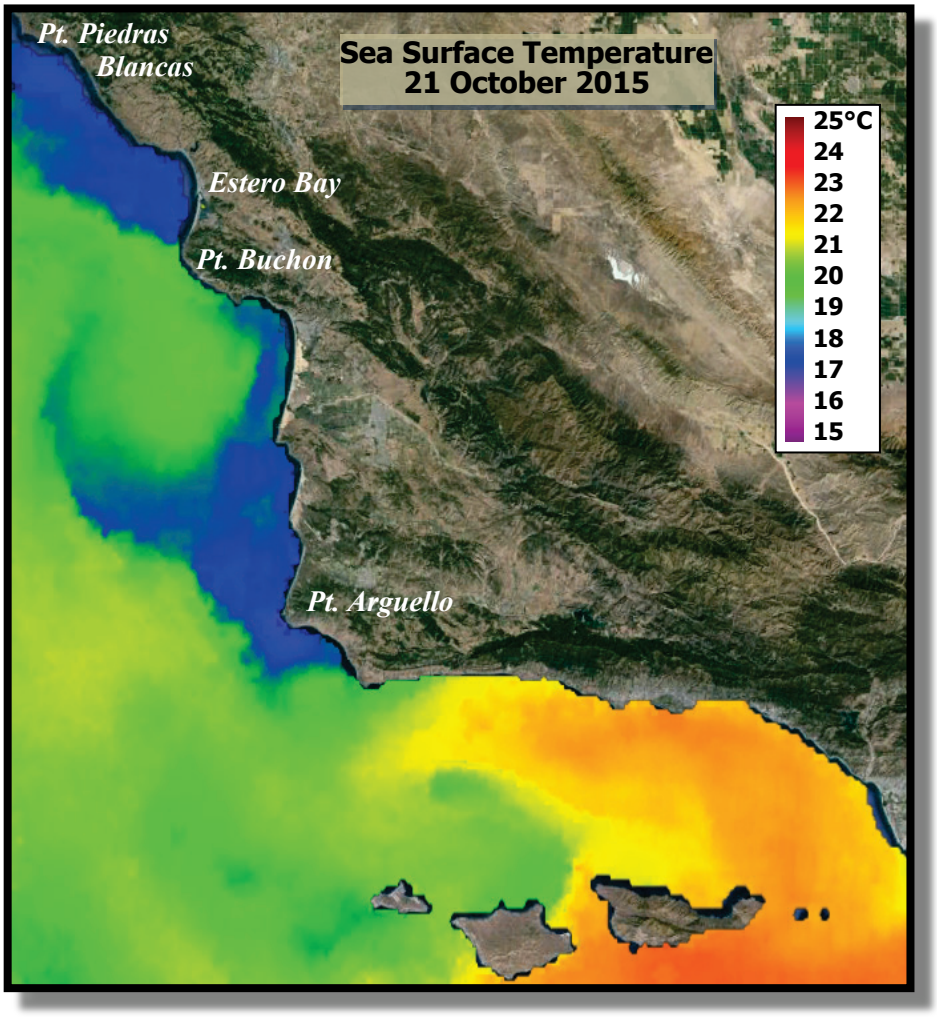
City of Morro Bay and
Cayucos Sanitary District

OFFSHORE MONITORING AND REPORTING PROGRAM

2015 ANNUAL REPORT



Marine Research Specialists

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Report to the

City of Morro Bay and Cayucos Sanitary District

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Morro Bay, California 93442
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OFFSHORE MONITORING AND REPORTING PROGRAM

2015 ANNUAL REPORT

Prepared by
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Submitted by
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March 2016

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Mr. Bruce Keogh
Wastewater Division Manager
City of Morro Bay
955 Shasta Avenue
Morro Bay, CA 93442

29 March 2016

Reference: 2015 Annual Monitoring Report

Dear Mr. Keogh:

Enclosed is the referenced report. It documents the continued effectiveness of the treatment process, the absence of marine impacts, and compliance with the discharge limitations and reporting requirements specified in the NPDES discharge permit.

Please contact the undersigned if you have any questions regarding this report.

Sincerely,

Douglas A. Coats

Douglas A Coats
Project Manager

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Bruce Keogh

Mr. Bruce Keogh
Wastewater Division Manager
City of Morro Bay

Date March 30, 2016

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LIST OF ACRONYMS AND DEFINITIONS

ACOE	**U.S. Army Corps of Engineers**
Anomaly	**An anomaly is a deviation or departure from ambient (mean) conditions in one of the six measured seawater properties: salinity, temperature, density, dissolved oxygen, alkalinity, or transmissivity. The amplitude of the anomaly is quantified as the difference between the measured seawater property at a given station and the mean of that property measured at all other stations at the same depth level or distance above the bottom.**
Anthropogenic	**Changes to the environment induced by human activities**
APCD	**San Luis Obispo County Air Pollution Control District**
ASP	**Amnesic Shellfish Poisoning**
BCCE	**Brown and Caldwell Consulting Engineers**
BEHP	**Bis 2-Ethyl Hexyl Phthalate is a compound that leaches out of plastics and is ubiquitous in the environment.**
BIP	**A Balanced Indigenous Population is as an ecological community that exhibits characteristics similar to those of nearby, healthy communities existing under comparable but unpolluted environmental conditions.**
BBL	**A benthic boundary layer is often synonymous with a bottom nepheloid layer (*see below* BNL) and is associated with increased turbulence and mixing caused by the decrease in current flow immediately above the seafloor that is required to meet the zero-velocity boundary condition at the seafloor.**
BNL	**The bottom nepheloid layer is a common phenomenon on continental shelves where increased turbidity near the seafloor is caused by the presence of naturally occurring particulates formed from light-weight flocs of detritus. Oscillatory bottom currents generated by passing surface gravity waves easily suspend these flocs.**
BMPs	**Best Management Practices**
BOD_5	**Five-day biochemical oxygen demand**
BTEX	**Benzene, toluene, ethyl benzene, and xylene**
Cal/OSHA	**California Department of Industrial Relations, Division of Occupational Safety and Health**
CAM-17	**CAM is the California Administrative Manual and CAM-17 refers to the list of 17 heavy metals identified in the California Code of Regulations (CCR 2003), Title 22, Chapter 11: Identification and Listing of Hazardous Waste.**
CCLEAN	**Central Coast Long-term Environmental Assessment Network**
CEQA	**California Environmental Quality Act**
CCR	**California Code of Regulations (CCR 2003)**
CDFG	**California Department of Fish and Game**
CDP	**Coastal Development Permit**

LIST OF ACRONYMS AND DEFINITIONS
(Continued)

Coordinate Datum	**All coordinates cited in this report are referenced to the WGS84 datum**
COP	**The California Ocean Plan (SWRCB 2005), which is regularly revised but the 2005 edition was in force when the current NPDES discharge permit was issued to MBCSD.**
CTD	**A CTD is an instrument package that continuously records conductivity, temperature, and depth, in addition to a number of other physical oceanographic parameters in the water column.**
CV	**A coefficient of variation is used to compare the relative amounts of variation in populations having different means. It is the standard deviation expressed as a percentage of the mean.**
DDT	**Dichloro Diphenyl Trichloroethane, a chlorinated pesticide**
DEHP	**Di(2-ethylhexyl) phthalate synonymous with Bis(2-ethylhexyl) phthalate**
dEIR	**Draft Environmental Impact Report**
DHS	**California Department of Health Services**
DMR	**Discharge Monitoring Report**
DMR-QA	**Discharge Monitoring Report Quality Assurance (DMR-QA) Study administered by the United States Environmental Protection Agency**
DO	**Dissolved Oxygen**
EIR	**Environmental Impact Report**
ELAP	**California Department of Health Services, Environmental Laboratory Accreditation Program**
ENSO	**El Niño–Southern Oscillation**
EQ	**Exceptional Quality is a standard for compost that meets the Federal and State requirements for beneficial reuse as a soil amendment in the local community.**
ERL	**Effects Range Low is a sediment toxicity concentration below which adverse biological effects are not expected to occur.**
ERM	**Effects Range Median is a sediment toxicity concentration above which adverse biological effects are expected to occur.**
ESA	**Endangered Species Act**
FOG	**Fats, Oils, and Greases**
GPM	**Gallons per Minute**
HAB	**Harmful Algal Bloom**
Hazwopper	**Hazardous Waste Operations and Emergency Response**
HCl	**Hydrochloric Acid**

LIST OF ACRONYMS AND DEFINITIONS
(Continued)

HCH	**Isomers of hexachlorocyclohexane including alpha, beta, gamma (lindane), and delta**
I&I	**Inflow and Infiltration**
Isopycnal	**A surface of constant seawater density**
JPA	**The Joint Powers Agreement between the City of Morro Bay and the Cayucos Sanitary District (MBCSD) outlines the contractual agreement between the two agencies for the operation of the WWTP**
Leachate	**A solution formed by leaching, especially a solution containing contaminants picked up through the leaching of soil**
LC_{50}	**Lethal 50% Concentration is a toxicity endpoint where 50% of the specimens will die after a 96-hour exposure period.**
LOE	**Line of Evidence used to evaluate whether a receiving-water measurement complied with permit limits**
MANOVA	**Multivariate Analysis of Variance**
MBAS	**Monterey Bay Analytical Services**
MBCSD	**The City of Morro Bay and Cayucos Sanitary District**
MCC	**A Motor Control Center manages the speed and torque of electric motors connected to the Center**
MTBE	**Methyl Tertiary Butyl Ether is an additive to gasoline that boosts octane to reduce air emissions but has contaminated groundwater in many regions after accidentally leaking from underground storage tanks.**
MDL	**Method Detection Limit is the lowest concentration that can be reported under ideal conditions where the sample contains only the compound of interest with a concentration in an optimal calibration range and in a medium that does not interfere with the performance of the analytical instrument.**
MGD	**Million Gallons per Day**
mg/Kg	**Milligrams per Kilogram = μg/g dry weight = parts per million**
mg/L	**Milligrams per Liter = aqueous parts per million**
Mixed liquor	**A mixture of activated sludge, wastewater, and oxygen where organic sewage constituents are biologically assimilated**
ML	**The Minimum Level is the method-specific minimum concentration of a substance that can be quantitatively measured in a sample given the current analytical performance used by most certified laboratories within California, as specified in the 2005 Ocean Plan.**
MLLW	**Mean Lower Low Water**
MMRP	**Major Maintenance and Repair Plan**
MMS	**Minerals Management Service**

LIST OF ACRONYMS AND DEFINITIONS
(Continued)

MPN	**Most Probable Number**
MRS	**Marine Research Specialists**
MT	**Metric Ton = 1,000 kg**
MWH	**Montgomery, Watson, Harza is the engineering firm selected for the design of the MBCSD treatment-plant upgrade.**
NEP	**National Estuary Program**
NMFS	**National Marine Fisheries Service**
NOAA	**National Oceanic and Atmospheric Administration**
NOEC	**No Observable Effect Concentration**
NORM	**Naturally Occurring Radioactive Material**
NPDES	**National Pollutant Discharge Elimination System**
NTU	**Nephelometric Turbidity Units**
O&G	**Oil and Grease**
O&M	**Operations and Maintenance**
OIT	**Operator-in-Training**
PAH	**Polynuclear Aromatic Hydrocarbons**
PCA	**Principal Component Analysis is a multivariate technique that arranges samples along an axis based on species composition. This arrangement is conducted independently along a number of dimensions (usually 2 or 3) that approximate some pattern of response of the intertidal community to underlying environmental gradients. PCA condenses the complex species-abundance database to a few factors responsible for observed variability within the intertidal community structure, while retaining ecologically meaningful biological information.**
PCB	**Polychlorinated Biphenyl**
PCi/L	**Pico-Curies per liter is a measure of aqueous radioactivity.**
Perturbation	**A perturbation is a small but detectable variation (anomaly) in one or more seawater properties caused by the presence of dilute effluent within the receiving waters. Individual Perturbations identified in this report are designated P1 through P12.**
PG&E	**Pacific Gas and Electric**
POTW	**Publicly Owned Treatment Works**
Power (1-β)	**The probability correctly rejecting the null hypothesis depending on the significance criterion, the variability of the sample results, and the size of the impact**
ppm	**Parts per million = mg/L in solution , or mg/Kg = μg/g dry weight**

LIST OF ACRONYMS AND DEFINITIONS
(Continued)

PQL	**Practical Quantification Limit is the lowest concentration that can be meaured with statistical reliability given the sample size and analytical method.**
PSDWF	**Peak seasonal dry-weather flow**
PSP	**Paralytic Shellfish Poisoning**
***p*-value**	**Low *p*-values (<0.05) indicate a high degree of confidence that the computed quantity is statistically significant.**
PWWF	**Peak wet-weather flow**
Pycnocline	**A region of rapid vertical change in the density field of the seawater column**
QA/QC	**Quality Assurance and Quality Control**
RAS	**Return Activated Sludge is continuously returned to the aeration tank to provide a seed of developed bacteria for rapid digestion of incoming wastewater. Some sludge is wasted (WAS) to prevent excessive solids buildup.**
RFP	**Request for Proposal**
ROV	**Remotely Operated Vehicle**
RPA	**The Reasonable Potential Analysis procedures in Appendix IV of the California Ocean Plan provide a quantitative methodology for statistically analyzing historical effluent data to determine the likelihood of exceeding permit limits in the future, and thus, whether continued monitoring is warranted.**
RWQCB	**State of California Regional Water Quality Control Board - Central Coast Region**
SAIC	**Science Applications International Corporation**
SBE	**Sea-Bird Electronics, Inc.**
SCBPPFCT	**Southern California Bight Pilot Project Field Coordination Team**
SCCWRP	**Southern California Coastal Water Research Project**
SEP	**Supplemental Environmental Project**
Sigma-T	**σ_t units are a measure of the density of water equal to the 1000 times the specific gravity minus one.**
SJCF	**San Joaquin Composting Facility located in Kern County California and owned by McCarthy Family Farms, Inc.**
STLC	**Soluble Threshold Limit Concentration applies to the measured concentration in the liquid extract from a biosolid sample, as determined by a Waste Extraction Test. The State of California classified biosolids with leachate concentrations exceeding the STLC as hazardous.**
SWRCB	**State Water Resources Control Board**
Thermocline	**A region of rapid vertical change in the temperature field of the seawater column**

LIST OF ACRONYMS AND DEFINITIONS
(Continued)

TIC	**Tentatively Identified Compound is a compound that can be seen by the analytical testing method, but its identity and concentration cannot be confirmed without further analytical investigation. Many analytical methods can report TICs but the analysis is not targeted specifically for their detection.**
TKN	**Total Kjeldahl Nitrogen**
TRC	**Total Residual Chlorine in effluent is determined from grab samples collected downstream of the chlorine contact chamber.**
TSS	**Total Suspended Solids**
TTLC	**Total Threshold Limit Concentration applies to the total wet-weight concentration of a contaminant within a bulk biosolid sample consisting of the entire millable solid matrix rather than just the leachate. Biosolids are designated as hazardous wastes in the State of California if measured bulk concentrations exceed the TTLC.**
TUa	**Acute Toxicity Units**
TUc	**Chronic Toxicity Units**
TVS	**Total Volatile Solids**
USEPA	**United States Environmental Protection Agency**
USFWS	**United States Fish and Wildlife Service**
USGPO	**United States Government Printing Office**
USMMS	**United States Minerals Management Service**
VFD	**Variable-Frequency Drives are electronic-motor-speed controllers used at the MBCSD WWTP to precisely control the influent pumping rate at the plant headworks by adjusting the frequency of electrical power sent to the pump motors.**
WAS	**Waste Activated Sludge is removed from the treatment process to prevent excessive solids buildup.**
WERF	**The Water Environment Research Foundation is a nonprofit organization that helps utilities and corporations manage water resources.**
WET	**Waste Extraction Tests measure the soluble leachate or the extractable amount of a substance contained within a bulk sample of biosolids. A WET is indicated if the bulk wet-weight concentration of a contaminant in a biosolids sample exceeds ten times the STLC.**
WRRF	**Water Resource Recovery Facility**
WRF	**Water Reclamation Facility**
WWTP	**City of Morro Bay-Cayucos Sanitary District Waste Water Treatment Plant**
ZID	**The Zone of Initial Dilution is a limited volume of water surrounding the outfall where wastewater rapidly mixes with receiving waters. Most receiving-water objectives of the Ocean Plan do not apply within the ZID.**

EXECUTIVE SUMMARY

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. The treatment plant discharges effluent to the open ocean environment of northern Estero Bay under the authority of National Pollutant Discharge Elimination System (NPDES) permit No. CA0047881. The current permit was issued in January 2009. The permit allows discharge of blended primary- and secondary-treated wastewater, although the vast majority of the wastewater receives secondary treatment. The discharge permit requires a monitoring and reporting program that evaluates short- and long-term effects of the effluent discharge on receiving waters, benthic sediments, and infaunal communities. This 2015 Annual Report partially satisfies those reporting requirements.

This document presents a comprehensive analysis of the extensive monitoring data collected over the last three decades. Virtually every aspect of the treatment process, receiving waters, and seafloor sediments is monitored. An exhaustive quantitative analysis of all measured parameters demonstrates that the effluent discharge consistently meets the permit requirements and has no discernible effect on the ocean environment. A comparison of the properties of the influent and effluent affirms the treatment plant's proficiency at removing contaminants and reducing organic loads within the wastewater stream. All offshore water-quality measurements indicate that the effluent plume was largely restricted to a narrow 15-m zone of initial dilution (ZID) around the outfall. Measurements within the effluent plume collected a few inches from a diffuser port quantified the plume's rapid dispersion, and demonstrated that the structure was operating better than predicted by modeling. Finally, the absence of adverse discharge-related impacts to the physics, chemistry, and biology of benthic sediments verified the effectiveness of the treatment process, the high dilution of effluent within receiving waters, and the low toxicity of the discharged effluent. The additional data presented in this report are consistent with conclusions based on historical data insofar as the treatment plant's continued low emission of contaminants, low toxicity of the effluent stream, and absence of impacts to the marine environment.

The plant operates under a 301(h)-permit that modifies the general NPDES requirements on suspended-solid and biochemical oxygen demand (BOD) emissions. All other NPDES limits, including restrictions on the discharge of toxic substances, apply to the MBCSD discharge without exception. Regardless, the partial-secondary treatment currently performed by the plant routinely achieves reductions in suspended solids and BOD that are close to, and often exceed, secondary treatment requirements.

Effluent monitoring during 2015 documented another year of high operational performance by the treatment plant. Major effluent constituents, including suspended solids (TSS), BOD, and oil and grease (O&G), all had much lower concentrations and mass emissions than the permitted maximums, as has consistently been the case throughout the history of the monitoring program. Although the treatment process efficiently removed major organic wastewater constituents such as suspended solids, BOD, O&G, and coliform bacteria, the general lack of other chemical contaminates within effluent was largely due to their absence within the influent stream. Like most publicly owned treatment works, the MBCSD plant is not designed to extract heavy metals and synthetic organic compounds from wastewater. Instead, the MBCSD effluent's low toxicity is primarily due to the lack of heavy industry within its service area. The few businesses that discharge to the sewer system produce wastewater that is similar to that of domestic sources, only on a larger scale. A digital database, maintained by collections system personnel, documents these sources. In addition, an ongoing public-outreach program and the convenience of an onsite household hazardous waste recycling facility further reduced the introduction of pollutants into the waste stream.

Throughout three decades of operation, the treatment plant has consistently outperformed expectations for wastewater treatment based on regulatory standards. During this time, there has been no indication of deterioration in plant performance, and effluent quality has consistently exceeded the performance criteria anticipated in the original design. On rare occasions where exceptions to standards or criteria have occurred, they have been the direct result of unforeseen external events, or the brief, unavoidable mechanical failure of a treatment-system component. In light of their diligent adherence to a program of preventative maintenance, the main challenge for plant personnel has been to respond quickly to unanticipated failures in system components or unforeseeable events.

Among the thousands of samples and measurements collected as part of the monitoring program during 2015, there were only two, unavoidable exceptions to the waste-discharge requirements specified in the NPDES permit. This near-perfect level of compliance is laudable and represents the culmination of many years of hard work by dedicated and experienced MBCSD personnel. Their knowledge and experience regularly enables them to enact appropriate proactive measures that ensure the smooth operation of this facility.

Quarterly offshore water-column surveys evaluated receiving-water quality. The high-precision measurements collected during the surveys were capable of resolving minute changes in ambient water properties. These measurements detected and delineated effluent as it mixed with receiving waters upon discharge from the diffuser. Slight anomalies in water properties associated with the presence of dilute effluent were observed very close to the diffuser structure within the ZID. These highly localized anomalies were still within the limits specified in the NPDES permit, even most of those collected well within the ZID, where such limits do not apply.

The physics, chemistry, and biology of benthic sediments around the outfall have also been monitored for 30 years. As has been the case throughout the three decades of monitoring, all measurements fully complied with requirements of the discharge permit and the objectives of the California Ocean Plan. Benthic environments are important indicators of the presence of marine pollution because they act as a major reservoir for most contaminants that enter the ocean. The lack of perceptible impacts to the benthic environment around the diffuser structure during 2015 confirmed that the treatment process effectively removed contaminants from the influent stream and that the diffuser structure efficiently diluted wastewater upon its discharge into receiving waters.

Three sediment-chemistry analyses document the absence of discharge-related benthic impacts. First, chemical concentrations measured within Estero Bay sediments during 2015, and in prior years of monitoring, were below thresholds identified as toxic to marine organisms. This includes samples collected close to the diffuser structure, as well as those collected more than 1 km away. In fact, measured concentrations were comparable to those found in benthic sediments collected throughout the region, but they were generally much less than those found within the Southern California Bight. Second, benthic samples collected during 2015 did not exhibit significant gradients of increasing contaminant concentration with increasing proximity to the outfall. Finally, there is no evidence of a buildup of wastewater constituents near the outfall over time, based on a comparison of the long record of measurements collected near and far from the discharge.

Infauna residing within seafloor sediments also serve as indicators of marine contamination because of their limited mobility and well-defined responses to pollution. Numbers of species, abundance, biomass and other parameters describing infaunal communities can indicate the presence of contaminant-induced stresses if, for example, gradients extending from a pollutant source to distant, unaffected areas are observed. More than 258,000 infaunal organisms have been collected and examined since the beginning of the benthic monitoring program 30 years ago. Throughout the monitoring program, there has never

been an indication of discharge-related impacts to benthic biota. Instead, the data have revealed a consistently healthy indigenous infaunal community, with uniformly high diversity that does not decline with proximity to the diffuser. In the 29 prior years prior to 2015, analyses demonstrated that the sediments surrounding the outfall supported an extraordinarily healthy marine community dominated by suspension-feeding organisms living in clean sediments.

These observations held true despite widespread and significant temporal variation in the abundance of individual organisms. However, a major change in the benthic environment occurred in 2015 when numerous large sand dollars dominated the benthic environment throughout the survey area. They displaced most of the resident suspension-feeding infauna and introduced opportunistic detritus feeders. Most measures of the health of the infaunal community declined as a result, including density, diversity, species counts, and richness. The concomitant decline in feeding indices were reminiscent of organic enrichment that had been observed within seafloor sediments immediately surrounding large ocean discharges in other regions prior to improvements in wastewater treatment during the 1980s.

However, the declines in the measures of infaunal wellbeing that were observed in 2015 survey were unrelated to benthic degradation caused by the discharge of organic contaminants from the MBCSD outfall. First, organic loading within wastewater discharged from the MBCSD outfall in 2015 was among the lowest on record. Second, the declines occurred uniformly throughout the offshore survey area with no evidence of a spatial gradient related to outfall proximity. Third, the concentrations of organic constituents measured within sediment samples collected at the infaunal sampling sites in 2015 were comparable to those of prior years. Instead, the observed decline was directly associated with the establishment of a mature sand dollar bed. One of the detritus-feeding species whose increased presence contributed most to the overall decline in the feeding index is one of the few that have been explicitly associated with sand dollar beds in other regions.

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1.0 INTRODUCTION

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. A 301(h)-modified National Pollutant Discharge Elimination System (NPDES) permit was originally issued to the MBCSD in March 1985 (Permit Number CA0047881). Region IX of the U.S. Environmental Protection Agency (USEPA) and the Central Coast California Regional Water Quality Control Board (RWQCB) jointly issued the permit. Following extensive evaluation processes, the USEPA and the RWQCB reissued the permit three times: March 1993 (RWQCB-USEPA 1993ab), December 1998 (RWQCB-USEPA 1998ab), and January 2009 (RWQCB-USEPA 2009ab). This report addresses compliance with the provisions of the most recent permit.

Marine Research Specialists (MRS) began conducting the Offshore Monitoring and Reporting Program for the MBCSD in July 1993. Since then, the treatment plant staff, MRS, and various subcontracted laboratories, have collected and analyzed samples as part of the monitoring program.

1.1 REPORT ORGANIZATION

This 2015 annual report summarizes results from the four major monitoring components that analyze the treatment plant, receiving waters, marine sediments, and benthic biota. The organization of this document is similar to that of previous annual reports for continuity with these four reporting aspects of the monitoring program. Other than this brief introductory chapter, the major sections include the following:

Chapter 2	Treatment Plant Performance
Chapter 3	Receiving Water Quality
Chapter 4	Bottom Sediments and Biota
Chapter 5	Conclusions and Recommendations

Chapter 2 details all aspects of the onshore portion of the monitoring program, including the operation and performance of the treatment plant and the disposition of biosolids during 2015. Chapter 3 documents the four offshore surveys that were conducted during 2015 to assess the quality of ocean waters where the effluent is discharged. Chapter 4 documents the analysis of sediment samples collected during an offshore survey in October 2015. It places the chemical and biological measurements in historical context by incorporating time-series analyses of the entire 30-year database. Finally, Chapter 5 reiterates the major conclusions of this report, and presents recommendations for future actions concerning the monitoring program and operation of the treatment plant.

In addition to these chapters, a large set of appendices provides detailed supporting documentation for the analyses in the body of this report. Appendix A lists the design specifications of the wastewater treatment plant and inventories the maintenance and repair activities conducted during 2015. Appendix B details the biological analysis of the offshore sediment samples and contains information about the taxonomists who performed the species-level identification of the specimens. Appendix C contains sample descriptions, including the location, depth, and grain-size characteristics of sediment samples. Appendix D contains a report of the annual outfall inspection that was conducted by diver. The original benthic chemistry report and quality assessment and quality control (QA/QC) analyses performed are provided in Appendix E. QA/QC procedures for the analytical laboratories are provided in Appendix F. This appendix also contains a listing of updates to the MBCSD treatment plant operations manual that were completed during 2015, and a summary of the analytical methods used by BC Laboratories in their chemical analyses of the samples.

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CHAPTER 2

Treatment Plant Performance

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2.0 TREATMENT PLANT PERFORMANCE

During 2015, the treatment plant efficiently removed nearly all organics and other solids from the wastewater stream. Analyses of key diagnostic constituents, including suspended solids, biochemical oxygen demand (BOD), and oil and grease (O&G), demonstrated the high operational performance of the plant. Similarly, periodic analyses of effluent for trace metals, pesticides, priority pollutants, and toxicity demonstrated the benign environmental character of the effluent. A proactive operation and maintenance (O&M) program minimized the number of avoidable exceptions to the limits specified in the NPDES discharge permit during 2015. The sections below use these analyses to evaluate regulatory compliance through a comparison between the measured wastewater characteristics and the limits cited in the NPDES discharge permit issued to the City of Morro Bay and Cayucos Sanitary District in January 2009 (RWQCB-USEPA 2009).

Data collected during 2015 augment 29 years of prior monitoring information, chronicling the high level of performance achieved by the treatment process over the last three decades. As in previous years, removal of suspended solids and oxygen-demanding materials during 2015 surpassed permit-required minimum limits. In many instances, the treatment plant's performance approached or exceeded the standards for full secondary treatment.

Despite processing a large fraction of sewage in the wastestream during 2015, the plant discharged only 19% of the allowed solids, while still attaining removal rates 16% higher than the permitted minimum. The treatment plant removed solids at a rate significantly exceeding the 85% requirement for full secondary treatment in all months except December, when the 83.8% removal rate was only slightly below the stringent treatment standard that does not apply to this discharge. Additionally, the average effluent suspended-solids concentrations during 6 months of the year remained at or below the 30-mg/L criterion for full secondary treatment. The annual average effluent suspended-solids concentration (31 mg/L) was less than half of the permitted maximum (70 mg/L), and the total solids emission (39 MT[1]) was only one-fifth of the allowed solids discharge (199 MT).

During 2015, the treatment plant also removed the vast majority (86%) of oxygen-demanding material from the influent stream. Technology-based requirements for BOD are generally unimportant for marine discharges because oxygen depletion is of little concern in the open ocean (Page 6 in National Academy of Sciences 1993). Nevertheless, the average BOD removal rate met or exceeded the 85% monthly standard for full secondary treatment during ten months of the year, while the lowest monthly removal rate of 82.3% was still more than two and a half times greater than the minimum permitted rate of 30%. Additionally, the annual average effluent BOD concentration (49 mg/L) was only 40% of the permitted maximum (120 mg/L), and the total mass emission (63 MT) was less than one-fifth of the allowed BOD discharge (342 MT).

The general absence of industrial contaminants in the wastestream attests to the benign nature of the influent, which is almost entirely generated by nonindustrial residential sources. Chemical analyses for 78 chemical compounds quantified low-level concentrations of only one ubiquitous chemical and four naturally occurring trace minerals within effluent samples. All measured concentrations were well below permit limitations. Chronic bioassays conducted on effluent samples that were also collected during 2015 determined that the discharge had very low toxicity to marine organisms, a result consistent with the prior 22-year record of testing.

[1] Metric tons or 1,000 Kg (1.1 short tons)

2.1 WASTEWATER TREATMENT PLANT

The Morro Bay/Cayucos Wastewater Treatment Plant (WWTP) is publicly owned and operated by the City of Morro Bay and the Cayucos Sanitary District (MBCSD). The WWTP is located in the City of Morro Bay, within San Luis Obispo County, along the central coast of California (Figure 2.1). The plant serves the Morro Bay and Cayucos communities, which, according to the 2010 census, have a combined population of approximately 12,835 (10,243 in Morro Bay and 2,592 in Cayucos). The WWTP discharged, on average, 0.93 million gallons per day (MGD) during 2015, the lowest on record for the three-decade-long monitoring history. The plant was designed to accommodate an average dry-weather flow of 2.06 MGD, a peak seasonal dry-weather flow (PSDWF) of 2.36 MGD, and a peak wet-weather flow (PWWF) of 6.64 MGD. The plant's flow did not even approach, much less surpass, any of these design limits during 2015.

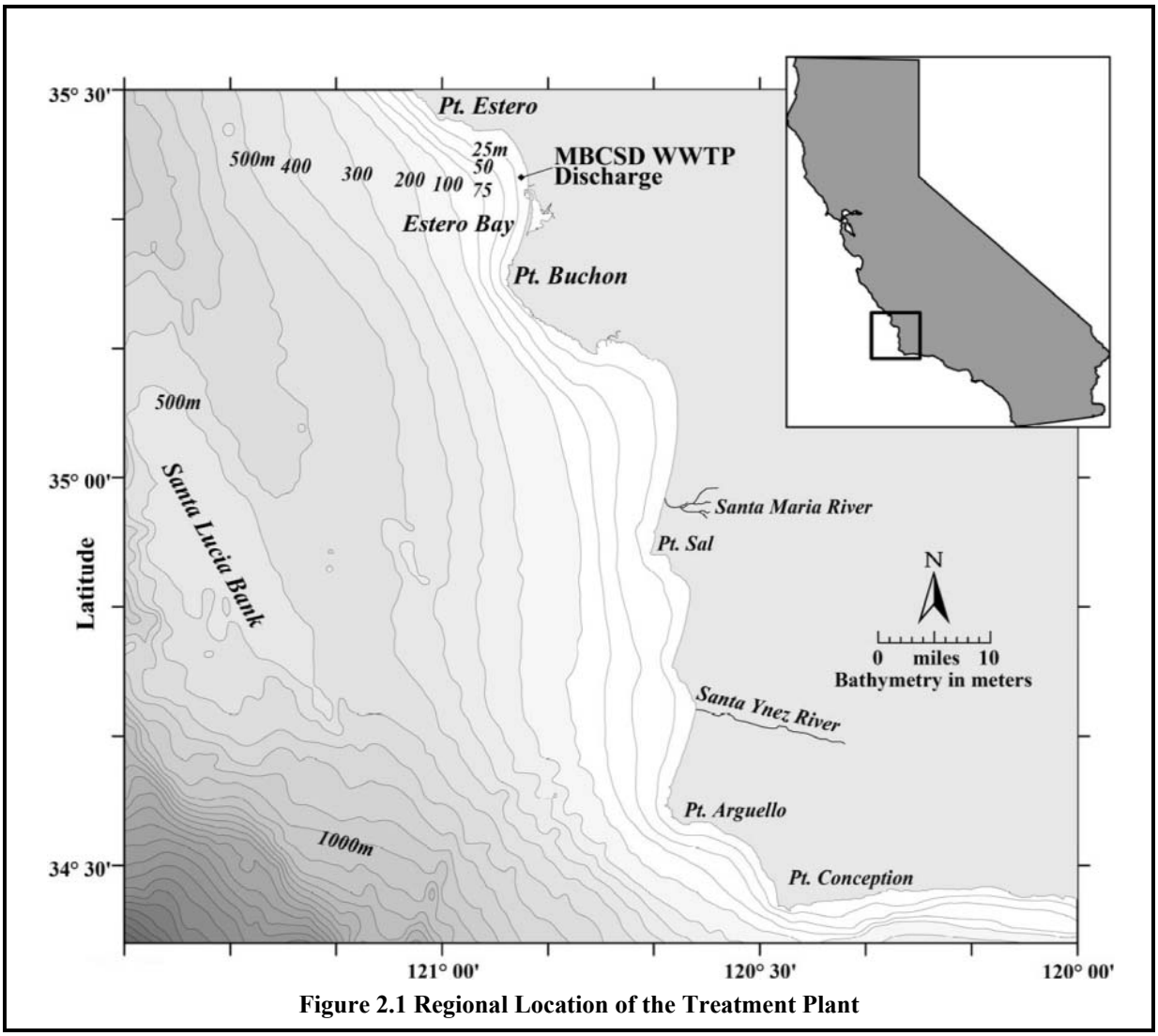

Figure 2.1 Regional Location of the Treatment Plant

2.1.1 Operations

During 2015, nine trained personnel operated the WWTP (Table 2.1). Bruce Keogh served as both the Wastewater Division Manager and the Laboratory Director; Les Girvin continued to serve as WWTP Supervisor. Dane Lundy was hired on 5 January and is employed as a Grade-I operator although he holds a Grade II certification. Adam Hegg started work as a part-time Grade I Operator in Training (OIT) on 28 July.

Table 2.1 Morro Bay/Cayucos WWTP Personnel During 2015

Name	Grade and Certification No.
Bruce Keogh	IV – 8978
John Gunderlock	V – 10500
Les Girvin	III – 8499
Steven Aschenbrenner	II – 7548
George Helms	II – 28158
David Bierman	II – 28745
Neza Chavira	II – 40669
Dane Lundy	II – 36547
Adam Hegg	I - OIT

WWTP personnel provided laboratory workspace to the National Estuary Program (NEP), which is dedicated to protecting and restoring the natural resources of Morro Bay and its watershed. NEP volunteers used the WWTP laboratory to analyze bacterial samples collected throughout the Morro Bay watershed.

WWTP personnel attended workshops, seminars, and continuing education classes throughout 2015. Training courses and seminars covered topics such as Government Transparency, First Aid CPR, Confined Space Entry, Occupational Hazard Assessments, Heat Stress, Hearing Conservation, Blood-Borne Pathogens, and Public Relations.

WWTP personnel also conducted plant tours for the public, members of various local agencies, and staff from other treatment plants. Some of the members of the Water Reclamation Facility Citizens Advisory Committee toured the plant on 12 November.

In addition to performing the periodic effluent analyses required by the NPDES Permit during 2015, the laboratories involved in the analyses of the MBCSD WWTP samples participated in laboratory performance evaluations intended to evaluate the accuracy of effluent measurements and ensure the overall quality of the monitoring reports. In particular, the adequacy of each laboratory's analytical chemistry capabilities was demonstrated during 2015 when acceptable results were achieved in Water Pollution Proficiency Testing Study WP-243, which is an annual requirement of laboratories certified by the State of California Environmental Lab Accreditation Program (ELAP) and is sponsored by the State Water Resources Control Board and the USEPA. Successful completion of Study WP-243 also satisfied regulatory requirements in the federally mandated Discharge Monitoring Report Quality Assurance Study 35 (DMR-QA 35). Additionally, on 26 May, the WWTP laboratory was recertified as an environmental testing laboratory pursuant to the provisions of the Health and Safety Code through May 31, 2017. The laboratory also

The MBCSD WWTP laboratory analyzed effluent parameters reported on a daily and weekly basis, including residual chlorine, suspended solids, turbidity, coliform, pH, and BOD. Aquatic Testing Laboratories evaluated the toxicity of effluent to marine organisms with semiannual bioassay tests. BC Laboratories, Weck Laboratories, Vista Analytical Services, and Monterey Bay Analytical Services determined the concentrations of a wide range of chemical compounds within effluent on a semiannual basis. BC Laboratories also performed the annual chemical analysis of biosolid and benthic-sediment samples, as described in Section 2.3 of this chapter, and in Chapter 4. Each laboratory's quality assurance and control plan is included in Appendix F of this report.

In recent years, both the City of Morro Bay and the Cayucos Sanitary District actively sought to identify and eliminate sources of inflow (rainwater runoff) and infiltration (of groundwater), known as I&I, within their respective collection systems. Reducing the volume of I&I entering the collection system minimizes the amount of non-wastewater unnecessarily processed by the WWTP. For example, collection system staff replaced some aging clay pipe with plastic pipe at various locations throughout Morro Bay. They institute mainline repairs to eliminate root infestations and sources of possible infiltration. In addition, conventional manholes throughout Morro Bay are being replaced with sealing manhole lid/ring combinations, and some manholes are epoxy sealed to further reduce I&I. Finally, staff conduct smoke testing to further identify potential sources of I&I.

Meanwhile, at the WWTP itself, personnel maintained a diligent and proactive preventative maintenance program that included major preemptive repairs of various components of the treatment process and the outfall. Some of the more important components of this effort were planned and budgeted well in advance as part of a Major Maintenance and Repair Plan (MMRP). These activities were documented in monthly operations summaries submitted to the RWQCB (MBCSD 2015a-l). They are also summarized in Table A.2 of Appendix A.

To assist WWTP staff in the O&M of major plant components, an O&M manual (dated November 1987) was completed following the plant upgrade in 1986. The O&M manual includes standard operating procedures as well as preventative and contingency plans for controlling and minimizing the effects of accidental discharges. The manual is reviewed and updated as new major equipment is placed online or when procedures are changed. A list of revisions and updates to the manual that were completed in 2015 are included as part of Appendix F of this report.

As part of routine maintenance procedures, divers inspect the ocean outfall's exterior and the diffuser structure for signs of damage annually. The outfall was inspected on 7 January 2015, and was found to be in good condition, with no broken or plugged diffuser ports. The outfall inspection report is included herein as Appendix D.

Figure 2.2 is a photograph of a diffuser port taken during a previous outfall inspection. It shows a dense cover of marine epifaunal organisms thriving on the outer surface of the diffuser port. A large colony of club-tipped anemones (*Corynactis californica*), bright pinkish-red in color, covers the top surface of the port. The continued presence of these filter-feeding organisms attests to the benign nature of the effluent discharge, and to the outfall's value as an artificial reef. Quantitative biological surveys conducted within the region found that these anemones are only occasionally observed on high-relief rock surfaces within Estero Bay, and then only in deeper water (>85 m) (Morro Group 1999). Ostensibly, their susceptibility to elevated suspended-sediment loads explains their rarity on nearshore, lower-relief rocky substrates. The preponderance of anemones on the diffuser attests to the minimal negative impact of the outfall's particulate discharge on marine organisms.

Among the routine maintenance and repair efforts listed in Table A.2, the WWTP staff also instituted a number of significant repairs in 2015 as part of the MMRP. The scope of MMRP projects exceeds normal O&M activities, can encompass entire treatment components, and may even require major infrastructure reconstruction. Some of the MMRP activities completed in 2015 are listed below.

Figure 2.2 Photograph of a Diffuser Port Discharging Effluent

One of the more significant maintenance events of 2015 involved the repair and rehabilitation of one of the three sludge digesters at the WWTP. Digester #2 had already been refurbished in prior years. The process involved a number of separate activities.

- Commission Digesters #2 and #3 as the primary and secondary digesters while Digester #1 was offline for repair;
- Operate two well pumps near Digester #1 to lower groundwater levels prior to draining the Digester;
- Transfer sludge to the active Digesters;
- Perform structural testing by coring into the walls of Digester #1 and compression testing the cores;
- Inspect, repair, and replace digester valves and sludge transfer lines; and
- Sandblast and recoat the Digester.

The cleaning, repair, and recoating project for Digester #1 was completed and the digester was brought back online as the operational secondary digester in August 2015.

On 14 October, the Secondary Clarifier was drained, cleaned, and inspected as part of a planned MMRP activity to rehabilitate the Clarifier. Numerous operational changes to the treatment process were required to maintain compliance with the discharge permit during the prolonged period required to complete tasks necessary to inspect and clean the Clarifier. When a major treatment component, such as the Secondary Clarifier or the Chlorine Contact Tank, is taken offline, wastewater quality can decline if the component is simply bypassed in the treatment process. Instead, at those times, WWTP staff perform major modifications to plant flow so that all effluent discharge from the WWTP can be temporarily suspended.

Regardless of whether the discharge would have still complied with requirements of the discharge permit, these efforts avoid dosing the marine environment with effluent that is not of the highest possible quality.

The October inspection of the Secondary Clarifier found that although some of the equipment within the Clarifier exhibited corrosion near the water interface, the Clarifier itself was found to be in satisfactory condition. At other times during the year, repairs were made to corroded areas of the catwalk and to various valves and pipes associated with the Clarifier. This effort is currently ongoing as part of the MMRP.

A significant series of other repair events in 2015 were related to a planned MMRP improvement to the Chlorine Contact Tank. The Tank is an important component of the disinfection process, which is the last step in the treatment process. After addition of sodium hypochlorite to the waste stream, mixing within the Tank ensures sufficient contact time with microorganisms before dechlorination with sodium bisulfite and discharge through the outfall. The entire disinfection process is complex, partially because of the diurnal variation in both organic loading and plant flow. At any given time, flow-paced dosing pumps inject sufficient amounts of sodium hypochlorite and sodium bisulfite to ensure adequate disinfection without dosing the marine environment with chlorine. Both chlorine concentrations and bacterial densities are regulated in the discharge permit. Because there is no redundancy in the disinfection process, when the Contact Tank is taken offline for repair, potential exceedances of one or both of the regulatory limits can occur.

WWTP personnel have devised some inventive methods to minimize environmental impacts while the Tank is offline. First, they minimize the downtime for the Tank by staging personnel, equipment and supplies onsite prior to draining the Tank. If exterior valves require repair, as was the case in July, they excavate and expose the valve prior to draining. In another case in July, they avoided draining the Tank altogether, by placing a small boat into the Tank to replace a damaged link in the drive chain.

Second, they limit impacts on the overall treatment process by conducting repairs very early in the morning, when plant flow is lowest. Also, rather than simply diverting untreated wastewater around the Tank during the repair, they prepare to temporarily stop flow through the WWTP by draining the Plant's Grit Chamber and a Primary Clarifier so that they can act as temporary detention basins. Then, they drain the contents of the Contact Tank into empty sludge beds for temporary storage and later treatment. Lastly, as inflow begins fills the temporary detention basins during the repair, they shut down the influent pumps and allow influent to backup in the trunk line for later treatment once the Tank is back online.

Despite these efforts, exceedance of at least one of the regulatory limits cannot be avoided during prolonged repairs to the Tank. This was the case on 15 April, when the WWTP staff made the conscious decision to maintain effluent disinfection at the expense of dechlorination, which resulted in the exceedance of maximum daily limit on total residual chlorine.[1] Appropriate notice was provided to the RWQCB and California Department of Health Shellfish Division prior to the anticipated chlorine increase. In addition to this unavoidable exceedance of a permit limit, one other exception to permit requirements occurred during 2015. It too was related to the dechlorination process when, on 11 December, the sodium-bisulfite dosing pump was accidently shut down after its circuit breaker was tripped, and the residual chlorine levels again increased above the maximum allowable daily concentration.

Although there were an unusually large number of other repairs to the Chlorine Contact Tank during in 2015, none resulted in a permit exceedance. Five of these repair events required draining of the Tank, and four were conducted to address unusual increases in effluent coliform density caused by an accumulation

[1] See Figure 2.13 later in this chapter.

of organic solids along the bottoms of the Tank's two contact chambers.[1] When it was found that occasional cleaning of the floor of the Tank with high-pressure hoses did not provide a long-term solution, modifications were made to the apparatuses used to remove solids the mixture within the Tank, including adding flights and decreasing their elevation above the Tank floor. Eventually, wooden fillets were added to the Tank walls to divert settling solids toward the middle of the Tank.

2.1.2 Plant History

The original WWTP, built in 1954, had a nominal capacity of 0.7 MGD and a 1-MGD maximum throughput. The original plant included a headworks structure, primary and secondary clarifiers, a biofilter, a single-stage digester, chlorination facilities, biosolids drying beds, and a short ocean outfall.

In 1964, the plant upgraded to a nominal capacity of 1 MGD and a 1.3-MGD maximum throughput to meet the demands of the growing coastal community. This upgrade added a pump station, a splitter box, a primary clarifier, a secondary clarifier, a biofilter, chlorination facilities, biosolids beds, and another primary digester, which allowed conversion of the existing digester to a secondary capacity. A new office and laboratory were also constructed during this upgrade.

During the 1970s, the City of Morro Bay developed a plan for additional upgrades to the WWTP facilities intended to augment the plant's capacity further. In 1980, the City began designing these planned improvements, including the construction of a new outfall to protect the marine environment better, and a facilities upgrade to provide full secondary treatment.

Following a yearlong study of oceanographic conditions within Estero Bay, design of the new outfall was completed in April 1981. The new outfall and diffuser system extended the discharge from the surfzone to a point much farther offshore. The deeper discharge increased the dilution of wastewater within the open-ocean environment. The new outfall was completed and placed in service in June 1982.

The design of the facility improvements, completed in September 1981, called for a final effluent suspended-solids concentration of 30 mg/L and an equivalent limit on BOD. However, aid from state or federal agencies to finance the construction to meet these full-secondary-treatment levels was not available. Since discharge through the new outfall was not causing any apparent adverse environmental impacts and the projected future throughput was low, the State determined that additional financial aid for upgrading the MBCSD WWTP to full secondary was not warranted. Instead, the City modified the design to provide secondary treatment to a majority (1 MGD) of the projected flow to comply with the state water-quality standards set forth in the California Ocean Plan (COP) (SWRCB 1990). State officials concurred with this level of treatment, provided that the USEPA approve a 301(h)-modified NPDES discharge permit that adjusted secondary-treatment requirements on suspended-solid and BOD emissions.

In a 16 March 1983 letter, RWQCB staff determined that the proposed discharge would comply with state water-quality standards pursuant to Title 40 of the Code of Federal Regulations, Section 125.60(b)(2) [40 CFR 125.60(b)(2)] (USGPO 1982a) and 40 CFR 125.63(b) of the 301(h) regulations dated November 1982 (USGPO 1982b).

Upgrades to the treatment plant completed between 1983 and 1985, increased the plant's capacity to a 2.06-MGD average dry-weather flow and a peak flow of 6.6 MGD. The plant now includes primary treatment of all influent by screening, grit removal, and primary sedimentation. Additionally, depending on the hydraulic conditions within the plant, up to 1 MGD of the flow can be diverted through a secondary-treatment process of trickling filters, clarifiers, and a solids-contact chamber. The secondary-

[1] See particularly the series of higher-than-normal densities in June and September in Figure 2.14, and the associated discussion later in this chapter.

treatment process utilizes two trickling filters, an aerated solids-contact channel, and a secondary sedimentation tank. The original 1954 sedimentation tank was converted into a chlorination system where the primary- and secondary-treated effluents are mixed and disinfected prior to dechlorination and discharge through the ocean outfall.

On 29 March 1985, an NPDES permit based on the previously approved Section-301(h) modification established water-quality standards for the MBCSD WWTP. The permit required treated effluent to achieve a suspended-solids content of no more than 70 mg/L (75% removal) and a maximum BOD of 120 mg/L (30% removal). The permit also required an extensive monitoring program to assure maintenance of environmental quality. The permit was valid for five years and expired on 8 March 1990. After an evaluation process, the permit was reissued in December 1992. During this evaluation period, improvements to the treatment facilities included the installation of a sludge-removal system within the Chlorine Contact Tank.

The MBCSD again applied for renewal of the permit in May 1997, supporting its application with an extensive technical review of more than 10 years of monitoring data (MRS 1997a). An administrative extension until 11 December 1998 allowed regulatory agencies additional time to review and issue the new permit (RWQCB 1998). In July 1998, RWQCB staff determined that the discharge described in the MBCSD application "*would comply with applicable state laws, including water quality standards, and would not result in additional treatment, pollution control, or other requirements on any other point or nonpoint source*." This permit was finalized and issued by USEPA on 26 January 1999, with an effective date of 1 March 1999.

Based on discussions between RWQCB, USEPA, and MBCSD staff and their consultants, the following revisions were also implemented in the 1999 permit:

- A 12.7% reduction in the allowed mass emission of suspended solids, BOD, and O&G;
- More extensive reporting requirements for biosolids;
- Elimination of shellfish monitoring;
- A revised benthic sampling pattern eliminating seasonal sampling and increasing the number of stations close to the diffuser structure;
- A revised receiving-water sampling program eliminating bottle casts and doubling the number of vertical profiles close to the diffuser structure; and
- Specification of mass emission goals for toxic chemicals.

Based on the historical absence of perceptible impacts from the discharge, and the projected continuation of consistently high effluent quality, the MBCSD again applied for a renewal of the discharge permit on 3 July 2003 (MBCSD 2003). As with the previous permits, the application requested continued discharge under the 301(h) provision that allows minor modifications to the BOD and suspended-solids requirements. On 4 February 2004, the RWQCB (2004) administratively extended the existing permit to allow time for further review. On 10 September 2005, the USEPA Region IX (2005) issued a tentative decision concurring with issuance of a permit to the MBCSD in accordance with Section 301(h) of the Clean Water Act. On 6 April 2006, the USEPA and RWQCB staff issued a joint notice for a proposed action to reissue the 301(h) modified NPDES discharge permit to the MBCSD. However, on 11 May 2006 the RWQCB and the USEPA conducted a joint public hearing addressing the reissuance of the MBCSD permit wherein the RWQCB voted to continue the hearing pursuant to the issuance of a biological evaluation by the USEPA (2007).

In 2008, the USEPA issued an Endangered Species Act (ESA) biological evaluation of continued discharge under a 301(h) modified discharge permit wherein they determined:

> *…that the continued wastewater discharge from the Morro Bay/Cayucos facility is not likely to adversely affect the brown pelican or southern sea otter, both of which occur in the vicinity of the subject discharge. EPA finds that any potential direct or indirect effects of the continued wastewater discharge would be insignificant to the brown pelican and southern sea otter.*

Pursuant to Section 7 of the ESA, the proposed action of the USEPA required consultation with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), which protect federally listed endangered species and designate critical habitat that may be affected by the proposed action. On 21 December 2007, the USFWS concurred with the USEPA "*determination that the proposed project is not likely to adversely affect the brown pelican or southern sea otter*."

Nevertheless, the USEPA incorporated three conservation measures into the new NPDES discharge permit to address concerns about potential contributions to otter morbidity by cat litter and domoic acid poisoning. First, the MBCSD would implement a public outreach program to minimize the input of cat-litter-box waste into the municipal sewer system. Second, the MBCSD would be required to monitor nutrient loading from the WWTP on a regular basis. Third, the facility would upgrade to a minimum of full secondary-treatment levels by 2014.

Based on the foregoing findings and the incorporation of conservation measures, the RWQCB unanimously adopted the new discharge permit on 4 December 2008. Subsequently, on 9 January 2009 the California Coastal Commission unanimously determined that the new discharge permit complied with the California Coastal Zone Management Act. On 14 January 2009, the USEPA issued the new NPDES permit, effective 1 March 2009. In addition to the conservation measures noted above, the following revisions were also implemented in the 2009 permit:

- Elimination of acute toxicity testing;
- Implementation of triggered shoreline coliform monitoring;
- Revision of benthic sampling pattern eliminating cross-shore stations and shifting from grab- to composite-sediment chemistry samples; and
- Revision of receiving-water sampling program reducing the number of vertical profiles and implementation of a tow-survey component.

Although the current NPDES permit was not finalized until January 2009, the MBCSD had actually begun to implement several of the proposed conservation measures years before. For example, in April 2006, the MBCSD, working to address the concerns of the USEPA and RWQCB, adopted an eight-year time schedule to rehabilitate and upgrade the treatment plant to tertiary treatment, including onsite composting, as the preferred alternative for upgrading the WWTP by 2014. The MBCSD subsequently adopted a draft facilities master plan that outlined the facilities necessary for a tertiary treatment capacity of 1.5 MGD in September 2007. Meanwhile, in August 2007 the City of Morro Bay and the Cayucos Sanitary District individually adopted revenue programs that identified increases in sewer-rate fees necessary for each community to finance the proposed plant upgrade and to provide revenue for needed sewer-system capital improvement projects. In July 2008, the City of Morro Bay implemented new residential and commercial water-use rates that increased the existing fees by 50%. Subsequent annual increases of 5% for residents and 7.25% for non-residents and commercial businesses continued through 2014.

During 2009, following completion of a flood hazard analysis, the City and District voted to relocate the treatment plant site to an elevated area adjacent to the existing treatment plant. In October 2009, the MBCSD public noticed a Request for Proposal (RFP) for Engineering Design Services for the upgrade, and the City of Morro Bay released a Revised Notice of Preparation for the project, reflecting changes to

the project description involving construction of treatment-plant components in the new location. Demolition of the existing plant was to occur after the relocated treatment-plant components were constructed and brought online. The engineering design contract was awarded at the February 2010 Joint Powers (JPA) meeting with a projected completion in 15 months.

The final Environmental Impact Report for the upgrade project was released in December 2010. The Morro Bay City Council certified the EIR and approved the Conditional Use Permit and Coastal Development Permit (CDP) for the upgrade project on 11 January 2011; however, the decision to issue the CDP was subsequently appealed to the California Coastal Commission. A *de novo* hearing was held in January 2013 at which the Commission denied the CDP for the proposed upgrade project at its current location.

Subsequently, at the 14 February 2013 JPA meeting, the MBCSD approved the development of an MMRP. The Plan was instituted to ensure uninterrupted operation of the existing WWTP in compliance with regulatory requirements during the extended operational period required for the development and construction of a new treatment facility.

On 26 August 2013, the MBCSD submitted an application to the RWQCB for a new discharge permit to replace the current 301(h) modified permit due to expire on 28 February 2014. Based on direction from the MBCSD and RWQCB staff, an application was submitted for a full secondary discharge permit with interim effluent limits on suspended solids and BOD. Presently, the existing NPDES discharge permit remains in force under administrative extension pending issuance of this new permit.

In a 19 February 2015 letter from RWQCB staff, they reiterated their intent to issue only one additional five-year NPDES permit for discharge from the existing WWTP. They indicated that the new permit would contain a time schedule for interim limits that would protect the MBCSD from excursions above full-secondary standards. Exceedance of secondary standards after five years from the date of permit issuance could be subject to minimum mandatory penalties.

Base on this regulatory schedule for WWTP decommissioning, and the success of the MMRP to date, which addressed a number of major components of the treatment process and provided a positive overall assessment of current plant condition, the MBCSD is reviewing approval of a phase out of the MMRP. Instead, individual pieces of treatment equipment within the WWTP will be proactively maintained though inspection, cleaning, repair, or replacement as part of the ongoing O&M effort. If the operational timeframe of the WWTP requires extension, and major treatment components begin to reach the end of their service life, the MMRP would be reinstituted.

During 2013 and 2014, the MBCSD explored various sites and treatment alternatives for a new facility to process wastewater currently treated by the existing WWTP. In early 2015, the City of Morro Bay selected a proposed Water Reclamation Facility (WRF) located east of the City and north of Highway 41. On 30 April, the Cayucos Sanitary District suspended participation with the City in their WRF and began planning a separate Water Resource Recovery Facility (WRRF). The District independently evaluated wastewater treatment alternatives, characterized flow rates and mass loadings specific to the District's collection system, identified beneficial uses for recycled water, evaluated potential facility locations, and developed a funding and financing strategy.

At the same time, City staff and their consultants pressed forward with the planning and design of the WRF, although the final facility location has yet to be determined. Relocation of the WRF will require major modifications to the wastewater collection system, including a new pumping station and a new force main to convey the raw wastewater to the new site. Evaluation of alternatives for the future recycled water system is underway. The Morro Valley aquifer has been evaluated to identify potential recharge

opportunities and a salinity control plan is being developed to reduce input of salts to the City's collection system in anticipation of a future water-reuse program.

Preliminary planning of all these facilities will be guided by a Facility Master Plan that is currently under development. It will further define the elements of the treatment process, facilities, and infrastructure. Contracts for overall program management and permitting services for the new WRF and future recycled water system are now in place. These efforts were based on numerous studies evaluating design and implementation constraints that were conducted during 2013 and 2014, and that resulted in identification of the Morro Valley as the preferred location for the new facility. The City has applied for a grant from the SWRCB for a recycled water feasibility study, as well as a planning loan under the State Revolving Fund program.

2.1.3 Regulatory Setting

The 1972 Federal Clean Water Act and its 1977 amendments established national water-quality goals and created a national permit system (NPDES) of minimum standards for the quality of discharged waters (USGPO 1997a). Pursuant to the new system, states established standards specific to water bodies and designated the types of pollutants to be regulated. Since 1973 the California State Water Resources Control Board and its nine Regional Water Quality Control Boards have been delegated the responsibility of administering permitted discharges into the coastal marine waters of California. The State Board prepares and adopts the COP, which incorporates the state water-quality standards that apply to all NPDES permits. The RWQCB established a Water Quality Control Plan for the basin containing San Luis Obispo County waters ("The Basin Plan" RWQCB 1994). The basin standards incorporate the applicable portions of the COP and specifically address the beneficial uses of marine waters adjacent to the outfall site. Water-quality objectives and toxic material limitations in the basin plan are designed to protect the beneficial uses of ocean waters within specific coastal areas. The basin plan identifies the following existing beneficial uses for the waters of Estero Bay:

- **Water Contact Recreation (REC-1).** Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water skiing, skin and scuba diving, surfing, and fishing.
- **Noncontact Water Recreation (REC-2).** Uses of water for recreational activities involving proximity to water but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life studies, hunting, sightseeing, and aesthetic enjoyment in conjunction with the above activities.
- **Industrial Service Supply (IND).** Uses of water for industrial activities that do not depend primarily on water quality, including, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.
- **Navigation (NAV).** Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels. The RWQCB interprets NAV as being present within any natural body of water that that has sufficient capacity to float watercraft for the purposes of commerce, trade, transportation, and pleasure.

- **Marine Habitat (MAR).** Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, fish, shellfish, and vegetation such as kelp, or wildlife such as marine mammals and shorebirds.
- **Shellfish Harvesting (SHELL).** Uses of water that support habitats suitable for the collection of filter-feeding shellfish such as clams, oysters, and mussels, for human consumption, commercial, or sport purposes. This includes waters that have in the past, or may in the future, contain significant shellfisheries.
- **Ocean Commercial and Sport Fishing (COMM).** Uses of water for commercial or recreational collection of fish, shellfish, or other organisms, including uses involving organisms intended for human consumption or bait purposes.
- **Preservation of Rare, Threatened, or Endangered Species (RARE).** Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.
- **Wildlife Habitat (WILD).** Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Section 301(b) of the Clean Water Act requires publicly owned treatment works to meet effluent limitations based on secondary treatment, which is defined in terms of limits on three effluent parameters (40 CFR 133; USGPO 1997a). These limitations are:

- Total suspended solids (TSS) concentrations not exceeding 30 mg/L as a 30-day average and removal rates not less than 85%;
- BOD concentrations not exceeding 30 mg/L as a 30-day average and removal rates not less than 85%; and
- Hydrogen-ion concentration (pH) between 6.0 and 9.0.

These limits were established based on the treatment capabilities of the best available technology at the time, rather than an evaluation of treatment necessary to reduce potential environmental impacts to an acceptable level within receiving waters. Recognizing that this level of treatment may not be necessary within ocean waters, Section 301(h) was added to the Act to allow an NPDES discharge permit to modify some or all of these full secondary-treatment requirements, if certain conditions are met. The MBCSD WWTP is a combined primary and secondary-treatment facility that has operated under a Section 301(h)-modified NPDES permit (number CA0047881) since March 1985. The modifications in this NPDES permit apply only to the TSS and BOD requirements, so all other NPDES limitations apply without exception, including those for wastewater pH and toxic compounds. The modification was issued only after the MBCSD satisfied the following additional conditions:

- Demonstrate the existence of a water-quality standard specific to the pollutant for which the modification is requested (40 CFR 125.61; USGPO 1997a). The COP specifies limits on TSS and dissolved-oxygen (DO) depression (SWRCB 2005). In January 2009, the California Coastal Commission determined that the discharge complies with the State Coastal Zone Program that incorporates COP standards.

