ	0.54	1.6	DNQ	0.29	2.3	DNQ	0.245
Arsenic, As	4.0	DNQ	2.56	16.6		16.64	22.4	DNQ	5.166
Cadmium, Cd	3.1	DNQ	0.35	2.2	DNQ	0.35	0.9	DNQ	0.038
Chromium, Cr	3.6	DNQ	0.71	3.0	DNQ	0.95	11.0	DNQ	1.593
Copper, Cu	249.6		45.15	241.5		41.93	174.4		17.213
Mercury, Hg	15.4		0.01	0.1		0.01	0.1	DNQ	0.001
Nickel, Ni	26.2	DNQ	2.41	28.0	DNQ	2.41	19.8	DNQ	2.560
Lead, Pb	22.5	DNQ	5.95	14.5	DNQ	6.70	7.4	DNQ	3.696
Zinc, Zn	510.8		5.89	522.9		5.47	298.8		3.995

Metal (mg/Kg)	2010		2010 MDL	2011		2011 MDL	2012		2012 MDL
Silver, Ag	1.30	DNQ	0.06	0.95	DNQ	0.04	1.64	DNQ	0.04
Arsenic, As	8.65	DNQ	1.33	10.56	DNQ	0.84	10.76	DNQ	0.84
Cadmium, Cd	1.13	DNQ	0.11	0.77	DNQ	0.07	0.62	DNQ	0.05
Chromium, Cr	7.63	DNQ	0.08	9.22		0.05	11.44		0.05
Copper, Cu	130.12		0.57	144.03		0.36	163.17		0.36
Mercury, Hg	0.11		0.00	0.10		0.00	0.17		0.00
Manganese, Mn							34.95		0.03
Nickel, Ni	26.26		0.38	30.91		0.24	32.20		0.24
Lead, Pb	7.65	DNQ	0.38	8.20	DNQ	0.24	8.53	DNQ	0.24
Selenium, Se	2.84	DNQ	0.51	2.37	DNQ	0.36	2.32	DNQ	0.36
Zinc, Zn	283.88		3.80	313.24		2.40	364.54		2.40

DNQ = Detected but not quantified

Mulitivariate Analysis of Variance (MANOVA) and Analysis of Variance (ANOVA) of Trace Metals 1997 to 2012

Mulitivarite Analysis of Variance (MANOVA)

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha = 0.05)
A: area	1	1.380235E+07	1.380235E+07	0.43	0.513001	0.100166
S	524	1.687755E+10	3.220906E+07			
Total (adjusted)	525	1.689135E+10				
Total	526					

Analysis of Variance (ANOVA)

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha = 0.05)
A: area	1	3940585	3940585	2.49	0.114913	0.350781
B: Analyte	15	1.604365E+10	1.069576E+09	676.97	0*	1.000000
AB	15	3.965750E+07	2643833	1.67	0.052647	0.913093
S	495	7.804987E+08	1579957			
Total Adjusted	525	1.689135E+10				
Total	526					

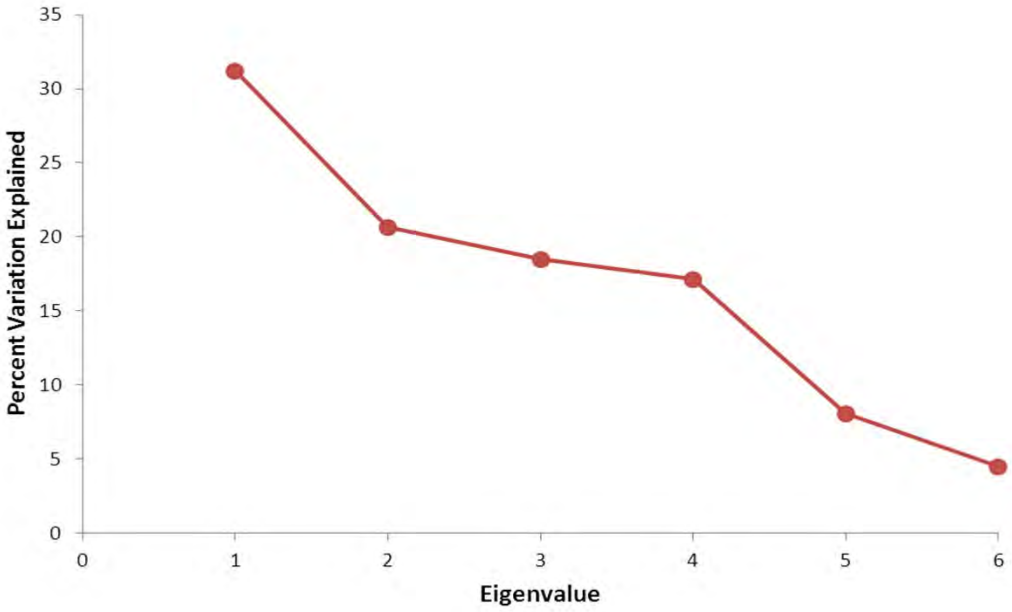
*Term signifcant at alpha = 0.05

Appendix D-10

Skree plot of PCA factors, Significant Eigenvalue, and Factor loading after Varimax rotation

1997 to 2012

Skree Plot of PCA Factors



Significant Eigenvalue

Factor	Eigenvalue	Percent of variation
		explained
1	1.8729	31.21
2	1.2384	20.64
3	1.1084	18.47
4	1.0273	17.12
Total		87.44

Factor Loading after varimax rotation

Variables	Factor1	Factor2	Factor3	Factor4
sMETq	-0.00761	**0.968698**	-0.02564	0.069492
sORG	-0.195714	0.072695	0.0721	**0.975131**
SLT-CLY	**-0.837399**	-0.251329	-0.19431	0.123944
TKN	-0.114009	-0.038322	**0.93724**	0.058219
TOC	**-0.74876**	0.294356	0.367601	0.18755
TVS	**-0.748103**	0.115937	0.425714	0.132874

APPENDIX E

BENTHIC INFAUNA

APPENDIX E
Benthic Infauna data
1997-2012

Appendix E-1

Traditional classification of benthic infauna collected from 1997 through 2012

- CNIDARIA
  - HYDROZOA
      - *Euphysa spp.*
  - ANTHOZOA *Anthozoa*
    - PENNATULACEA
      - *Stylatula spp.*
      - *Edwardsia juliae*
      - *Halcampa decemtentaculata*
- PLATYHELMINTHES
      - *Turbellaria*
- NEMERTEA
      - *Carinoma mutabilis*
      - *Carinoma sp.*
      - *Tubulanidae sp. B*
      - *Tubulanus cingulatus*
      - *Tubulanus nothus*
      - *Tubulanus pellucidus*
      - *Tubulanus spp.*
      - *Lineidae*
      - *Cerebratulus californiensis*
      - *Cerebratulus spp.*
      - *Micrura spp. (?)*
      - *Paranemertes californica*
      - *Paranemertes californica*
      - *Monostylifera sp. B*
- MOLLUSCA
  - APLACOPHORA
    - CHAETODERMATIDA
      - *Falcidens longus*
  - GASTROPODA
    - NATICIDAE
      - *Glossaluax reclusiana*
      - *Polinices draconis*
      - *Polinices lewisii*
      - *Polinices spp.*
    - RISSOIDAE
      - *Alvania compacta*
      - *Alvania rosana*
    - BARLEEIIDAE
      - *Barleeia haliotiphila*
    - EPITONIIDAE
      - *Epitonium spp.*
    - EULIMIDAE
      - *Balcis spp.*
    - COLUMBELLIDAE
      - *Astyris gausapata*
      - *Mitrella spp.*
      - *Mitrella spp.*
    - NASSARIIDAE
      - *Caesia fossatus*
      - *Caesia rhinetes*
    - OLIVELLIDAE
      - *Callianax pycna*
    - BORSONIIDAE
      - *Ophiodermella spp.*
    - MANGELIIDAE
      - *Kurtziella plumbea*
      - *Kurtzina beta*
    - TURRIDAE
    - ACTEONIDAE
      - *Rictaxis punctocaelatus*
    - APLUSTRIDAE
      - *Parvaplustrum sp. A*
    - PYRAMIDELLIDAE
      - *Brachystomia angularis*
      - *Cyclostremella californica*
      - *Odostomia churchi*
      - *Odostomia spp.*
      - *Turbonilla spp.*
    - HETEROBRANCHIA
      - *Opisthobranchia*
      - *Cephalaspidea*
    - DIAPHANIDAE
      - *Diaphana californica*
    - HAMINOEIDAE
      - *Haminoea virescens*
      - *Haminoea sp.*
    - PHILINIDAE
      - *Philine auriformis*
      - *Philine spp.*
    - AGLAJIDAE
      - *Aglaja ocelligera*
      - *Melanochlamys diomedea*
    - CYLICHNIDAE
      - *Acteocina spp.*
      - *Cylichna attonsa*
      - *Cylichna spp.*
    - GASTROPTERIDAE
      - *Gastropteron pacificum*
    - RETUSIDAE
      - *Volvulella cylindrica*
      - *Volvulella panamica*
      - *Volvulella spp.*
  - NUDIBRANCHIA
      - *Armina californica*
      - *Dendronotus spp.*
      - *Dirona spp.*
      - *Eubranchus misakiensis*

Appendix E-1 (cont.)

Traditional classification of benthic infauna collected from 1997 through 2012

BIVALVIA
NUCULANIDAE
Saccella penderi
Saccella spp.
Saccella taphria
YOLDIIDAE
Yoldia cooperii
Yoldia seminuda
Yoldia spp.
MYTILIDAE
Modiolus capax
Modiolus rectus
Modiolus rectus
Modiolus spp.
Mytilus spp.
PECTINIDAE
Leptopecten latiauratus
LUCINIDAE
THYASIRIDAE
Axinopsida serricata
LASAEIDAE
Kellia sp. SF1
Kellia spp.
Kurtiella coani
Kurtiella grippi
Kurtiella pedroana
Kurtiella sp. SF1
Kurtiella tumida
Kurtiella spp.
NEOLEPTONIDAE
Neolepton salmoneum
CARDIIDAE
Clinocardium nuttallii
Trachycardium quadragenarium
TELLINIDAE
Macoma acolasta
Macoma nasuta
Macoma yoldiformis
Macoma spp.
Tellina bodegensis
Tellina modesta
Tellina nuculoides
Tellina spp.
SOLENIDAE
Solen rostiformis
Solen sicarius
PHARIDAE
Siliqua lucida
Siliqua sp. SF1
Siliqua spp.
HIATELLIDAE
Hiatella arctica
Saxicavella nybakkeni
Saxicavella pacifica
VENERIDAE
Leukoma staminea
Compsomyax subdiaphana
Nutricola confusa
Nutricola tantilla
Nutricola spp.
Venerupis philippanarum
PETRICOLIDAE
Cooperella subdiaphana
MACTRIDAE
Mactromeris catilliformis
Simomactra sp.
Tresus spp.
MYIDAE
Cryptomya californica
PANDORIDAE
Heteroclidus punctatus
Pandora bilirata
LYONSIIDAE
Lyonsia californica
THRACIIDAE
Asthenothaerus spp.
Thracioidea sp. SF1
SCAPHOPODA
GADILIDAE
Gadila aberrans
SIPUNCULA
Golfingia sp. A
Siphonosoma ingens
Sipunculus nudus
Themiste spp.
ECHIURA
Listriolobus pelodes
ANNELIDA
POLYCHAETA
CAPITELLIDAE
Capitella capitata complex
Heteromastus filobranchus
Heteromastus filiformis Cmplx
Heteromastus spp.
Mediomastus acutus
Mediomastus spp.
Notomastus lineatus
Notomastus hemipodus
Notomastus spp.

Appendix E-1 (cont.)

Traditional classification of benthic infauna collected from 1997 through 2012

COSSURIDAE
- *Cossura candida*
- *Cossura spp.*

MALDANIDAE
- *Axiothella rubrocincta*
- *Euclymeninae*
- *Euclymeninae sp. SF1*
- *Petaloclymene pacifica*

OPHELIIDAE
- *Armandia brevis*
- *Ophelia assimilis*
- *Travisia gigas*

ORBINIIDAE
- *Leitoscoloplos pugettensis*
- *Naineris uncinata*
- *Phylo felix*
- *Scoloplos armiger*
- *Scoloplos sp. SF1*
- *Scoloplos spp.*

PARAONIDAE
- *Aricidea (Acmira) catherinae*
- *Aricidea (Acmira) horikoshii*
- *Aricidea (Acmira) lopezi*
- *Aricidea (Acmira) spp.*
- *Aricidea (Aedicira) pacifica*
- *Aricidea (Aedicira) sp. A*
- *Aricidea (Aedicira) spp.*
- *Aricidea (Aricidea) wassi*
- *Aricidea (Aricidea) sp. SF1*
- *Aricidea (Aricidea) sp. SF2*
- *Aricidea (Aricidea) sp. SF3*
- *Aricidea spp.*
- *Paraonella platybranchiata*

SCALIBREGMATIDAE
- *Scalibregma californicum*

APHRODITIDAE
- *Aphrodita refulgida*
- *Aphrodita spp.*

POLYNOIDAE
- *Lepidasthenia berkeleyae*
- *Lepidasthenia longicirrata*
- *Lepidasthenia spp.*
- *Halosydna brevisetosa*
- *Halosydna spp.*
- *Arcteobia cf. anticostiensis*
- *Harmothoe imbricata complex*
- *Harmothoe spp.*
- *Hesperonoe laevis*
- *Malmgreniella liei*
- *Malmgreniella spp.*
- *Tenonia priops*

PHOLOIDAE
- *Pholoe glabra*
- *Pholoe spp*
- *Pholoides asperus*

SIGALIONIDAE
- *Sigalion spinosus*
- *Sthenelais berkeleyi*
- *Sthenelais tertiaglabra*
- *Sthenelais verruculosa*
- *Sthenelais sp.*
- *Sthenolepis fimbriarum*

PISIONIDAE
- *Pisione remota*

CHRYSOPETALIDAE
- *Paleanotus bellis*

HESIONIDAE
- *Heteropodarke heteromorpha*
- *Microphthalmus spp. complex*
- *Podarke spp.*
- *Podarkeopsis glabrus*

NEREIDIDAE
- *Nereis neoneanthes*
- *Nereis spp.*
- *Platynereis bicanaliculata*

PILARGIDAE
- *Ancistrosyllis groenlandica*
- *Ancistrosyllis spp.*
- *Parandalia fauveli*
- *Pilargis berkeleyae*
- *Sigambra sp. SF2*
- *Sigambra spp.*

SYLLIDAE
- *Autolytinae*
- *Eusyllis transecta*
- *Exogone lourei*
- *Sphaerosyllis californiensis*
- *Streptosyllis sp. SF1*
- *Syllis (Ehlersia) hyperioni*
- *Syllis spp.*
- *Typosyllis farallonensis*
- *Typosyllis nipponiica*
- *Typosyllis spp.*

GLYCERIDAE
- *Glycera americana*
- *Glycera capitata*
- *Glycera macrobranchia*
- *Glycera robusta*
- *Glycera tenuis*
- *Glycera spp.*
- *Hemipodia simplex*

Appendix E-1 (cont.)

Traditional classification of benthic infauna collected from 1997 through 2012

- GONIADIDAE
  - *Glycinde picta*
  - *Glycinde sp. SF1*
  - *Glycinde spp.*
  - *Goniada maculata*
  - *Goniada spp.*
- NEPHTYIDAE
  - *Micronephtys cornuta*
  - *Nephtys caeca*
  - *Nephtys caecoides*
  - *Nephtys californiensis*
  - *Nephtys ferruginea*
  - *Nephtys sp. SF1*
  - *Nephtys spp.*
- PHYLLODOCIDAE
  - *Eteone ?californica*
  - *Eteone fauchaldi*
  - *Eteone longa?*
  - *Eteone (Mysta) sp. SF1*
  - *Eteone pacifica*
  - *Eteone sp. SF3*
  - *Eteone sp. SF4*
  - *Eteone spp.*
  - *Eumida longicornuta*
  - *Hesionura coineaui difficilis*
  - *Paranaitis sp. SF1*
  - *Phyllodoce cuspidata*
  - *Phyllodoce groenlandica*
  - *Phyllodoce hartmanae*
  - *Phyllodoce longipes*
  - *Phyllodoce multipapillata*
  - *Phyllodoce spp.*
  - *Phyllodoce williamsi*
  - *Phyllodoce williamsi*
- SPHAERODORIDAE
- AMPHINOMIDAE
  - *Pareurythoe californica*
- DORVILLEIDAE
- DOR *Dorvillea rudolphi*
  - *Ophryotrocha sp. SF1*
  - *Protodorvillea gracilis*
  - *Protodorvillea spp.*
- LUMBRINERIDAE
  - *Lumbrinerides platypygos*
  - *Lumbrineris japonica*
  - *Lumbrineris californiensis*
  - *Lumbrineris limicola*
  - *Ninoe spp.*
  - *Scoletoma luti*
  - *Scoletoma spp.*
- OENONIDAE
  - *Arabella iricolor*
  - *Drilonereis falcata*
  - *Drilonereis spp.*
- ONUPHIDAE
  - *Diopatra ornata*
  - *Onuphis sp. A*
  - *Onuphis spp.*
- OWENIIDAE
  - *Galathowenia oculata*
  - *Owenia collaris*
- SABELLARIIDAE
  - *Neosabellaria cementarium*
- SABELLIDAE
  - *Chone mollis*
  - *Chone spp.*
  - *Euchone hancocki*
  - *Euchone spp.*
  - *Paradialychone ecaudata*
  - *Paradialychone eiffelturris*
  - *Potamethus sp. A*
- CIRRATULIDAE
  - *Aphelochaeta cf. elongata*
  - *Aphelochaeta monilaris*
  - *Aphelochaeta sp. SF3*
  - *Aphelochaeta petersenae*
  - *Aphelochaeta spp.*
  - *Chaetozone bansei*
  - *Chaetozone columbiana*
  - *Chaetozone spp.*
  - *Tharyx spp.*
- FLABELLIGERIDAE
  - *Pherusa neopapillata*
- AMPHARETIDAE
  - *Ampharete acutifrons*
  - *Ampharete finmarchica*
  - *Ampharete labrops*
  - *Ampharete spp.*
  - *Amphicteis scaphobranchiata*
  - *Amphicteis spp.*
  - *Melinna oculata*
  - *Schistocomus sp. A*
- PECTINARIIDAE
  - *Pectinaria californiensis*
- TEREBELLIDAE
  - *Amaeana occidentalis*
  - *Amaeana spp.*
  - *Polycirrus sp. I*
  - *Polycirrus sp. SF1*
  - *Polycirrus spp.*

Appendix E-1 (cont.)

Traditional classification of benthic infauna collected from 1997 through 2012

Eupolymnia heterobranchia
Eupolymnia spp.
Lanassa venusta
Nicolea sp. SF1
Pista elongata
Pista estevanica
Pista sp. SF1
Pista wui
Pista spp.
Streblosoma sp. SF1
Streblosoma spp.
CHAETOPTERIDAE
Mesochaetopterus taylori
Mesochaetopterus sp. SF1
Mesochaetopterus spp.
Phyllochaetopterus cf. claparedi
Spiochaetopterus costarum
MAGELONIDAE
Magelona berkeleyi
Magelona californica
Magelona hartmanae
Magelona pitelkai
Magelona sacculata
Magelona spp.
POECILOCHAETIDAE
Poecilochaetus johnsoni
TROCHOCHAETIDAE
Trochochaeta franciscanum
SPIONIDAE
Apoprionospio pygmaea
Boccardia pugettensis
Boccardia spp.
Carazziella sp. A
Dipolydora brachycephala
Dipolydora commensalis
Dipolydora socialis
Dipolydora sp. SF1
Dipolydora magna
Dipolydora spp.
Dispio uncinata
Laonice cirrata
Paraprionospio alata
Polydora cornuta
Polydora narica
Polydora spp.
Prionospio lighti
Prionospio steenstrupi
Prionospio spp.
Scolelepis squamata
Spiophanes berkeleyorum
Scolelepis occidentalis
Scolelepis sp. SF1
Scolelepis sp. SF2
Scolelepis sp. SF3
Scolelepis spp.
Spio butleri
Spiophanes duplex
Spiophanes norrisi
Spiophanes spp.
Streblospio benedicti
ARCHIANNELIDA
POLYGORDIIDAE
PROTODRILIDAE
SACCOCIRRIDAE
HIRUDINEA
OLIGOCHAETA
ENCHYTRAEIDAE
TUBIFICIDAE
ARTHROPODA
PYCNOGONIDA
Achelia alaskensis
Pycnogonum stearnsi
CRUSTACEA
CIRRIPEDIA
Balanus spp.
COPEPODA
HARPACTICOIDA
OSTRACODA
Leuroleberis sharpei
Xenolebris californica
Ostracoda sp. SF2
Euphilomedes carcharodonta
Euphilomedes spp.
Eusarsiella zostericola
Podocopida
MYSIDACEA
Acanthomysis spp.
Archaeomysis grebnitzkii
Holmesimysis costata
Holmesimysis macropsis
Holmesimysis sp. A
Holmesimysis spp.
Neomysis kadiakensis
Neomysis spp.
AMPHIPODA
AORIDAE
Aoroides inermis
Aoroides spinosus
Aoroides spp.
Grandidierella japonica

COROPHOIDEA
- *Monocorophium acherusicum*
- *Monocorophium insidiosum*
- *Monocorophium sp.*
- *Sinocorophium heteroceratum*
- *Cheirimedeia zotea*
- *Cheirimedeia spp.*
- *Protomedeia penates*
- *Protomedeia spp.*

CAPRELLIDAE
- *Caprella californica*
- *Caprella equilibra*
- *Caprella mendax*
- *Caprella natalensis*
- *Caprella spp.*
- *Metacaprella anomala*
- *Tritella pilimana*

ISAEIDAE
- *Cheirophotis spp.*

DULICHIIDAE
- *Dyopedos arcticus*

PODOCERIDAE
- *Podocerus spongicolus*

ISCHYROCERIDAE
- *Ericthonius brasiliensis*
- *Ericthonius spp.*
- *Ischyrocerus anguipes*
- *Ischyrocerus pelagops*
- *Ischyrocerus sp. SF2*
- *Jassa marmorata*
- *Jassa spp.*
- *Microjassa barnardi*

PHOTIDAE
- *Gammaropsis sp.*
- *Photis bifurcata*
- *Photis brevipes*
- *Photis californica*
- *Photis conchicola*
- *Photis macinerneyi*
- *Photis parvidons*
- *Photis spp.*

PLEUSTIDAE
- *Gnathopleustes pugettensis*

STENOTHOIDAE
- *Stenothoides bicoma*
- *Stenethoides burbanki*
- *Stenothoe spp.*

OEDICEROTIDAE
- *Americhelidium shoemakeri*
- *Americhelidium sp. SD1*
- *Pacifoculodes barnardi*
- *Americhelidium spp.*
- *Westwoodilla tone*

SYNOPIIDAE
- *Tiron biocellata*

ARGISSIDAE
- *Argissa hamatipes*

LILJEBORGIIDAE
- *Listriella diffusa*
- *Listriella goleta*
- *Listriella spp.*

HAUSTORIIDAE
- *Eohaustorius spp.*

PHOXOCEPHALIDAE
- *Foxiphalus obtusidens*
- *Grandifoxus grandis*
- *Grandifoxus cf. grandis*
- *Rhepoxynius abronius*
- *Rhepoxynius fatigans*
- *Rhepoxynius lucubrans*
- *Rhepoxynius menziesi*
- *Rhepoxynius tridentatus*
- *Rhepoxynius variatus*
- *Rhepoxynius vigitegus*
- *Rhepoxynius spp.*
- *Mandibulophoxus gilesi*
- *Eobrolgus spinosus*
- *Metaphoxus frequens*