- Demonstrate that the discharge does not adversely impact public water supplies or interfere with the protection and propagation of balanced, indigenous biological populations (40 CFR 125.62). The USFWS (1998 2007) and the NMFS (1998 2004) determined that the discharge would not adversely impact threatened or endangered species, or critical habitats, pursuant to the ESA.
- Conduct a monitoring and reporting program capable of evaluating the effects of the discharge (40 CFR 125.63). The monitoring program described in this report satisfies this requirement.
- Demonstrate that the discharge will not result in any additional treatment requirements on any other point or nonpoint source (40 CFR 125.64). The footprint of the MBCSD discharge does not overlap that of other discharges.
- Determine whether the WWTP is subject to pretreatment requirements. Since there are no known sources of toxic pollutants or pesticides in the influent, the WWTP is exempt from general pretreatment requirements in lieu of a pollution prevention program. In addition, since the discharge is considered small, it is exempt from the urban pretreatment requirement (40 CFR 125.65).
- Demonstrate whether the pollution-prevention program meets the requirement for a nonindustrial source control program (40 CFR 125.66). The MBCSD pollution prevention program implements public education and source reduction programs to limit the entrance of toxic pollutants or pesticides into the treatment plant.
- Demonstrate that there will be no new, substantially increased discharges of BOD and TSS beyond those specified in the permit (40 CFR 125.67). The historically high performance of the plant process, the limited projected growth in population and industry within the service area, and the analyses provided in this report demonstrate this.
- Ensure that the WWTP exceeds the minimum requirements for primary treatment (40 CFR 125.60). The WWTP performs "*treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biochemical oxygen demanding material and of the suspended solids in the treatment works influent, and disinfection, where appropriate*" (40 CFR 125.58(r); USGPO 1997a).

The MBCSD WWTP is categorized as a Class III wastewater treatment facility by the Office of Operator Certification within the California State Water Resources Control Board. The Board reclassified the facility in 2001 from a Class IV facility based on the advanced treatment process and the plant's low flow volume. A typical Class IV facility treats more than 20 MGD in the primary process, while the MBCSD plant processes a total flow of less than 2 MGD and carries out partial-secondary treatment of a large portion of the flow.

During 2015, the California Department of Public Health developed a Management Plan for Commercial Shell Fishing within Morro Bay. The Plan provides reporting guidelines in the event of a sewage spill to the Bay or adjacent ocean. WWTP staff provided comments on the Plan, and signed a Statement of Agreement concerning its implementation.

2.1.4 Description of the Treatment and Outfall System

The WWTP operating characteristics are listed in Table A.1 of Appendix A. All wastewater is treated through a primary treatment process, which includes screening, grit removal, and primary sedimentation, as shown in Figure 2.3. Typically, a portion of the flow is diverted for an additional secondary-treatment process using biofilters, a solids-contact chamber, and a secondary clarifier. The secondary process consists of parallel single-stage, high-rate, trickling filters whose combined outflow goes to a solids-contact channel and then to a secondary sedimentation tank. When flows exceed 1 MGD, secondary-treated effluent can be subsequently blended with primary-treated effluent, before the entire blend is chlorinated for disinfection and then dechlorinated. The disinfected and dechlorinated effluent is discharged into Estero Bay through a 4,400-ft (1,341-m) outfall terminating in a multi-port diffuser system. Waste biosolids are anaerobically digested, dried, composted and used as soil conditioner and fertilizer. A schematic of the biosolid process is shown in Figure 2.15 on Page 2-37.

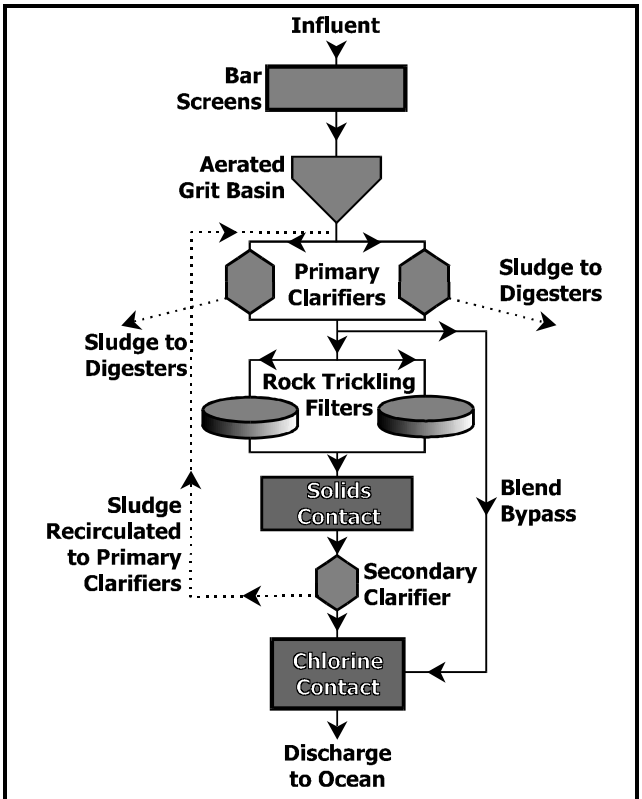

Figure 2.3 Schematic of the Wastewater Treatment Process

The location of the Morro Bay-Cayucos WWTP and outfall within Estero Bay is shown in Figure 2.4 on the following page. The treated wastewater is released into unstressed, open-ocean waters at 35°23'11"N latitude and 120°52'29"W longitude. The effluent flows through a 27-in (0.69-m) diameter outfall that extends approximately 4,400 ft (1,341 m) in a northwesterly direction. The outfall terminates in a multi-port diffuser approximately 2,700 ft (827 m) from shore. The 170-ft (51.8 m) long diffuser lies at a water depth of 50 ft (15.2 m), measured relative to the mean lower low water (MLLW) datum. Twenty-eight of the 34 available diffuser ports are currently open. The remaining six ports can be made operational if the sustained discharge exceeds 6.60 MGD.

Because of its location, the MBCSD discharge does not interfere with maintenance of water quality and designated beneficial uses within Estero Bay (listed in Section 2.1.3 on Page 2-11). The discharge occurs in well-flushed, open coastal waters where re-entrainment or accumulation of effluent will not violate applicable water-quality standards, even if combined with pollutants from other sources. Intakes and outfalls from other publicly owned treatment works are distant from the MBCSD outfall. For example, water intake for the Morro Bay desalinization plant is from saltwater wells and not from the open ocean where the MBCSD discharge occurs. Similarly, surface discharge of water from the desalination plant, when it does occur, is far south of the MBCSD discharge point and does not add chemical loads to the ocean environment.

2.1.5 Pollution Prevention Program

The MBCSD's Pollution Prevention Program aims to minimize the introduction of incompatible contaminants, such as pollutants and pesticides, into the treatment process. The NPDES permit requires an annual status report detailing efforts to comply with the requirements for a Pollution Prevention Program. This section serves as that report. Additionally, the current permit includes a specific requirement to document educational and outreach efforts regarding proper cat-waste disposal.

Figure 2.4 Location of the MBCSD Outfall and Monitoring Stations within Estero Bay

As in previous years, three aspects of pollution prevention were emphasized during 2015: public outreach, industrial waste source control and identification, and diligent monitoring of influent and effluent for industrial contaminants.

Industrial Waste Survey

During 2015, as in previous years, elevated levels of industrial pollutants were not detected within the MBCSD wastewater stream. Instead, the comprehensive monitoring conducted for more than 27 years indicates that effluent discharged from the MBCSD treatment plant consists primarily of benign constituents typical of wastewater generated from domestic sources. In fact, based on analyses of past water usage, domestic sources contributed approximately 80% (0.75 MGD) of the wastewater processed by the plant in 2015, with commercial businesses and government agencies contributing the remaining amount.

However, this usage-based approach overestimates the influence of nondomestic sources on the treatment process. For example, a substantial portion of the water-use attributed to the government agencies is utilized for the irrigation of landscaping, sports fields, and agricultural uses, which would not be expected to flow into the collection system. These agencies include the City of Morro Bay, Morro Bay High School, the San Luis Coastal School District, Morro Elementary School, and the State Department of Parks (Morro Bay State Park). Additionally, the compounds added to the wastestream by both large commercial and government users are not particularly toxic to humans or aquatic organisms and do not generally interfere with the treatment process.

This general lack of chemical contaminates within the wastestream arises because the local economy within the MBCSD service area relies primarily on tourism and commercial fishing, with no heavy industry or manufacturing of any environmental significance. Beginning in 1999, a digital database has been used to catalogue business names, addresses, and contact information for all of the potential industrial users within the service area. This database has been used to quantify the comparatively low volume of influent derived from light industrial sources within the service area. For example, slightly more than 50 restaurants and an approximately equal number of hotels are found in the service area during any given year.

The list of businesses in the database is adapted and updated regularly based on business license applications filed with the City of Morro Bay and input provided by the Cayucos Sanitary District. Businesses with no potential for industrial discharges, such as offices and retail stores, are classified separately from those with the potential for light-industrial discharge. Businesses that either do not generate wastewater at all, or discharge only domestic wastewater (e.g., theaters, beauty shops, and barbershops), are excluded from the industrial-discharge classification. For the remaining businesses, waste discharge volumes are estimated from water usage history obtained from City Water Department billing records. Follow-up activities for these businesses include scheduled return visits, surprise onsite inspections, and formal tours of the facilities. Based on the initial inspection phase of the survey, certain dischargers were identified for continued close monitoring with scheduled annual site visits. These light industrial facilities include commercial laundries, car washes, dry cleaners, print shops, and the oil-water separator maintained by the City of Morro Bay. These businesses are also targeted with unannounced inspections.

Commercial laundry facilities use industrial-grade detergents, bleaches, surfactants, and brighteners that can potentially harm the bacteria within the plant's secondary-treatment system. In addition, solvents, oils, and other substances removed from soiled laundry have the potential to release contaminates into the wastestream. Other users with light industrial discharges include nursing homes, hotels, a dry cleaner, and various local car washes. Car-wash discharges are considered industrial in nature because of the volume of solids, oils, and grease that are washed from vehicles. As mitigation, the car washes pretreat their wastewater with grease separators before discharging it into the collection system.

The sewer-use ordinance within the City of Morro Bay municipal code also prohibits smaller contributors, like gas stations and repair garages, from disposing known contaminants into the collection system. Similarly, the municipal code requires restaurants and self-service car washes to install and maintain grease traps within their sewer line connections.

In addition to chemical input from light industry, the WWTP itself intentionally introduces three chemicals (ferrous chloride, sodium hypochlorite, and sodium bisulfate) into the treatment process. Ferrous chloride is used primarily to control hydrogen sulfide emissions during flaring of digester gas and heating of the digesters at the WWTP, as required by the APCD. Wastewater facilities commonly disinfect effluent prior to discharge with some form of chlorine; the WWTP uses sodium hypochlorite. However, because even low concentrations of residual chlorine can be hazardous to aquatic life, the MBCSD treatment plant adds sodium bisulfite to the wastestream to remove excess total chlorine residual once disinfection is complete.

Not surprisingly, the sodium bisulfate added to the MBCSD treatment process for dechlorination generally tracks the monthly sodium hypochlorite dose used by the plant. Dosage also tracks seasonal changes in the fraction of organic matter entering the plant, which typically increases during the summer due to an increased tourist population within the service area, and decreased I&I. For example, in 2015, the highest hypochlorite usage (3,508 gallons) and second-highest bisulfate usage (2,838 gallons) occurred in July, reflecting a seasonal increase due to increased throughput in the summer months. The lowest usage of both chemical compounds (2,434 gallons and 2,370 gallons respectively) occurred during the month of February.

Public Outreach

The MBCSD utilizes online and written literature as well as direct communication through multiple workshops, presentations, talks, and plant tours in order to educate consumers and local businesses about the organization and operation of the treatment plant; best management practices (BMPs); and techniques for the proper disposal of a variety of household wastes.

The City's website includes a series of pages devoted to an overview of the wastewater treatment plant and collection-system operations. The web pages contain pertinent information on current topics of interest. These include the status and history of the pending transition to an offsite WRF, and topics covered in the presentation described above. In addition, digital copies of all of the treatment plant's self-monitoring reports from 2005 onward, including, for example, this annual monitoring report are also available online. Finally, the website provides links to the USEPA website and other outside sources of information on specific disposal concerns.

Pursuant to the conservation measures recommended by the USEPA (2007) in their biological evaluation conducted in preparation for issuance of the current NPDES discharge permit, the City's website also incorporates updated information on BMPs for cat-litter disposal and avoiding its introduction into the collection system. During the most recent permit renewal process, USEPA staff postulated that minimizing the input of cat-litter-box wastes into the municipal sewer system would help reduce the introduction of the parasite *T. gondii* into the marine environment, thereby mitigating a known disease vector affecting southern sea otters. RWQCB staff incorporated the USEPA's concerns into a special provision within the plant's final NPDES permit requiring the creation of a cat-litter public-outreach program.

However, immediately following the finalization of the permit, on 21 January 2009, Johnson et al. (2009) published the results of a detailed field study of southern sea otter exposure to *T. gondii,* which unequivocally refuted claims that the incidental disposal of cat litter to the MBCSD system contributed to the observed impacts on otter morbidity from *T. gondii* infection. The authors of the 2009 study confirmed that the epicenter of *T. gondii* exposure in otters was not located within Estero Bay, as erroneously asserted by NRDC (2006) and Miller et al (2002). More importantly, they also hypothesized that, based in part on the new epicenter location, "a more important source of infection might be bobcats and mountain lions" instead of housecats. In fact, the world's largest reported outbreak of human toxoplasmosis was linked to a municipal drinking-water reservoir in British Columbia that had been contaminated by cougar feces (Bowie et al. 1997; Aramini et al. 1998).

Nevertheless, MBCSD staff have maintained their public outreach and education efforts on the proper disposal of cat litter. For example, informational newsletters are occasionally distributed with monthly water bills. The inserts include information on newly implemented water-conservation requirements, proper disposal of pet wastes, and emergency contact information for sewer emergencies. Additionally, discussions of cat litter BMPs were included in presentations made to local realty groups as well as to members of the public during tours of the treatment plant.

In particular, on 17 June, Mr. Bruce Keogh, Mr. Rob Livick (Public Works Director, City of Morro Bay), and Mr. Robert Enns (President, Cayucos Sanitary District Board), gave presentations at the Scenic Coast Association of Realtors Bimonthly Education Meeting held in Morro Bay. The presentation included a summary of the progress on the new water reclamation facilities currently under consideration by both the City and the District, and the sewer fee schedules for the City and Sanitary District. The presentation also provided public outreach on *T. gondii*, best management practices for cat litter disposal, including not flushing cat litter, information on the Countywide pharmaceutical take back program, proper disposal of fats, oils, and greases (FOG), collection system do's and dont's, information on the household hazardous waste facility at the WWTP, and the lateral inspection program.

MBCSD does not anticipate any changes to the cat-litter public-outreach program in the coming year. They will continue to use newsletters, public presentations, and plant tours to communicate with the general public on the topic of cat litter and waste disposal. In addition, MBCSD staff will continue to make periodic visits to specific commercial and professional establishments to encourage them to establish and implement appropriate policies and procedures to dispose of feline wastes properly.

Other public-outreach endeavors by the MBCSD include its involvement in the collection of household hazardous and pharmaceutical wastes. Beginning in August 2000, the MBCSD collaborated with the Integrated Waste Management Authority to establish a permanent household hazardous-waste collection facility at the treatment plant. The WWTP offers free waste disposal to all residents of San Luis Obispo County every Saturday from 11:00 a.m. to 3:00 p.m., except holiday weekends.

The disposal facility remains one of the top waste-disposal sites in the county in terms of the volume of material collected. Between 20 and 50 individuals utilize the facility each weekend. From July 2014 to June 2015, the WWTP disposal facility processed more than 51,000 pounds of household hazardous waste, a large portion of which was recycled. The majority of waste consisted of flammable or poisonous materials. Without the permanent hazardous waste facility, much of this material would have gone to a landfill or would have passed through the WWTP plant and into the ocean.

Source Identification

Past and ongoing efforts to eliminate or reduce contaminants entering the WWTP's wastestream have been successful, and as evidence of that success, elevated contaminant concentrations within effluent samples are rarely detected during the periodic chemical assays. Although no unusual contaminants were detected within the wastestream during 2015, anomalous concentrations of individual chemicals have been reported in the past. On those occasions, MBCSD personnel successfully traced the contaminants to the source and worked with the source owner to eliminate the contamination.

In 2006, the State Water Resources Control Board adopted new statewide waste-discharge requirements for sanitary sewer systems, which transferred responsibility for managing the introduction of FOG, and other components from the WWTP to the Collections Department under the City of Morro Bay's Sewer System Management Plan[1]. Ongoing source identification and resolution efforts conducted by the City on an annual basis include a grease-trap inspection program for businesses subject to the requirements. The MBCSD regularly conduct scheduled inspections as well as spot checks at approximately 52 businesses. During inspections, MBCSD personnel discussed BMPs with restaurant staff, provided educational materials such as a BMP handbook and made recommendations for grease trap maintenance as necessary.

[1] City of Morro Bay Sewer System Management Plan, originally approved June, 2009, reapproved June, 2014. City of Morro Bay Public Services Department, Wastewater Collections Division

They also distributed "*no grease*" stickers to display above sinks to raise awareness and act as a reminder of proper disposal methods. Known industrial dischargers were also inspected for compliance with source control processes and procedures. Industrial inspections typically include Mission Linen, Morro Bay Harbor Patrol, Morro Bay Car Wash, Village Dry Cleaners, Rite-Aid, and Culligan Water.

2.2 WASTEWATER CHARACTERIZATION

Monthly wastewater characterizations documented a number of different aspects of the treatment plant's performance in 2015 (Table 2.2). Removal rates quantified the plant's ability to reduce major organic constituents within the wastestream. Effluent concentrations characterized the overall quality of effluent discharged through the ocean outfall, while mass emissions quantified the cumulative load of wastewater constituents introduced into the marine environment.

Treatment-plant personnel periodically collected wastewater samples throughout 2015. Results from the analyses of those samples were used to compute the monthly averages of the principal influent and effluent characteristics listed in Table 2.2. WWTP personnel performed the laboratory analyses to determine the principal physicochemical properties of the effluent, including concentrations of suspended solids, BOD, pH, total residual chlorine (TRC), turbidity, settleable solids, and total coliform bacteria. The frequency and the duration of individual sampling and testing events varied among the parameters. For example, average reductions in suspended solids and BOD were determined from 24-hour composite samples of influent and effluent that were collected and analyzed at least weekly. Analyses for the concentrations of most of the remaining constituents were conducted only on effluent samples. Discrete effluent grab samples were analyzed for pH, TRC, temperature, turbidity, and settleable solids on a daily basis. Effluent grab samples were also analyzed for total coliform five times per week, whereas O&G concentrations were determined by BC Laboratories from weekly samples. Effluent ammonia was determined from monthly grab samples.

Detailed analyses of these measurements confirm that, during 2015, the plant exceeded wastewater treatment expectations based on the regulatory standards. Over the plant's long history, there has never been an indication of deteriorating plant performance, and effluent quality has consistently exceeded expectations based on the original design criteria. Rare exceptions to standards or criteria have been brief, and have been the direct result of unavoidable repairs to, or mechanical failures of a treatment-system component. As a byproduct of a diligent preventative maintenance program, the plant has operated at a high level of efficiency with little equipment down time. The primary challenge for plant personnel is to respond quickly to unanticipated failures in system components and to external events that affect the treatment process.

2.2.1 Flow Rate

Flow through the plant in 2015 remained far below both the plant's design capacity and the limits established in the NPDES discharge permit. The waste discharge requirements (RWQCB-USEPA 2009) state that the "*peak seasonal dry weather flow shall not exceed a monthly average of 2.36 MGD.*" Plant throughput never approached this flow limitation during 2015 (Table 2.2), not even during winter (October through March) when the limitation does not apply due to the expectation of increased flows from precipitation events. In fact, the highest average monthly flow, 1.093 MGD in July, was less than half of the peak dry weather limit.

Table 2.2 Monthly Averages of Influent and Effluent Parameters

		Suspended Solids				Biochemical Oxygen Demand			
Month	Flow (MGD)	Influent (mg/L)	Effluent (mg/L)	Removal (percent)	Emission (kg/day)	Influent (mg/L)	Effluent (mg/L)	Removal (percent)	Emission (kg/day)
January	0.975	361	25	92.4	93	359	42	87.4	150
February	0.983	297	32	88.6	117	370	64	82.3	235
March	0.952	511	32	93.3	113	429	45	89.2	170
April	0.935	575	28	95.3	98	440	46	89.8	150
May	0.921	393	36	91.6	123	375	49	86.8	177
June	0.974	380	36	89.8	129	369	53	85.6	188
July	1.093	345	26	92.6	106	349	42	87.8	189
August	0.967	426	25	94.3	90	352	51	85.4	182
September	0.901	478	21	95.5	70	380	54	85.3	191
October	0.866	323	30	90.8	96	336	43	87.0	134
November	0.849	300	39	89.5	123	348	45	87.2	149
December	0.760	270	39	83.9	111	334	53	83.8	151
Average	**0.931**	**389**	**31**	**91.5**	**106**	**370**	**49**	**86.5**	**172**
Monthly Limitation	**≤2.36**[1]		**≤70**	**≥75.0**	**≤546**		**≤120**	**≥30.0**	**≤936**
Annual Total (MT)					**39**				**63**
Nominal Annual (MT/year)					**≤199**				**≤342**

Table 2.2 (continued) Monthly Averages of Influent and Effluent Parameters

	pH					Oil and Grease		
Month	Influent	Effluent	Turbidity (NTU)	Settleable Solids (ml/L)	Median[2] Total Coliform (MPN/100ml)	Influent (mg/L)	Effluent (mg/L)	Emission (kg/day)
January	7.9	7.5	28	<0.1[3]	<2	34	≈2.9[4,5]	≈10
February	7.9	7.5	30	<0.1	2	63	≈1.8	≈6
March	7.9	7.5	31	<0.1	<2	57	≈1.8	≈6
April	7.8	7.5	30	<0.1	<2	130	≈3.3	≈11
May	7.9	7.6	29	<0.1	<2	110	≈2.0	≈6
June	7.9	7.6	31	<0.1	6	85	<1.7	<7
July	7.8	7.6	30	<0.1	<2	110	<1.7	<7
August	7.8	7.5	29	<0.1	2	62	<1.7	<6
September	7.9	7.5	25	<0.1	2	17	≈1.9	≈7
October	7.8	7.6	28	<0.1	<2	100	≈2.0	≈6
November	7.8	7.5	28	<0.1	<2	45	<1.7	<5
December	7.9	7.5	34	<0.1	<2	160	<1.7	<4
Average	**7.9**	**7.5**	**29**	**<0.1**	**<2**	**81**	**<1.7**	**<6**
Monthly Limitation		**6-9**	**≤75**	**≤1.0**	**≤23**		**≤25.0**	**≤195**

[1] Peak Seasonal Dry-Weather Flow (PSDWF)
[2] Computed from samples collected in the 30 days prior to the last day of the month (MBCSD 1997a)
[3] The "*less-than*" symbol (<) indicates that the substance was not detected at a concentration above the method detection limit (MDL), which is listed after the "<" symbol.
[4] The monthly median O&G concentration is used to evaluate plant performance because it provides a more robust measure of central tendency when one or more individual concentrations are not reliably quantified (see Section IV.C.8.C of the COP). O&G concentrations measured all but 2 of the 52 weekly effluent samples were below the 5-mg/L practical quantification limit (PQL), as shown by the gray shading in Figure 2.9c on Page 2-27.
[5] The "*approximation*" symbol (≈) indicates that the median concentration for the month was also too low to be reliably quantified; namely, it was below the practical quantification limit (PQL).

I&I associated with a highly unusual rainstorm in mid-July contributed to the monthly WWTP throughput (solid black spike at the bottom of Figure 2.5). Although increased inflow generated by this storm resulted in the highest daily flow for the year (1.552 MG), the event was brief. Over a longer term, the elevated July monthly flow was largely associated with an overall increase in population due to summer tourism; particularly over the 4th of July holiday. Between 2 July and 6 July, 6.4 MG of wastewater was processed, including the second, third, and fourth highest daily flows of the year (dashed line in Figure 2.5).

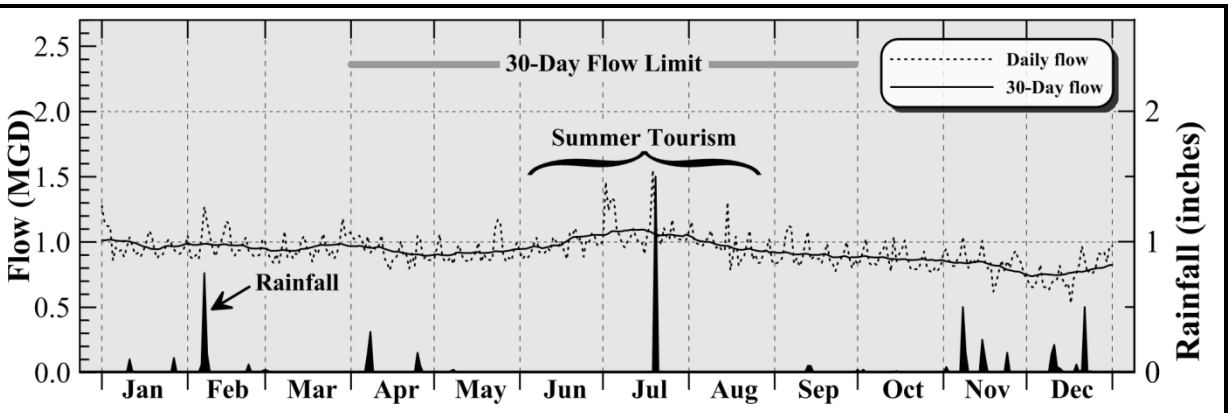

Figure 2.5 Plant Flow and Rainfall

The second highest monthly flow, 0.983 MGD in February, was associated with I&I from an isolated rainstorm that deposited 0.96 inches at the WWTP. That rainfall event produced a succession of daily flow volumes in excess of 1 MGD in early February. Similar, isolated increases in daily flow were generated by smaller rainfall events in the months of November and December.

Overall, however, only 5.83 inches of rain fell at the treatment plant during 2015. This is far below the average annual precipitation measured at the plant over the last decade (12.5 inches), and marks the fourth straight year of below-average precipitation. Additionally, rainfall events during 2015 were widely separated in time, and only a limited amount of precipitation was generally deposited during each storm. As a result, their influence on monthly plant flows was limited compared to the influence of increased populations during the summer tourist season.

The influence of summer tourism on the long-term flow record is apparent as a steady increase in the 30-day running average flow beginning in mid-June (solid line in Figure 2.5). The long-term flow peaked at 1.10 MGD in mid-July, and then steadily decreased through the beginning of December. Nevertheless, the mid-July maximum in the 30-day running average flow represented only 46% of the monthly allowance for peak dry-season flow, which is indicated by the thick shaded line that spans the '*dry*' season (April through September) in Figure 2.5.

Although I&I and population fluctuations affected plant flow over the short term, longer term flow rates declined significantly during 2015, culminating with a December monthly flow that was the lowest on record. The 2015 annual average flow rate of 0.93 MGD was also a historical low. At least some of this decrease was related to the successful water-conservation measures implemented by the citizens of Cayucos and Morro Bay. The City of Morro Bay reduced water usage in 2015 by 13.5%, significantly surpassing the 12% mandatory water restriction goal imposed by statewide limits that went into effect in April 2015.

2.2.2 Suspended Solids, Turbidity, and Settleable Solids

Suspended solids, turbidity, and settleable solids measure the particulate load within wastewater. One of the principal functions of the treatment process is to remove organic particulates from the wastestream. The treatment plant's removal of nearly all (91.5%) solids from influent (Figure 2.6b; Table 2.2) demonstrates the high overall plant performance throughout 2015. As such, the plant's solids removal rate far exceeded the minimum required by the NPDES permit, which specifies removal of only 75% of the suspended solids on a monthly basis.

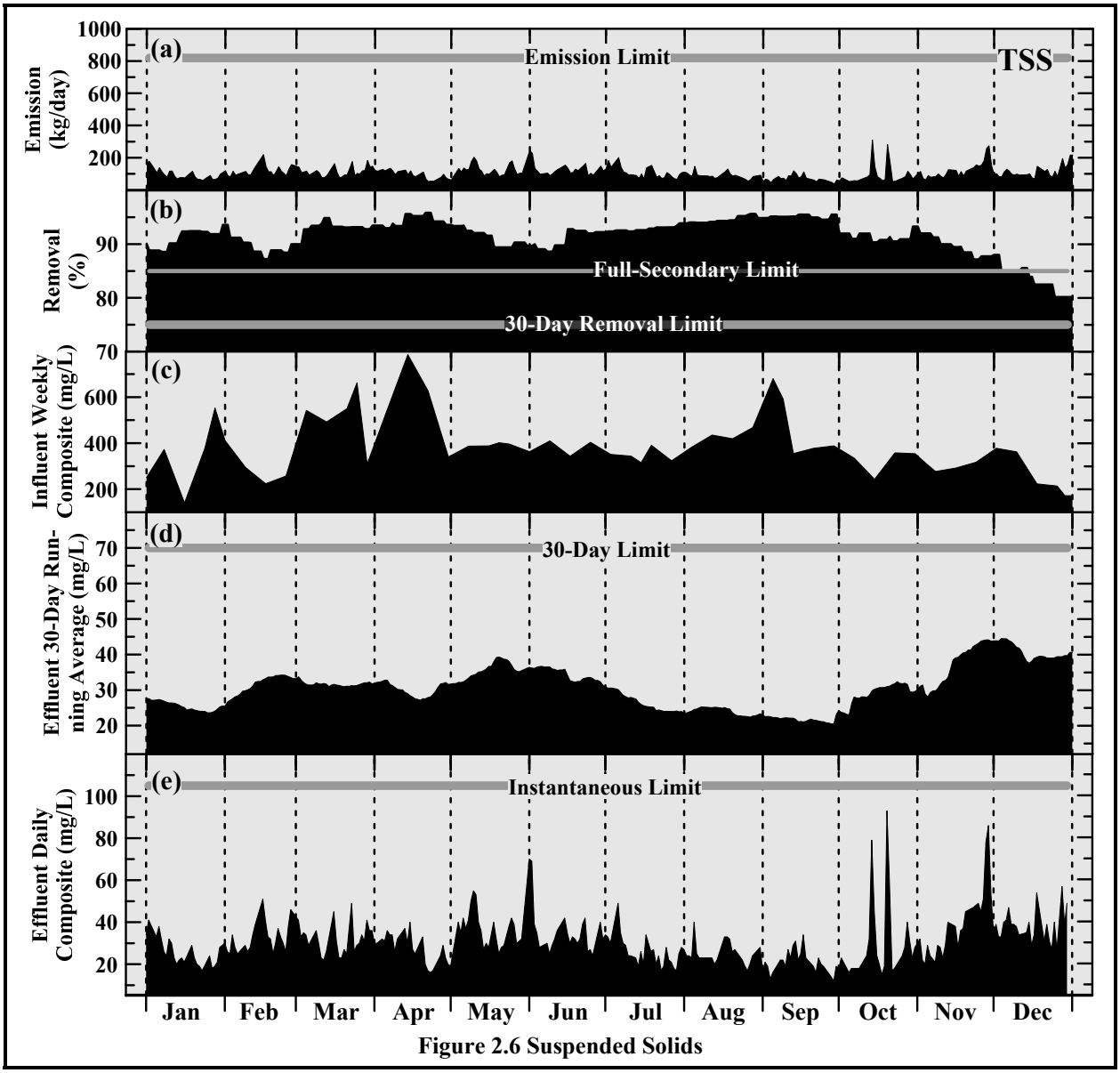

Figure 2.6 Suspended Solids

In fact, the plant's annual removal rate of 91.5% substantially exceeded the 85% monthly removal rate established for full-secondary treatment. Moreover, the WWTP achieved removal rates equivalent to full secondary treatment consistently throughout the year, with monthly averages exceeding the standard in

every month except December, when the 83.8% removal was only slightly below the standard. However, the slight reduction in the average December removal amount was not due to a decline in the efficacy of the treatment process; instead, it resulted from a decrease in the influent TSS concentration. This conclusion is apparent from a comparison of the time series shown in Figure 2.6; namely, removal rates in December (Figure 2.6b) exhibit a steady decline that matches the decline in influent TSS concentrations (Figure 2.6c). During that same period, no concomitant increase in effluent TSS concentration (Figure 2.6de) occurred that would suggest a decline in plant efficiency.

The foregoing discussion demonstrates that removal rate is not always a good indicator of changes in plant performance. Because influent concentration is in the denominator of the removal-rate equation, changes in its value, which are not related to plant performance, have a greater influence on the determination of removal rate than does effluent concentration. From a process standpoint, removal of solids from the influent stream at a constant rate is not possible when there is less organic material available to remove from it. From an environmental standpoint, only the solids loading within the discharge stream is of concern, not the influent loading.

Regulators recognize that requiring a high removal rate is unnecessary when effluent TSS concentrations are low to begin with. Consequently, the NPDES discharge permit imposes the 75% monthly removal rate only when the requirement would result in an effluent TSS concentration that exceeds 60 mg/L (RWQCB-USEPA 2009, SWRCB 2005). Thus, removal rate is not a requirement for discharge compliance when influent TSS concentrations fall below 240 mg/L.[1] The 60-mg/L effluent TSS threshold is more stringent than the monthly permit limit of 70 mg/L for effluent TSS concentrations. During 2015, the average TSS concentration of 31 mg/L was only about half the TSS threshold where removal-rates become relevant.

Regardless of its compliance applicability, the WWTP achieved an annual average removal rate 16.5% higher than the permit requirement. Moreover, it met the 75% removal rate on a regular basis throughout the year, not just on a monthly or annual basis. This is evident from a comparison of the 75% removal requirement shown by the thick grey line at the bottom of Figure 2.6b, and the 30-day running-mean removal rate, shown in black.

Because of the plant's consistently high removal rates throughout the year, effluent TSS concentrations easily met the monthly and instantaneous permit requirements. Not only were the averages for each calendar month well below the monthly limit of 70 mg/L (Table 2.2), but the 30-day running mean never approached the limit at any time during the year (Figure 2.6c). Similarly, none of the daily measurements of TSS concentrations within effluent samples exceeded the permitted instantaneous limit (Figure 2.6d).

The low effluent TSS concentrations, combined with the low overall flow rate, resulted in TSS emissions that were far below the allowable solids emission (Figure 2.6a). Over the entire year, the WWTP only discharged 39 metric tons of suspended solids to the ocean. This mass emission is only one-fifth of the projected 199 metric tons that would have been discharged if effluent had contained the permitted TSS concentration of 70 mg/L and the throughput reached the nominal average dry-weather flow of 2.06 MGD

Similar to TSS removal rates, the effluent concentrations routinely surpassed the secondary-treatment standard for solids concentrations. Specifically, benchmark monthly effluent TSS concentrations during 6 months of the year were at or below the 30-mg/L maximum concentration required to meet full-secondary standards (Table 2.2).

[1] 240 mg/L is four-times the 60-mg/L threshold on effluent concentration that determines the applicability of removal rate for compliance evaluations.

Effluent turbidity is related measure of solids loading that has direct implications for the wellbeing of the marine environment. Marked turbidity increases can limit the penetration of ambient light and negatively affect primary production, namely, photosynthesis that drives phytoplankton blooms at the base of the food chain. Thus, because of its environmental importance, and because it may not correlate with effluent TSS, the NPDES discharge permit also limits increases in effluent turbidity. However, as with TSS concentrations within MBCSD effluent, turbidity has also been correspondingly low. This is visually apparent in the diffuse cloud emanating from the diffuser shown in Figure 2.2 on Page 2-5. Particulate loads within discharged wastewater are light, and the turbidity apparent in the photograph is largely an artifact of differences in the refractive index at the seawater-wastewater interface.

Quantitative data collected as part of the MBCSD monitoring confirms the low overall turbidity of the effluent, and the imperceptible impact its discharge has on receiving seawater clarity. Chapter 3 of this report analyzes transmissivity measurements collected offshore during quarterly receiving-water surveys. The transmissivity data show that the turbidity associated with effluent discharge dissipates rapidly shortly after discharge, and that the only perceptible changes in water clarity associated with particulate loading are found extremely close to discharge ports near the seafloor where little ambient light penetrates. This general absence of perceptible impacts on receiving-water clarity is a result of the low turbidity measured within effluent onshore and immediately prior to discharge. Effluent turbidity has historically been very low, and well below the permitted limits; 2015 was no exception (Table 2.2 and Figure 2.7).

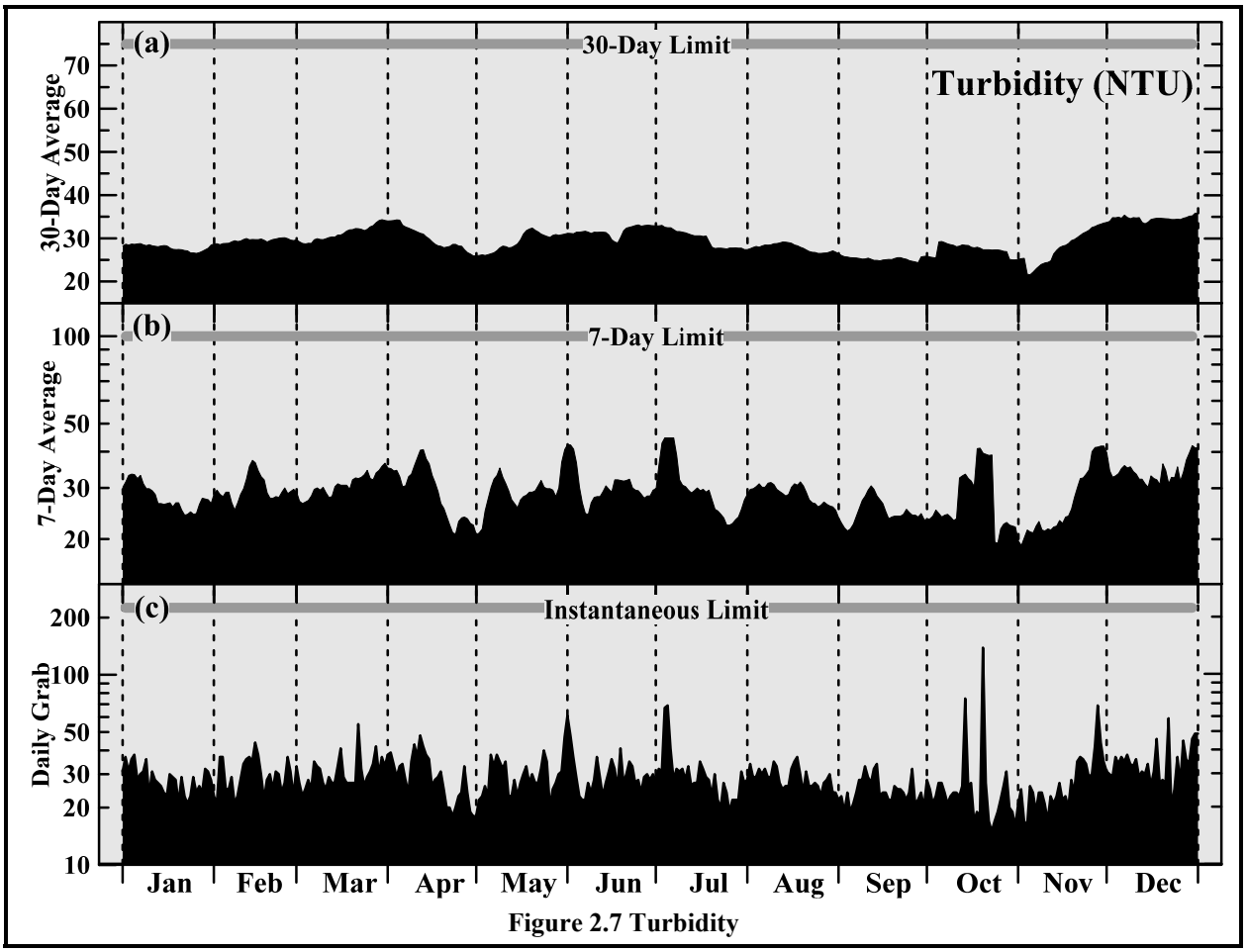

Figure 2.7 Turbidity

Settleable solid concentrations, which are the only remaining solids-related measures of effluent quality, echo the findings described above. Namely, the monthly averages not only remained well below the permitted limits, but were also below the low detection limit of 0.1 ml/L (Table 2.2). Only six of the 365 daily effluent samples contained detectable amounts of settleable solids, and none of the reported individual measurements exceeded the monthly average limit of 1 ml/L, much less the respective weekly and instantaneous limits of 1.5 ml/L and 3.0 ml/L.

Thus, during 2015 as in prior years, all measures of effluent solids demonstrated that the treatment process exceeded performance expectations by regularly removing a greater amount of solids from the influent stream, and by discharging a small fraction of the maximum anticipated solids load to the marine environment. The consistently low monthly averages for effluent TSS, turbidity, and settleable solids attest to the overall effectiveness of the treatment plant's screening, grit removal, sedimentation, filtration, and clarifying processes (Table 2.2).

2.2.3 Biochemical Oxygen Demand

In combination with solids removal, a primary function of the treatment process is to reduce organic loading within the wastewater stream. The effectiveness of the organic removal process is closely linked to that of the solids removal process because the majority of organic constituents tend to be associated with wastewater particulates. However, the measure of organic loading, namely BOD, differs from the direct physicochemical measurements of solids concentrations. Instead, BOD indirectly measures organic loading within the wastewater stream by determining the amount of oxygen required for aerobic bacteria to decompose organic matter in a sample of wastewater. Organic material, which supports bacterial degradation and demands oxygen, can harm the environment if its decomposition severely depletes DO within receiving waters. Specifically, prolonged oxygen depletion can disrupt benthic and demersal communities and can also cause mass mortalities of aquatic life (Diaz and Rosenberg, 1995).

However, DO depletion is typically only of concern in semi-enclosed water bodies, such as bays and estuaries, which are environments that differ vastly from the highly oxygenated open-coastal marine environment of Estero Bay. In fact, because of higher oxygen-replenishment capabilities, an evaluation by the National Academy of Sciences (1993) questioned the environmental benefits of imposing technology-based BOD limits on open-ocean dischargers, namely, requiring secondary-treatment standards for BOD.

Nevertheless, the NPDES discharge permit sets limits on the discharge of BOD, and BOD constitues another important parameter for evaluating the overall performance of the treatment process. Because of the complexity and duration required of BOD determinations, evaluation is only required on a weekly basis (Figure 2.8). Given the performance of the solids removal process during 2015, the exceptionally high BOD removal is not surprizing. On an annual basis, the WWTP reduced influent organics by more than 86.5%, as determined by the average of weekly composite samples analyzed for BOD (Table 2.2;) Thus, the WWTP removed organic material at a rate nearly three-times greater than the 30% removal rate required by the NPDES discharge permit. Additionally, as with TSS removal, regulators recognize that high BOD removal rates are irrelevant when influent BOD concentrations are low enough to achieve an effluent BOD of 60 mg/L with a lesser removal rate. Nevertheless, the WWTP consistently removed BOD at much higher rates even though average effluent BOD concentrations remained below the applicability threshold of 60 mg/L in all 12 months of the year. The actual monthly removal rate even exceeded the 85% removal rate established for secondary treatment in ten months, and the rates were only slightly below the secondary treatment standard in the other two months.

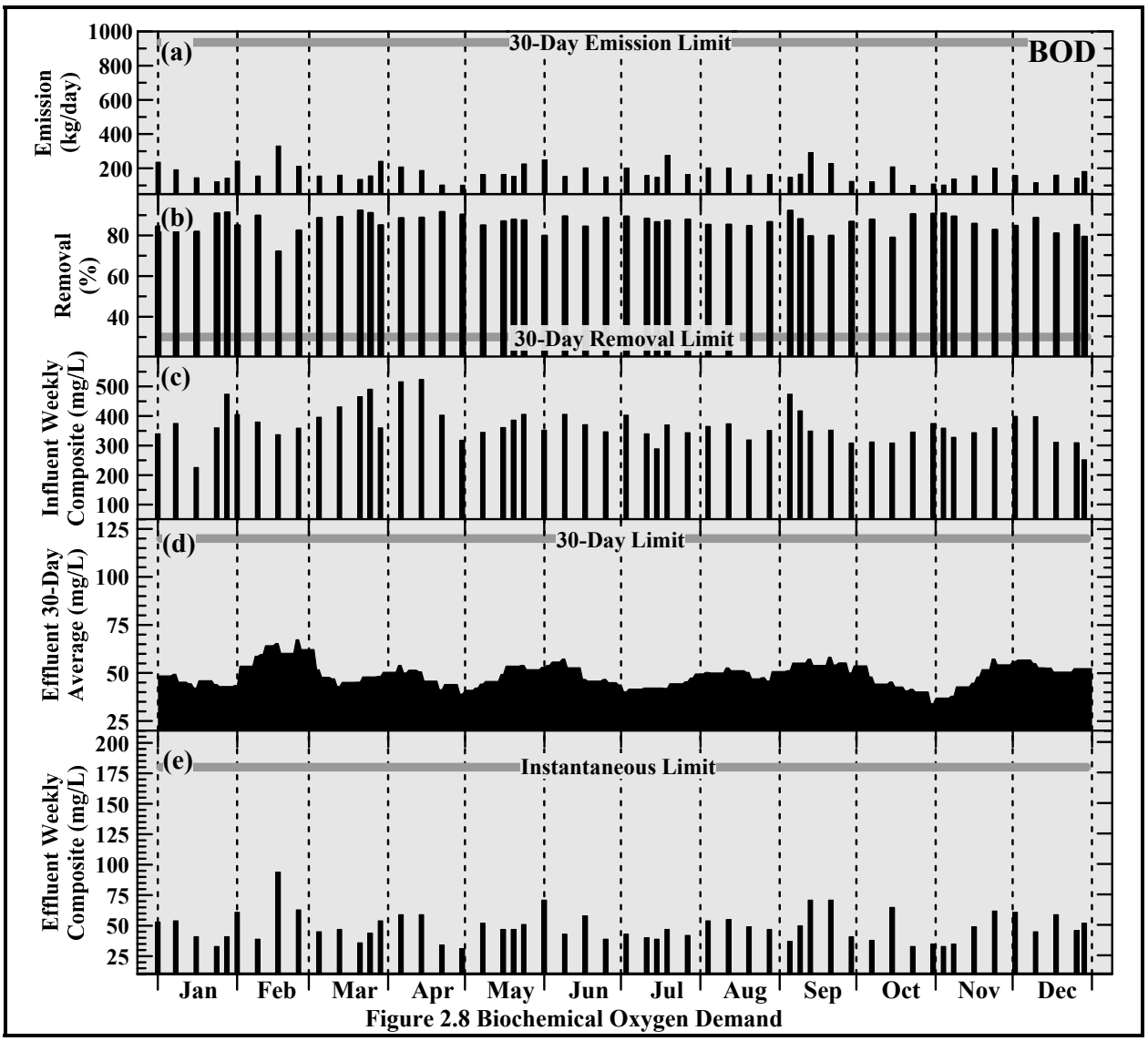

Figure 2.8 Biochemical Oxygen Demand

BOD concentrations within individual effluent samples were consistently low throughout the year (Figure 2.8e) and accordingly, the running 30-day average remained well below the limit that applies to averages over calendar months (Figure 2.8d). Additionally, as with TSS, the low BOD concentrations combined with low flow in 2015 resulted in an extraordinarily low annual BOD emission of 63 MT, which is only 18% of the 342 MT allowed by the discharge permit.

2.2.4 Oil and Grease

During 2015, the treatment process reduced average O&G concentrations within the influent stream by at least 50-fold (Table 2.2). The actual amount of the reduction cannot be precisely determined because O&G concentrations within all but two of the 52 weekly effluent samples were too low to be quantified. The two quantifiable concentrations, the 6.6 mg/L in January (see the inset in Figure 2.9c) and the 5.4 mg/L in April, only marginally exceeded the 5.0-mg/L PQL for the O&G analysis method (dark gray

shading in the Figure). Although the presence of O&G was detected within some of the remaining 50 samples, 30 of the samples had concentrations too low to be detected even with the very sensitive analysis method (light gray shading in the Figure).

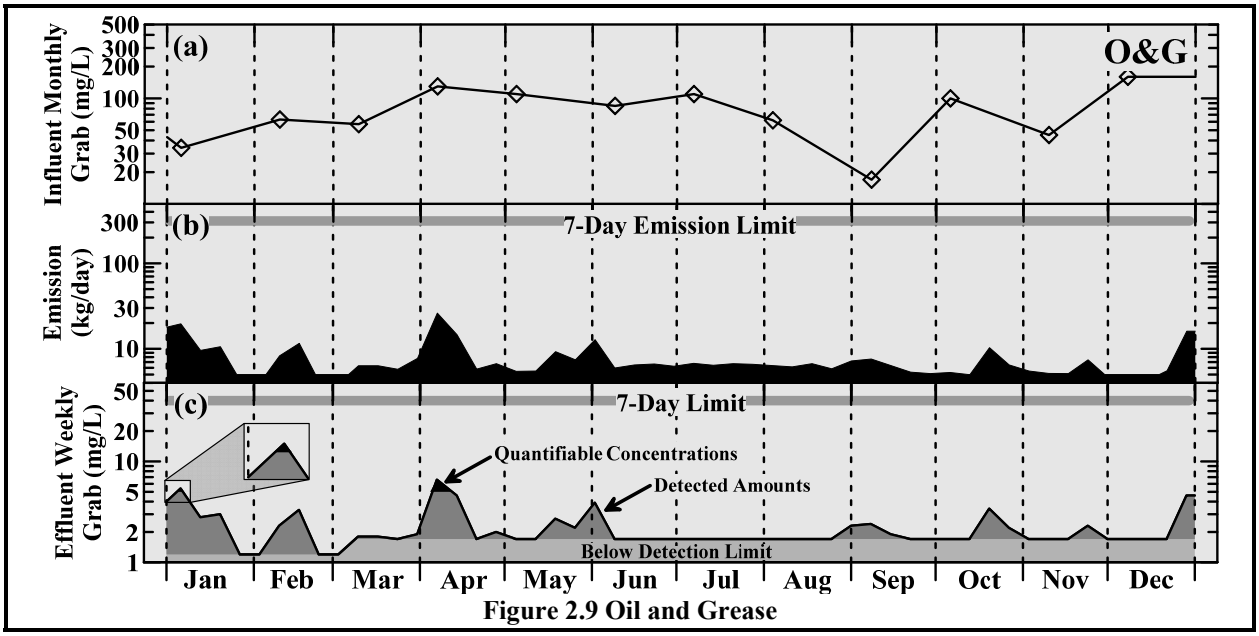

Figure 2.9 Oil and Grease

The long series of consistently low O&G concentrations measured in the 2015 effluent samples was highly unusual in the three-decade-long database. However, the low effluent concentrations did not arise because of a marked decrease in the influent O&G concentrations (Figure 2.9a). In fact, the annual average influent concentrations in 2015 were higher than the three-decade-long average. When combined with the lowest flow on record, the 2015 weekly emissions were more than an order of magnitude below the allowed emission (Figure 2.9b).

2.2.5 pH

The MBCSD discharge permit requires that hydrogen-ion concentrations (pH) within effluent samples remain between 6 and 9 at all times. Section 301(h) of the Clean Water Act allows an NPDES discharge permit to be issued that exceeds these pH limitations. However, because the plant's partial-secondary treatment can routinely treat wastewater to comply with the pH standards for full-secondary treatment, the MBCSD discharge permit does not allow this exception. Moreover, the general absence of heavy-industrial input into the collection system creates an influent stream with a nominal pH that meets the discharge requirement even without treatment.

Because influent pH (dashed line in Figure 2.10) remained within the discharge limits (shaded area) throughout 2015, effluent pH measurements also remained within the allowable range by default (solid line). Comparison of the two time histories demonstrates that the treatment process significantly moderated short-term pH fluctuations within the influent. Additionally, average annual effluent pH (7.54) was slightly less alkaline than the influent (7.85) and substantially less alkaline than the receiving seawater (8.0).

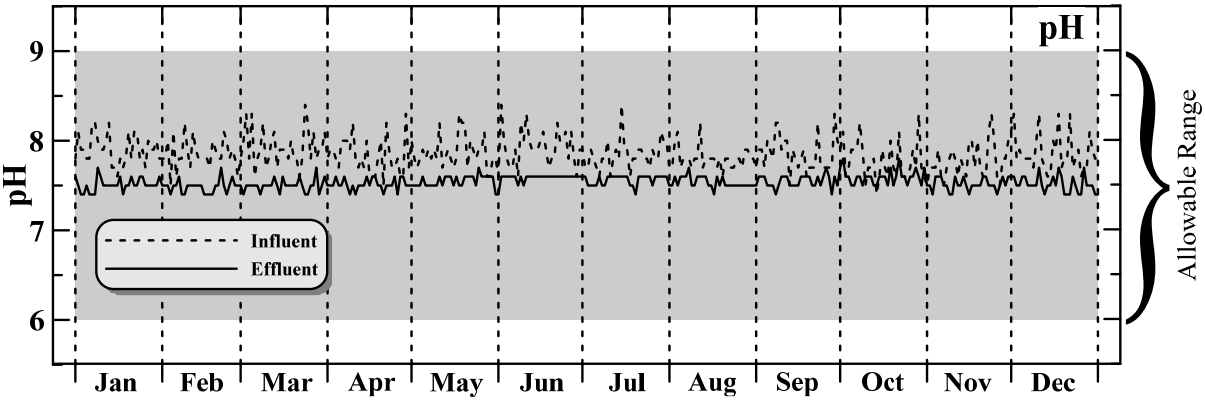

Figure 2.10 Hydrogen-Ion Concentration

2.2.6 Temperature

Although the NPDES permit does not limit effluent temperature, it is an important physical property to document because the difference between effluent and receiving-water temperature dictates the amount of mixing that occurs shortly after the wastewater is discharged into the ocean. The warmer the effluent compared to seawater, the greater the buoyancy of the plume and the more turbulence generated by its rise within the water column (see Section 3.2 on Plume Dispersion). Effluent temperature, shown by the dark shading in Figure 2.11, exhibits a distinct semiannual cycle that tracks seasonal insolation, as does air temperature. Typically, effluent temperatures begin gradually increasing in spring (May), peak in mid-to-late summer (July through mid-October), and then decline relatively quickly during the fall (mid-October through December).

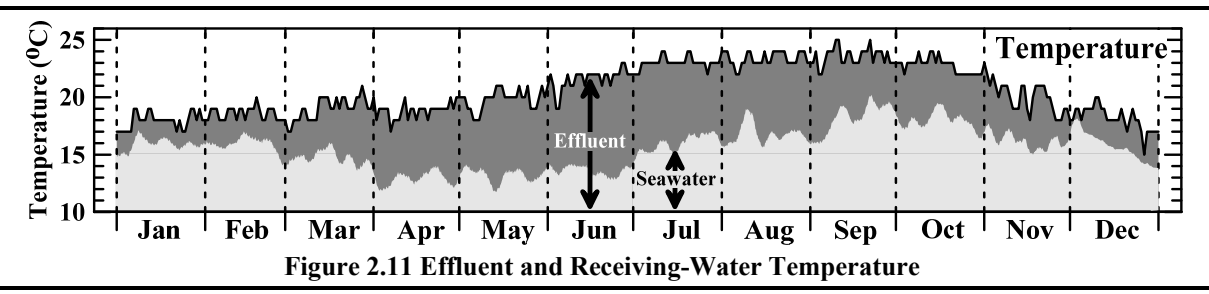

Figure 2.11 Effluent and Receiving-Water Temperature

Because of the strong and sustained influence of upwelling during 2015, seawater temperatures, shown by the light shading, did not track seasonal-insolation trends in effluent temperature. Specifically, in response to the onset of intense southeastward winds in April, cool deep seawater was brought to the sea surface near the discharge location. Upwelling counteracted the warming effects of solar insolation throughout spring and into early summer (see Sections 3.2.3 and 3.2.4).

Differences in the timing of these thermal influences produced a period of large thermal contrast, which persisted from April through September. Effluent temperatures were between 5ºC and 6ºC higher throughout most of this period. However, during June and July, the thermal contrast was larger and reached 8ºC at the end of June as onshore surface waters continued to warm while seawater temperature was suppressed by upwelling. This large thermal contrast would normally enhance buoyancy-induced dispersion of the effluent plume significantly. However, upwelling also causes water-column

stratification, which can limit vertical movement of the plume and offset the buoyancy-enhanced turbulence to some extent. The strength of upwelling winds began to decrease at the beginning of July and sea-surface temperatures began a slow increase that extended through the end of September. Thus, buoyancy-induced vertical mixing of the discharge plume was greatest during the late summer and early fall of 2015 when thermal contrasts were still large and water-column stratification had decreased.

2.2.7 Ammonia

The concentration of ammonia as nitrogen (NH_3-N) was uniformly low throughout 2015, as has been the case in prior years. Median concentrations, computed over 180-day periord, were consistently close to 50 mg/L, which is a little more than half of the longterm permit limit (Figure 2.12). Individual grab samples analyzed for ammonia on a monthly basis during 2015 had concentrations at or below 65 mg/L, which is one-fifth of the 322-mg/L daily-maximum permit limit, and one-twelfth of the instantaneous maximum (804 mg/L) established to protect marine aquatic life.

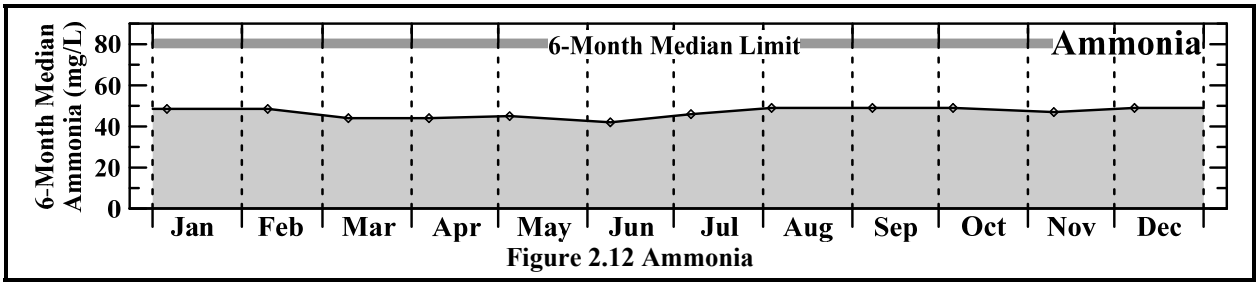

Figure 2.12 Ammonia

2.2.8 Residual Chlorine

Total residual chlorine (TRC) quantifies the amount of chlorine remaining in effluent grab samples that are collected after disinfection with sodium hypochlorite and subsequent dechlorination, or buffering, with sodium bisulfite. These daily effluent grab samples are collected when flow reaches its daily maximum, and concentrations of effluent constituents, as well as hypochlorite and bisulfite dosage, are expected to be at their highest levels.

As discussed previously, the complex disinfection process strives to balance chlorination and dechlorination to obtain adequate disinfection (coliform reduction) without dosing the marine environment with high levels of chlorine. The complexity arises because chlorine demand is constantly changing due to continuous variations in flow and organic loading within the wastestream. Hypochlorite and bisulfite dose is controlled by both total-chlorine-residual and flow-paced pumps that automatically inject precisely measured amounts of these chemicals into the wastestream. After hypochlorite injection, disinfection is achieved by allowing wastewater to mix, and "contact" bacteria within the Chlorine Contact Tank over a period of time. After discharge from the Tank, any "residual" chlorine not removed by bacteria is eliminated by adding bisulfite prior to discharge through the ocean outfall. For conservatism, bisulfite is normally overdosed to remove detectable TRC from the wastestream, and in 2015, no measurable TRC was found in all but two of the 265 effluent samples tested (Figure 2.13). This was the case even though the analytical procedure is capable of resolving a minute 0.05-mg/L TRC concentration. This zero-tolerance approach to long-term TRC control resulted in no measurable 6-month median concentration during 2015, and thus, the discharge complied with the applicable long-term TRC limit of 0.27 mg/L specified in the discharge permit

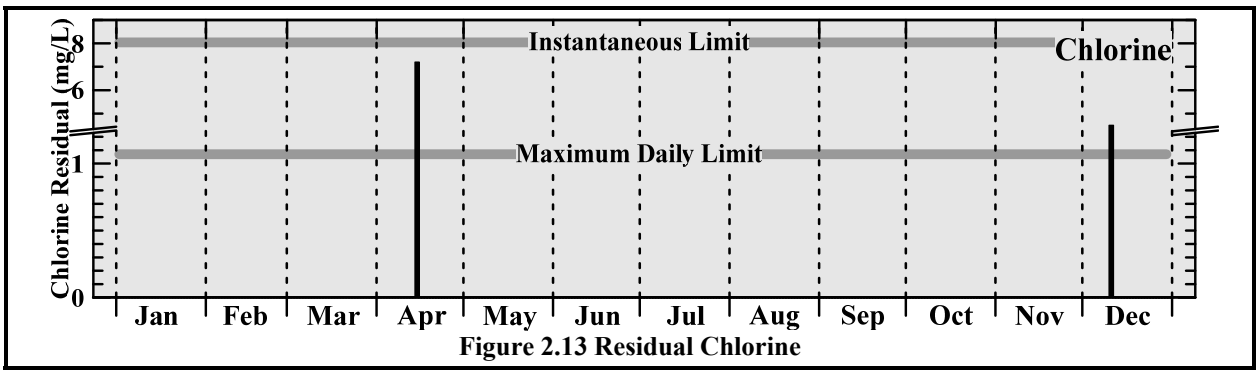

Figure 2.13 Residual Chlorine

The entire disinfection process is critically dependent on the performance of the Chlorine Contact Tank and the Chlorine-Residual/Flow-Paced Dosing Pumps. In contrast to some other treatment components, there is no available redundancy for these critical disinfection components. Instead, treatment plant personnel must remain constantly vigilant, and be ready to step-in and initiate direct control over the disinfection and dechlorination processes, sometimes with very short notice. In that regard, they installed an auto-dialing alarm system to notify them by phone immediately when there are unusual excursions in TRC at any time day or night. They purposefully set a narrow range on the alarm points to facilitate a quick response, but at the expense of numerous false alarms. During 2015, for example, they responded to chlorine-residual alarms on 21 separate occasions (See Table A.2). Unfortunately, on 11 December, they were unable to bring the bisulfite-dosing pump immediately back online after its circuit breaker was tripped. This resulted in a 4.5 mg/L TRC measurement that exceeded the 1.07-mg/L daily limit but remained well below the permitted instantaneous limit (8.04 mg/L).

The only other exceedance of a permit limit during 2015 was again associated with the disinfection process. However, in this case, the exceedance of the daily TRC limit resulted from an intentional decision to maintain disinfection while the Chlorine Contact Tank was offline for planned repairs and maintenance. Although the Tank was only offline for approximately 20 hours on 15 April, both disinfection and dechlorination could not be fully achieved, and in the interest of human health, the disinfection process was maintained. The brief absence of dechlorination resulted in a TRC measurement of 7.2 mg/L within an isolated effluent grab sample. This exceeded the maximum daily limit, but not the instantaneous limit. However, it is likely that the actual chlorine dose to the marine environment was substantially less because of TRC decay during the detention (travel) time in the outfall. The RWQCB and the Department of Health Services were notified in advance of the anticipated exceedance.

2.2.9 Coliform Bacteria

The efficacy of the disinfection process is tracked by regular measurements of coliform populations within effluent samples. As part of the NPDES permit provisions, samples collected on five consecutive days each week were analyzed for the most probable number of total coliform organisms per 100 ml (MPN/100 ml). Figure 2.14b shows that when there are detectable coliform populations, their densities vary widely among individual measurements. WWTP personnel strive to maintain densities close to the detection limit of 2 MPN/100 ml, and during 2015, 77% of the 284 measurements were at or below this detection level. However, due to the complexities of the disinfection process that were described previously, elevated densities are occasionally observed. Two higher-than-normal observations stood out, a 900 MPN/100 ml on 29 May triggered an inspection and cleaning of the Chlorine Contact Tank in early June (See Table A.2). Although the reading was elevated compared to most other measurements, it was only 40 percent of the permitted instantaneous maximum of 2,400 MPN/100 ml. A second comparatively

elevated measurement of 300 MPN/100 ml on 9 September prompted WWTP staff to drain, inspect, and clean the Chlorine Contact Tank again.

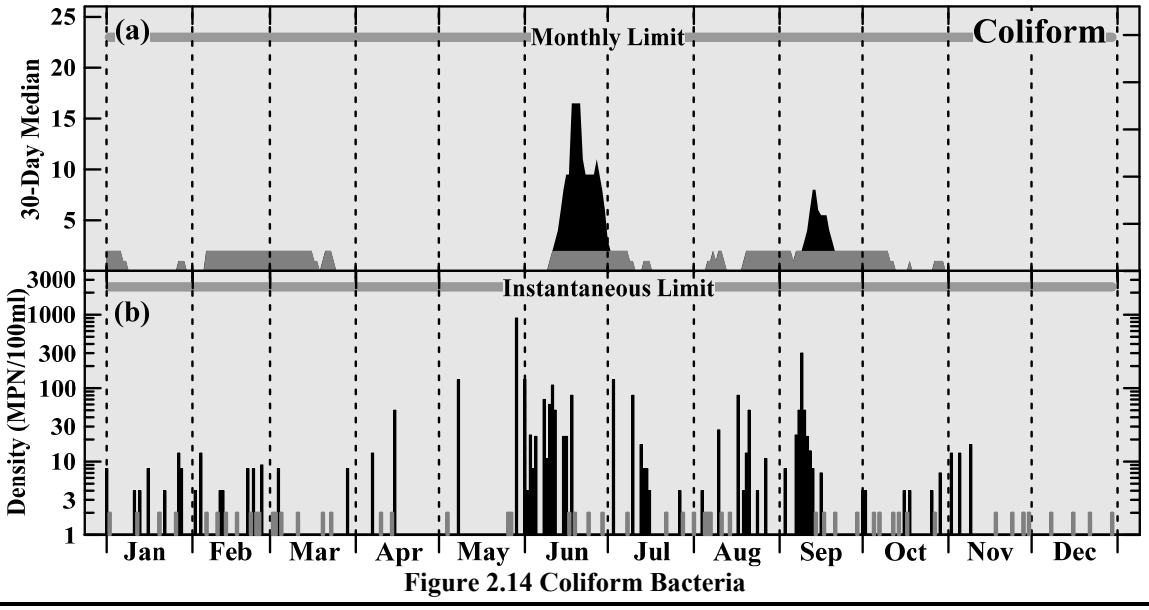

Figure 2.14 Coliform Bacteria

In addition to these isolated measurements of elevated coliform density, WWTP staff became concerned about an overall decline in the performance of the disinfection process. Longer-term trends in performance are revealed by a 30-day running median (Figure 2.14a). Because more than three-quarters of the individual measurements were at or below the detection limit during 2015, the 30-day running was also at or below detectable densities throughout most of the year (gray shading in Figure 2.14). However, clusters of marginally elevated densities among individual effluent samples (Figure 2.14b) resulted in an unusual increase in the median on two occasions; one during the second half of June, and the other in the middle of September (Figure 2.14a). Note that because the 30-day median is retrospective, the median values are shifted 15 days to the right in Figure 2.14a; thus, the median increase in the latter half of June actually resulted from the cluster of measureable densities during the first half of June.

Although these two cases of elevated median density were highly unusual, the peak running-median value of 16.5 MPN/100 ml remained well below the permit limit of 23 MPN/100 ml applicable to the 30-day median values. Furthermore, because compliance evaluations are based on a calendar month, the June month-end median of 6 MPN/100 ml was the only value above the detection limit appropriate for comparison to the permit limit (Table 2.2).

The ability to achieve compliance aside, WWTP staff identified the decline in the effectiveness of the disinfection process early on. Throughout most of 2015, they sought to identify and mitigate potential causes for the decline; all of which were related to the performance of the Chlorine Contact Tank. On six separate occasions, the Tank was drained, cleaned, inspected, and repaired. These major efforts were not undertaken lightly. Because there is no redundancy in this treatment component, substantial planning is required to accommodate both the interruption in plant throughput, and the interruption in the chlorination/dechlorination process. In the case of prolonged servicing of the Tank on 15 April, exceedance of TRC limit was unavoidable. The decline in disinfection performance was eventually determined to be from an accumulation of organic solids around the base of the Tank's sidewalls. This problem was mitigated in late 2015 by the addition of wooden fillets along the sides of the Tank.

2.2.10 Toxicity

In 2015, effluent was tested semiannually, in January and July, for toxicity using chronic bioassays[1] of composite effluent samples (Table 2.3). The chronic bioassays found consistently low effluent toxicity, with levels much less than the discharge permit limits.

Table 2.3 Comparison of Measured Toxicity Levels with Permit Limitations

Sample Date	Bioassay Test	End Point (%)	Concentration (TU)	Limit (TU)
21 January	Red Abalone (*Haliotis Rufescens*) Larval Development	5.6	17.9	134
22 July	Red Abalone (*Haliotis Rufescens*) Larval Development	5.6	17.9	134

Chronic bioassays have historically been conducted on giant kelp (*Macrocystis pyrifera*). Toxicity screening studies conducted in 1993 indicated that giant kelp was more sensitive to MBCSD effluent than other species typically used in bioassays at that time, such as the larvae of the inland silverside (*Menidia beryllina*) and the bay mussel (*Mytilus edulis*) (MRS 1994). Over the following 17 years, bioassays repeatedly demonstrated that giant kelp are only minimally affected by exposure to the treatment plant effluent. As required by the current discharge permit, however, a new screening study was conducted on effluent samples collected in July 2009 and January 2010. Those screening assays assessed the effluent's effect on the development of larval red abalone (*Haliotis rufescens*) in addition to that of giant kelp. These screening bioassays indicated that larval abalone are slightly more sensitive to effluent than kelp zoospores; therefore, all subsequent bioassays have been conducted on larval abalone.

The chronic toxicity tests conducted in January and July 2015 measured growth response in larval red abalone after exposure to a range of effluent dilutions.[2] The results of the 2015 abalone bioassays confirm the effluent's continued low chronic toxicity. All chronic-toxicity endpoints were less than one-seventh of the applicable permit limitation of 134 chronic toxic units (TUc) for the daily maximum toxicity. The reported TUc were based on a "*No Observable Effects Concentration*" (NOEC), which is the highest effluent concentration that does not cause an adverse effect statistically different from a control sample. They indicate that the chronic bioassays did not find adverse effects when abalone were exposed to effluent concentrations as high as 5.6%, whereas the permit allows adverse effects in concentrations as low as 0.75%.

2.2.11 Nutrients

During the review process for the current MBCSD discharge permit (USEPA 2007), concerns were raised regarding the relative contribution of nutrients discharged to the ocean by coastal treatment plants, such as the MBCSD WWTP, and their potential role in the promotion of harmful algal blooms (HABs). HABs occur when periodic explosions of growth in naturally occurring algae, which form the base of the marine food web, result in extensive monocultures (blooms) of particular species that are harmful to humans or other life. In addition to harm caused through the production of toxins by these species, large phytoplankton blooms can negatively affect the marine ecosystem simply from their accumulated biomass.

Considerable research has been conducted in an effort to understand the environmental factors that promote HABs. Through these studies, processes such as coastal upwelling and river runoff have been implicated as the primary factors that create physical and chemical conditions (e.g., high nutrient

[1] Acute bioassay testing requirements were eliminated in the current MBCSD discharge permit, in accordance with previous updates to the California Ocean Plan.

[2] The semiannual effluent reports contain raw test data, pertinent quality assurance/quality control (QA/QC) data, and chains of custody for the chronic bioassays (MRS 2015gh).

concentrations) conducive to the development of phytoplankton blooms (Trainer et al. 2002, Kudela et al. 2004). In particular, upwelling conditions, which are discussed in Chapter 3 of this report, have been chiefly implicated in the generation of HABs along the central California coastline (Trainer et al. 2000, Kudela et al. 2005).

In addition to these natural processes, increased human activity and pollution are also thought to be contributing factors to the recently observed increase in the frequency and intensity of HABs. For that reason, the USEPA proposed a conservation measure for "*Regular monitoring of nutrient loading from the* [MBCSD] *facility's ocean outfall*" in their biological evaluation. Open-ocean dischargers, such as the MBCSD treatment plant, are not normally required to monitor for bio-stimulatory nutrients because energetic, well-flushed marine environments rapidly dilute and disperse discharged nutrients, preventing their accumulation to deleterious levels. For this reason, there are no numerical objectives for nutrient compounds (except ammonia) promulgated in the COP. However, in response to the concerns regarding nutrient loading and HABs, MRS (2008b) designed and instituted a nutrient-monitoring requirement for the MBCSD effluent monitoring program that includes the semiannual analyses of nitrate [NO_3^-], urea [$CO(NH_2)_2$], ortho-phosphate [$(PO_4)^{3-}$], and dissolved silica [SiO_2].

These particular compounds were selected because they represent limiting macronutrients for phytoplankton growth within the euphotic zone of the ocean, and have been associated with the stimulation of phytoplankton growth (Kudela and Cochlan 2000). Ammonia [NH_3] is another nitrogen compound typically associated with phytoplankton growth. However, ammonia concentrations are already regularly measured as part of the MBCSD discharge permit's waste-discharge requirements.

In fulfillment of the current permit requirement, nutrient assays of MBCSD effluent were conducted on grab samples collected in January and July 2015. The results were consistent with those of prior years, and demonstrate that nutrient concentrations within the MBCSD effluent, and their mass loading to the marine environment from discharge, are small compared to both other central-coast dischargers and the contribution from regional streams and rivers (Table 2.4). Specifically, although concentrations of urea within MBCSD effluent (≤ 0.108 mg/L) were comparable to those of the three large central-coast WWTPs to the north (≤ 0.110 mg/L), the concentrations of nitrate, phosphate, and silica within MBCSD effluent were substantially lower than those of the other dischargers. The MBCSD nitrate levels, in particular, were two orders of magnitude lower than those of the other WWTPs within the central-coast region. Nitrate and silica concentrations within MBCSD effluent were also less than the average concentrations found within central-coast rivers and streams; although, urea and phosphate concentrations were higher, as was the case for the other central-coast WWTPs.

Table 2.4 Nutrient Concentrations and Loading from Central-Coast Ocean Discharges

		Concentration (mg/L)				Mass Emission (kg)			
Source		**Nitrate**	**Urea**	**Phosphate**	**Silica**	**Nitrate**	**Urea**	**Phosphate**	**Silica**
MBCSD	January	0.1	0.089	1.2	11.0[1]	<129.	127.	<850.	14,000.[1]
	July	<0.1	0.108	<0.1	11.0[1]				
Santa Cruz		9.52	0.087	7.7	30.2	139,000.	1,360.	117,000.	489,000.
Watsonville		10.52	0.110	13.6	35.6	105,000.	1,250.	154,000.	364,000.
Monterey		4.82	0.084	3.4	41.0	85,600.	1,100.	30,300.	488,000.
Streams and Rivers[2]		3.58	0.021	0.14	25.6	1,660,000.	33,500.	340,000.	25,200,000.

[1] During 2015, *Total* rather than *Dissolved* concentrations of Silica as SiO_2 were inadvertently reported by the laboratory and, as a result, its concentrations and mass emission are expected to higher than those reported in the past, and those reported by other dischargers.

[2] Average concentrations and total emissions from fourteen streams and rivers discharging to the northern central coast from July 2005 and June 2006 (CClean 2007)

Notwithstanding the slightly higher urea and phosphate concentrations within effluent, potential environmental effects from nutrient discharge are dictated by the total mass emissions contributed by the various sources (right side of Table 2.4). After accounting for the relatively small MBCSD discharge, its total nutrient loading to the marine environment during 2015 was 40-times smaller than any of the three large WWTPs, all of which discharge into the waters of the Monterey Bay National Marine Sanctuary. Similarly, total nutrient loading from the MBCSD discharge was three orders-of-magnitude smaller than the contribution from runoff within the central-coast region.

2.2.12 Chemical Compounds

In addition to the effluent properties and bioassay results described above, 78 chemical contaminants are regulated by the COP, and have their effluent concentrations limited in the discharge permit. Effluent composite samples were analyzed in January and July 2015 for the presence of these chemical compounds, which include trace metals, chlorinated and nonchlorinated phenolic compounds, volatile organic compounds, organochlorine pesticides, PCBs, cyanide, base-neutral compounds, and radionuclides (Table 2.5). The COP regulates the discharge of these compounds for the protection of marine life and the protection of human health from exposure to both carcinogenic and noncarcinogenic substances.

Table 2.5 Chemical Compounds Detected within Effluent Samples

	Concentration (µg/L)			Mass Emission (kg/yr)	
Compound	**Limit**	**January**	**July**	**Goal**	**Measured**
Protection of Marine Aquatic Life					
Arsenic	670.	≈1.4[1]	≈1.0	17.	≈1.55
Copper	140.	**24.**	**18.**	690.	**27.1**
Lead	270.	**1.5**	**0.82**[2]	465.	**1.50**
Nickel	670.	≈4.6	≈5.1	142.	≈6.28
Selenium	2,010.	≈1.5	**2.1**	65.	≈2.31
Zinc	1,620.	**77.**	**87.**	244.	**105.**
Nonchlorinated phenolics	4,020.	—[3]	**2.5**	—	—
Radionuclides (pCi/L) α	15.	—	**–0.178**	—	—
Radionuclides (pCi/L) β	50.	—	**16.**	—	—
Protection of Human Health (Non-Carcinogens)					
Toluene	11,400,000.	—	≈0.39	4.	≈0.50
Protection of Human Health (Carcinogens)					
Chloroform	17,400.	—	≈0.72[4]	5.	≈0.93
Dioxin (pg/L)	0.52	—	≈0.0343	1.48 mg	≈0.044 mg

[1] The "*approximation*" symbol (≈) indicates that the detected concentration was too low to be reliably quantified, namely, it was below the Minimum Level (ML). Consequently, the number listed after the symbol represents an estimated concentration. Accurately quantified concentrations are indicated by bold typeface.

[2] The reported concentration was below the practical quantification limit (PQL) and was flagged "as estimated" by the chemistry laboratory. However, in accordance with the guidance from the COP and the NPDES permit, the reported value is listed "as measured" herein, because the value exceeded the ML.

[3] The "*dash*" symbol (—) indicates that analysis of the compound was not required as part of the monitoring program, or that a mass-emission goal was not specified in the discharge permit.

[4] The reported concentration was above the PQL and accordingly, was not flagged "as estimated" by the chemistry laboratory. However, in accordance with the guidance from the COP, the reported value is listed here as an estimated concentration because the measured value was below the minimum limit (ML).

As has been the case in the historical record of 3,495 chemical assays spanning 23 years of MBCSD effluent monitoring, the 2015 analyses detected concentrations of only a few ubiquitous compounds at levels well below the regulatory limits. Those detected compounds are discussed below, while detailed discussions of effluent chemistry, along with the corresponding concentration limits, minimum reporting levels, laboratory data sheets, pertinent QA/QC data, and chains of custody for all the chemical constituents were provided in the semiannual self-monitoring reports (MRS 2015gh).

The chemical assays found only six of the 78 chemical compounds present in quantifiable amounts within the 2015 effluent samples.[1] The measured concentrations for all six compounds were significantly less than the permitted limits. Annual mass emissions of these compounds also met the goals in the discharge permit's reporting provisions. The compounds with quantifiable concentrations included three trace metals (copper, lead, and zinc), selenium, radionuclides, and a non-chlorinated phenolic compound.

The analyses also detected five additional compounds in the semiannual effluent samples, but at concentrations that were too low for reliable quantification. Specifically, the concentrations of these compounds were higher than the method detection limit (MDL)[2] but less than the minimum level (ML). Reporting of these detected-but-not-quantified concentrations is required under the current NPDES discharge permit; although, they are not compared to effluent limitations for compliance evaluation.

Trace Metals

Three of the quantifiable concentrations were associated with commonly occurring metals: copper, lead, and zinc. Unlike synthetic organic compounds, trace metals occur naturally within the mineralogy of sediments along the central California coast and are ubiquitous in the local sedimentary environment. All three of the metals were detected in quantifiable amounts within seafloor sediment samples collected at all the benthic survey stations, including the distant reference station B1 (see Section 4.2). These metals enter the wastewater collection system through erosion of natural mineral deposits along the central California coast as well as through corrosion of household plumbing systems. Regardless of their source, the effluent metal concentrations were at most one-sixth of levels deemed deleterious to marine organisms, and the highest metal mass emission was less half of the emission goal recommended in the discharge permit.

These three metals have been detected at quantifiable levels in over two-thirds of the effluent samples collected during the last 23 years and therefore, do not represent a new or increased source of contaminants entering the collection system. Moreover, the long monitoring history unequivocally demonstrates that there is no reasonable potential for these metal concentrations to exceed the discharge permit limits in the future (Refer to the recommendation concerning reductions in monitoring frequency in Section 5.4).

Selenium

Selenium, a naturally occurring metalloid that is present within the mineralogy of the central California coast, was also found in quantifiable concentrations within the July 2015 effluent sample, but not the January sample. Low-level concentrations of selenium in MBCSD effluent have typically been associated with the mobilization of naturally occurring selenium in surficial soils following rainfall events. However,

[1] Quantifiable concentrations are listed in bold typeface in Table 2.5.
[2] The method detection limit is the lowest concentration that can be reported under ideal conditions, when the sample contains only the compound of interest in a concentration within an optimal calibration range and within a medium that does not interfere with the performance of the analytical instrument.

as with the other detected elements, selenium's measured concentration was low compared to its permit limit and therefore, not of ecological concern.

Radionuclides

As with the trace metals described above, the presence of measurable alpha (α) and beta (β) radioactivity within the 2015 effluent sample was not unusual. Radionuclides have regularly been detected within MBCSD effluent samples, largely because naturally occurring radioactive material (NORM) is present throughout the earth's crust and because radioactive decay can be quantified at extraordinarily low levels. Consequently, the permit limits specified for radionuclides are not derived in the same manner as for other chemical constituents.

Permit limits for other constituents are based on their potential for adverse impacts after discharge, and include an allowance for the 133-fold minimum dilution that occurs immediately after discharge. Limits on radioactivity, however, are based on the California Code of Regulations, Title 22, §64441 and §64443, and are the same as those established for drinking water; they do not account for post-discharge dilution. Regardless of their origin, the levels of radioactivity measured within the July 2015 effluent sample were well within drinking-water standards.

The low decay levels measured within the July 2015 effluent samples were typical of most prior effluent samples and of naturally occurring sediments of the region. Alpha particle activity arises from natural mineral deposits that enter the collection system through erosion. Beta particle activity arises from radioactive decay in both natural and man-made materials.

Phenolic Compounds

3&4-methylphenol (*p*-cresol) was the only phenolic compound quantified in effluent samples collected in 2015. Other phenolic compounds were not detected in the samples and consequently, *p*-cresol's 2.5-µg/L concentration was the only contributor to the estimated total nonchlorinated phenolic compounds within the July effluent grab sample. Interestingly, this compound was not detected in the effluent composite sample collected around the same time. The concentrations of individual phenolic compounds are determined in both the grab and composite effluent samples. For compliance evaluation, the sum of the concentrations of individual chlorinated and nonchlorinated phenolic compounds within the grab sample are separately compared with permit limits. However, in the effluent composite sample, the reported concentrations of individual phenolic compounds are also reported. The fact that *p*-cresol was detected in the grab sample, but not in the composite sample indicates that its presence was transient.

p-cresol is a natural product in many foods as well as in crude oil and tar. It is also detected in animal and human urine. In addition to its industrial uses, *p*-cresol is also used as an antiseptic and disinfectant because of its bactericidal and fungicidal properties. As a metabolite of toluene, *p*-cresol is a known toxin; however, the combined concentrations of all nonchlorinated phenolic compounds in the July 2015 grab sample would have to be nearly three orders of magnitude higher than the measured concentrations to be of concern to marine organisms.

2.3 BIOSOLIDS

The monitoring and reporting requirements of the NPDES permit (RWQCB-USEPA 2009) stipulate characterization of biosolids in accordance with 40 CFR 503 (USGPO 1997b). To that end, this section describes the disposition of the approximately 261 dry metric tons of biosolids generated by the WWTP during 2015. The discussion also addresses the major compounds within the biosolids produced by the plant, because they determine the suitability of biosolids for future composting and land application. The

complete biosolids report[1] was submitted to the USEPA, RWQCB, and San Luis County Environmental Health Services and is incorporated herein by reference.

2.3.1 Solids Treatment Process

Solids removed by the primary clarifiers (Figure 2.3 on Page 2-14) are processed as shown in the schematic of Figure 2.15. Sludge is stabilized within two mixed-primary digesters that heat the sludge to temperatures between 96°F and 98°F (36°C to 37°C). Heated sludge is then transferred to a secondary digester with heat exchange from the primary digesters. Solids settle in the secondary digester and the supernate is returned to the wastewater treatment process. The primary digesters' capacities are 170,544 gallons (Digester #1) and 192,000 gallons (Digester #2), and the secondary digester's capacity is 166,000 gallons (Digester #3), giving a total capacity of 528,000 gallons (2 megaL).

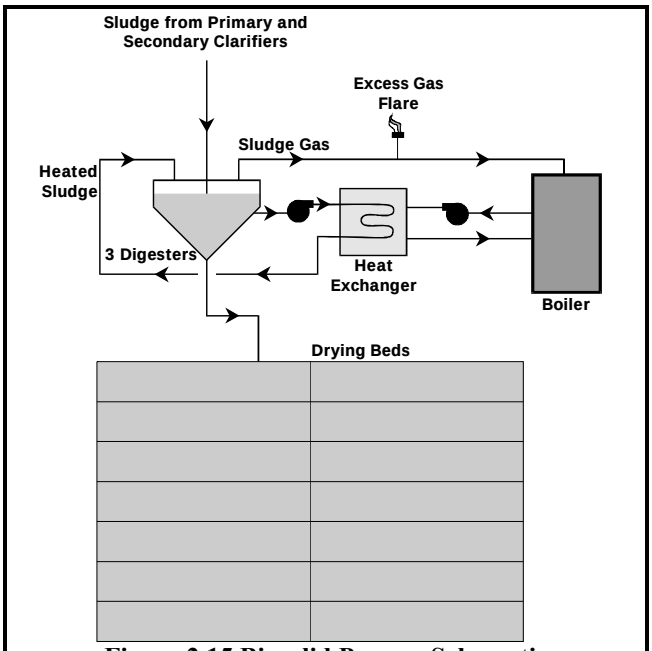

Figure 2.15 Biosolid Process Schematic

During 2015, however, solids stabilization was achieved with only one primary digester in series with a secondary digester. Digester #2 served as the primary digester throughout the year with an average daily raw sludge-pumping rate of 10,400 gallons per day. Average detention time for the primary digestion process was 18.4 days. While Digester #1 was offline for cleaning and coating during the first part of the year, Digester #3 served as the secondary digester. In August 2015, Digester #1 was brought online as the secondary digester. Average detention time for the combined primary and secondary digestion processes was 34.8 days.

Stabilized sludge drawn from the secondary digester was transferred to one of 12 sludge-drying beds. Each of these 5,200 ft^2 (483 m^2) beds has an under-drain and decanting system that recirculates runoff through the treatment process. Twelve to 14 inches (33 cm) of sludge were applied to the beds. Drying times typically range from two to four months depending on the weather conditions. Once dried, the biosolids were removed from the beds and stored in a concrete containment area that also drained rainfall runoff through the treatment system. Biosolids were stored in this area until they were removed from the WWTP. Biosolids storage times are generally less than one year.

On October 21, 23, and 26, 357.6 wet tons (or 256.9 dry metric tons) of biosolids were hauled to the Liberty Composting Facility, which operates under Solid Waste Information System Permit No. 15-AA-0287. Approximately 4.1 dry metric tons of biosolids remained in storage at the WWTP at the end of 2015. The biosolids transferred to the Liberty Composting Facility will be used for soil amendment after completion of composting at the facility. Prior to shipping, the MBCSD provided a Title 22 Certification for Non-hazardous Materials and a Class-B biosolid certification statement based on chemical analyses described below.

[1] Morro Bay/ Cayucos Wastewater Treatment Plant 2015 Annual Sewage Sludge Report, 27 January 2016

2.3.2 Chemical Compounds

In compliance with the Monitoring and Reporting Program, chemical analyses were conducted on a composite of biosolid samples collected from the drying beds on 9 September July 2015. Those beds contained biosolids that were ready for shipment from the WWTP at the time. The full laboratory results, including chains of custody, instrument calibration reports, and analyses of method blanks and spikes, were reported by MRS (2015b). They are compared with regulatory limits in Table 2.6 on the following page.

The data in the table shows that biosolid contaminant concentrations were significantly less than regulatory thresholds that would designate them as hazardous, or that would limit their use for land application or composting. The analyses tested for the presence of more than 150 potential contaminants and measured seven other properties and nutrients within the biosolid sample. Nevertheless, only a few compounds were detected, primarily naturally occurring trace metals.

All trace-metal concentrations were below the total threshold limit concentrations (TTLC) that would designate the biosolids as hazardous. One metal, copper, had a bulk wet-weight concentration that exceeded 10-times the soluble threshold limit concentration (STLC). Accordingly, a waste extraction test (WET) was conducted to assess its water solubility. This elutriate test demonstrated that the copper within the biosolids sample had very low solubility with a 5.1-mg/L dissolved concentration that was five times lower than the 25-mg/L STLC level where leaching into groundwater may be of concern. The low solubility shows that the copper was tightly bound into a mineral matrix, with little bioavailability.

The insolubility of copper is further confirmed by the low concentrations found in the plant's semiannual effluent samples (18 µg/L and 24 µg/L in Table 2.5). Copper occurs naturally in the mineralogy of ambient sediments in the central coast region, and, as a result, its presence in biosolids is not unexpected. Additionally, copper enters the collection system through the internal corrosion of household plumbing systems. Nevertheless, the dry-weight concentrations for all detected metals in the biosolid sample, including copper, were well below the federally-mandated thresholds, including the monthly limit for materials suitable for agricultural land application (as represented in the three right-most columns of Table 2.6).

The other compounds listed in Table 2.6 further characterize the biosolids, as mandated in the waste discharge requirements. Additionally, a modified WET test (STLC) for total dissolved solids was conducted in response to a request from the composter.

Table 2.6. Comparison between Measured Biosolid Concentrations and State and Federal Limits

		Wet Weight				Dry Weight		
		Measured		Limit		Measured	Limit	
Constituent	Units	Bulk	WET[1]	STLC[2]	TTLC[3]	Bulk	Monthly[4]	Ceiling[5]
Solids	%	71.2	—[6]	—	—	—	—	—
Cyanide	ppm	2.4	—	—	—	3.0	—	—
Antimony	ppm	≈2.1[7]	—	15.	500.	≈2.6	—	—
Arsenic	ppm	≈2.1	—	5.	500.	≈2.6	41.	75.
Barium	ppm	380.	—	100.	10,000.	470.	—	—
Beryllium	ppm	ND	—	0.75	75.	ND	—	—
Boron	ppm	33.	—	—	—	40.	—	—
Cadmium	ppm	3.2	—	1.	100.	3.9	39.	85.
Chromium (Total)	ppm	50.	—	560.	2,500.	61.	—	—
Chromium (Hexavalent)	ppm	5.	<0.07[8]	5.	500.	6.4	—	—
Cobalt	ppm	≈4.9	—	80.	8,000.	≈6.0	1,500.	4,300.
Copper	ppm	**490.**[9]	5.1	25.	2,500.	600.	1,500.	4,300.
Lead	ppm	41.	—	5.	1,000.	51.	300.	840.
Mercury	ppm	0.94	—	0.2	20.	1.20	17.	57.
Molybdenum	ppm	33.	—	350.	3,500.	41.	—	—
Nickel	ppm	44.	—	20.	2,000.	54.	420.	420.
Selenium	ppm	9.9	—	1.	100.	12.	100.	100.
Silver	ppm	4.7	—	5.	500.	5.8	—	—
Thallium	ppm	ND	—	7.	700.	ND	—	—
Vanadium	ppm	23.	—	24.	2,400.	28.	—	—
Zinc	ppm	1,100.	—	250.	5,000.	1,400.	2,800.	7,500.
Bis(2-ethylhexyl) phthalate	ppm	≈40.	—	—	—	≈50.	—	—
Hydrogen-Ion	pH	6.55	—	—	—	—	—	—
Phosphate	ppm	67,000.	—	—	—	84,000.	—	—
Ammonia	ppm	6,600.	—	—	—	8,300.	—	—
TKN	ppm	29,000.	—	—	—	36,000.	—	—
Organic Nitrogen	ppm	22,400.	—	—	—	27,700.	—	—
Nitrate as NO_3	ppm	2,500.	—	—	—	3,200.	—	—
Oil & Grease	ppm	54,000.	—	—	—	68,000.	—	—
Total Dissolve Solids	ppm	—	4,600.	—	—	—	—	—

[1] Waste Extraction Tests (WET) measure the soluble leachate or the extractable amount of a substance contained within a bulk sample of biosolids. A WET is indicated if the bulk wet-weight concentration of a contaminant exceeds 10 times the STLC.

[2] Soluble Threshold Limit Concentrations (STLC) apply to the measured concentration in the liquid extract from a biosolid sample, as determined by a WET. Biosolids with leachate concentrations exceeding the STLC are classified as hazardous in the State of California, as described in the California Code of Regulations (CCR 2003).

[3] Total Threshold Limit Concentrations (TTLC) apply to the total wet-weight concentration of a contaminant within a bulk biosolid sample consisting of the entire millable solid matrix, rather than just the leachate. Biosolids are designated as hazardous wastes in the State of California if measured bulk concentrations exceed the TTLC, as described in the CCR (2003).

[4] Federally mandated dry-weight limits imposed on biosolids suitable for application on agricultural land apply to monthly average concentrations as defined in Table 3 of the Code of Federal Regulations (USGPO 1997b). [40 CFR §503.13(b)(1)].

[5] Federally mandated dry-weight ceiling concentrations above which biosolids are considered hazardous waste as defined in Table 1 USGPO (1997b).

[6] "—" indicates that the measurement was not required or its limit was not specified.

[7] Concentrations preceded by an "*approximation*" symbol (≈) were too low to be reliably quantified and represent estimated concentrations because they were reported below the minimum level (ML) but above the method detection limit (MDL).

[8] A "*less-than*" symbol (<) indicates that the substance was not detected at a concentration above the MDL, which is listed after the "<" symbol.

[9] Bulk concentrations shown in bold were greater than 10 times the STLC and a WET was conducted.

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CHAPTER 3

Receiving Water Quality

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3.0 RECEIVING WATER QUALITY

This chapter describes environmental conditions within the ocean waters immediately adjacent to the MBCSD wastewater discharge during 2015. The first section details the monitoring program that assesses compliance with the water-quality objectives of the California Ocean Plan (COP; SWRCB 2005) as embodied in the NPDES permit covering the MBCSD discharge (hereinafter referred to as "*the NPDES permit*," RWQCB–USEPA 2009). The second section discusses the disposition of the effluent plume within the receiving waters, and how it is influenced by the hydraulic design of the outfall and stratification of the receiving waters. The final section of this chapter provides a synopsis of the offshore measurements collected during the four water column surveys conducted in 2015 (MRS 2015cdef) and compares them with the waste discharge requirements specified in the NPDES permit. Quantitative analyses of continuous instrumental measurements and the qualitative visual observations are also addressed in the last section. The observations demonstrate that the diffuser structure was operating as designed by efficiently diluting treated wastewater within the zone of initial dilution (ZID) that surrounds the outfall.

During all four of the 2015 offshore receiving-water surveys, dilute wastewater was detected within the receiving waters. The weak discharge-related perturbations in the water-property fields indicated that the treated wastewater was rapidly mixed upon discharge, and that all but one of the observed perturbations were small compared to the natural variability in seawater properties observed along this portion of the central California coast. One excursion in transmissivity ranged beyond limits expected for ambient receiving seawater at the time of the January survey. However, this measurement was recorded very close to a discharge port and within the effluent jet shortly after discharge. Based on the high initial-dilution levels measured during the surveys, maximum end-of-pipe contaminant concentrations allowed by the NPDES permit would easily achieve the receiving-water objectives of the COP. In summary, the highly localized, transient seawater perturbations associated with the effluent discharge were too small to be of environmental significance.

3.1 MONITORING PROGRAM

Wastewater chemistry (Chapter 2), receiving waters (this chapter), and the biology and physicochemistry of seafloor sediments (Chapter 4) constitute the three major components of the MBCSD monitoring program. During 2015, and for the past 29 years, the receiving-water monitoring program has included requirements for quarterly offshore surveys conducted near the wastewater discharge within northern Estero Bay, and surfzone coliform sampling along the adjacent shoreline. Measurements collected during the offshore surveys include instrumentally recorded seawater-properties, flow velocity determined from drifter trajectories, qualitative observations of general oceanographic and meteorological conditions, and visual observations of aesthetic impacts and beneficial uses.

3.1.1 Objectives of Sampling

Receiving-water monitoring is required under provisions of a 301(h)-modified NPDES permit to determine compliance with the water-quality objectives of the COP (SWRCB 2005) and the Central Coast Basin Plan (RWQCB 1994). The monitoring program also satisfies the provisions of the Clean Water Act (40 CFR 125.63c), which require a receiving-water monitoring program that "*provide*[s] *adequate data for evaluating compliance with water quality standards or water quality criteria*." In addition, water column measurements provide background information on the vertical structure of ambient marine waters

near the discharge location. This information aids in estimating minimum initial dilution rates, which occur when the receiving waters are strongly stratified, as described in Section 3.2.2.

3.1.2 Scope of Monitoring

One goal of the monitoring program is to assess whether the discharge meets the water-quality objectives embodied in the COP. These objectives, summarized in Table 3.1 on the following page, ensure the reasonable protection of beneficial uses and prevention of nuisance. They apply to samples collected within the discharge's wastefield after initial dilution has been completed. Initial dilution is the rapid, turbulent mixing of wastewater and seawater in the area immediately surrounding the point of discharge.

Ambient seawater is forcibly entrained into the discharge plume by two physical processes. Close to the diffuser ports, the momentum of the wastewater jet induces turbulent shear that rapidly entrains near-bottom seawater, thereby diluting the effluent. Additional turbulent mixing occurs as the warm, buoyant effluent-seawater mixture rises through the water column. This buoyancy-induced entrainment can cause the density of the effluent plume to approach that of ambient seawater (neutral buoyancy) at some point in the water column. Depending on water-column stratification at the time of the discharge, the plume either can reach the surface or become trapped at some intermediate depth level. Thus, initial dilution, where a majority of effluent dilution is achieved shortly after discharge, is complete when the diluted wastewater ceases to rise in the water column and begins to spread horizontally.

To better assess compliance with the COP standards, the receiving-water monitoring program was extensively modified when a previous NPDES permit was issued in 1999 (RWQCB–USEPA 1998b). Prior to 1999, the effluent plume was rarely observed in the instrumental measurements and when it was, its lateral extent was largely indeterminate. This was partially due to the widely spaced water-sampling stations that, at the time, coincided with the benthic sampling pattern. Additionally, the earlier NPDES permit required collection of discrete water samples to be analyzed for suspended solids, coliform, and oil and grease. This water-bottle sampling was time-consuming and compromised the synoptic nature of the instrumental measurements. Beginning with the 1999 surveys, bottle casts were eliminated and the lateral extent of the survey was reduced from 1000 m to 100 m, while the number of sampling stations was doubled from eight to sixteen. Rapid instrumental sampling within this tighter sampling pattern consistently provided high-resolution synoptic snapshots of the ocean waters immediately surrounding the outfall. As a result, the disposition of the effluent plume has been accurately delineated in all 68 surveys conducted since the beginning of 1999.

Further improvements to the receiving-water monitoring program were implemented in 2009 as part of the current NPDES permit (RWQCB–USEPA 2009). For example, the navigational accuracy of positioning systems had advanced to the point where the location of individual measurements could be precisely determined relative to the discharge point. This precise determination of the plume's spatial extent is important for assessing compliance with water-quality objectives that only apply beyond the ZID. With that in mind, the receiving-water monitoring program in the current NPDES permit added a requirement for a tow survey, where the instrumentation package is towed horizontally across and around the diffuser structure at two different depth levels. Collection and analysis of this tow data began with the second-quarter receiving-water survey conducted in 2009. Additionally, all surveys since that time have included vertical profiles of seawater properties at six sampling stations aligned along a north-south transect, and spanning an alongshore-distance of 100 m on either side of the diffuser structure.

Table 3.1 Water-Quality Objectives of the California Ocean Plan

B. Bacterial Characteristics

1. Water-Contact Standards

Within a zone bounded by the shoreline and a distance of 1,000 feet from the shoreline or the 30-foot depth contour, whichever is further [sic] from the shoreline and in areas outside this zone used for water contact sports, as determined by the Regional Board, but including all kelp beds, the following bacterial objectives shall be maintained throughout the water column:

a. The 30-day geometric mean of the five most-recent seawater samples from each site shall not exceed a total coliform density of 1,000 per 100 ml; a fecal coliform density of 200 per 100 ml; or an enterococcus density of 35 per 100 ml.

b. A single seawater sample shall not exceed a total coliform density of 10,000 per 100 ml; a fecal coliform density of 400 per 100 ml; an enterococcus density of 104 per 100 ml, or a total coliform density of 1,000 per 100 ml when the fecal to total coliform ratio exceeds 0.1.

The "Initial Dilution Zone" of wastewater outfalls shall be excluded from designation as "kelp beds" for purposes of bacterial standards and Regional Boards should recommend extension of such exclusion zone where warranted to the State Board. Adventitious assemblages of kelp plants on waste discharge structures (e.g., outfall pipes and diffusers) do not constitute kelp beds for purposes of bacterial standards.

2. Shellfish Harvesting Standards

Throughout the water column in all areas where shellfish may be harvested for human consumption, as determined by the Regional Board, the median total coliform density shall not exceed 70 per 100 ml and not more than 10 percent of the samples shall exceed 230 per 100 ml.

C. Physical Characteristics

1. Floating particulates and grease and oil shall not be visible.
2. The discharge of the waste shall not cause aesthetically undesirable discoloration of the ocean surface.
3. Natural light shall not be significantly reduced at any point outside the initial dilution zone as a result of the discharge of waste.
4. The rate of deposition of inert solids and the characteristics of inert solids in ocean sediments shall not be changed such that benthic communities are degraded.

D. Chemical Characteristics

1. The dissolved oxygen concentration shall not at any time be depressed more than 10 percent from which occurs naturally, as a result of the discharge of oxygen demanding waste materials.
2. The pH shall not be changed at any time more than 0.2 units from that which occurs naturally.
3. The dissolved sulfide concentration of waters in and near sediments shall not be significantly increased above that present under natural conditions.
4. The concentration of substances set forth in Chapter II, Table B in marine sediments shall not be increased to levels which would degrade indigenous biota.
5. The concentration of organic materials in marine sediments shall not be increased to levels which would degrade marine life.
6. Nutrient materials shall not cause objectionable aquatic growths or degrade indigenous biota.
7. Numerical water quality objectives in Table B apply to all discharges within the jurisdiction of this plan.

E. Biological Characteristics

1. Marine communities, including vertebrate, invertebrate and plant species, shall not be degraded.
2. The natural taste, odor and color of fish, shellfish, or other marine resources used for human consumption shall not be altered.
3. The concentration of organic materials in fish, shellfish or other marine resources used for human consumption shall not be bioaccumulated to levels that are harmful to human health.

F. Radioactivity

1. Discharge of radioactive waste shall not degrade marine life.

An automated instrument package, commonly referred to as a CTD,[1] was used to collect precise *in situ* measurements of seawater properties during each of the four quarterly receiving-water surveys of 2015. Measured seawater parameters consisted of temperature, salinity, dissolved oxygen (DO),

[1] Conductivity, temperature, and depth (CTD)

acidity/alkalinity (pH), and light transmittance (transmissivity or water clarity). Qualitative visual observations made during the offshore surveys provided ancillary information on any potential wastewater contributions to levels of floating particulates, seawater discoloration, odors, algal blooms, and surface water clarity. Wildlife and recreational use, as well as general weather and sea state, were also noted.

In addition to the quarterly sampling used to delineate the discharge plume offshore, regular monitoring of the adjacent surfzone along Atascadero State Beach has historically been conducted to assess aesthetic conditions conducive to the site-specific beneficial uses described in Section 2.1.3. Bacteriological conditions along the shoreline are of particular interest for shellfish harvesting and for water-contact recreation, namely swimming and surfing. However, disinfection of MBCSD effluent routinely reduces bacterial densities to levels well below receiving-water standards prior to discharge, and the more-than 100-fold dilution that occurs shortly after discharge renders the plant's bacterial loading imperceptible. Consequently, surfzone bacterial samples are too distant to be materially affected by the discharge, and are instead dominated exclusively by onshore sources and runoff (MRS 1994 – 2010). Therefore, the current NPDES permit no longer requires regular monitoring of surfzone bacteria, but triggers monitoring at eight surfzone locations along Atascadero State Beach only when there is an upset in the WWTP's disinfection process that causes total coliform density in the effluent to exceed 2400 MPN/100 ml.

The surfzone stations are located at gradient distances upcoast and downcoast relative to Station C, which is positioned at the onshore site closest to the offshore discharge location (See Table 3.2 and Figure 3.1). During 2015, as in prior years, no instances of elevated effluent coliform triggered the requirement for surfzone sampling.

Table 3.2 Target Locations of Surfzone Sampling Stations

Station	Description	Along-Shore Distance[1] (m)	Latitude[2]	Longitude
A1	Upcoast Reference	1330 N	35° 23.967' N	120° 52.116' W
A	Upcoast Midfield	912 N	35° 23.750' N	120° 52.067' W
B	Upcoast Nearfield	488 N	35° 23.517' N	120° 52.000' W
C	Onshore of Diffuser	0	35° 23.250' N	120° 51.950' W
D	Downcoast Nearfield	426 S	35° 23.033' N	120° 51.917' W
E	Downcoast Midfield	922 S	35° 22.767' N	120° 51.900' W
F	Downcoast Reference	1602 S	35° 22.400' N	120° 51.883' W
G	Morro Creek[3]	— [4]	—	—

Other beneficial uses designated for this coastal area, such as fishing and non-water-contact recreation, including beachcombing, boating, and picnicking, were addressed by visual observations of aesthetic conditions, which were documented during the offshore surveys conducted in 2015. These auxiliary observations included weather conditions, ocean currents, tides, and any evidence of water discoloration, floating oil and grease, turbidity, odor, or materials of sewage origin on the beach or in the water.

[1] Along-shore distance and direction from Station C
[2] As described in the glossary, all coordinates cited in this report are referenced to the WGS84 datum
[3] Immediately before flowing to the ocean
[4] Location varies with the along-shore migration of the mouth of Morro Creek

Figure 3.1 Locations of Receiving-Water and Surfzone Sampling Stations

3.1.3 Sampling Station Design

Offshore receiving-water sampling focuses on the water column close to the discharge location (Figure 3.1). The beginning of the diffuser structure lies 827 m from the shoreline, while the diffuser structure itself extends an additional 52 m toward the northwest along the seafloor.

Twenty-eight of the 34 available ports discharge effluent along a 42 m section of the diffuser structure. The diffuser ports were hydraulically designed to dilute effluent rapidly within the receiving seawater immediately upon discharge. Most of this turbulent mixing occurs within a zone of initial dilution (ZID), which by regulatory assertion alone, extends laterally to a distance of approximately 15 m from the center of the diffuser structure.

Over longer periods, energetic waves, tides, and coastal currents within Estero Bay further disperse the effluent plume within open-ocean receiving waters beyond the ZID. Areas of special concern, such as sanctuaries and estuaries, are too distant to be materially affected by the treated wastewater discharge. For example, the southern boundary of the Monterey Bay National Marine Sanctuary is located 38 km to the north, while the entrance to Morro Bay lies 2,800 m to the south of the discharge. In 1995, Morro Bay

was included in the National Estuary Program; however, because of its distance from the discharge, incursion of unmixed wastewater into the Bay is highly unlikely. Direct seawater exchange between the discharge point and Morro Bay is restricted by Morro Rock, which lies between the outfall and the south-facing entrance to the Bay. Morro Rock is the largest physiographic feature along the adjacent coastline and extends into Estero Bay approximately 2,000 m south of the point of discharge (Figure 3.1).

During 2015, vertical seawater measurements were recorded at six offshore stations situated at three gradient distances upcoast and downcoast from the ZID (Figure 3.2). The sampling pattern was designed to evaluate the discharge's region of influence during each quarterly water-quality survey. The two closest stations, which are on the outer margin of the ZID, were located 15 m from the closest point on the diffuser structure. The remaining more-distant stations were located relative to the center point of the diffuser structure.

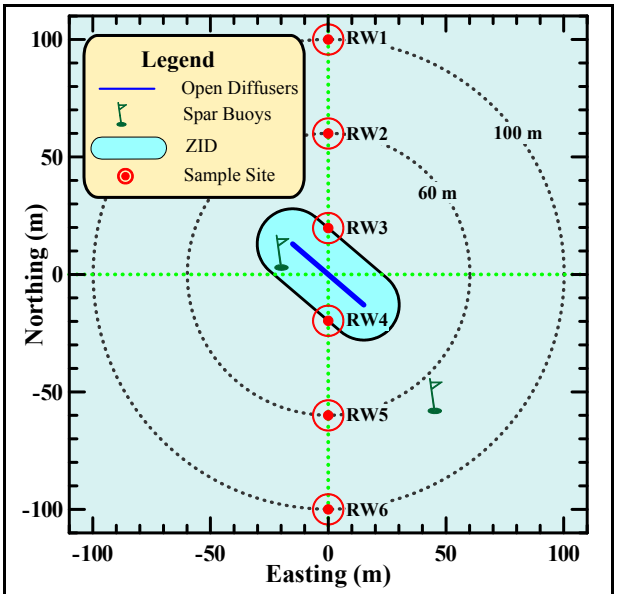

Figure 3.2 Target Locations of Receiving-Water Stations

It is important to consider the "*closest-approach*" distance when evaluating impacts at stations near the wastewater discharge. Although the discharge has historically been considered a "*point source*" for most large-scale modeling purposes, it does not occur at a single location of infinitesimal size. Because the discharge is distributed along a 42 m section of the seafloor, its finite size affects assessments of wastewater dispersion at sites close to the discharge. Specifically, the amount of wastewater dispersion at a given point in the water column is determined more by its distance to the closest diffuser port rather than its distance to the center point of the diffuser structure. Near the source, this "*closest-approach*" distance can be much less than the actual distance to the center of the diffuser structure (Table 3.3, Figure 3.2). As such, it would be unsuitable to design a nearfield sampling pattern based solely on center-point distances rather than closest-approach distances.

Table 3.3 Target Locations of Receiving-Water Stations

Station	Description	Latitude	Longitude	Closest Approach Distance[1] (m)	Center Distance[2] (m)
RW1	Upcoast Midfield	35° 23.253' N	120° 52.504' W	88.4	100
RW2	Upcoast Nearfield	35° 23.231' N	120° 52.504' W	49.4	60
RW3	Upcoast ZID	35° 23.210' N	120° 52.504' W	15.0	20
RW4	Downcoast ZID	35° 23.188' N	120° 52.504' W	15.0	20
RW5	Downcoast Nearfield	35° 23.167' N	120° 52.504' W	49.4	60
RW6	Downcoast Midfield	35° 23.145' N	120° 52.504' W	88.4	100

With the closest-approach distances in mind, the six receiving-water monitoring stations were aligned along a north-south axis at the same isobath (15.2 m) as the diffuser center point. Stations RW3 and RW4 were positioned at the boundary of the ZID at a distance of 15 m upcoast and downcoast of the closest

[1] Distance from the closest open diffuser port
[2] Distance to the center of the open diffuser section

diffuser ports (Table 3.3). Stations RW2 and RW5 were located at nearfield distances (60 m) from the diffuser center point. Midfield Stations RW1 and RW6 represent reference stations situated 100 m upcoast and downcoast of the center point. Depending on the direction of the local oceanic currents at the time of sampling, one or more of these near and midfield stations could conceivably be influenced by wastewater discharge. Under those circumstances, the midfield station on the opposite side of the diffuser acts as a reference station. Comparisons of water properties at these antipodal stations quantify departures from ambient seawater properties that are used in the evaluation of compliance with the NPDES discharge permit.

3.1.4 Navigation

Vessel positioning within the compact offshore sampling pattern improved markedly with the advent of Differential Global Positioning Systems (DGPS). DGPS, with typical position errors of less than 4 m, significantly enhances the accuracy of traditional GPS navigation systems, which have position errors as large as ±15 m, a span equaling the width of the ZID itself. At the beginning of 1998, the survey vessel F/V *Bonnie Marietta* was fitted with a Furuno™ GPS 30 and FBX2 differential beacon receiver. This navigational system was used on 29 July 1998 to locate the position of the open section of the diffuser structure precisely (MRS 1998b), and to establish the new target locations for the offshore monitoring stations listed in Table 3.3.

Specifying the precise location of each measurement relative to the diffuser is crucial for accurate interpretation of the water property fields. For example, during vertical profiling, the actual sampling locations do not coincide with the exact target coordinates listed in Table 3.3. The combined influences of winds, waves, and currents induce vessel offsets of tens of meters within the minute or so it takes to complete the water-property profile at each station. Even during quiescent periods, drift is induced by residual vessel momentum remaining after station approach. Prior to the use of DGPS, these offsets could not be reliably resolved by the available navigation, but, during the 2015 surveys, the sampling locations were precisely determined throughout the vertical profiling conducted at each station.

Determination of vessel drift during vertical profiling is an important consideration because it caused some of the measurements in 2015 to be collected within the ZID, where the water-quality objectives in the COP do not apply (see shaded entries in Table 3.4). The average closest-approach distances in Table 3.4 can be compared with the target distances listed in Table 3.3 to assess the fidelity of the sampling locations with respect to diffuser-structure proximity. From the standpoint of an ideal compliance evaluation, all measurements would be made at or slightly beyond the ZID boundary, namely, at distances of more than 15 m from the diffuser structure. However, measurements collected well within the ZID, and

Table 3.4 Station Proximity to the Discharge

		Closest-Approach Distance[1] (m)				
Station	**Description**	**Target**	**January**	**June**	**July**	**October**
RW3	Upcoast ZID	15.0	**17.5**[2]	**15.3**	**10.1**	**17.0**
RW4	Downcoast ZID	15.0	**4.7**	**14.9**	**12.5**	**16.2**
RW2	Upcoast Nearfield	49.4	52.0	58.0	55.6	48.9
RW5	Downcoast Nearfield	49.4	44.2	41.1	47.1	47.2
RW1	Upcoast Midfield	88.4	104.2	86.8	93.2	92.4
RW6	Downcoast Midfield	88.4	77.0	92.0	79.8	83.6

[1] Distance from the closest open diffuser port to the average station position
[2] All or portions of the profiles highlighted in bold typeface with shading were sampled within the ZID

close to the diffuser structure, are also valuable because they capture the dynamics of the plume while it is still undergoing rapid initial mixing, and thus lend timely insight into the dispersive capabilities of the diffuser structure. These close-in measurements have demonstrated that the MBCSD discharge routinely meets the COP receiving-water objectives within the ZID and well before completion of the initial dilution process.

3.1.5 Sampling Equipment and Methodology

The 38-ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, provided vessel support for the four offshore surveys conducted in 2015. Bonnie Luke of Marine Research Specialists (MRS) oversaw deployment of the CTD and collected auxiliary measurements of biological, meteorological, and oceanographic conditions during the January survey. Douglas Coats, also of MRS, provided data-acquisition and navigational support during all the surveys. Dean Dusette, also of MRS, assisted with the deployment and recovery of the CTD and drifter in conjunction with crewmembers William Skok and Marc Tognazzini during the October survey. Marc Tognazzini also collected auxiliary measurements of biological, meteorological, and oceanographic conditions during the October survey.

Standard observations for weather, seas, water clarity/coloration, Secchi depth, and the presence of any odors and floating debris were recorded during each of the surveys. Wind speeds and air temperatures were measured with a Kestrel® 2000 Thermo-Anemometer. These observations were collected during the vertical profiling conducted with the CTD at each of the six stations.

Auxiliary Measurements

During vertical profiling at each station, a Secchi disk was lowered through the water column to determine its depth of disappearance. This provided a visual measure of the water clarity within the upper water column. The depth of disappearance is inversely proportional to the average amount of organic and inorganic suspended material along a line of sight immediately below the sea surface. As such, Secchi depth is a measure of ambient light penetration, which can be limited during upwelling when plankton density increases within the near-surface euphotic zone. The depth of the euphotic zone, where most oceanic photosynthesis occurs, extends to approximately twice the Secchi depth. Because Secchi depths are less precise than measurements collected with electronic sensors, these and the other qualitative observations described above, were ancillary to the digital measurements of seawater parameters collected by the CTD throughout the water column.

At the beginning of each survey, a drifter was deployed at the center of the open section of the diffuser structure. The drifter was drogued at mid-depth (7 m) using the curtain shade design of Davis et al. (1982). In this configuration, the drifter trajectory was largely determined by the oceanic flow field rather than surface winds. Satellite navigation onboard the drifter allowed continuous recording of the precise position of the drifter throughout its deployment. Additionally, the vessel's locations during deployment and recovery of the drifter were recorded for navigational comparison. These trajectory measurements established the ambient flow velocity throughout each survey, and indicated the path of plume transport to aid in the interpretation of seawater property distributions.

Instrumental Measurements

A Sea Bird Electronics SBE-19plusV2 CTD instrument package was used during all four of the 2015 surveys. It was deployed in both a vertical water-profiling mode, as well as a horizontal-tow configuration. It collected measurements of conductivity, temperature, light transmittance, dissolved oxygen (DO), pH, and pressure at a sampling rate of 4 Hz (0.25-second intervals). Submersible pumps on

the CTD continuously flushed water through the conductivity cell and oxygen plenum at a constant rate, independent of the CTD's motion through the water.

The six seawater properties used to assess receiving-water quality in this report were derived from the continuously recorded output of the CTDs' probes and sensors. Pressure housing limitations on the oxygen and pH sensors confine the CTD to depths less than 200 m (Table 3.5), which is well beyond the maximum depth of the deepest station in the outfall survey. The precision and accuracy of the various probes, as reported in manufacturer's specifications are also listed in the Table. Salinity (‰, parts-per-thousand) was calculated from conductivity measurements reported in units of Siemens/m. Density was derived from contemporaneous temperature (°C) and salinity data, and was expressed as 1000 times the specific gravity minus one, which is a unit of sigma-T (σ_t).

Table 3.5 Specifications for the CTD Instrument

Component	Depth[1]	Units	Range	Accuracy	Resolution
Housing (19p-1a; Acetron Plastic)	680	m	0 to 680	—	—
Pump (SBE 5P)	3400	—	—	—	—
Pressure (19p-2h; Strain-Gauge)	680	dBar	0 to 680	±1.7	± 0.10
Conductivity	3400	Siemens/m	0 to 9.0	± 0.0005	± 0.00005
Salinity	3400	‰	0 to 58	± 0.004	± 0.0004
Temperature	3400	° C	–5 to 35	± 0.005	± 0.0001
Transmissivity (WETLabs C-Star)[2]	2000	%	0 to 91.3[3]	± 0.3	± 0.03
Oxygen (SBE 43)	200	%Saturation	0 to 120	± 2	—
pH (SBE 18)	200	pH	0 to 14	± 0.1	± 0.006

All three of the physical parameters (salinity, temperature, and density) helped determine the lateral extent of the effluent plume during the tow phase of the surveys. Additionally, during the vertical-profiling phase, they quantified layering, or vertical stratification and stability of the water column, which affects the behavior and dynamics of the effluent as it mixes with seawater within the ZID. Data on the three remaining seawater properties, light transmittance (water clarity), hydrogen-ion concentration (acidity/alkalinity – pH), and dissolved oxygen (DO), further characterized receiving waters and were used to assess compliance with water-quality criteria. Light transmittance was measured as a percentage of the initial intensity of a transmitted beam of light detected at the opposite end of a 0.25-m path. Increased transmittance indicates increased water clarity and decreased turbidity.

The SBE-19plusV2 CTD system was placed into service in mid-2011 and offers many advantages over the previous SBE-19 Seacat unit that was used in previous surveys for two decades. For example, the 4 Hz sampling rate on the new instrument collects data at twice the rate of the older unit, allowing much higher spatial resolution for a given tow, or descent rate. The probes and sensors on the current CTD also have a much faster response time, further enhancing the spatial resolution of seawater properties. Finally, the probes and sensors on the current CTD unit are more stable and exhibit negligible long-term drift. As a result, and in accordance with the manufacturer's recommendations, the current CTD package does not require regular recalibration of the sensors prior to each field survey.

[1] Maximum depth limit in meters
[2] 25-cm path length of red (660 nm) light
[3] The transmissometer was calibrated to yield 100% transmission in air, and the maximum transmission of 660nm light in pure water is 91.3%.

During the 2015 surveys, the CTD was held below the sea surface for several minutes prior to vertical profiling to allow the sensors to equilibrate. Subsequently, the CTD was raised to within 0.5 m of the sea surface and vertical profiling commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at all six stations were recorded during a single deployment of the CTD package by towing it below the water surface while transiting between adjacent stations. Upon retrieval of the CTD, the data were downloaded to a portable computer and examined for completeness and range acceptability. Data recorded during vertical profiling were processed in accordance with standard analysis procedures (SCBFMC 2002), which resulted in bin-averaged data across 0.5-m standard depth intervals. The profile data were collated in individual survey reports (MRS 2015cdef) and digitally archived within the USEPA STORET database.

Following collection of the vertical profiles, the CTD was redeployed and continuously towed around and across the ZID at two separate depths in accordance with the receiving-water monitoring requirements of the current NPDES discharge permit. An example of the tow pattern, from the second-quarter survey, is shown in Figure 3.3.

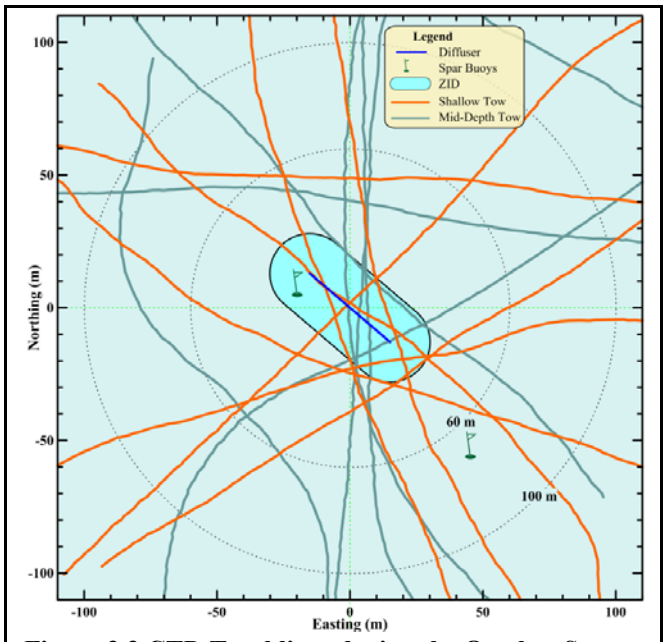

Figure 3.3 CTD Tracklines during the October Survey

Prior to the tow surveys, the CTD instrument package was fitted with a horizontal wing to enhance vertical stability during the tow. The CTD was deployed with its sensor probes in a forward-looking configuration, and a clump weight was placed on the main towline to help achieve the proper initial tow depth. The appropriate length of towline was deployed for tows near the sea surface, where it passed close to the diffuser structure at least five times. Subsequently, an additional length of towline was paid-out, and a minimum of five passes were made at mid-depth. Monitoring of real-time sensor output was used to evaluate the CTD's progress and adjust the tow depth, which was accomplished by small adjustments to vessel speed.

3.2 PLUME DISPERSION

Offshore monitoring is conducted to determine whether the wastewater discharge is causing significant impacts on the receiving waters of Estero Bay beyond the ZID. Section 3.3.1 makes this determination by comparing the water quality at the boundary of the ZID, and gradient areas beyond the ZID, with background seawater properties. However, the complex interaction between physical oceanographic processes and ambient seawater properties near the outfall makes detection of the relatively minor discharge-related changes challenging. The significance of potential water-quality impacts is assessed through a comparison between the amplitude of discharge-related anomalies and the inherent variability in ambient seawater properties. Statistically speaking, if the amplitude of the effluent anomaly is small compared to the inherent variability in ambient seawater properties, then the discharge impact on water quality cannot be deemed significant.

The following two subsections describe the nature of wastewater dispersion from the MBCSD diffuser structure. The first subsection discusses the configuration of the multiport diffuser structure and describes how its hydraulic design determines the dimensions of the ZID. The second subsection describes the dynamics of the rapid mixing that occurs within the ZID upon discharge from the diffuser structure.