DEXAMINIDAE
- *Atylus tridens*

AMPELISCIDAE
- *Ampelisca abdita*
- *Ampelisca agassizi*
- *Ampelisca careyi*
- *Ampelisca cristata*
- *Ampelisca milleri*
- *Ampelisca spp.*

MELITIDAE
- *Desdimelita desdichada*
- *Melita dentata*

MELPHIDIPPIDAE
- *Melphisana sp. SF1*

MELITIDAE
- *Megamoera subtener*

MEGALUROPIDAE
- *Gibberosus myersi*

LYSIANASSIDAE
- *Lysianassidae sp. SF1*
- *Wecomedon spp.*

- PACHYNIDAE
  - *Pachynus barnardi*
- URISTIDAE
  - *Anonyx adoxus*

ISOPODA
- ANTHURIDAE
  - *Haliophasma geminatum*
- PARANTHURIDAE
  - *Paranthura elegans*
- IDOTEIDAE
  - *Edotia sublittoralis*
  - *Edotia spp.*
  - *Synidotea consolidata*
  - *Synidotea laticauda*
  - *Synidotea spp.*
- PARAMUNNIDAE
  - *Munnogonium tillerae*
  - *Munnogonium spp.*
  - *Pleurogonium sp. SF1*
- SPHAEROMATIDAE
  - *Gnorimosphaeroma oregonensis*
  - *Tecticeps convexus*
- ANCINIDAE
  - *Bathycopea daltonae*
- JANIRIDAE
  - *Ianiropsis derjugini*
- MUNNIDAE
  - *Munna spp.*

TANAIDACEA
- PARATANAIDAE
  - *Leptochelia dubia*

CUMACEA
- LEUCONIDAE
  - *Eudorella pacifica*
  - *Leucon spp.*
- NANNASTACIDAE
  - *Campylaspis spp.*
- LAMPROPIDAE
  - *Hemilamprops californicus*
  - *Lamprops carinata*
  - *Lamprops tomalesi*
  - *Lamprops triserratus*
  - *Lamprops spp.*
  - *Mesolamprops dillonensis*
- DIASTYLIDAE
  - *Anchicolurus occidentalis*
  - *Diastylis santamariensis*
  - *Diastylis spp.*
  - *Diastylopsis dawsoni*
  - *Diastylopsis tenuis*
  - *Diastylopsis spp.*

- DECAPODA
  - CARIDEA
    - HIPPOLYTIDAE
      - *Heptacarpus stimpsoni*
      - *Heptacarpus spp.*
      - *Heptacarpus spp.*
    - CRANGONIDAE
      - *Crangon franciscorum*
      - *Crangon nigricauda*
      - *Crangon nigromaculata*
      - *Crangon sp. SF1*
      - *Crangon spp.*
    - LISSOCRANGON
      - *Lissocrangon stylirostris*
  - ANOMURA
    - CALLIANASSIDAE
      - *Neotrypaea spp.*
      - *Anomura*
    - DIOGENIDAE
      - *Isocheles pilosus*
    - PAGURIDAE
      - *Pagurus spp.*
    - PORCELLANIDAE
    - BLEPHARIPODIDAE
      - *Blepharipoda occidentalis*
  - BRACHYURA
    - INACHOIDIDAE
    - PARTHENOPIDAE
      - *Heterocrypta occidentalis*
    - CANCRIDAE
      - *Cancer productus*
      - *Metacarcinus gracilis*
      - *Metacarcinus magister*
      - *Romaleon antennarium*
    - PINNOTHERIDAE
      - *Fabia subquadrata*
      - *Opisthopus transversus*
      - *Scleroplax granulata*
      - *Pinnixa franciscana*
      - *Pinnixa spp.*

NEMATODA

ECHINODERMATA
- ASTEROIDEA
  - *Pisaster brevispinus*
- OPHIUROIDEA
  - *Amphiodia digitata*
  - *Amphiodia spp.*
- ECHINOIDEA
  - *Dendraster excentricus*

Appendix E-1 (cont.)

Traditional classification of benthic infauna collected from 1997 through 2012

HOLOTHUROIDEA
- *Dendrochirotida*
- *Pentamera rigida*
- *Leptosynapta spp.*
- *Holothuroidea sp. SF1*
- *Paracaudina chilensis*

PHORONIDA
- *Phoronis spp.*

BRACHIOPODA
- *Inarticulata*

ECTOPROCTA
- *Filicrisia franciscana*
- *Tricellaria ternata*

HEMICHORDATA
- *Enteropneusta*

UROCHORDATA

ASCIDIACEA
- *Molgula manhattensis*

Appendix E-2

Benthic infauna collected in 2012

STATION 01

Spiophanes norrisi	2230
Photis spp.	291
Scoletoma luti	175
Protomedeia penates	148
Owenia collaris	113
Photis macinerneyi	80
Callianax pycna	66
Onuphis spp.	40
Mediomastus spp.	33
Tellina modesta	31
Pectinaria californiensis	30
Onuphis sp. A	22
Photis parvidons	21
Glycinde picta	19
Bathycopea daltonae	17
Lineidae	17
Euphilomedes carcharodonta	15
Glycera macrobranchia	15
Leukoma staminea	15
Pacifoculodes barnardi	15
Pleurogonium sp. SF1	15
Astyris gausapata	14
Ischyrocerus pelagops	14
Glycinde spp.	14
Diastylis santamariensis	13
Diastylopsis dawsoni	13
Carinoma mutabilis	12
Macoma spp.	10
Pandora bilirata	10
Tritella pilimana	10
Clinocardium nuttallii	9
Kurtiella tumida	9
Crangon nigromaculata	8
Magelona hartmanae	8
Tenonia priops	8
Argissa hamatipes	7
Terebellidae	7
Macoma nasuta	6
Magelona sacculata	6
Amphiodia spp.	5
Cylichna attonsa	5
Synidotea consolidata	5
Ampelisca careyi	4
Amphiodia digitata	4
Paranemertes californica	4
Scoloplos sp. SF1	4
Caesia rhinetes	3
Modiolus capax	3
Nephtys caecoides	3
Spiophanes berkeleyorum	3
Sthenelais verruculosa	3
Edotia sublittoralis	2
Enteropneusta	2
Glossaluax reclusiana	2
Goniada maculata	2
Halcampa decemtentaculata	2
Hemilamprops californicus	2
Kurtziella plumbea	2
Nassariidae	2
Nemertea	2
Podarkeopsis glabrus	2
Siliqua lucida	2
Tubulanidae sp. B	2
Americhelidium shoemakeri	1
Ampelisca cristata	1
Ampharete acutifrons	1
Amphicteis scaphobranchiata	1
Anthozoa	1
Apoprionospio pygmaea	1
Aricidea (Aedicira) sp. A	1
Aricidea (Aricidea) sp. SF3	1
Cardiidae	1
Cheirimedeia zotea	1
Cooperella subdiaphana	1
Dendraster excentricus	1
Dendrochirotida	1
Eteone (Mysta) sp. SF1	1
Eumida longicornuta	1

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Gastropteron pacificum	1
Haliophasma geminatum	1
Leitoscoloplos pugettensis	1
Leptopecten latiauratus	1
Mesochaetopterus sp. SF1	1
Mesolamprops dillonensis	1
Micronephtys cornuta	1
Nematoda	1
Odostomia spp.	1
Ostracoda sp. SF2	1
Paradialychone eiffelturris	1
Pentamera rigida	1
Photis brevipes	1
Phyllodoce williamsi	1
Pinnixa franciscana	1
Polynoidae	1
Sigambra sp. SF2	1
Tecticeps convexus	1
Tresus spp.	1
Typosyllis farallonensis	1
STATION 02	
Spiophanes norrisi	4237
Photis spp.	1099
Photis macinerneyi	412
Scoletoma luti	170
Protomedeia penates	99
Glycinde picta	90
Ischyrocerus pelagops	69
Carinoma mutabilis	59
Tellina modesta	57
Pleurogonium sp. SF1	48
Callianax pycna	34
Tresus spp.	33
Leukoma staminea	29
Astyris gausapata	25
Mediomastus spp.	24
Clinocardium nuttallii	22
Diastylis santamariensis	17
Glycinde spp.	17
Tiron biocellata	17

Amphiodia spp.	14
Owenia collaris	13
Podarkeopsis glabrus	12
Tritella pilimana	11
Onuphis sp. A	10
Pacifoculodes barnardi	9
Kurtiella tumida	8
Onuphis spp.	7
Magelona hartmanae	6
Nephtys caecoides	6
Foxiphalus obtusidens	5
Odostomia spp.	5
Tenonia priops	5
Cylichna spp.	4
Eumida longicornuta	4
Glycera macrobranchia	4
Leitoscoloplos pugettensis	4
Sthenelais verruculosa	4
Euphilomedes carcharodonta	3
Gastropteron pacificum	3
Modiolus capax	3
Bathycopea daltonae	2
Crangon nigromaculata	2
Diastylopsis dawsoni	2
Edotia sublittoralis	2
Kurtziella plumbea	2
Mactromeris catilliformis	2
Micronephtys cornuta	2
Pectinaria californiensis	2
Pherusa neopapillata	2
Phyllodoce williamsi	2
Phylo felix	2
Rhepoxynius fatigans	2
Sipuncula	2
Stylatula spp.	2
Typosyllis farallonensis	2
Amaeana occidentalis	1
Ampharete spp.	1
Anthozoa	1
Armandia brevis	1

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Compsomyax subdiaphana	1
Dendraster excentricus	1
Eteone ?californica	1
Eudorella pacifica	1
Halcampa decemtentaculata	1
Kurtiella coani	1
Leptochelia dubia	1
Macoma spp.	1
Magelona sacculata	1
Maldanidae	1
Monostylifera sp. B	1
Nassariidae	1
Onuphidae	1
Pentamera rigida	1
Photis parvidons	1
Phyllodoce hartmanae	1
Phyllodoce williamsi	1
Prionospio lighti	1
Scolelepis sp. SF1	1
Scolelepis squamata	1
Terebellidae	1

STATION 04

Spiophanes norrisi	2168
Photis spp.	322
Callianax pycna	235
Protomedeia penates	226
Owenia collaris	178
Scoletoma luti	167
Photis macinerneyi	143
Pectinaria californiensis	135
Mediomastus spp.	69
Tellina modesta	69
Glycinde spp.	52
Glycinde picta	33
Apoprionospio pygmaea	28
Lineidae	28
Diastylopsis dawsoni	25
Onuphis spp.	23
Leukoma staminea	22
Nephtys caecoides	20
Macoma nasuta	19
Pleurogonium sp. SF1	18
Onuphis sp. A	17
Pandora bilirata	17
Diastylis santamariensis	16
Magelona sacculata	16
Micronephtys cornuta	16
Photis parvidons	12
Macoma spp.	11
Onuphidae	11
Podarkeopsis glabrus	11
Tritella pilimana	10
Dendrochirotida	9
Euphilomedes carcharodonta	9
Magelona hartmanae	9
Spiophanes berkeleyorum	9
Pacifoculodes barnardi	8
Phylo felix	8
Caesia rhinetes	7
Ischyrocerus pelagops	7
Scoloplos sp. SF1	7
Tenonia priops	7
Bathycopea daltonae	6
Glycera macrobranchia	6
Amphiodia spp.	5
Odostomia spp.	5
Phyllodoce hartmanae	5
Terebellidae	5
Ampelisca careyi	4
Cylichna spp.	4
Eteone sp. SF4	4
Halcampa decemtentaculata	4
Paradialychone eiffelturris	4
Amphiodia digitata	3
Eumida longicornuta	3
Modiolus capax	3
Rhepoxynius fatigans	3
Sthenelais verruculosa	3
Americhelidium shoemakeri	2
Ampelisca cristata	2

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Aphelochaeta petersenae	2
Aricidea (Acmira) catherinae	2
Axinopsida serricata	2
Clinocardium nuttallii	2
Crangon nigromaculata	2
Kurtziella plumbea	2
Macoma acolasta	2
Maldanidae	2
Microphthalmus spp. complex	2
Nemertea	2
Neotrypaea spp.	2
Paranemertes californica	2
Synidotea consolidata	2
Tresus spp.	2
Yoldia cooperii	2
Ampharetidae	1
Anthozoa	1
Argissa hamatipes	1
Astyris gausapata	1
Carinoma mutabilis	1
Dendraster excentricus	1
Diopatra ornata	1
Enteropneusta	1
Eteone fauchaldi	1
Euchone hancocki	1
Euclymeninae sp. SF1	1
Gastropteron pacificum	1
Goniada maculata	1
Heteroclidus punctatus	1
Holothuroidea	1
Kurtiella tumida	1
Lanassa venusta	1
Leitoscoloplos pugettensis	1
Lumbrineridae	1
Pinnixa spp.	1
Polynoidae	1
Spiochaetopterus costarum	1
Tubulanus spp.	1
Turbellaria	1

STATION 06

Spiophanes norrisi	7145
Photis spp.	771
Photis macinerneyi	373
Scoletoma luti	119
Callianax pycna	81
Ischyrocerus pelagops	76
Glycinde picta	64
Protomedeia penates	53
Eumida longicornuta	39
Pleurogonium sp. SF1	31
Carinoma mutabilis	27
Diastylopsis dawsoni	17
Glycinde spp.	17
Photis parvidons	15
Magelona hartmanae	11
Mediomastus spp.	10
Onuphis sp. A	10
Pacifoculodes barnardi	10
Onuphis spp.	9
Amphiodia spp.	8
Magelona sacculata	8
Tritella pilimana	6
Podarkeopsis glabrus	5
Tenonia priops	5
Diastylis santamariensis	4
Euphilomedes carcharodonta	4
Glycera macrobranchia	4
Nephtys caecoides	4
Leitoscoloplos pugettensis	3
Lumbrineris californiensis	3
Phyllodoce hartmanae	3
Phylo felix	3
Rhepoxynius fatigans	3
Tellina modesta	3
Americhelidium shoemakeri	2
Gastropteron pacificum	2
Spiochaetopterus costarum	2
Terebellidae	2
Amphiodia digitata	1

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Apoprionospio pygmaea	1
Argissa hamatipes	1
Aricidea (Aedicira) sp. A	1
Aricidea (Aricidea) sp. SF2	1
Aricidea (Aricidea) sp. SF3	1
Armandia brevis	1
Astyris gausapata	1
Crangon nigromaculata	1
Cylichna spp.	1
Eteone fauchaldi	1
Glycinde sp. SF1	1
Kurtiella tumida	1
Kurtziella plumbea	1
Neotrypaea spp.	1
Nephtys spp.	1
Phyllodoce williamsi	1
Polynoidae	1
Sipuncula	1
Tubulanidae sp. B	1
Tubulanus pellucidus	1

STATION 25

Spiophanes norrisi	3867
Photis spp.	1504
Photis macinerneyi	613
Protomedeia penates	495
Scoletoma luti	147
Owenia collaris	123
Glycinde spp.	93
Tellina modesta	80
Pectinaria californiensis	76
Callianax pycna	56
Ischyrocerus pelagops	49
Pleurogonium sp. SF1	47
Diastylis santamariensis	41
Glycinde picta	36
Onuphis spp.	27
Amphiodia spp.	26
Photis parvidons	26
Astyris gausapata	25
Macoma nasuta	25
Mediomastus spp.	23
Diastylopsis dawsoni	21
Onuphis sp. A	17
Tritella pilimana	15
Glycera macrobranchia	14
Tenonia priops	13
Onuphidae	12
Pacifoculodes barnardi	12
Pandora bilirata	12
Kurtiella tumida	11
Nephtys caecoides	11
Lineidae	10
Magelona hartmanae	10
Bathycopea daltonae	9
Paranemertes californica	8
Euphilomedes carcharodonta	7
Leitoscoloplos pugettensis	7
Nemertea	7
Cylichna spp.	6
Eumida longicornuta	6
Leukoma staminea	6
Clinocardium nuttallii	5
Odostomia spp.	5
Synidotea consolidata	5
Americhelidium shoemakeri	4
Carinoma mutabilis	4
Halcampa decemtentaculata	4
Magelona sacculata	4
Dendraster excentricus	3
Dendrochirotida	3
Gastropteron pacificum	3
Mactridae	3
Micronephtys cornuta	3
Pista wui	3
Rhepoxynius fatigans	3
Amphiodia digitata	2
Cardiidae	2
Edotia sublittoralis	2
Eteone fauchaldi	2
Glycinde sp. SF1	2

Lumbrineridae	2
Mesolamprops dillonensis	2
Paradialychone eiffelturris	2
Podarkeopsis glabrus	2
Polynoidae	2
Sthenelais verruculosa	2
Terebellidae	2
Ampelisca cristata	1
Ampharete acutifrons	1
Anthozoa	1
Apoprionospio pygmaea	1
Argissa hamatipes	1
Bivalvia	1
Chaetozone columbiana	1
Diaphana californica	1
Gastropoda	1
Goniada maculata	1
Mactromeris catilliformis	1
Maldanidae	1
Mesochaetopterus sp. SF1	1
Modiolus capax	1
Neotrypaea spp.	1
Nereididae	1
Paracaudina chilensis	1
Phyllodoce groenlandica	1
Phyllodoce longipes	1
Phylo felix	1
Rhepoxynius lucubrans	1
Sigalion spinosus	1
Solen sicarius	1
Spiochaetopterus costarum	1
Stylatula spp.	1
Tiron biocellata	1
Tresus spp.	1
Tubulanidae sp. B	1
Tubulanus nothus	1
Tubulanus pellucidus	1
Typosyllis farallonensis	1

STATION 28

Spiophanes norrisi	576
Owenia collaris	293
Mediomastus spp.	193
Scoletoma luti	168
Pectinaria californiensis	130
Apoprionospio pygmaea	93
Tellina modesta	77
Magelona sacculata	66
Protomedeia penates	57
Photis spp.	45
Diastylopsis dawsoni	43
Callianax pycna	35
Glycinde spp.	25
Photis macinerneyi	25
Terebellidae	24
Micronephtys cornuta	23
Onuphis sp. A	20
Pacifoculodes barnardi	20
Rhepoxynius lucubrans	20
Glycinde picta	19
Amphiodia spp.	18
Macoma nasuta	18
Magelona hartmanae	16
Diastylis santamariensis	15
Leitoscoloplos pugettensis	15
Paradialychone eiffelturris	15
Prionospio lighti	14
Nephtys caecoides	12
Spiophanes berkeleyorum	12
Dendrochirotida	10
Lumbrineridae	10
Nemertea	10
Onuphidae	10
Rhepoxynius fatigans	10
Kurtiella tumida	9
Leukoma staminea	9
Pleurogonium sp. SF1	9
Cylichna attonsa	8
Modiolus capax	8

Scoloplos spp.	2
Spiophanes norrisi	2
Aricidea (Aricidea) sp. SF3	1
Cardiidae	1
Lineidae	1
Mandibulophoxus gilesi	1
Orbiniidae	1
Paraonidae	1
Phoronis spp.	1
Photis macinerneyi	1
Tecticeps convexus	1
STATION 32	
Rhepoxynius fatigans	147
Mediomastus spp.	118
Magelona sacculata	41
Protomedeia penates	21
Leitoscoloplos pugettensis	19
Tellina modesta	16
Mactromeris catilliformis	13
Pectinaria californiensis	12
Scoletoma luti	12
Spiophanes berkeleyorum	12
Magelona hartmanae	11
Onuphis sp. A	11
Nemertea	10
Kurtiella coani	8
Kurtiella tumida	7
Ampelisca cristata	6
Glycinde picta	6
Amaeana occidentalis	5
Aphelochaeta petersenae	5
Neotrypaea spp.	5
Americhelidium shoemakeri	4
Cylichna attonsa	4
Lineidae	4
Pacifoculodes barnardi	4
Paraprionospio alata	4
Podarkeopsis glabrus	4
Glycera macrobranchia	3
Odostomia spp.	3
Pleurogonium sp. SF1	3
Prionospio lighti	3
Apoprionospio pygmaea	2
Carinoma mutabilis	2
Cirratulidae	2
Enteropneusta	2
Euclymeninae	2
Glycinde spp.	2
Listriella goleta	2
Macoma nasuta	2
Nephtys caecoides	2
Paraonidae	2
Rhepoxynius lucubrans	2
Spiophanes norrisi	2
Ampharete acutifrons	1
Amphiodia spp.	1
Callianax pycna	1
Chone mollis	1
Corophoidea	1
Diastylopsis dawsoni	1
Glossaluax reclusiana	1
Hesperonoe laevis	1
Maldanidae	1
Malmgreniella spp.	1
Onuphidae	1
Phoronis spp.	1
Phyllodoce hartmanae	1
Phylo felix	1
Polynoidae	1
Scoloplos sp. SF1	1
Spiophanes spp.	1
Terebellidae	1
Tubulanus pellucidus	1
Turbonilla spp.	1
STATION 33	
Spiophanes norrisi	807
Mediomastus spp.	146
Protomedeia penates	140
Rhepoxynius fatigans	88
Stylatula spp.	76

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Scoletoma luti	53
Photis spp.	37
Mactromeris catilliformis	33
Pennatulacea	31
Pleurogonium sp. SF1	25
Tellina modesta	25
Glycinde spp.	18
Onuphis sp. A	17
Diastylopsis dawsoni	16
Leukoma staminea	15
Pectinaria californiensis	15
Onuphis spp.	14
Glycinde picta	13
Photis macinerneyi	13
Aphelochaeta petersenae	11
Clinocardium nuttallii	11
Phoronis spp.	11
Nephtys caecoides	10
Enteropneusta	9
Diastylis santamariensis	8
Bathycopea daltonae	7
Lineidae	7
Amphiodia spp.	6
Magelona sacculata	6
Amaeana occidentalis	5
Callianax pycna	5
Odostomia spp.	5
Scoloplos sp. SF1	5
Ampelisca cristata	4
Ampharete acutifrons	4
Maldanidae	4
Pandora bilirata	4
Compsomyax subdiaphana	3
Dendraster excentricus	3
Goniada maculata	3
Lanassa venusta	3
Leitoscoloplos pugettensis	3
Macoma spp.	3
Solen sicarius	3
Tenonia priops	3
Americhelidium shoemakeri	2
Apoprionospio pygmaea	2
Cardiidae	2
Cylichna attonsa	2
Dendrochirotida	2
Euchone hancocki	2
Ischyrocerus pelagops	2
Macoma nasuta	2
Mediomastus acutus	2
Mesochaetopterus sp. SF1	2
Nemertea	2
Neotrypaea spp.	2
Photis parvidons	2
Podarkeopsis glabrus	2
Sabellidae	2
Tubulanus pellucidus	2
Ampharete labrops	1
Autolytinae	1
Carinoma mutabilis	1
Cheirimedeia zotea	1
Euclymeninae sp. SF1	1
Eumida longicornuta	1
Glossaluax reclusiana	1
Glycera macrobranchia	1
Heteromastus spp.	1
Kurtziella plumbea	1
Lumbrineridae	1
Lumbrineris californiensis	1
Macoma acolasta	1
Magelona hartmanae	1
Malmgreniella liei	1
Malmgreniella spp.	1
Mesolamprops dillonensis	1
Metacarcinus gracilis	1
Micronephtys cornuta	1
Nassariidae	1
Onuphidae	1
Paradialychone eiffelturris	1
Polycirrus sp. I	1
Polynoidae	1