The final two subsections describe oceanographic processes that affect ambient seawater properties within northern Estero Bay and determine the range in natural variability caused by these processes. These measures of natural-variability are used to establish thresholds for determining whether discharge-induced changes are significant. Regional processes cause major fluctuations in the character of the receiving waters near the diffuser, and large seasonal changes in the vertical structure directly affect the dispersive capability of the outfall.

3.2.1 Zone of Initial Dilution

Treated wastewater from the MBCSD WWTP is discharged into northern Estero Bay through a 1,450-m outfall-diffuser system (Table 3.6). The existing outfall was constructed in 1982 with an upgraded 0.686-m diameter steel pipe lined and coated with cement mortar. The outfall extends to a water depth of about 15.2 m (50 ft), approximately 0.5 nautical miles offshore of Atascadero State Beach. At its terminus is a multiport linear diffuser consisting of 34 ports, each 5.08 cm in diameter. The ports are spaced 1.52 m apart on alternating sides of the pipe. The current discharge volume from the WWTP only requires the use of 28 of the 34 available ports.

Table 3.6 Hydraulic Characteristics of the Outfall

Parameter	Measurement
Outfall diameter (m)	0.686
Outfall length (m)	
Land	207
Ocean	1,449
Diffuser diameter (m)	0.686
Diffuser length (m)	51.8
Port orientation (° from horizontal)	0
Port diameter (m)	0.0508
Orifice contraction coefficient	0.89
Center point depth of outfall ports (m MLLW)	15.2
Number of ports open	28[1]
Port spacing[2] (m)	1.52
Design flow rate for each port (m^3/s)	0.01[3]

For regulatory and modeling purposes, an idealized ZID is envisioned around the diffuser structure, where the most intense turbulent mixing of effluent is thought to take place shortly after discharge. The ZID is assumed to extend beyond the dimensions of the diffuser structure to a horizontal distance equal to the water depth (USEPA 1994). The water depth at the center point of the diffuser structure is 15.24 m (50 ft) measured relative to the MLLW tidal datum. Consequently, the ZID forms a vertical cylinder whose horizontal cross-section is an elongated ellipse as shown in Figure 3.2 on Page 3-6. Based on the diffuser specifications, the dimensions of the ZID are 73.15 m (240 ft) in length, 31.2 m (102.4 ft) in width, and 15.24 m (50 ft) in height. The length is twice the water depth (15.24 m) added to the 42.67 m (140 ft) long diffuser section where ports are open. The width of the ZID is twice the water depth added to the inside diameter (0.68 m) of the diffuser pipe. Coatings, which add 0.2 m to the outside diameter of the pipe, and the angled diffuser ports, which extend beyond the edge of the pipe, were neglected for the purposes of determining ZID dimensions. Based on these dimensions, the ZID covers an ocean surface area of approximately 3000 m^2 and contains 12 million gallons of seawater. At the nominal discharge rate of 1 MGD, it would take twelve days for the wastewater discharge to fill a volume equal to the ZID.

[1] 28 of 34 ports available
[2] Ports are located on alternating sides of the diffuser. Distance between ports on the same side of the diffuser is 3.04 m.
[3] This flow rate applies when 34 ports are open, with a total flow of 0.340 m^3/s (7.76 MGD) through the diffuser structure. The outfall design capacity is 0.358 m^3/s (8.17 MGD).

In reality, at any given time, the actual initial-dilution zone departs markedly from the idealized vertical cylinder described above. On a regular basis, the prevailing currents carry the effluent plume well beyond the boundaries of the idealized ZID, long before it achieves buoyant equilibrium and well before initial mixing is complete. Nevertheless, because wastewater is rapidly diluted upon discharge, the water-quality objectives of the COP are consistently met, even within the boundary of the ZID.

3.2.2 Critical Initial Dilution Ratio

Within a few minutes of after discharge, wastewater dilution is determined by the physical characteristics of the diffuser system and stratification within the receiving waters. This initial rapid mixing occurs within the ZID, and close to the diffuser structure. There, the turbulent processes associated with the high-velocity discharge jets emanating from the diffuser ports, and the buoyant rise of the effluent plume through the water column, entrain seawater and result in the rapid dilution of discharged wastewater. Subsequent transport and dispersion by regional oceanographic processes further dissipate the effluent, albeit at a slower rate. The dispersion associated with these oceanographic processes is not considered part of initial dilution.

The limiting concentrations for wastewater constituents specified in the NPDES permit (see Chapter 2) were determined by applying the critical initial dilution ratio for the MBCSD outfall to the open-ocean water-quality objectives specified in the COP for individual contaminants (Table B of SWRCB 2005). The critical initial dilution applicable to the MBCSD outfall was conservatively estimated to be 133:1 (Tetra Tech 1992). The following example shows how this dilution factor was applied to determine the wastewater limits that were established for cadmium in the NPDES permit. The COP's water-quality objective for cadmium in receiving waters has an instantaneous maximum concentration of 0.01 mg/L or less (SWRCB 2005). Based on modeling under extremely stratified conditions, there will be at least 133 parts of ambient water mixed with each part of wastewater after completion of initial mixing. From the definition of dilution (Fischer et al. 1979), the concentration of a particular contaminant in wastewater is given by:

$$C_e \equiv C_o + D\left(C_o - C_s\right) \qquad \text{Equation 3.1}$$

where: C_e = the concentration of a constituent in the wastewater effluent,
C_o = the concentration of the constituent in the ocean after dilution by D,
D = the dilution ratio of the volume of seawater mixed with wastewater, and
C_s = the background concentration of the constituent in ambient seawater.

The background concentration (C_s) for cadmium in seawater is negligible, so the wastewater limit is ($D+1$) times the COP objective (C_o). Thus for cadmium, the instantaneous maximum concentration within wastewater is restricted to 1.34 mg/L, or 134 times the seawater objective of 0.01 mg/L. Specifically, under the worst-case scenario, wastewater containing 1.34 mg/L of cadmium will dilute to a concentration of 0.01 mg/L upon reaching the boundary of the ZID, and the COP receiving-water objective will be met. This is how the maximum effluent limit on cadmium concentrations (1.34 mg/L) was established in the NPDES discharge permit granted to the MBCSD.

The foregoing calculation demonstrates how strongly the assumed initial dilution influences the wastewater limitations that are specified in the NPDES discharge permit. Because a low value (133:1) was specified for the critical initial dilution, conservative wastewater limitations have been established for the MBCSD discharge. As discussed in Section 3.3.1, however, direct observations recorded close to the diffuser during the 2015 surveys indicate that dilutions much higher than 133:1 were achieved well within the ZID and below the assumed plume-trapping depth of 6.4 m. In fact, the original plume modeling that established the 133:1 critical dilution (Tetra Tech 1992) included 34 open diffuser ports instead of the 28 ports that are currently in use, thereby underestimating the ejection velocity and associated turbulent mixing rate achieved by individual diffuser ports.

Additionally, the model assumed that the receiving waters at the point of discharge were highly stratified. However, the stringent vertical stratification profile used in the modeling is not typical of the receiving-water conditions surrounding the outfall. Specifically, the critical initial dilution computed by the original modeling was overly conservative because the density profile used to establish the MBCSD critical initial dilution was collected 1 km south of the diffuser structure, where the water column was excessively stratified due to the influence of the thermal discharge from the Morro Bay power plant.[1] At the time the "critical" density profile was measured, the power plant was discharging heated water to the ocean near Station F, next to Morro Rock (see Figure 3.1 on Page 3-5).

Because this southerly monitoring station consistently exhibited anomalous water properties relative to the ambient conditions near the MBCSD outfall, it was discarded when the receiving-water monitoring program was revised in 1999. Nevertheless, the original plume modeling, which established both the critical initial dilution ratio currently applied to the outfall and the present effluent discharge limits, incorporated an artificially stratified profile from this station. The model predicted that the receiving waters would trap the effluent plume 6.4 m below the sea surface. More recent dilution modeling, however, demonstrates that with weaker vertical stratification representative the water column near the diffuser, a critical initial dilution of approximately 200:1 with a plume trapping depth of 1.4 m best characterizes the worst-case outfall performance (Lindstrom 1998).

Nevertheless, even with dilutions of only 133:1, the highly sensitive instruments on the CTD have a difficult time detecting the influence of the dilute wastewater constituents, except very close to diffuser ports. Accordingly, most wastewater-induced perturbations in water quality are imperceptible beyond the ZID, particularly in the presence of the large, natural oceanic variability that exists within northern Estero Bay.

3.2.3 Regional Oceanographic Processes

A broad suite of complex oceanographic processes determines the disposition of coastal marine waters within northern Estero Bay. Close to shore, an energetic wave field occasionally dominates the oceanographic conditions along this section of the central California coast. This wave energy increases the turbulence within nearshore waters, and causes significant sediment resuspension and sand transport along the outfall corridor. Farther offshore, bands of counter currents move ocean waters in alternating directions along the continental shelf.

[1] The plant is not currently operating and is scheduled for permanent decommissioning. It is owned by Dynegy Corporation, but has formerly been owned by the following entities: Pacific Gas and Electric, Duke Energy, LS Power Group, and Icahn Enterprises.

This large-scale, along-shore current flow is interrupted by cross-shore tidal currents and by turbulent jets that occasionally form at major promontories, such as Point Piedras Blancas, Point Buchon, and Point Arguello (Figure 3.4). These narrow, energetic jets transport materials far from the coast, and are repeatedly observed extending from upwelling centers located south of major coastal headlands in satellite imagery. In addition to these processes, wind-driven upwelling alters the vertical distribution of water properties within Estero Bay and contributes to the remarkably high productivity of the marine waters there.

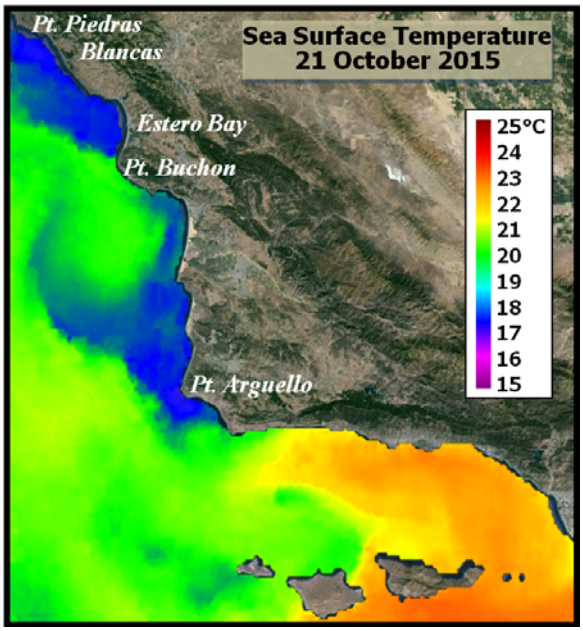

Figure 3.4 Satellite Image of the Sea Surface Temperature Pattern associated with Upwelling

The open-ocean flow field largely controls ambient seawater properties within Estero Bay. Beyond the continental slope (>50 miles offshore), the diffuse, southward-flowing California Current represents the eastern limb of the clockwise-flowing gyre that covers much of the North Pacific Ocean. Before turning south to form the California Current, subarctic water is carried along at high latitudes where it is exposed to atmospheric cooling, nutrient regeneration, and precipitation. As a result, the waters of the California Current are characterized by a seasonably stable low salinity (32‰ to 34‰), low temperature (13°C to 20°C), and high nutrient concentrations. Because of this stabilizing effect, seawater off the central coast undergoes less seasonal variation than surface waters at similar latitudes along the eastern seaboard.

Immediately shoreward of the California Current, along the continental slope and shelf, is the northward flowing Davidson countercurrent, which carries warmer, more saline, and less oxygenated waters from the Southern California Bight. The Davidson Current exhibits a strong seasonal variability in intensity that coincides with large-scale changes in coastal winds. Specifically, throughout much of the year, winds along the central coast blow from the northwest, parallel to the coast and in opposition to the northward-flowing Davidson Current. These strong northwesterly winds induce upwelling near Points Estero, Buchon, and Sal. During the upwelling season, surface water near the coast is transported offshore by the prevailing winds, and is replaced by deep cool, nutrient-rich seawater near the coast as shown by the dark blue shading in Figure 3.4. When these northwesterly winds relax, usually between December and February, the Davidson Current strengthens. A spring transition back to strong southwestward winds typically occurs fairly rapidly between March and June. Despite reversals observed elsewhere along the California Coast, however, the Davidson current maintains a sustained subsurface northward flow near Estero Bay (Coats et al. 1991).

Significant inter-annual variations in oceanographic properties and marine fauna have also occurred along the central California coast, and have strongly influenced the waters of Estero Bay throughout the last half century (Figure 3.5). These large amplitude variations are associated with the El Niño–Southern Oscillation (ENSO), which cycles at a period of 3 to 5 years (Graham and White 1988). El Niño and its

counterpart, La Niña, are oscillations of the ocean-atmosphere system in the tropical Pacific. El Niño is characterized by unusually warm sea surface temperatures and La Niña by unusually cool temperatures in the equatorial Pacific Ocean. Periods when El Niño conditions prevail are indicated in red in Figure 3.5, while La Niña conditions are shown in blue.

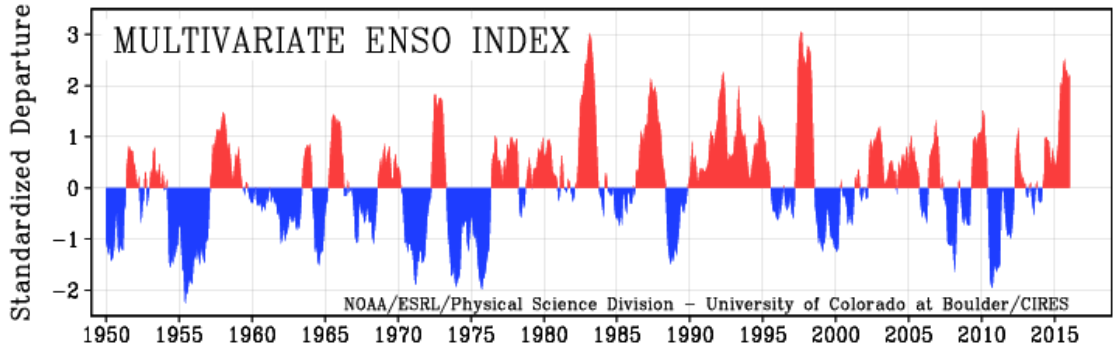

Figure 3.5 Long-Term Variation in the El Niño Index

The El Niño event that was occurring at the time of this report (rightmost red region in the Figure) ranks among the top three events of the last half-century. During strong El Niño periods, basin-wide changes in the dynamic balance of wind-driven currents result in modified flow patterns along the coastline of western North and South America (Chelton et al. 1982). Changes in the study region include an anomalous strengthening of Davidson Current outflow from the Southern California Bight. El Niño events also generally coincide with increased winter storm activity, reductions in zooplankton biomass, and the introduction of marine organisms typically found far to the south.

Conversely, during La Niña events, high pressure builds in the eastern equatorial Pacific while low pressure develops to the west, producing a stronger equatorial pressure gradient. The easterly trade winds strengthen, causing upwelling off the coastlines of North America, Peru, and Ecuador to intensify, and causing a reduction in sea surface temperatures throughout the Eastern Pacific Ocean, including along California's central coast. The low sea surface temperatures along the equator also cause the Pacific storm track to shift northward, typically resulting in drier conditions throughout the southern United States.

In addition to, and superimposed on these large-scale oceanic flows are a variety of transient phenomena including intense eddies, swirls, filaments, meanders, and narrow jets of flow. Many of these cross-shore turbulent features are evident in the complex surface-flow pattern depicted in satellite images. For example, in Figure 3.4, upwelling-induced reductions in sea surface temperature, delineated in shades of dark blue, stretch southward along the coast. Near Pt. Arguello, an offshore-directed jet carried the cool water offshore. This type of cross-shore flow feature is capable of transporting significant quantities of coastal heat, nutrients, and pollutants to offshore waters (Savoie et al. 1991).

Tidal currents provide another mixing mechanism for ocean waters in the study region, although they are not responsible for significant net transport. Estero Bay experiences astronomical tides of diurnal inequality, meaning that the two daily sets of tidal extrema are of unequal amplitude. Tidal fluctuations of as much as 2.1 m can combine with storm surges of up to 0.3 m. Typically, however, the tidal range near the outfall site is approximately 1 m between mean high and low water.

At shorter periods, shoaling internal waves and surface gravity waves also serve to mix coastal water properties in both the horizontal and vertical directions within the receiving waters. This region of the central coast is relatively unprotected and experiences a comparatively high flux of wave energy, especially in winter when distant North Pacific storms generate episodic swell events that can travel great distances. Under certain conditions, this wave energy impinges on Atascadero State Beach at oblique angles, generating substantial alongshore transport within the coastal littoral cell between Point Estero and Morro Rock (Figure 3.6). The wave-generated littoral cell can extend well off-shore into Estero Bay, encompassing the MBCSD discharge location.

Figure 3.6 Coastal Configuration of Estero Bay

Four primary meteorological sources generate waves in this region: 1) extratropical winter cyclones in the northern hemisphere, 2) northwesterly winds after the spring transition to upwelling conditions, 3) tropical disturbances off shore of Mexico, and 4) extratropical storm swells generated in the southern hemisphere during summer. The first two are the dominant influences on the wave climate along this section of the central California coast, while the last two generate swells from the south, which are diminished near the outfall site by the sheltering effects of Point Buchon (Figure 3.6).

Winter storm waves generated by extratropical winter cyclones are often accompanied by locally severe weather along the south-central coast. These extratropical storms are associated with low-pressure systems that develop along the polar front in the North Pacific Ocean, and that propagate westward toward the central coast. Thus, major wave events often coincide with an increased discharge from the outfall due to heavy rainfall and increased I&I. These storms occur predominantly from December through March. In fact, more than 95% of all major deepwater wave events (H_S>4 m) occur between the months of November and April (Everts Coastal 1996).

With the exception of major storm events, prevailing northwesterly winds are the predominant mechanism for generating waves near the outfall. These winds dominate during the spring and summer when a high-pressure system is established over the eastern North Pacific Ocean. The winds are highly coherent over this section of the central coast and, consequently, can generate wind waves over a large fetch (Chelton et al. 1987). However, these locally generated waves tend to be of shorter period and smaller height than those generated by major winter storms.

3.2.4 Ambient Seawater Properties

A detailed understanding of ambient seawater properties, and their natural variation within the region surrounding the outfall, is an integral part of compliance evaluation. The receiving-water limitations in the NPDES permit echo the objectives listed in the COP (Table 3.1 on Page 3-3), and the Central Coast Basin Plan (RWQCB 1994). The offshore receiving-water surveys are designed to assess compliance with objectives dealing with undesirable alterations to six physical and chemical characteristics of seawater. Other components of the monitoring program, described in other chapters of this report, address the remaining permit limits.

For the receiving waters, the NPDES permit states that wastewater constituents within the discharge shall not cause the limits listed in Table 3.7 to be exceeded (See Sections V.E through V.K of the permit). The first two receiving-water limits, P1 and P2, rely on qualitative visual observations for compliance evaluation. Compliance with the remaining four receiving-water limitations can be quantitatively evaluated by comparing instrumental measurements with the specific numerical limits listed in the NPDES permit. For example, the numeric limits on absolute values of DO (>5 mg/L) and pH (7.0 to 8.3), which reflect Basin Plan objectives, can be directly compared with field measurements within the dilute wastewater plume.

Table 3.7 Permit Provisions Addressed by the Offshore Receiving-Water Surveys

Limit#	Provision	Source	Limit
P1	V.E	COP C.1	Floating particles or oil and grease to be visible on the ocean surface
P2	V.F	COP C.2	Aesthetically undesirable discoloration of the ocean surface
P3	V.I	Basin Plan	Temperature of the receiving water to adversely affect beneficial uses
P4	V.G	COP C.3	Significant reduction in the transmittance of natural light at any point outside the initial dilution zone
P5	V.J	Basin Plan COP D.1	The DO concentration outside the zone of initial dilution to fall below 5.0 mg/L or to be depressed more than 10 percent from that which occurs naturally
P6	V.K	Basin Plan COP D.2	The pH outside the zone of initial dilution to be depressed below 7.0, raised above 8.3, or changed more than 0.2 units from that which occurs naturally

However, both P5 and P6 also contain narrative statements, which originate in the COP and define unacceptable water-quality impacts as "*significant*" excursions beyond those that occur "*naturally*." Quantitative evaluation of these limits requires a further comparison of field measurements with numerical thresholds that reflect the natural variation in transmissivity, DO, and pH within the receiving waters surrounding the outfall. The 30-year record of quarterly receiving-water surveys conducted as part of the MBCSD monitoring program provides the necessary insight into this natural temporal and spatial variation in ambient seawater properties close to the outfall.

Natural variation in seawater properties is driven by a varying combination of the oceanographic processes described in the previous section. These processes determine the range in ambient seawater properties caused by natural spatial variation within the survey region at a given time (e.g., vertical stratification), and by temporal variations caused by seasonal and interannual influences (e.g. El Niño and La Niña). Of particular interest are upwelling and downwelling processes that not only determine average properties at a given time, but also the degree of water-column stratification, or spatial variability, present during any given survey. An accurate characterization of stratification helps distinguish discharge-related changes that arise from the presence of wastewater constituents and are subject to the compliance evaluation, from changes that arise because of the upward transport of ambient seawater, which are specifically excluded from the compliance evaluation.

Most of the variability in the ambient seawater database arises from temporal changes in average seawater properties among surveys. Within individual surveys, vertical differences in seawater properties far exceed lateral differences, except during winter surveys when downwelling events can create a uniform water column. The dominating influence of seasonal variability on receiving-water properties, in terms of differences in both vertical stratification and average properties, is reflected in the conditions observed

during the four offshore surveys conducted in 2015 (Table 3.8). As is evident in the table, the strength of upwelling that prevailed at the time of each survey tended to influence the degree of stratification.

Table 3.8 Oceanographic Conditions during the Quarterly Receiving-Water Surveys

Conditions	January (winter)	June (spring)	July (summer)	October (fall)
Tide	Flood	Flood	Flood	Flood
Wave Height (from)	1-2 NW	1-2 NW	1-2 NW	3-4 NW
Flow Direction (toward)	NNW	SSE	SSE	N
Flow Speed (cm/s)	11.4	9.5	7.7	10.3
ZID Residence Time (min)	2.0	2.5	3.3	2.5
Stratification	Limited	Strong	Strong	Limited
Water Clarity	Moderate	Low	Low	High
Upwelling	Weak	Intense	Intense	Weak
Plume Visible	Yes	No	No	Yes
Plume Signature	Yes	Yes	Yes	Yes

All four of the 2015 surveys were conducted when some degree of upwelling and water-column stratification was present. Blue shaded areas in Figure 3.7 represent times when northwesterly winds prevailed near Estero Bay, driving surface waters offshore, and inducing upwelling near the coast, while the yellow diamonds identify the individual receiving water surveys. As seen in the figure, receiving-water surveys have generally been conducted during periods of moderate upwelling. Occasionally, however, the first quarter (winter) surveys have been conducted when little or no upwelling was occurring, or when downwelling from successive winter storms produced a nearly uniform water column. During 2015, both the January and October surveys were conducted when very weak upwelling or even downwelling was present. Downwelling displaces deep watermasses offshore, where they no longer provide a nearshore vertical contrast in seawater properties, and a uniform (unstratified) water column is produced within the survey area.

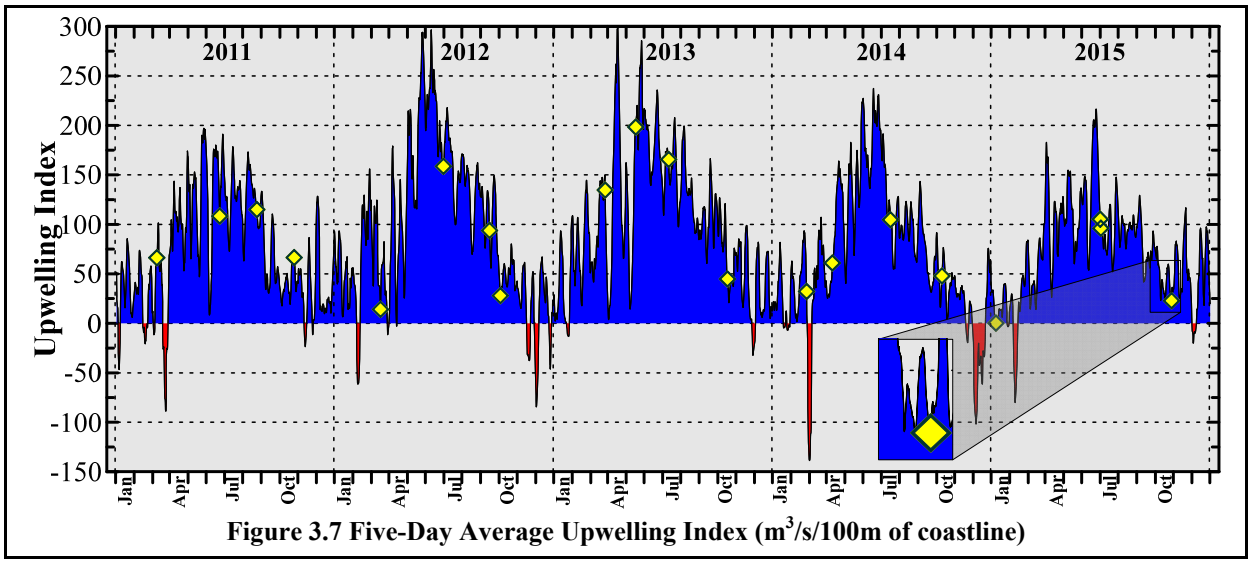

Figure 3.7 Five-Day Average Upwelling Index (m^3/s/100m of coastline)

The influence of upwelling on stratification is evident in temperature profiles collected during each of the quarterly surveys in 2015 (Figure 3.8). The profiles were measured at locations upstream of the diffuser structure and thus were not affected by the discharge plume. Stratification is virtually imperceptible in the profiles from the surveys conducted in January and October 2015 (black and green). In contrast, the June and July profiles (blue and red) exhibit a distinct shallow thermocline between 2 and 4 m. Although their sea surface temperatures were comparable to those of the January survey, markedly cooler water was present at depth. This reflects the presence of a cool deep watermass that was transported shoreward by the upwelling process.

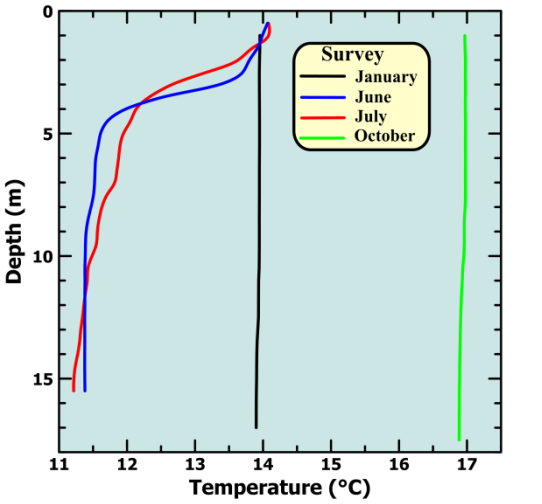

Figure 3.8 Temperature Profiles at Upstream Reference Station

The June and July profiles are typical of upwelling conditions when northwesterly winds along the central California coast drive surface waters offshore, allowing cooler, denser, saltier, and oxygen-poor water at depth to "upwell" near the coast to replace it. Although upwelling is recognized as the primary driver behind the productive fisheries of the central California coast, its persistence can eventually deplete oxygen levels within the bottom waters of Estero Bay, as occurred around the time of the June and July surveys (Figure 3.9).

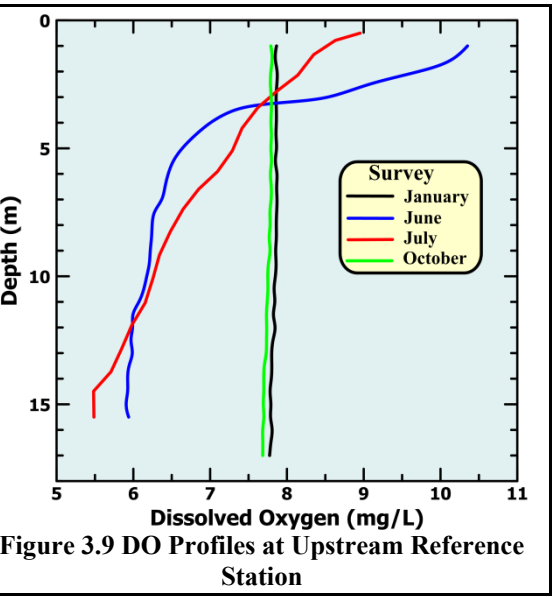

Figure 3.9 DO Profiles at Upstream Reference Station

Upwelling conditions initially facilitate phytoplankton blooms that produce oxygen and consume carbon dioxide. However, as phytoplankton die and fall to the seafloor, their decomposition consumes more of the available oxygen in the nearshore waters than they contribute. Normally, the northwesterly winds that promote upwelling intermittently relax, allowing seawaters on the continental shelf to mix and replenish the subsurface waters with oxygen.

With the onset of the spring transition in April 2015, however, sustained northwesterly winds caused DO levels to decline at depth. As a result, DO levels measured near the seafloor during the July 2015 survey (red line in Figure 3.9) to approach the Basin Plan limit of 5 mg/L. In prior years, DO concentrations within ambient seawater at depth fell well below the Basin Plan limit (MRS 2011), and in 2015, the lower threshold of natural DO variation dropped to 4.14 mg/L.[1]

[1] See Table 3.10 later in this report. Also note that DO concentrations as low as 3.73 mg/L would have met the COP objective for DO depression during the July survey (Table 3.11).

3.3 COMPLIANCE EVALUATION

This section evaluates the compliance of the 2015 discharge with the six receiving-water permit limits listed in Table 3.7. The water-quality limitations are based on criteria in the COP (Table 3.1), the Central Coast Basin Plan, and other state and federal policies that were designed to protect marine life and beneficial uses of ocean waters. Because the limits only pertain to changes in water properties that are caused by the presence of wastewater constituents beyond the ZID, instrumental measurements undergo a series of screening procedures prior to numeric comparison with the NPDES permit thresholds.

The quantitative analyses described in this section focus on water-property excursions caused by the presence of wastewater constituents beyond the ZID, and whose amplitudes can be reliably discerned against the backdrop of ambient fluctuations. A detailed understanding of ambient seawater properties, and their natural variability within the region surrounding the outfall, is therefore, an integral part of the compliance evaluation presented in this section.

These analyses of data collected during 2015 demonstrate that the MBCSD discharge complied with the NPDES discharge permit, as has been the case for the prior quarter century of high-resolution monitoring. Moreover, although observations within the ZID are not subject to compliance evaluations, they often meet the prescribed limits because dilution levels exceed the conservative design specifications assumed in the NPDES discharge permit. Thus, the quantitative evaluation described in this section documents an outfall and treatment process that was continuing to perform at a high level during 2015.

3.3.1 Screening for Applicability

Evaluating whether any of the 40,567 receiving-water measurements collected during 2015 exceeds a permit limit is a complex process. For example, apparently significant excursions in an individual seawater property may be unrelated to the presence of wastewater constituents, and may instead be due to any number of confounding factors. These confounding factors include natural processes, statistical uncertainty, instrumental error, entrainment of ambient bottom waters within the rising effluent plume, ongoing initial mixing within and beyond the ZID, and other anthropogenic influences unrelated to the discharge, such as dredging discharges or oil spills.

Because of this complexity, prior to comparison with Basin-Plan numerical limits and COP objectives, measurements are sequentially screened to restrict attention to: 1) the oceanic area where permit provisions apply; 2) changes due to the presence of wastewater particulates; and 3) changes large enough to be reliably detected against the backdrop of natural variation (Table 3.9).

Measurement Location

The COP states that compliance with its receiving-water objectives "*shall be determined from samples collected at stations representative of the area within the waste field where initial dilution is completed*." Initial dilution includes the mixing that occurs from the turbulence associated with both the ejection jet, and the buoyant plume's subsequent rise through the water column. Although currents often transport the plume beyond the ZID before the initial dilution process is complete, the COP states that dilution estimates shall be based on "*the assumption that no currents, of sufficient strength to influence the initial dilution process, flow across the discharge structure*." Because of this, the regulatory mixing distance, which is equal to the 15.2-m water depth of the discharge, provides a conservative boundary to screen receiving-water data for subsequent compliance evaluation. Application of this initial screening question to the 2015 dataset eliminated 5,148 of the original receiving-water observations from further consideration because they were recorded within the ZID (Table 3.9, Question 1).

Table 3.9 Receiving-Water Measurements screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer No	Answer Yes[1]	*Parameter*
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	*5,148*	*35,419*	All
Wastewater Constituents	2. Did the beyond-ZID measurement coincide with a quantifiable salinity anomaly (≤550:1 dilution level) indicating the presence of detectable wastewater constituents?	*35,200*	*219*	All
Natural Variation	3. Did seawater properties associated with a quantifiable salinity anomaly depart significantly from the expected range in ambient seawater properties present at the time of the survey?	*219*	*0*	Temperature
		219	*0*	Transmissivity
		219	*0*	DO
		219	*0*	pH

Presence of Wastewater Constituents

The NPDES discharge permit also restricts application of the numerical receiving-water limits to excursions caused by the presence of wastewater constituents. This confines the compliance analysis to changes caused "*as the result of the discharge of waste*," as specified in the COP, rather than to anomalies that arise from the movement of ambient seawater that becomes entrained in the rising effluent plume. Analyses of high-quality data collected during quarterly receiving-water surveys over the past decade have demonstrated that the direct influence of dilute wastewater is almost never observed in any seawater property other than salinity, except very close (<1 m) to a diffuser port and within its ejection jet.

In fact, negative salinity anomalies are the only consistent indicator of the presence of wastewater constituents within receiving water. Wastewater salinity is negligible compared to that of the receiving seawater, so the presence of a distinct salinity minimum provides *de facto* evidence of the presence of wastewater constituents. Because of the large contrast between the nearly fresh wastewater and the salty receiving water, low salinity provides a powerful tracer of dilute wastewater that is unrivaled by other seawater properties. The contrast between effluent and seawater temperature, DO, pH, and transmissivity is much smaller, and as such, their wastewater signatures dissipate rapidly upon discharge with very little mixing. Wastewater's near lack of salinity, however, allows the presence of effluent constituents to be identified even after being diluted to levels substantially greater than the 133-fold critical initial dilution assumed in the NPDES discharge permit.

The association between negative salinity anomalies and wastewater constituents is so robust that the dilution achieved at a given point within the effluent plume can be determined directly from the amplitude of the salinity anomalies. By rearranging Equation 3.1, the dilution ratio (D) can be computed from the salinity anomaly ($A=C_o - C_s$) as follows:

$$D \equiv \frac{(C_e - C_o)}{(C_o - C_s)} \approx \frac{-C_o}{(C_o - C_s)} \propto A^{-1} \qquad \textbf{Equation 3.2}$$

[1] Number of remaining CTD observations of potential compliance interest based on this screening question

where:

D = the dilution ratio of the volume of seawater mixed with wastewater,
C_o = the salinity of the wastewater-seawater mixture after dilution by D,
C_s = the background seawater salinity, and
$A = C_o - C_s$ = the salinity anomaly.

The salinity concentration measured within MBCSD effluent (C_e) is small compared to that of both the receiving seawater (C_s) and, after dilution by more than 100-fold, the salinity of the effluent-seawater mixture (C_o). After dilution, C_o is nearly constant and close to that of ambient salinity (C_s). Consequently, its variation can be neglected in the equation and, to a close approximation; dilution levels are directly proportional to the inverse of the salinity anomaly itself (A). Thus, lower effluent dilution at a given location within receiving waters is directly reflected by a larger-amplitude salinity anomaly.

The smallest reduction in salinity that can be reliably detected within receiving waters is 0.062‰, which reflects a dilution level of at least 542-fold when substituted into Equation 3.2. This plume-detection threshold was determined from a statistical analysis of the naturally occurring variability in salinity readings measured near the outfall over a five-year period between 2004 and 2008. Thus, wastewater that has mixed with 542 parts of seawater no longer has a salinity signature that can be reliably discerned against the backdrop of natural variation. This dilution threshold was rounded up to 550-fold for added conservatism in the screening analysis (Table 3.9, Question 2).

The 550:1 plume-detection threshold is more than four-times higher than the 133:1 minimum initial dilution ascribed to the worst-case outfall performance, and upon which compliance with the Table B receiving-water objectives of the COP is ensured through specification of end-of-pipe limits on effluent contaminant concentrations in the NPDES discharge permit. Consequently, discernible salinity anomalies are more than capable of detecting out-of-compliance measurements within receiving waters, while measurements with anomaly amplitudes below the plume-detection threshold have wastewater concentrations far too dilute to be of compliance interest.

Application of this screening question to the 35,419 observations that were measured outside the ZID during 2015 surveys determined that only 219 measurements were associated with reductions in salinity that could potentially be related to the presence of dilute wastewater constituents (Table 3.9, Question 2).

Natural Variation

Another integral part of the compliance evaluation is determining whether a particular measurement differed from other observations at the same depth level because of naturally occurring variations in seawater properties at the time of the survey, or whether it was perceptibly altered by the presence of wastewater constituents (Table 3.9, Question 3). Thus, natural variability must be accurately quantified for each survey as part of the compliance evaluation.

The natural range in ambient seawater properties differs among surveys, largely because of differences in upwelling-induced vertical stratification. It is important to consider this vertical variation when evaluating whether a particular measurement extends beyond its natural range. Departures (anomalies) from background conditions are traditionally defined as the difference between a given measurement and the average of seawater properties measured at the same depth level, but at locations beyond the discharge's influence. However, when the water column is highly stratified, ambient seawater properties near the seafloor differ from those within the rest of the water column, and their juxtaposition within the rising effluent plume can appear as a lateral anomaly at mid-depth. These entrainment-generated anomalies

regularly appear within the rising effluent plume when the water column is strongly stratified by upwelling. However, the amplitudes of these entrainment-generated anomalies are unrelated to both the concentration of wastewater constituents within a given measurement, and the quality of the effluent that is being discharged at that particular time.

As described in Section 3.2.4, only significant departures in temperature, light transmittance, DO, and pH are relevant for evaluating compliance with receiving water limits. Thresholds for evaluating whether any of these measured properties extended beyond the natural conditions were determined for each receiving-water survey conducted during 2015 (Table 3.10). Excursions beyond the thresholds identify measurements that warrant comparison with the specific numeric thresholds identified in permit provisions (Table 3.7).

Table 3.10 Thresholds for Significant Departures from Natural Conditions

Water Property	January	June	July	October
Temperature (ºC)	>14.78	>14.73	>14.54	>17.80
Transmissivity (%)	<77.7	<67.5	<66.5	<79.5
DO (mg/L)	<6.39	<4.49	<4.14	<6.30
pH (minimum)	<8.049	<7.815	<7.820	<7.986
pH (maximum)	>8.242	>8.296	>8.203	>8.186

The thresholds of natural variation for each water property were established using a two-step process that is analogous to COP Appendix VI. First, one-sided 95% confidence bounds on transmissivity (-10.2%), temperature (+0.82°C), DO (-1.4 mg/L), and pH (± 0.94) were determined from an analysis of the same five-year database used to characterize within-survey salinity variation. These bounds quantify the spatial variability inherent in the ambient receiving waters surrounding the outfall at any given time. Second, the confidence bounds were combined with 95th percentiles determined from background seawater properties for each individual survey during 2015, thereby capturing seasonal differences among surveys, including the degree of vertical stratification. The percentiles were determined from vertical profiles excluding measurements potentially affected by the discharge. The resulting set of thresholds quantifies significant departures from natural conditions that prevailed at the time of each survey. Because the thresholds incorporate ambient vertical variability, many of the entrainment-generated anomalies artificially created by the upward movement of the plume during stratified conditions are excluded from further compliance consideration, and attention is focused only on potentially significant anomalies caused by the presence of wastewater constituents themselves.

Of the 219 measurements in 2015 that were potentially related to the presence of wastewater constituents beyond the ZID, however, none had a water property that extended outside the expected range in ambient seawater properties listed in Table 3.10.

3.3.2 Numerical Limits

The last four permit provisions (P3 through P6 in Table 3.7) provide numerical limits that identify unacceptable changes in receiving-water properties. These provisions are derived from three regulatory documents: the Central Coast Basin Plan, the COP, and by reference, the California Thermal Plan. In addition, Secchi depth measurements collected during the four quarterly surveys can be compared with the permit limit on the transmission of natural light (P4 in Table 3.7).

COP Objectives

The COP allows DO to be depressed 10% below "that which occurs naturally" due to the presence of oxygen-demanding material within effluent (COP §II.D.1; Permit Provision P5 in Table 3.7). Likewise, pH is allowed to extend 0.2 units beyond natural ranges (COP §II.D.2; Permit Provision P6 in Table 3.7).

Numerical permit limits are therefore determined by applying COP allowances to the thresholds of natural variability listed in Table 3.10. After applying these allowances, the permitted range in wastewater-induced excursions in pH and DO encompass a slightly broader range (*cf*., Table 3.11 and Table 3.10). However, because none of the 219 measurements that were left after applying the first two screening questions in Table 3.9 exceeded the natural variability thresholds, all of the measurements were also in compliance with the COP receiving-water objectives.

Table 3.11 COP Limits on Discharge-Related Changes to Seawater

Water Property	January	June	July	October
Temperature (ºC)	>14.78	>14.73	>14.54	>17.80
Transmissivity (%)*	<77.7	<67.5	<66.5	<79.5
*Applicable Depth (m)	All	0-8	0-9	All
DO (mg/L)	<5.75	<4.04	<3.73	<5.67
pH (minimum)	<7.849	<7.615	<7.620	<7.786
pH (maximum)	>8.442	>8.496	>8.403	>8.386

The COP objective limiting significant reductions in the transmission of natural light can be translated into a numerical permit limit. Because the COP does not specify an allowance beyond natural conditions, the permitted minimum transmissivities (Table 3.11) match the lower bound of the natural transmissivity range applicable to each survey (Table 3.10). However, the penetration of ambient sunlight is largely restricted to the euphotic zone, which extends to twice the Secchi depth. Thus, the limit on transmissivity reductions only applies within the depth range of the euphotic-zone listed after the asterisk in Table 3.11.

For example, a turbid benthic nepheloid layer (BNL) sometimes forms immediately above the seafloor during upwelling events. Such was the case during the July 2015 survey (MRS 2015e) when localized reductions in water clarity arose from naturally occurring surficial sediments and light flocs of detritus that were suspended within a 2-m thick BNL. When it occurs, the BNL is widespread, and is a natural phenomenon unrelated to the particulate discharge from the diffuser structure. Regardless, because the transmissivity decrease within the July-2015 BNL was located below 12 m, it had no effect on the transmission of natural light that only penetrated to a depth of 9 m at the time of the survey (Table 3.11).

In addition to determining the extent of the euphotic zone, Secchi depth measurements also provide independent statistical tests for assessment of potential impacts to the penetration of natural light (Table 3.12). However, the Secchi depth's measure of light transmission is far less precise than the instrumentally recorded transmissivities used in the screening analysis. Secchi depths are determined visually, by lowering a standard-sized disk into the water column, and noting the depth at which it disappears. Because of the somewhat subjective nature of the measurement, Secchi depths are generally only reported to the nearest 0.5 m. In addition, artificial differences in the reported depth among stations can be introduced, for example, from changes in ambient light arising from changes in cloud cover as the survey progresses, or from collecting measurements inside or outside of the survey vessel's shadow.

Table 3.12 Average Secchi Depths (m) measured near the Diffuser and at Distant Locations

Survey	Nearfield[1]	Reference
January	8.5	8.8
June	5.3	4.3
July	4.5	4.5
October	13.0	12.0

Nevertheless, as with the transmissivity measurements, no significant reduction in the transmission of natural light near the diffuser structure was found among the Secchi depth measurements. Although the 8.5-m average nearfield Secchi depth was slightly less than the 8.8-m reference-station average during the January survey (Table 3.12), the difference was far too small to be resolved given the inherent measurement error in the Secchi depth measurements. Specifically, a one-tailed two-sample t-test

[1] within 30 m of the diffuser structure

assuming unequal variances found no statistically significant reduction in the nearfield mean depths at the 95% confidence level (p>0.41).[1] Thus, the 0.3 m reduction in the January nearfield mean was too small to be of significance given the scatter in data and the overall ±0.5 m precision in the measurements.

Secchi depths were uniformly shallower during the June and July surveys when upwelling-induced increases in plankton density within the upper water column limited the euphotic zone to the upper water column. At these times, less-turbid seawater entrained in the rising effluent plume can actually result in a localized reduction in turbidity and the associated increase the penetration of ambient light results in deeper Secchi depths. During the June survey, for example, the two Secchi depths (5 and 6 m) measured immediately south of diffuser structure and along the path of plume transport were significantly deeper than the 4-m depths measured at other stations (p=0.009). In that case, the present of the less-turbid effluent plume near the sea surface actually improved the penetration of ambient light.

Finally, although the COP remains silent regarding thermal changes, it incorporates the California Thermal Plan (SWRCB 1972) requirements by reference (COP Introduction §C.3). The Thermal Plan limits temperature increases in coastal waters from new discharges to less than 2.2°C (4°F). At no time during any of the 2015 surveys was this threshold on temperature increases exceeded. In fact, maximum temperatures within the rising effluent plume were uniformly below that of the surrounding seawater because cooler seawater near the seafloor had been entrained in the plume shortly after discharge.

Basin Plan Limits

As demonstrated in the screening analysis (Table 3.9), excursions in water properties associated with presence of dilute wastewater constituents beyond the ZID did not extend beyond the expected range in ambient seawater properties. However, in contrast to the COP limits, which are benchmarked to "*that which occurs naturally*," and thus allow adaption to seasonal and interannual changes in the ambient marine environment surrounding the outfall, the Basin Plan contains fixed numerical limits restricting DO concentrations to no less than 5 mg/L (P5 in Table 3.7), and pH levels to a range of 7.0-to-8.3 pH units (P6). As such, the Basin Plan's inflexible DO and pH limits fail to account for natural oceanographic processes, like upwelling, that may result in excursions well beyond those limits.

Although none of the 2015 receiving-water observations ranged beyond the Basin Plan limits on pH, the highest pH of 8.206 approached the Plan's upper-bound limit. Regardless, the applicability of the fixed Basin Plan limits to ocean waters remains highly questionable. In fact, published range-acceptability criteria that are used to assess the validity of CTD data in this and other regional monitoring programs characterize seawater with DO as low 3 mg/L and with pH as high as 8.5 as being reasonable along the California mainland shelf.[2] Not surprisingly, pH and DO concentrations measured within ambient seawater near the MBCSD outfall occasionally range beyond the Basin-Plan limits.

For example, some or all of the measurements collected during the January and April 2010 surveys, the August 2011 survey, and the May 2013 survey exceeded the Basin Plan's upper bound pH threshold of 8.3 units (MRS 2011, MRS 2012, MRS 2013). Thus, perfunctory application of the Basin Plan's pH threshold could lead to the incorrect conclusion that the discharge had caused unacceptable increases in pH during these surveys.

[1] As defined in the acronym list at the beginning of this report, the "*p*-value" determines the significance of any perceived difference in mean Secchi depths by testing it against a null hypothesis of no difference in means. It quantifies the probability that a perceived difference in mean depths could have occurred by chance. When p<0.05, there is less than a 5% risk that the observed spatial gradient was happenstance due to random fluctuations.

[2] Table 3 in the field operations manual for the Southern California Bight Study (SCBFMC 2002)

As with pH, DO concentrations within ambient seawater surrounding the outfall also occasionally fall outside the boundaries considered acceptable by the Basin Plan. Such was the case during the June 2014 survey when 266 observations ranged below the minimum Basin Plan limit of 5 mg/l (MRS 2015a). As with the pH measurements, these DO observations were well within the range considered typical of ambient waters at the time of that survey, and therefore complied with the COP portion of the NPDES permit provisions. The low DO concentrations arose because the deep watermass that was transported shoreward and into the survey area by upwelling was naturally depleted in oxygen. DO concentrations below 5 mg/L have been observed in a number of past water-quality surveys in conjunction with prolonged upwelling events (MRS 2011, 2012, 2013, and 2014). On a statistical basis, natural variability in DO concentrations during both the June and July 2015 surveys could be expected to range below the Basin Plan limit (Table 3.10).

Clearly, DO and pH variations beyond their respective fixed limits were simply not envisioned for coastal ocean waters when the Basin Plan was promulgated in 1972. The fixed Basin Plan limits were largely designed for discharges to onshore surface waters (e.g. streams and lakes), where little natural variation in pH and DO is expected. In contrast to the Basin Plan limits, the COP recognizes the potential for inherent variation in the receiving-water characteristics, and specifies limits on excursions in these two water properties relative to background levels present at the time of the survey. Because the COP receiving-water objectives are designed to be adequately protective of the marine environment, application of the fixed Basin Plan limits to the same receiving-water characteristics already covered by the COP is not only redundant but also inappropriate. For these reasons, this annual report as well as past monitoring reports (MRS 2011, 2012, 2013, 2014, and 2015a) have recommended removal of the Basin Plan limits from future MBCSD discharge permits (see the recommendation in Section 5.4).

The Basin Plan also limits temperature excursions to those that will not adversely affect beneficial uses (P3 in Table 3.7). As documented in Table 3.9, however, the presence of dilute wastewater particulates beyond the ZID exerted no perceptible thermal influence during 2015 and thus, could not have affected any of the beneficial uses designated for the receiving waters surrounding the outfall.

3.3.3 Other Lines of Evidence

The screening analysis described in Section 3.3.1 serves to restrict attention to the oceanic area where the permit provisions apply, and to eliminate excursions that were either unrelated to the discharge, or too small to be of consequence given the natural variability in the receiving waters. As a result, all of the 2015 observations were eliminated from further compliance analysis. However, within the eliminated measurements lies a body of additional evidence that further substantiates the finding that the receiving-water measurements recorded during the 2015 surveys complied with the limitations specified in the NPDES discharge permit. Three of these major other lines of evidence are described below: the high mixing performance of the outfall, the low discharge volume, and the high quality of the effluent that was discharged.

Abductive inference (Suter 2007) is a process for analyzing these varied lines of evidence. It emphasizes a pattern of reasoning which accounts for both the discrepancies among multiple lines of evidence as well as concurrences. It has been used to implement sediment-quality guidelines for California estuaries (SWRCB 2009). Application of this "*best explanation*" approach to the water quality dataset serves to limit the uncertainty associated with each individual CTD measurement and provide a more robust compliance assessment. Together, these lines of evidence significantly strengthen the conclusion that the discharge fully complied with the NPDES permit during 2015. In particular, it supports the finding that dilute wastewater constituents had no tangible effect on the ocean environment surrounding the outfall.

Mixing Performance

The high-spatial-resolution tow measurements recorded during 2015 demonstrated that even well within the ZID, wastewater was being diluted to levels far higher than expected from the dilution modeling. Although compliance screening eliminates observations within the ZID because the permit limits do not apply there, these close-in observations foretell whether the outfall is capable of routinely meeting the 133-fold dilution necessary to achieve COP objectives that apply after completion of the initial dilution process.

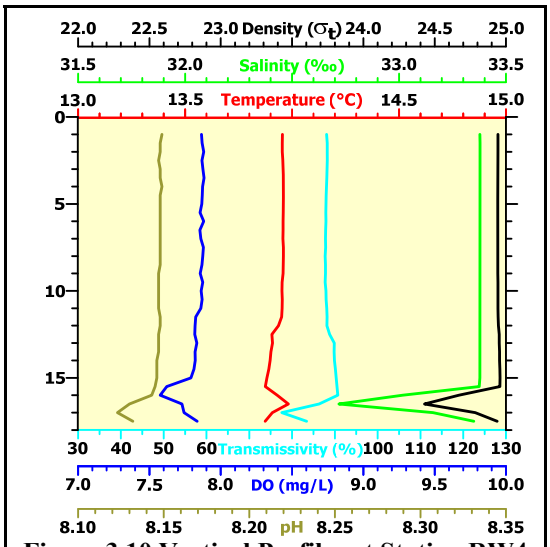

Figure 3.10 Vertical Profiles at Station RW4 during the January 2015 Survey

CTD data collected near the end of the downcast at Station RW4 during the January survey provided unusual insight into the dilution process almost immediately after discharge (Figure 3.10). As the CTD approached the seafloor, it passed within 22 cm of a diffuser port where it encountered its wastewater ejection jet. At that point, a dilution of only 48-fold was measured, which is by far, the lowest ever recorded in the history of the monitoring program.

The extremely low salinity (32.72‰) measured 1 m above the seafloor (green line in Figure 3.10) was 0.66‰ below seawater salinity. Equation 3.2 shows that this large salinity reduction was generated by wastewater that had mixed with 48 parts of seawater at the measurement location. Even at this very early stage of the initial dilution process, the turbulent ejection jet had achieved one-third of the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater prior to discharge. The measurement was located 1m above the seafloor both because the buoyant jet rapidly carries the plume upward in the water column shortly after discharge, and because the diffuser ports themselves are slightly elevated above the seabed. At that point in the mixing process, the wastewater plume was highly buoyant, as documented by its very low density (black line in Figure 3.10), and would continue to rapidly disperse as it continued to rise in the water column.

By the time the plume had traversed half the water column; wastewater had been diluted 228-fold (red shading in Figure 3.11). The initial-dilution process was still incomplete at that point; yet dilution was 70% higher than the critical initial dilution determined from conservative modeling. Moreover, the high dilution was measured 2.4 m deeper than the 6.4-m trapping depth identified in the modeling. As the buoyant plume reached the 2.7-m depth of the January shallow tow, measured dilutions exceeded 485-fold and were 3.6-times higher than those predicted by the modeling. With these high observed dilutions, the COP receiving-water objectives were being easily achieved by the limits on chemical concentrations that are promulgated by the NPDES discharge permit issued to the MBCSD.

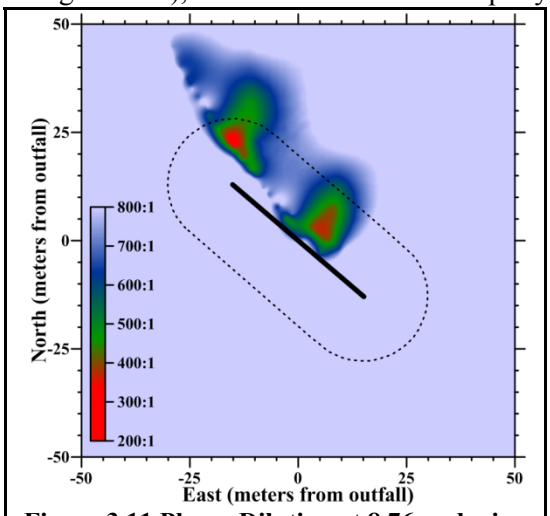

Figure 3.11 Plume Dilution at 8.76 m during the January 2015 Survey

Limited Discharge Volume

In addition to high dilution, the small volume of wastewater discharge explains why wastewater constituents within the discharge plume generally do not exhibit a perceptible influence on seawater properties, even shortly after discharge. As such, the limited discharge volume provides another line of evidence supporting the conclusion that the MBCSD discharge complied with permit limits designed to protect receiving water quality. The unusual January measurements shown in Figure 3.10 indicate that the influence of wastewater constituents begins to disappear at a dilution close to 48-fold, and at a distance of less than 0.5 m from each diffuser port. The small excursions in temperature, DO, pH, and transmissivity captured near 16.5 m in Figure 3.10 provide a rare glimpse of the presence of dilute wastewater constituents within receiving waters. Differences in these seawater properties that are occasionally observed within the discharge plume are normally generated by the upward transport of ambient seawater entrained near the seafloor. When the water column is stratified, these plume anomalies arise from the juxtaposition of shallow and deep ambient seawater.

However, the January anomalies shown in Figure 3.10 were unusual in that they were produced by the wastewater itself. For example, the slightly higher 0.11ºC temperature perturbation (red line) is consistent with warmer wastewater. Normally, thermal anomalies within the plume appear as decreases in temperature due to the upward transport of cooler seawater entrained near the seafloor. Similarly, on the day of the survey, the wastewater pH, at 7.4, was much lower than that of the receiving seawater (8.15), and resulted in a localized 0.022 reduction in pH shortly after discharge (gold line). Likewise, oxygen-demanding material within wastewater caused a temporary and localized 0.24 mg/L DO decrease (dark blue line). Although these excursions are readily apparent in Figure 3.10 against the backdrop of the vertically uniform water column that was present during the January survey, their amplitudes were small, chiefly because the volume of wastewater emanating from each diffuser port was minute compared to the volume of seawater entrained within the discharge jet. In fact, these excursions did not even approach the thresholds for significant departures from natural conditions (Refer to the "*January*" column in Table 3.10).[1]

The decrease in transmissivity was the one exception that ranged beyond the natural variability threshold for the January survey. At 17 m, the presence of dilute wastewater particulates caused transmissivity to decline to 77.6% (light blue line in Figure 3.10). This was only slightly below the 77.7% threshold in Table 3.10 and did not constitute an exception to permitted limits because it was measured within the ZID. Nevertheless, this observation of a perceptible wastewater-induced departure from natural conditions was highly unusual.[2] Of the 40,567 measurements collected in 2015, it was the only significant excursion beyond natural conditions. In fact, the last instance of a significant excursion was in October 2012, when a marginally significant transmissivity decrease was observed when the CTD again passed very close to a diffuser port.

Effluent Quality

Another independent line of evidence demonstrates why wastewater discharge does not normally contribute materially to turbidity within the dilute effluent plume; or to excursions in DO, pH, and temperature. Specifically, the high treatment level achieved by the MBCSD WWTP results in the removal

[1] In Figure 3.10, the maximum temperature of 13.9825ºC did not exceed the 14.78ºC threshold in Table 3.10; the minimum pH of 8.123 remained well above the lower bound 8.049 pH threshold; and the minimum DO of 7.57587 mg/L did not even approach the 6.39-mg/L DO threshold for natural seawater variations.

[2] As discussed previously, salinity is the only seawater property within the discharge plume that regularly ranges significantly below ambient seawater salinity.

of nearly all (91.5%) of the suspended solids and oxygen-demanding material (86.5%) from the wastestream prior to discharge (Table 2.2). The small residual amount of remaining material is then easily dispersed by the high-efficiency diffuser structure that discharges into the particularly well-flushed, open-ocean environment within Estero Bay.

For example, discharge of low concentrations of oxygen-demanding material, results in only small, transient, and highly localized DO reductions, such as those captured in Figure 3.10. In fact, when DO within ambient seawater at depth is naturally depleted during periods of strong stratification; dilute wastewater can result in a localized increase in DO concentration within the plume. This is because effluent is oxygenated by recent contact with the atmosphere during the treatment process, whereas receiving waters at depth are typically depleted in DO during periods of pronounced upwelling.

Furthermore, at typical effluent BOD concentrations near 50 mg/L, organic-decay modeling demonstrates that the DO demand within the MBCSD effluent immediately upon discharge would be less than 3 mg/L (Page II-8 of MRS 2003a). After mixing to the 133-fold critical initial dilution level, the dilute BOD loading would induce a minuscule DO depression of no more than 0.022 mg/L. Because similar levels of DO depression are typical of most ocean dischargers, the National Academy of Sciences (Page 9; 1993) determined that DO depletion from the discharge of municipal effluent is "*not of ecological concern in the ocean or open coastal waters*," and when it is of concern, such as in estuaries, it is "*more likely to result from eutrophication by nutrients rather than point source inputs of BOD*" (Page 9 of 1993).

The potential for water-quality impacts from the MBCSD solids discharge can be predicted in a similar manner. For example, the perceptible transmissivity decrease caused by dilute wastewater particulates discussed above can be confirmed using measured dilutions and the effluent TSS concentration measured onshore at the time of the January survey. The suspended-solids concentration measured onshore, within at the WWTP prior to discharge on 7 January 2015 was only 31.6 mg/L. Measurements within the ejection jet at Station RW4 demonstrate that the effluent had been diluted by only 48-fold. At this low dilution, the effluent particulate loads would have reduced ambient transmissivity by at least 5%, which is comparable to the decrease documented in Figure 3.10. The plume had been diluted by 228-fold by the time it had risen to mid-depth, where the predicted transmissivity reduction would be 1%, which is also comparable to the decrease observed during the mid-depth tow. After approaching the completion of the initial dilution process however, when effluent had achieved dilutions exceeding 485-fold, the 0.5% expected transmissivity reduction due to the presence of wastewater particulates was negligible compared to 4.7% natural fluctuation in ambient transmissivity (see the "*January*" column in Table 3.13).

Table 3.13 Comparison between Projected Transmissivity Reductions caused by Wastewater Particulates and the Lower Bound of Background Seawater Fluctuations

Parameter	January	June	July	October
Initial Dilution	485	379	513	550
Effluent TSS (mg/L)	31.6	32.0	33.8	28.0
Transmissivity (%)				
Projected Reduction	0.5	0.6	0.4	0.5
Natural Range[1]	4.7	10.4	13.3	8.6

[1] Observed difference between the most extreme transmissivity measurements collected beyond the influence of the discharge

After completion of initial dilution, predicted water-quality impacts from wastewater particulate loads were similarly small for the other three surveys in 2015 (Table 3.13). Effluent TSS concentrations prior to discharge were similar among the surveys, and ranged from 28.0 mg/L to 33.8 mg/L. Because of strong stratification at the time of June survey, a slightly reduced, 379-fold dilution was found at the completion of the initial dilution process, when the plume became trapped 4-m below the sea surface. Even with this lower dilution, however, the projected 0.6% reduction in transmissivity due to the presence of wastewater particulates was comparable to that of other surveys. All of the projected reductions were small compared to the range in ambient transmissivity values measured beyond the plume's influence.

These comparisons demonstrate that the low concentrations of suspended-solids and oxygen-demanding materials within the wastewater treated by the WWTP have negligible influence on the receiving seawater after dilution.

3.3.4 Visual Observations

Two remaining permit provisions (P1 and P2 in Table 3.7) are not addressed by the foregoing analysis of instrumental observations. These provisions assess whether floating particulates, oil and grease, or any aesthetically undesirable discoloration of the ocean surface was present during the receiving-water surveys conducted in 2015. These permit provisions are instead addressed by visual observations made during each of the surveys. The visual observations collected during 2015 found no evidence of these discharge-related impacts to the ocean surface.