Sthenelais verruculosa	1
Synidotea consolidata	1
Terebellidae	1
Yoldia cooperii	1
STATION 34	
Mediomastus spp.	307
Protomedeia penates	148
Stylatula spp.	78
Macoma nasuta	52
Carazziella sp. A	50
Kurtiella tumida	49
Amaeana occidentalis	43
Scoletoma luti	38
Rhepoxynius lucubrans	33
Aphelochaeta petersenae	26
Rhepoxynius fatigans	24
Spiophanes berkeleyorum	23
Amphiodia spp.	22
Tellina modesta	22
Leitoscoloplos pugettensis	19
Polynoidae	19
Glycinde spp.	17
Nematoda	16
Pectinaria californiensis	16
Amphicteis scaphobranchiata	13
Corophiidae	13
Dendrochirotida	13
Diastylopsis dawsoni	12
Micronephtys cornuta	11
Pleurogonium sp. SF1	10
Magelona hartmanae	9
Nemertea	9
Euclymeninae sp. SF1	8
Onuphis sp. A	8
Ampharete acutifrons	6
Glycinde picta	6
Tenonia priops	6
Cylichna attonsa	5
Pacifoculodes barnardi	5
Photis spp.	5
Phylo felix	5
Streblosoma sp. SF1	5
Terebellidae	5
Ampelisca cristata	4
Astyris gausapata	4
Leukoma staminea	4
Pandora bilirata	4
Paraprionospio alata	4
Pholoe glabra	4
Pista wui	4
Podarkeopsis glabrus	4
Saccella spp.	4
Callianax pycna	3
Clinocardium nuttallii	3
Dipolydora spp.	3
Lepidasthenia berkeleyae	3
Lumbrineris californiensis	3
Odostomia spp.	3
Prionospio lighti	3
Sigambra sp. SF2	3
Ampelisca careyi	2
Ampharete spp.	2
Apoprionospio pygmaea	2
Axiothella rubrocincta	2
Crangon nigromaculata	2
Eteone ?californica	2
Kurtiella coani	2
Malmgreniella spp.	2
Modiolus capax	2
Nereis neoneanthes	2
Paradialychone eiffelturris	2
Paraonidae	2
Philine auriformis	2
Pinnixa franciscana	2
Scoloplos sp. SF1	2
Solen sicarius	2
Sthenelais verruculosa	2
Tubulanus nothus	2
Aricidea (Aricidea) sp. SF3	1
Axinopsida serricata	1

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Cooperella subdiaphana	1
Edwardsia juliae	1
Enteropneusta	1
Gastropoda	1
Glossaluax reclusiana	1
Haliophasma geminatum	1
Ischyrocerus pelagops	1
Kurtzina beta	1
Lineidae	1
Mactromeris catilliformis	1
Neotrypaea spp.	1
Nephtys caecoides	1
Onuphidae	1
Onuphis spp.	1
Pachynus barnardi	1
Petaloclymene pacifica	1
Pherusa neopapillata	1
Poecilochaetus johnsoni	1
Turbonilla spp.	1
Yoldia cooperii	1
STATION 35	
Diastylopsis dawsoni	290
Mediomastus spp.	165
Owenia collaris	67
Ampelisca cristata	60
Protomedeia penates	49
Pectinaria californiensis	33
Spiophanes berkeleyorum	33
Amphiodia spp.	32
Callianax pycna	24
Tellina modesta	21
Sigambra sp. SF2	20
Diastylis santamariensis	17
Stylatula spp.	17
Aphelochaeta petersenae	14
Pleurogonium sp. SF1	14
Glycinde spp.	13
Photis spp.	13
Astyris gausapata	12
Glycinde picta	10
Paraprionospio alata	9
Kurtiella tumida	8
Magelona hartmanae	8
Modiolus rectus	7
Ischyrocerus pelagops	6
Leitoscoloplos pugettensis	6
Macoma nasuta	6
Nematoda	6
Dendrochirotida	5
Micronephtys cornuta	5
Nemertea	5
Nutricola confusa	5
Onuphis spp.	5
Cheirimedeia zotea	4
Dipolydora magna	4
Magelona sacculata	4
Onuphis sp. A	4
Photis macinerneyi	4
Amphicteis scaphobranchiata	3
Apoprionospio pygmaea	3
Axinopsida serricata	3
Munnogonium tillerae	3
Onuphidae	3
Americhelidium shoemakeri	2
Ampharete acutifrons	2
Aricidea (Acmira) catherinae	2
Bivalvia	2
Clinocardium nuttallii	2
Cylichna spp.	2
Euclymeninae sp. SF1	2
Lineidae	2
Maldanidae	2
Neotrypaea spp.	2
Nephtys caecoides	2
Odostomia spp.	2
Ostracoda	2
Pholoe glabra	2
Prionospio lighti	2
Scoletoma luti	2
Scoloplos sp. SF1	2

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Siliqua lucida	2
Ampharete labrops	1
Caesia rhinetes	1
Carinoma sp.	1
Cylichna attonsa	1
Echiura	1
Enteropneusta	1
Glossaluax reclusiana	1
Listriella diffusa	1
Lumbrineridae	1
Mactromeris catilliformis	1
Magelona berkeleyi	1
Mesolamprops dillonensis	1
Modiolus spp.	1
Monocorophium acherusicum	1
Pachynus barnardi	1
Paranemertes californica	1
Phoronis spp.	1
Rhepoxynius fatigans	1
Saccella taphria	1
Sthenelais verruculosa	1
Tenonia priops	1
Terebellidae	1
STATION 36	
Spiophanes norrisi	567
Protomedeia penates	172
Scoletoma luti	143
Tellina modesta	78
Mactromeris catilliformis	63
Pectinaria californiensis	42
Mediomastus spp.	38
Glycinde spp.	28
Onuphis sp. A	27
Rhepoxynius fatigans	21
Glycinde picta	16
Owenia collaris	14
Diastylopsis dawsoni	12
Magelona sacculata	12
Enteropneusta	11
Nephtys caecoides	11
Pleurogonium sp. SF1	11
Callianax pycna	10
Photis spp.	9
Apoprionospio pygmaea	8
Aphelochaeta petersenae	7
Leitoscoloplos pugettensis	7
Stylatula spp.	6
Dendrochirotida	5
Leukoma staminea	5
Macoma nasuta	5
Malmgreniella spp.	5
Kurtiella tumida	4
Nemertea	4
Bathycopea daltonae	3
Cardiidae	3
Dendraster excentricus	3
Onuphidae	3
Photis macinerneyi	3
Amaeana occidentalis	2
Ampharete acutifrons	2
Carinoma mutabilis	2
Cheirimedeia zotea	2
Isaeidae	2
Magelona hartmanae	2
Modiolus capax	2
Odostomia spp.	2
Pacifoculodes barnardi	2
Scoloplos sp. SF1	2
Streblosoma spp.	2
Synidotea consolidata	2
Ampharetidae	1
Amphiodia digitata	1
Amphiodia spp.	1
Aricidea (Aedicira) pacifica	1
Axinopsida serricata	1
Bivalvia	1
Cheirophotis spp.	1
Diastylis santamariensis	1
Eteone ?californica	1
Glossaluax reclusiana	1

Hemilamprops californicus	1
Ischyrocerus pelagops	1
Kurtziella plumbea	1
Lanassa venusta	1
Lepidasthenia berkeleyae	1
Macoma acolasta	1
Magelona berkeleyi	1
Micronephtys cornuta	1
Mysidacea	1
Pandora bilirata	1
Paradialychone eiffelturris	1
Photis brevipes	1
Photis parvidons	1
Phyllodoce spp.	1
Polynoidae	1
Prionospio lighti	1
Rictaxis punctocaelatus	1
Sabellidae	1
Streblosoma sp. SF1	1
Tenonia priops	1
Terebellidae	1
Tubulanus pellucidus	1
STATION 37	
Spiophanes norrisi	488
Protomedeia penates	98
Mediomastus spp.	74
Callianax pycna	53
Scoletoma luti	53
Tellina modesta	25
Carinoma mutabilis	17
Glycinde picta	13
Glycinde spp.	12
Owenia collaris	12
Axiothella rubrocincta	11
Leitoscoloplos pugettensis	10
Magelona sacculata	7
Pectinaria californiensis	7
Photis spp.	7
Bathycopea daltonae	6
Enteropneusta	6
Kurtiella tumida	6
Amphiodia digitata	5
Nephtys caecoides	5
Stylatula spp.	5
Americhelidium shoemakeri	4
Aphelochaeta petersenae	4
Apoprionospio pygmaea	4
Cylichna attonsa	4
Diastylopsis dawsoni	4
Mactromeris catilliformis	4
Onuphis sp. A	4
Tenonia priops	4
Cerebratulus californiensis	3
Cylichna spp.	3
Dendraster excentricus	3
Kurtiella coani	3
Pleurogonium sp. SF1	3
Glycera macrobranchia	2
Harmothoe spp.	2
Magelona hartmanae	2
Onuphis spp.	2
Pacifoculodes barnardi	2
Phylo felix	2
Amaeana occidentalis	1
Ampharete acutifrons	1
Ampharetidae	1
Aricidea spp.	1
Bivalvia	1
Caesia rhinetes	1
Cirratulidae	1
Clinocardium nuttallii	1
Corophoidea	1
Eteone fauchaldi	1
Euphilomedes carcharodonta	1
Kurtzina beta	1
Lineidae	1
Macoma nasuta	1
Modiolus capax	1
Modiolus rectus	1
Neotrypaea spp.	1

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Odostomia spp.	1
Onuphidae	1
Paraonella platybranchiata	1
Phoronis spp.	1
Photis macinerneyi	1
Podarkeopsis glabrus	1
Sinocorophium heteroceratum	1
Spiophanes berkeleyorum	1
Synidotea consolidata	1
Terebellidae	1

STATION 38

Spiophanes norrisi	191
Protomedeia penates	132
Diastylopsis dawsoni	87
Scoletoma luti	58
Mediomastus spp.	53
Callianax pycna	42
Tellina modesta	35
Glycinde spp.	28
Photis spp.	28
Rhepoxynius fatigans	26
Stylatula spp.	19
Onuphis sp. A	18
Amphiodia spp.	17
Onuphis spp.	17
Astyris gausapata	13
Dendrochirotida	13
Aphelochaeta petersenae	11
Scoloplos sp. SF1	10
Ampelisca careyi	8
Apoprionospio pygmaea	8
Pleurogonium sp. SF1	8
Ampelisca cristata	7
Pectinaria californiensis	7
Pennatulacea	7
Terebellidae	7
Clinocardium nuttallii	6
Lanassa venusta	6
Nephtys caecoides	6
Amphicteis scaphobranchiata	5
Carinoma mutabilis	5
Lineidae	5
Micronephtys cornuta	5
Odostomia spp.	5
Cylichna spp.	4
Glycinde picta	4
Pista wui	4
Cheirimedeia zotea	3
Halcampa decemtentaculata	3
Kurtiella tumida	3
Leitoscoloplos pugettensis	3
Maldanidae	3
Pandora bilirata	3
Photis brevipes	3
Photis parvidons	3
Phyllodoce hartmanae	3
Pista spp.	3
Spiophanes spp.	3
Sthenelais verruculosa	3
Tenonia priops	3
Tubulanus pellucidus	3
Amaeana occidentalis	2
Americhelidium shoemakeri	2
Axinopsida serricata	2
Diaphana californica	2
Diastylis santamariensis	2
Edwardsia juliae	2
Enteropneusta	2
Ischyrocerus pelagops	2
Kurtziella plumbea	2
Leukoma staminea	2
Magelona hartmanae	2
Magelona spp.	2
Onuphidae	2
Onuphis spp.	2
Owenia collaris	2
Paraprionospio alata	2
Polynoidae	2
Rictaxis punctocaelatus	2
Spiophanes berkeleyorum	2

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Ampharetidae	1
Aricidea (Aricidea) sp. SF3	1
Caesia rhinetes	1
Chaetozone columbiana	1
Cylichna attonsa	1
Gastropteron pacificum	1
Gnathopleustes pugettensis	1
Goniada maculata	1
Macoma acolasta	1
Mactromeris catilliformis	1
Mangeliidae	1
Nassarius spp.	1
Neotrypaea spp.	1
Phyllodoce longipes	1
Phylo felix	1
Tritella pilimana	1
STATION 39	
Mediomastus spp.	133
Scoletoma luti	82
Diastylopsis dawsoni	63
Spiophanes norrisi	48
Glycinde spp.	46
Tellina modesta	45
Pista wui	39
Protomedeia penates	36
Callianax pycna	32
Rhepoxynius fatigans	28
Astyris gausapata	24
Dendrochirotida	16
Lanassa venusta	16
Amphiodia spp.	15
Magelona sacculata	12
Clinocardium nuttallii	10
Magelona hartmanae	10
Enteropneusta	9
Micronephtys cornuta	9
Pectinaria californiensis	9
Stylatula spp.	9
Chaetozone columbiana	8
Ampelisca cristata	7
Aphelochaeta sp. SF3	7
Glycinde picta	7
Maldanidae	7
Nephtys caecoides	7
Odostomia spp.	7
Onuphis sp. A	7
Onuphis spp.	7
Ampelisca careyi	5
Apoprionospio pygmaea	5
Hemilamprops californicus	5
Leukoma staminea	5
Photis spp.	5
Tenonia priops	5
Cylichna spp.	4
Goniada maculata	4
Kurtiella tumida	4
Macoma nasuta	4
Phylo felix	4
Amphicteis scaphobranchiata	3
Euphilomedes carcharodonta	3
Glycera macrobranchia	3
Lineidae	3
Solen sicarius	3
Aricidea (Aricidea) sp. SF3	2
Carinoma mutabilis	2
Cheirimedeia zotea	2
Dyopedos arcticus	2
Gastropteron pacificum	2
Halcampa decemtentaculata	2
Inarticulata	2
Leitoscoloplos pugettensis	2
Modiolus capax	2
Nematoda	2
Nemertea	2
Neotrypaea spp.	2
Pleurogonium sp. SF1	2
Polynoidae	2
Prionospio lighti	2
Scoloplos sp. SF1	2
Terebellidae	2

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Ampharete acutifrons	1
Ampharete spp.	1
Autolytinae	1
Axiothella rubrocincta	1
Compsomyax subdiaphana	1
Cylichna attonsa	1
Dendraster excentricus	1
Diaphana californica	1
Diastylis santamariensis	1
Diastylis spp.	1
Edwardsia juliae	1
Eteone ?californica	1
Euchone hancocki	1
Flabelligeridae	1
Kurtziella plumbea	1
Lepidasthenia berkeleyae	1
Lumbrineridae	1
Magelona berkeleyi	1
Magelona spp.	1
Nassariidae	1
Pacifoculodes barnardi	1
Pandora bilirata	1
Paraprionospio alata	1
Philine auriformis	1
Photis brevipes	1
Scolelepis spp.	1
Spiochaetopterus costarum	1
Spiophanes spp.	1
Sthenelais verruculosa	1
Yoldia cooperii	1
STATION 40	
Spiophanes norrisi	681
Callianax pycna	194
Scoletoma luti	76
Photis macinerneyi	39
Photis spp.	39
Glycinde picta	32
Amaeana occidentalis	31
Tellina modesta	30
Glycinde spp.	26
Mediomastus spp.	26
Malmgreniella spp.	16
Diastylopsis dawsoni	15
Nemertea	13
Leitoscoloplos pugettensis	11
Kurtiella coani	10
Carinoma mutabilis	9
Modiolus rectus	8
Onuphis sp. A	8
Bathycopea daltonae	7
Protomedeia penates	7
Glycera macrobranchia	5
Magelona sacculata	5
Neotrypaea spp.	5
Edotia sublittoralis	3
Owenia collaris	3
Rhepoxynius vigitegus	3
Americhelidium shoemakeri	2
Cerebratulus californiensis	2
Kurtiella tumida	2
Macoma nasuta	2
Pacifoculodes barnardi	2
Pectinaria californiensis	2
Amphiodia spp.	1
Anthozoa	1
Aphelochaeta petersenae	1
Aphelochaeta spp.	1
Aricidea (Aedicira) pacifica	1
Dyopedos arcticus	1
Eobrolgus spinosus	1
Eteone ?californica	1
Eteone sp. SF3	1
Ischyrocerus pelagops	1
Isocheles pilosus	1
Mesochaetopterus spp.	1
Microphthalmus spp. complex	1
Nematoda	1
Nephtys caecoides	1
Nereis neoneanthes	1
Paracaudina chilensis	1

Paranemertes californica	1
Paraonella platybranchiata	1
Podarkeopsis glabrus	1
Polycirrus sp. I	1
Stylatula spp.	1
Tiron biocellata	1
Tubulanus pellucidus	1

STATION 43

Mandibulophoxus gilesi	133
Eohaustorius spp.	38
Americhelidium sp. SD1	9
Kurtiella tumida	9
Rhepoxynius menziesi	8
Rhepoxynius vigitegus	5
Callianax pycna	4
Carinoma mutabilis	2
Caesia rhinetes	1
Foxiphalus obtusidens	1
Magelona spp.	1
Nephtys caecoides	1
Odostomia spp.	1
Pacifoculodes barnardi	1
Scolelepis squamata	1
Syllidae	1
Tellina nuculoides	1

STATION 45

Callianax pycna	1253
Diastylopsis dawsoni	44
Carinoma mutabilis	40
Pacifoculodes barnardi	17
Spiophanes norrisi	8
Chaetozone bansei	4
Mesolamprops dillonensis	4
Protomedeia penates	4
Scoloplos armiger	4
Photis spp.	3
Amaeana occidentalis	2
Glycinde spp.	2
Mediomastus spp.	2
Tellina nuculoides	2
Apoprionospio pygmaea	1
Bathycopea daltonae	1
Dendraster excentricus	1
Diastylis santamariensis	1
Enteropneusta	1
Kurtiella tumida	1
Magelona sacculata	1
Malmgreniella spp.	1
Mandibulophoxus gilesi	1
Nematoda	1
Neotrypaea spp.	1
Nephtys caecoides	1
Onuphis sp. A	1
Pectinaria californiensis	1
Phoxocephalidae	1
Rhepoxynius fatigans	1
Scoletoma luti	1
Sinocorophium heteroceratum	1
Tellina modesta	1

STATION 47

Callianax pycna	584
Carinoma mutabilis	25
Diastylopsis dawsoni	25
Pacifoculodes barnardi	16
Mediomastus spp.	12
Rhepoxynius lucubrans	12
Scoloplos armiger	12
Eohaustorius spp.	10
Phylo felix	7
Tellina modesta	5
Chaetozone columbiana	4
Tecticeps convexus	4
Amaeana occidentalis	3
Kurtiella sp. SF1	3
Rhepoxynius vigitegus	3
Scoletoma luti	3
Spiophanes norrisi	3
Capitella capitata complex	2
Kurtiella coani	2
Magelona sacculata	2

Onuphis sp. A	2
Photis spp.	2
Caesia fossatus	1
Caesia rhinetes	1
Dendraster excentricus	1
Diastylis santamariensis	1
Nephtys caecoides	1
Nereis neoneanthes	1
Pagurus spp.	1
Polynoidae	1

STATION 48

Spiophanes norrisi	957
Photis spp.	176
Diastylopsis dawsoni	99
Callianax pycna	88
Photis macinerneyi	85
Protomedeia penates	28
Glycinde spp.	26
Pectinaria californiensis	22
Glycinde picta	19
Ischyrocerus pelagops	11
Carinoma mutabilis	10
Mediomastus spp.	7
Scoletoma luti	7
Nemertea	6
Edotia sublittoralis	4
Isaeidae	4
Pacifoculodes barnardi	4
Amphiodia spp.	3
Pleurogonium sp. SF1	3
Tellina nuculoides	3
Apoprionospio pygmaea	2
Caesia rhinetes	2
Dendraster excentricus	2
Hydrozoa	2
Kurtiella coani	2
Mesochaetopterus sp. SF1	2
Synidotea consolidata	2
Tellina modesta	2
Amaeana occidentalis	1
Americhelidium shoemakeri	1
Ampelisca careyi	1
Cerebratulus spp.	1
Chaetozone bansei	1
Cooperella subdiaphana	1
Enteropneusta	1
Glycera macrobranchia	1
Kurtziella plumbea	1
Lineidae	1
Mesolamprops dillonensis	1
Mysidacea	1
Neotrypaea spp.	1
Photis brevipes	1
Tenonia priops	1
Travisia gigas	1
Tritella pilimana	1

STATION 50

Spiophanes norrisi	585
Protomedeia penates	241
Diastylopsis dawsoni	143
Rhepoxynius fatigans	107
Callianax pycna	68
Glycinde spp.	66
Nematoda	64
Tellina modesta	58
Scoletoma luti	54
Photis spp.	49
Mediomastus spp.	48
Rhepoxynius abronius	36
Onuphis sp. A	34
Stylatula spp.	21
Euphilomedes carcharodonta	16
Nephtys caecoides	16
Dendrochirotida	14
Magelona hartmanae	14
Kurtiella tumida	13
Macoma nasuta	13
Glycinde picta	12
Micronephtys cornuta	10
Ampelisca careyi	9

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Pectinaria californiensis	9
Photis macinerneyi	8
Amphiodia spp.	7
Apoprionospio pygmaea	7
Leukoma staminea	7
Nemertea	7
Cylichna spp.	6
Leitoscoloplos pugettensis	6
Magelona sacculata	6
Podarkeopsis glabrus	6
Tresus spp.	6
Carinoma mutabilis	5
Enteropneusta	5
Aricidea (Aricidea) sp. SF2	4
Astyris gausapata	4
Kurtziella plumbea	4
Lineidae	4
Photis brevipes	4
Phyllodoce hartmanae	4
Prionospio lighti	4
Anthozoa	3
Lumbrineridae	3
Paraonidae	3
Phyllodoce longipes	3
Pista wui	3
Rhepoxynius spp.	3
Spiophanes berkeleyorum	3
Amaeana occidentalis	2
Aphelochaeta petersenae	2
Aricidea spp.	2
Bathycopea daltonae	2
Cheirimedeia zotea	2
Diastylis santamariensis	2
Diastylopsis spp.	2
Goniada maculata	2
Lanassa venusta	2
Mesolamprops dillonensis	2
Micrura spp. (?)	2
Neotrypaea spp.	2
Phyllodocidae	2
Pleurogonium sp. SF1	2
Tenonia priops	2
Ampelisca cristata	1
Argissa hamatipes	1
Aricidea (Acmira) horikoshii	1
Aricidea (Aedicira) pacifica	1
Aricidea (Aricidea) sp. SF3	1
Axinopsida serricata	1
Caesia rhinetes	1
Cardiidae	1
Cylichna attonsa	1
Dendraster excentricus	1
Eohaustorius spp.	1
Euchone hancocki	1
Gadila aberrans	1
Glycera macrobranchia	1
Holothuroidea	1
Kurtiella coani	1
Lepidasthenia longicirrata	1
Lumbrineris californiensis	1
Macoma acolasta	1
Malmgreniella spp.	1
Mandibulophoxus gilesi	1
Mangeliidae	1
Mediomastus acutus	1
Odostomia spp.	1
Owenia collaris	1
Pacifoculodes barnardi	1
Pandora bilirata	1
Paranemertes californica	1
Pinnixa franciscana	1
Scolelepis sp. SF2	1
Scolelepis spp.	1
Scoloplos sp. SF1	1
Spiochaetopterus costarum	1
Sthenelais verruculosa	1
Streblosoma sp. SF1	1
Terebellidae	1
Tubulanidae sp. B	1
Turbonilla spp.	1
Yoldia cooperii	1

Appendix E-2 (cont.)