3.4 BENEFICIAL USE

Additional visual observations compiled from the 2015 receiving-water surveys demonstrated that the coastal waters near the outfall and along adjacent shoreline continued to be beneficially used by humans and wildlife. There was no evidence indicating that the discharge detracted from the beneficial uses that were identified for northern Estero Bay in the Basin Plan (see Section 2.1.2). Specifically, fish, marine mammals, and seabirds were observed utilizing the area within and around the ZID area as marine habitat (*viz.,* the *MAR* beneficial-use identified for the waters of Estero Bay in the Central-Coast Basin Plan, as outlined in Section 2.1.2). The presence of pedestrians, equestrians, sailboats, and commercial and recreational fishing boats attested to the use of the waters for water recreation (*REC-1* and *REC-2*), transportation (*NAV*), and fishing (*COMM*).

CHAPTER 4

Marine Sediments and Benthic Biota

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4.0 MARINE SEDIMENTS AND BENTHIC BIOTA

This chapter describes the coastal benthos within Estero Bay where the MBCSD effluent is discharged. The MBCSD Offshore Monitoring Program includes benthic observations to assess potential impacts of wastewater discharge on marine sediments and the infaunal community near the outfall. Benthic environments are important indicators of the presence of marine pollution because they are the major reservoir for most contaminants that enter the ocean. Deleterious changes in the benthic environment, resulting from the deposition of effluent particulates, have been observed around other coastal outfalls (e.g., Stull et al. 1986a); however, no such impacts have been found after three decades of benthic monitoring around the MBCSD outfall. This includes the October 2015 survey described in this chapter.

In the marine ecosystem, organic and inorganic matter are dynamically interrelated, and the quality of the material deposited on the seafloor directly affects the health of infaunal communities. Therefore, both the physicochemical and biological properties of the benthos are described in this chapter. Infauna residing within sedimentary environments serve as indicators of contaminated sediments because of their limited mobility and well-defined responses to pollution. Numbers of species, abundance, biomass, and other parameters of community composition can indicate contaminant-caused stresses if, for example, gradients are observed extending from a pollutant source to more distant, unaffected areas.

This chapter presents the full results of the benthic survey conducted on 26 October 2015. Physical properties of sediments are tabulated in Appendix C and laboratory chemistry results from the survey are provided in Appendix E of this report, while benthic biological data are provided in Appendix B. BC Laboratories conducted the relevant chemical analyses following methods described by Tetra Tech (1986ab). Marine Research Specialists performed the infaunal community analyses and data synthesis.

The following section describes the benthic-monitoring program, including collection methods and station design. The second section of this chapter presents the findings related to the physicochemical analysis of the sediments. The third section describes the health of the benthic infaunal community residing within Estero Bay during 2015.

4.1 MONITORING PROGRAM

As with the marine receiving-water monitoring described in Chapter 3, sediment samples were collected at reference and outfall stations to investigate any potential discharge-related impacts to the benthos. The samples were analyzed for physicochemical properties and infaunal community composition in order to compare the benthic environment at these two sets of stations, as well as at gradient stations in between.

4.1.1 Scope of Monitoring

On 26 October 2015, offshore sediment samples were collected at seven stations within Estero Bay (Figure 4.1). The field sampling and laboratory procedures adhered to the requirements of the Monitoring and Reporting Program described in the discharge permit (RWQCB-USEPA 2009). During the three decades of offshore monitoring, the benthic-monitoring program has undergone a number of major modifications. The original permit, issued in 1985, required semiannual sediment collection at six stations with physicochemical analysis of a composite of three replicate grab samples collected at each station. The stations were distributed around the outfall along a north-south isobath. Five of these original stations have continued to be sampled throughout the monitoring program. The sixth station, a "*reference*" station, located 1 km to the south, was dropped when the permit was reissued in 1993 because it was found to be unrepresentative of the benthic environment near the outfall.

Figure 4.1 Benthic Sampling Stations

The discharge permit that was reissued in 1993 (RWQCB-USEPA 1993ab) also changed laboratory protocols. It required separate chemical analysis of each of the replicate samples collected at the five Stations. Statistical analysis of the scatter in chemical concentrations for the replicate samples at each individual station quantified the within-station variability and quantified the power of the monitoring program to detect spatial differences among stations. In particular, this report uses the replicate chemical analyses conducted in 1993 and 1994 to establish confidence intervals around concentrations measured at each station. If the observed differences in chemical concentrations among stations are less than the inherent uncertainty in the concentration at a given station, as defined by variability in replicate samples, then the spatial differences between stations cannot be considered statistically meaningful. In 1995, after the within-station variability had been quantified, chemical analysis reverted to a composite protocol where aliquots from each of the three replicates collected from a station were homogenized into a single composite sample in the laboratory before extraction.

Further modifications were implemented when the NPDES permit was reissued in 1998 (RWQCB-EPA 1998ab). After 13 years of monitoring, the amplitude of seasonal fluctuations had been adequately determined, eliminating the need for a post-winter survey. As a result, the focus of monitoring shifted to the determination of interannual changes in spatial patterns. To that end, four additional benthic sampling

stations, located 60 m from the outfall, were added to the five historical stations. The cross-shore configuration of two of these new stations (Stations 8 and 9) provided a more spatially balanced sampling pattern capable of detecting potential impacts that might not be restricted to along-shore directions. Finally, chemical analyses were performed on a single grab sample collected at each of the nine stations.

Based on an analysis of the previous 23 years of benthic data, the current permit (RWQCB-EPA 2009), adopted in January 2009, also instituted several changes to the program. First, chemical analysis protocols reverted to those utilized prior to 1998, where aliquots from each of three replicates collected at a station are homogenized into a single composite sample prior to analysis. This reduces uncertainty in the reported station concentrations by reducing within-station variability. Second, the permit eliminated the analyses of sulfides within benthic porewater samples. High-resolution analyses conducted over the previous six years had definitively demonstrated that the Estero Bay sediments do not contain measureable levels of dissolved sulfides. Finally, the cross-shore benthic monitoring stations (Stations 8 and 9) were eliminated from the sampling pattern because the inherent differences in the benthic environments caused by their difference in water depth confounded the interpretation of trends at the remaining stations.

The current permit also eliminated the sampling requirement at the northern reference station (Station B1); because of its physical separation (1 km) from the outfall, the reference station has a measurably different infaunal community composition (MRS 1998bi) and sediment physicochemistry from the remaining stations. However, as one of the six original sampling stations in the program, the long record of grain size, infaunal, and metal-concentration data acquired at Station B1 has immeasurable value for the insight it provides into the larger scale processes working within Estero Bay as a whole. Therefore, sampling for these parameters at Station B1 has been continued through 2015.

4.1.2 Sampling Station Design

Benthic sampling in 2015 was conducted at the seven stations shown in Figure 4.1 on Page 4-2 and in Figure 4.2 on Page 4-6. The target positions for sample collection are specified in the current NPDES permit and are summarized in Table 4.1. The stations lie along a north-south isobath (15.2 m) that intersects the center of the diffuser structure. Two stations (B4 and B5) are located within 20 m of the center of the diffuser structure, at the edge of the "zone of initial dilution" (ZID). The locations of these two stations coincide with those of the receiving-water Stations RW3 and RW4 (Figure 3.2). Two additional stations (B3 and B6) are located at nearfield distances (60 m) from the diffuser structure and coincide with Stations RW2 and RW5. Finally, the midfield stations (B2 and B7) are separated by three diffuser lengths from the discharge (150 m). The seventh, reference station (B1) is located 1 km north of the outfall, well beyond the discharge's sphere of influence.

Table 4.1 Target Locations of Benthic-Sediment Sampling Stations

				Distance (m)	
Station	**Description**	**Latitude**	**Longitude**	**Closest**[1]	**Center**[2]
B1	Upcoast Reference	35° 23.730' N	120° 52.677' W	1,000	1,016
B2	Upcoast Midfield	35° 23.280' N	120° 52.504' W	138	150
B3	Upcoast Nearfield	35° 23.231' N	120° 52.504' W	49	60
B4	Upcoast ZID	35° 23.210' N	120° 52.504' W	15	20
B5	Downcoast ZID	35° 23.188' N	120° 52.504' W	15	20
B6	Downcoast Nearfield	35° 23.167' N	120° 52.504' W	49	60
B7	Downcoast Midfield	35° 23.118' N	120° 52.504' W	138	150

[1] Distance from the closest open diffuser port
[2] Distance to the center of the open diffuser section

As described in Section 3.1.3, the finite length of the diffuser structure creates ambiguity in the distance measured from the outfall. For discussion purposes, station separations are usually referenced to the center of the diffuser. However, in terms of contaminant dispersion, the closest-approach distance is the controlling parameter.

The upcoast reference station (B1), midfield stations (B2 and B7), and ZID stations (B4 and B5) have all been regularly sampled throughout the 30 years of benthic monitoring. The two nearfield stations (B3 and B6) were incorporated into the program in 1999, and improved the program's ability to resolve potential benthic impacts related to effluent discharge. Although sampling is no longer required at Station B1 under the current permit, samples were voluntarily collected at the station and analyzed for grain size, infaunal composition, and trace-metal concentrations.

The extraordinarily long record of infauna, grain size, and trace metals has provided valuable insights into previously unknown trends in Estero Bay's regional benthic conditions. Therefore, although these trends are unrelated to the MBCSD discharge, the lengthy time history at Station B1 was deemed of enough scientific value to warrant continued sampling there. However, although required for compliance evaluation at the other stations, sediment oil and grease concentrations have not been found to be diagnostic of the seafloor environment, or the effects of the MBCSD discharge, so the voluntary sampling at Station B1 did not include these constituents.

4.1.3 Benthic Sample Collection and Processing

Field sampling and laboratory procedures adhered to the requirements of MBCSD Monitoring and Reporting specified in the permit (RWQCB-USEPA 2009). The 38-ft F/V *Bonnie Marietta*, owned and operated by Mark M. Tognazzini of Morro Bay, provided vessel support during the offshore survey. Dr. Douglas Coats of Marine Research Specialists (MRS) logged navigation fixes, and collected sediment subsamples for chemical assay. Cletis England, a biologist with MRS, sieved and processed infaunal samples. Dean Dusette, also of MRS assisted in benthic grab deployment and retrieval, in conjunction with Vessel Crewmember Marc Tognazzini. William Skok was the marine-equipment technician responsible for deck operations.

Equipment

Sediment chemistry and benthic infaunal samples were collected using a chain-rigged Young grab whose design was modified from that of a Van Veen sediment sampler. The pair of jaws on the grab acquires sediments from a 0.1-m^2 area of the seafloor. The stainless-steel grab is coated with Dykor® and is equipped with a frame that enhances its penetration, stability, and proficiency in collecting a level, undisturbed sample. Dykor® has properties similar to Teflon®; it improves the chemical inertness of the grab sampler, limiting contamination of the sediment chemistry samples by the grab itself, particularly from trace metals. The grab was completely refurbished by sandblasting and recoating with Dykor® in 1999. At that time, a stainless steel lip was also welded to the mouth of the jaw to improve the seal, which aids in sample retention during ascent.

At each of the seven monitoring stations, three replicate grab samples were collected and composited for analyses of sediment chemical composition and bulk properties, and five replicate grab samples were collected for benthic infaunal analyses (Table C.1).

Offshore navigation aboard the survey vessel was supplied by a Furuno™ GPS 30 coupled to an FBX2 differential beacon receiver. Global positioning satellite (GPS) navigational fixes were recorded digitally at 1-second intervals. Electronic recordings of waypoints were used to mark the seafloor trip-time of the grab sampler and other pertinent information. Navigational errors inherent in standard GPS readings were

greatly reduced with the use of a Differential GPS (DGPS) system that was first implemented by the U.S. Coast Guard. DGPS incorporates a second signal from a nearby land-based beacon. Because the beacon is fixed at a known location, the position error in the reading from the GPS satellites can be precisely calculated. This correction is continuously transmitted to the DGPS receiver and results in extremely accurate offshore navigation, typically with position errors of less than 2 m.

Physicochemical Samples

Prior to and during the survey, the sampling equipment was thoroughly cleaned to eliminate the introduction of non-sediment contaminants into the samples, and to prevent cross-contamination between stations. Before the survey, the grab sampler and sediment scoops were washed with Alconox®, deionized water, and 10% Hydrochloric Acid (HCl). During the survey, the grab and sampling utensils were washed with Alconox®, rinsed with seawater, and subsequently decontaminated with deionized water, methanol, and 1% HCl prior to sampling at each station.

Surficial sediments were collected from the upper 2 cm of the single grab sample recovered from the seafloor at each of the seven benthic stations. Sufficient sample volumes were collected to provide material for QA/QC analyses. Samples were stored in the appropriate glass or plastic containers and refrigerated at approximately 4°C prior to analysis. Chain of custody forms accompanied all sample shipments from the field and between laboratories. Appendix E[1] contains the chains of custody, laboratory QA/QC analysis, and the chemical results as reported by the laboratory, while Appendix C includes a physical description of the samples.

The sediments from each of the seven benthic-monitoring stations were separately analyzed for the analytes listed in Table 4.2. A summary of the analytical methods used and their authority is provided in Appendix E.

Table 4.2. List of Analytes in Sediment Samples

• Sediment particle size	• Biochemical oxygen demand	• Total Kjeldahl nitrogen (TKN)
• Moisture content	• Oil and grease[2]	• Total volatile solids (TVS)
• 11 trace metals		

Infaunal Samples

In addition to samples collected for sediment chemistry, five replicate grab samples were collected at each of seven benthic-monitoring stations for infaunal analyses. Upon retrieval of the grab, each sample was inspected for acceptability. Acceptance criteria are based on penetration depth, surface condition, and overall sample integrity and are reported in Table C.1 in Appendix C of this report. Sediment samples that met the acceptability criteria were lightly washed, and elutriated onto a 1.0-mm mesh sieve. The extracted material was then washed into a labeled 16-oz. jar and preserved with 10% buffered formalin. After a minimum fixation period of 48 hours, the formalin was rinsed from the samples on a 0.5-mm mesh sieve and the samples were transferred to 70% alcohol for processing, preservation, and storage. After transfer to alcohol, the infaunal samples were stained with a Rose Bengal solution to aid in sorting of the organisms into the following major taxonomic groups: annelida and nemertea, mollusca, crustacea, echinodermata, and miscellaneous phyla.

All individual organisms were enumerated and identified to species level where possible. Voucher collections have aided in the consistent identification of organisms collected throughout the 30-year

[1] Note that the chemistry results reported by the laboratory in Appendix E for Stations B6 and B7 were reversed due to a labeling error in the field. Results reported elsewhere in this document have been corrected for this error.
[2] As discussed previously, the sediments from the voluntary sampling conducted at B1 were not analyzed for oil and grease.

benthic-monitoring program. The voucher collections contain specimens representative of each species identified, and are augmented as new taxa are collected. The qualifications and experience of the taxonomic specialists responsible for species identification are presented at the end of Appendix B.

Sampling Location Offsets

Figure 4.2 shows the position of the chemistry (blue) and infaunal (green) grabs, relative to each target location (red) that were recorded during the October survey. As described in Chapter 3, a number of factors influence the offset of the actual grab locations from the target locations listed in Table 4.1. Because the vessel is anchored during sediment grab sampling, differences between the sampling and target positions arise because the vessel swings about the anchor location along a scope of approximately 20 m. How the vessel will set relative to its anchor position is difficult to predict based on the constantly changing wind, wave, and current conditions. Changes in position during sampling at an individual station arise because of these changing conditions, in addition to movement from anchor drag. The within-station position changes during the October 2015 survey are apparent in Figure 4.2 by the spatial dispersion among the three sediment-chemistry grab samples and five infaunal grab samples collected at each station.

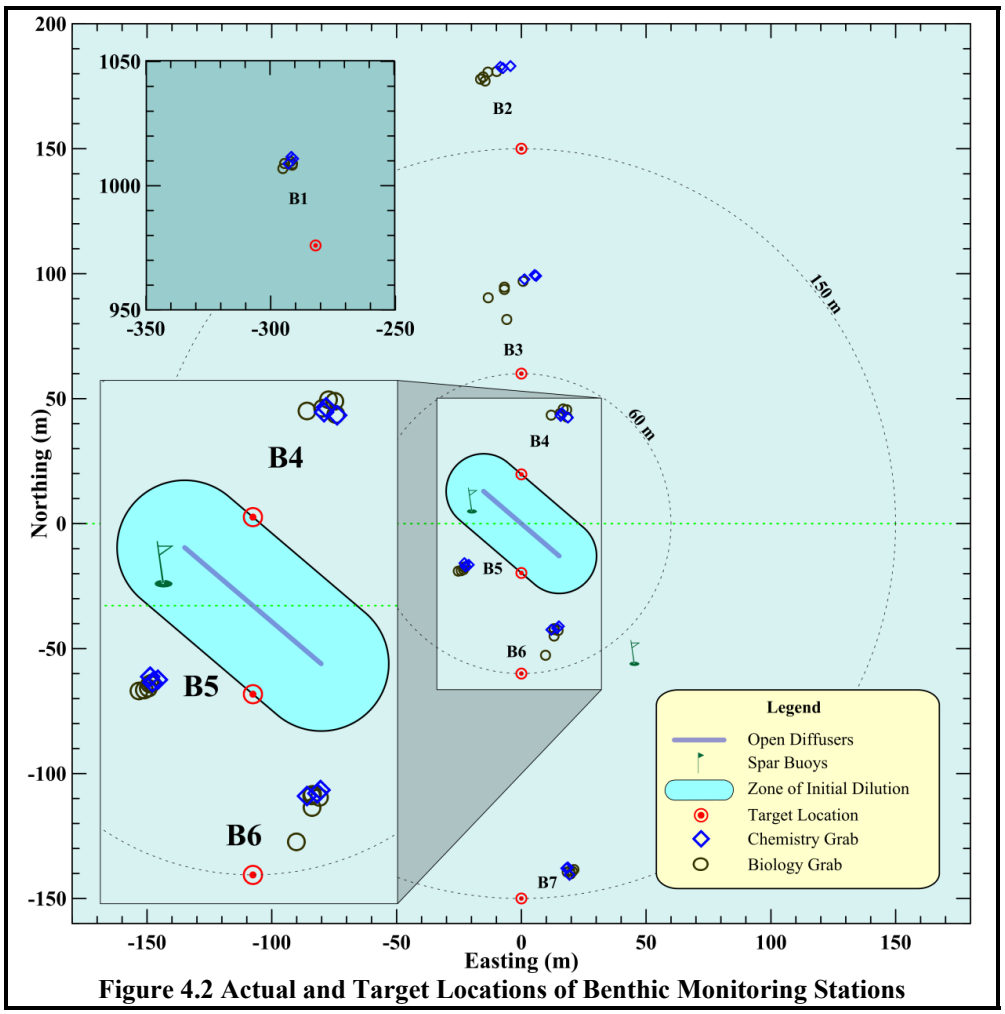

Figure 4.2 Actual and Target Locations of Benthic Monitoring Stations

Table 4.3 lists the average position of the eight grabs collected at each station. Although it is not possible to collect samples at the precise target locations, knowledge of the actual location where samples were collected allows the spatial offsets to be factored into the gradient analysis. For example, the samples collected at the Upcoast ZID Station were 13 m farther from diffuser structure than the Downcoast Nearfield Station locations, even though the ZID-station target locations are 14-m closer (Table 4.1). Thus, in the gradient analyses presented in this chapter, Station B6 is listed before Station B4, which departs from the normal distance ranking found in most surveys. Without the benefit of differential GPS navigation, this and most other spatial offsets would never have been resolved. The enhanced resolution provided by differential GPS even lends insight into minute spatial differences between individual grab samples that would not have been resolved otherwise.

Table 4.3 Average Location of Benthic-Sediment Grab Samples at each Station

				Distance (m)		
Station	**Description**	**Latitude**	**Longitude**	**Closest**[1]	**Center**[2]	**Offset**[3]
B1	Upcoast Reference	35° 23.736' N	120° 52.692' W	1034	1051	35
B2	Upcoast Midfield	35° 23.288' N	120° 52.496' W	168	181	32
B3	Upcoast Nearfield	35° 23.233' N	120° 52.489' W	82	94	34
B4	Upcoast ZID	35° 23.214' N	120° 52.492' W	44	47	29
B5	Downcoast ZID	35° 23.177' N	120° 52.497' W	28	29	23
B6	Downcoast Nearfield	35° 23.168' N	120° 52.484' W	31	46	21
B7	Downcoast Midfield	35° 23.118' N	120° 52.479' W	126	140	22

Because of the many unavoidable factors affecting vessel offset, differences between the target position and average grab location were comparable to the 30-m width of the ZID at the two ZID stations (B4 and B5). Vessel positioning at the ZID stations is complicated by the potential for diffuser damage from the anchor and chain. For example, the vessel was setting 30 m northeast of its anchor location at the time Upcoast ZID Station (B4) was sampled (See the inset in Figure 4.2). Collecting grab samples at the target location would have required deploying the anchor 30 m to the southwest of the target location, and on the opposite side of the diffuser structure. As a result, the anchor chain would have laid across the structure, potentially causing damage to the structure, the anchoring tackle, or both. Because samples collected at Downcoast Nearfield Station (B6) had a similar offset from the anchor location, their average location was actually closer to the diffuser structure than the samples collected at Station B4.

Slightly larger offsets occurred at several of the more distant stations to the north, including the Reference Station B1, where fidelity to the target locations is less important. Of particular note, wind speeds increased and shifted direction over the course of the survey, making the prediction of vessel offset relative to anchoring location difficult as the sampling progressed from north to south.[4] Because of this, offsets relative to target locations differed at the three northernmost stations (Table 4.3, Figure 4.2).

4.1.4 Benthic Analysis

A wide variety of physical, chemical, and biological parameters was determined from the 56 sediment samples collected during the October 2015 survey. This report examines these parameters for any potential discharge-related spatial patterns. They are also compared to historical measurements to reveal

[1] Distance from the closest open diffuser port
[2] Distance to the center of the open diffuser section
[3] Average offset from Target Locations listed in Table 4.1
[4] Grab trip times are listed in Table C.1 of Appendix C.

any potential temporal trends that could be associated with a buildup of contaminants. Finally, the interrelation between biological and physicochemical parameters is evaluated for possible toxicological effects.

Organic-Loading Properties

Sediment samples collected at the seven benthic-monitoring stations during the October 2015 survey were analyzed for moisture content, grain size, organic properties, and eleven trace metals. The organic-loading parameters, oil and grease (O&G), total volatile solids (TVS), total Kjeldahl nitrogen (TKN), and biochemical oxygen demand (BOD), are considered relevant for sewage-outfall monitoring. If the volume of organic solids discharged by the outfall is not adequately dispersed, then a buildup of O&G, TVS, TKN, and BOD can occur, and can impact areas beyond the ZID.

BOD measures the depletion of dissolved oxygen caused by aerobic microorganisms during decomposition of organic material. Excessive BOD can be deleterious to marine organisms if decomposition significantly depletes dissolved oxygen levels. This can occur when aerobes metabolize excess organic matter deposited by wastewater discharge.

The TVS concentration quantifies the amount of organic matter in the solid fraction of bottom sediments. It is reported as percentage of dry-sample weight. TKN measures the amount of organic nitrogen present as ammonia, as well as that bound into organic compounds in the aqueous phase of the benthic samples. However, natural TKN levels vary widely among seafloor sediment samples, so anthropogenic (human-induced) impacts are difficult to discern from TKN measurements alone. Similarly, other properties that can indicate organic loading from effluent discharge, including dissolved sulfides, O&G, and BOD, are problematic to sample, analyze, and interpret.

For example, O&G concentrations are often below detection limits, even close to the discharge. Similarly, BOD is difficult to accurately measure in sediment samples, and interference from errant pieces of organic material, such as drifting kelp, has resulted in erroneously high levels at some stations in previous surveys. Specifically, Station B9 in 2000, and various stations prior to 1995 (Figure 4.9b on Page 4-26) exhibited anomalously elevated BOD concentrations. Because of persistent interference during BOD determinations, overall confidence in BOD results for benthic sediment samples remains low.

Trace Metals

In contrast to synthetic chemicals, the presence of trace metals within seafloor sediments is not necessarily indicative of anthropogenic input. Most trace metals are found in detectable concentrations within naturally occurring mineral deposits. Some metals provide essential minerals needed by marine organisms to survive. However, elevated levels of certain trace metals can be indicative of anthropogenic input, and excessive levels can cause deleterious effects in marine organisms.

Nine trace metals have been measured in seafloor sediments since the inception of the monitoring program. They are arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. The toxicity of these metals to marine organisms has also been examined in numerous laboratory bioassays and field experiments (Long and Morgan 1991, Long et al. 1995). These studies have been summarized in the form of biological effects levels, most notably an effects-range low (ERL), below which toxic effects are not expected, and an effects-range median (ERM), above which adverse biological effects are anticipated. The potential for impacts from concentrations in the range between these thresholds cannot be reliably predicted.

In 1998, the analysis of aluminum and iron within benthic sediments was added to the monitoring program. Unlike the other nine metals, aluminum and iron are not particularly toxic to marine organisms, and their naturally occurring concentrations are relatively insensitive to anthropogenic input. This latter

attribute makes them ideal tracers of natural variations in all the trace metals. Consequently, they have been used to normalize observed concentrations in the other nine metals so that background variation is reduced and anthropogenic trends can be revealed. In particular, iron has been used as a reference element for determining anthropogenic enrichment of trace metals within the Southern California Bight (Schiff and Weisberg 1997) and in many other offshore regions (e.g. Daskalakis and O'Conner 1995).

Physical Properties

Moisture content and grain-size distribution are two important physical properties of marine sediments. Moisture content is a measure of the volume of pore water present in the sediment samples. While not an indicator of discharge effects, it is an important parameter used to convert chemical concentrations measured in the wet sediment sample to a dry-weight basis. Dry-weight concentrations allow a more direct comparison of chemical concentrations associated with bulk sediments by eliminating variations in sample mass that arise from arbitrary differences in water content. Moisture content is also used, along with salinity measurements, to eliminate the bias introduced by salt content in grain-size determinations.

Grain-size distribution is important to quantify because an increase in fine sediments near a municipal ocean outfall can be indicative of excessive effluent-solids deposition. In addition, the amount of fine sediment directly affects the composition of the infaunal community that resides within the sediments; although the precise mechanism for this relationship is rarely clear (Snelgrove and Butman 1994). Finally, natural variation in trace-metal concentrations has been correlated with the fine-sediment (mud) fraction and, like aluminum and iron, mud concentrations have been used to normalize metal concentrations (Dossis and Warren 1980, Ackerman et al. 1983, Horowitz and Elrick 1987).

Accurate measurement of the fine sediment fraction is particularly important for use in the interpretation of the marine biological data. Otherwise, variability in a benthic community's composition could be erroneously ascribed to effluent discharge, when instead it may be the result of natural variation in the distribution of fine particulates. One of the major difficulties in the accurate measurement of the fine fraction within marine sediments is that the standard pipette method described by Plumb (1981) and Folk (1980) overestimates the finest (clay) fraction. This occurs because the procedure incorrectly includes the weight of the dissolved solids (salt) when weighing the dried pipette extraction. This often generates an artificial bimodal grain-size distribution, where the smallest (clay) fraction exceeds the next largest (silt) fraction.

In 1994, the anomalous character of the bimodal size distribution in the MBCSD database led to a number of internal investigations and confirmatory grain-size analyses by outside laboratories (MRS 1995). The refined analysis method that is now in use accounts for the presence of dissolved solids by correcting for the measured salinity in the pipette fractions (MRS 1998i and Coats et al. 1999). This refined particle-size analysis method was instituted in the MBCSD monitoring program beginning in 1998. As a result, the finest size fractions determined in sediment samples collected after October 1997 are far more accurate than those determined in prior surveys. Therefore, some of the long-term trends in the MBCSD grain-size database can be ascribed to improvements in methodology, rather than actual changes in the benthic environment.

Biological Parameters

Determining whether the discharge is causing adverse biological effects involves assessing whether a balanced indigenous population (BIP) of shellfish, fish, and wildlife exists in areas potentially affected by the discharge. A BIP is an ecological community, which exhibits characteristics similar to those of nearby, healthy communities existing under comparable environmental conditions beyond the influence of the discharge. Certain biological characteristics of the community are examined in a BIP evaluation, including spatial and temporal distributions of species composition, abundance, biomass, dominance, and

diversity. Other overall biological indicators of a BIP include trophic (feeding-habit) structure and the presence or absence of sensitive indicator species. Most marine monitoring programs determine the presence of a BIP using data on the infaunal organisms that live within sediments surrounding a potential pollutant source.

When assessing a BIP, infauna have many advantages over other marine organisms, such as marine mammals or finfish. First, infauna are relatively easy to collect in numbers large enough for reliable statistical testing. Second, they have limited mobility and cannot easily escape exposure to pollutants. Finally, decades of monitoring studies have established well-defined responses of infaunal taxa to pollutant stress.

In the earliest MBCSD monitoring surveys, analysis of biological samples produced two types of data on infaunal organisms: the number of organisms for each taxon, and the biomass of major taxonomic groups within each sample. Biomass is difficult to interpret, however, because the erratic presence of large, undersampled organisms severely skews the results. In addition, in practice, the heavy calcareous shells and exoskeletons of mollusks and crustaceans are troublesome to remove, and alcohol evaporation during weighing affects the determination of wet-weight biomass. Because of these problems, the USEPA does not recommend biomass for inclusion in 301(h) monitoring programs (USEPA 1987). Therefore, beginning in 1998, the NPDES permit no longer required this analysis.

Pollution affects marine ecosystems by changing the number and type of benthic organisms found in the sediments. However, subtle changes in community composition are not always readily apparent in the large volume of raw data generated by a long-term monitoring program. Over the three decades of MBCSD monitoring, 258,000 specimens representing 390 individual taxa have been collected. To assess whether the infaunal community has been impacted, these data must be summarized into concise parameters that are indicative of pollutant stresses.

Biodiversity is a common indicator of the well-being of ecological systems, and forms the cornerstone of most impact-assessment studies. Unfortunately, biodiversity is difficult to define quantitatively, in part because it has two major components: species richness and evenness. Species richness measures the variety (number) of species, while evenness measures the distribution of individuals (abundance) among the species (Magurran 1988). Healthy ecosystems are thought to be both rich in species and have an even distribution of individuals among those species.

Although no single measure can accurately represent changes in both evenness and richness along a pollution gradient, many indices attempt to do so. The Shannon Diversity Index (H') is the most widely used diversity index because it exhibits some degree of sensitivity to both evenness and richness. In addition, most diversity indices only measure the diversity within a local area at a particular time, *viz*., among replicate samples from a single station (α-diversity). In contrast, pollutant stresses tend to induce marked changes in community composition between samples separated spatially and temporally (β-diversity; Smith et al. 1979). Multivariate analysis techniques are better suited to the evaluation of β-diversity than are individual indices.

Most diversity indices are also poorly suited for describing potential impacts to infaunal communities because they lack biological meaning, show little correlation with environmental quality, and are difficult to interpret ecologically (Hurlbert 1971, Goodman 1975, Washington 1984, Green 1979). As a result, ambiguous or biased estimates of diversity often occur. Therefore, many indices are not recommended for routine inclusion in 301(h) monitoring programs (USEPA 1987). Nevertheless, the current NPDES permit requires that a number of infaunal community indices be reported and examined for temporal trends (RWQCB-USEPA 2009). However, because of limitations associated with the indices, spatial differences with respect to outfall proximity, which are evaluated using standard statistical hypothesis tests, must be

interpreted carefully. Table 4.4 lists the infaunal indices computed in this report. The associated algorithms and guidance on how to interpret them are presented in Appendix B.1.

Table 4.4 Infaunal Parameters Evaluated in the Monitoring Program

• Number of individuals	• Number of species
• Number of individuals per species	• Species richness (*S*) (Magurran 1988)
• Margalef species richness (d) (Margalef 1951)	• Shannon-Wiener index (*H'*)
• Simpson dominance (*C*') (Simpson 1949, Wittaker 1965)	• Brillouin index (*h*)
• Pielou evenness index (*J*') (Pielou 1977)	• Swartz dominance (S_w)
• Infaunal Trophic Index (*ITI*)	

4.2 MARINE SEDIMENT QUALITY

The quality of marine sediments surrounding the MBCSD outfall provides a definitive measure of potential marine impacts caused by wastewater discharge. Specifically, discharge-related impacts have been demonstrated in outfall monitoring programs offshore both central and southern California, wherein marked changes in the benthic environment have been observed surrounding the discharge locations (Phillips and Hershelman 1996, Stull et al. 1986b). Discharge-related impacts have also been observed on the continental shelf south of Estero Bay, where sediments were found to exhibit small but statistically significant chemical signatures indicative of drilling mud discharges over widespread areas (Hyland et al. 1994, Coats et al. 1991, Coats 1994). If the MBCSD effluent discharge were causing significant impacts to the marine environment, similar changes in sediment properties would be evident near the diffuser structure. The challenge is to distinguish changes that are caused by naturally occurring processes from those that result from human activities.

Physicochemical changes in sediments provide a good indication of marine impacts for four main reasons. First, because outfalls are located on the seafloor, sediments are proximal to the source of potential contamination. Second, many contaminants are hydrophobic and tend to preferentially adhere to the fine particulates as they settle out of the effluent plume. Third, contaminants incorporated into seafloor sediments tend to have a long residence time because of the slow dispersive processes that prevail within pore waters. Finally, infaunal organisms that live within seafloor sediments are continuously exposed to contaminants because they cannot easily escape the source of pollution. If seafloor sediments or pore waters become polluted, infaunal organisms can be impacted. Sedentary infaunal organisms provide a food source for other, more mobile organisms, such as finfish and shellfish. These trophic relationships can lead to bioaccumulation of contaminants within the marine food chain.

Despite the sensitivity of the benthos to effluent discharge, there has never been any indication of deleterious impacts to seafloor sediments resulting from the MBCSD discharge, including during 2015. The lack of negative benthic impacts is largely due to the comparatively low mass-emission of anthropogenic chemicals from the outfall. There has never been a large industrial contributor to the MBCSD influent stream, and the total discharge volume is small compared to ocean dischargers to the south, where discharge volumes can be over 100-times greater (e.g., SCCWRP 2006).

The lack of benthic impacts is evident from three sets of analyses performed on the chemical properties of sediment samples collected around the MBCSD outfall during the October 2015 survey. Each of these analyses is discussed in the following subsections. First, concentrations of potential contaminants measured in sediment samples were below levels that have been empirically linked to toxicity in marine organisms. Second, the spatial pattern of sediment concentrations near the outfall during 2015 bore no consistent relation to outfall proximity. Third, sediment concentrations do not exhibit significant long-term trends that would suggest a buildup of contaminants close to the outfall.

4.2.1 Concentrations below Toxic Levels

In keeping with the COP, narrative receiving-water limitations contained within MBCSD's NPDES discharge permit (RWQCB-USEPA 2009) state that the discharge should not cause chemical substances in marine sediments "*to be increased above levels which would degrade indigenous biota.*" This requirement was established because contaminants that reside in sediments for long periods have the potential to exert acute and chronic effects on resident marine organisms (NOAA 1991ab, Finney and Huh 1989, Bertine and Goldberg 1977).

Over the 30 years of continuous benthic monitoring, there has never been any indication of an effluent-related degradation of marine organisms within Estero Bay. In large part, this is due to the consistently low chemical concentrations within the discharged effluent (see Chapter 2). As a result, contaminant concentrations measured within Estero Bay sediments, both near and distant to the outfall, have been below thresholds reliably determined to be harmful to marine biota. In fact, the comparatively pristine marine environment of Estero Bay is reflected in benthic contaminant levels that are well below concentrations measured in sediments offshore southern California.

Thresholds of Biological Effect

Over the years, marine monitoring programs have placed considerable emphasis on benthic contamination. This experience has resulted in a set of thresholds of biological concern that can be used to screen chemical concentrations measured within marine sediment samples at any location. Specifically, these biological benchmarks can be used to assess whether the chemical concentrations measured in sediments have the potential for adverse biological effects. Although the thresholds are not regulatory criteria, they provide toxicological guidelines that help assess the potential environmental significance of specific chemical concentrations measured in the field.

The toxicological benchmarks advanced by NOAA (Long and Morgan 1991) are used in this report to evaluate sediment chemical concentrations measured during 2015. These guidelines are based on a correlation between chemical concentrations and observed biological effects in numerous modeling, laboratory, and field studies (Long et al. 1995). The studies identify two toxicological endpoints, an Effects-Range Low (ERL) and an Effects-Range Median (ERM) concentration. The lower toxicological endpoint (ERL) is associated with the concentration of a particular compound that produced an adverse biological effect in only 10% of the data. Below the ERL, adverse biological effects are unlikely. Above the ERM, which is based on the median of the toxicological data, adverse effects are considered likely to occur. The most conservative benchmark (ERL) was used in this report to determine the potential for marine biological impacts from most of the chemical concentrations that were measured within Estero Bay during 2015. These benchmarks provide a reliable screening tool for most, but not all sediment contaminants. For example, the relationship between nickel concentrations and the incidence of effects in the toxicological database is very weak. Consequently, even the upper (ERM) benchmark for nickel is a poor predictor of levels where biological effects might be expected.

Both trace-metals and organic contaminants are of concern in the benthic environment. However, their natural occurrence differs markedly. Synthetic compounds, such as PAHs, PCBs, and pesticides, are organic constituents that can have the most significant anthropogenic impact if found in sufficient concentrations. However, in this and many other marine sediment studies, their concentrations are below detection levels. In contrast, trace metals occur naturally in the marine environment and are commonly detected in sediment samples. Because of this, trace metals serve as a powerful surrogate for evaluating the regional transport and fate of a host of other particulate contaminants.

Grain-Size Distribution

Within deep offshore basins, sediment trace metals accurately record the history of contaminant accumulation because they are ubiquitous and long-lived. However, these deep benthic sediments often contain significant fractions of fine-grained sediments, which support an increased number of trace-metal bonding sites per unit of volume. Thus, large differences in trace metal concentrations among sediment samples can be caused by natural differences in mud fractions that are unrelated to human activities. Because of this, many marine benthic studies divide (normalize) trace metal concentrations by the mud fraction. Normalization is intended to reduce inherent natural variability, revealing anthropogenic contaminant patterns normally masked by the natural association between metals and fine particulates (Dossis and Warren 1980).

While this approach works well in deep quiescent basins, it is not applicable in nearshore environments where energetic oceanographic processes erode fine particles, leaving behind coarser, more transport-resistant sandy sediments. Sandy sediments usually have comparatively low metal concentrations. In addition, metals tend to be incorporated into the mineralogy of the sand grains themselves, rather than adsorbed onto their surfaces, as is the case with silts and clays. Therefore, metals are less likely to dissolve and become assimilated by marine organisms residing within sandy sediments. Because of the lower bioavailability of metals within sands, NOAA does not recommend mud-fraction normalization of trace-metals for samples with less than 20% fine-grained material (Long and Morgan 1991). Because the Estero Bay sediments consist almost entirely of sand (>97.4%; Table 4.5; Appendix Table C.3), iron- and aluminum-normalized concentrations are assessed instead.

Table 4.5 Grain-Size Distribution (%) within Sea-floor Sediment Samples Collected on 26 October 2015

	Clay (9 to 12ϕ)	Silt (5 to 8ϕ)	Fine to Medium Sand (1 to 4ϕ)	Coarse Sand (1ϕ)	Very Coarse Sand (0ϕ)	Gravel (-1ϕ to –3ϕ)
Station B1	0.56	1.56	97.26	0.42	0.16	0.05
Station B1[1]	0.48	1.64	97.14	0.23	0.13	0.40
Station B2	0.62	1.15	97.80	0.24	0.12	0.07
Station B3	0.49	1.01	98.09	0.25	0.08	0.08
Station B4	0.44	1.02	97.54	0.15	0.09	0.76
Station B4[1]	0.42	0.79	98.47	0.20	0.11	0.02
Station B5	0.46	0.98	97.87	0.31	0.08	0.29
Station B5[1]	0.52	0.99	98.23	0.10	0.04	0.11
Station B6	0.41	0.88	98.38	0.13	0.07	0.13
Station B7	0.41	0.98	97.75	0.21	0.13	0.51
Mean[2]	**0.48**	**1.08**	**97.87**	**0.22**	**0.10**	**0.19**

Irrespective of trace-metal normalization, grain-size distributions can be indicative of a buildup of effluent particulates within the surficial sediments if, for example, there is an increase in fine fractions close to the discharge point. Additionally, the overall character of the grain-size distribution reflects the dynamics within a particular benthic environment. For example, higher mud fractions reflect more-quiescent depositional environments, while well-sorted sands result from energetic wave environments that winnow fine particulates as they constantly rework the surficial sediments. Accordingly, the predominance of sand-sized particulates in the grain-size distributions within the 2015 sediment samples reflects the high-energy environment near the outfall.

The sediment samples collected in October 2015 consisted of well-sorted fine sands with a distribution skewed slightly toward the finer fractions (Appendix Table C.4). During 2015, mean particle diameters ranged from 144 to 149 μm, lying in the middle of the fine-sand portion of the grain-size distribution. The high degree of sorting is reflected by low standard deviations ($\sigma<0.5$). The small, but consistently positive

[1] Duplicate analysis of sediment sample
[2] Mean computed after arc-sine transformation

skew to the distribution reflects a slight excess in the finer fractions relative to larger fractions in the tails of the distributions. Together, these properties point to a highly energetic flow regime that tends to winnow fines from the surficial sediments. The contribution of larger-diameter fractions was negligible in that the combined coarse sand and gravel fractions (≤1ϕ) represented less than 08% of the total sample weight, except within the samples collected at Stations B4 and B7, which had respective coarse fractions of 1.0 and 0.85% (Table 4.5), largely due to errant pieces of large pebble-sized material. At most stations, the components of the largest fractions consisted mainly of fragments of shell hash, including the remains of sand dollars that are randomly distributed on the surface of sediments in many shallow subtidal coastal areas.

Undetected and Nontoxic Metals

In 2015, most trace-metal concentrations within sediment samples were either not detected or were below levels that are considered potentially toxic to marine organisms (*cf.* mean, ERL, and ERM concentrations in Table 4.6). The only exception was nickel, which is described in more detail below. Although cadmium, mercury, and silver were not detected in any of the seven 2015 sediment samples, they have been detected occasionally in prior monitoring surveys but at concentrations too low to be reliably quantified. For all of these metals, the respective maximum detectable concentrations, 0.072, 0.05, and 0.07 mg/Kg, were well below the lowest toxic-effects levels (ERLs) of 1.2, 0.15, and 1.0 mg/Kg where biological effects can first become apparent, and far below the median effects levels (ERMs) where biological impacts are expected. Thus, even if cadmium, mercury, and silver were present in Estero Bay sediments in concentrations approaching detectable levels, they would be unlikely to affect marine organisms.

Table 4.6 Metal Concentrations (mg/Kg-dry) within Seafloor Sediment Samples Collected on 26 October 2015

Station	Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Silver	Zinc
B1	6,400	2.9	<0.068[1]	62	3.1	9,800	2.3	<0.047	44	<0.07	17
B2	6,100	3.9	<0.068	50	3.5	10,200	2.5	<0.047	50	<0.07	17
B3	6,200	3.7	<0.067	52	3.6	10,300	2.5	<0.047	52	<0.07	18
B4	6,300	3.6	<0.068	52	3.8	10,500	2.5	<0.047	57	<0.07	18
B5	6,400	3.6	<0.068	53	3.6	10,400	2.3	<0.047	51	<0.07	18
B6	6,200	3.6	<0.070	51	3.4	10,100	2.3	<0.048	53	<0.07	17
B7	6,000	3.3	<0.072	47	3.2	9,700	2.2	<0.050	50	<0.07	17
Mean[2]	**6,200**	**3.5**	**<0.069**	**52**	**3.5**	**10,100**	**2.4**	**<0.047**	**48**	**<0.07**	**17**
ERL	—[3]	**8.2**	**1.2**	**81**	**34.0**	—	**46.7**	**0.15**	**20.9**	**1.0**	**150**
ERM	—	**70.0**	**9.6**	**370**	**270.0**	—	**218.0**	**0.71**	**51.6**	**3.7**	**410**
SCB[4]	—	**6.2**	**0.2**	**28**	**12.0**	—	**10.4**	—	**29**	**0.2**	**45**

[1] The "*less-than*" symbol (<) indicates that the substance was not detected at a concentration above the dry-weight-adjusted method detection limit (MDL), which is listed after the "<" symbol.
[2] After logarithmic transformation
[3] Guideline not specified
[4] Concentration that would be considered enriched (99th percentile) relative to background concentrations in the Southern California Bight after normalization by iron (Schiff and Weisberg 1997)

Two of the remaining nine metals, namely aluminum and iron, are not toxic to marine organisms. As described previously, these two metals were added to the monitoring program in 1998 to track natural variations in concentrations of other trace metals that occur because of inherent differences in mineralogy. The other six metals (arsenic, chromium, copper, nickel, lead, and zinc) have been consistently detected within Estero Bay sediments throughout the history of the benthic-monitoring program. Although they each have the potential for anthropogenic enrichment, their mean concentrations have remained comparable to ambient levels for the region. In 2015, as in previous years, five of these six metals had concentrations well below the ERL where biological effects can begin to become apparent. Only the mean nickel concentration was above the ERL. Each of the six detected metals is described below.

Arsenic

Although present in measurable amounts (≤3.9 mg/Kg), the mean arsenic concentration in Estero Bay sediments was less than half of the lowest toxicity level (8.2 mg/Kg) where adverse biological impacts would first begin to appear, and an order of magnitude smaller than the ERM (70 mg/Kg) where biological impacts become probable. For comparison, approximately 75% of the area within the Southern California Bight (SCB) has arsenic concentrations exceeding the mean level measured in Estero Bay during 2015 (Schiff and Gossett 1998). After adjustment for the mean iron concentration, average arsenic levels would have to be 2.7 mg/Kg higher to be considered enriched relative to background concentrations in marine sediments to the south (SCB = 6.2 mg/Kg in Table 4.6).

Pure arsenic is a highly poisonous metallic element used in insecticides, herbicides, solid-state doping agents, and various alloys. However, these anthropogenic sources of arsenic do not constitute a significant component of the wastewater processed by the MBCSD. Instead, most of the arsenic present in the Estero Bay sediments derives from erosion of enriched onshore mineral deposits. Although arsenic occurs naturally in central-coast sediments, mine tailings may contain higher residual levels due to the increased presence of arsenopyrites in the ore, overburden, and soil. Arsenic from mine tailings may be released into surface and ground waters through erosion, and reach Estero Bay through runoff within the adjacent watershed (MRS 2000b).

Chromium

Chromium is enriched within the sediments of the entire south central-coast region, including within Estero Bay. This enrichment is reflected in the 52-mg/Kg mean chromium concentration collected in samples surrounding the outfall in 2015, which is nearly double the 28-mg/Kg that would be considered impaired for sediments within the SCB (Table 4.6). However, chromium concentrations within all the 2015 sediment samples remained below the lowest toxicity benchmark where biological effects might first be observed. The highest concentration (62 mg/Kg-dry) was measured at reference Station B1, and was still well below the ERL of 81 mg/Kg. More importantly, the maximum concentration was one-sixth of the level where biological effects become probable (ERM=370 mg/Kg). Even at that concentration, the potential for marine effects is probably overstated, given that that the incidence of effects in the toxicological studies used to establish the levels for chromium were "*greatly influenced and exaggerated by data from multiple tests conducted in only two field surveys*" (Long et al. 1995).

The ambiguity in chromium's toxic effects levels partially arises from the fact chromium has several oxidation states, each of which has a vastly different toxicity. The presence of hexavalent and metallic oxidation states of chromium generally arises from anthropogenic sources, particularly industrial processes; however, the relatively non-toxic trivalent form of chromium found within the Estero Bay sediment samples occurs naturally in chromite ore. This is evident from the lack of measurable levels of hexavalent forms in sediment samples collected prior to 1999, when chromium speciation analyses were performed (MRS 1996, 1997c, 1998bi, and 1999b). The elevated chromium levels within Estero Bay

sediments originate in naturally occurring chromite minerals that are introduced to the Central Coast's waters by fluvial transport of eroded ultrabasic minerals found in the Franciscan formation. The Franciscan formation outcrops along the headlands north of Point Estero and in the Santa Ynez Mountains. Thus, although chromite ore is a widely distributed mineral deposit, it is more prevalent along the south-central coast of California than in most other areas (SAIC 1986).

The presence of higher chromium concentrations within central-coast sediments often leads to misinterpretation by regulators and scientists unfamiliar with the local mineralogy. For example, only around 25% of the SCB has sediments with chromium concentrations higher than those of Estero Bay. Most of this area of higher chromium concentrations lies within Santa Monica Bay, where a high mass-emission of contaminants from publicly owned treatment works occurred prior to 1988. However, elevated chromium levels were also observed within the Santa Barbara Basin in the northern reaches of the SCB, which led to speculation that those sediments were impaired as well, even though they can be also be ascribed to the increased presence of naturally occurring chromite ore in the region (Chow and Earl 1978). The erroneous characterization of an impaired condition in the northern SCB was prompted by an incorrect assertion by Schiff and Gossett (1998) that the elevated chromium concentrations were "*highly predictive of adverse biological effects*" in their review of contaminant concentrations within the SCB. That assertion was in direct conflict with published findings by the developers of the biological-effects levels, who stated that the chromium effect levels were exaggerated (Long et al. 1995).

While erosion of naturally occurring chromite ore along the central coast explains its overall enrichment within the marine sediments of northern Estero Bay, ordinary erosional processes may not be able to account for the trend of increasing chromium concentrations that was observed in the decade prior to 2000. During that time, increases in chromium, arsenic, copper, and nickel that were unrelated to the MBCSD discharge (MRS 2010a) were documented throughout the Estero Bay region. Although these metals are naturally enriched in onshore mineral deposits, nearshore depositional sediments should have reached equilibrium with onshore sediments that have been eroding within the adjacent watershed throughout geologic time. Instead, the increases in marine sediment concentrations that were observed in the monitoring program during that time suggest that the erosion of these mineral deposits was being accelerated by human activities, such as mining. As described by MRS (2000b, 2001), sediment samples collected in conjunction with a supplementary environmental project indicated that erosion around abandoned chromite mines was the likely cause for increasing metal concentrations within the marine sediments of Estero Bay.

Copper

As with arsenic and chromium, copper commonly occurs within the minerals found along the central coast. However, the 3.5-mg/Kg average copper concentration within marine sediments collected at the seven benthic-monitoring stations in 2015 is well below the 12-mg/Kg concentration considered enriched relative to background levels within the SCB sediments. Approximately 90% of the SCB sediments have higher copper concentrations than those measured in Estero Bay. All of the sediment samples collected within Estero Bay during 2015 had copper concentrations that were also far below levels that would begin to affect marine organisms (ERL=34 mg/Kg). In contrast to chromium, the biological effect levels of copper are well defined by toxicological studies. Consequently, biological impacts from the observed copper levels within Estero Bay sediments are highly unlikely given that the highest measured copper concentration (3.8 mg/Kg) was 70-times lower than the ERM level where adverse effects become probable.

Lead and Zinc

Lead and zinc concentrations within Estero Bay sediments are also low compared to ERL levels where adverse biological effects first become noticeable. Additionally, they are low compared to concentrations within the SCB, where approximately 95% of the area has higher concentrations. Most of the elevated lead and zinc concentrations offshore southern California were measured within Santa Monica Bay and on the Palos Verdes Shelf, where large wastewater treatment plants have discharged for many decades. However, most of the metal emissions from these treatment plants occurred prior to the substantial improvements in effluent quality that were realized in 1988. Unfortunately, the historical discharges from these outfalls accumulated within adjacent sediments and have persisted for decades (Stull et al. 1986b). In contrast, the historically low emission of chemicals from the MBCSD treatment plant has had no measurable effect on the high sediment quality within Estero Bay.

Nickel

Although unrelated to wastewater discharge, nickel is the only metal whose concentration within Estero Bay sediments that consistently exceeds its ERL level (Table 4.6). In fact, in the three decades of benthic monitoring, none of the 268 samples collected has contained nickel in concentrations less than the ERL of 20.9 mg/Kg. Additionally, nineteen of the samples have had concentrations exceeding the nickel ERM of 51.6 mg/Kg where biological impacts to marine organisms would normally be expected to occur, including two samples collected in 2015. However, despite measured nickel concentrations that consistently exceed marine-toxicological benchmarks, no apparent deleterious impacts to infaunal organisms living within northern Estero Bay sediments have been observed. There are two reasons for this.

First, nickel exhibits a very weak relationship between the incidence of effects and concentrations in the database used to establish the toxic-effect ranges (Long et al. 1995). Because of this weak toxicological relationship, specification of bulk nickel concentrations that induce adverse reactions in marine biota is highly uncertain. Much of this uncertainty arises from wide variability in nickel bioavailability. When nickel is in a dissolved form, or adheres to the surfaces of fine-grained sediments, it is much more likely to affect organisms that ingest or come into contact with the sediments. Conversely, nickel that is bound into the mineralogy of larger sand grains, as is the case within MBCSD benthic monitoring area, has little influence on marine organisms.

The second reason for the lack of impacts from elevated nickel concentrations stems from the fact that nickel occurs naturally in the mineralogy of the southern portion of the central California coast (Steinhauer et al. 1994). Because nickel and chromium often co-occur in mineral deposits, it is likely that the increased nickel concentrations found offshore also derive from the Franciscan geologic formation that outcrops at Point Estero. Thus, much of the measured nickel is bound into the mineral matrix of the sand grains themselves, where marine fauna cannot readily metabolize it. Additionally, if there is a slightly higher dissolved-phase nickel concentration within the pore waters of Estero Bay, it has probably been present for epochs, and benthic organisms in the region may have adapted accordingly.

Nickel and chromium are the only metals whose measured bulk concentrations in Estero Bay sediments consistently exhibit "*anthropogenic enrichment*" relative to background concentrations in the SCB (Schiff and Weisberg 1997). However, this designation is incorrect because much of the regional enrichment along the central California coast arises from natural erosional processes, rather than from accelerated erosion of contaminated mine tailings. In fact, the influence of regional mineralogy is also plainly evident in the SCB database where "*background*" nickel concentrations steadily increase from south to north. As with chromium, Schiff and Gossett (1998) did not account for this natural variability in ore deposits and erroneously ascribed observed nickel gradients within the northern SCB to anthropogenic contamination.

Organic Loading

Organic-loading parameters including moisture content, mud fraction, BOD, and O&G measured in the sediment samples collected in 2015 were comparable to levels typically measured in most prior benthic surveys (Table 4.7). Although TKN and TVS concentrations measured in both 2014 and 2015 within Estero Bay sediments were perceptibly higher than in previous years, there are no well-established biological effects levels for any of these parameters.

Table 4.7 Non-metal Concentrations (mg/Kg-dry)[1] within Seafloor Sediment Samples Collected on 26 October 2015

Station	Moisture (%)	BOD	Oil & Grease	TKN	Volatile Solids (%)
B1	23.1	39	—[2]	156	1.78
B2	23.3	34	<33	169	2.31
B3	22.6	34	<32	181	2.35
B4	23.2	40	<33	182	2.54
B5	23.2	40	<33	169	2.33
B6	25.4	38	<34	147	2.20
B7	28.2	43	<35	153	2.01
Mean[3]	**24.1**	**38**	**<33**	**165**	**2.21**

4.2.2 Spatial Distribution Unrelated to Outfall Proximity

In 2015, as in previous years, the spatial distribution of sediment chemicals did not exhibit a pattern indicative of a benthic environment impaired by the MBCSD wastewater discharge. Specifically, there was no consistent evidence that sediment chemical concentrations near the diffuser structure were elevated relative to distant sites. A gradient of steadily increasing contaminant concentrations with increasing outfall proximity would provide *prima facie* evidence of discharge-related impacts to the marine environment. This pattern of impairment has been observed around larger outfalls servicing more industrialized locales (Phillips and Hershelman 1996, Stull et al. 1986b, Stull 1995, Diener et al. 1995). The lack of contaminant loading around the MBCSD outfall was confirmed through application of rigorous statistical hypothesis tests, and by qualitative visual comparisons of concentrations ranked by distance from the diffuser structure.

The bar graphs in Figure 4.4 show trace-metal concentrations ranked by distance from the diffuser. Potential outfall-related impacts would appear as bar heights steadily decreasing from left to right in many, if not all of the trace metals. However, none of the metals readily exhibits an enrichment trend related to outfall proximity except perhaps nickel. Although nickel's linear spatial gradient was found to be marginally statistically significant (p=0.04, see Table 4.8 on Page 4-21 later in this Section), it was so slight that the actual spatial differences among stations were encompassed with the uncertainty in concentrations measured at individual stations. This uncertainty is quantified by the 95% confidence intervals shown to the left of each bar graph.[4] They indicate that perceived differences in concentrations measured among stations in 2015 were smaller than the inherent sampling error, and by definition, have a low degree of confidence.

Thus, Figure 4.4 shows that, in 2015, most of the observed differences among stations can be ascribed to inherent sampling variability, rather than to actual spatial changes in chemical concentrations within the sediments. The only exceptions were the nickel and arsenic concentrations, which appear to be significantly lower than average at the Reference Station B1 (black bars in Figure 4.4), where they ranged slightly below the lower confidence bound. This suggests that any perceived spatial gradients related to outfall proximity were caused by an unusually low concentration at the reference station, rather than elevated concentrations at the ZID stations.

[1] Unless otherwise indicated as "%"
[2] Sample not analyzed for O&G
[3] Arc-sine transformation for % and logarithmic transformation for mg/Kg
[4] The 95% confidence intervals reflect the inherent sampling uncertainty at any given station and were determined from the variability in concentrations found among three individual replicate samples collected and separately analyzed at each station in 1993 and 1994.

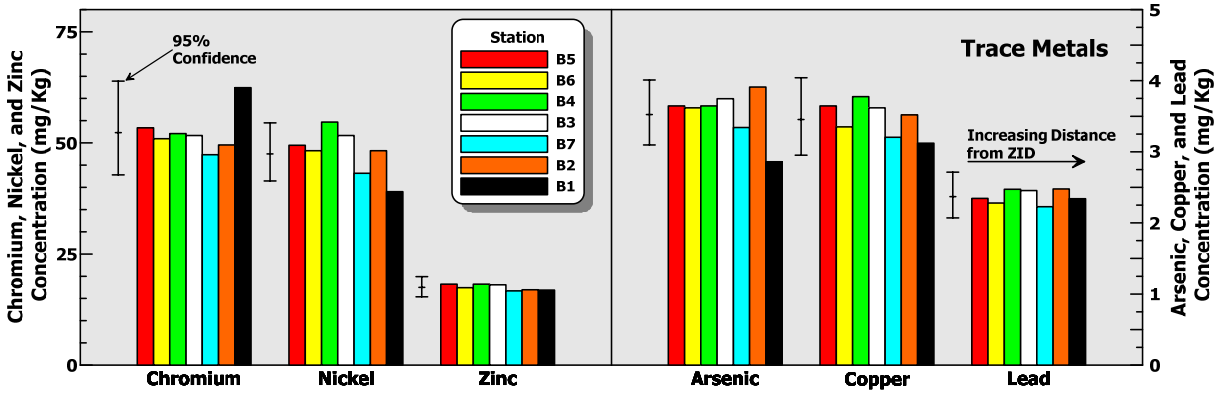

Figure 4.4 Trace-Metal Distribution within Sediment Samples Collected during 2015

Moreover, any potential spatial differences that may be apparent in the raw data were probably the result of natural processes rather than outfall discharge. This is apparent from the iron distribution in the lower frame of Figure 4.3. As with the nickel concentrations in Figure 4.4, iron exhibits a general decline in concentration with distance from the discharge, including a perceptively lower concentration at Station B1. As described previously, human activities have little influence on aluminum, iron, and mud concentrations within seafloor sediments. Because of this, normalization by these concentrations is a common practice in impact-assessment studies because it can reveal anthropogenic patterns that are otherwise masked by variability in background trace-metal concentrations. Similarly, they can eliminate spatial differences that may appear to be related to a discharge impact, when they are in fact due to natural variability.

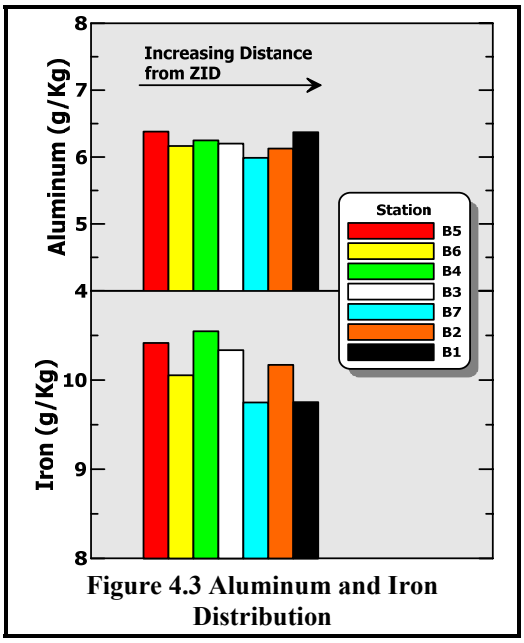

Figure 4.3 Aluminum and Iron Distribution

Accordingly, when the raw concentrations in Figure 4.4 are normalized by aluminum and iron (Figure 4.3), the potentially significant differences among samples are eliminated (Figure 4.5). Specifically, the lower nickel and arsenic concentrations at Station B1 are mirrored by lower iron concentrations (*cf.* the black bars in Figure 4.4 and Figure 4.3). After normalization, however, all of the concentrations lie within their respective 95% confidence intervals and perceived spatial gradients related to increased concentrations near the outfall are eliminated.

Although spatially ranked bar charts provide a useful visualization of potential trends, statistical hypothesis tests provide a more rigorous, quantitative method for assessing potential spatial gradients such as those described above for raw nickel concentrations. Specifically, these tests establish whether the MBCSD discharge could be causing an increase in metal concentrations close to the outfall compared to the more distant stations. Two types of spatial tests were performed on the data collected during 2015 (Table 4.8). First, a test for the presence of a spatial gradient was performed by fitting a line to the concentration versus distance data. If the concentrations consistently decrease with distance, then the negative slope of the line will be statistically significant and possibly indicative of outfall-related impacts.