Benthic infauna collected in 2012

STATION 51

Callianax pycna	772
Spiophanes norrisi	29
Pacifoculodes barnardi	25
Mandibulophoxus gilesi	17
Diastylopsis dawsoni	14
Rhepoxynius menziesi	8
Eohaustorius spp.	6
Glycera macrobranchia	4
Photis macinerneyi	4
Nemertea	3
Onuphis sp. A	3
Photis spp.	3
Americhelidium shoemakeri	2
Kurtiella tumida	2
Rhepoxynius vigitegus	2
Scoloplos armiger	2
Tellina modesta	2
Caesia rhinetes	1
Carinoma mutabilis	1
Clinocardium nuttallii	1
Foxiphalus obtusidens	1
Leitoscoloplos pugettensis	1
Nephtys caecoides	1
Nephtys spp.	1
Phoronis spp.	1
Protomedeia penates	1
Scoletoma luti	1

STATION 52

Spiophanes norrisi	111
Callianax pycna	68
Chaetozone bansei	12
Carinoma mutabilis	11
Glycera tenuis	9
Pacifoculodes barnardi	9
Nephtys caecoides	8
Diastylopsis dawsoni	4
Eohaustorius spp.	4
Tellina modesta	3
Heteropodarke heteromorpha	2
Lineidae	2
Rhepoxynius menziesi	2
Scoloplos armiger	2
Americhelidium shoemakeri	1
Apoprionospio pygmaea	1
Caesia rhinetes	1
Eumida longicornuta	1
Leitoscoloplos pugettensis	1
Onuphis sp. A	1
Photis macinerneyi	1
Rhepoxynius lucubrans	1
Rhepoxynius spp.	1
Rhepoxynius vigitegus	1
Scoletoma luti	1
Sigalion spinosus	1
Spiophanes spp.	1

STATION 53

Spiophanes norrisi	1672
Protomedeia penates	273
Photis spp.	73
Onuphis sp. A	65
Rhepoxynius lucubrans	55
Glycinde spp.	46
Scoletoma luti	37
Amphiodia spp.	31
Onuphis spp.	31
Euphilomedes carcharodonta	29
Callianax pycna	28
Dendrochirotida	27
Tellina modesta	27
Glycinde picta	26
Nephtys caecoides	25
Mesolamprops dillonensis	22
Photis macinerneyi	19
Rhepoxynius fatigans	18
Mediomastus spp.	17
Pista wui	16
Diastylopsis dawsoni	15
Lanassa venusta	15
Diastylis santamariensis	12

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Carinoma mutabilis	9
Photis parvidons	9
Enteropneusta	8
Halcampa decemtentaculata	8
Ampelisca cristata	7
Kurtziella plumbea	7
Pandora bilirata	7
Ampelisca careyi	6
Apoprionospio pygmaea	6
Astyris gausapata	6
Micronephtys cornuta	6
Bathycopea daltonae	5
Magelona hartmanae	5
Odostomia spp.	5
Cylichna spp.	4
Nematoda	4
Neotrypaea spp.	4
Pectinaria californiensis	4
Aphelochaeta petersenae	3
Cheirimedeia zotea	3
Cylichna attonsa	3
Leukoma staminea	3
Lineidae	3
Mactromeris catilliformis	3
Magelona sacculata	3
Pacifoculodes barnardi	3
Pleurogonium sp. SF1	3
Stylatula spp.	3
Tenonia priops	3
Terebellidae	3
Amphicteis scaphobranchiata	2
Amphiodia digitata	2
Anthozoa	2
Argissa hamatipes	2
Crangon nigromaculata	2
Gastropteron pacificum	2
Leitoscoloplos pugettensis	2
Macoma nasuta	2
Paraonidae	2
Phyllodoce hartmanae	2
Phyllodoce spp.	2
Phylo felix	2
Saccella spp.	2
Scolelepis sp. SF2	2
Scoloplos sp. SF1	2
Ampharete acutifrons	1
Caesia rhinetes	1
Cardiidae	1
Euchone hancocki	1
Ischyrocerus pelagops	1
Kurtiella tumida	1
Macoma acolasta	1
Modiolus capax	1
Nassariidae	1
Nemertea	1
Nereis neoneanthes	1
Owenia collaris	1
Paranemertes californica	1
Paraprionospio alata	1
Phyllodoce longipes	1
Polynoidae	1
Sigalion spinosus	1
Solen sicarius	1
Spiophanes spp.	1
Sthenelais verruculosa	1
Xenolebris californica	1
STATION 54	
Spiophanes norrisi	381
Photis spp.	100
Photis macinerneyi	98
Ischyrocerus pelagops	54
Carinoma mutabilis	45
Diastylopsis dawsoni	34
Pacifoculodes barnardi	27
Scoletoma luti	26
Glycinde picta	13
Callianax pycna	8
Tellina modesta	5
Glycinde spp.	4
Rhepoxynius spp.	4

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Onuphis sp. A	3
Eobrolgus spinosus	2
Glycera macrobranchia	2
Nematoda	2
Pleurogonium sp. SF1	2
Rhepoxynius abronius	2
Rhepoxynius lucubrans	2
Tecticeps convexus	2
Americhelidium shoemakeri	1
Amphipoda	1
Armandia brevis	1
Cylichna spp.	1
Eohaustorius spp.	1
Eusyllis transecta	1
Isaeidae	1
Leitoscoloplos pugettensis	1
Nemertea	1
Nephtys caecoides	1
Tenonia priops	1
Tresus spp.	1
STATION 56	
Spiophanes norrisi	6150
Protomedeia penates	290
Owenia collaris	249
Photis spp.	199
Scoletoma luti	90
Glycinde picta	85
Callianax pycna	72
Photis macinerneyi	64
Onuphis spp.	60
Glycinde spp.	59
Mediomastus spp.	48
Tellina modesta	42
Diastylopsis dawsoni	41
Pectinaria californiensis	35
Micronephtys cornuta	33
Nephtys caecoides	27
Pandora bilirata	21
Magelona hartmanae	20
Amphiodia spp.	19
Lineidae	19
Euphilomedes carcharodonta	17
Onuphis sp. A	17
Pleurogonium sp. SF1	17
Rhepoxynius fatigans	15
Diastylis santamariensis	14
Pacifoculodes barnardi	12
Odostomia spp.	11
Spiophanes spp.	11
Tenonia priops	11
Eumida longicornuta	9
Macoma nasuta	8
Paradialychone eiffelturris	8
Apoprionospio pygmaea	6
Ischyrocerus pelagops	6
Scoloplos sp. SF1	6
Magelona sacculata	5
Argissa hamatipes	4
Cylichna attonsa	4
Sthenelais verruculosa	4
Terebellidae	4
Ampelisca careyi	3
Aricidea (Acmira) catherinae	3
Bathycopea daltonae	3
Caesia rhinetes	3
Kurtiella tumida	3
Kurtziella plumbea	3
Leukoma staminea	3
Macoma spp.	3
Phyllodoce hartmanae	3
Podarkeopsis glabrus	3
Spiochaetopterus costarum	3
Stylatula spp.	3
Tresus spp.	3
Americhelidium shoemakeri	2
Ampharete acutifrons	2
Cheirimedeia zotea	2
Cooperella subdiaphana	2
Crangon nigromaculata	2
Goniada maculata	2

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Maldanidae	2
Mesolamprops dillonensis	2
Neotrypaea spp.	2
Nereis neoneanthes	2
Ophiodermella spp.	2
Photis parvidons	2
Spiophanes berkeleyorum	2
Synidotea consolidata	2
Tritella pilimana	2
Tubulanidae sp. B	2
Ampelisca milleri	1
Amphipoda	1
Aphelochaeta petersenae	1
Axinopsida serricata	1
Bivalvia	1
Edwardsia juliae	1
Enteropneusta	1
Eteone fauchaldi	1
Euclymeninae sp. SF1	1
Gastropteron pacificum	1
Glycera macrobranchia	1
Halcampa decemtentaculata	1
Inarticulata	1
Leitoscoloplos pugettensis	1
Lumbrineridae	1
Magelona berkeleyi	1
Magelona spp.	1
Microphthalmus spp. complex	1
Nemertea	1
Onuphidae	1
Paraprionospio alata	1
Pista spp.	1
Pista wui	1
Siliqua lucida	1
Yoldia cooperii	1
STATION 58	
Owenia collaris	301
Spiophanes norrisi	174
Scoletoma luti	153
Mediomastus spp.	151
Tellina modesta	147
Pectinaria californiensis	135
Magelona sacculata	77
Callianax pycna	67
Apoprionospio pygmaea	64
Diastylopsis dawsoni	56
Magelona hartmanae	37
Macoma nasuta	29
Leukoma staminea	24
Mactromeris catilliformis	24
Onuphis sp. A	24
Modiolus capax	23
Leitoscoloplos pugettensis	22
Protomedeia penates	22
Micronephtys cornuta	21
Spiophanes berkeleyorum	19
Photis spp.	15
Onuphidae	14
Nemertea	13
Amphicteis scaphobranchiata	12
Lineidae	11
Pista wui	11
Amphiodia spp.	8
Kurtiella tumida	8
Pacifoculodes barnardi	8
Carinoma mutabilis	7
Ischyrocerus pelagops	7
Nephtys caecoides	7
Photis macinerneyi	7
Argissa hamatipes	6
Glycinde picta	6
Rhepoxynius fatigans	6
Streblosoma spp.	6
Dendrochirotida	5
Glossaluax reclusiana	5
Nematoda	5
Pandora bilirata	5
Cylichna spp.	4
Diastylis santamariensis	4
Sthenelais verruculosa	4

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Tubulanus pellucidus	4
Aphelochaeta petersenae	3
Astyris gausapata	3
Caesia rhinetes	3
Enteropneusta	3
Kurtziella plumbea	3
Paradialychone eiffelturris	3
Paraonidae	3
Ampharete spp.	2
Anthozoa	2
Holothuroidea	2
Malmgreniella spp.	2
Odostomia spp.	2
Photis brevipes	2
Podarkeopsis glabrus	2
Sigambra sp. SF2	2
Siliqua lucida	2
Spiochaetopterus costarum	2
Terebellidae	2
Amaeana occidentalis	1
Ampharete acutifrons	1
Aricidea (Aedicira) pacifica	1
Balcis spp.	1
Cossura spp.	1
Crangon spp.	1
Dendraster excentricus	1
Dipolydora magna	1
Edotia sublittoralis	1
Edwardsia juliae	1
Eteone fauchaldi	1
Euphilomedes carcharodonta	1
Glycera americana	1
Glycera macrobranchia	1
Glycinde spp.	1
Macoma acolasta	1
Nassariidae	1
Neotrypaea spp.	1
Nereis neoneanthes	1
Paracaudina chilensis	1
Pentamera rigida	1
Pholoe glabra	1
Pinnixa franciscana	1
Pleurogonium sp. SF1	1
Poecilochaetus johnsoni	1
Prionospio lighti	1
Sabellidae	1
Stylatula spp.	1
Tenonia priops	1

STATION 59

Spiophanes norrisi	5417
Photis spp.	938
Photis macinerneyi	559
Callianax pycna	135
Ischyrocerus pelagops	130
Pleurogonium sp. SF1	128
Protomedeia penates	127
Glycinde picta	112
Scoletoma luti	109
Glycinde spp.	57
Pectinaria californiensis	55
Owenia collaris	45
Onuphis spp.	37
Macoma spp.	33
Diastylis santamariensis	30
Amphiodia spp.	21
Micronephtys cornuta	20
Onuphis sp. A	19
Diastylopsis dawsoni	17
Nephtys caecoides	16
Tellina modesta	16
Clinocardium nuttallii	13
Eumida longicornuta	13
Macoma nasuta	13
Magelona hartmanae	13
Glycinde spp.	9
Pacifoculodes barnardi	9
Tenonia priops	9
Apoprionospio pygmaea	8
Leitoscoloplos pugettensis	8
Odostomia spp.	8

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Podarkeopsis glabrus	8
Rhepoxynius fatigans	8
Mediomastus spp.	7
Cardiidae	6
Gastropteron pacificum	6
Lumbrineridae	6
Modiolus capax	5
Pandora bilirata	5
Tritella pilimana	5
Crangon nigromaculata	4
Phyllodoce hartmanae	4
Scolelepis sp. SF1	4
Aricidea (Aricidea) sp. SF3	3
Ischyrocerus anguipes	3
Kurtziella plumbea	3
Paradialychone eiffelturris	3
Paranemertes californica	3
Prionospio lighti	3
Spiophanes berkeleyorum	3
Americhelidium shoemakeri	2
Ampharete acutifrons	2
Aricidea (Aedicira) pacifica	2
Bathycopea daltonae	2
Carinoma mutabilis	2
Cylichna spp.	2
Diaphana californica	2
Euphilomedes carcharodonta	2
Glycera americana	2
Leukoma staminea	2
Lineidae	2
Magelona sacculata	2
Microphthalmus spp. complex	2
Nemertea	2
Neotrypaea spp.	2
Photis brevipes	2
Photis parvidons	2
Sthenelais verruculosa	2
Anthozoa	1
Aphelochaeta spp.	1
Astyris gausapata	1
Caprellidae	1
Cooperella subdiaphana	1
Dendraster excentricus	1
Dendrochirotida	1
Edwardsia juliae	1
Eteone fauchaldi	1
Glycera macrobranchia	1
Glycinde sp. SF1	1
Halcampa decemtentaculata	1
Holothuroidea	1
Kurtiella tumida	1
Lumbrineris californiensis	1
Magelona spp.	1
Mesochaetopterus sp. SF1	1
Modiolus rectus	1
Monocorophium acherusicum	1
Nematoda	1
Neomysis spp.	1
Onuphidae	1
Opisthopus transversus	1
Phyllodoce longipes	1
Pinnixa franciscana	1
Rhepoxynius spp.	1
Scoloplos sp. SF1	1
Siliqua lucida	1
Sinocorophium heteroceratum	1
Solen sicarius	1
Synidotea consolidata	1
Terebellidae	1
Tiron biocellata	1
Tresus spp.	1
Tubulanidae sp. B	1
Tubulanus pellucidus	1
Typosyllis farallonensis	1
Yoldia cooperii	1

STATION 60

Spiophanes norrisi	4566
Protomedeia penates	289
Photis spp.	247
Rhepoxynius fatigans	100

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Photis macinerneyi	87
Glycinde picta	70
Callianax pycna	67
Scoletoma luti	67
Glycinde spp.	36
Euphilomedes carcharodonta	29
Mediomastus spp.	24
Tellina modesta	24
Pleurogonium sp. SF1	21
Micronephtys cornuta	19
Carinoma mutabilis	15
Onuphis spp.	15
Ampelisca cristata	14
Amphiodia spp.	13
Tenonia priops	13
Onuphis sp. A	11
Diastylis santamariensis	10
Pacifoculodes barnardi	10
Kurtzina beta	9
Eumida longicornuta	8
Nephtys caecoides	8
Nematoda	7
Terebellidae	7
Crangon nigromaculata	6
Diastylopsis dawsoni	6
Odostomia spp.	6
Ampelisca careyi	5
Dyopedos arcticus	5
Ischyrocerus pelagops	5
Kurtiella coani	5
Glycinde sp. SF1	4
Leitoscoloplos pugettensis	4
Magelona hartmanae	4
Nemertea	4
Stylatula spp.	4
Amphiodia digitata	3
Podarkeopsis glabrus	3
Rhepoxynius lucubrans	3
Americhelidium shoemakeri	2
Astyris gausapata	2
Caesia rhinetes	2
Cerebratulus californiensis	2
Cheirimedeia zotea	2
Clinocardium nuttallii	2
Enteropneusta	2
Eteone ?californica	2
Gastropteron pacificum	2
Kurtiella tumida	2
Kurtziella plumbea	2
Leukoma staminea	2
Onuphidae	2
Owenia collaris	2
Paraprionospio alata	2
Pectinaria californiensis	2
Phylo felix	2
Polynoidae	2
Sthenelais verruculosa	2
Ampelisca spp.	1
Argissa hamatipes	1
Cephalaspidea	1
Cylichna spp.	1
Diaphana californica	1
Gammaridea	1
Goniada maculata	1
Leptochelia dubia	1
Leptosynapta spp.	1
Lineidae	1
Lumbrineris californiensis	1
Macoma nasuta	1
Macoma spp.	1
Mactridae	1
Maldanidae	1
Neotrypaea spp.	1
Opheliidae	1
Pandora bilirata	1
Paranemertes californica	1
Photis brevipes	1
Phyllodoce hartmanae	1
Prionospio lighti	1
Scolelepis squamata	1

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Scoloplos armiger	1
Sigalion spinosus	1
Spiochaetopterus costarum	1
Tritella pilimana	1
STATION 61	
Spiophanes norrisi	5881
Photis spp.	754
Photis macinerneyi	364
Protomedeia penates	241
Scoletoma luti	159
Callianax pycna	75
Glycinde picta	64
Glycinde spp.	52
Mediomastus spp.	28
Eumida longicornuta	27
Ischyrocerus pelagops	27
Pleurogonium sp. SF1	21
Micronephtys cornuta	17
Onuphis sp. A	17
Owenia collaris	16
Rhepoxynius fatigans	15
Magelona hartmanae	13
Amphiodia spp.	12
Nephtys caecoides	12
Diastylis santamariensis	11
Euphilomedes carcharodonta	11
Diastylopsis dawsoni	10
Lineidae	9
Tellina modesta	9
Onuphis spp.	8
Photis parvidons	8
Nemertea	7
Pacifoculodes barnardi	7
Scoloplos sp. SF1	7
Crangon nigromaculata	6
Glycinde sp. SF1	6
Leitoscoloplos pugettensis	5
Macoma spp.	5
Pectinaria californiensis	5
Glycera macrobranchia	4
Paranemertes californica	4
Podarkeopsis glabrus	4
Terebellidae	4
Aricidea (Acmira) catherinae	3
Astyris gausapata	3
Cylichna spp.	3
Pinnixa franciscana	3
Tenonia priops	3
Ampelisca careyi	2
Argissa hamatipes	2
Dyopedos arcticus	2
Goniada maculata	2
Leukoma staminea	2
Lumbrineridae	2
Nereis neoneanthes	2
Pandora bilirata	2
Paradialychone eiffelturris	2
Spiochaetopterus costarum	2
Spiophanes berkeleyorum	2
Tritella pilimana	2
Typosyllis farallonensis	2
Americhelidium shoemakeri	1
Ampharete spp.	1
Amphipoda	1
Aphelochaeta petersenae	1
Aphelochaeta spp.	1
Apoprionospio pygmaea	1
Armandia brevis	1
Dendrochirotida	1
Edotia sublittoralis	1
Euclymeninae sp. SF1	1
Kurtziella plumbea	1
Lissocrangon stylirostris	1
Mesochaetopterus sp. SF1	1
Microphthalmus spp. complex	1
Nematoda	1
Neotrypaea spp.	1
Odostomia spp.	1
Ostracoda sp. SF2	1
Paraonidae	1

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Siliqua lucida	1
Tubulanus pellucidus	1

STATION 62

Spiophanes norrisi	2672
Protomedeia penates	300
Callianax pycna	156
Rhepoxynius fatigans	119
Glycinde spp.	90
Mediomastus spp.	90
Nematoda	89
Photis spp.	69
Glycinde picta	58
Euphilomedes carcharodonta	50
Rhepoxynius lucubrans	47
Scoletoma luti	37
Kurtiella tumida	34
Tellina modesta	25
Ampelisca careyi	20
Mesolamprops dillonensis	18
Onuphis sp. A	16
Nephtys caecoides	14
Photis macinerneyi	13
Micronephtys cornuta	12
Amphiodia spp.	11
Diastylopsis dawsoni	10
Halcampa decemtentaculata	10
Pacifoculodes barnardi	10
Ampelisca cristata	9
Carinoma mutabilis	8
Astyris gausapata	7
Lineidae	7
Nemertea	7
Diastylis santamariensis	6
Onuphis spp.	6
Tenonia priops	6
Dendrochirotida	5
Macoma nasuta	5
Pectinaria californiensis	5
Podarkeopsis glabrus	5
Spiophanes berkeleyorum	5
Magelona hartmanae	4
Pleurogonium sp. SF1	4
Stylatula spp.	4
Yoldia cooperii	4
Ampharete labrops	3
Apoprionospio pygmaea	3
Bathycopea daltonae	3
Caesia rhinetes	3
Clinocardium nuttallii	3
Cylichna spp.	3
Eumida longicornuta	3
Pagurus spp.	3
Paranemertes californica	3
Phyllodoce spp.	3
Pista wui	3
Polynoidae	3
Scolelepis sp. SF2	3
Amphiodia digitata	2
Aricidea (Acmira) catherinae	2
Glycera macrobranchia	2
Haliophasma geminatum	2
Lanassa venusta	2
Leitoscoloplos pugettensis	2
Neotrypaea spp.	2
Owenia collaris	2
Photis parvidons	2
Phyllodoce hartmanae	2
Rhepoxynius spp.	2
Spiochaetopterus costarum	2
Anonyx adoxus	1
Argissa hamatipes	1
Axinopsida serricata	1
Chaetozone columbiana	1
Crangon nigromaculata	1
Dendraster excentricus	1
Epitonium spp.	1
Kurtziella plumbea	1
Macoma acolasta	1
Magelona sacculata	1
Magelona spp.	1

Maldanidae	1
Neomysis kadiakensis	1
Nudibranchia	1
Odostomia spp.	1
Paraonidae	1
Paraprionospio alata	1
Scolelepis spp.	1
Scoloplos sp. SF1	1
Sigalion spinosus	1
Sthenelais verruculosa	1
Terebellidae	1
Tubulanidae sp. B	1
STATION 63	
Spiophanes norrisi	2829
Callianax pycna	146
Photis spp.	145
Ischyrocerus pelagops	125
Scoletoma luti	93
Rhepoxynius fatigans	78
Photis macinerneyi	77
Onuphis sp. A	59
Protomedeia penates	52
Glycinde picta	51
Glycinde spp.	48
Onuphis spp.	31
Eumida longicornuta	28
Pacifoculodes barnardi	28
Pleurogonium sp. SF1	20
Tellina modesta	20
Euphilomedes carcharodonta	16
Amphiodia spp.	11
Nephtys caecoides	11
Carinoma mutabilis	10
Ampelisca careyi	9
Lineidae	9
Mediomastus spp.	9
Diastylopsis dawsoni	8
Kurtziella plumbea	8
Macoma spp.	8
Odostomia spp.	8
Photis brevipes	8
Bathycopea daltonae	7
Magelona hartmanae	7
Pectinaria californiensis	6
Diastylis santamariensis	5
Micronephtys cornuta	5
Americhelidium shoemakeri	4
Clinocardium nuttallii	4
Heptacarpus spp.	4
Ampharete acutifrons	3
Nematoda	3
Nemertea	3
Pandora bilirata	3
Phyllodoce hartmanae	3
Tenonia priops	3
Tritella pilimana	3
Astyris gausapata	2
Axinopsida serricata	2
Glycera macrobranchia	2
Glycinde sp. SF1	2
Halcampa decemtentaculata	2
Leukoma staminea	2
Magelona sacculata	2
Mesolamprops dillonensis	2
Paranemertes californica	2
Scoloplos sp. SF1	2
Sthenelais verruculosa	2
Terebellidae	2
Amphipoda	1
Argissa hamatipes	1
Aricidea (Aricidea) sp. SF3	1
Bivalvia	1
Caesia rhinetes	1
Crangon nigromaculata	1
Cylichna spp.	1
Dendrochirotida	1
Enteropneusta	1
Gastropteron pacificum	1
Hemilamprops californicus	1
Holothuroidea	1

Kurtiella tumida	1
Leitoscoloplos pugettensis	1
Magelona berkeleyi	1
Metacarcinus gracilis	1
Microphthalmus spp. complex	1
Nassariidae	1
Onuphidae	1
Owenia collaris	1
Phyllodoce spp.	1
Podarkeopsis glabrus	1
Polynoidae	1
Sigalion spinosus	1
Stylatula spp.	1
Tubulanus spp.	1
Yoldia cooperii	1
STATION 64	
Spiophanes norrisi	548
Photis spp.	353
Photis macinerneyi	179
Diastylopsis dawsoni	114
Callianax pycna	111
Scoletoma luti	72
Tellina modesta	61
Apoprionospio pygmaea	45
Macoma nasuta	45
Magelona sacculata	43
Onuphis spp.	35
Pacifoculodes barnardi	31
Magelona hartmanae	25
Onuphis sp. A	24
Pleurogonium sp. SF1	23
Owenia collaris	22
Ischyrocerus anguipes	18
Mediomastus spp.	14
Glycinde picta	13
Protomedeia penates	13
Amphiodia spp.	12
Paradialychone eiffelturris	12
Carinoma mutabilis	11
Glycinde spp.	11
Spiophanes berkeleyorum	11
Pandora bilirata	10
Cylichna spp.	8
Nephtys caecoides	8
Rhepoxynius fatigans	8
Lumbrineridae	7
Diastylis santamariensis	5
Pectinaria californiensis	5
Astyris gausapata	4
Kurtzina beta	4
Micronephtys cornuta	4
Ampharete acutifrons	3
Leukoma staminea	3
Nemertea	3
Odostomia spp.	3
Onuphidae	3
Scoloplos armiger	3
Tenonia priops	3
Americhelidium shoemakeri	2
Argissa hamatipes	2
Glycera macrobranchia	2
Leitoscoloplos pugettensis	2
Magelona berkeleyi	2
Melanochlamys diomedea	2
Nassariidae	2
Nematoda	2
Podarkeopsis glabrus	2
Spiochaetopterus costarum	2
Ampharetidae	1
Aphelochaeta petersenae	1
Bathycopea daltonae	1
Clinocardium nuttallii	1
Eteone spp.	1
Eumida longicornuta	1
Euphilomedes carcharodonta	1
Kurtziella plumbea	1
Lineidae	1
Lumbrineris californiensis	1
Maldanidae	1
Modiolus spp.	1

Nuculanidae	1
Orbiniidae	1
Paraonidae	1
Photis parvidons	1
Phylo felix	1
Polinices draconis	1
Prionospio lighti	1
Sabellidae	1
Tritella pilimana	1
STATION 65	
Spiophanes norrisi	646
Scoletoma luti	149
Lumbrineridae	111
Photis spp.	99
Apoprionospio pygmaea	84
Magelona sacculata	76
Pectinaria californiensis	61
Photis macinerneyi	52
Mediomastus spp.	49
Diastylopsis dawsoni	39
Glycinde spp.	36
Tellina modesta	28
Macoma spp.	23
Callianax pycna	21
Pandora bilirata	19
Onuphis spp.	18
Pacifoculodes barnardi	18
Pleurogonium sp. SF1	18
Lineidae	16
Magelona hartmanae	15
Protomedeia penates	15
Glycera macrobranchia	14
Ischyrocerus pelagops	12
Nematoda	12
Onuphis sp. A	12
Paradialychone eiffelturris	11
Spiophanes berkeleyorum	11
Amphiodia spp.	10
Macoma nasuta	10
Glycinde picta	9
Onuphidae	9
Owenia collaris	9
Nephtys caecoides	6
Kurtziella plumbea	5
Maldanidae	5
Micronephtys cornuta	5
Ampharetidae	4
Leitoscoloplos pugettensis	4
Scoloplos sp. SF1	4
Americhelidium shoemakeri	3
Ampharete acutifrons	3
Aphelochaeta petersenae	3
Armandia brevis	3
Cylichna attonsa	3
Mesolamprops dillonensis	3
Argissa hamatipes	2
Carinoma mutabilis	2
Eumida longicornuta	2
Gastropteron pacificum	2
Glycinde sp. SF1	2
Magelona spp.	2
Rhepoxynius fatigans	2
Spiochaetopterus costarum	2
Spiophanes spp.	2
Tenonia priops	2
Terebellidae	2
Yoldia cooperii	2
Ampharete spp.	1
Amphicteis scaphobranchiata	1
Aricidea (Acmira) catherinae	1
Astyris gausapata	1
Caesia rhinetes	1
Cheirimedeia zotea	1
Crangon nigromaculata	1
Cylichna spp.	1
Euclymeninae sp. SF1	1
Euphilomedes carcharodonta	1
Galathowenia oculata	1
Glycera americana	1
Hemilamprops californicus	1

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Kurtiella tumida	1
Leukoma staminea	1
Microphthalmus spp. complex	1
Nassariidae	1
Pista wui	1
Solen sicarius	1
Spiophanes duplex	1
STATION 66	
Spiophanes norrisi	1035
Protomedeia penates	115
Rhepoxynius fatigans	112
Mediomastus spp.	74
Glycinde spp.	45
Photis spp.	36
Scoletoma luti	32
Kurtiella tumida	31
Nematoda	29
Ampelisca careyi	22
Magelona hartmanae	21
Ampelisca cristata	20
Micronephtys cornuta	19
Onuphis sp. A	19
Glycinde picta	17
Diastylopsis dawsoni	16
Tellina modesta	15
Spiophanes berkeleyorum	14
Magelona sacculata	13
Mesolamprops dillonensis	13
Pacifoculodes barnardi	11
Apoprionospio pygmaea	9
Euphilomedes carcharodonta	9
Nephtys caecoides	8
Rhepoxynius lucubrans	8
Spiophanes spp.	8
Argissa hamatipes	7
Astyris gausapata	7
Pectinaria californiensis	7
Callianax pycna	6
Photis brevipes	6
Amphiodia spp.	5
Nemertea	5
Odostomia spp.	5
Paranemertes californica	5
Pleurogonium sp. SF1	5
Tenonia priops	5
Aricidea (Acmira) catherinae	4
Axinopsida serricata	4
Bathycopea daltonae	4
Carinoma mutabilis	4
Paraprionospio alata	4
Phyllodoce hartmanae	4
Pista wui	4
Cheirimedeia zotea	3
Glycinde sp. SF1	3
Halcampa decemtentaculata	3
Lineidae	3
Onuphis spp.	3
Pagurus spp.	3
Amphicteis scaphobranchiata	2
Caesia rhinetes	2
Caprella californica	2
Crangon nigromaculata	2
Eumida longicornuta	2
Glycera macrobranchia	2
Ischyrocerus pelagops	2
Kurtziella plumbea	2
Lanassa venusta	2
Paracaudina chilensis	2
Saccella spp.	2
Scoloplos armiger	2
Spiochaetopterus costarum	2
Turbonilla spp.	2
Ampharete acutifrons	1
Amphiodia digitata	1
Anthozoa	1
Aoroides inermis	1
Aphelochaeta petersenae	1
Caprellidae	1
Chaetozone columbiana	1
Compsomyax subdiaphana	1

Cylichna spp.	1
Dendrochirotida	1
Diastylis santamariensis	1
Dipolydora magna	1
Dipolydora spp.	1
Enteropneusta	1
Euclymeninae sp. SF1	1
Glossaluax reclusiana	1
Glycera spp.	1
Goniada maculata	1
Kurtiella coani	1
Leitoscoloplos pugettensis	1
Macoma nasuta	1
Modiolus capax	1
Photis macinerneyi	1
Podarkeopsis glabrus	1
Polynoidae	1
Sthenelais verruculosa	1
Tiron biocellata	1
Tubulanus pellucidus	1

STATION 67

Spiophanes norrisi	1574
Photis spp.	341
Photis macinerneyi	124
Rhepoxynius fatigans	115
Scoletoma luti	75
Protomedeia penates	66
Onuphis sp. A	40
Onuphis spp.	32
Callianax pycna	31
Glycinde spp.	27
Ampelisca careyi	22
Tellina modesta	18
Euphilomedes carcharodonta	17
Pacifoculodes barnardi	15
Diastylopsis dawsoni	12
Nephtys caecoides	12
Glycinde picta	11
Hemilamprops californicus	10
Photis parvidons	10
Amphiodia spp.	9
Carinoma mutabilis	8
Gastropteron pacificum	6
Pleurogonium sp. SF1	6
Micronephtys cornuta	5
Diastylis santamariensis	4
Eumida longicornuta	4
Kurtziella plumbea	4
Leitoscoloplos pugettensis	4
Leukoma staminea	4
Macoma spp.	4
Pandora bilirata	4
Tenonia priops	4
Americhelidium shoemakeri	3
Apoprionospio pygmaea	3
Bathycopea daltonae	3
Lineidae	3
Magelona sacculata	3
Nematoda	3
Terebellidae	3
Tritella pilimana	3
Ampelisca cristata	2
Amphiodia digitata	2
Axinopsida serricata	2
Cylichna spp.	2
Glycera macrobranchia	2
Magelona hartmanae	2
Odostomia spp.	2
Onuphidae	2
Pectinaria californiensis	2
Phyllodoce longipes	2
Polynoidae	2
Sthenelais verruculosa	2
Ampharete acutifrons	1
Argissa hamatipes	1
Astyris gausapata	1
Cerebratulus californiensis	1
Crangon nigromaculata	1
Diaphana californica	1
Enteropneusta	1

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Glycinde sp. SF1	1
Kurtiella tumida	1
Maldanidae	1
Mediomastus spp.	1
Microphthalmus spp. complex	1
Modiolus capax	1
Nassariidae	1
Ostracoda sp. SF2	1
Paranemertes californica	1
Phyllodoce hartmanae	1
Spiochaetopterus costarum	1
Spiophanes berkeleyorum	1
Stylatula spp.	1
STATION 68	
Spiophanes norrisi	578
Rhepoxynius fatigans	134
Cheirimedeia zotea	121
Protomedeia penates	67
Glycinde spp.	54
Mediomastus spp.	48
Nematoda	45
Callianax pycna	36
Ampelisca cristata	35
Kurtiella tumida	34
Ampelisca careyi	25
Onuphis sp. A	23
Tellina modesta	19
Glycinde picta	17
Magelona sacculata	17
Photis spp.	14
Astyris gausapata	12
Amphiodia spp.	10
Hemilamprops californicus	10
Micronephtys cornuta	10
Magelona hartmanae	9
Ostracoda sp. SF2	9
Pacifoculodes barnardi	9
Pista wui	9
Diastylopsis dawsoni	8
Americhelidium shoemakeri	7
Apoprionospio pygmaea	7
Bathycopea daltonae	7
Stylatula spp.	7
Edwardsia juliae	6
Scoletoma luti	6
Tenonia priops	6
Aphelochaeta petersenae	5
Carinoma mutabilis	5
Crangon nigromaculata	5
Nassariidae	5
Nephtys caecoides	5
Odostomia spp.	5
Pectinaria californiensis	4
Ampelisca agassizi	3
Caesia rhinetes	3
Euphilomedes carcharodonta	3
Isaeidae	3
Lineidae	3
Turbonilla spp.	3
Amphicteis scaphobranchiata	2
Anthozoa	2
Aricidea (Aricidea) sp. SF2	2
Cylichna spp.	2
Dendrochirotida	2
Eteone sp. SF3	2
Euclymeninae sp. SF1	2
Glossaluax reclusiana	2
Lamprops tomalesi	2
Mesochaetopterus sp. SF1	2
Micrura spp. (?)	2
Nemertea	2
Neotrypaea spp.	2
Pachynus barnardi	2
Phyllodoce longipes	2
Podarkeopsis glabrus	2
Scolelepis sp. SF2	2
Tritella pilimana	2
Ampharetidae	1
Amphiodia digitata	1
Anonyx adoxus	1

Aricidea (Acmira) catherinae	1
Armandia brevis	1
Axinopsida serricata	1
Cardiidae	1
Chaetodermatida	1
Diastylis santamariensis	1
Dyopedos arcticus	1
Enteropneusta	1
Gastropteron pacificum	1
Goniada maculata	1
Goniada spp.	1
Halcampa decemtentaculata	1
Lumbrineris californiensis	1
Mangeliidae	1
Neomysis spp.	1
Nereis neoneanthes	1
Photis macinerneyi	1
Pleurogonium sp. SF1	1
Spiochaetopterus costarum	1
Streblosoma spp.	1
Tubulanus pellucidus	1
Typosyllis farallonensis	1
STATION 69	
Spiophanes norrisi	2079
Protomedeia penates	175
Rhepoxynius fatigans	107
Glycinde spp.	80
Scoletoma luti	80
Cheirimedeia zotea	62
Mediomastus spp.	60
Glycinde picta	59
Astyris gausapata	53
Terebellidae	38
Tellina modesta	33
Onuphis sp. A	32
Ampelisca cristata	31
Hemilamprops californicus	28
Nematoda	27
Dendrochirotida	24
Kurtiella tumida	24
Ampelisca careyi	21
Amphiodia spp.	20
Callianax pycna	18
Onuphis spp.	15
Photis spp.	15
Lanassa venusta	10
Pista wui	10
Edwardsia juliae	8
Lineidae	8
Micronephtys cornuta	8
Nephtys caecoides	8
Tritella pilimana	8
Apoprionospio pygmaea	7
Diastylopsis dawsoni	6
Macoma spp.	6
Magelona hartmanae	6
Maldanidae	6
Eumida longicornuta	5
Odostomia spp.	5
Pleurogonium sp. SF1	5
Tiron biocellata	5
Diastylis santamariensis	4
Leukoma staminea	4
Magelona sacculata	4
Polynoidae	4
Amphicteis scaphobranchiata	3
Bathycopea daltonae	3
Gastropteron pacificum	3
Kurtziella plumbea	3
Pectinaria californiensis	3
Phyllodoce hartmanae	3
Aphelochaeta petersenae	2
Cylichna attonsa	2
Euphilomedes carcharodonta	2
Glycera macrobranchia	2
Lumbrineris californiensis	2
Metacarcinus gracilis	2
Pacifoculodes barnardi	2
Photis parvidons	2
Streblosoma spp.	2

Appendix E-2 (cont.)

Benthic infauna collected in 2012

Tenonia priops	2
Amaeana occidentalis	1
Ampelisca agassizi	1
Ampharete acutifrons	1
Ampharete spp.	1
Amphiodia digitata	1
Argissa hamatipes	1
Aricidea (Aedicira) sp. A	1
Armandia brevis	1
Caesia rhinetes	1
Crangon nigromaculata	1
Cylichna spp.	1
Eusyllis transecta	1
Gastropoda	1
Glycera americana	1
Glycinde sp. SF1	1
Goniada maculata	1
Halcampa decemtentaculata	1
Lepidasthenia spp.	1
Lissocrangon stylirostris	1
Modiolus spp.	1
Onuphidae	1
Pandora bilirata	1
Paranemertes californica	1
Pherusa neopapillata	1
Podarkeopsis glabrus	1
Prionospio lighti	1
Scoloplos sp. SF1	1
Spiophanes duplex	1
Turbonilla spp.	1
Typosyllis farallonensis	1
Yoldia cooperii	1
STATION 70	
Spiophanes norrisi	436
Scoletoma luti	111
Apoprionospio pygmaea	38
Mactromeris catilliformis	21
Magelona sacculata	20
Tellina modesta	20
Diastylopsis dawsoni	14
Onuphis spp.	14
Photis spp.	14
Mediomastus spp.	13
Lineidae	12
Pectinaria californiensis	12
Onuphidae	11
Pleurogonium sp. SF1	11
Macoma spp.	10
Photis macinerneyi	10
Pacifoculodes barnardi	8
Scoloplos sp. SF1	8
Leukoma staminea	7
Glycera macrobranchia	6
Nemertea	5
Nephtys caecoides	5
Ampharete acutifrons	4
Ampharetidae	4
Carinoma mutabilis	4
Magelona hartmanae	4
Pandora bilirata	4
Americhelidium shoemakeri	3
Amphiodia spp.	3
Aricidea (Aricidea) sp. SF2	2
Bathycopea daltonae	2
Glycinde spp.	2
Leitoscoloplos pugettensis	2
Mesolamprops dillonensis	2
Nematoda	2
Ampharete labrops	1
Callianax pycna	1
Glycera spp.	1
Glycinde sp. SF1	1
Macoma nasuta	1
Magelona spp.	1
Mangeliidae	1
Mediomastus acutus	1
Neotrypaea spp.	1
Odostomia spp.	1
Onuphis sp. A	1
Oweniidae	1

Paradialychone eiffelturris	1
Phoronis spp.	1
Scolelepis sp. SF2	1
Spiochaetopterus costarum	1
Sthenelais verruculosa	1
Synidotea consolidata	1
Tecticeps convexus	1
STATION 71	
Spiophanes norrisi	519
Tellina modesta	115
Photis spp.	116
Scoletoma luti	65
Photis macinerneyi	59
Apoprionospio pygmaea	41
Pacifoculodes barnardi	36
Onuphis spp.	35
Diastylopsis dawsoni	31
Macoma spp.	29
Hemilamprops californicus	23
Magelona sacculata	20
Callianax pycna	18
Pectinaria californiensis	18
Mactromeris catilliformis	17
Magelona hartmanae	16
Micronephtys cornuta	16
Leukoma staminea	14
Pleurogonium sp. SF1	14
Ischyrocerus pelagops	13
Astyris gausapata	12
Mediomastus spp.	12
Lineidae	10
Pandora bilirata	10
Glycinde spp.	9
Nematoda	9
Scoloplos sp. SF1	8
Glycera macrobranchia	7
Nephtys caecoides	7
Onuphis sp. A	7
Aphelochaeta petersenae	5
Clinocardium nuttallii	5
Eumida longicornuta	5
Glycinde picta	5
Mesolamprops dillonensis	5
Carinoma mutabilis	4
Cylichna spp.	4
Diastylis santamariensis	4
Kurtziella plumbea	4
Lumbrineridae	4
Macoma nasuta	4
Protomedeia penates	4
Gastropteron pacificum	3
Nassariidae	3
Onuphidae	3
Owenia collaris	3
Rhepoxynius fatigans	3
Spiophanes berkeleyorum	3
Ampelisca careyi	2
Amphiodia spp.	2
Aricidea (Aricidea) sp. SF3	2
Caesia rhinetes	2
Enteropneusta	2
Glycera americana	2
Glycinde sp. SF1	2
Leitoscoloplos pugettensis	2
Maldanidae	2
Odostomia spp.	2
Paradialychone eiffelturris	2
Siliqua lucida	2
Tritella pilimana	2
Americhelidium shoemakeri	1
Ampelisca cristata	1
Ampharete spp.	1
Aricidea (Aedicira) sp. A	1
Cheirimedeia zotea	1
Dendrochirotida	1
Diaphana californica	1
Eteone spp.	1
Euclymeninae sp. SF1	1
Glossaluax reclusiana	1
Lumbrineris californiensis	1

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Magelona spp.	1
Modiolus capax	1
Modiolus rectus	1
Nemertea	1
Nereis neoneanthes	1
Phylo felix	1
Pinnixa franciscana	1
Scolelepis sp. SF2	1
Scolelepis spp.	1
Streblosoma sp. SF1	1
Terebellidae	1
Tresus spp.	1
Yoldia cooperii	1

STATION 72

Scoletoma luti	205
Mactromeris catilliformis	125
Mediomastus spp.	103
Spiophanes norrisi	95
Protomedeia penates	94
Tellina modesta	78
Callianax pycna	66
Onuphis sp. A	53
Diastylopsis dawsoni	44
Pectinaria californiensis	32
Rhepoxynius fatigans	30
Glycinde spp.	29
Kurtiella tumida	25
Enteropneusta	22
Nemertea	21
Magelona hartmanae	19
Magelona sacculata	18
Owenia collaris	17
Aphelochaeta petersenae	16
Leitoscoloplos pugettensis	16
Apoprionospio pygmaea	14
Odostomia spp.	10
Amphiodia spp.	9
Glycera macrobranchia	8
Dendrochirotida	7
Pleurogonium sp. SF1	7
Spiophanes berkeleyorum	7
Stylatula spp.	7
Caesia rhinetes	6
Lineidae	6
Pandora bilirata	6
Photis spp.	6
Dendraster excentricus	5
Anthozoa	4
Aricidea (Aricidea) sp. SF3	4
Edwardsia juliae	4
Glycinde picta	4
Lanassa venusta	4
Lepidasthenia longicirrata	4
Leukoma staminea	4
Macoma nasuta	4
Nassariidae	4
Nephtys caecoides	4
Paraonidae	4
Streblosoma spp.	4
Tubulanus pellucidus	4
Yoldia cooperii	4
Amaeana occidentalis	3
Ampelisca cristata	3
Ampharetidae	3
Hydrozoa	3
Nematoda	3
Phylo felix	3
Solen sicarius	3
Streblosoma sp. SF1	3
Tenonia priops	3
Ampelisca careyi	2
Cylichna attonsa	2
Glossaluax reclusiana	2
Ischyrocerus pelagops	2
Kellia sp. SF1	2
Kurtziella plumbea	2
Modiolus capax	2
Neotrypaea spp.	2
Onuphidae	2
Paraprionospio alata	2

Pholoe glabra	2
Sigambra sp. SF2	2
Terebellidae	2
Veneridae	2
Ampharete acutifrons	1
Ampharete spp.	1
Aoroides inermis	1
Aricidea (Acmira) horikoshii	1
Aricidea (Aedicira) pacifica	1
Aricidea (Aedicira) sp. A	1
Astyris gausapata	1
Axinopsida serricata	1
Cardiidae	1
Carinoma mutabilis	1
Diastylis santamariensis	1
Eteone fauchaldi	1
Goniada maculata	1
Isaeidae	1
Lepidasthenia spp.	1
Magelona berkeleyi	1
Maldanidae	1
Malmgreniella spp.	1
Mangeliidae	1
Pacifoculodes barnardi	1
Photis macinerneyi	1
Photis parvidons	1
Pista wui	1
Podarkeopsis glabrus	1
Prionospio lighti	1
Rhepoxynius lucubrans	1
Scoloplos sp. SF1	1
Sthenelais verruculosa	1

STATION 73

Spiophanes norrisi	10861
Photis spp.	326
Glycinde picta	307
Ischyrocerus pelagops	218
Glycinde spp.	206
Photis macinerneyi	176
Megamoera subtener	136
Scoletoma luti	111
Tresus spp.	77
Phyllodoce williamsi	54
Tellina modesta	47
Foxiphalus obtusidens	42
Carinoma mutabilis	40
Owenia collaris	39
Clinocardium nuttallii	35
Pacifoculodes barnardi	35
Tiron biocellata	33
Gnathopleustes pugettensis	20
Pleurogonium sp. SF1	18
Synidotea consolidata	17
Paranemertes californica	15
Diastylopsis dawsoni	10
Mactromeris catilliformis	10
Odostomia spp.	10
Callianax pycna	9
Cylichna spp.	9
Phyllodoce williamsi	9
Podarkeopsis glabrus	9
Eumida longicornuta	8
Kurtiella coani	7
Protomedeia penates	7
Amphiodia spp.	6
Glycinde sp. SF1	6
Leukoma staminea	6
Kurtiella tumida	5
Tritella pilimana	5
Harmothoe imbricata complex	4
Bathycopea daltonae	3
Dyopedos arcticus	3
Edotia sublittoralis	3
Flabelligeridae	3
Mediomastus acutus	3
Mediomastus spp.	3
Nephtys caecoides	3
Pectinaria californiensis	3
Rhepoxynius abronius	3
Americhelidium shoemakeri	2