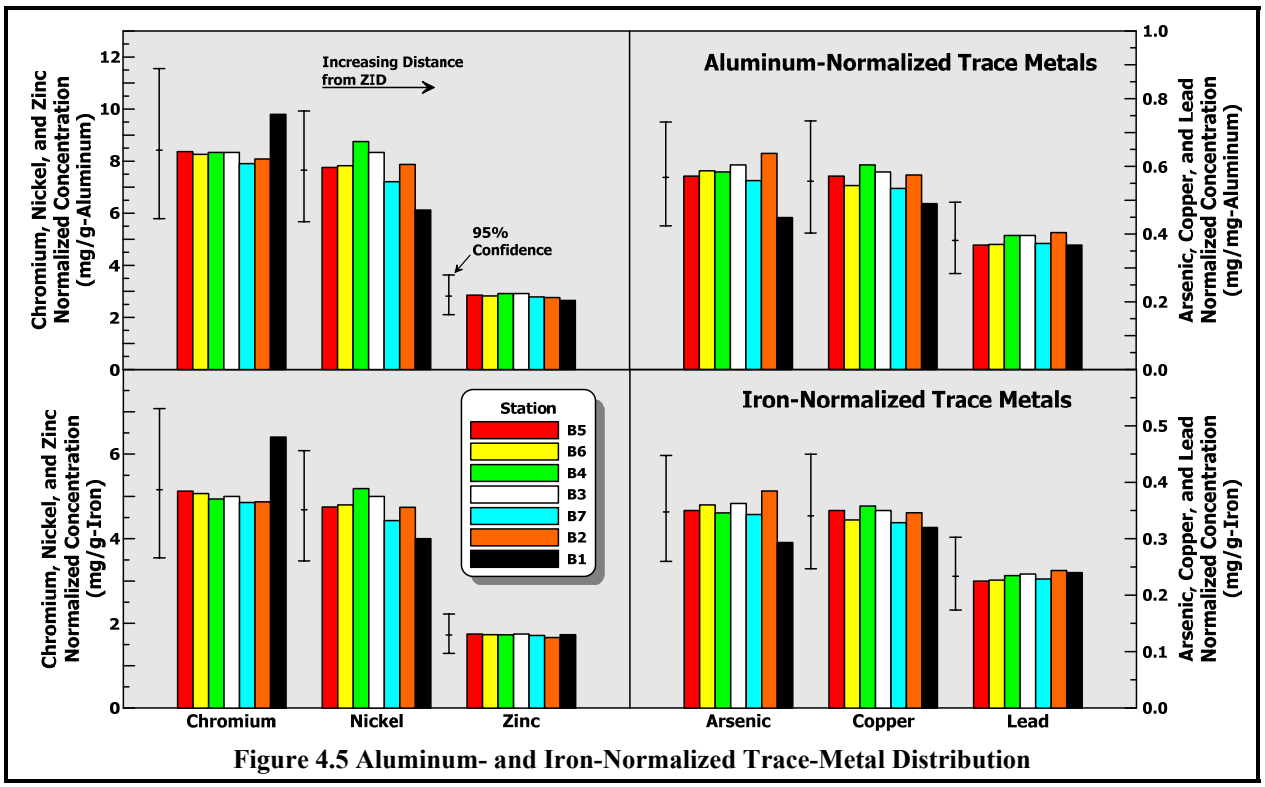

Figure 4.5 Aluminum- and Iron-Normalized Trace-Metal Distribution

The second statistical test evaluated whether mean concentrations at the four stations that lie within 88 m of the discharge differed significantly from average of the three distant stations (Stations B1, B2, and B7), that are located more than 125 m away. In contrast to the first type of test for spatial gradients, the second hypothesis test did not evaluate whether the concentrations steadily changed along a gradient; instead, it assessed whether the average concentration in the group of stations close to the outfall was significantly higher than that of distant stations, which would again be indicative of outfall-related impacts.

The "*p*-value" determines the significance of any perceived spatial gradient by testing it against a null hypothesis of no trend. It quantifies the probability that a perceived spatial gradient could have occurred by chance. When $p<0.05$, there is less than a 5% risk that the observed spatial gradient was happenstance due to random fluctuations. This threshold for designating potentially significant spatial gradients is consistent with the 95% confidence levels promulgated by the COP and used throughout this report. However, it is important to keep in mind that during any given year, a sediment constituent may exhibit an anomalous concentration at one or more stations that results in a spatial gradient that appears to be related to outfall proximity, for example, when that gradient is determined to be statistically "*significant*" at the 95% confidence level. Nonetheless, by the very definition of the 95% confidence level, one in twenty tests would be expected to reveal a "*significant*" gradient when, in fact, none exists.

Over the years, many constituents have been tested for spatial gradients, and occasionally the analysis identifies one that appears to be statistically significant at some particular time. Upon further analysis, however, the gradient has always been found to be unrelated to the discharge. Additionally, approximately half of the time, the statistically "*significant*" gradients reflect decreasing concentrations with increasing proximity to the outfall, which is opposite the spatial gradient expected from impacts associated with effluent discharge.

Table 4.8 Tests for Higher Contaminant Concentrations near the Diffuser

Parameter	Linear Trend		Difference in Means (mg/Kg)				Iron-normalized[1] *p*	Aluminum-normalized *p*
	Slope	*p*[2]	Near[3]	Distant[4]	*t*[5]	*p*[2]		
Aluminum (g/Kg)	0.001	[0.87]	6.25	6.16	0.73	0.27	[0.18]	NA
Arsenic	-0.057	0.08	3.66	3.34	1.01	0.21	0.32	0.28
Chromium	0.038	[0.19]	52.0	52.7	-0.15	[0.45]	[0.29]	[0.35]
Copper	-0.037	0.11	3.59	3.28	2.08	0.06	0.09	0.11
Iron (g/Kg)	-0.016	0.10	10.3	9.9	2.56	**0.04**	NA	0.18
Lead	0.000	[0.98]	2.39	2.35	0.47	0.34	[0.16]	0.48
Nickel	-0.069	**0.04**	51.0	43.3	2.42	0.07	0.07	0.09
Zinc	-0.020	0.10	18.0	16.9	5.62	**0.01**	0.11	**0.03**
BOD	-0.007	0.84	37.9	38.5	-0.21	[0.43]		
TKN	-0.012	0.68	169	159	1.04	0.18		
TVS (%)	-0.024	**0.05**	2.35	2.03	1.91	0.10		
Mud (%)	0.037	**[0.01]**	1.40	1.75	-1.68	[0.12]		

For example, in the 2015 database, three sediment parameters exhibited a statistically significant spatial gradient. Consistent with the visual impression from the second bar graph in Figure 4.4, linear regression of raw nickel concentrations revealed a negative gradient (-0.069 in the *Slope* column of Table 4.8) that was large enough to be statistically significant with a *p*-value of 0.04 (significant *p*-values less than or equal to 0.05 are highlighted in bold in the table). However, as discussed previously, the significance of the slope is entirely due to a low concentration at the Reference Station B1, rather than a spatial gradient at the remaining stations closer to the outfall. Furthermore, the Reference Station value is particularly influential in the regression analysis because of its spatial separation from the other stations. Without Station B1, the nickel linear trend is far from significant (p=0.44). TVS and mud also exhibited significant linear trends related to outfall proximity, and are discussed below.

As with the trend tests, only two significant spatial differences were found when average concentrations at groups of stations near and far from the outfall were tested. The results of tests for significant differences in mean concentrations are shown in the remaining columns of Table 4.8. Average iron and zinc concentrations were significantly higher among the stations near the outfall (p=0.04 and p=0.01 in the "*Difference in Means*" columns of Table 4.8). As described previously, spatial differences in raw iron concentrations are unrelated to the discharge, and when zinc is normalized by iron, the difference in its near and far average is no longer significant (p=0.11 in the second to the last column of Table 4.8). Similarly, normalization by aluminum reduces the significance of the zinc difference (p=0.03 in the last

[1] Results of hypothesis tests performed on trace-metal concentrations normalized by the iron and aluminum concentration to reduce the potential influence of inherent variability in background metal concentrations.

[2] *p*-value or probability that a linear gradient is not significant or that a higher nearfield mean concentration is not significant (null hypotheses). In this study, *p*-values less than 0.05 (95% confidence) indicate that there is a linear gradient or that nearfield means are significantly higher, and the null hypothesis can be rejected (shown in bold font). Note, however, that a "*one-sided*" *t*-test was performed, in which only higher, rather than lower, nearfield concentrations are meaningful. Consequently, *p*-values for negative *t*-values are not pertinent and are indicated with brackets.

[3] Mean concentration computed among Stations B3, B4, B5, and B6, which lie within 88 m of a diffuser port (the largest closest-approach of chemistry grabs in Figure 4.2). For percent concentrations, an arc-sine transform was applied to the concentrations prior to hypothesis testing. For other units, a logarithmic transform was applied.

[4] Mean concentration computed among Stations B1, B2, and B7, which lie more than 125 m from a diffuser port.

[5] *t*-value computed from the difference in near and far mean concentrations relative to measurement variability. A negative *t*-value indicates that the computed mean concentration was lower at stations near the diffuser, opposite of that expected in an environment impacted by effluent discharge.

column of Table 4.8). Regardless of the ambiguous results from tests on mean zinc concentrations, the 1.1 mg/L perceived difference in raw concentrations was small compared to the scatter in concentrations measured at individual stations (namely, the 95% confidence interval encompasses all the measured zinc concentrations in the third bar graph in Figure 4.4).

Table 4.8 also provides the results of statistical tests for spatial gradients in concentrations of the four organic loading parameters (Figure 4.6). The trends that are visually apparent in distance-ranked TVS and mud concentrations (bottom bar graphs in Figure 4.6) resulted in statistically significant linear regressions (p=0.05 and p=0.01 in the "*Linear Trend*" columns of Table 4.8). However, the significance of the TVS trend was marginal, and the mud trend was opposite of the trend expected from the deposition of wastewater particulates, namely, increased fines near the outfall. Accordingly, the significance of the mud trend is enclosed by brackets in Table 4.8 because it is irrelevant to the compliance assessment.

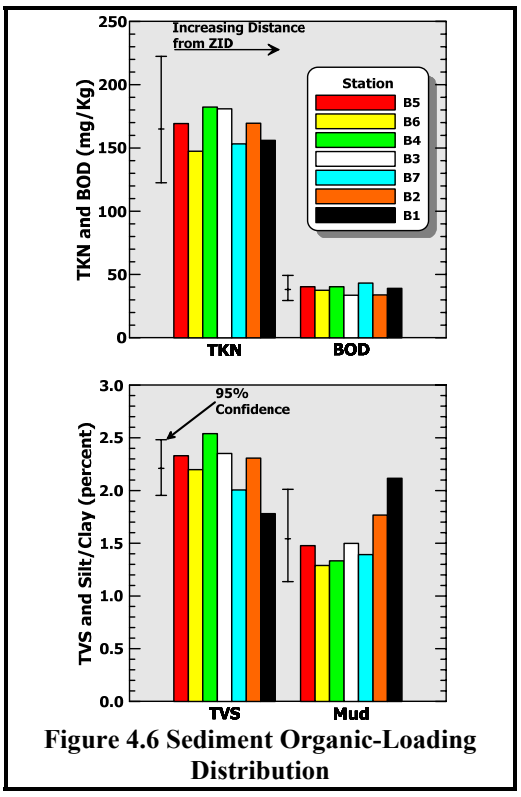

Figure 4.6 Sediment Organic-Loading Distribution

Upon closer examination of the bottom bar graphs of Figure 4.6, the apparent spatial gradients are largely the result of an anomalous concentration at Reference Station B1, rather than a regularly increasing or decreasing sequence at the other stations. For both TVS and mud, the concentrations at Station B1 (black bars) are the only ones that range beyond the 95% confidence intervals describing the uncertainty in measurements at individual stations. As with the nickel trend described previously, the perceived TVS and mud trends are far from significant (p=0.55 and p=0.16) without the inclusion of Station B1 data.

As discussed in Sections 4.1.1 and 5.4, the sedimentary environment at Station B1 has been found to be consistently and fundamentally different from that of the other monitoring stations. This is primarily due to Station B1's larger, 1-km distance from the outfall, and more northerly location within Estero Bay (Figure 4.1), where more-quiescent oceanographic conditions prevail.[1] Because of its depositional environment, sediment samples collected at Station B1 have mud fractions that have historically been measurably greater than in samples collected at all other monitoring stations. This was again the case in 2015, when the mud fraction at Station B1 was 75% greater than other stations (black bar in the lower right of Figure 4.6). This influential measurement caused a highly significant spatial gradient (p=0.01 at bottom of Table 4.8) in the mud distribution. However, the positive gradient is opposite of what would be expected from a buildup of fine wastewater particulates around the outfall, so this statistical test is irrelevant for the compliance analysis and the associated p-value is enclosed in brackets.

[1] The prevailing wave field is from the northwest and much of northern Estero Bay is in the wave shadow of Point Piedras Blanca and Point Estero (Figure 3.7). Station B1's northerly location is more protected from swells arriving from the northwest.

4.2.3 No Buildup over Time Related to Wastewater Discharge

The previous section examined the spatial distribution of sediment constituents at a single point in time, namely, during the October 2015 survey. However, the characteristics of ambient sediments at individual stations can be inherently different because of slight differences in their water depth, or because of differences in the depositional characteristics of their geographic location. For example, as stated previously, Station B1 lies in a more quiescent area north of the outfall. These factors complicate the interpretation of any perceived spatial gradients with respect to effluent discharge. Examining changes in spatial distributions over time, however, significantly improves the power to detect potential discharge-related impacts. Specifically, if there were any measurable marine impacts from wastewater discharge, they would be revealed by a long-term buildup of contaminants in sediments surrounding the outfall, as compared to distant stations. Consequently, examining spatial gradients in contaminant concentrations over time can reveal discharge-related trends that may be masked in a spatial analysis applied to a single survey.

However, perceived temporal trends in contaminant concentrations must be interpreted carefully because natural and anthropogenic processes unrelated to the effluent discharge can also cause large and widespread changes in chemical concentrations within sediments. These regional influences are apparent in the time series of sediment chemical concentrations shown in Figure 4.7, Figure 4.8, and Figure 4.9. Specifically, the large-amplitude fluctuations that occur over periods of a few years reflect widespread seasonal and interannual changes in the sedimentary environment. Similarly, overall trends in the concentrations of five sediment constituents that are apparent in the decade-and-a-half prior to 2000 are in response to even longer-term influences (Figure 4.7abc, Figure 4.8a, and Figure 4.9c).

Nevertheless, these large interannual fluctuations and long-term increases tend to occur in unison at all stations, so the spatial differences among samples collected at a given time (i.e., within a given survey) are comparatively small. In other words, the fluctuations in concentrations generally tracked one another through time. This indicates that changes in sediment concentrations that arise from regional influences throughout Estero Bay are far larger than those induced by any localized effects are. During a given survey, spatial differences in sediment concentrations tend to remain within the 95% confidence interval (shown to the right of each time series in the figures) that quantifies the uncertainty in individual measurements.

As described in the previous section, these confidence bounds indicate that most spatial differences within a given survey are not statistically significant, while interannual fluctuations and long-term trends are large enough to be reliably quantified in the presence of sampling uncertainty. Any subtle spatiotemporal trends in sediment chemical composition that may be related to the MBCSD discharge are difficult to discern in the presence of these large regional excursions in sediment chemistry.

The pre-2000 long-term increase in the sediment concentrations of a number of metals, predominately arsenic, chromium, nickel, and copper, was the subject of intensive investigation in prior annual reports (MBCSD 1999b, 2000a, 2001 – 2010) and in an independent, separate field study (MRS 2000b). Those analyses unequivocally demonstrate that the observed increase could not be caused by the MBCSD discharge because: 1) the accumulation occurred at all stations, including stations distant from the outfall, 2) the MBCSD metals emission was far too small to account for the widespread increase, and 3) the discharge remained unchanged while the trend in average concentrations leveled out after 2000. Instead, the steady increase in sediment metal concentrations prior to 2000 was ascribed to accelerated erosion of contaminated mine tailings at abandoned chromite mines within the adjacent watershed. After 2000, sediment concentrations appear to have reached equilibrium with the metal loading from the watershed's runoff into Estero Bay.

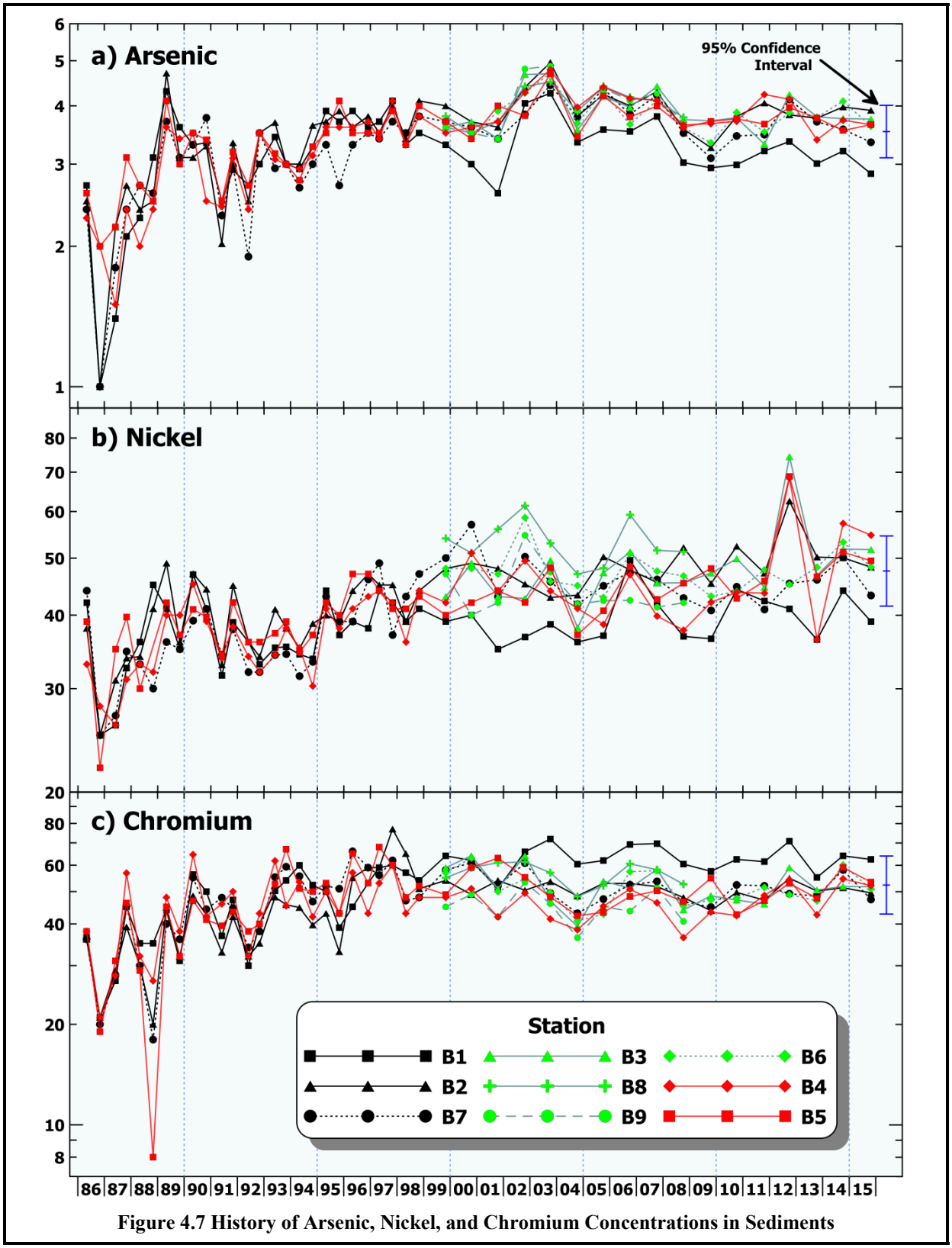

Figure 4.7 History of Arsenic, Nickel, and Chromium Concentrations in Sediments

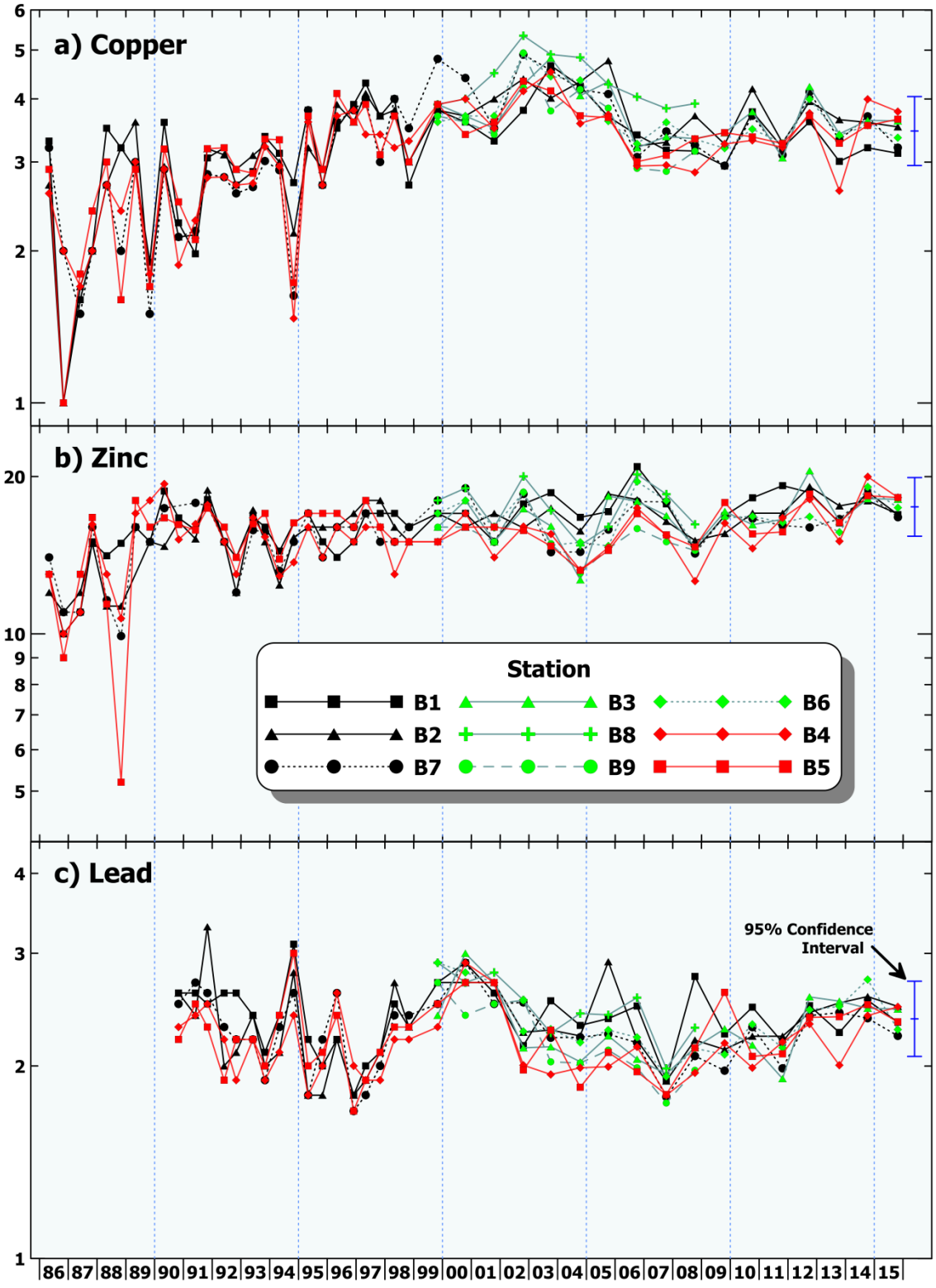

Figure 4.8 History of Copper, Zinc, and Lead Concentrations in Sediments

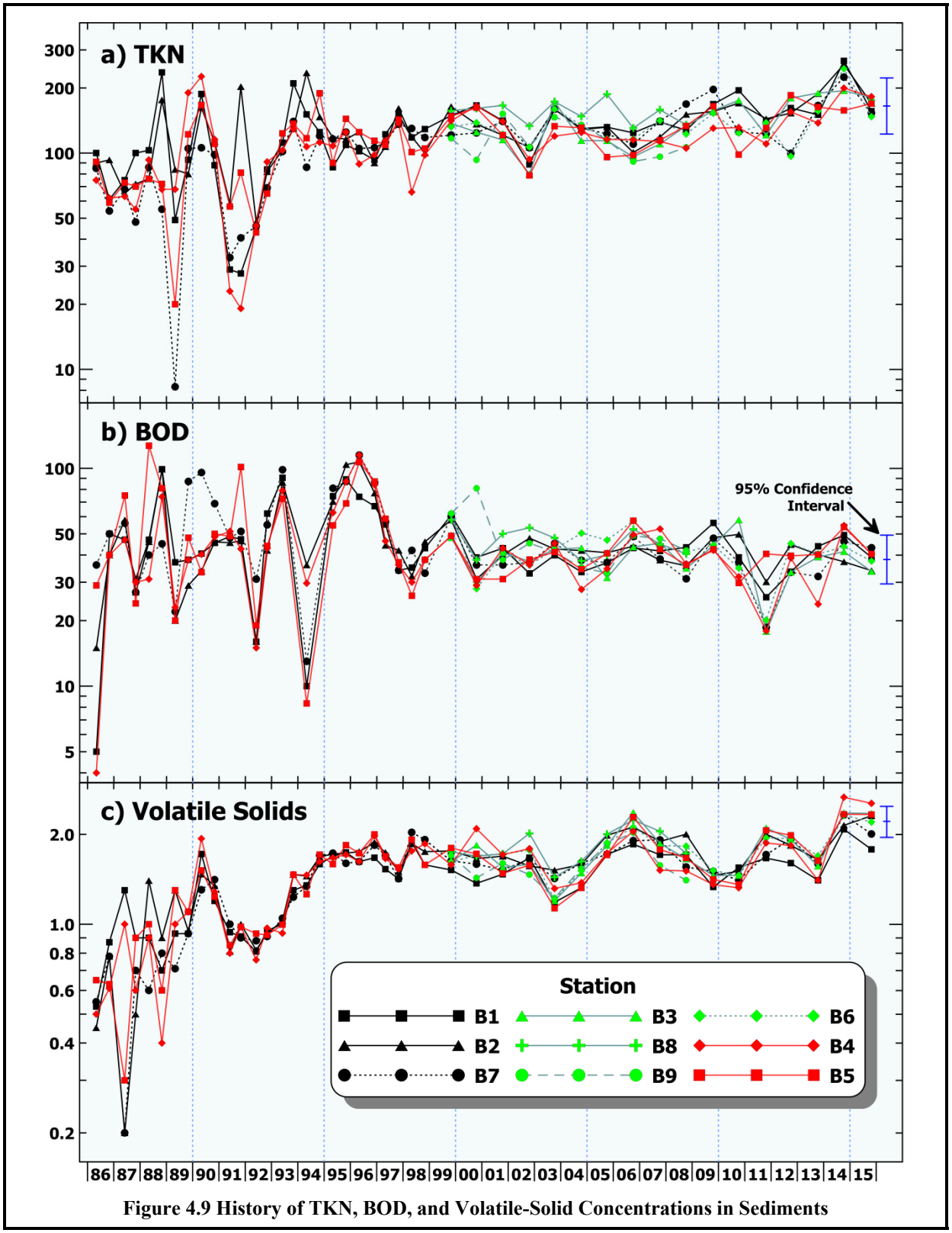

Figure 4.9 History of TKN, BOD, and Volatile-Solid Concentrations in Sediments

Discerning subtle localized impacts within the backdrop of large interannual fluctuations and long-term trends is aided by a special statistical technique for assessing the presence of parallel time histories. Parallelism tests overcome limitations associated with purely spatial or purely temporal approaches to impact evaluation (Coats et al. 1999, Skalski et al. 2001). This technique assumes that the large temporal excursions in concentrations occur in unison at all stations and represent a simultaneous response to regional influences unrelated to the MBCSD discharge. Under those circumstances, discharge-related spatiotemporal changes would appear as a gradual separation of the colors in Figure 4.7, Figure 4.8, and Figure 4.9, as contaminants preferentially accumulate near the outfall over time. Concentrations at nearfield stations (shown in red) would slowly increase relative to concentrations at mid-field (green) and distant reference stations (black). However, because of the large coherent fluctuations that occur over time, subtle spatiotemporal changes may be present but not visually apparent in the time series.

Analysis of the difference between average concentrations at stations located near the outfall, and those that are distant from the outfall, effectively removes the temporal oscillations that occur on a seasonal and interannual basis. Specifically, if the time series of average concentrations near the outfall parallel those of distant stations, then there is little evidence of a discharge-related accumulation. A parallelism test is also insensitive to inherent differences in the sedimentary environment at the two groups of stations, as was previously described for Reference Station B1, for example. Distant stations may have consistently higher (or lower) average concentrations because of natural spatial differences in the benthic environment, but because the parallelism test only deals with trends in the difference between the two groups of stations, rather than their absolute values, such natural spatial variations are appropriately eliminated from the compliance evaluation.

Time series of differences in sediment concentrations at ZID and distant stations are presented in Figure 4.10. If contaminants discharged by the MBCSD discharge were accumulating in sediments near the outfall, then concentrations at stations nearest the outfall (B4 and B5) would slowly increase relative to distant stations (B1, B2, and B7). These increases would appear as positive slopes in the average difference shown in Figure 4.10. A regression test for a statistically significant trend (slope) in the difference is equivalent to a test of the null hypothesis that the contaminant concentrations at impacted and non-impacted sites remain constant (parallel) over time.

During 2015, arsenic, nickel, lead, and TVS each exhibited slightly positive slopes, suggesting the possibility of a buildup of wastewater contaminants close to the discharge compared to more distant stations. However, the associated *p*-values (0.06, 0.02, 0.64, and 0.36), which measure confidence in the slope of the line, indicate that only the nickel trend was reliably resolved.

All of the other chemicals exhibit negative slopes indicating that ZID concentrations have generally decreased over time relative to the reference stations. Because this trend is opposite of that expected from a buildup of contaminants near the discharge, the parallelism hypothesis test is irrelevant for a compliance evaluation, so the associated *p*-values for the parallelism test are listed with brackets surrounding them in Figure 4.10. Nevertheless, significant negative slopes are still of interest because they can indicate large-scale spatial gradients within the sediments of Estero Bay, albeit unrelated to the outfall.

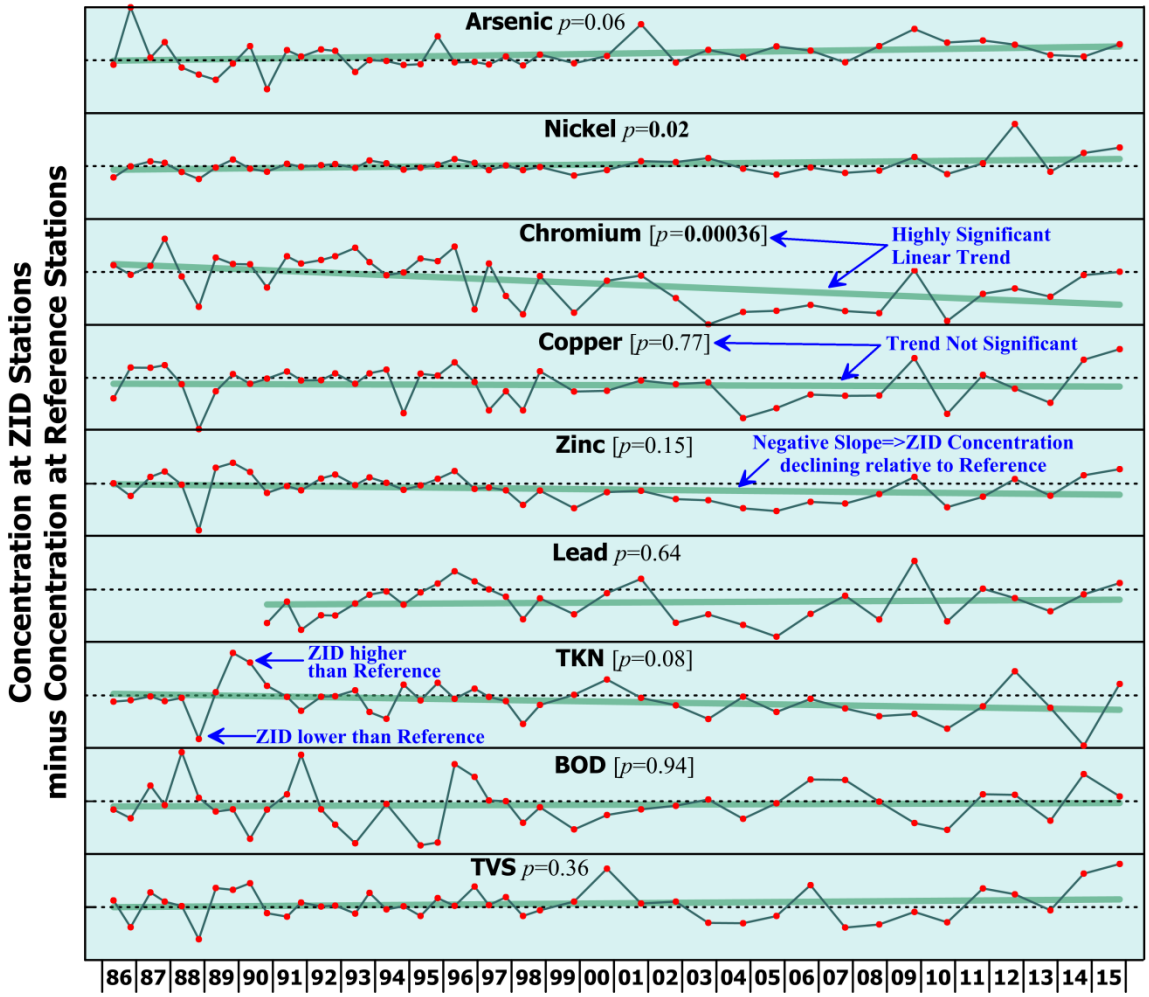

Figure 4.10 Difference in Average Concentrations at ZID and Reference Stations

For example, chromium exhibits the strongest case by far for rejecting parallelism (p=0.00036), and accepting the alternative hypothesis that chromium concentrations are actually increasing at distant stations compared to those near the outfall. This relationship is confirmed by the individual time series shown in Figure 4.7c. Early in the record, chromium concentrations at the most-distant reference station (B1), shown by the black squares, were comparable to those of other monitoring stations. In the latter half of the record, however, chromium concentrations at Station B1 can be seen to diverge from rest of the group. Specifically, in each of the last thirteen years, concentrations of chromium have been higher at Station B1 than at any of the other stations. However, this probably results from Station B1's large geographic separation from the rest of the monitoring stations. Specifically, the slightly higher chromium concentrations at Station B1 probably result from its proximity to the mouth of Toro creek whose watershed encompasses a relict chromite mine, and where erosion of the mine tailings may be preferentially deposited.

An important attribute of parallelism is that it only addresses trends, and masks inherent differences in overall concentrations within the two groups of stations. This attribute is apparent in the linear regression line of concentration differences in lead (green line in the fourth-from-the-bottom frame in Figure 4.10), which is consistently offset below the zero-difference line (dashed line in the frame). This aspect differs from the other regression lines in the figure, and indicates the average lead concentrations at the ZID stations were almost always lower than the reference station averages. However, the parallelism test appropriately ignores this consistent offset that is probably due to some naturally-occurring inherent difference between the two groups of stations. Instead, parallelism focuses on changes over time, namely the slope of the regression line, which for lead, provides strong evidence that the trends were parallel (p=0.64) and that there was no preferential buildup at either group of stations over time.

The history of nickel concentrations provided the only statistically significant departure from parallelism in 2015. Normally, this would indicate a potential buildup at sites closer to the outfall (p=0.02 in the second frame of Figure 4.10). However, the significance departure resulted from a single, highly influential outlier in 2012. The outlier was influential in the regression, not only because of its amplitude, but because it occurred near the end of the time series. Had these measurements been made in the middle of the time series, for example during the year-2000 survey, it would have had little or no effect on the determination of the slope of the regression line. Without this influential outlier, nickel concentrations near and far from the diffuser were parallel with a high degree of confidence (p=0.11).

The striking departure found in some of the 2012 nickel concentrations are clearly apparent in the individual time series shown in Figure 4.7b where extraordinarily high nickel concentrations were measured sediment samples collected at Stations B2, B3, B4, and B5 while the other stations had concentrations comparable to prior years. The raw nickel concentrations measured at these stations in 2012 all greatly exceeded the highest concentration (61 mg/Kg) measured in three decades of monitoring, and the 74-mg/Kg concentration measured in the sample collected at Station B3 in 2012, was 20% higher than the previous maximum. The reason for the anomalously elevated nickel concentrations remains unknown. Nickel is present in naturally high concentrations within the mineralogy along the central California coast, and it is possible that variation in erosion and deposition was responsible for the observed variability in 2012. However, nickel and chromium tend to co-occur within the chromite deposits, yet chromium concentrations do not mirror the nickel distribution in the year-2012 sample set. It is also possible that sample contamination in the field or laboratory was responsible for the elevated measurements. Regardless of the reason for the high nickel concentrations measured at some stations in 2012, they were unrelated to the effluent discharge because they did not consistently increase with proximity to the outfall.

The parallelism analysis provides insights into the distribution of contaminants within the ambient sediments of northern Estero Bay independent of the MBCSD discharge. As described above, lead concentrations at the ZID stations (Stations B4 and B5) are typically lower than at the reference stations, but the spatial gradient has not changed over time. In contrast, chromium concentrations at the more distant stations (B1, B2, and B7) have been steadily increasing relative to the ZID sites. With few exceptions, arsenic, copper, zinc, TKN, BOD, and TVS concentrations are all spatially uniform, and have remained so over the past three decades. Although all the previously described aspects of the sedimentary environment of Estero Bay are unrelated to the discharge, they suggest care is warranted when assessing potential impacts to the seafloor from human activities in the region.

4.3 BENTHIC INFAUNAL COMMUNITY

The infauna living within the surficial sediments of northern Estero Bay provide additional insights into the ambient seafloor environment in the region. They are also particularly effective for compliance determinations that assess the presence of a BIP surrounding the outfall. They act as sentinels that are responsive to possible impacts caused by wastewater discharge that may be too minor to be revealed in the analysis of chemical constituents alone. Infauna are the best biological indicators of marine pollution because they have limited mobility and cannot easily escape exposure to contaminants in their immediate environment. Other organisms, such as marine mammals and finfish, range widely, making it impossible to determine where contaminant exposure may have occurred.

The diffuser structure lies on the seafloor, where particulate contaminants discharged into marine waters ultimately settle and accumulate. Because infauna reside within seafloor sediments, they are close to the potential source of pollution. Additionally, infaunal species vary in their sensitivity to pollutant stressors. As such, changes in relative abundance among species can signal the presence of subtle alterations in their environment. Infauna are also important organisms to monitor because of their low trophic level within the marine food web. They are a major food source for more-mobile epifaunal and pelagic marine organisms, such as crabs, finfish, and marine mammals.

In recognition of infauna's role as an early detector of marine pollution, the MBCSD discharge permit requires regular monitoring of the overall health of the benthic community within Estero Bay. As such, infaunal monitoring addresses the COP requirement that the discharge not degrade indigenous marine biota (see Objective E.1 in Table 3.1 on Page 3-3). The benthic monitoring has now amassed three decades of infaunal data. During that time, 258,000 specimens representing 390 individual taxa have been collected, identified, and enumerated. Throughout the monitoring program, there has never been an indication of deleterious discharge-related impacts to the benthic community. Instead, the data have revealed a consistently healthy indigenous infaunal community with uniformly high diversity beyond the ZID, and no evidence of degradation in the infaunal assemblages related to ZID proximity.

These observations hold true despite widespread variations in the abundance of individual organisms. Over the years, the dominance of individual taxa have waxed and waned in response to natural changes in the environment. Additionally, for many taxa, distinct differences in abundance are evident between the winter and summer sampling seasons. Other species come and go in response to powerful long-term variations in the oceanographic environment. One such variation is the El Niño – Southern Oscillation, whose impact has been clearly evident in the benthic environment of northern Estero Bay on at least four occasions during the last three decades of MBCSD monitoring (NOAA 2010). The first event was in 1988, and the second began at the end of 1997 and extended into 1998. Its influence on benthic organisms was still evident during 1999. Another minor event may have occurred in 1991; however, the event with the largest influence on faunal populations around the outfall occurred in 2009 when the faunal density was 100-times higher than historical average due to a huge explosion in the sand-dollar population. The effects of this initial population boom continued to be apparent through 2014 as the original cohort matured and grew in size. As described in this section, this cohort profoundly affected the entire infaunal community in 2015 when numerous mature sand dollars (*Dendraster exentricus*) dramatically altered the benthic environment and displaced a large fraction of the sediment that is normally collected within each grab.

Over 3,640 individual organisms, mostly consisting of sand dollars, were enumerated in the 35 sediment samples that were collected during the benthic survey conducted in October 2015. A compendium of the taxonomic identifications and enumerations conducted on the year-2015 sediment samples is provided in Tables B.1 through B.8 in Appendix B at the back of this report. Tables B.9 and B.10 list infaunal indices

that were computed from infaunal data, as required by the NPDES monitoring and reporting program. This section of the annual report combines these data with biological data collected over the prior 29 years to determine whether there have been discharge-related impacts to the benthic biota.

Three analyses were conducted to evaluate whether there have been deleterious impacts to benthic organisms as a result of the discharge. First, the organisms that inhabit the sediments around the outfall were evaluated to determine whether they indicative of an indigenous community. In the past, the indigenous infauna were dominated by filter-feeding organisms that thrive only in clean sediments, but in 2015, the infaunal community throughout the survey area transformed into one more typical of dense sand-dollar beds. Second, infaunal data collected during 2015 were assessed for evidence of spatial gradients indicative of biotic degradation attributable to effluent discharge. Third, the variations in time histories of community parameters were examined for long-term spatiotemporal trends indicative of an increasingly degraded benthic environment around the outfall. The historical record shows that infauna at individual stations tend to respond in unison to large interannual and seasonal influences on the infaunal community. To date, the indigenous benthic community remains healthy, with no perceptible influence from ambient contaminant levels, including the previously discussed long-term trends in some trace-metal concentrations that occurred throughout Estero Bay prior to 2000.

4.3.1 Excluded Organisms

In the past, fluctuations in the population of two organisms, *Diopatra ornata* and *D. exentricus,* have had a profound effect on the MBCSD infaunal database. However, these organisms and their attached taxa are not particularly diagnostic of changes in sediment quality, and their presence frequently confounds impact assessments. Consequently, their populations were removed from the database prior to the impact assessments described in this section.

Tube Worms

Since 2000, the parchment tubes of the Ornate Tubeworm (*D. ornata*) have routinely been separated in the field prior to sieving of the infauna. Ornate tubeworms are so called for the elaborate layering of pieces of shells, algae, sticks, and other debris on the outside of their large parchment tubes (Figure 4.11). Large numbers of nestling epibionts reside on the microhabitats created by these tube casings, including small crabs and other crustaceans, particularly Gammarid amphipods. Inclusion of these epibionts in the infaunal database can dramatically skew the enumeration of marine infaunal organisms in samples where they are present. Removal of the *D. ornata* parchment tubes in the field, prior to sieving, limits sample contamination by the epibionts associated with these tubes. The tubeworms themselves, however, are included in the enumerations because they tend to congregate in higher densities close to both natural reefs and manmade structures, such as outfalls (Davis et al. 1982).

Figure 4.11 Photograph of a Tubeworm (*Diopatra* sp.)

No *D. ornata* tube casings were found in the infaunal sediment grab samples collected during the October 2015 survey, although, in most prior surveys, a few individual specimens are normally observed and removed prior to sieving offshore. Their absence during the 2015 benthic survey was due to the presence

of dense bed of mature sand dollars (*D. exentricus*) that disturbed surficial sediment and associated infauna within all the grab samples collected during the 2015 survey (Woodin 1978). In prior surveys, removal of the parchment tubes prior to sieving helped limit the introduction of associated epibionts, but some of these organisms also reside in sediment immediately surrounding the tubes (Wooden 1978), and as a result, their influence was still partially evident in the historical infaunal record. Thus, even though the tubes were removed immediately upon retrieval of the sediment grab samples, those samples were found to contain fauna that were distinct from the communities in all the other replicate samples (MRS 2013–2015a).

Sand Dollars

Statistical analyses performed on the 2015 benthic samples also excluded enumerations of Pacific sand dollars (*D. excentricus*). Although sand dollars can be sensitive to pollution, they are excluded from the database prior to statistical analysis because they exhibit extreme population fluctuations from year to year (Figure 4.12), which can potentially mask discharge-related impacts on less-dominant taxa. Additionally, because they tend to reside on the sediment surface, they are not, strictly speaking, infauna, and because of their large size at maturity compared to the dimensions of the grab sampler, there is a greater risk of undersampling sand dollar populations as compared to most infauna. Lastly, because their populations can be extremely patchy, surveys prior to 2015 have found that even closely spaced replicate grab samples contain vastly different abundances, confounding the determination of spatial trends in their distribution across the survey area.

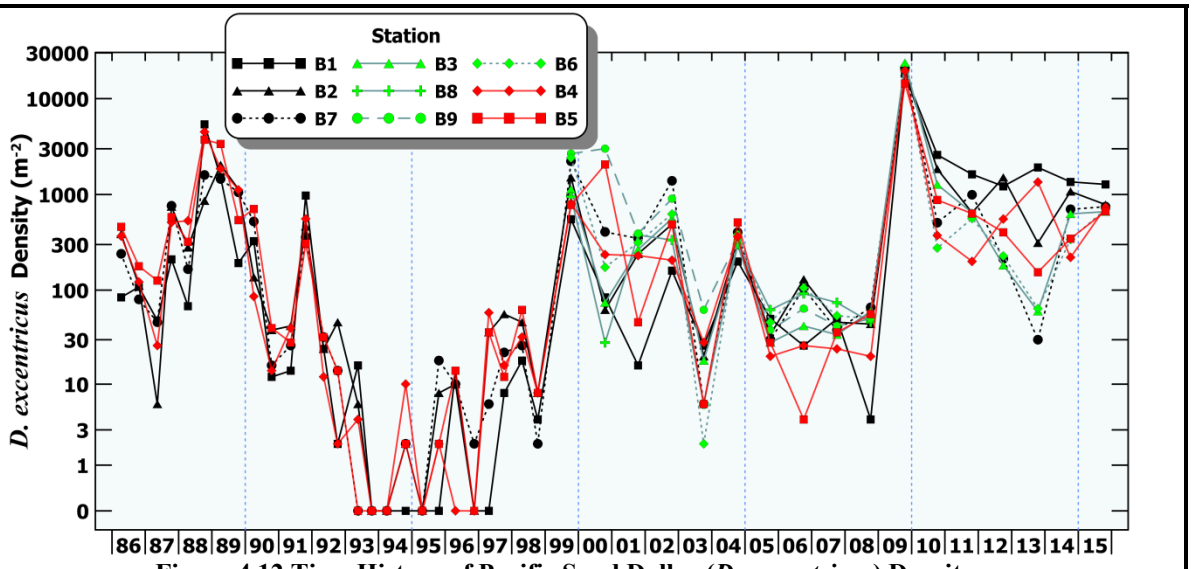

Figure 4.12 Time History of Pacific Sand Dollar (*D. excentricus*) Density

Sand Dollar Biology

Sand dollars form dense beds just seaward of the wave break. At that location, predation is limited because predators such as sea stars can move over the sand-dollar bed only at significant risk of tumbling into the surf zone with a passing wave (Morin et al. 1985). Consequently, sand-dollar beds migrate shoreward in the summer and seaward in the winter in response to seasonal wave action (Oliver et al. 1980). A winter of strong wave action, frequently associated with El Niño events, may reduce predation, permitting enhanced recruitment of juvenile sand dollars. Specifically, the increased sand-dollar

recruitment that occurred in late 1988, 1991, 1999, and 2009 may have been related to El Niño events that occurred around the same times (Figure 4.12).

Sand-dollar beds are often dominated by a single age cohort, suggesting that recruitment is episodic and only occasionally successful (Cameron 1980, Oliver et al. 1980, Morin et al. 1985, Cameron and Rumrill 1982). During low-population years, the exclusion of *D. excentricus* specimen counts from the database had little impact on the statistical analyses of benthic populations. This was the case between 1992 and 1998 when average sand dollar densities were less than 50 m^{-2}. However, because their numbers overwhelmingly dominate the population statistics during and following high-recruitment years, inclusion of sand-dollar enumerations has the potential to mask any influence of the discharge on less-dominant taxa. The populations of some of these other taxa are sensitive to potential discharge impacts and are generally more stable over the long-term, which allows slight population changes arising from localized anthropogenic impacts to be more easily discerned.

Figure 4.13 Comparison of the Sand Dollar cohort in a) 2009, b) 2010, c) 2011, and d) 2012

2009 Sand Dollar Recruitment

For example, the extremely successful recruitment event that took place in 2009 resulted in the collection of more than 67,000 individual sand dollars, while only 4,289 other infaunal specimens were collected during that survey (MRS 2010). In the presence of such an extreme sand-dollar population, consistent year-to-year evaluation of infaunal community structure could only be achieved by excluding the large sand dollar population from the diversity indices computed for 2009. Although these juveniles incurred a high mortality rate (>90%) over the following year, the cohort of sand dollars originating from this recruitment event steadily increased in size as they matured (Figure 4.13abcd). Another smaller recruitment event occurred in 2013 and resulted in the presence of two distinct cohorts in that database, one consisting of small, first-year juveniles, and the other consisting of large, mature sand dollars.

During 2014 and 2015, the sand dollar population was again comprised solely of adult specimens from the original 2009 cohort. The number of sand dollars collected during each respective survey (2,331 and 2,788 individuals) was nearly double the amassed total of all other benthic organisms collected during the 2014 survey (1,334 individuals) and more than triple the number of other infauna collected during the 2015 survey (853 specimens; refer to Table B.1 in Appendix B). Because of their large numbers, inclusion of sand-dollar counts in the databases overwhelmed computations of population statistics and masked variations in community structure among other infaunal taxa.

For example, community indices computed with the inclusion of the 2015 *D. excentricus* population (Table B.9) were vastly different from indices computed without their inclusion (Table B.10). Most indices, such as dominance and diversity, measure the uniformity in abundance among species. When an overwhelmingly dominant sand dollar population is included in the indices, trends in the diversity due to population differences in other taxa are completely masked. For example, the Swartz dominance index (*Sw*, see Section B.1.2) is normally a relatively diagnostic and stable measure of the overall health of the infaunal community. However, because sand dollars represented more than 75% of the identifiable species in 22 of the 35 replicate samples collected during 2015, the index remained at unity (See the *Sw* column in Table B.9); and as such, provided no information about the relative abundances of all the other less-abundant taxa. Exclusion of sand dollars from the computation of indices (Table B.10) permits the influence of these other taxa to be discerned in the indices. Note that the infaunal trophic index (*ITI*) was unaffected by the exclusion of sand dollars because they are not members of the feeding guilds quantified by that index.

Thus, exclusion of the sand-dollar population enhances the impact evaluation by allowing other less abundant, but potentially more pollution-sensitive taxa to participate in the analysis. Moreover, the sand-dollar time history does not exhibit a readily apparent relationship to outfall proximity over time. As with the chemical constituent time histories, any trend in the spatial distribution of sand-dollar populations that is related to outfall proximity would be evident in the sand-dollar population history (Figure 4.12) as a gradual separation between the time histories for the ZID stations (red), for midfield stations (green), and for stations well away from the diffuser structure (black). Instead, large fluctuations in the overall record of sand-dollar abundance tend to occur equally at all stations. However, the spatial distribution of 2009 cohort was a notable exception in that the sand dollar density was consistently higher at Upcoast Reference Station B1 in all six years following the recruitment event, except in 2012 when it was a close second (black squares in Figure 4.12).

Other Sand Dollar Influences

As described above, the overwhelming influence of sand dollar variability on infaunal population statistics is easily eliminated by simply excluding their counts prior to the analyses. However, the presence of sand dollars can also strikingly affect the benthic infaunal analysis in two other ways. In contrast to the influence of high numbers on population statistics, these two other influences cannot be mitigated, and in 2015, their presence severely compromised the ability compare that year's data with prior non-*Dendraster* infaunal analyses. First, the presence of numerous large sand dollars within grab samples markedly reduced the sediment volume remaining within the grab samples. Second, their presence altered the infaunal community by introducing parasitic and opportunistic taxa capable of coexisting with them, and by eliminating taxa that normally reside in a less-disturbed benthic environment. The burrowing activity of sand dollars reworks surficial sediments and eliminates delicate suspension-feeding taxa that are considered sensitive to pollution because their populations decline upon exposure in undisturbed benthic environments. The overwhelming presence of sand dollars also allows the incursion of the few opportunistic taxa that can coexist with sand dollars, and that under other circumstances, would be considered pollution tolerant (Chia 1969; Rhoads and Young 1971; Woodin 1978; Merrill and Hobson 1970; and Smith 1981).

Reduced Sediment Volume in 2015

The population record shown in Figure 4.12 does not provide an indication of these other two sand-dollar influences, particularly in 2014 and 2015. The Figure shows that sand dollar density has been relatively constant for the last six surveys, after the initial recruitment of a huge number of tiny specimens in 2009

(Figure 4.13a). While the number of sand dollars collected since that survey has remained relatively constant, their size has increased dramatically (Figure 4.13bcde). The resulting increase in sand-dollar volume successively displaced greater amounts of sediment within the grab samples. Thus, the amount of sediment actually processed for infaunal organisms has steadily decreased with each successive survey and in 2015, the presence of very large, mature sand dollars left little sediment in the grab for sieving offshore. As a result, infaunal sample sizes steadily declined in recent years and beginning with the 2014 survey, the markedly smaller sediment volumes dramatically affected every aspect of infaunal community evaluation, and made comparison with data collected in prior years untenable.

The increased significance of reduced sediment-sample sizes was immediately evident upon recovery of the first benthic grab sample collected during the October 2015 survey. However, nothing could be done to ameliorate its impact. Sampling requirements specified in the NPDES discharge permit preclude methods that could increase sediment sample volume and result in a more reliable and historically consistent infaunal assessment. Increased volumes could have been acquired by collecting additional replicate samples at each station, but the discharge permit specifies the number of replicate infaunal samples to be collected at each station and in the field, it would be difficult to determine the number of extra grabs needed to match the sample volumes collected in prior years.

The discharge permit also prescribes the target locations for benthic sampling, disallowing intentional relocation of the sampling stations slightly shoreward, or farther offshore, to avoid the sand dollar bed. At any given time, sand dollar beds tend to be isolated within a narrow water-depth range, but sampling at locations other than the fixed target sites along the diffuser isobath would confound the assessment of potential gradients extending from the discharge. Reduced sediment sample volumes resulting from large sand dollar volumes only became problematic in 2014 and 2015 when much older and larger individual sand dollars were present. Population increases associated with past sand dollar recruitment events (in 1988, 1991, and 1999 in Figure 4.12) generally dissipated within a year or two of the initial recruitment. In addition to predation[1] and other factors, observed declines in sand dollar populations after recruitment events may have resulted from the cross-shore movement of the sand dollar bed out of the survey area in response to changes in wave climatology from year to year (Merrill and Hobson 1970).

This was not the case for the 2009 recruitment. The initial population explosion was much larger than the increases seen in prior events, and it produced a populous cohort of surviving individuals that remained in the survey area for the following six years. Not only was their abundance relatively constant during this six-year post-recruitment period, but the population was much denser than most prior recruitments except during the initial short-lived recruitment itself. As the large number of maturing sand dollars grew in size, they began to occupy increasingly larger portions of the grab samples collected in each successive survey. In the years immediately following the 2009 recruitment, adequate sediment volumes were collected despite the presence of numerous small sand dollars. However, during the 2014 survey, strikingly lower sediment volumes were recovered from the grabs; and in 2015, seafloor sediment occupied only a small fraction of the grab sample. As a result, the infaunal population was severely undersampled during the 2015 survey, which compromised accurate characterization of the community and precluded reliable comparisons with the historical database. These sediment sample-volume artifacts are readily apparent in the population statistics described below.

[1] Surveys conducted in the year immediately following prior recruitment events encountered increased numbers of sea stars, usually ochre stars (*Pisaster ochraceus*), which are a primary sand-dollar predator. In contrast, few sea stars were encountered in the benthic surveys conducted after the 2009 recruitment, and this lack of predation may have contributed to the observed longevity of the sand dollar population. The recent absence of sea stars in the survey area may be related to the outbreak of sea star wasting disease, which particularly impacts ochre stars.

Taxonomic Influence

In addition to their impact on sample volume, the presence of a large swath of mature sand dollars within the survey area directly affected infaunal community composition by introducing opportunistic taxa that are capable of coexisting with them, and by eliminating suspension feeders that normally reside on the surface of an undisturbed benthos. Specifically, sand dollar predation on small crustaceans, such as amphipods and isopods, virtually eliminated some of these normally prevalent taxa from the 2015 database. Other impacts on the infaunal community arose indirectly through enhanced competition for food and space. Sand dollars can be both deposit and suspension feeders, and when little sediment is available, or has low organic content, they survive by suspension feeding (Timko 1976). Most other infauna do not have the same trophic flexibility and losses due to competition with the fully mature cohort of sand dollars in 2014 and 2015, undoubtedly contributed to the observed declines in abundance and diversity within the remaining infaunal community, as well as the other anomalous observations described below.

4.3.2 Indigenous Infaunal Community

The type and abundance of benthic organisms directly reflect the quality of the marine sediments where they live. Infaunal communities residing in degraded sediments tend to exhibit low species richness and diversity because they are populated by only a few opportunistic taxa that feed on detritus and thrive in sediments that are high in subsurface organics. In contrast, clean sediments are populated by diverse assemblages of organisms that include filter feeders, which extract nutrients from suspended particulates. These suspension feeders are sensitive to excessive organic particulate loads such as those that can be discharged from low-performance treatment works. Historically, the widespread presence of suspension feeders around the MBCSD outfall clearly indicates that the discharge was not adversely affecting them. One such suspension feeder is the club-tipped anemone (*C. californica*) that carpets the diffuser ports (see the photograph in Figure 2.2 on Page 2-4). Their presence is indicative of the benign nature of the suspended sediments discharged by the treatment plant.

In this and past reports, the overall health of the benthic community within Estero Bay is characterized by the principal population parameters computed from samples collected at each station over the duration of the monitoring program. The community parameters provide a succinct description of the abundance, diversity, richness, and trophic (feeding) structure of benthic biota. Figure 4.14 shows the temporal variability in mean community parameters that were computed for each of the nine historic benthic monitoring stations, seven of which have been monitored continuously, including in 2015. Each major category of community parameter is discussed in the sections that follow.

Abundance

Population density, shown in Figure 4.14a, measures the total abundance, or number of organisms, within a 1-m^2 area of the seafloor. It is the most basic single measure of a community of organisms, but lacks valuable insight as to how the abundance is distributed among the differing taxa. Because of this deficiency, it is not a useful ecological measure by itself. Nonetheless, major declines in organism density can occur after a rapid increase in sediment contamination. This initial decline is often followed by a marked increase in total abundance as opportunistic species repopulate the degraded environment.

Throughout the monitoring program history, the number of organisms collected at each station has fluctuated enormously. Although the range in abundance covers an order of magnitude, differences in abundance among individual stations within any given survey were generally smaller. Namely, all the stations tend to track the temporal fluctuations as a group, and spatial differences among stations within a

given survey are generally no larger than the wide temporal fluctuations between surveys. The relatively large temporal fluctuation places perceived spatial differences within a given survey into context; namely, if an ecosystem is able to accommodate seasonal and interannual population fluctuations with amplitudes exceeding spatial gradients, then the spatial differences observed during a given survey are probably not environmentally significant.

In that regard, prior to 1999 when seasonal survey data was available, the largest population changes occurred on a seasonal basis. Post-summer populations (those sampled during the October survey) were generally a factor of three higher than the post-winter populations. The reduced winter population, which was only measured prior to 1999, is a response to harsher oceanographic conditions when storms generate intense wave-induced currents that scour the bottom near the 15-m water depth of the outfall. Post-summer populations reflect recruitment of the more delicate annelid worms that can only survive during quiescent benthic-flow regimes. The absence of winter surveys after 1998 accounts for the uniformly higher densities that are apparent in Figure 4.14a for most of the last half of the monitoring record.

Spatial gradients in density tend to be masked by the large temporal fluctuations. In particular, abundances at stations near the outfall (shown in red) were not consistently lower than the density at distant stations (shown in black), and this lack of spatial distinction has remained constant throughout the monitoring program. It demonstrates that any accumulation of sediment chemicals from the effluent discharge over the last three decades has had no discernible impact on infaunal abundance, particularly when compared to large seasonal and interannual population fluctuations.

2009 Sand Dollar Recruitment

Following the major sand-dollar recruitment in 2009, overall infaunal densities (excluding sand dollars) began to decline. In 2010, infaunal density dropped to levels comparable to those of the post-winter surveys conducted prior to 1999. Infaunal densities remained at about these levels through 2013, probably in response to competition for food and space, and to predation by the large population of sand dollars. During the six surveys conducted after the 2009 recruitment, sand dollar abundance at Upcoast Reference Station B1 was almost always the highest (black squares in Figure 4.12) and accordingly, the density of other infaunal organisms at that station were often lower than at other stations (black squares in Figure 4.14a).

However, in 2014 and 2015, infaunal densities precipitously declined and reached the lowest densities recorded in the 30-year database. This dramatic recent decline in the abundance of infauna cannot be easily ascribed to predation or competition for resources, particularly considering that the numbers of sand dollars in 2014 and 2015 were comparable to prior post-recruitment years (Figure 4.12). Instead, as previously discussed, the recent sharp decline in infaunal populations was partially an artifact of undersampling caused by the physical presence of the numerous mature sand dollars within the grab samples. The sheer volume of sand dollars displaced the sediment normally collected with grab samples. Consistent sediment-sample volumes are necessary for an accurate intercomparison of infaunal abundances determined from the enumeration of taxa within individual grab samples. For that reason, infaunal sampling protocols require a grab penetration depth[1] of at least 7 cm to ensure that a sufficient volume of sediment is collected to assess the indigenous community adequately. Nevertheless, when large sand dollars occupy most of the grab volume, infaunal populations within the remaining sediment are undersampled, leading to an under-reported density.