Appendix E-2 (cont.)
Benthic infauna collected in 2012

Amphiodia digitata	2
Aphelochaeta petersenae	2
Bivalvia	2
Dendraster excentricus	2
Gastropoda	2
Gastropteron pacificum	2
Glycera macrobranchia	2
Goniada maculata	2
Heptacarpus stimpsoni	2
Mesochaetopterus sp. SF1	2
Nemertea	2
Pherusa neopapillata	2
Scolelepis squamata	2
Streptosyllis sp. SF1	2
Amaeana occidentalis	1
Ampelisca spp.	1
Diastylis santamariensis	1
Glossaluax reclusiana	1
Hesionidae	1
Leitoscoloplos pugettensis	1
Lumbrineris californiensis	1
Magelona sacculata	1
Notomastus lineatus	1
Philine auriformis	1
Photis parvidons	1
Phyllodoce hartmanae	1
Polynoidae	1
Scoloplos sp. SF1	1
Sthenelais verruculosa	1
Tenonia priops	1
Turbellaria	1
STATION 75	
Spiophanes norrisi	3452
Photis spp.	836
Photis macinerneyi	382
Ischyrocerus pelagops	168
Glycinde picta	115
Scoletoma luti	86
Carinoma mutabilis	72
Callianax pycna	49
Tellina modesta	42
Pacifoculodes barnardi	40
Rhepoxynius abronius	25
Diastylopsis dawsoni	24
Glycinde spp.	23
Onuphis sp. A	16
Paranemertes californica	14
Clinocardium nuttallii	11
Synidotea consolidata	11
Rhepoxynius lucubrans	10
Aoroides inermis	9
Eobrolgus spinosus	9
Glycera macrobranchia	9
Pleurogonium sp. SF1	9
Kurtiella coani	8
Lissocrangon stylirostris	7
Odostomia spp.	6
Paradialychone eiffelturris	6
Phyllodoce williamsi	6
Onuphis spp.	5
Americhelidium shoemakeri	4
Nephtys caecoides	4
Apoprionospio pygmaea	3
Bathycopea daltonae	3
Diastylis santamariensis	3
Eumida longicornuta	3
Phyllodoce hartmanae	3
Siliqua lucida	3
Tecticeps convexus	3
Tresus spp.	3
Tritella pilimana	3
Armandia brevis	2
Eteone (Mysta) sp. SF1	2
Gnathopleustes pugettensis	2
Lineidae	2
Nassariidae	2
Onuphis spp.	2
Owenia collaris	2
Pandora bilirata	2
Protomedeia penates	2

Ampharete labrops	1
Amphiodia spp.	1
Crangon nigromaculata	1
Cylichna spp.	1
Edotia sublittoralis	1
Eohaustorius spp.	1
Holothuroidea	1
Kurtiella tumida	1
Leitoscoloplos pugettensis	1
Leukoma staminea	1
Macoma spp.	1
Modiolus rectus	1
Munnogonium tillerae	1
Photis brevipes	1
Podarkeopsis glabrus	1
Rhepoxynius vigitegus	1
Spiochaetopterus costarum	1
Sthenelais verruculosa	1
Tenonia priops	1
Turbellaria	1
STATION 77	
Spiophanes norrisi	5033
Photis spp.	233
Ischyrocerus pelagops	212
Photis macinerneyi	183
Leukoma staminea	155
Scoletoma luti	119
Mediomastus spp.	110
Pleurogonium sp. SF1	108
Mactromeris catilliformis	85
Glycinde picta	82
Kurtiella tumida	65
Glycinde spp.	45
Bivalvia	34
Callianax pycna	33
Pacifoculodes barnardi	33
Onuphis sp. A	32
Macoma spp.	31
Macoma nasuta	30
Onuphis spp.	23
Podarkeopsis glabrus	20
Protomedeia penates	20
Rhepoxynius fatigans	20
Pectinaria californiensis	17
Nephtys caecoides	16
Diastylopsis dawsoni	15
Magelona sacculata	14
Clinocardium nuttallii	10
Glycera macrobranchia	10
Lineidae	10
Micronephtys cornuta	10
Owenia collaris	10
Paradialychone eiffelturris	10
Tellina modesta	9
Apoprionospio pygmaea	8
Cylichna spp.	8
Nemertea	8
Odostomia spp.	7
Enteropneusta	6
Macoma acolasta	6
Prionospio lighti	6
Siliqua lucida	6
Amphiodia spp.	5
Caesia rhinetes	5
Nematoda	5
Diastylis santamariensis	4
Gastropteron pacificum	4
Magelona hartmanae	4
Sthenelais verruculosa	4
Tenonia priops	4
Dendraster excentricus	3
Euphilomedes carcharodonta	3
Fabia subquadrata	3
Rhepoxynius lucubrans	3
Tiron biocellata	3
Americhelidium shoemakeri	2
Aphelochaeta petersenae	2
Argissa hamatipes	2
Carinoma mutabilis	2
Dendrochirotida	2

Eteone sp. SF4	2
Eumida longicornuta	2
Halcampa decemtentaculata	2
Modiolus capax	2
Nassariidae	2
Nereis neoneanthes	2
Phyllodoce williamsi	2
Scoloplos sp. SF1	2
Sigalion spinosus	2
Amaeana occidentalis	1
Ampharete acutifrons	1
Aricidea (Aricidea) sp. SF3	1
Bathycopea daltonae	1
Cancridae	1
Crangon nigromaculata	1
Crangonidae	1
Eusyllis transecta	1
Glycera americana	1
Glycinde sp. SF1	1
Kurtiella coani	1
Leitoscoloplos pugettensis	1
Mesolamprops dillonensis	1
Neotrypaea spp.	1
Pandora bilirata	1
Photis parvidons	1
Phyllodoce hartmanae	1
Pinnixa franciscana	1
Polynoidae	1
Sigambra sp. SF2	1
Spiochaetopterus costarum	1
Spiophanes berkeleyorum	1
Synidotea consolidata	1
Tecticeps convexus	1
Terebellidae	1
Tubulanus pellucidus	1
STATION 78	
Spiophanes norrisi	6565
Photis spp.	813
Photis macinerneyi	497
Callianax pycna	146
Protomedeia penates	141
Scoletoma luti	136
Ischyrocerus pelagops	91
Glycinde picta	84
Glycinde spp.	47
Carinoma mutabilis	19
Eumida longicornuta	19
Tellina modesta	16
Amphiodia spp.	14
Pleurogonium sp. SF1	12
Diastylopsis dawsoni	10
Onuphis sp. A	10
Owenia collaris	9
Photis parvidons	9
Micronephtys cornuta	8
Diastylis santamariensis	7
Magelona hartmanae	7
Crangon nigromaculata	6
Odostomia spp.	6
Paranemertes californica	6
Pectinaria californiensis	6
Euphilomedes carcharodonta	5
Leitoscoloplos pugettensis	5
Macoma nasuta	5
Mediomastus spp.	5
Rhepoxynius fatigans	5
Scoloplos sp. SF1	5
Eteone fauchaldi	4
Glycinde sp. SF1	4
Nephtys caecoides	4
Pacifoculodes barnardi	4
Tenonia priops	4
Magelona sacculata	3
Paradialychone eiffelturris	3
Argissa hamatipes	2
Callianassidae	2
Gastropteron pacificum	2
Amphiodia digitata	1
Apoprionospio pygmaea	1
Armandia brevis	1

Bivalvia	1
Corophoidea	1
Cylichna spp.	1
Diaphana californica	1
Dyopedos arcticus	1
Edwardsia juliae	1
Glycera macrobranchia	1
Goniada maculata	1
Kurtiella tumida	1
Kurtzina beta	1
Leukoma staminea	1
Lumbrineris californiensis	1
Mesochaetopterus spp.	1
Nematoda	1
Nemertea	1
Nereis neoneanthes	1
Onuphis spp.	1
Paraonidae	1
Paraprionospio alata	1
Pentamera rigida	1
Pherusa neopapillata	1
Phyllodoce hartmanae	1
Phyllodoce longipes	1
Pista spp.	1
Podarkeopsis glabrus	1
Saccella taphria	1
Scoloplos armiger	1
Spiophanes berkeleyorum	1
Synidotea consolidata	1
Synopiidae	1
Tresus spp.	1
Tubulanidae sp. B	1
Typosyllis farallonensis	1
Yoldia cooperii	1
STATION 79	
Spiophanes norrisi	1135
Callianax pycna	129
Diastylopsis dawsoni	124
Apoprionospio pygmaea	100
Pacifoculodes barnardi	80
Tellina modesta	69
Scoletoma luti	64
Owenia collaris	57
Nemertea	54
Spiophanes norrisi	51
Mediomastus spp.	43
Onuphis sp. A	35
Photis spp.	34
Magelona sacculata	33
Ischyrocerus pelagops	32
Pectinaria californiensis	27
Nephtys caecoides	26
Macoma nasuta	25
Glycinde picta	22
Kurtiella tumida	20
Tecticeps convexus	18
Yoldia cooperii	16
Diastylopsis tenuis	15
Photis macinerneyi	14
Leitoscoloplos pugettensis	9
Amphiodia spp.	8
Bathycopea daltonae	8
Glycinde spp.	8
Diastylis santamariensis	7
Pleurogonium sp. SF1	7
Americhelidium shoemakeri	5
Magelona hartmanae	5
Onuphidae	5
Podarkeopsis glabrus	4
Edotia sublittoralis	3
Modiolus capax	3
Tiron biocellata	3
Aoroides inermis	2
Bivalvia	2
Eteone ?californica	2
Glycinde sp. SF1	2
Leukoma staminea	2
Micronephtys cornuta	2
Nereis neoneanthes	2
Odostomia spp.	2

Pandora bilirata	2
Paradialychone eiffelturris	2
Ampelisca careyi	1
Argissa hamatipes	1
Aricidea (Aricidea) sp. SF1	1
Aricidea (Aricidea) sp. SF3	1
Caesia rhinetes	1
Crangon nigromaculata	1
Cylichna spp.	1
Diastylopsis spp.	1
Eteone spp.	1
Glycera americana	1
Glycera macrobranchia	1
Halosydna brevisetosa	1
Holothuroidea	1
Mactromeris catilliformis	1
Modiolus rectus	1
Neomysis spp.	1
Neotrypaea spp.	1
Pista sp. SF1	1
Protomedeia penates	1
Scoloplos sp. SF1	1
Sigambra sp. SF2	1
Spiochaetopterus costarum	1
Sthenelais verruculosa	1
Tenonia priops	1

STATION 80

Eobrolgus spinosus	63
Rhepoxynius lucubrans	61
Callianax pycna	44
Spiophanes norrisi	44
Scoloplos armiger	14
Aoroides inermis	11
Chaetozone bansei	11
Protomedeia penates	7
Carinoma mutabilis	6
Eohaustorius spp.	6
Rhepoxynius fatigans	6
Rhepoxynius vigitegus	6
Scoletoma luti	6
Pacifoculodes barnardi	5
Photis spp.	5
Diastylopsis dawsoni	4
Photis macinerneyi	4
Mediomastus spp.	3
Nephtys caecoides	3
Tellina modesta	3
Americhelidium shoemakeri	2
Apoprionospio pygmaea	2
Lineidae	2
Amphiodia spp.	1
Anomura	1
Bathycopea daltonae	1
Caesia rhinetes	1
Euphilomedes carcharodonta	1
Glycinde spp.	1
Halosydna brevisetosa	1
Ischyrocerus anguipes	1
Kurtiella coani	1
Lumbrineris californiensis	1
Magelona sacculata	1
Nemertea	1
Neomysis kadiakensis	1
Nereis neoneanthes	1
Pagurus spp.	1
Scolelepis sp. SF2	1
Sthenelais verruculosa	1

Appendix E-3

Community measures for each staion 1997- 2012

Parameter = Abundance

Station	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
01	2520	252	478	676	1144	1108	1256	632	261	183	785	717	659	616	1558	3691
02	1069	237	185	1425	1561	1394	1472	444	351	176	662	751	652	1502	2446	6753
04	1954	257	753	1821	2163	916	1048	420	376	395	1919	1012	494	1531	5971	4322
06	1238	200	552	1047	1019	819	1548	891	537	182	492	747	568	4226	2259	8973
25	3511	268	466	866	1738	1294	1024	740	306	122	952	764	486	784	1614	7699
28	1457	672	1030	1056	2814	1129	2319	512	851	615	734	768	1024	1026	2583	2346
31	352	143	104	183	2065	1589	1112	225	71	116	97	368	533	928	293	1252
32	573	382	566	975	1358	825	857	440	451	267	932	784	593	462	1387	565
33	525	120	360	953	1656	963	808	349	400	170	403	2927	1563	1255	1542	1788
34	841	318	826	1379	1783	723	793	370	690	503	772	1177	643	461	1174	1274
35	1088	NS	902	1140	1150	984	2327	1098	NS	NS	767	1070	990	1499	1126	1078
36	880	280	620	733	1678	499	588	375	239	187	419	11715	766	877	1328	1412
37	782	160	484	879	3240	733	545	273	445	227	604	2573	665	375	1048	1006
38	794	226	993	1260	1646	480	783	503	223	295	505	4915	1097	1689	1010	1001
39	828	473	649	991	1269	873	1995	335	620	305	682	1095	533	719	1485	884
40	234	142	154	568	1236	2154	578	361	305	98	1720	1537	1662	2045	706	1338
41	408	41	24	44	139	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
42	509	87	49	57	1017	NS	NS	78	NS	NS	NS	NS	NS	666	NS	NS
43	33	30	114	67	166	78	369	259	71	64	129	99	147	310	198	217
44	1991	469	938	NS	NS	NS	NS	1229	NS	NS	NS	NS	NS	NS	NS	NS
45	172	132	175	691	869	1704	1838	177	101	NS	445	259	699	403	691	1408
46	1423	222	NS	NS	NS	NS	NS	2558	NS	NS	NS	NS	NS	NS	NS	NS
47	175	125	172	74	586	2531	1656	162	105	62	95	157	194	NS	112	749
48	72	126	283	544	1122	1537	429	232	103	NS	177	384	891	356	254	1595
49	178	191	341	NS	NS	NS	NS	1120	NS	NS	NS	NS	NS	190	NS	NS
50	1640	256	859	1432	1018	445	691	568	583	170	651	956	499	1094	1939	1894
51	153	129	107	109	161	177	1462	351	131	110	49	71	285	NS	141	908
52	90	54	50	738	810	2355	1780	1153	67	42	93	408	250	156	224	260
53	1244	212	462	985	958	828	586	297	509	230	808	698	367	2382	4032	2776
54	784	120	126	311	2292	1355	4234	331	164	114	140	200	225	1037	1904	828
55	1376	93	205	773	1063	1007	1062	424	175	86	313	481	754	4475	4713	NS
56	1923	252	586	1433	1852	968	835	273	238	271	739	723	487	3424	5163	7908
57	933	83	160	924	4691	3672	5896	833	156	115	278	888	525	7228	2277	NS
58	1782	264	727	1777	2903	1857	2604	661	682	392	1038	1449	649	815	2948	1830
59	1241	991	740	2134	1914	878	3222	493	412	422	618	1337	904	1924	4589	8287
60	1229	254	1001	1305	1052	1013	1306	514	266	270	662	618	249	3877	3131	5918
61	1184	243	511	1140	1345	894	2264	288	636	348	825	899	429	3189	2324	7987
62	793	210	773	1693	1119	663	862	611	483	264	689	530	359	2281	2840	4153
63	1663	204	612	1489	1592	719	1435	260	391	191	540	956	648	3395	2118	4059
64	1087	346	430	1481	1684	1040	3121	892	247	256	772	886	452	1372	2778	1971
65	1246	386	476	1140	2314	697	1362	393	393	207	519	1507	471	937	2545	1810
66	648	325	503	1073	1187	599	574	445	110	276	1089	704	313	1965	2144	1916
67	1015	304	770	1349	1195	599	516	455	116	235	714	762	841	3015	3352	2687
68	575	306	489	888	700	529	510	417	757	685	1368	850	352	1154	1732	1512
69	772	254	483	1072	1306	910	674	510	614	161	1109	748	291	4125	1529	3276
70	1340	403	598	1118	1585	1084	2262	440	297	470	492	1497	248	633	1984	863
71	1374	200	950	1133	1477	843	1091	450	423	278	516	906	741	2017	2629	1427
72	NS	305	702	1600	1342	436	739	1982	386	217	784	8426	8426	519	1635	1617
73	NS	NS	NS	NS	NS	1211	1188	304	298	128	375	585	408	4106	1440	13007
74	NS	NS	NS	NS	NS	1237	1825	572	214	140	416	1018	399	1531	2505	NS
75	NS	NS	NS	NS	NS	1654	5295	339	252	148	285	260	704	609	4302	5523
76	NS	NS	NS	NS	NS	1079	2300	581	723	597	1074	920	849	1399	3875	NS
77	NS	NS	NS	NS	NS	1385	2312	882	256	393	523	801	778	1203	2484	6996
78	NS	NS	NS	NS	NS	1227	2453	415	402	391	631	725	971	2123	2974	8783
79	NS	NS	NS	NS	NS	2601	3139	709	541	252	655	2382	1202	6796	2310	2342
80	NS	NS	NS	NS	NS	NS	NS	874	266	99	662	915	154	506	2444	335

NS = not sampled

Appendix E-3 (cont.)

Community measures for each staion 1997- 2012

Parameter = Shannon-Weiner Diversity

Station	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
01	2.68	3.33	3.52	3.50	3.26	3.03	2.40	3.05	3.60	3.00	2.12	3.45	3.43	2.30	2.07	1.95
02	2.92	2.48	3.39	2.96	3.42	2.68	2.75	3.20	3.33	2.47	1.98	2.97	2.24	1.54	1.63	1.52
04	2.80	3.20	3.37	3.55	3.25	3.25	3.18	3.53	3.24	2.74	1.82	3.40	2.76	2.08	1.02	2.29
06	3.13	2.82	3.07	3.53	3.51	2.27	2.41	2.79	3.17	3.07	3.50	2.82	2.46	0.69	1.46	0.95
25	2.72	2.93	3.41	3.68	3.49	2.95	3.01	3.20	3.48	2.80	2.09	3.27	3.14	2.68	1.74	1.89
28	2.82	2.43	3.46	3.46	3.02	3.09	2.50	3.01	3.20	3.56	3.24	3.56	2.80	3.03	2.18	3.13
31	2.66	2.89	3.02	2.82	2.02	0.97	1.89	3.17	2.88	2.47	2.62	2.45	2.38	1.87	2.09	0.66
32	3.21	3.25	3.17	3.14	2.94	2.47	2.80	2.69	3.19	2.81	2.59	2.18	3.14	2.88	2.34	2.88
33	3.21	3.43	3.29	3.61	2.77	2.78	2.94	3.04	2.65	3.16	3.10	1.56	1.47	1.24	1.63	2.44
34	3.32	3.42	3.24	2.97	3.16	3.00	3.13	3.06	2.87	2.80	3.15	3.36	3.38	2.90	3.55	3.31
35	3.65	NS	2.74	2.89	2.80	2.15	2.75	2.07	NS	NS	3.08	3.00	2.60	2.31	3.32	3.04
36	3.51	2.79	3.32	3.30	2.77	3.00	3.23	2.84	3.40	3.14	3.21	0.57	2.66	2.50	2.14	2.49
37	2.32	3.22	3.33	3.19	1.95	2.78	2.52	2.86	2.99	3.18	2.15	1.49	2.58	2.90	2.77	2.29
38	3.32	2.97	2.47	3.39	2.73	2.84	3.03	3.23	3.46	3.61	3.46	1.15	2.39	1.64	2.73	3.24
39	3.77	3.53	3.35	3.91	3.26	3.14	2.92	3.47	3.37	3.59	3.56	2.88	3.12	2.14	3.12	3.52
40	2.94	3.22	3.36	3.48	2.25	1.32	2.40	3.38	3.14	2.80	2.17	2.15	1.03	1.52	1.96	2.07
41	1.08	1.73	2.59	2.27	1.94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
42	1.60	1.76	1.91	2.08	1.10	NS	NS	1.82	NS	NS	NS	NS	NS	1.53	NS	NS
43	2.22	1.82	1.59	2.26	1.84	2.28	1.12	1.85	1.81	1.47	1.93	1.90	1.67	2.07	2.04	1.42
44	1.71	1.73	1.97	NS	NS	NS	NS	1.58	NS	NS	NS	NS	NS	NS	NS	NS
45	2.74	2.82	2.53	2.95	2.77	2.17	1.87	2.93	3.11	NS	2.68	2.19	1.60	1.13	1.59	0.61
46	1.64	1.94	NS	1.73	NS	NS	NS	1.73	NS	NS	NS	NS	2.99	NS	NS	NS
47	2.72	2.76	2.78	2.41	1.78	0.91	1.37	3.21	2.92	2.49	2.92	2.83	1.16	NS	2.65	1.15
48	2.61	2.96	2.91	3.00	2.49	2.38	2.00	2.82	3.07	NS	3.09	2.35	3.25	1.41	2.40	1.65
49	1.58	1.41	1.67	0.71	NS	NS	NS	0.71	NS	NS	NS	NS	NS	2.21	NS	NS
50	2.74	3.47	3.34	3.47	3.72	3.26	3.21	2.99	2.96	2.95	3.30	3.34	1.39	2.78	2.21	2.91
51	2.58	1.79	2.46	2.85	2.43	2.60	1.24	1.93	2.45	2.33	1.80	2.88	0.97	NS	2.12	0.81
52	2.61	1.78	2.66	1.18	1.92	1.14	1.43	0.95	2.72	2.58	2.19	1.69	3.38	2.05	1.87	1.94
53	3.38	3.48	3.48	3.65	3.53	2.96	3.26	3.57	3.60	3.25	3.14	3.46	2.53	1.52	1.32	2.00
54	2.46	3.06	2.97	3.19	1.73	2.00	1.66	2.85	3.08	2.75	2.20	2.94	1.38	1.74	1.49	1.96
55	2.14	3.12	2.50	2.33	3.09	2.33	2.35	3.31	3.11	2.53	1.75	2.80	3.49	0.55	1.01	NS
56	2.95	3.09	3.47	3.69	3.41	2.76	2.44	3.03	3.57	3.16	3.57	3.43	1.74	1.33	0.89	1.21
57	2.56	2.59	2.93	2.68	2.08	1.16	1.31	2.44	2.94	2.81	3.11	2.83	3.09	0.95	1.60	NS
58	3.02	3.18	3.58	3.53	3.06	2.69	2.66	3.12	3.09	3.70	2.97	3.34	3.23	2.56	3.16	3.21
59	3.09	1.52	3.20	3.49	2.94	3.44	2.24	3.09	3.38	2.77	2.84	2.52	3.37	2.25	1.14	1.56
60	3.28	3.20	3.18	3.71	3.65	2.99	2.56	3.42	3.02	3.11	3.05	3.68	3.17	0.85	1.33	1.23
61	3.07	3.27	3.53	3.42	3.47	3.11	2.65	3.36	3.59	2.99	3.37	2.67	3.51	0.99	1.26	1.00
62	3.41	3.34	3.69	3.51	3.41	3.62	3.46	3.64	3.36	3.35	3.01	3.48	3.18	1.59	1.58	1.78
63	3.06	3.31	3.65	3.64	3.23	3.09	2.62	3.33	3.44	3.66	3.28	2.56	2.78	0.97	2.00	1.55
64	2.83	3.13	3.32	3.70	2.87	3.18	2.43	3.01	3.28	3.06	3.02	3.19	3.22	1.41	1.20	2.74
65	3.04	3.47	3.60	3.61	3.00	3.53	3.23	3.43	3.25	3.33	3.18	2.73	3.46	2.79	2.13	2.77
66	3.77	2.82	3.23	3.51	3.53	3.43	3.60	3.37	3.20	3.31	3.14	3.54	1.86	2.04	1.89	2.32
67	3.23	3.19	3.59	3.81	3.29	3.39	3.65	3.54	2.95	3.23	3.30	3.35	3.46	0.90	1.69	1.77
68	3.72	2.75	3.37	3.41	3.49	3.07	3.31	3.54	2.44	3.17	3.18	3.63	3.23	2.41	1.79	2.78
69	3.59	3.00	3.42	3.57	3.43	3.34	3.71	3.54	3.10	3.33	3.06	3.72	3.23	0.87	1.61	1.81
70	3.04	2.96	3.11	3.37	3.35	3.03	2.16	3.19	3.18	2.40	2.59	2.08	3.25	2.59	1.89	2.13
71	3.38	3.44	3.43	3.78	3.16	3.43	3.13	2.94	3.03	3.74	3.23	3.05	2.60	1.82	1.42	2.81
72	NS	3.51	3.36	3.38	3.21	3.32	3.27	0.87	3.39	3.24	2.83	0.91	2.45	1.93	3.13	3.40
73	NS	NS	NS	NS	NS	2.24	2.49	3.43	2.99	3.07	1.79	2.99	3.16	1.03	1.64	0.94
74	NS	NS	NS	NS	NS	2.72	2.66	3.27	3.05	3.19	3.23	3.07	1.21	2.28	1.59	NS
75	NS	NS	NS	NS	NS	2.09	1.19	3.12	3.17	2.82	3.02	3.34	2.86	1.27	1.16	1.37
76	NS	NS	NS	NS	NS	2.69	3.14	3.08	3.22	3.07	3.42	3.26	2.92	2.83	3.21	NS
77	NS	NS	NS	NS	NS	3.09	2.61	2.73	3.02	2.71	3.12	3.29	2.67	2.46	1.65	1.53
78	NS	NS	NS	NS	NS	3.05	2.09	3.10	3.29	3.13	3.25	3.12	2.05	1.15	1.25	1.14
79	NS	NS	NS	NS	NS	2.16	2.49	2.51	2.98	2.69	2.82	2.37	2.93	0.92	1.69	2.30
80	NS	NS	NS	NS	NS	NS	NS	1.48	3.09	2.71	1.73	2.02	NS	1.88	1.29	2.70

NS = not sampled

Appendix E-3 (cont.)

Community measures for each staion 1997- 2012

Parameter = Number of Species

Station	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
01	79	55	70	68	77	90	74	70	55	43	50	75	81	46	88	98
02	76	43	47	84	99	85	85	58	65	28	50	57	48	67	66	79
04	86	47	73	109	95	74	92	72	64	44	71	79	60	64	86	97
06	74	38	59	86	80	66	84	65	68	41	75	65	48	60	60	59
25	96	52	64	87	107	76	80	69	55	30	56	69	64	63	74	96
28	73	63	89	92	105	76	96	59	85	77	75	74	78	75	84	107
31	41	35	28	33	65	42	38	45	28	29	24	38	37	41	23	20
32	64	63	62	75	86	60	63	59	62	45	65	57	67	58	67	62
33	66	42	58	85	96	72	58	49	54	47	52	62	53	56	63	86
34	80	53	84	92	106	78	73	53	66	69	92	96	82	54	92	95
35	94	NS	79	85	78	73	87	56	NS	NS	97	85	67	77	75	82
36	87	49	73	73	90	48	64	49	54	42	65	80	68	53	68	78
37	52	40	65	73	79	54	51	41	53	47	55	68	51	51	71	67
38	78	37	71	91	85	53	60	71	54	66	75	85	79	54	78	83
39	99	78	81	101	97	76	93	64	79	73	103	82	79	45	100	93
40	37	40	45	72	57	62	48	65	50	28	64	62	60	68	40	56
41	20	9	16	14	20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
42	16	10	12	15	12	NS	NS	13	NS	NS	NS	NS	NS	25	NS	NS
43	14	12	17	16	17	19	15	18	9	11	15	17	14	24	21	17
44	21	12	18	NS	NS	NS	NS	19	NS	NS	NS	NS	NS	NS	NS	NS
45	35	32	35	66	60	61	53	40	34	NS	48	32	50	34	44	33
46	16	13	NS	NS	NS	NS	NS	16	NS	NS	NS	NS	36	NS	NS	NS
47	29	31	32	18	40	50	48	37	29	18	32	32	42	NS	28	30
48	23	33	45	52	63	54	54	46	34	NS	40	46	71	37	29	45
49	15	11	13	NS	NS	NS	NS	12	NS	NS	NS	NS	NS	19	NS	NS
50	86	64	89	96	98	63	69	66	66	37	74	88	21	76	92	104
51	25	16	21	28	28	28	39	25	24	21	13	25	21	NS	21	27
52	25	14	20	34	37	48	38	36	24	17	23	25	68	23	28	27
53	85	52	87	98	93	83	75	60	87	56	87	79	36	82	90	89
54	60	34	31	50	65	57	78	45	37	29	26	37	39	49	39	33
55	62	33	40	53	79	73	62	65	42	23	30	49	73	59	51	NS
56	91	42	65	107	100	64	68	47	61	49	78	71	32	83	74	92
57	64	24	36	59	88	75	92	43	34	29	48	63	71	85	50	NS
58	99	54	75	103	101	81	91	66	74	70	87	95	72	65	108	92
59	73	46	62	102	77	90	89	56	67	48	59	78	51	85	91	105
60	83	48	84	98	99	80	91	75	43	50	71	89	62	92	81	88
61	75	52	72	88	87	78	73	62	79	61	83	68	63	74	72	76
62	73	55	89	108	89	85	83	84	73	56	82	82	68	78	95	88
63	86	48	77	112	89	84	75	56	65	61	73	61	47	79	79	80
64	69	54	51	108	82	64	92	61	44	52	73	70	62	57	63	73
65	82	68	67	96	103	86	90	63	52	47	60	67	63	64	98	75
66	86	51	65	91	100	72	79	68	38	65	96	81	59	82	101	91
67	78	57	81	108	91	73	83	74	31	53	84	78	67	77	87	70
68	78	53	65	93	78	62	71	75	63	76	102	98	53	77	90	88
69	86	46	68	94	85	84	91	75	73	45	93	114	46	86	66	86
70	79	60	59	78	98	75	84	60	54	45	50	68	78	52	79	52
71	92	48	84	100	94	78	88	58	60	70	64	83	56	78	90	83
72	NS	58	74	84	91	57	69	49	67	44	72	100	40	72	87	98
73	NS	NS	NS	NS	NS	74	74	61	48	39	39	60	57	72	50	76
74	NS	NS	NS	NS	NS	85	101	63	49	41	64	79	28	78	52	NS
75	NS	NS	NS	NS	NS	74	74	53	44	33	35	44	75	32	58	67
76	NS	NS	NS	NS	NS	66	91	71	74	64	98	74	61	89	124	NS
77	NS	NS	NS	NS	NS	95	89	57	52	48	57	73	73	66	72	94
78	NS	NS	NS	NS	NS	89	80	53	64	50	74	68	55	65	69	78
79	NS	NS	NS	NS	NS	82	82	40	59	45	57	74	32	77	60	70
80	NS	NS	NS	NS	NS	NS	NS	41	47	24	35	49	NS	32	39	40

NS = not sampled

Appendix E-3 (cont.)

Community measures for each staion 1997- 2012

Parameter = Pielou's Evenness

Station	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
01	0.61	0.83	0.82	0.83	0.75	0.68	0.57	0.72	0.90	0.80	0.54	0.80	0.60	0.46	0.43	0.69
02	0.67	0.66	0.88	0.67	0.74	0.61	0.63	0.79	0.80	0.74	0.51	0.73	0.37	0.39	0.35	0.64
04	0.63	0.83	0.78	0.75	0.71	0.77	0.71	0.82	0.78	0.72	0.43	0.78	0.50	0.23	0.50	0.66
06	0.72	0.77	0.76	0.79	0.80	0.54	0.56	0.67	0.75	0.83	0.81	0.68	0.17	0.36	0.23	0.63
25	0.59	0.74	0.82	0.82	0.75	0.68	0.69	0.75	0.87	0.82	0.52	0.77	0.65	0.40	0.41	0.69
28	0.66	0.59	0.77	0.77	0.64	0.72	0.55	0.75	0.72	0.82	0.75	0.83	0.70	0.49	0.67	0.69
31	0.72	0.81	0.90	0.81	0.48	0.27	0.52	0.83	0.87	0.73	0.83	0.67	0.50	0.67	0.22	0.65
32	0.77	0.78	0.77	0.73	0.66	0.61	0.67	0.67	0.77	0.74	0.62	0.54	0.71	0.56	0.70	0.69
33	0.76	0.92	0.81	0.81	0.61	0.65	0.72	0.79	0.67	0.82	0.78	0.38	0.31	0.39	0.55	0.66
34	0.76	0.86	0.73	0.65	0.68	0.69	0.73	0.77	0.68	0.66	0.70	0.74	0.73	0.79	0.73	0.73
35	0.80	NS	0.63	0.65	0.64	0.51	0.61	0.52	NS	NS	0.67	0.68	0.53	0.77	0.69	0.64
36	0.79	0.73	0.77	0.76	0.62	0.77	0.78	0.73	0.85	0.84	0.77	0.13	0.63	0.51	0.57	0.68
37	0.59	0.88	0.80	0.74	0.45	0.70	0.64	0.77	0.75	0.82	0.54	0.35	0.74	0.65	0.55	0.66
38	0.76	0.83	0.58	0.75	0.61	0.71	0.74	0.76	0.87	0.86	0.80	0.26	0.41	0.63	0.73	0.69
39	0.82	0.81	0.76	0.85	0.71	0.72	0.65	0.84	0.77	0.84	0.77	0.65	0.56	0.68	0.78	0.75
40	0.81	0.87	0.88	0.81	0.56	0.33	0.62	0.81	0.80	0.84	0.52	0.52	0.36	0.53	0.51	0.65
41	0.36	0.80	0.94	0.86	0.65	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.72
42	0.58	0.74	0.77	0.77	0.43	NS	NS	0.71	NS	NS	NS	NS	0.48	NS	NS	0.64
43	0.84	0.73	0.58	0.81	0.65	0.77	0.41	0.64	0.82	0.61	0.71	0.67	0.65	0.67	0.50	0.67
44	0.61	0.73	0.69	NS	NS	NS	NS	0.54	NS	NS	NS	NS	NS	NS	NS	0.64
45	0.77	0.81	0.71	0.71	0.67	0.54	0.49	0.79	0.88	NS	0.69	0.63	0.32	0.42	0.17	0.62
46	0.61	0.77	NS	NS	NS	NS	NS	0.62	NS	NS	NS	NS	NS	NS	NS	0.67
47	0.81	0.80	0.80	0.83	0.48	0.24	0.36	0.89	0.87	0.86	0.84	0.82	NS	0.80	0.34	0.70
48	0.83	0.85	0.76	0.75	0.60	0.59	0.52	0.74	0.87	NS	0.84	0.61	0.39	0.71	0.43	0.68
49	0.58	0.59	0.64	NS	NS	NS	NS	0.29	NS	NS	NS	NS	0.75	NS	NS	0.57
50	0.61	0.83	0.75	0.76	0.81	0.79	0.76	0.71	0.71	0.82	0.77	0.75	0.64	0.49	0.63	0.72
51	0.80	0.64	0.81	0.85	0.73	0.78	0.34	0.60	0.77	0.77	0.70	0.89	NS	0.70	0.24	0.69
53	0.76	0.88	0.78	0.80	0.77	0.67	0.76	0.87	0.81	0.81	0.70	0.79	0.71	0.34	0.29	0.45
54	0.60	0.87	0.86	0.81	0.41	0.51	0.38	0.76	0.85	0.82	0.68	0.81	0.38	0.45	0.41	0.56
55	0.52	0.89	0.68	0.59	0.70	0.55	0.57	0.79	0.83	0.81	0.51	0.72	0.81	0.13	0.26	NS
56	0.65	0.83	0.83	0.79	0.74	0.67	0.59	0.79	0.87	0.81	0.82	0.80	0.50	0.30	0.21	0.27
57	0.61	0.82	0.82	0.66	0.46	0.27	0.30	0.65	0.83	0.84	0.80	0.68	0.73	0.21	0.41	NS
58	0.65	0.80	0.83	0.76	0.66	0.62	0.60	0.75	0.72	0.87	0.66	0.73	0.76	0.61	0.68	0.71
59	0.72	0.40	0.77	0.75	0.68	0.77	0.51	0.78	0.80	0.71	0.70	0.58	0.86	0.51	0.25	0.33
60	0.74	0.83	0.71	0.81	0.79	0.68	0.57	0.79	0.80	0.80	0.72	0.82	0.77	0.19	0.30	0.27
61	0.71	0.84	0.83	0.76	0.78	0.72	0.63	0.82	0.82	0.73	0.76	0.63	0.85	0.23	0.29	0.23
62	0.79	0.84	0.82	0.75	0.76	0.82	0.78	0.82	0.78	0.83	0.68	0.79	0.75	0.37	0.35	0.40
63	0.68	0.86	0.83	0.77	0.72	0.71	0.61	0.83	0.82	0.89	0.77	0.62	0.72	0.22	0.46	0.35
64	0.67	0.79	0.84	0.79	0.65	0.76	0.54	0.74	0.87	0.77	0.70	0.75	0.78	0.35	0.29	0.64
65	0.69	0.83	0.85	0.79	0.65	0.80	0.73	0.83	0.82	0.86	0.78	0.65	0.83	0.67	0.46	0.64
66	0.84	0.72	0.77	0.78	0.77	0.81	0.83	0.80	0.88	0.79	0.69	0.81	0.46	0.46	0.41	0.51
67	0.74	0.79	0.82	0.81	0.73	0.80	0.83	0.83	0.86	0.81	0.75	0.77	0.82	0.21	0.38	0.42
68	0.85	0.70	0.80	0.75	0.80	0.75	0.78	0.82	0.59	0.73	0.69	0.79	0.81	0.56	0.40	0.62
69	0.80	0.79	0.81	0.78	0.77	0.76	0.83	0.82	0.72	0.87	0.68	0.79	0.84	0.20	0.38	0.41
70	0.69	0.72	0.76	0.77	0.73	0.70	0.50	0.79	0.80	0.63	0.66	0.49	0.75	0.66	0.43	0.54
71	0.75	0.89	0.78	0.82	0.69	0.79	0.71	0.73	0.74	0.88	0.78	0.69	0.65	0.42	0.32	0.64
72	NS	0.87	0.78	0.76	0.71	0.82	0.78	0.23	0.81	0.86	0.66	0.20	0.66	0.45	0.70	0.74
73	NS	NS	NS	NS	NS	0.52	0.59	0.84	0.77	0.84	0.49	0.73	0.78	0.24	0.42	0.22
74	NS	NS	NS	NS	NS	0.61	0.58	0.79	0.78	0.86	0.78	0.70	0.36	0.52	0.40	NS
75	NS	NS	NS	NS	NS	0.50	0.29	0.79	0.84	0.81	0.85	0.88	0.66	0.37	0.29	0.32
76	NS	NS	NS	NS	NS	0.67	0.70	0.73	0.75	0.74	0.75	0.76	0.71	0.63	0.67	NS
77	NS	NS	NS	NS	NS	0.68	0.59	0.68	0.77	0.70	0.77	0.77	0.62	0.59	0.39	0.34
78	NS	NS	NS	NS	NS	0.68	0.50	0.78	0.79	0.80	0.75	0.74	0.51	0.28	0.29	0.26
79	NS	NS	NS	NS	NS	0.50	0.58	0.69	0.73	0.71	0.70	0.55	0.85	0.21	0.41	0.54
80	NS	NS	NS	NS	NS	NS	NS	0.40	0.80	0.85	0.49	0.52	NS	0.54	0.35	0.73

NS = not sampled

Appendix E-4

Benthic infauna collected in 2010 Stations 78 and 79

STATION 78

Spiophanes norrisi	1704
Scoletoma luti	65
Photis spp.	46
Callianax pycna	36
Photis macinerneyi	28
Magelona sacculata	21
Glycinde spp.	20
Glycinde picta	17
Ischyrocerus pelagops	13
Diastylopsis dawsoni	12
Onuphis sp. A	12
Mediomastus spp.	11
Pacifoculodes barnardi	9
Amphiodia spp.	8
Magelona hartmanae	8
Apoprionospio pygmaea	7
Diastylis santamariensis	7
Tellina modesta	7
Tenonia priops	6
Argissa hamatipes	5
Nephtys caecoides	5
Euphilomedes carcharodonta	4
Modiolus capax	4
Phyllodoce hartmanae	4
Protomedeia penates	4
Saccella taphria	4
Caesia rhinetes	3
Clinocardium nuttallii	3
Onuphis spp.	3
Pleurogonium sp. SF1	3
Rhepoxynius fatigans	3
Eteone ?californica	2
Glycinde sp. SF1	2
Leukoma staminea	2
Macoma nasuta	2
Photis parvidons	2
Poecilochaetus johnsoni	2
Scoloplos armiger	2
Ampelisca milleri	1
Ampharete acutifrons	1
Ampharete labrops	1
Amphipoda	1
Axinopsida serricata	1
Dendrochirotida	1
Glycera macrobranchia	1
Kurtiella tumida	1
Leitoscoloplos pugettensis	1
Lumbrineris californiensis	1
Mactromeris catilliformis	1
Maldanidae	1
Nassariidae	1
Nematoda	1
Odostomia spp.	1
Onuphidae	1
Ostracoda sp. SF2	1
Paranemertes californica	1
Pectinaria californiensis	1
Phyllodocidae	1
Prionospio lighti	1
Rictaxis punctocaelatus	1
Scoloplos sp. SF1	1
Sthenelais verruculosa	1
Terebellidae	1
Travisia gigas	1
Turridae	1

Appendix E-4 (cont.)

Benthic infauna collected in 2010 Stations 78 and 79

STATION 79

Spiophanes norrisi	5733
Photis spp.	186
Scoletoma luti	162
Mediomastus spp.	121
Photis macinerneyi	102
Pacifoculodes barnardi	35
Glycinde picta	34
Tellina modesta	34
Onuphis spp.	33
Paradialychone eiffelturris	33
Apoprionospio pygmaea	32
Onuphis sp. A	22
Glycinde spp.	20
Callianax pycna	19
Leukoma staminea	18
Pleurogonium sp. SF1	13
Kurtiella tumida	12
Amphiodia spp.	11
Lineidae	11
Leitoscoloplos pugettensis	10
Sthenelais verruculosa	9
Cylichna spp.	7
Macoma nasuta	7
Macoma spp.	7
Eteone sp. SF4	6
Odostomia spp.	6
Pandora bilirata	6
Pectinaria californiensis	6
Bivalvia	5
Diastylopsis dawsoni	5
Nephtys caecoides	5
Tenonia priops	5
Ampharete acutifrons	4
Cardiidae	4
Clinocardium nuttallii	4
Mactromeris catilliformis	4
Magelona hartmanae	4
Ampharetidae	3
Glycera macrobranchia	3
Magelona sacculata	3
Opheliidae	3
Podarkeopsis glabrus	3
Ampharete labrops	2
Bathycopea daltonae	2
Eumida longicornuta	2
Ischyrocerus pelagops	2
Nassariidae	2
Paranemertes californica	2
Scoloplos sp. SF1	2
Siliqua lucida	2
Stylatula spp.	2
Synidotea consolidata	2
Tubulanus pellucidus	2
Amaeana occidentalis	1
Aricidea (Aedicira) pacifica	1
Aricidea (Aedicira) sp. A	1
Aricidea (Aricidea) sp. SF3	1
Axinopsida serricata	1
Caesia rhinetes	1
Cylichna attonsa	1
Dendrochirotida	1
Diastylis santamariensis	1
Edotia sublittoralis	1
Gastropoda	1
Glycinde sp. SF1	1
Kurtziella plumbea	1
Mediomastus acutus	1
Modiolus rectus	1
Phoronis spp.	1
Photis parvidons	1
Phyllodoce hartmanae	1
Rhepoxynius abronius	1
Sabellidae	1
Spiophanes berkeleyorum	1
Streptosyllis sp. SF1	1
Tecticeps convexus	1
Typosyllis farallonensis	1

APPENDIX F

DEMERSAL FISH AND EPIBENTHIC INVERTEBRATES

APPENDIX F

DEMERSAL FISH AND EPIBENTHIC INVERTEBRATES, 1997 to 2008

Appendix F-1

SWOO Regional Monitoring Program community trawls 1982 - 2008 by station and year with the number of times sampled per year and (the number of trawls per station) and additional trawls required for bioaccumulation 1999 - 2008

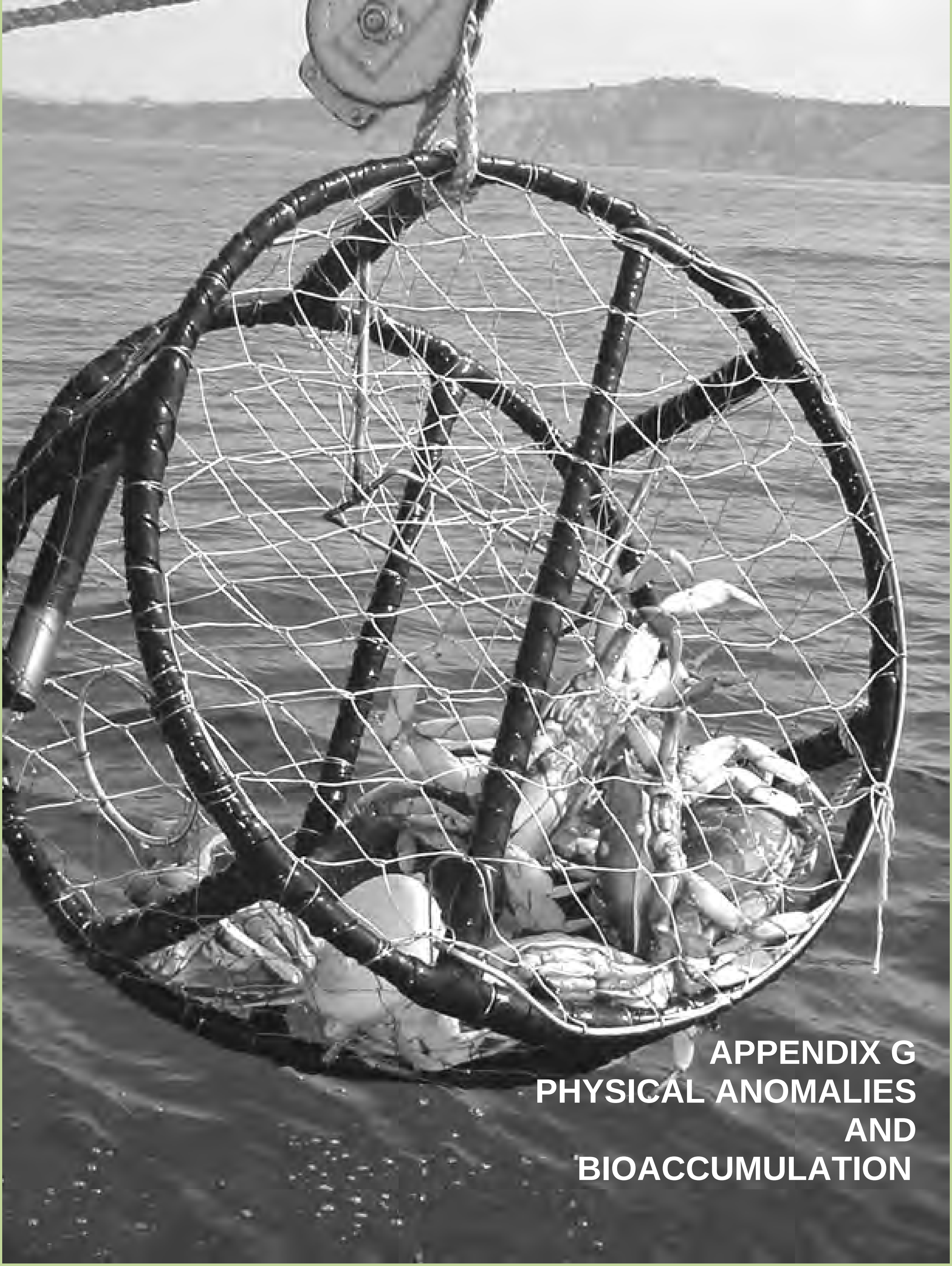
Station/Year	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
01	1(2)	2(2)	2(2)			3(2)	3(2)	3(2)	2(2)	2(2)	2(2)	1(2)	2(2)	2(2)	2(2)	See Appendix F-2	See Appendix F-2	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)
02	1(2)	2(2)	2(2)				3(2)											1(1)	1(1)	1(1)	1(1)						
03	1(2)	2(2)	2(2)						2(2)	2(2)																	
04	1(2)	2(2)	2(2)			3(2)		3(2)			2(2)	1(2)	2(2)	2(2)	2(2)			1(1)	1(1)	1(1)	1(1)						
05	1(2)	2(2)	2(2)			3(2)	3(2)	3(2)	2(2)	2(2)																	
06	1(2)	2(2)	2(2)			3(2)	3(2)	3(2)			2(2)	1(2)	2(2)	2(2)	2(2)			1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)
07						3(2)	3(2)	3(2)																			
28																		1(1)	1(1)	1(1)	1(1)						
29						3(2)	3(2)	3(2)																			
30						3(2)	3(2)	3(2)	2(2)	2(2)																	
31											2(2)	1(2)	2(2)	2(2)	2(2)			1(1)	1(1)	1(1)	1(1)						
32																		1(1)	1(1)	1(1)	1(1)						
34																											
35																		1(1)	1(1)	1(1)	1(1)						
36																		1(1)	1(1)	1(1)	1(1)						
37																		1(1)	1(1)	1(1)	1(1)						
38																		1(1)	1(1)	1(1)	1(1)						
39																		1(1)	1(1)	1(1)	1(1)						
42																		1(1)	1(1)	1(1)	1(1)						
50																		1(1)	1(1)	1(1)	1(1)						
53																		1(1)	1(1)	1(1)	1(1)						
57																		1(1)	1(1)	1(1)	1(1)						
62																		1(1)	1(1)	1(1)	1(1)						
63																											
65																		1(1)	1(1)	1(1)	1(1)						
66																		1(1)	1(1)	1(1)	1(1)						
70																		1(1)	1(1)	1(1)	1(1)						
74																					1(1)						
Number of additional trawls required to obtain sufficient English sole for bioaccumulation analyses:																		12	0	3	12	11	10	21	6	8	11