[1] Refer to the Penetration Depth measurements for the 2015 samples in Table C.1 in Appendix C.

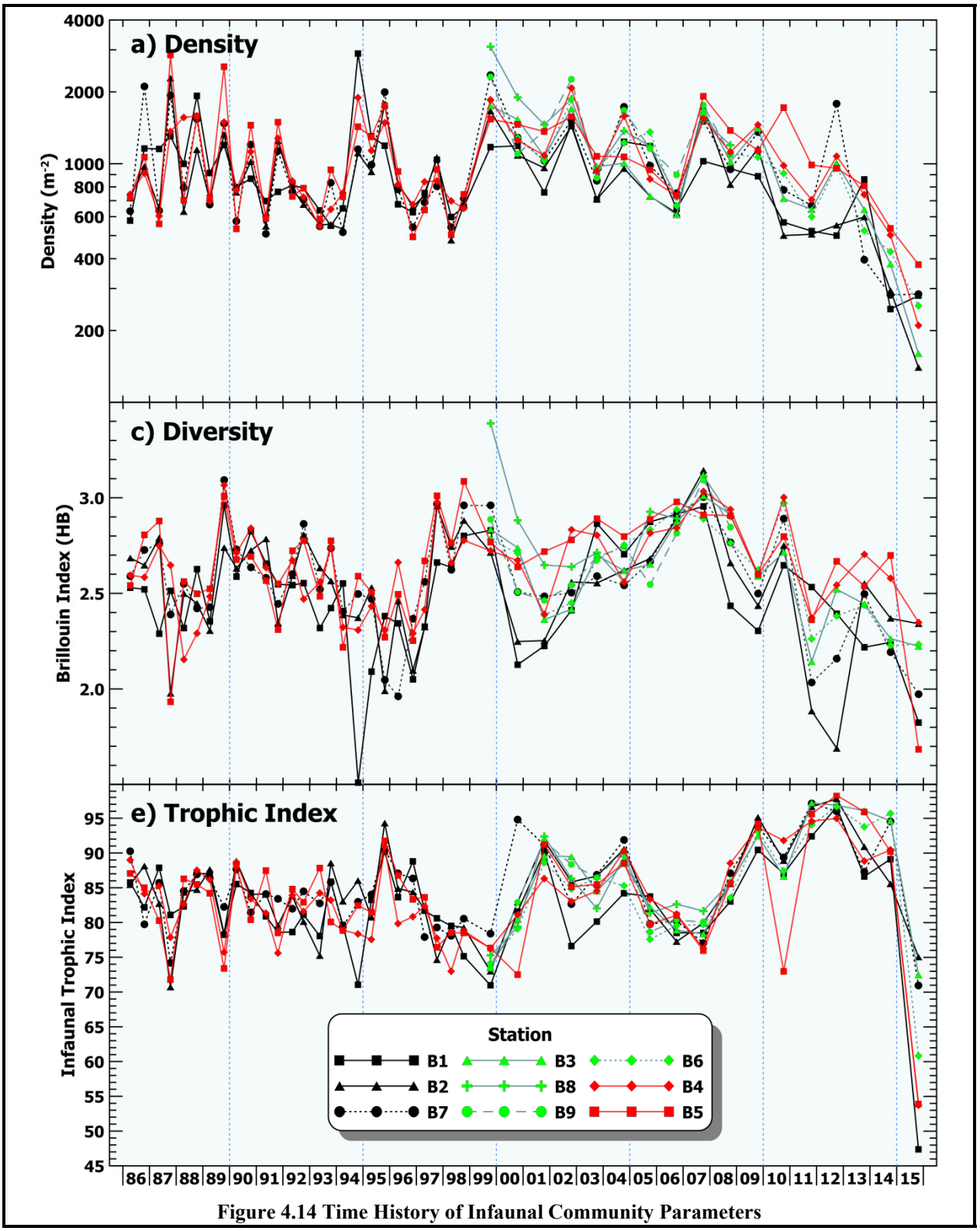

Figure 4.14 Time History of Infaunal Community Parameters

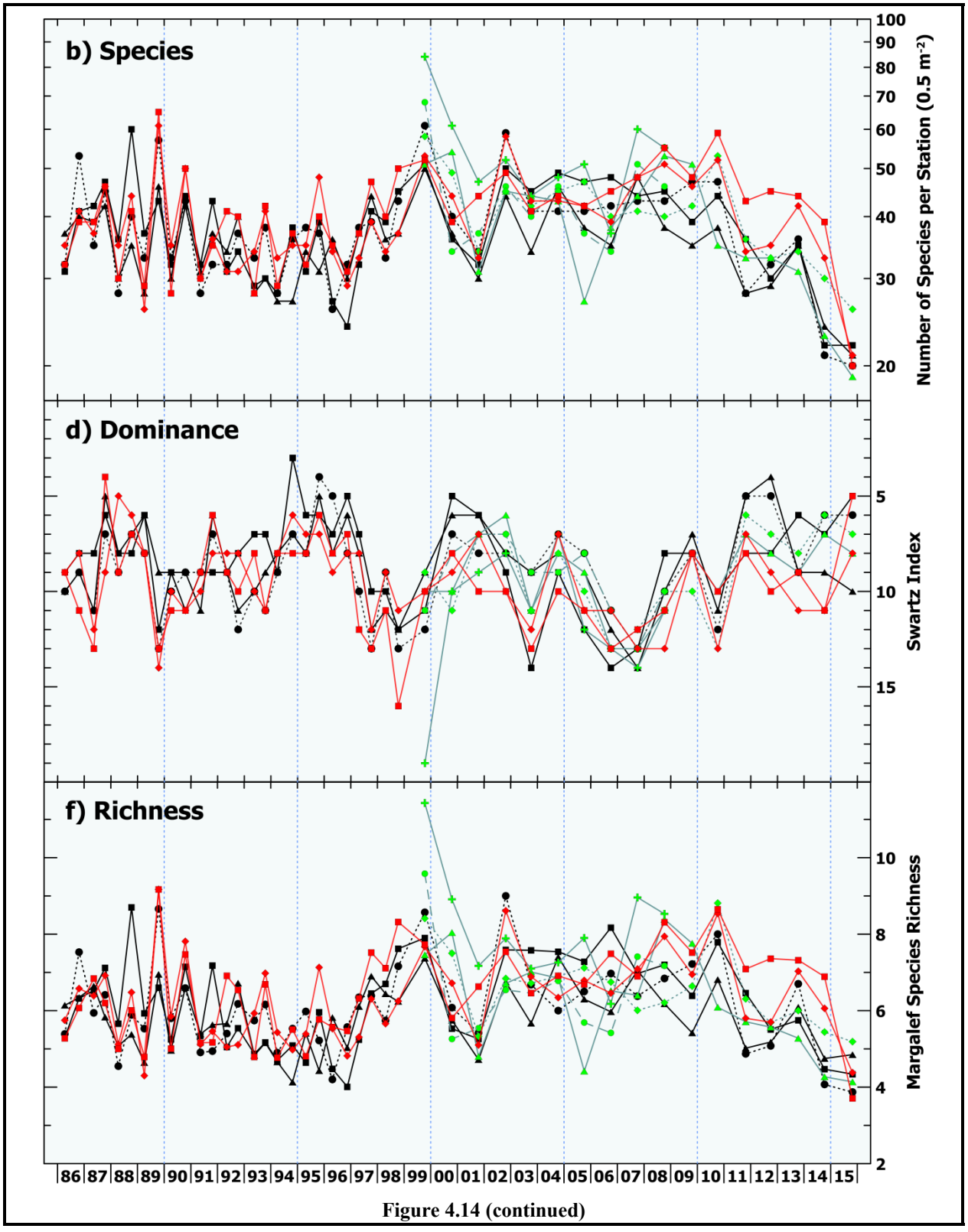

Figure 4.14 (continued)

Number of Species

The total number of species is another measure of the overall health of benthic communities (Figure 4.14b). Everything else being equal, infaunal communities respond to environmental stresses by becoming less diverse, as reflected by a substantial reduction in the number of species. However, the number of species encountered in a sample is directly related to the number of organisms in the sample, i.e., it is inherently related to sample abundance. Because rare species are generally undersampled, the number of species automatically increases in samples with more organisms. Thus, it is difficult to tell if a decreased number of species is due to an actual decline in biodiversity, or simply due to decreased sample sizes (abundance). Irrespective of the influence of sample size, however, reductions in species counts would suggest a decline in diversity and degradation in the marine environment.

Because of its interrelationship with population density, most temporal fluctuations in species counts tend to track the fluctuations in abundance. Accordingly, at least some of the variability in the numbers of species is an artifact of the sample size (abundance) rather than purely an increase in species richness or diversity. As with the density time histories, species counts were lower in the last six years compared to those of the prior decade, and were markedly lower in 2014 and 2015, particularly at the stations containing numerous large sand dollars.

In general, however, there is no obvious long-term spatial gradient in numbers of species that suggesting that sedimentary conditions near the outfall have been preferentially degraded. Specifically, there is no obvious divergence in the colors over time, where species counts at stations near the outfall, shown in red, steadily decline relative to stations far from the outfall (black). As with abundance, spatial differences in within the 2015 species dataset itself were limited, and comparable to seasonal and interannual fluctuations of past surveys, even though the overall number of species had declined to the lowest levels on record.

Beginning in 1996, there was a brief three-year increase in the overall number of species encountered in the MBCSD samples. This trend culminated in 1999, when 84 species were collected at Station B8 alone (green line with crosses). However, this increase was largely due to the increased prevalence of ornate tubeworms (*D. ornata*) within some of the samples. For example, between 1990 and 1996, only one, and usually no *D. ornata* specimens were collected during any given survey. However, in the post-winter surveys of both 1997 and 1998, two ornate tubeworms were encountered. In 1999, four of these tubeworms were found at Station B8 alone. These tubes were not removed prior to sieving as they are now, and as discussed previously, the inclusion of numerous epibionts associated with their tube casings contributed to the steady increase in species counts, culminating in the unusually large number of species recorded in 1999.

Reduced Sediment Volume in 2015

As with density, the historically low numbers of species reported in 2014 and 2015 could easily be explained by the reduced sediment volume caused by the presence of large sand dollars. Based on rarefaction analysis,[1] the observed decrease from 40 to 20 species would have resulted from a five-fold reduction in sediment volume. Based on anecdotal visual observations of the grab samples collected during the 2015 survey, sand dollars typically filled about 80% of the grab volume prior to sieving. Thus, their displacement of benthic sediments could easily explain the observed decrease in both infaunal density and average species per station. Nevertheless, other field studies that accounted for differences in sediment volume within sand dollar beds also found reduced diversity and numbers of infaunal species within the beds (Smith 1981).

[1] Rarefaction (Hurlbert 1971) provides an estimate of species counts as a function of sample size.

Diversity

A large number of interrelated diversity indices have been developed in an attempt to account for the inherent relationship between the number of species and sample size or abundance. Two common indices are the Shannon Diversity (*H'*) and the Brillouin index (*HB*) (Appendix B.1.1). Both exhibit nearly identical time histories in the MBCSD database, so only the Brillouin index is shown in Figure 4.14c.

Ostensibly, diversity should decrease in a degraded benthos, although significant reductions can also occur in the absence of anthropogenic stresses. Nevertheless, within the MBCSD database, temporal trends in diversity do not exhibit any evidence of a deteriorating benthic environment near the outfall; namely, a steadily decreasing diversity at ZID stations relative to distant station. On the contrary, in the past four years the highest diversity has been observed at one of the two stations located closest to the outfall (shown in red).

Nevertheless, because of the aforementioned sediment-volume undersampling in 2014 and 2015, diversity measures were of questionable accuracy in those two years. This may account for the unusually wide range in diversity indices found in the 2015 database. Prior to the 2009 sand-dollar recruitment, diversity measured at individual stations within a given survey were fairly similar; except for the two prominent outliers in 1994 and 1999.

The markedly high diversity (3.39) that was measured at nearfield Station B8 in 1999 was an artifact of the enumeration of additional epibionts residing on the casings of ornate tubeworms. As discussed previously, the presence of large numbers of epibiont species heavily influenced both the overall abundance, and number of species counted at this station during the 1999 survey (Figure 4.14ab).

The second unusual outlier is the very low diversity (1.51) that was found at Reference Station B1 during the October 1994 survey (black square ■ in Figure 4.14c). As with outlier described above, there were an unusually high number of organisms enumerated in the samples collected at this station in 1994 (Figure 4.14a). However, in this case, the increased abundance was associated with a single species, the spioniform polychaete worm *Magelona sacculata*. Nearly 1,000 specimens were collected at Station B1 during the October 1994 survey. Because of the numeric dominance of this one taxon, the computed diversity at this station was the lowest measured in the 30-year database.

Dominance

The Swartz species dominance index differs from the community indices discussed previously because it does not make an *a priori* assumption concerning how individuals are distributed among species. Because it is non-parametric, it is less sensitive to the limitations that plague other community indices. The index is defined as the total number of species accounting for 75% of the individual organisms collected. As such, it represents an inverted measure, in which increased dominance is associated with lower values of the Swartz index.[1] Increased dominance is expected in degraded benthic communities where a few opportunistic, pollution-tolerant taxa abound in the absence of a wider array of pollution-sensitive organisms. As with the other community parameters, Figure 4.14d shows that differences in dominance among stations from a given survey were generally comparable to, or smaller than temporal fluctuations. Overall dominance was generally high during 2015, with as few as five species sharing numerical superiority. Additionally, in the past five surveys, the range in dominance among stations was much larger than in most previous surveys. Again, this may reflect the varying influence of large sand dollar populations among the replicate grab samples.

[1] Note that the vertical axis of the Swartz index plot is inverted in Figure 4.14d so that values that are located higher in the plot represent increased dominance.

By far the lowest historical dominance occurred in samples collected at Station B8 during 1999. During that survey, nineteen species accounted for 75% of the specimens collected. However, up to 10 of the 19 dominant species that were found at Station B8 during 1999 were epibionts associated with the presence of ornate tubeworms. The exclusion of these tubeworms from subsequent surveys has resulted in more stable and representative values of the Swartz index.

Clean-Sediment Feeding Guilds

The Infaunal Trophic Index (*ITI*) (Word 1978, 1980, 1990) compares the abundance of four soft-bottom assemblages that are distinguished by their feeding behavior. Because sensitivity or tolerance to organic enrichment differs among the four groups, shifts in the dominance of individual feeding guilds, as reflected by a change in the Trophic Index, can be indicative of a benthic environment degraded by excess organic material. The *ITI* ranges between 0 and 100. When species in Group I (suspension feeders) and Group II (surface-detritus feeders) dominate, index values are above 58, indicating that sediments are relatively clean, or at least devoid of organic material. Lower infaunal indices occur when populations of species in Group III (surface deposit feeders) and Group IV (subsurface detritus feeders) are prevalent. Their increased presence is assumed to result when sediments are rich in the organic material that acts as a food source for these types of infaunal organisms.

With the exception of 2015, the *ITI* has been exceptionally high throughout the MBCSD monitoring program; often exceeding 80, and after 2009, exceeding 90 (Figure 4.14e). These very high index values reflect a community dominated by suspension-feeding organisms, with few organisms that depend on organic material within the substrate to survive. Prior to 2015, the exceptionally clean sediments of Estero Bay have always been documented with a trophic index well above the critical *ITI* of 58, below which organically enriched benthic conditions are potentially responsible for the composition of the infaunal community. In fact, trophic indices have always exceeded 70 at the MBCSD benthic stations sampled during the 29 years prior to 2015, confirming the consistent dominance of suspension and surface-detritus feeders in the relatively clean sedimentary environment offshore Morro Bay and Cayucos.

Moreover, there is no consistent pattern of organic degradation close to the outfall evident in the *ITI* time series. Increasing effluent-related degradation due to the deposition of organic particulates around the outfall would appear as a gradual separation in colors over time, with stations closest to the diffuser structure (shown in red) eventually having the lowest *ITI*. This would be followed by a slightly higher *ITI* at nearfield stations, shown in green. Instead, as with the other community indices, and with the chemical concentrations measured within benthic sediments, there is no consistent pattern of color separation from year to year. Even in 2015, when the *ITI* declined precipitously, no spatially consistent separation in colors was apparent that would indicate the decline preferentially greater at the ZID stations.

Pre-2009 Outliers

Before addressing the striking *ITI* decline in 2015, two other previous outliers warrant discussion because they reflected a reduced *ITI* at ZID Station B5 that stood-out from the other *ITI*s reported in the same year at other stations (red squares in 2000 and 2010 in Figure 4.14e). Although these two *ITI*s were not particularly low compared to *ITI*s reported in some other years, under certain circumstances, they could indicate short-term habitat degradation from the discharge of organic particulates within wastewater. Detailed analysis in Section 4.4 of MRS (2011) did, in fact, identify the outfall as the source of organic material that caused a marked increase in subsurface detritus feeders at that particular sampling station. However, instead of wastewater discharge, the source of the organics was the debris field that exists immediately adjacent to the outfall structure. These two instances of anomalously low *ITI*s arose because Station-B5 grab samples were inadvertently collected extremely close to the diffuser structure. In addition to their low *ITIs*, the sediment samples contained significant amounts of shell hash and surficial debris

that made them visually and volumetrically distinguishable from other samples collected slightly farther from the diffuser.

Significant amounts of organic debris accumulate in the sediments next to seafloor structures like the outfall pipe, as epifauna die and slough off the structure. In the case of the outfall, debris is also purposely dislodged by divers cleaning the diffusers, or accidentally dislodged when the grab unintentionally hits the structure. Like the shell mounds below offshore platforms, the accumulation of organic debris can be quite large but is restricted to the seafloor immediately adjacent to the structure. Consequently, the outfall structure's debris field is rarely encountered except when grab samples are collected within a few meters of the outfall. In addition to the organic enrichment, these structural debris fields contain highly disturbed sediments that support a unique community of benthic organisms that also happen to have an affinity for high concentrations of organic material, which weighs heavily in the reduction of the *ITI*.

2015 ITI Decline

As with the two anomalously low *ITI*s described above, the abrupt *ITI* decrease observed at all stations in 2015 cannot be ascribed to the discharge of organic particulates within wastewater. The *ITI* results in 2015 were highly variable among replicate samples collected at each individual station in 2015, and the resulting station *ITI*s spanned a remarkably wide range (28) compared to prior years (typically 10; Figure 4.14e). Within the highly variable *ITI* results from 2015, there was no evidence a consistent gradient of decreasing *ITI* with outfall proximity.

Additionally, the large overall *ITI* decrease in 2015 was not due to a marked increase in the populations of subsurface detritus feeders (Group IV). Instead, the decline was mostly due to a large reduction in the population of suspension-feeding organisms. The decline in 2015 was particularly dramatic when compared with the *ITI*s measured in surveys conducted a few years before in 2011 and 2012, when the *ITIs* were the highest ever observed in the entire 30-year benthic monitoring program (Figure 4.14e). With *ITIs* as high as 98, the infaunal community at that time consisted almost entirely of suspension feeders (Group I) residing in sediments largely devoid of organic content.

If the MBCSD effluent discharge had accelerated accumulation of organic particulates around the outfall in 2015, the *ITI* reduction would have been greater at the ZID stations, and the population of deposit and detritus feeders would have markedly increased at those stations. Instead, the large *ITI* decline at all stations in 2015 largely resulted from the elimination of most suspension-feeding organisms, which amplified the modest increase in the populations of surface and subsurface detritus feeders (Trophic Groups II and IV). This conclusion follows from a comparison between populations that contributed to the ITI in 2012 and 2015. In 2012, the population of suspension feeders was nearly 13-times greater than in 2015, while the population of other trophic groups only increased by 70% in 2015 relative to 2012. Group-I suspension feeders are only included in the denominator of the *ITI* equation (Section B.1.4 in Appendix B), but not in the numerator. As such, in the absence of the large suspension-feeding population in 2015, the influence of the modest increase in the population of other trophic groups was significantly amplified, and resulted in the marked *ITI* decline.

Moreover, the sharp decline in the 2015 suspension feeding population was not related to an inhospitable benthic environment created by a sudden increase in sediment organic content, which is what the *ITI* is intended to measure. Measures of organic loading within the benthic grab samples collected in 2015 were comparable to those of the prior 15 years (Figure 4.9). Instead, the demise of suspension feeders was undoubtedly related to the large increase in sand-dollar volume within the surficial sediments in 2015. The presence of numerous large sand dollars in 2015 affected the suspension-feeding population in several ways.

Figure 4.15 A Gammarid Amphipod

As previously discussed, the large sand dollar volume resulted in a sharp reduction in the volume of surficial sediment collected in the grab samples in 2015 compared to all prior years. Undersampling causes a disproportionate reduction in the number of organisms collected from the most populous taxonomic group, which for past MBCSD benthic surveys has been the assemblage of active suspension-feeding Gammarid amphipods. These organisms are small shrimp-like crustaceans (Figure 4.15). Specifically, *Foxiphalus xiximeus*, *Majoxiphalus major*, *Rhepoxynius abronius*, and *Rhepoxynius menziesi* have dominated the infauna collected in the MBCSD monitoring program as a whole, and because they are all members of Trophic Group I, their near elimination in 2015 weighed heavily on the observed decline in the *ITI*. For example, in 2012, 156 *F. xiximeus* and *M.major* specimens were collected, while in 2015, only eight of these organisms were found. Similarly, the number of *R. menziesi* declined by an order of magnitude in 2015, and *R. abronius* disappeared entirely.

Undersampling is probably not the only reason for the sand-dollar-induced decline in these gammarid populations. These amphipods are known to be extremely sensitive to pollution (Pearson and Rosenberg, 1978) and because of this, are routinely used in bioassay testing of marine sediments (ASTM, 1991; USEPA-USACOE, 1991, 1993). However, as described in Section 4.2, there was no material change in sediment quality in 2015, and no new known source of pollution within Estero Bay. Instead, the extraordinary amphipod population decline was probably caused by habitat disturbance, competition for space and food, and predation by the numerous large sand dollars that were present in 2015.

While sensitive to sediment pollution, gammarid amphipods are also sensitive to bioturbation caused by burrowing sand dollars, which can result in changes in surficial grain size and moisture content that result in amphipod mortality (DeWitt et al. 1988). In contrast to prior years, when, except for a few sand dollars, a generally smooth sediment surface was observed in grab samples, the surface of grab samples collected in 2015 consisted almost entirely of large sand dollars with little or no surficial sediment visible. The resulting high seafloor rugosity in 2015 physically limited the mobility of organisms that normally reside on the sediment surface and feed on suspended material.

In addition to direct competition for space on the sediment surface, the sand dollars increasingly compete for food with suspension feeders as their density increases (Fodrie et al. 2007). At low density, sand dollars are predominately deposit-feeders. Thus, in prior years, the physically smaller sand dollars produced lower density beds, and in their deposit-feeding mode, preferentially competed with Group II and IV detritus-feeding organisms rather than suspension feeders. At least in part, this competition was responsible for the lower population of detritus feeders that were observed during, and in the five years following the 2009 sand-dollar recruitment event. The low numbers of detritus feeders resulted in the exceptionally high *ITI* observed during that period.

However, with the marked increase in the density of sand-dollars in 2015, suspension feeding became the sand dollar's preferred trophic mode. Reduced competition with detritus feeders resulted in the small observed increase in numbers that brought Group II and IV populations closer to historical levels, when sand dollars were less prevalent. In contrast, increased competition with Group I suspension feeders contributed to their near elimination in the 2015 database. The combined effect of a near-normal deposit

feeding population and a severe reduction in suspension feeders resulted in the historically low *ITI*s observed in 2015.

In addition to competition for food, small crustaceans, such as gammarid amphipods, can comprise the majority of sand dollar prey (Timko 1976). Thus, the population of gammarid amphipods, which are highly influential in the determination of the *ITI*, can be further reduced because of predation by adult sand dollars. While it is unclear what combination of these potential interactions between infauna and the sand dollar bed was responsible for the observed *ITI* decline in 2015, it is clear that the presence of numerous large sand dollars was directly responsible for the low *ITI*, rather than some new pollutant source within Estero Bay sediments, particularly one related to the MBCSD effluent discharge.

4.3.3 Infaunal Diversity Unrelated to Outfall Proximity

The previous section documented the overall health of the infaunal community surrounding the outfall using a 30-year record of infaunal community indices. This section investigates whether spatial gradients related to outfall proximity exist in the infaunal data collected during 2015 alone. As described in Appendix B.1, four of the biological indices are more informative than the other indices. They include the Brillouin Diversity Index, the Swartz Dominance Index, the Margalef Richness Index, and the *ITI*. The 2015 spatial distribution of average values for these four indices is shown in Figure 4.16.[1]

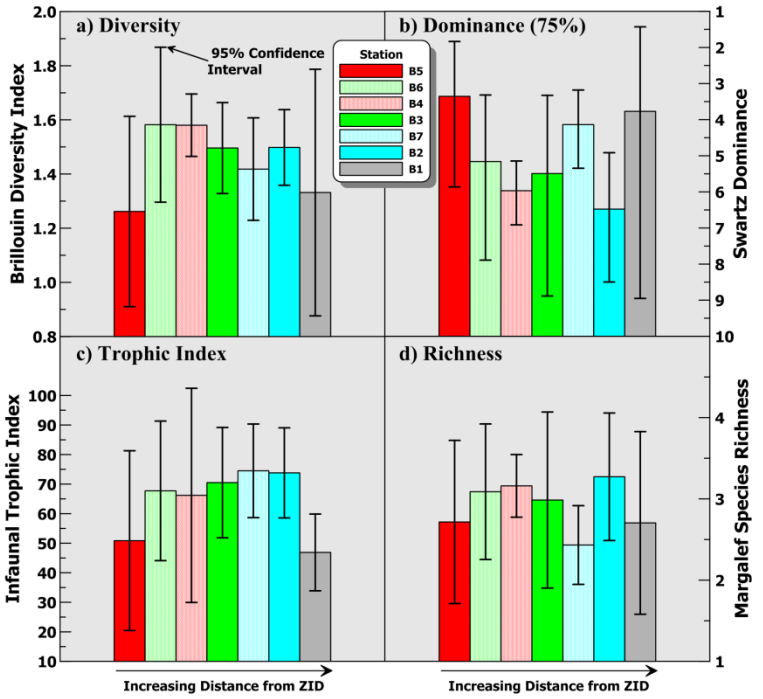

Figure 4.16 Spatial Distribution of Mean Biological Indices in Samples Collected during 2015

The bars shown in Figure 4.16 are arranged in order of increasing distance from the diffuser structure. The red-colored bars, which are associated with the two ZID stations, are normally both positioned on the far left of the bar chart because those stations are usually located closest to the diffuser. However, as described previously, grabs collected at Nearfield Station B6 (second bar) in 2015 happened to be located closer than those of ZID Station B4 (third bar). Thus, the spatial sequencing of those bars is reversed in Figure 4.16 compared to prior reports. The blue and gray bars, which are farthest to the right, represent the three distant stations, which lie more than 125 m from the outfall.

Impacts to infaunal communities from the discharge would be reflected in the bar chart as a spatial gradient of steadily increasing diversity, *ITI*, and richness from left to right (Figure 4.16acd). In contrast,

[1] Note that the values plotted in the time histories of Figure 4.14 are station totals, and differ from the averages among replicate samples plotted in Figure 4.16 for 2015.

dominance would be expected to decrease with increasing distance from the outfall (Figure 4.16b). However, none of these spatial gradients is visually apparent in the Figure, especially considering the wide-ranging scatter among individual replicates collected at each individual station, which are reflected by the confidence intervals shown for each bar.

Consideration of the confidence intervals provides a more quantitative approach to evaluating whether significant spatial differences exist among the infaunal indices. They provide a statistical test to determine whether the average value at a given station is significantly different from that of another station, irrespective of their distance from the outfall.[1] The height of the bars in Figure 4.16 reflects the average index computed from the five replicate samples collected at each station. The 95% confidence intervals surrounding those averages quantify the variability among replicate samples collected at each individual station. As such, the confidence intervals reflect the inherent uncertainty in determining the average station values. Thus, if the average at one station is encompassed within the confidence interval at another station (or vice versa), then no statistical significance can be ascribed to any perceived difference between the averages at those two stations, at least with any degree of confidence (viz., a 95% confidence level, $p \leq 0.05$).

Visual inspection of Figure 4.16 indicates that the differences in average indices between most pairs of stations were encompassed by their associated confidence intervals. Of the 84 pairwise comparisons, 9 pairs of average station indices were found to be significantly different at the 95% confidence level. None of the station pairs of average diversity were statistically different from one another (Figure 4.16a). However, average dominance at Downcoast ZID Station B5 was significantly higher than at the Upcoast ZID Station B4 and at the Upcoast Midfield Station B2 [Compare the first (solid red) bar with the third and sixth bars in Figure 4.16b]. Similarly, the average dominance at the Downcoast Midfield Station B7 (fifth bar) was elevated compared to those same two stations; while average richness at that station was significantly lower (Figure 4.16d). The average *ITI* at Reference Station B1 (rightmost bar in Figure 4.16c) was significantly lower than at Stations B3, B7, and B2 (three bars immediately to the left).

While these pair-wise hypothesis tests found significant differences in 11% of the tests, none of those tests were indicative of a consistent spatial gradient related to outfall proximity; namely, consistently lower diversity, *ITI*, or richness for the bars on the left; or higher dominance for those bars. Furthermore, by definition of a 95% confidence interval, one-in-twenty tests (5%) are likely to result in a finding of significance by chance alone. Specifically, the test statistic was not adjusted for multiple comparisons. Bonferroni adjustment for six comparisons (independent tests of station pairs for each index) increases the likelihood of incorrectly finding a significant difference from one-in-twenty to one-in-four. After applying a Bonferroni correction for multiple comparisons, the only actual significant difference was the lower average *ITI* at Reference Station B1 compared to the *ITI* at Midfield Stations B2 and B7. A lower *ITI* at the reference site is opposite of a spatial gradient that would reflect impairment of the benthos by the MBCSD discharge.

4.3.4 Spatiotemporal Infaunal Trends Unrelated to Outfall Proximity

As with the chemical constituents within northern Estero Bay sediments, subtle spatiotemporal trends in the infaunal community can be difficult to discern in the time series shown in Figure 4.14. The parameters exhibit wide fluctuations between seasons and years. Compared to these large temporal oscillations, the spatial differences among samples collected at a given time (i.e., within a given survey) were

[1] This is equivalent to an unpaired two-sample Student *t*-test of the null hypothesis that there is no difference in mean values between stations at the 95% confidence level assuming unequal variances and a two-tailed distribution.

comparatively small. In other words, the stations generally tracked one another through time. This indicates that changes in infaunal communities that arise from regional influences throughout Estero Bay are far larger than those induced by any localized effects are. Therefore, within a given survey, spatial differences in infaunal parameters can be difficult to differentiate, and are likely to be confounded by larger natural differences in the sedimentary environment, as well as other zoogeographic influences.

The limitations associated with purely spatial or purely temporal approaches to impact evaluation are largely eliminated through application of the same statistical analysis technique used in Section 4.2.3. It is based on tests for nonparallel trends at impact and reference sites (Coats et al. 1999, Skalski et al. 2001). In this application, these parallelism statistical tests are capable of discerning subtle temporal trends in the difference between average indices at stations located near the outfall, and those that are distant from the outfall, even though the indices as a whole fluctuate widely from survey to survey. As described previously, discharge-related spatiotemporal changes would appear in Figure 4.14 as a gradual separation of the colors as contaminants accumulate near the outfall and affect the resident organisms. However, because of the large coherent fluctuations that occur over time, subtle spatiotemporal changes in community indices may be present but not visually apparent in that kind of presentation. Taking the difference in average values at sites distant and proximal to the outfall removes the coherent temporal oscillations that occur on a seasonal and interannual basis. In effect, parallelism assumes that the large temporal excursions in indices occur in unison at all stations and represent a simultaneous response to regional influences. Time series of differences in parameters at ZID and distant stations are presented in Figure 4.17.

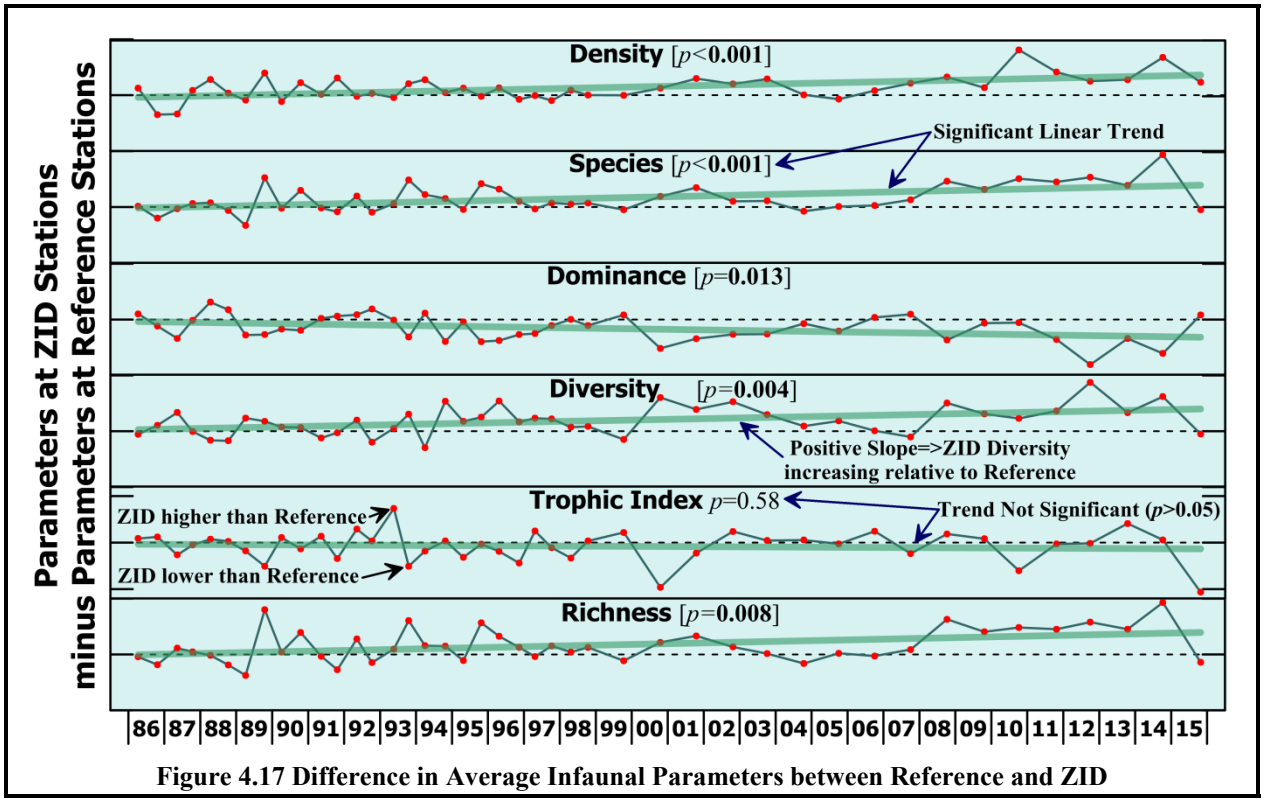

Figure 4.17 Difference in Average Infaunal Parameters between Reference and ZID

If the MBCSD discharge were negatively affecting the benthic community over time, the infaunal community indices at stations near the outfall (B4 and B5) would slowly diverge from those of the more distant stations (B1, B2, and B7). This would appear as a trend or slope in the difference in average indices shown in Figure 4.17. A regression test for a statistically significant trend (slope) in the difference is equivalent to a test of the null hypothesis that the population responses at impacted and non-impacted sites are parallel over time.

Parallelism tests applied to the 30-year time series found slight, but statistically significant trends in all the indices except the *ITI* (p=0.58). The significant, positive linear trends in density, number of species, diversity, and richness demonstrate that the time histories at the ZID and reference stations were not parallel. Instead, these indices have been steadily increasing at the ZID stations, as compared to the reference stations. Similarly, dominance was found to be significantly decreasing at Stations close to the outfall, as compared to distant stations. All of these temporal trends are opposite of those that would occur if the MBCSD the effluent discharge was having a deleterious impact on the benthos near the outfall. Increasingly greater abundance, diversity, and richness, and declining dominance at stations close to the outfall reflects an increasingly healthier infaunal community compared to the distant reference stations.

Because the observed trends are opposite of what would be expected from a community that was being negatively impacted by the MBCSD discharge, the parallelism tests are irrelevant to the impact assessment even though parallelism was rejected for five of the six indices. Accordingly, their p-values are enclosed in brackets in Figure 4.17 to reflect their inapplicability. This was the case for all of the infaunal community indices except the nearly imperceptible negative trend in the *ITI*, which was so small that parallelism was strongly indicated (p =0.58).

4.3.5 Infaunal Community Structure

Determining whether adverse biological conditions exist near the MBCSD outfall involves assessing whether the existing benthic environment supports a balanced indigenous population (BIP). A BIP is an ecological community that exhibits characteristics similar to those of nearby, healthy communities existing under comparable, but unpolluted, environmental conditions. In evaluating a BIP, infauna have an important advantage over other marine organisms, such as marine mammals or finfish. Infauna are relatively easy to collect in numbers large enough for reliable statistical testing, and they do not move about over large areas, so their response is site specific.

In addition, decades of analysis has demonstrated that benthic pollution affects marine ecosystems by changing the infaunal community structure in well-defined ways, namely, changes in the number and type of benthic organisms found within the sediments. However, evaluating the well-being of the infaunal community, and testing its variation over time and space is complicated by the multitude of individual taxa collected within each replicate grab sample. Subtle changes in community composition are not always readily apparent in the large volume of raw data generated by field surveys.

The multivariate complexity of infaunal abundance data makes a BIP analysis challenging because it is difficult to summarize the health of the community into a concise parameter that is indicative of existing environmental conditions. Biodiversity is a common indicator of the well-being of ecological systems, and forms the cornerstone of most impact-assessment studies. It was the basis for the impact assessment described in the previous two sections. However, as described in Section 4.1.4 and Appendix B.1, diversity and other univariate parameters can miss subtle changes in community structure that are reflected by differences in the abundance of individual taxa, but not in the individual indices. For example, two grab samples can have identical infaunal indices, without having a single species in

common. One sample may consist entirely of opportunistic pollution-tolerant taxa, and the other sample could contain high numbers of pollution-sensitive taxa, but that important distinction would be completely missed by an analysis of the infaunal community indices alone.

Despite the univariate indices' inability to capture potential changes in community structure, most benthic monitoring studies routinely report standard infaunal community indices, and rely on them in their examinations of temporal and spatial trends. As described in previous sections, the historical record of univariate analyses provides a useful backdrop for evaluating the large infaunal dataset, but the potential for changes at the species level must also be examined. One of the difficulties with infaunal indices is that they only reflect the diversity within a local area (i.e. within an individual replicate grab sample) at a particular time (α-diversity). In contrast, pollution and other stresses tend to induce changes in community composition wherein completely different (pollution-tolerant) taxa begin to inhabit an impacted area. This results in infaunal assemblages that differ substantially across the samples collected through time at widely separated locations. This kind of diversity is measured by β-diversity (Smith et al. 1979). Thus, analysis of individual measures of α-diversity within samples is not well suited to an infaunal dataset containing moderate levels of β-diversity (heterogeneity), such as in the 2015 infaunal dataset. Compositional differences among the 35 samples collected in 2015 were moderately large, as demonstrated by a Whittaker (1972) β-diversity of 3.2.[1] This high level of β-diversity suggests that the summary univariate indices may be incapable of differentiating subtle trends in community structure among the samples.

Multivariate techniques are much better suited to the evaluation of datasets with high β-diversity. The 2015 dataset used in this multivariate analysis consisted of a matrix of counts for 45 taxa[2] in the 35 samples. Analyzing this complex matrix for potential differences among samples by comparing differences in each individual species is intractable, not just because of the large numbers of species, but because many pairs of samples have few species in common. In response to these challenges, landscape ecologists have, over the last 50 years, developed specialized multivariate analysis tools. These techniques are highly effective at extracting the dominant patterns from complex species-sample databases. The multivariate techniques employed here exploit redundancies (correlations) in the abundance of individual species among the samples, and compress the data into the most meaningful patterns.

Inherent Sampling Variability

As with the other field measurements, it is crucial to determine the inherent variability associated with the infaunal community at a given station. Variability among repeated replicate grab samples collected from an individual station at a particular time lends insight into the inherent uncertainty in average values reported for each station. This within-station variability is essential for testing hypotheses concerning the significance of perceived differences between samples collected at different locations. If the inherent sampling variability is statistically larger than the observed difference between the two stations, then the spatial difference cannot be considered statistically significant.

[1] β_w measures the ratio of the total number of species in the dataset to the average number species in the samples, minus one. If β_w=0, then all the samples have the same number of species. β_w=3.2 indicates that the entire database had more than four distinct communities, with 4.2-times as many species (45) as the average individual grab sample (10.8).

[2] Because the multivariate analysis examines differences in community structure among the samples, and not specifically diversity, additional specimens could be included in the database. These additional specimens were not identified to species level, usually because they were juveniles and too small for reliable taxonomic identification.

A dendrogram (tree diagram) produced from the multivariate species database provides a convenient graphical means for determining the relative magnitudes of within-station and between-station infaunal variability among the samples (Figure 4.18). Testing the relative variability among the 35 individual grab samples collected during 2015 indicates whether differences among replicates collected at a station are smaller than the differences between the stations, indicating that spatial differences are large enough to be reliably resolved, even in the presence of inherent sampling uncertainty associated with station averages.

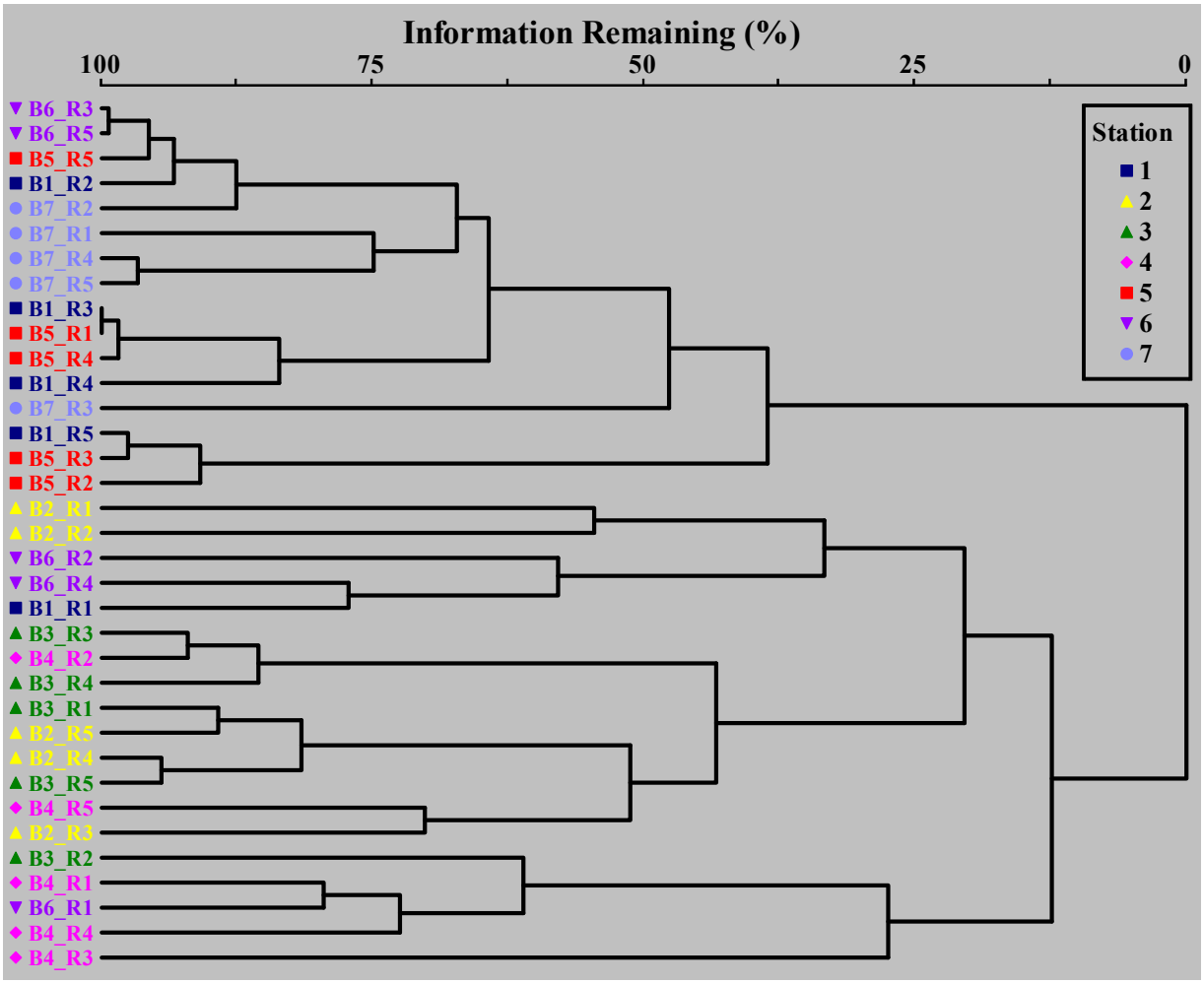

Figure 4.18 Dendrogram of Similarities among Infaunal Assemblages within the 35 Infaunal Grab Samples

The relative similarity in the infaunal assemblages among samples, or groups of samples, is graphically displayed using a dendrogram, a branching (tree) diagram. Sample pairs that have the most similar assemblages coalesce into a branch toward the left on the percent-information-remaining axis. The horizontal axis at the top of the dendrogram reflects the amount of information (variability) that is left in the sample-species matrix after two samples are combined. Combining samples with relatively similar species composition results in a minimal loss of information (variability) in the original species-sample matrix. For example, the short branches connecting the pair of dark-purple, downward-pointing triangles at the top of Figure 4.18 shows that the infaunal assemblages within Replicates R3 and R5 from Station

B6 were nearly identical, and considering them as a single combined assemblage results in a minimal (<0.7%) loss of multivariate information. As more samples, or other groups, are added to each branch, the differences in the assemblages associated with each group become increasingly larger, and as each group is combined into a new group, more overall information about the differences in the assemblages is lost.

A statistical analysis of multivariate variance (MANOVA) provides a more-rigorous evaluation of the clustering tendency as a whole, and found that the within-station similarity among replicate samples was far greater than expected by chance (p<0.0002). The p-value cited here, and throughout this section, is the probability that the measured difference between stations could have occurred by chance alone. It is determined by comparing the magnitude of the difference between stations, with the scatter in the replicate samples collected at a particular station. If the scatter in replicate samples is large compared to the difference in sites, then the station difference is more likely to be an artifact of chance alone, rather than a real spatial difference. Generally, differences in groups are considered statistically significant when p-values are less than 0.05, which corresponds to a 5% (1-in-20) probability that the difference would have occurred by chance alone. Thus, the observed infaunal differences among the seven stations in 2015 were very unlikely (0.02% chance) to have been due to random sampling uncertainty. However, this does not mean that the communities within each pair of stations were perfectly distinct from one another. Instead, it implies that the within-station fidelity among all 35 replicate samples was definitely greater than if the samples were randomly assigned to stations.

In contrast to the survey-wide MANOVA, one conducted on individual pairs of stations demonstrates that four pairs of stations contained communities that were not easily distinguishable from one another. The replicates from Upcoast Stations B2, B3, and B4 were not well differentiated from one another by their infaunal communities (p>0.31), and the same was true for Downcoast Nearfield and Midfield Stations B6 and B7 (p=0.11). This finding suggests that stations located near each other had infaunal communities statistically indistinguishable from one another, but that the groups of stations located on opposite sides of the diffuser structure contained dissimilar sets of infauna.

The low station-fidelity among replicate samples from the three stations located north of the outfall is reflected in the dendrogram branches in the lower half of Figure 4.18. Replicates from the Upcoast Midfield Station B2 (yellow triangles) often clustered first with replicates from Stations B3 (green triangles) and B4 (fuchsia diamonds), rather than with other replicates from Station B2. In fact, the infaunal community within the first two Station-B2 replicates (yellow triangles for R1 and R2 near the middle of the dendrogram) only coalesced with the other replicates from that station within one of the last branches of the dendrogram, where only 20% of the information (variability) remained after almost all individual replicates had been combined into only three groups (branches).

Similarly, infaunal communities within replicates from the two southernmost stations (B6 and B7; dark purple triangles and light purple circles) tended to cluster first with replicate samples from other stations. In fact, Replicates B6_R2 and B6_R4 near the center of the dendrogram had infaunal communities that showed greater similarity to the upcoast group of stations. They did not coalesce with other replicates from that station until the very last branch of the dendrogram, when all samples had been combined into only two groups, and no information (variability) remained in the dataset.

Spatial Variability

The two major branches in the dendrogram of Figure 4.18 demonstrate that most replicate samples collected at stations south of the diffuser structure (Stations B5, B6, and B7 in the upper branch), contained an infaunal community that differed from that of the group of stations upcoast of the diffuser structure (Stations B2, B3, and B4 in the lower branch). This north-south trend suggests a naturally occurring spatial pattern of along-shore change rather than a pattern indicative of impairment surrounding

the outfall, which would be reflected by groupings related to outfall proximity. The influence of this external factor on community composition can be better explored using another related multivariate analysis technique, known as ordination analysis.

In past surveys, zoogeographic differences over the large distance that separates Station B1 have accounted for the unique infaunal community that resides there. This was also the case in 2015 because of its consistently greater sand-dollar density (Figure 4.12) and greater mud fraction (Figure 4.6). As with the chemistry database, the different infaunal community at Station B1 confounds compliance analyses and the requirement for sampling at that station was removed when the current discharge permit was issued. Although it continues to be sampled for historical consistency, the inclusion of data from Station B1 often skews the ordination analysis substantially, masking subtler differences in the community structure among the remaining stations immediately surrounding the outfall.

A two-dimensional ordination[1] diagram provides a visual interpretation of the differences in the infaunal communities found in the 30 samples remaining after exclusion of data from Station B1 (individual color-coded sample points in Figure 4.19). It distills the major infaunal differences among samples as a separation between sample points in the multivariate hyperspace. As such, the diagram's axes do not represent distances in physical dimensions. Instead, the locations of the points within the diagram characterize the composition of the assemblage within individual benthic samples. The distance between a pair of points measures the degree of difference in the species compositions contained within those samples. Widely separated points (e.g., the red diamonds of B4R3 in the upper left quadrant, and of B4R4 in the lower right quadrant) have dissimilar infaunal assemblages, namely, few species in common, and large differences in the abundance of those species that are common between the samples. In contrast, points that lie close to one another (e.g., all five of the red squares associated with Station B5 located along the negative X-axis) have assemblages with many common species and similar abundances among those common species.

In addition, separation between sample points along the horizontal axis of the ordination plot characterizes a variation in species composition that fundamentally departs from the variation in community composition along the vertical axis. In past surveys, changes along the major (horizontal) axis often reflected a large-scale zoogeographic difference while the secondary vertical axis usually coincided with a local environmental gradient in the samples, such as water depth or mud content. Potentially influential environmental variables are jointly displayed on the ordination diagram of Figure 4.19 as blue arrows radiating from the center point of the diagram. The angle and length the arrows reflect the direction and strength of the relationship between each external factor and the infaunal community within individual samples.

Mud Content and Alongshore Location

Two closely related external factors defined the distribution of samples along the X-axis. Northward alongshore location exhibited the greatest correlation with differences in infaunal community structure, which reflects the aforementioned zoogeographic separation of communities north and south of the diffuser structure. This X-axis sample distribution is distinctly different from the distribution expected from discharge impacts, which would consist of an along-axis gradient with red-colored (ZID) samples at one extreme, followed by green-colored (nearfield) samples near the origin, and black (midfield) samples

[1] The multivariate ordination was derived from a non-metric multidimensional scaling (Mather 1976, Kruskal, 1964) of Sørensen (Bray-Curtis) distance (Sørensen, 1948), the same multivariate distance measure used in the dendrogram. There was a 6.8 percent chance (p=0.068) that the stress measure of the final solution's fit could have occurred by chance based on Monte Carlo randomization tests. The method is unconstrained by the external factors, but the influence of those factors can be evaluated by superimposing them on the ordination diagram.

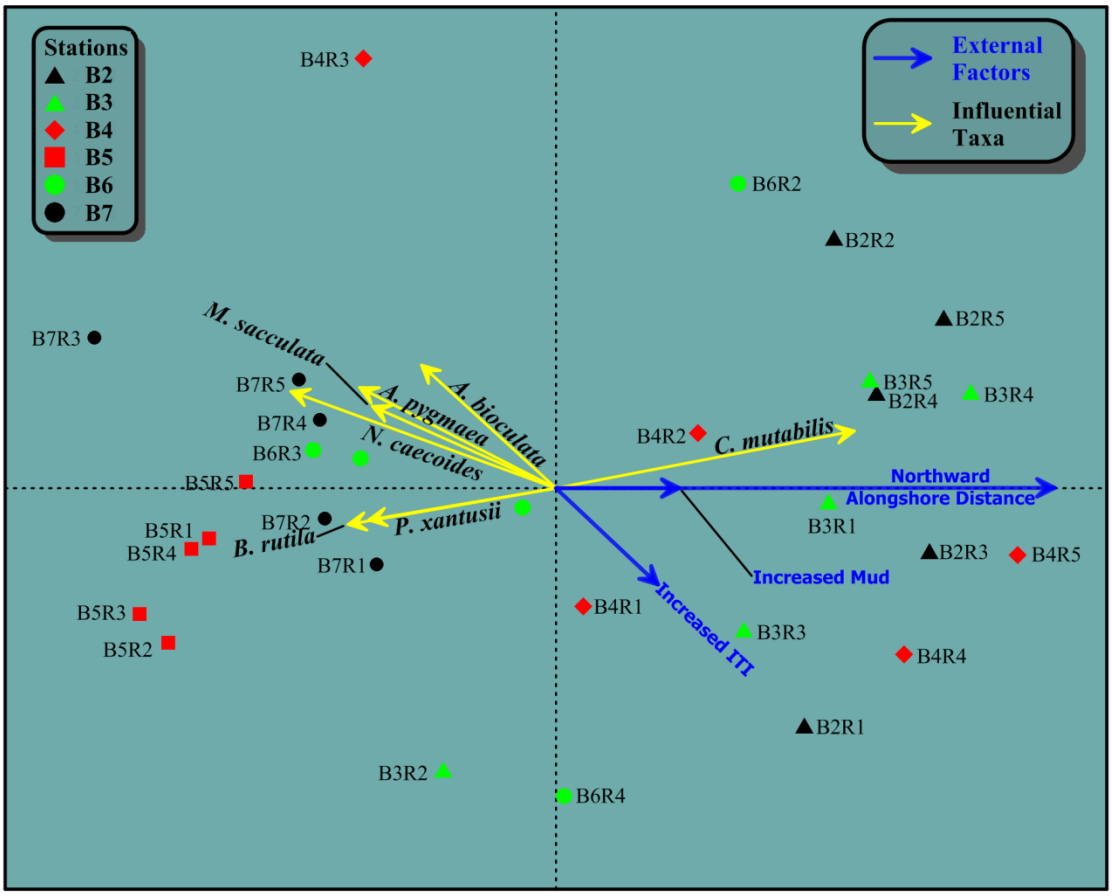

Figure 4.19 Joint Plot of the Ordination, Key Taxa, and External Factors that Differentiate the 2015 Samples

at the opposite extreme. Instead, samples collected to the south (B5, B6, and B7) tend to populate the left hemisphere (negative X), while northern stations (B2, B3, and B4) tend to be located in the right hemisphere (along the positive portion of the X-axis).

Although alongshore location clearly dictated the spatial distribution of infaunal communities in 2015, the actual external environmental factor that caused the difference in communities is equivocal. Certainly, stations to the north of the diffuser structure, where prevailing oceanographic conditions are more quiescent, is the dominant factor, but the specific aspect of the benthic environment that caused the infaunal differences is unclear. Decreased wave and bottom-current energy can change the sand-dollar distribution as well as the mud content of surficial sediments. Both have a profound impact on infauna. In 2015, however, increasing mud content was precisely correlated with the distribution along the X-axis; although the strength of the correlation was somewhat less than alongshore distance (overlapping blue arrows extending along the positive X-axis of Figure 4.19).

Feeding Guilds

In contrast to prior years, the distribution of samples along the Y-axis of the ordination plot were not well resolved in 2015 (p=0.068 versus p =0.032 for the one-dimensional X-axis solution) due to the lack of structure within the two-dimensional correlation matrix. The lack of structure in the second dimension

resulted because the Y-axis distribution resulted from an isolated sample (B4R3) that was flagged as a very large outlier (2.8 σ).[1] In ordination space, Replicate Sample B4R3 (red diamond in the upper left quadrant of Figure 4.19) contained an infaunal community very distinct from all other samples. Additionally, only spatially unrelated samples B3R2, B6R4, and B2R1 separated along the negative Y-axis.

The only obvious external factor that partially correlated with the distribution along the Y-axis was the *ITI* (blue arrow pointing toward the lower right quadrant of Figure 4.19). Although *ITI* also covaried with increased mud and northward distance along the X-axis, it pointed almost directly away from the outlier Sample B4R3, indicating that the distribution of sample points along the Y-axis was partially related to trophic feeding guilds. At 36, the *ITI* measured within replicate grab sample B4R3 was among the lowest in 2015, and indicated that the outlier infaunal community within that sample consisted largely of detritus feeders.

As previously discussed in regard to community indices, differences in infaunal communities identified by the ordination analysis resulted from a combination of predation, exclusion, and competition for other resources; as well as from a sampling-size artifact associated with reduced sediment volumes caused by the presence of numerous adult sand dollars within all the grab samples. These varying sand-dollar influences introduced significant scatter within the 2015 infaunal populations that was unprecedented in the 30-year database. The sand-dollar influence masked the subtler trends associated with mud-content and zoogeography that have often been observed in past surveys.

Key Taxa

The abundances of individual species within a given replicate sample, as compared to that of another sample, are difficult to discern and interpret when an investigator is faced with the enormous amount of information contained in the 2015 infaunal database listed in Table B.1. Although perusal of the table may reveal patterns for specific taxa, it is difficult to decide how important the differences in counts of one taxon are, relative to another. Additionally, many species co-occur and yield the same distribution among samples, further confusing the interpretation. Finally, the most abundant taxa are often not the most diagnostic of potential impacts because they are present in substantial numbers within all the samples. As described previously, multivariate community analysis was designed to distill this complex set of information quantitatively, to eliminate redundant or marginal patterns, and to produce most important information concerning how the communities within individual samples relate to one another. In that regard, the ordination methodology also identifies which taxa primarily influence the community differences among replicate samples. Those influential taxa often have life-history information, such as a tolerance or sensitivity to pollution and organic loading, which can lend further insight into the potential impacts from effluent discharge.

As described previously, the distribution of sample points along the horizontal axis of the ordination plot characterizes a variation in species composition that fundamentally departs from the variation in community composition along the vertical axis. In past surveys, the secondary (vertical) axis usually coincided with a local environmental gradient in the samples, such as water depth or mud content. However, as with the sample point distribution along X-axis in Figure 4.19, the distribution of 2015 data along the vertical axis departs from historical trends, and is not easily ascribed to actual physical differences in the benthic environment during 2015.

[1] Accordingly, in the related multivariate dendrogram analysis of Figure 4.18, Replicate Sample B4R3 at the bottom of the dendrogram was the last isolated sample to merge with other groups when only 27.5% of the information remained.

An indicator species analysis compliments the multivariate sample analysis described above, and is graphically overlain in yellow on the joint plot of Figure 4.19. As with the external environmental factors, the degree of influence key individual taxa had on the overall distribution of the samples is represented by the yellow arrows (vectors) superimposed on the ordination plot. The length of an arrow for an individual taxon reflects how strongly it participated in differentiating the samples, and its direction points toward samples that have a comparatively elevated abundance of that taxon. Conversely, arrows pointing away from samples reflect a comparatively low abundance of an indicator taxon.

The indicator species associated with the 2015 database differed greatly from those of past surveys. Both taxonomists, who have been identifying and enumerating species collected as part of the MBCSD monitoring program for the past 23 years (see Appendix B.3), expressly stated that the 2015 samples were strikingly different from all prior surveys. For example, absent were the large populations of Gammarid amphipods, whose slight fluctuations in species densities were often diagnostic of subtle physicochemical changes in the benthic environment and were routinely correlated with the distribution of samples in the ordination hyperspace.

Sand Dollar Parasites

Instead, new indicator taxa were responsible for characterizing differences among individual samples in 2015. In particular, the Xantus swimming crab (*Portunus xantusii*) has never been observed in the MBCSD database prior to 2015. The occurrence of new species the database is unusual given that the database consists of 258,000 specimens from 390 taxa spanning 29-years of sampling. Although *P. xantusii* are members of a "swimming" family of decapods, all the specimens collected in 2015 were juveniles that spend their time nestled in the substrate, and therefore, are considered infauna.

Most of the specimens of this new species were found in samples collected at the Downcoast ZID Station B5, which is why their indicator arrow points toward the relatively tight grouping of all five replicate samples from that station (yellow arrow pointing along the negative X-axis and toward the red squares in Figure 4.19). It is highly likely that their presence and distribution in the 2015 database was directly related to the unusually large population of mature sand dollars found in the survey. This conclusion follows from the distribution of the co-occurring species of the parasitic marine snail *Balcis rutila*[1] (Figure 4.20). Sand dollars are a well-known host of these parasitic snails (Lovell 2003, Morin et al. 1985), and their distribution among the 2015 samples was almost perfectly correlated with the distribution of the *P. xantusii*, (refer to the slightly longer yellow arrow that overlaps the *P. xantusii* arrow in Figure 4.19).

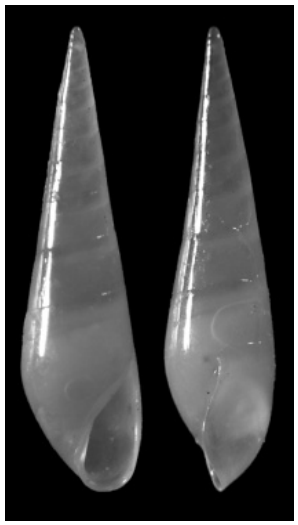

Figure 4.20 *B. rutila*

Moreover, the overwhelming influence of the sand dollar population on the infaunal community in 2015 is clear from the dominant presence of this sand-dollar parasite. *B. rutila* was the most populous taxon within the 2015 database, and accounted for 34% of the non-*Dendraster* specimens (Table B.1). Only one-quarter as many specimens of the next most populous species were collected. One-third of all the specimens of these sand dollar parasites were collected at Station B5 alone, which accounts for their strong differentiating influence on that station's replicate samples in the ordination diagram. Four times as many specimens were collected south of the diffuser structure, compared to the northern stations.