Appendix F-2

SWOO Regional Monitoring Program community trawls 1997 - 1998 by station and year with the number of times sampled per year and (the number of trawls per station)

Stations sampled within strata were not at the same location year to year

Station	1997	1998
A-1	1(1)	
A-2	1(1)	
A-3	1(1)	
A-4	1(1)	
B-1	1(1)	
B-2	1(1)	
B-3	1(1)	
B-4	1(1)	
C-1	1(1)	
C-2	1(1)	
C-3	1(1)	
C-4	1(1)	
D-1	1(1)	
D-2	1(1)	
D-3	1(1)	
D-4	1(1)	
E-1	1(1)	
E-2	1(1)	
E-3	1(1)	
E-4	1(1)	
F-1	1(1)	
F-2	1(1)	
F-3	1(1)	
F-4	1(1)	
G-1	1(1)	
G-2	1(1)	
G-3	1(1)	
G-4	1(1)	
H-1	1(1)	
H-2	1(1)	
H-3	1(1)	
H-4	1(1)	
A-1		1(1)
A-2		1(1)
A-3		1(1)
B-1		1(1)
B-2		1(1)
B-3		1(1)
D-1		1(1)
D-2		1(1)
D-3		1(1)
E-1		1(1)
E-2		1(1)
E-3		1(1)
E-4		1(1)
F-1		1(1)
F-2		1(1)
F-3		1(1)
G-1		1(1)
G-2		1(1)
G-3		1(1)
H-1		1(1)
H-2		1(1)



APPENDIX G
PHYSICAL ANOMALIES AND BIOACCUMULATION

APPENDIX G

PHYSICAL ANOMALIES AND BIOACCUMULATION, 1997 to 2012

Appendix G-1

Characteristics of Dungeness crab used for bioaccumulation analyses, collected from SWOO Reference and Outfall

		Survey year															
	Parameter	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Reference Area	Mean carapace width (mm)	168	ND	166	179	180	185	188	183	179	188	187	145	174	186	186	182
	Mean weight/crab (g)	663	ND	608	745	734	938	870	750	740	859	759	456	677	801	803	791
	% Lipid in muscle tissue	0.01	0.07	0.70	0.31	0.20	0.05	0.03	0.04	0.04	0.04	0.04	0.04	2.13	0.30	0.47	0.67
	% Lipid in hepatopancreas tissue	4	5	27	18	14	14	23	24	20	20	20	20	14	9	9	22
	average # organisms/replicate	9	ND	8	10	10	10	10	10	10	10	10	10	9	10	10	10
Outfall Area	Mean carapace width (mm)	179	ND	176	185	182	196	190	184	186	189	188	139	175	184	190	185
	Mean weight/crab (g)	768	ND	667	830	740	978	840	760	782	516	718	406	680	795	880	818
	% Lipid in muscle tissue	0.03	0.08	0.40	0.27	0.25	0.06	0.03	0.05	0.05	0.04	0.05	0.05	2.24	0.55	0.40	0.91
	% Lipid in hepatopancreas tissue	3	4	26	12	15	12	19	20	18	18	18	18	12	5	14	25
	average # organisms/replicate	10	ND	11	10	10	10	10	10	10	10	10	10	9	10	10	10

ND = no data available

Lipids content analyses performed by one lab for years 1997-1998 and a different lab for subsequent years

Appendix G-2

Reporting and detection (Det.) limits (ppb) for organic compounds assessed 1997-2012. (NA = not assessed)

		1997 Reporting Limit	1998 Reporting Limit	1999 Det. Limit	2000 Det. Limit	2001 Det. Limit	2002 Det. Limit	2003 Det. Limit	2004 Det. Limit	2005 Det. Limit	2006 Det. Limit	2007 Det. Limit	2008 Det. Limit	2009 Det. Limit	2010 Det. Limit	2011 Det. Limit	2012 Det. Limit
4,4'-DDE		10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
4,4'-DDD		10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
4,4'-DDT		10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
Naphthalene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Acenaphthylene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Acenaphthene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Fluorene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Phenanthrene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Anthracene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Fluoranthene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Pyrene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Benz[a]anthracene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Chrysene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Benzo[b]fluoranthene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Benzo[k]fluoranthene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Benzo[e]pyrene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Perylene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Benzo[a]pyrene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Indeno[1,2,3-cd]pyrene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Dibenz[a,h]anthracene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
Benzo[ghi]perylene		10	10	10	2	2	2	2	2	2	2	2	2	2	2	2	2
2,4'-Dichlorobiphenyl	PCB 008	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',5-Trichlorobiphenyl	PCB 018	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,4,4'-Trichlorobiphenyl	PCB 028	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',5,5'-Tetrachlorobiphenyl	PCB 052	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,5'-Tetrachlorobiphenyl	PCB 044	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3',4,4'-Tetrachlorobiphenyl	PCB 066	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',4,5,5'-Pentachlorobiphenyl	PCB 101	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
3,4,4',5-Tetrachlorobiphenyl	PCB 081	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2
3,3',4,4'-Tetrachlorobiphenyl	PCB 077	NA	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2',3,4,4',5-Pentachlorobiphenyl	PCB 123	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2
2,3',4,4',5-Pentachlorobiphenyl	PCB 118	10	10	NA	2	NA	NA	NA	NA	NA	2	2	2	2	2	2	2
2,2',4,4',5,5'-Hexachlorobiphenyl	PCB 153	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
3,3',4,5,5'-Pentachlorobiphenyl	PCB 127	NA	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,3',4,4'-Pentachlorbiphenyl	PCB 105	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4,4',5-Hexachlorobiphenyl	PCB 137	NA	NA	4	2	2	2	2	2	2	2	2	2	2	2	2	2
3,3',4,4',5-Pentachlorobiphenyl	PCB 126	NA	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4',5,5',6-Heptachlorobiphenyl	PCB 187	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,3',4,4'-Hexachlorobiphenyl	PCB 128	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,3',4,4',5'-Hexachlorobiphenyl	PCB 157	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2
2,2',3,4,4',5,5'-Heptachlorobiphenyl	PCB 180	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,3',4,4',5-Heptachlorobiphenyl	PCB 170	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,3',4,4',5,5'-Heptachlorobiphenyl	PCB 189	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2
2,2',3,3',4,4',5,6-Octachlorobiphenyl	PCB 195	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,3',4,4',5,5',6-Nonachlorobipheny	PCB 206	NA	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
Decachlorobiphenyl	PCB 209	NA	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,4',5-Trichlorobiphenyl	PCB 31	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2',3,4-Trichlorobiphenyl	PCB 33	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',4',5-Tetrachlorobiphenyl	PCB 49	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,4,4',5-Tetrachlorobiphenyl	PCB 74	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3',4',5-Tetrachlorobiphenyl	PCB 70	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,5',6-Pentachlorobiphenyl	PCB 95	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,3',4'-Tetrachlorobiphenyl	PCB 56	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,4,4'-Tetrachlorobiphenyl	PCB 60	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',4,4',5-Pentachlorobiphenyl	PCB 99	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3',4,5-Pentachlorobiphenyl	PCB 97	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4,5'-Pentachlorobiphenyl	PCB 87	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,3',4',6-Pentachlorobiphenyl	PCB 110	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,4,4',5-Pentachloropbiphenyl	PCB 114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2
2,2',3,5,5',6-Hexachlorobiphenyl	PCB 151	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4',5',6-Hexachlorobiphenyl	PCB 149	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,3',4,6'-Hexachlorobiphenyl	PCB 132	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4,5,5'-Hexachlorobiphenyl	PCB 141	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,3',4,4',6-Hexachlorobiphenyl	PCB 158	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4,4',5',6-Heptachlorobiphenyl	PCB 183	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3',4,4',5,5'-Hexachlorobiphenyl	PCB 167	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2
2,2',3,3',4,5,6'-Heptachlorobiphenyl	PCB 174	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,3',4',5,6-Heptachlorobiphenyl	PCB 177	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,3,3',4,4',5-Hexachlorobiphenyl	PCB 156	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
3,3',4,4',5,5'-Hexachlorobiphenyl	PCB 169	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2
2,2',3,3',4,5,5',6'-Octachlorobiphenyl	PCB 201	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4,4',5,5',6-Octachlorobiphenyl	PCB 203	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,3',4,4',5,5'-Octachlorobiphenyl	PCB 194	10	10	4	2	2	2	2	2	2	2	2	2	2	2	2	2
2,2',3,4,4',5-Hexachlorobiphenyl	PCB 138	10	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix G-3

Organic compounds detected in crab tissues at reference and outfall areas 1997-2012 (wet weight, ppb). Where no value is indicated, all replicates were below detection limits; some values may be less than the value indicated, as when one or more replicates were below detection limits.

		Crab Muscle																															
		SWOO Reference area																SWOO Outfall area															
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
PESTICIDES:	4,4'-DDE		13	5	13		4	11	10	11	10	7	10	6	8	9	3		21	5	13		4	10	8	13	8	4	15	4	9	4	5
	4,4'-DDD				2						4																2						
	4,4'-DDT						4				3												2				2	12					
PAHs:	Acenaphthene				28	32		12	4	11		6	5	4	2		2				21			3		6			3	8	2		2
	Acenaphthylene				8	41	17			7	2	4	4	3	2						5	15	5			8	2		2	5	2		
	Anthracene				6				2	2	2															2	2						
	Benz[a]anthracene						3	2															2										
	Benzo[b]fluoranthene																																
	Benzo[k]fluoranthene						5			3																6	3						
	Benzo[ghi]perylene						2														3												
	Benzo[a]pyrene																																
	Benzo[e]pyrene									2																2							
	Chrysene						5	2						2									3				3					2	2
	Dibenz[a,h]anthracene						3																										
	Fluoranthene						79	7	3			19											48	2	4			17					
	Fluorene					34	35	3	3	6		15		2	3								21		2	4		7		3	3		
	Indeno[1,2,3-cd]pyrene						4			2																2							
	Naphthalene	22			51	181	113	17				9	2.2	22	5			25			40	31	68	4				8		3	4		
	Perylene																																
	Phenanthrene					36	159	11	5			33			4								94		8			31			3		
	Pyrene						68	3	3			13		3									41		4			12				2	
PCBs:	PCB 008																																
	PCB 018																																
	PCB 028				3																												
	PCB 31				3																												
	PCB 33				2																												
	PCB 044																																
	PCB 49				2																												
	PCB 052																																
	PCB 56				3																												
	PCB 60				3																												
	PCB 066																																
	PCB 70				2																												
	PCB 077																																
	PCB 74																																
	PCB 081																																
	PCB 87				3																												
	PCB 95																																
	PCB 97																																
	PCB 99																																
	PCB 101																																
	PCB 105																																
	PCB 110																																
	PCB 114																																
	PCB 118																																
	PCB 123																																
	PCB 126																																
	PCB 127																																
	PCB 128																																
	PCB 132				2			2		2	2	2									3			2		2	2						
	PCB 137				2																			2									
	PCB 138																																
	PCB 141																																
	PCB 149																																
	PCB 151																																
	PCB 153				2				2	2														2		2			2				
	PCB 156				4																												
	PCB 157																																
	PCB 158				2																												
	PCB 167																																
	PCB 169																																
	PCB 170																																
	PCB 174				3																												
	PCB 177																																
	PCB 180																																
	PCB 183																																
	PCB 187																																
	PCB 189																																
	PCB 194																																
	PCB 195																																
	PCB 201																																
	PCB 203																																
	PCB 206																																
	PCB 209																																

Appendix G-3 (cont.)

Organic compounds detected in crab tissues at reference and outfall areas 1997-2012 (wet weight, ppb). Where no value is indicated, all replicates were below detection limits; some values may be less than the value indicated, as when one or more replicates were below detection limits.

		Crab Hepatopancreas																															
		SWOO Reference area																SWOO Outfall area															
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
PESTICIDES:	4,4'-DDE	217	473	380	268	131	153	121	86	70	46	115	67	101	59	71	32	290	460	195	169	130	193	135	85	61	57	140	59	65	48	61	43
	4,4'-DDD				2	3	2					3									2	2	2					3					
	4,4'-DDT	14		142		2												17		105													
PAHs:	Acenaphthene							23		12		4		2										21		11				3			
	Acenaphthylene				3			11		2		4	2								4			9		2		3	3				
	Anthracene				3			3													3			2				3					
	Benz[a]anthracene																											3					
	Benzo[b]fluoranthene					3																2										2	
	Benzo[k]fluoranthene					3				3						2						2				2							
	Benzo[ghi]perylene					3																2											
	Benzo[a]pyrene					2																											
	Benzo[e]pyrene																																
	Chrysene					3		2			2	3									2	2			2		2	5				3	
	Dibenz[a,h]anthracene																					3											
	Fluoranthene						16	21			2	56											12	11	2		3	60					
	Fluorene						12	5		10		19		5									10			10		19		3			
	Indeno[1,2,3-cd]pyrene					2																3											
	Naphthalene	18					32	38	7			42	5	2	4								25	24	31			37	3	5	4	3	
	Perylene					3																											
	Phenanthrene						37	46				79	3		5				11				29	24	2			83	3		4		
	Pyrene						13	18				55							37				10	8	2			59				3	
PCBs:	PCB 008					2										5																	
	PCB 018					3																											
	PCB 028					3												10															
	PCB 31					3																											
	PCB 33																																
	PCB 044					3																											
	PCB 49			5		3														4	2												
	PCB 052			4	2	3						2								4	2	2						3					
	PCB 56																																
	PCB 60																																
	PCB 066					3														10													
	PCB 70					3																											
	PCB 077																																
	PCB 74					2																											
	PCB 081																																
	PCB 87			5								3	3	2														4		3			
	PCB 95			5	2	2	2													95	2	3	2										
	PCB 97					2	2																2										
	PCB 99		12	14	4	4	5		2									20	11	6	4	4	5										
	PCB 101	12	17	10		6	8	4	2			5	4	4	2	3	3	14	16	5		6	6		3			7	3	4		4	4
	PCB 105					3														4													
	PCB 110			7	2	5	5	2	2				6	2						5	3	6	4							3			
	PCB 114																																
	PCB 118				4	7	6	4	2		2	5	4	4		3	2		11		5	6	5		3		2	7	3	4		3	3
	PCB 123																																
	PCB 126			12	2	4	3		2											5	2	3	2										
	PCB 127					3														4													
	PCB 128			5		3	2													4								3					
	PCB 132			73	31	29	40	20	17	9	7	24	13	12	7			30		48	28	31	36		10	7	2	28	12	9	8		
	PCB 137			29	4	14	17	12	3	2	4	6	6	8	4	8	7			15	8	14	13		4	2	3	11	5	7	4	9	10
	PCB 138	20	36																31														
	PCB 141			4	2		2						4							4			2										
	PCB 149		15	23	7	9	11	6	4	2	3	7	5	6	2	3	3		14	14	7	11	11		3	2	2	8	4	5	3	4	4
	PCB 151			7	2		2													5	2		2										
	PCB 153	24	45	41	15	20	22	15	7	7	7	17	10	13	6	9	7	24	41	22	18	21	21		10	4	5	28	9	12	6	9	11
	PCB 156			4	2		2													4													
	PCB 157																																
	PCB 158			39	15	11	15	10	4	2		8	3	6	3			27		21	13	11	15		3	2		9	4	6	3		
	PCB 167																											2					
	PCB 169																																
	PCB 170			7	3	5	5	3	2		2	4	2							4	4	4	4		2		2	5					2
	PCB 174			5	2	2	3														2	2	3										
	PCB 177			8	3	3	4	2				3								5	3	3	4		2			3					
	PCB 180		20	18	9	10	12	7	4		4	9	5	7	3	4	4	14	14	9	10	11	10		5		3	14	5	6	3	4	5
	PCB 183			11	3	2	4		2			5						11		15	2	3	3					3					
	PCB 187		17	16	7	11	10	8	4	3	3	3	8	7	3	4	4	14	15	10	7	11	9		5	2	3	14	5	7	3	4	5
	PCB 189																																
	PCB 194			4	2	2	3		2												2	2	3					3					
	PCB 195					3																											
	PCB 201			5	2	2	3		2												2	3	3										
	PCB 203			5	2	2	3													4	2	2	2					2					
	PCB 206					3	2																										
	PCB 209					3																											

Appendix G-4

Detection limits (DL) for trace metals in tissues, 1997-2012

	1997 (µg/g)	1998 (µg/g)	1999 (µg/g)	2000 (µg/g)	2001 (µg/g)	2002 (µg/g)	2003 (µg/g)	2004 (µg/g)	2005 (µg/g)
Silver (Ag)	0.081	0.025	0.03	0.025	0.02	0.015	0.030	0.030	0.010
Aluminum (Al)	1.04	0.5	0.50	0.500	0.3	0.26	0.300	0.300	0.200
Arsenic (As)	0.49	1	1.00	1.00	1	0.5	0.500	0.500	0.100
Cadmium (Cd)	0.037	0.01	0.10	0.100	0.1	0.05	0.100	0.100	0.010
Chromium (Cr)	0.22	0.1	0.10	0.100	0.1	0.05	0.100	0.100	0.100
Copper (Cu)	0.088	0.1	0.10	0.100	0.3	0.05	0.100	0.100	0.100
Iron (Fe)	0.43	0.5	0.50	0.500	0.2	0.26	0.500	0.500	0.200
Mercury (Hg)	0.020	0.02	0.02	0.0200	0.005	0.010	0.010	0.010	0.020
Manganese (Mn)	0.016	0.1	0.10	0.100	0.4	0.05	0.100	0.100	0.050
Nickel (Ni)	0.031	0.035	0.04	0.040	0.03	0.10	0.100	0.100	0.200
Lead (Pb)	0.23	0.09	0.100	0.100	0.3	0.10	0.200	0.200	0.100
Selenium (Se)	0.92	1	1.00	1.000	0.03	0.51	0.500	0.500	2.000
Zinc (Zn)	0.31	0.1	0.10	0.100	0.1	0.05	0.100	0.100	0.100

	2006 (mg/kg)	2007 (mg/Kg)	2008 (mg/Kg)	2009 (mg/Kg)	2010 (mg/Kg)	2011 (mg/Kg)	2012 (mg/Kg)
Silver (Ag)	0.008	0.001	0.002	0.001	0.007	0.006	0.003
Aluminum (Al)	0.15	0.060	0.76	3.9	2.5	2.12	16
Arsenic (As)	5.52	0.03	0.10	0.05	0.17	0.17	0.08
Cadmium (Cd)	0.070	0.005	0.007	0.01	0.015	0.09	0.04
Chromium (Cr)	0.58	0.003	0.08	0.02	0.01	0.13	0.06
Copper (Cu)	0.110	0.051	0.030	0.06	0.07	0.43	0.5
Iron (Fe)	0.15	0.60	0.76	0.325	2.5	2.13	2
Mercury (Hg)	0.016	0.003	0.018	0.015	0.02	0.013	0.006
Manganese (Mn)	0.150	0.009	0.023	0.16	0.07	0.06	0.5
Nickel (Ni)	0.480	0.003	0.005	0.03	0.05	0.17	0.08
Lead (Pb)	0.14	0.01	0.02	0.02	0.05	0.11	0.05
Selenium (Se)	3.72	0.02	0.05	0.01	0.07	0.06	0.03
Zinc (Zn)	0.34	0.08	0.76	0.6	0.51	1.28	0.6

Appendix G-5

Mean concentrations (ppm, dry weight) of trace metals detected in tissues of Dungeness

	Crab Muscle							
	Reference area				Outfall area			
	1997	1998	1999	2000	1997	1998	1999	2000
Silver	NS	0.76	0.76	0.51	NS	3.30	1.07	0.58
Aluminum	NS	36.1	43.8	20.2	NS	7.6	13.8	6.7
Arsenic	NS	92.0	84.6	76.4	NS	91.5	91.0	94.4
Cadmium	NS	0.03	0.26	0.14	NS	0.06	< 0.10	< 0.10
Chromium	NS	0.10	1.38	0.30	NS	0.10	1.12	0.28
Copper	NS	43.0	46.3	29.3	NS	41.5	43.7	**37.1**
Iron	NS	17.3	52.7	24.3	NS	19.3	32.9	21.7
Mercury	NS	0.21	0.63	0.50	NS	0.25	0.67	0.51
Manganese	NS	0.7	1.4	0.8	NS	0.7	1.1	0.8
Nickel	NS	0.09	0.18	0.10	NS	0.19	0.15	0.07
Lead	NS	0.19	0.20	< 0.10	NS	0.11	0.19	0.12
Selenium	NS	3.4	4.7	3.2	NS	3.3	4.4	4.0
Zinc	NS	184	200	163	NS	176	184	168

	Crab Hepatopancreas							
	Reference area				Outfall area			
	1997	1998	1999	2000	1997	1998	1999	2000
Silver	NS	4.02	10.70	9.45	NS	6.09	11.82	6.40
Aluminum	NS	11.9	23.0	22.9	NS	2.5	23.2	10.2
Arsenic	NS	86.9	115.2	136.1	NS	112.1	83.8	121.3
Cadmium	NS	82.50	86.48	103.20	NS	79.30	75.75	101.33
Chromium	NS	0.15	0.29	0.29	NS	0.11	0.34	0.33
Copper	NS	170.2	315.8	395.6	NS	227.5	412.6	291.0
Iron	NS	255.9	262.2	321.9	NS	247.3	296.4	395.1
Mercury	NS	0.26	0.43	0.54	NS	0.28	0.73	0.58
Manganese	NS	6.0	8.9	7.4	NS	7.0	7.8	9.0
Nickel	NS	4.03	2.33	3.06	NS	3.08	3.78	4.30
Lead	NS	0.18	0.20	0.25	NS	0.15	0.32	0.29
Selenium	NS	11.8	13.9	17.1	NS	13.3	14.5	20.1
Zinc	NS	159	128	198	NS	151	152	320

NS = No sample data

Bold font indicates statistically significantly higher than corresponding tissue at other area; one-tailed Student's T-test, unequal variance, $\alpha = 0.05$.