[1] For consistency in the MBCSD database, the historical name, *B. rutila*, is used in this report even though the name has been revised to *Melanella rutila*, which is synonymous with *Polygireulima rutila* (Lovell 2003).

In the years prior to the 2015 population explosion in *B. rutila*, when at total of 291 specimens were collected, their numbers were consistently low, but steadily increasing as the population of host sand dollars matured and grew in size. No specimens were found in the 2009 recruitment year, or in the two following years, when sand dollars were still juveniles (Figure 4.13abc). However, one-to-two specimens of the parasitic snails began to appear in 2012 and 2013, when sand dollars reached the sub-adult stage (Figure 4.13d). As sand dollars further matured in 2014, eight specimens were found, and in 2015 when numerous large sand dollars packed into almost every available portion of the surficial sediments, their associated parasites utterly dominated the non-*Dendraster* infaunal community.

The ribbon whole worm (*Carinoma mutabilis*) is the parasitic snail's antithesis (refer to the yellow arrow that extends along the positive X-axis in a direction opposite of the *P. xantusii* and *B. rutila* arrows in Figure 4.19). This soft-bodied unsegmented worm (Figure 4.21) thrives by burrowing in undisturbed sand and mud where it feeds on other small invertebrates such as annelids and crustaceans. Despite the low number of *C. mutabilis* specimens collected in 2015, the worm played a pivotal role in separating the samples along the X-axis in Figure 4.19. Nearly 80% of the specimens were found in samples collected north of the diffuser structure during 2015. The increased amount of mud at those stations probably provided a more hospitable environment for these large worms. In the absence of large sand dollars in prior surveys, this infaunal species was often the dominant taxon. For example, in 2008, when its Gammarid amphipod food source was abundant within undisturbed sediments in the absence of sand dollars, the population was nearly 100 times greater than in 2015.

Figure 4.21 *C. mutabilis*

Feeding Guilds

As described in previous sections, *ITI*s measured in 2015 were far lower and much more variable among samples than in the prior 29 years of MBCSD sampling. The marked overall *ITI* reduction in 2015 was ascribed to the general absence of active suspension-feeding Gammarid amphipods whose dominant populations in prior years have always been uniformly distributed among samples. Their abrupt decline in 2015 was attributed to predation, and to competition for food and space by the numerous mature sand dollars.

The abruptness of the *ITI* decline may have been triggered by a rapid switch in the sand dollar feeding mode from deposit feeding to suspension feeding between 2013 and 2015 as a result of their increased density (Fodrie et al. 2007). After switching to a suspension-feeding mode, the sand dollars directly competed with the amphipods for food, which certainly contributed to the rapid overall amphipod decline. Additionally, as a result the switch in feeding mode, the 2015 sand dollar population no longer competed with the organic detritus feeders. The resulting modest increase in the numbers of these opportunistic detritus feeders also contributed to the overall *ITI* decline in 2015, although to a lesser extent than the loss of the Gammarid amphipod population. However, in contrast to the universal amphipod decline in 2015, the increase in detritus feeding organisms occurred randomly within a few of the grab samples. That random occurrence among samples accounts for the extraordinarily large *ITI* variability observed in 2015.

Despite their patchiness, these key opportunistic taxa were identified by the ordination analysis. However, in contrast to the external factors of mud content and geographic location, which correlate perfectly with the distribution of samples along the X-axis in Figure 4.19, the feeding-guild distribution, as represented

by the blue *ITI* vector extending into the lower right quadrant, covaries with the sample-point distribution along both axes. Additionally, because of their patchy distribution, the influence of these opportunistic taxa on the ordination was much weaker than that of the alongshore distance, as is evident from a comparison of the lengths of the two blue arrows in Figure 4.19.

Because of the uniformly low numbers of Gammarid amphipods and other Group-I suspension-feeding organisms, there were no key taxa associated with increases in the *ITI* (namely, no yellow arrows aligned along the blue "Increased *ITI*" arrow in Figure 4.19). Instead, all of the key taxa were associated with the opportunistic detritus-feeding organisms, whose increased presence caused a reduction in the *ITI* (in samples located in the upper left quadrant, opposite of the blue *ITI* vector), or whose reduced population resulted in a slightly higher-than average *ITI* (in samples located in the lower right quadrant).

Three of the key opportunistic taxa were annelid worms (*Apoprionospio pygmaea*,[1] *Magelona sacculata*, and *Nephtys caecoides*) that are members of the Group II surface detritus-feeding guild. Their increased presence in some of the replicate grab samples led to computed *ITI*s that were slightly lower than the survey average. However, their distribution did not exhibit any clear pattern of station-fidelity or spatial distribution other than a weak preference for samples collected in the southern portion of the survey area (negative X values in Figure 4.19).

Figure 4.22 *A. bioculata*

However, these surface detritus feeders tended to co-occur with the Opheliid lug worm *Armandia bioculata*[2] (Figure 4.22). This non-selective subsurface detritus feeder normally thrives in sediments that are organically enriched below the sediment interface. Because of its feeding strategy, Word (1978) included it in the Group-IV feeding guild than often reflects sediments degraded by deposition of organic particulates around wastewater outfalls. Consequently, its presence reduced the computed *ITI* to a much greater extent than the three co-occurring surface detritus feeders. In particular, three times as many *A. bioculata* specimens were found within Grab Sample B4R3 as compared to the next most populous sample, and accordingly, that sample had one of the lowest *ITI*s found in the 2015 database. In the ordination, its sample point (red diamond in the upper left quadrant of Figure 4.19) was widely separated from the other sample points because of its elevated *A. bioculata* abundance (yellow *A. bioculata* arrow that points toward that sample point).

A. bioculata's influence on the *ITI* computation during 2015 suggests that the presence of this opportunistic sub-surface detritus feeder was indicative of an increase in organic loads within the samples where it was found. However, there was no evidence of a substantial increase in concentration of sediment organic material during 2015 (Figure 4.9). Instead, like *B. rutila* and *P. xantusii*, *A. bioculata* is known to thrive within sand dollar beds (Smith 1981). Field studies have consistently found significantly higher numbers of *A. bioculata* with sand dollar beds than in adjacent sediments with identical concentrations of organic material. Thus, the large *ITI* reduction observed in the 2015 database was not related to degradation in sediment quality, but instead was caused by the increased prevalence of several detritus feeding taxa that happen to have an affinity for sand dollar beds.

[1] This name is used for consistency with the historical MBCSD database; it has been superseded by the currently accepted taxonomic designation is *Prionospio pygmaea*.

[2] This name is used for consistency with the historical MBCSD database; but is synonymous with, or has been superseded by *Armandia brevis*.

Overall, the multivariate ordination demonstrates that the differences in the infaunal community structure at various sampling locations were largely controlled by alongshore location and the presence of numerous mature sand dollars. The multivariate results were consistent with the findings from the analyses of infaunal community indices and sediment chemistry. Together, the weight of quantitative evidence demonstrates that, even within sediments immediately adjacent to the outfall structure, there was no evidence of a buildup of organic wastewater particulates from the discharge of the MBCSD effluent, and that a balanced indigenous population of marine organisms resides throughout the region, including within the area near the MBCSD outfall.

CHAPTER 5

Conclusions and Recommendations

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5.0 CONCLUSIONS AND RECOMMENDATIONS

The MBCSD monitoring program was designed to evaluate the performance of the wastewater treatment plant and to monitor the quality of effluent discharged to the ocean. This annual report evaluated compliance with the NPDES discharge permit and documented potential discharge impacts through quantitative analyses of an extensive data set of effluent constituents, receiving-water measurements, sediment chemistry analyses, and marine biological enumerations. Of the thousands of measurements collected as part of the monitoring program during 2015, only two exceeded the discharge limitations; both related to the dechlorination process.

On 15 April, dechlorination was briefly suspended while the Chlorine Contact Tank was drained and taken offline for planned repairs. Despite the best efforts by WWTP staff, exceedance of at least one of the regulatory limits could not be avoided during the 20-hour Tank repair. The WWTP staff made the conscious decision to maintain effluent disinfection at the expense of dechlorination, which resulted in the exceedance of maximum daily limit on total residual chlorine. Because the permit exceedance was anticipated well in advance of the repair, appropriate notice was provided to the RWQCB and California Department of Health Shellfish Division prior to the observed chlorine increase. The other unavoidable exceedance of the daily permit limit on residual chlorine was unanticipated and occurred on 11 December when the sodium-bisulfite dosing pump was accidently shut down after its circuit breaker was tripped.

5.1 TREATMENT PLANT

The MBCSD Wastewater Treatment Plant (WWTP) has been operating under the provisions of a 301(h)-modified NPDES permit since 1986, with 2015 marking the 30th year of consistently high performance by this treatment facility. In fact, many of the best measures of treatment performance have been achieved during the past decade of operation (Table 5.1). For example, the low average effluent Total Suspended Solids (TSS) concentration in 2015 (31 mg/L) was the direct result of the treatment process's exceptional efficiency, which removed over 91% of the influent solids. This was the case even though the influent solids concentration in 2015 was the third highest in the 30-year record. Nevertheless, as a result of the Plant's exceptional performance in 2015, the solids discharge was only 19% of that allowed under the NPDES permit.

Reductions in the discharge of oil and grease (O&G) and biochemical oxygen demanding (BOD) materials also attest to the plant's overall high standard of performance. As with TSS, the discharge of O&G and BOD remained exceptionally low in 2015, while their corresponding removal rates have been high compared to the average rates achieved over the three decades of monitoring.

5.1.1 Overall Performance

Measurements of wastewater characteristics acquired throughout 2015 demonstrate that the treatment process exceeded expectations based on the original plant design, the NPDES discharge permit, and federal regulatory standards. For example, during 2015, the plant removed 16% more suspended solids than the minimum permitted, and the BOD removal rate was more than two and a half times greater than the minimum permitted rate of 30%. During eleven months of the year, effluent BOD concentrations remained below the 60-mg/L threshold where minimum 75% removal-rate requirements are considered applicable (See the recommendation in Section 5.4). Similarly, effluent TSS concentrations remained far below that concentration threshold throughout the entire year.

Table 5.1 Average Annual Wastewater Parameters

		Suspended Solids				Biochemical Oxygen Demand			
Year	Flow (MGD)	Influent (mg/L)	Effluent (mg/L)	Removal (percent)	Emission (MT)	Influent (mg/L)	Effluent (mg/L)	Removal (percent)	Emission (MT)
1986	1.42	332	32.8	89.8	64	235	77.0	67.2	151
1987	1.51	274	21.8	92.0	45	257	52.0	79.8	108
1988	1.51	397	29.8	90.0	62	242	43.9	81.9	92
1989	1.46	321	37.3	88.4	75	259	69.8	73.1	141
1990	1.38	345	36.0	89.6	69	261	75.7	71.0	144
1991	1.28	280	30.5	89.1	54	236	66.9	71.6	118
1992	1.41	310	43.0	86.3	84	224	59.3	73.5	116
1993	1.54	339	33.0	89.6	70	222	39.0	81.9	83
1994	1.38	310	32.0	89.4	61	249	33.0	86.4	63
1995	1.55	270	30.6	87.6	69	208	31.4	83.9	67
1996	1.55	344	33.1	89.9	70	241	35.7	85.0	73
1997	1.64	283	36.0	86.6	79	231	38.6	83.0	85
1998	1.95	236	38.8	83.9	101	216	39.1	81.5	99
1999	1.68	386	44.0	86.7	102	287	49.5	82.5	118
2000	1.77	337	37.4	87.5	91	271	50.3	81.1	125
2001	1.48	450	37.6	89.5	74	396	62.7	83.1	127
2002	1.14	374	49.2	86.0	77	386	67.5	82.4	101
2003	1.06	314	39.2	86.7	56	311	56.3	81.3	81
2004	1.09	354	28.9	91.3	44	336	53.3	83.8	81
2005	1.25	373	24.3	93.3	42	303	49.8	83.0	88
2006	1.19	335	20.5	93.2	34	291	45.3	83.8	75
2007	1.09	381	20.9	94.1	31	330	44.4	86.0	68
2008	1.10	337	20.0	94.1	30	331	38.4	88.3	58
2009	1.09	328	25.3	92.3	38	311	37.6	87.4	56
2010	1.19	383	26.6	92.1	42	350	49.4	85.2	85
2011	1.24	343	26.8	92.4	45	312	52.2	83.2	89
2012	1.10	379	27.1	92.5	41	322	49.9	83.5	77
2013	0.96	351	29.9	90.4	39	327	55.7	82.6	74
2014	0.94	377	29.2	91.3	37	352	51.4	85.3	66
2015	0.93	389	30.8	91.5	39	370	48.9	86.5	63
Average	**1.33**	**341**	**31.7**	**89.9**	**59**	**289**	**50.8**	**81.6**	**93**
Limitation	**2.06**		**70.0**	**75.0**	**199**		**120.0**	**30.0**	**342**

Table 5.1 Average Annual Wastewater Parameters (continued)

Year	Oil and Grease				Turbidity (NTU)	pH	Chronic Toxicity (TUc)	Ammonia as NH_3-N (mg/L)
	Influent (mg/L)	Effluent (mg/L)	Removal (percent)	Mass Emission (MT)				
1986	64	13.8	78.4	27	26	7.7		18
1987	44	6.2	85.9	13	23	7.5		
1988	38	6.3	83.4	13	40	7.5		
1989	28	6.1	78.2	12	49	7.4		26
1990	34	8.5	75.0	16	55	7.4		26
1991	73	6.9	90.5	12	50	7.3		18
1992	33	5.3	83.9	10	56	7.3		9
1993	26	6.0	76.9	13	43	7.4	19.42[1]	20
1994	60	4.1	93.2	8	36	7.5	4.37	27
1995	63	5.1	91.9	11	32	7.5	4.35	23
1996	52	7.9	84.8	17	34	7.7	4.83	23
1997	49	5.3	89.2	12	32	7.7	7.80	23
1998	51	5.4	89.4	15	34	7.6	7.80	19
1999	52	6.2	88.1	14	48	7.5	5.00	25
2000	74	5.5	92.6	13	39	7.5	5.60	24
2001	47	4.6	90.2	9	41	7.4	5.60	28
2002	39	4.4	88.7	7	41	7.5	4.98	31
2003	44	5.3	87.9	7	34	7.5	7.80	27
2004	47	3.7	92.0	6	26	7.5	5.60	29
2005	62	4.4	92.9	8	23	7.6	5.60	27
2006	44	4.1	90.6	7	26	7.6	4.36	28
2007	52	4.0	92.4	6	27	7.6	4.36	28
2008	84	4.4	94.8	7	30	7.5	5.56	27
2009	93	4.5	95.1	7	29	7.5	15.82[2]	32
2010	76	4.7	93.8	9	31	7.6	10.88[2]	34
2011	75	4.0	94.6	7	26	7.6	13.95	27
2012	91	5.0	94.5	8	26	7.6	13.95	33
2013	115	4.5	96.1	6	25	7.5	24.55	40
2014	81	4.0	95.1	5	28	7.5	17.90	50
2015	81	1.7	97.9	<3	28	7.5	17.90	45
Average	**59**	**5.4**	**89.3**	**10**	**35**	**7.5**	**9.48**	**27**
Limitation		**25.0**			**75**	**6-9**	**134.00**	**80.4**

[1] Screening bioassay of three marine species
[2] Screening bioassay of two marine species

Moreover, the plant routinely achieved treatment levels that exceeded the removal requirements applicable to full secondary treatment. For example, monthly solids-removal rates substantially surpassed the 85% full secondary criterion in eleven months, while BOD removal rates achieved full secondary levels during ten months of the year. Other effluent constituents were also correspondingly low during 2015. The discharge of settleable solids was imperceptible, and monthly averages of effluent turbidity, pH, ammonia, and coliform density remained well within the applicable permit limitations.

The continued high overall performance of the treatment process during 2015 was the direct result of vigilant control by plant personnel, a proactive program of preventative maintenance, and the successful completion of numerous MMRP projects. Plant personnel actively sought out and corrected potential mechanical problems with plant components before they occurred, and responded quickly to the occasional unforeseen failure. In 2015, and in recent prior years, their constant attention to the idiosyncratic disinfection process undoubtedly prevented excursions beyond allowable discharge limits.

The benefits of current and past efforts to reduce rainwater inflow and groundwater infiltration (I&I), and to more accurately measure plant flow, are also evident in the record of annual average flow rates listed in Table 5.1. These efforts account for the marked decline in plant throughput in 2002, when average daily flow dropped below 1.3 MGD and remained at or below 1.25 MGD for the last decade-and-a-half. In all fifteen years prior to that time, annual flow remained above 1.25 MGD.

5.1.2 Flow Rate

Historically, the most influential factor affecting flow rate was a metering inaccuracy that resulted in flow overtotalization. A study conducted in 2002 found that rates reported by the effluent flow meter were consistently overestimated by as much as 25%. Without this overtotalization, average flow over the 30-year record would be closer to 1.17 MGD rather than the reported 1.33 MGD. Because of overestimated flow prior to 2002, the annual mass emissions were also overestimated. Consequently, the average emissions over the entire plant history, shown in bold at the bottom of Table 5.1, are slightly inflated. Specifically, the reported average annual TSS emission of 59 MT is actually closer to 51 MT. Similarly, the average annual BOD emission reported at 93 MT is, in reality, closer to 81 MT, and the reported 10 MT of O&G discharged is closer to 9 MT. Even after accounting for past overtotalization, the 2015 emissions of TSS, BOD, and O&G (39, 63, and <3 MT) were still well below the historical averages (51, 81, and 9 MT).

In 2002, overtotalization was largely eliminated after the more accurate influent flow meter was commissioned, and flow began to be reported based on its measurements. However, on occasion, flow is still overtotalized due to aberrant influent-flow readings, for example, when the influent flume becomes temporarily surcharged after water backs up into the influent channel behind the plant headworks. Nevertheless, judicious use of corrected effluent flow totals effectively eliminated significant flow overtotalization after 2002. The most accurate annual flow totals have been achieved through application of an adjustment to the flow reported by the effluent meter as described in the recommendation presented in Section 5.4 below.

However, these past flow-measurement improvements and I&I reductions do not account for the marked decrease in plant flow over the last three years. At less than 1 MGD, the reported flows were the lowest on record, with 2015 being the lowest at 0.93 MGD. Some of this recent flow decrease can be attributed to reduced groundwater infiltration into the collection system due to a lowering of the water table during the prolonged drought. However, at least some of the decrease in 2015 was undoubtedly related to the successful water-conservation measures implemented by the citizens of Cayucos and Morro Bay. The

City of Morro Bay reduced water usage in 2015 by 13.5%, significantly surpassing the 12% mandatory water-restriction goal imposed by statewide limits that went into effect in April 2015.

Additionally, the very low monthly flows reported in November and December 2015 happened to coincide with the installation of a new influent flow meter on 18 November. Despite a series of rainstorms, the December reported flow of 0.760 MGD was the lowest monthly flow ever recorded at the treatment plant. Moreover, it was much lower (0.064 MGD) than the next lowest flow of 0.824 MGD measured in October 2014. Despite the coincidental timing, the unusually low flows cannot be ascribed to underreporting by the new meter because its accuracy was reconfirmed during a subsequent calibration in March 2016. Nevertheless, as described in the Recommendations Section 5.4, the empirical relationship between the influent and effluent flow meters changed slightly after the new influent meter was commissioned. Consequently, derivation of the adjustment formula for use in 2016 was based on only a limited number of recent measurements rather than on an entire year of data.

5.1.3 Effluent Constituents

The treatment process was designed to remove organic particulates from the wastewater stream and disinfect effluent. As with most municipal treatment plants, it was not designed to eliminate chemical contaminants dissolved in wastewater. Instead, a vigorous pollution-prevention program is in place, which aims to limit the introduction of chemical contaminants at the source, before they enter the collection system. The multifaceted pollution-prevention program includes public education efforts, an onsite hazardous waste collection facility, source identification, a pharmaceutical take-back program, and inspections of commercial and industrial users. Domestic users generate more than 80% of the sewage processed at the WWTP; non-industrial users or light industry, which generate wastewater similar to that of domestic sources but on a larger scale, contribute the remaining portion of the WWTP's influent. In the absence of heavy industry within the service area, there is a concomitant lack of industrial pollutants within the MBCSD wastewater.

As in prior years, a few common metals and ubiquitous chemical compounds appeared in low concentrations within the effluent and biosolid samples collected during 2015. Of the 78 chemical compounds tested for in the semi-annual effluent samples, only a few were present in quantifiable amounts. Additionally, the measured concentrations of these compounds were all well below applicable NPDES discharge limits. In most cases, the concentrations were orders of magnitude lower than their respective limits. The associated mass emissions were also well below the limits identified in the discharge permit.

Quantified compounds within the effluent included three commonly occurring trace metals (copper, lead, and zinc), selenium, radionuclides, and a non-chlorinated phenolic compound. The three trace metals all occur naturally within the mineralogy of sediments along the central California coast. These metals also enter the collection system through internal corrosion of household plumbing systems. The metalloid selenium also occurs naturally in the sedimentary environment, and is less likely to arise within plumbing systems. As a natural product in many foods, and in animal and human urine, the phenolic compound, *p*-cresol is commonly found in wastewater and has been regularly detected within the MBCSD effluent samples at low concentrations. Lastly, some level of radioactivity in effluent samples is expected because of naturally occurring radionuclides. Nonetheless, radiation levels were still well within the limits established for drinking water standards and were similar to historical levels.

Bioassays conducted over the past decade have consistently demonstrated the MBCSD effluent's low toxicity to marine organisms. The chronic bioassays conducted in 2015 again confirmed the benign nature of MBCSD effluent. Average toxicity levels in 2015 were seven-times lower than the permitted limit.

As with effluent samples, chemical analyses of biosolid samples quantified only very low concentrations of some commonly occurring wastewater constituents. In addition to the bulk organic compounds, the only constituents with quantifiable concentrations were 14 ubiquitous metal, metalloids, and cyanide. All measured concentrations were well below regulatory limits that would make the biosolids hazardous or unsuitable for composting and land application.

5.2 RECEIVING WATERS

The receiving-water environment was monitored on a quarterly basis to evaluate the oceanographic conditions near the outfall, particularly with respect to any adverse impacts from wastewater discharge. Comparisons of water quality at the boundary of the zone of initial dilution (ZID) with gradient areas beyond the dilution zone documented compliance with the receiving-water objectives of the California Ocean Plan (COP) as specified in the NPDES discharge permit. Extremely sensitive electronic probes provided a detailed picture of water quality during the four surveys conducted in 2015. Precision navigation, in combination with high-resolution data on light transmittance, density, temperature, salinity, pH, and dissolved oxygen delineated the limited spatial extent of the dilute effluent plume within receiving waters.

During all four surveys, small anomalies in water properties associated with the submerged wastewater plume were detected. In all cases, the water-quality fluctuations were restricted to the ZID, were generated by the upward displacement of ambient seawater and not the presence of wastewater constituents, or were insignificant compared to the larger ambient variations resulting from natural oceanographic processes. Several of these plume measurements captured the signature of wastewater while it was undergoing rapid initial mixing within the ejection jet emanating from a diffuser port. Dilution rates determined from these close-in measurements were compared with expected critical initial dilution ratios based on modeling used to design the outfall. They demonstrated that the diffuser structure had dispersed the wastewater to a much greater extent than predicted by the modeling.

Because tests for compliance with the receiving-water limitations in the discharge permit only apply outside the ZID, these close-in measurements were not subject to the standards in the COP. Nevertheless, plume observations collected within the ZID were routinely below the permit limits applicable to observations collected outside this narrow 15-m mixing zone. None of the observed conditions suggested that unmixed wastewater was tangibly affecting receiving waters within or beyond the ZID. As with prior monitoring, water quality parameters measured in the 2015 surveys confirmed that the diffuser was operating efficiently and that wastewater was diluted 48-fold immediately following discharge from the diffuser ports and well before the completion of the initial-dilution process.

5.3 SEAFLOOR SEDIMENTS

The monitoring program has evaluated physical, chemical, and biological conditions within the benthic sediments around the outfall for three decades. Temporal fluctuations in these factors have been directly related to natural influences, the largest of which occur on seasonal and interannual time scales. The more notable faunal variations have typically involved interannual population fluxes within individual taxa. For example, substantial increases in the abundance of juvenile Pacific sand dollars (*Dendraster excentricus*) were documented in 1989, 1991, 1999, and 2009. During and after these episodic recruitment events, sand dollar populations overwhelmingly dominated the infaunal community, with the residual effects of successful recruitment persisting over a few of the following years. However, the residual effect of the 2009 sand dollar recruitment was more prolonged, and extended into 2015. The marked population increases in sand dollars have often coincided with the well-recognized global climate fluctuation known

as El Niño. These major changes affect all of the benthic monitoring stations, including the distant reference site, and are related to inherent oceanographic variability rather than the discharge of effluent.

To test for outfall-related effects, a large number of biological indices and parameters were computed from an enumeration of the 258,000 specimens collected over 30 years of benthic monitoring. None of these parameters exhibited statistically significant spatial distributions related to the effluent discharge or long-term spatiotemporal trends indicative of an increasingly degraded benthic habitat near the outfall.

Not only were spatial differences found in individual surveys small compared to inherent sampling variability, but also the differences were generally smaller than seasonal and interannual changes in community structure that arose from natural environmental oscillations, such as El Niño. Despite large temporal fluctuations in the composition of the infaunal community, its health has remained consistently high in the 29 years of monitoring prior to the 2015 survey. During that time, the benthic environment within the survey area around the outfall was populated by an infaunal community dominated by pollution-sensitive suspension-feeding organisms.

However, a major change occurred in 2015 when numerous large sand dollars totally dominated every aspect of the sedimentary environment throughout the offshore survey area. This population of sand dollars originated with the vast number of juveniles that were recruited during the 2009 El Niño event. As this original 2009-cohort matured over the following six years, sand dollars displaced a steadily increasing amount of ambient surficial sediment and the infauna that resided in it. This trend culminated in 2015 with a large and abrupt decline in nearly every measure of the health of the benthic infaunal community, including infaunal density, diversity, species counts, and richness. The declines were unrelated to the MBCSD discharge because they occurred uniformly throughout the survey area with no evidence of a spatial gradient related to outfall proximity.

The most dramatic decline occurred in the infaunal trophic index (*ITI*), which estimates the wellbeing of the infaunal community from the relative sizes of the suspension-feeding infaunal population, which typically reside in clean sediments, and the pollution-tolerant detritus-feeding population, which opportunistically occupy organically enriched seafloor habitats. Prior to improvements in wastewater treatment during the 1980s, marked *ITI* declines were observed within seafloor sediments immediately surrounding large ocean discharges in other regions. However, the *ITI* decline measured in the MBCSD survey area in 2015 was unrelated to organic loading within sediments because the concentrations of organic constituents measured in 2015 were comparable to those of prior years.

Instead, the *ITI* decline was directly due to the development of the mature sand dollar bed that eliminated nearly all suspension-feeding infauna through predation, and competition for space and food. In addition, the large sand dollar bed provided a suitable habitat for a number of parasitic and opportunistic species not typically seen in the MBCSD samples. In fact, a species of crab was found in 2015 that was previously unseen in the MBCSD database, which is remarkable considering 258,000 specimens representing 390 individual taxa have been collected over the 30 years of monitoring. Although some these new species were detritus feeders that weighted heavily in the observed *ITI* reduction in 2015, their presence was not related to habitat degradation from an accumulation of organic contaminants. Field studies conducted on uncontaminated sediments in other regions confirmed that many of those same species were far more prevalent within sand dollar beds than in seafloor areas immediately adjacent to the beds. Clearly, the presence of the mature sand dollar bed had a profound effect on the benthic environment within the MBCSD survey area during 2015.

Spatiotemporal analyses were also conducted on the large dataset of sediment physicochemistry spanning the 30 years since benthic monitoring began in 1986. Those analyses demonstrated that there was no buildup of sediment contaminants surrounding the outfall. In addition, trace-metal and organic

concentrations collected both near and far from the outfall in 2015 remained below thresholds considered harmful to marine biota. In fact, sediment trace-metal concentrations within Estero Bay were well below concentrations found in the vast majority of samples collected offshore Southern California. This attests to the pristine nature of the ocean environment in northern Estero Bay. Nickel and chromium are the only trace metals with comparatively elevated concentrations within Estero Bay sediments. However, the concentrations of these particular metals are naturally elevated in the chromite mineral ores found in the region. As a result, the Estero Bay sediment metal concentrations are comparable to those in nearby benthic environments, such as Port San Luis (NOAA 1991a), and the Morro Bay Estuary (Tenera and Marine Research Specialists 1997).

These sediment-chemistry analyses, in conjunction with analyses of infaunal community structure, provide strong empirical evidence that the sediments surrounding the outfall, along with the organisms within them, have not been perceptibly impacted by the discharge, even after three decades of operation and monitoring.

5.4 RECOMMENDATIONS

The 30 years of monitoring data summarized in this annual report demonstrate that the MBCSD WWTP has been operating as designed, and that the discharge of effluent has not adversely impacted the marine environment within Estero Bay. Occasional adjustments made to the monitoring program have substantially increased its capacity to detect minute environmental impacts, yet conclusions regarding the lack of impacts have continued to hold true into 2015.

Over the years, adjustments have been made to the monitoring program based on recommendations for improving its ability to detect impacts and assess compliance. Few recommendations have dealt with changes to the treatment plant or its process, largely because of the consistently high performance of the plant and outfall system. Thus, as in past reports, most of the following recommendations pertain to proposed revisions to the monitoring program:

- **Reduce the monitoring frequency for effluent chemical parameters.** Pursuant to the provisions within the current NPDES permit, a reduction in the monitoring frequency of effluent chemical concentrations is warranted (MBCSD 2004; MRS 2004b, 2009b). The MBCSD discharge permit allows a change in monitoring frequency to once-in-the-life of the permit for those compounds that are undetected in the first year of monitoring. During 2009 sampling, which was the first year of sampling under the current permit, 73 chemical constituents met this criterion. Additionally, application of the SWRCB's (2005) statistical methodology to two decades of MBCSD effluent measurements unequivocally demonstrates that there is no reasonable potential for exceedance of permit limits for those 73 compounds, or for the remaining compounds currently monitored on an annual basis. As a result, the COP does not require continued annual monitoring of any of the compounds. Concentrations measured in effluent samples collected in subsequent years, including 2015, only serve to strengthen those conclusions. The reduction in monitoring frequency is further justified by the historically high level of compliance, a proposed monitoring frequency that is consistent with other similar-sized dischargers, and an ongoing bioassay program that provides a more sensitive all-inclusive evaluation of effluent quality.
- **Reinstate analysis for trace metals, grain size, and infauna at benthic Station B1**. Although the physical environment at Station B1 departs from that at the outfall stations, its 1 km distance from the outfall provides valuable insight into large-scale environmental processes within Estero Bay that are independent of the discharge. Additionally, Station B1 has been continuously sampled throughout the 30-year monitoring program. Even though benthic monitoring at this location is no longer required by

the current discharge permit, voluntary collection and analysis of sediment samples has continued through 2015. Continued sampling at this location is recommended to maintain historical consistency with the long-term time series, and to provide insight into regional processes affecting Estero Bay as a whole.

- **Eliminate the Cat-Litter Public-Outreach Program.** The current discharge permit requires an annual reevaluation of the implementation goals of the Cat-Litter Public-Outreach work plan. A requirement for development and submittal of a work plan was included in the current permit as a conservation measure because concerns were raised that Estero Bay was a "hot-spot" for otter mortality associated with *T. gondii* infection. Disposal of cat litter into the MBCSD collection system was thought by some to be a contributing factor to the high exposure and infection rates found in live animals and carcasses tested from the Estero Bay area. However, shortly after final approval of the current MBCSD permit in 2009, results from a comprehensive field study (Johnson et al. 2009) were published that confirmed that disease vectors unrelated to WWTP discharge are responsible for the observed *T. gondii* exposure in otters, and that the epicenter for infection is not within Estero Bay. As such, there is little scientific rationale for the continuation of a dedicated outreach program specific to cat-litter disposal in the MBCSD collection system.

  Instead, existing public-outreach efforts required under the permit should continue to incorporate efforts to keep regulatory agencies and the public abreast of the latest scientific findings in order to reduce existing misconceptions about the MBCSD discharge's effects on otter health and the significance of *T. gondii* within the watershed. Nevertheless, although the current MBCSD efforts at public education and outreach regarding cat litter disposal are comprehensive, and have included the use of the internet, posters, newsletters, and public talks and tours, they remain uncodified by a formal work plan, as required in the current NPDES permit. Therefore, until the RWQCB revisits the validity of the concerns underlying the inclusion and necessity of this conservation measure, the MBCSD should continue to work towards finalizing a cat-litter public-outreach work plan in accordance with the permit requirements.

- **Remove Basin-Plan receiving-water limits on pH and DO from the NPDES discharge permit**. As discussed in Section 3.3.2, the Basin Plan limits on pH and DO that are incorporated into the current NPDES discharge permit issued to the MBCSD are inappropriate for open ocean dischargers. The fixed Basin Plan limits were largely designed for discharges to onshore surface waters, where there is little natural variation in pH and DO within the receiving waters. Conversely, natural oceanographic processes, such as upwelling, regularly cause the DO and pH within the ambient receiving water surrounding the MBCSD outfall to range beyond the Basin Plan limits. In contrast to the Basin Plan limits, the COP recognizes the potential for inherent variation in the receiving-water characteristics and specifies limits on excursions in these two water properties relative to background levels present at the time of the survey. Because the COP receiving-water objectives are designed to be adequately protective of the marine environment, application of the fixed Basin Plan limits to the same receiving-water characteristics already covered by the COP is not only redundant but also inappropriate.

- **Remove the effluent nutrient-monitoring requirement**. A provision for nutrient monitoring was incorporated into the current discharge permit to address concerns regarding the MBCSD's potential nutrient contribution to the generation of harmful algal blooms offshore central California. As discussed in Section 2.2.11, however, chemical analyses conducted to date demonstrate that nutrient concentrations within the MBCSD effluent, and mass loading to the marine environment from its discharge, are insignificant compared to both other central-coast dischargers, and the contribution

from regional streams and rivers. Specifically, nutrient loading from the MBCSD WWTP is several orders-of-magnitude lower than both runoff and discharge from other central-coast WWTPs, and far smaller than the nutrient loading from naturally occurring processes such as upwelling. Additionally, it is clear that nutrient loads from the MBCSD discharge are unrelated to the frequency or intensity of the algal bloom occurring along this stretch of coastline. Consequently, continued nutrient monitoring provides no scientifically valid or usable information relevant to the prediction or management of algal blooms, and should be discontinued.

- **Each year, establish an annual schedule for BOD sampling that addresses all three of the competing permit requirements governing collection frequency. Clarify BOD sampling requirements and correct associated footnote errors in future discharge permits issued to the MBCSD.** Under the current permit, there are three separate requirements dealing with the collection of weekly effluent samples for BOD analysis:

    1. The first requirement for '*weekly*' sampling stipulates that one sample must be collected during each complete week of the year. Presumably, each calendar week extends from Sunday through Saturday as indicated by the definition of the *Average Weekly Effluent Limitation* on *Page A-1* of the permit. This requirement results in the collection of approximately 52 BOD samples each year, except when the calendar week extends into a prior or future year, and the weekly sample is collected on a day that falls outside of the current year. In such cases, a given year may have as many as 54 '*weekly*' samples, or as few as 50 samples.
    2. The second sampling requirement arises from the definition of a monthly average in the *Central Coast Standard Provisions* that are incorporated in the NPDES permit (*Page D-20*). It requires the use of at least four sample-results to compute a monthly average.
    3. Interpretation of the third weekly sampling requirement is confounded by the incorrect application of *Footnote 1* to the sampling frequency requirement for effluent BOD that is listed on *Page E-6* of the NPDES Permit. That footnote refers to influent, rather than effluent sampling. Nevertheless, assuming that the correct footnote for weekly BOD sampling is *Footnote 2*, each day of the 7-day week must be represented in each two-month period. This is typically achieved by rotating the day of the week used for sampling and by duplicating sampling on one day of the week once during each eight-week period.

    Designing a sampling schedule, which accomplishes all three of these requirements efficiently, is a complex process. For example, application of only the first or third sampling requirements may occasionally result in less than four samples being drawn in a given month. Advance preparation of an annual schedule for BOD sampling during 2015 will help to achieve the permit requirements efficiently while minimizing extraneous sampling.

- **Quantify when percent-removal limitations apply.** Section IV.B on Page 16 of the NPDES discharge permit issued to the MBCSD states that "*The Discharger shall, as a 30-day average, remove at least 75% of suspended solids and 30% of BOD_5 from the influent stream before discharging wastewater to the ocean, except that the limit shall not be less than 60 mg/L*" (RWQCB-USEPA 2009). The statement is unnecessarily confusing and makes quantitative evaluation of compliance difficult. Specifically, the statement does not make it clear that the applicability of the removal-rate requirements is conditional, and thus, may not apply in monthly compliance evaluations.

The limitation derives from the first note to Table A of the COP (SWRCB 2005), which makes it clear that the applicability of the requirement is conditional: "*…the discharger shall remove 75% of suspended solids from the influent stream at any time the influent concentration exceeds four times* [the lower effluent concentration limit]." In the case of the MBCSD discharge, the effluent TSS threshold of applicability is 60 mg/L, so the influent TSS threshold is 240 mg/L. Because the target BOD removal-rate is 30%, the influent BOD threshold of applicability is 86 mg/L. Although the MBCSD TSS and BOD influent concentrations rarely if ever drop below these thresholds of applicability, the discharge permit should, at a minimum, explicitly state that the removal-rate requirements are conditional on exceedance of the influent thresholds identified above.

In practice, MBCSD effluent TSS and BOD concentrations are almost always below the 60 mg/L effluent threshold and when this is the case, compliance with the removal-rate requirement is guaranteed. Specifically, if the sub-60-mg/L effluent concentration was not achieved by removal exceeding the 75%/30% requirements, then the requirements do not apply (because the influent concentration must have been less than the 240 mg/L or 86 mg/L thresholds to begin with). Because of this, the removal-rate requirement should be simplified for compliance evaluations by dischargers and regulators alike. Simply stated, the permit requirement should read: *When monthly effluent TSS or BOD concentrations exceed 60 mg/L, the discharger shall remove at least 75% of the solids, or 30% of the BOD from the influent stream.*

- **Apply a correction formula when reporting daily flow using effluent flow-meter measurements.** Daily plant throughput is normally determined by totalizing the readings from the influent flow meter. The influent flow-meter readings are used because they measure the volume of wastewater processed by the treatment plant more accurately than the effluent flow meter. On rare occasions, however, the influent flow meter reports erroneously high values. Typically, these outliers are obvious in the flow record and result from easily identifiable causes such as surcharging of the influent trunk line during major rain events, when equipment malfunctions occur at the headworks, or, as in 2015, when inflow to the WWTP is intentionally stopped and allowed to backup in the trunk line to facilitate equipment repair. On those occasions, daily flow should be reported using measurements from the effluent flow meter that have been adjusted downward to account for that meter's overtotalization.

  Historically, the effluent flow meter has been found to overtotalize the actual flow by approximately 25% [MRS 2003b]. A comparison of daily flow totals reported by the influent and effluent meters during 2015 (Figure 5.1), however, provides an updated formula for adjusting the effluent flow-meter readings that is more representative of current conditions:

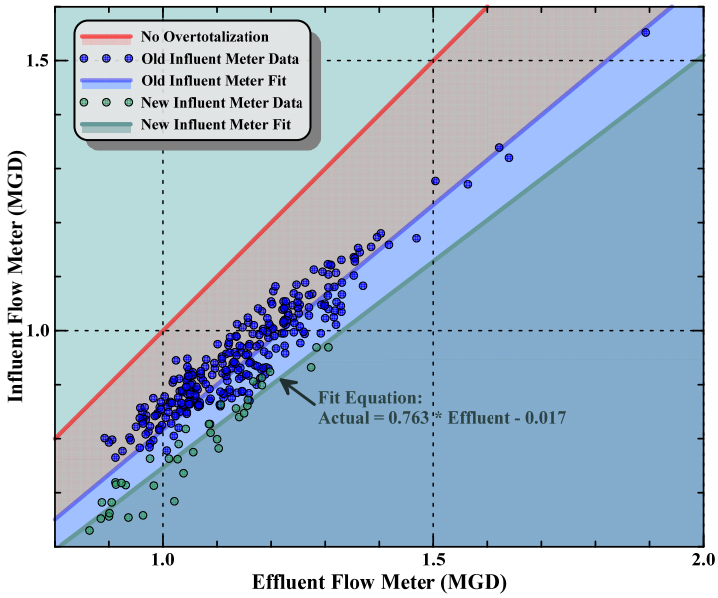

Figure 5.1 Relationship between Flow Reported by the Influent and Effluent Meters during 2015

$$A = 0.763 \times E - 0.017 \qquad \text{Equation 5.1}$$

where: A = the actual plant flow in MGD, and
E = the flow measured by the effluent meter.

Equation 5.1 was determined from a linear regression on pairs of daily flow observations that were measured by the influent and effluent meters after a new influent meter was installed on 18 November 2015 (green dots in Figure 5.1). The new meter indicated that overtotalization by the effluent meter was slightly greater than that predicted using readings from the previous influent meter in 2015 (dark blue dots).[1] For example, an effluent reading of 1 MGD best matched the old meter's 2015 readings after adjusting it by 0.071 MGD less than that predicted by Equation 5.1. However, the actual adjustment that was occasionally applied to effluent-meter readings to report flow in 2015 was based on 2014 data, when the estimated overtotalization was closer to that predicted by Equation 5.1.[2]

The relationship between influent and effluent readings changes slowly over time due to inherent drift in the meters, or sporadically when either meter is recalibrated, serviced, or replaced, as was the case with the influent meter at the end of 2015. Thus, while updating the adjustment equation annually is useful, the actual changes are small compared to the overall adjustment for overtotalization of the effluent meter (difference from the red line in Figure 5.1), and well within the data scatter (cloud of points surrounding the blue and green regression lines in the Figure).

Consequently, daily flow predicted by adjusting the effluent flow-meter data (red time series in Figure 5.2) closely tracks the flow reported by the influent meter (blue time series) throughout 2015. Most exceptions are obvious, and occur when the water level within the influent metering flume was artificially elevated because wastewater has backed-up behind the headworks. Normally, the influent measurements, which are based on precision water-level measurements, provide a more accurate determination of flow than the impeller-based effluent meter.

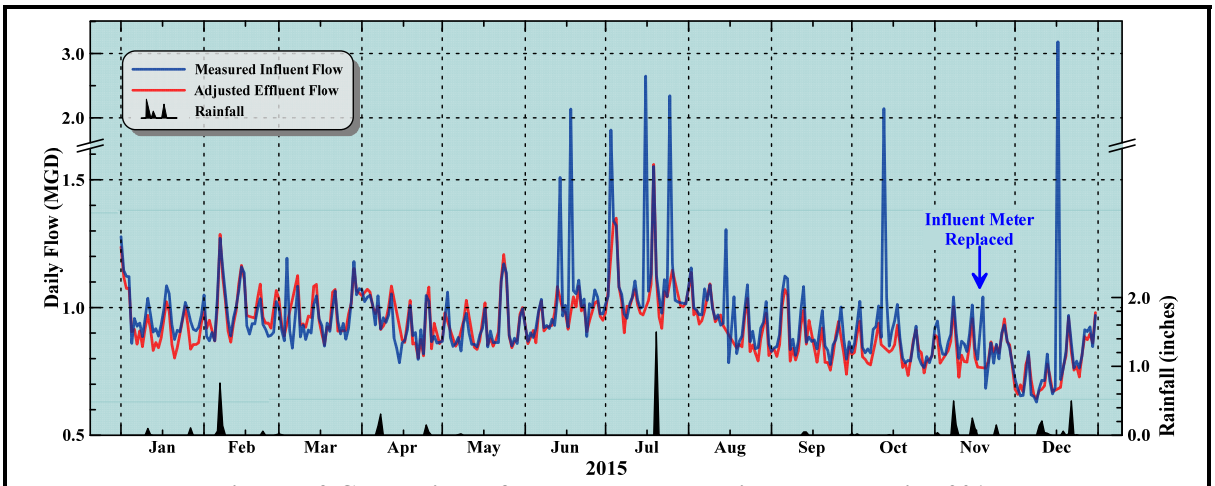

Figure 5.2 Comparison of Measured and Predicted Flow during 2015

[1] During the first 11.5 months of 2015, the relationship between influent (A) and effluent (E) readings was approximated by $A = 0.832 \times E - 0.015$.

[2] Based on an analysis of flow data in 2014 (Chapter 5 of MRS 2015a), the recommended adjustment to effluent flow data in 2015 was $A = 0.784 \times E - 0.015$. Thus, for example, a 1 MGD effluent flow reading would have been adjusted downward to 0.769 MGD, as opposed to 0.746 MGD using Equation 5.1 from this report. This amounts to an additional 0.023 MGD in overtotalization predicted by Equation 5.1.

During 2015, nine events caused the influent flume to become surcharged and resulted in unrealistically high influent flow measurements. Most are evident as excursions above 1.5 MGD in the blue time series in Figure 5.2 that are not tracked by the effluent flow in red. As described in Section 2.1.1 and Appendix A, about half of these events occurred when flow into the WWTP was briefly interrupted while draining the Chlorine Contact Tank to inspect, repair, and maintain the Tank, and to address solids buildup. On those, and a few other occasions when influent-flow measurements were either anomalous or missing, daily flow volumes were reported using the effluent flow-meter data adjusted for overtotalization. These and other obvious outliers were also excluded when the revised relationship between meter readings (Equation 5.1) was determined.

With the exception of these few outliers, the time series of adjusted effluent data shows excellent agreement with the influent data throughout 2015, and lends confidence in its use when the influent meter becomes surcharged. The availability of precise and closely matching measurements from both the influent meter and the adjusted effluent meter also provides valuable redundancy in the event that one of the meters is taken offline for repairs or calibration. To ensure reporting of the most accurate daily flow totals on a regular basis, future NPDES discharge permits issued to the MBCSD should explicitly state that flow data from either the influent meter or effluent meter (after adjustment) may be used to establish the daily flow volumes. To ensure that adjustments to effluent flow readings continue to be as accurate and timely as possible, the coefficients in Equation 5.1 should be recomputed at least annually, or when significant modifications are made to the meters or flow system.

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CHAPTER 6

Literature Cited

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6.0 LITERATURE CITED

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APPENDIX A

Wastewater Treatment Plant Specifications
Maintenance and Repair Activities

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Table A.1 WWTP Specifications

Parameter	Quantity
Waste Loading	
Flow (MGD)	
Average dry-weather flow	2.06
PSDWF	2.36
Peak dry-weather flow	6.64
PWWF	6.60
Strength	
BOD_5 (mg/L)	280
Suspended solids (mg/L)	280
Grit (ft^3/mg)	10
Waste quantities at PSDWF	
BOD_5 (mt/day)	2.5
Suspended Solids (mt/day)	2.5
Grit (ft^3/day)	23.6
Preliminary Treatment	
Mechanically Cleaned Bar Screen	
Number	1
Capacity (MGD)	8.2
Channel Monster	
Number	1
Capacity (MGD)	7.0
Influent Pumps (variable speed)	
Number	3
Capacity each (MGD)	3.3
Total head (m)	9.6
Aerated Grit-Removal Tanks	
Number	1
Length (m)	9.1
Width (m)	4.9
Depth (m)	2.4
Detention time at PWWF (min)	6.3
Grit Pumps	
Number	2
Capacity (gpm)	250
Primary Treatment	
Sedimentation Tanks	
Number	2
Diameter (m)	
Tank 1	15.2
Tank 2	12.2
Average side water depth (m)	
Tank 1	2.74
Tank 2	2.74
Surface loading rate PSDWF (10^3 L/m^2/day)	29.74
Detention time at PWWF (hr.)	2.2
Total Treatment	
Overall treatment efficiencies (%)	
BOD_5	57
Suspended solids	75
Expected effluent quality (mg/L)	
BOD_5	120
Suspended solids	70
Solids stabilization	
Anaerobic digester loading (mt/day)	
Primary solids	1.6
Secondary solids	0.4
Assumed sludge volatile content (%)	
Primary solids	70
Secondary solids	82
Sludge volume (m^3/day)	50.7
Digester 1 (existing, fixed cover)	
Diameter (m)	12.2
Side water depth (m)	4.9
Volume (m^3)	629
Digester 2 (existing, fixed cover)	
Diameter (m)	12.2
Side water depth (m)	5.8
Volume (m^3)	725
Digester 3 (new, floating cover)	
Diameter (m)	10.7
Side water depth (m)	6.9
Volume (m^3)	646
Hydraulic detention time based on net volume of digesters 2 and 3 (days)	23
Assumed volatile solids reduction (%)	55
Expected sludge gas production (m^3/day)	804
Sludge Drying Beds	
Number	12
Length each (m)	49.4
Width each (m)	9.8
Solids Loadings (kg ft^{-1} yr^{-1})	78.3

Parameter	Quantity
Assumed removal efficiency (%)	
BOD_5	35
Suspended solids	65
Primary effluent quality (mg/L)	
BOD_5	182
Suspended solids	98
Secondary treatment	
Biofilters (existing, in partial secondary treatment mode of operation)	
Flow distribution at PSDWF (MGD)	
Biofilter 1	0.39
Biofilter 2	0.58
Diameter (m)	
Biofilter 1	18.3
Biofilter 2	21.3
Net media surface area (m^2)	
Biofilter 1	262
Biofilter 2	350
Average media height (m)	
Biofilter 1	1.4
Biofilter 2	1.5
Media Volume (m^3)	
Biofilter 1	360
Biofilter 2	532
Specific organic loading rate (lbs BOD_5/day/1000 ft^3)	47
Circulated flow (MGD)	
Biofilter 1	1.37
Biofilter 2	2.04
Hydraulic loading rate (gpm/ft^2 media surface)	
Biofilter 1	0.34
Biofilter 2	0.38
Circulation Pumps	
Biofilter 1	
Capacity (gpm)	950
Total head (m)	3.4
Biofilter 2	
Capacity (gpm)	1420
Total head (m)	4.3
Stand-by (2-speed)	
Capacity (gpm)	960 1660
Total head (m)	3.4 4.4

Parameter	Quantity
Interstage pumping	
Biofilter Effluent Pumps (variable speed)	
Number	2
Capacity each (gpm)	2300
Total head (m)	8.2
Secondary sedimentation Tanks	
Number	1
Diameter (m)	16.8
Tank surface area (m^2)	221
Tank volume (m^3)	3125
Average water depth (m)	4.6
Overflow rate at PSDWF (10^3 L/m^2/day)	16.6
Expected secondary treatment effluent quality (mg/L)	
BOD_5	30
Suspended Solids	30
Chlorination	
Chlorine Contact Tank (existing)	
Number of passes	2
Length (m)	
Pass 1	16.8
Pass 2	22.9
Width each pass (m)	4.6
Average depth (m)	2.3
Total volume (m^3)	413
Detention time at PDWF (min)	24
Chlorinators	
Pre-chlorinator	
Number	1
Initial capacity (kg/day)	227.3
Ultimate capacity (kg/day)	909.1
RAS chlorinator	
Number	1
Capacity (kg/day)	227.3
Ultimate capacity (kg/day)	90.9
Sodium Hypochlorite Post Chlorinator	
Chemical feed pumps	3
Combined Capacity (kg/day)	5450
Dechlorination	
Sodium Bisulfite System	
Chemical feed pumps	3
Combined Capacity (kg/day)	1226

Table A.2 WWTP Maintenance and Repair Activities

- Coated and repaired Digester #1 (*January-August*)
  - Commissioned Digester #2 as the primary digester while Digester #1 was offline
    - Commissioned Digester #3 as the secondary digester
  - Operated well pumps in two dewatering wells to lower the groundwater levels around Digester #1
  - Performed structural tests on Digester #1 that found it in satisfactory condition (*January*)
    - Cored into the walls at five locations for compression testing
    - Visually inspected the interior and exterior walls of the Digester
    - Recommended sandblasting and coating of the digester interior among other repairs
  - Repaired pipes and valves on Digester #1 (*January*)
    - Replaced the bonnets on the lower circulation lines entering the Digester
    - Replaced or repaired six-inch valves on the sludge transfer pipe
  - Repaired the pipe system feeding the heat exchanger in Digester #3 in anticipation of future modifications and cleaning (*January*)
  - Sandblasted and recoated the interior of Digester #1 (*May-June*)
  - Purged and verified valves and sludge-transfer lines, and replaced a faulty pipe feeding the upper and lower supernatant lines on the east side of Digester #1 with a new six-inch PVC pipe (*August*)
  - Commissioned Digester #1 as a secondary digester after filling it with disinfected effluent, sealing all the manways, injecting nitrogen gas into the remaining gas space, and opening the Digester to the digester-gas system (*August 17*)
  - Commissioned Digester #3 after installation of a new gas-recirculation blower and motor, and adding a new local remote switch (*August*)
- Prepared for commissioning of a new 2500-gallon Ferrous-Chloride Storage Tank to provide increased operational flexibility and reduced shipping costs (*January*)
  - Purchased the new Tank
  - Modified supply and discharge pipes
  - Modified the ferrous-chloride containment structure
- Inspected and repaired the Outfall Pipeline and Diffuser System (*January 7*)
  - Received the inspection report and Outfall video from Carson Porter Diving, indicating the outfall was in good condition with no plugged or broken diffusers
  - Replaced the bolts on the upper flanges of the Diffusers
- Responded to chlorine-residual alarms (*January 7*, *February 7*, *February 16*, *April 10*, *April 29, May 3-8, June 2-4, July 19, September 2 & 3, October 14 & 19* and *December 10 &18*)
  - Retained the narrow range in the alarm set-points that provides quick response-times but occasional false alarms
  - Conducted the following activities during each response occasion:
    - Confirmed the dosing pumps were operating
    - Calibrated the chlorine residual analyzers
    - Inspected the entire dosing system and found no problems
- Replaced the supply and discharge tubing and fittings on Sodium-Hypochlorite Pumps #1, #2, and #3 (*February 3*)
- Serviced the Emergency Auxiliary Generator (*February*)
  - Tested the Generator under full load
  - Installed a spare DC-420 Main Utility Breaker (*February 3*)
  - Replaced the Generator batteries (*February 24*)
- Installed a valve and pipe system to isolate and control Biofilter Circulation Pumps (*February*)
  - Discontinued effluent discharge during installation of a new fourteen-inch butterfly valve in the discharge pipe of Biofilter Effluent Pump #P4505 (*February 4*)
    - Drained the Grit Chamber and Primary Clarifier #2 in anticipation of the interruption in discharge
    - Temporarily routed WWTP throughput into the Chamber and Clarifier during the repair

  - Discontinued effluent discharge during installation of new fourteen-inch and twelve-inch butterfly valves to isolate and control biofilter recirculation pumps (*February 19*)
    - Drained the Grit Chamber and Primary Clarifier #2 in anticipation of the interruption in discharge
    - Temporarily routed WWTP throughput into the Chamber and Clarifier during the repair
  - Replaced the remaining twelve-inch butterfly valve used to isolate and control biofilter recirculation pumps without interruption in effluent discharge because of the flow controls afforded by the previously installed valves (*February 20*)
- Tested and replaced the high-level alarm floats in Primary Clarifiers #1 and #2 (*February 17* and *March 16*)
- Reinstalled the motor for the Main Influent Pump #2 after steam cleaning, rewinding, dipping and baking, and replacing the bearings on the pump (*February 25*)
- Repaired the catwalks above Primary Clarifiers #1 and #2 (*March-April*)
- Mounted and aligned new Aeration Air Blowers (*March* and *May*)
- Serviced and repaired the Sodium-Hypochlorite Dosing System (*March 2*)
  - Replaced the Sodium-Hypochlorite Dosing Pump #1
  - Replaced the upper check-ball housings on Pumps #2 and #3 after finding wear that resulted in incomplete seating and inefficient pumping
- Reported daily flow totals using an adjusted reading from the effluent flow meter rather the influent flow meter readings that are normally used
  - Adjusted the reported flow using effluent flow-meter reading based on the equation provided on Page 5-9 of the 2014 Annual Report (MRS 2015a)
  - On *March 4*, adjusted the erroneously high influent flow of 1.193 MGD measured when the influent flume was surcharged after all three Main Influent Pumps were shut down for thirty minutes during testing of new Influent Screens under simulated high-flow conditions
  - On *June 14*, adjusted the erroneously high influent flow of 1.509 MGD measured when the Influent Flume was surcharged after a large rag lodged on Influent Screen #1
  - On *June 18*, adjusted the erroneously high influent flow of 2.135 MGD measured when the Influent Flume was surcharged after shutting down the Influent Pumps to clean the Chlorine Contact Tank
  - On *July 3*, adjusted the erroneously high influent flow of 1.808 MGD measured when the Influent Flume was surcharged when the Influent Screens were not manually reset after a power outage and debris buildup on the Screens caused influent to backup into the Trunk Line
  - On *July 16*, adjusted the erroneously high influent flow of 2.648 MGD measured when the Influent Flume was surcharged after shutting down the Influent Pumps to repair a valve on the Chlorine Contact Tank
  - On *July 25*, adjusted the erroneously high influent flow of 2.345 MGD measured when the Influent Flume was surcharged due to debris built up on the Influent Screens because they were not unlocked after routine maintenance activities
  - On *October 13*, adjusted the erroneously high influent flow of 2.141 MGD measured when the Influent Flume was surcharged after shutting down the Influent Pumps to drain the Secondary Clarifier
  - On *November 18*, reported an adjusted effluent flow due to the absence of a valid influent-flow total while the newly installed flow-meter was calibrated
  - On *November 19*, adjusted the erroneously high influent flow of 1.041 MGD measured when the Influent Flume was surcharged after shutting down the Influent Pumps to drain the Chlorine Contact Tank
  - On *November 30*, reported an adjusted effluent flow due to the absence of a valid influent flow total while the newly installed flow-totalizer was reset
  - On *December 17*, adjusted the erroneously high influent flow of 3.182 MGD measured when the Influent Flume was surcharged after shutting down the Influent Pumps to drain the Chlorine Contact Tank
- Installed a new heating element and controls in the Sodium-Bisulfite Storage Tank to prevent sodium-bisulfite crystallization at low temperatures (*March 12*)
- Replaced four handheld radios used for internal communication within the WWTP (*March 20*)
- Disassembled , inspected, cleaned, tested, and adjusted the burner for Boiler #2 (*April 1*)
  - Replaced a faulty fan motor
- Removed and repaired Sump Pump #2 in the lower headworks (*April 8*)

- Drained and repaired the Chlorine Contact Tank (*April 15*)
  - Prepared for servicing the Chlorine Contact Tank
    - Executed a contract with the repair-service provider
    - Mobilized equipment and supplies onsite
    - Notified the staffs of the Regional Water Quality Control Board and the California Department of Health Shellfish Division of an anticipated discharge violation resulting from the temporary inability to dechlorinate effluent
    - Drained the Grit Chamber and Primary Clarifier #2 in anticipation of the interruption in discharge (*April 13*)
      - Identified in-plant return flows associated with the Clarifier draining as the cause of the unusually elevated 785-mg/L influent TSS reading on *April 14* (see Figure 2.6c)
    - Discontinued effluent discharge and temporarily routed WWTP throughput into the Chamber and Clarifier prior to repair (*April 14*)
    - Drained the contents of the Chlorine Contact Tank into an empty sludge bed where it was dechlorinated, thereby minimizing the effluent volume discharged to the ocean with elevated chlorine levels during the repair
  - Conducted the repair (*April 15*)
    - Bypassed the Chlorine Contact Tank and dechlorination process, and directed chlorinated and disinfected effluent directly into the outfall
    - Notified regulatory agencies that the 7.2 mg/L TRC concentration measured during the repair exceeded the 1.07 mg/L Daily Maximum discharge limit (see Figure 2.13)
    - Installed a new idler shaft and sprockets, and a new drive shaft and sprockets in the south Chlorine Contact Tank
      - Repaired the wear strips located on the floor of the Tank
    - Extended the guide rails located at the west end of the north Tank
      - Installed new wear shoes on the flights in the Tank
      - Performed minor repairs to the wear strips
      - Drained and inspected the flash mixer and 3W pumps
- Identified and repaired a leak in the six-inch potable-water supply line at the main entrance to the WWTP (*April 16*)
- Fabricated and installed new seal-water lines on the Biofilter-Recirculation and Secondary-Effluent Pumps (*April 22*)
- Drained and refilled Primary Clarifier #2 to retrieve lost equipment (*April 28*)
- Installed a retainer for the suction tubing on the influent composite sampler to allow relocation of the intake and facilitate collection of representative influent composite samples (*May 5*)
- Drained and repaired Primary Clarifier #2 (*May 5-8*)
  - Repaired the metal framework on the flights and skimmer-cage assembly
  - Replaced the metal arm used as the scum collector and the steel post used to support the skimmer assembly
  - Responded to repeated high chlorine-residual alarms due to refilling of the Clarifier which affected flow to the Chlorine Contact Tank (*May 3-8*)
- Addressed potential concerns with the efficacy of the disinfection process (*June 1-18*)
  - Identified an increase in the measured density of effluent coliform bacteria (see Figure 2.14)
  - Posited that the coliform increase was caused by an accumulation of organic solids in the bottom of the Chlorine Contact Tank
  - Briefly drained the Contact Tank to inspect and clean it (*June 18*)
    - Pumped the Tank contents to an empty Sludge Bed
    - Discontinued flow to the Tank by stopping the Influent Pumps and allowing influent to accumulate in the Trunk Line
      - Reported the daily flow total using the Effluent Meter because the Influent Meter was surcharged
    - Removed an abnormal amount of solids that had accumulated on the floor of the Tank using high-pressure hoses

- Repaired the Primary Scum and Sludge Pumps by installing new discharge pipes and six-inch valves (*June*)
- Installed new six- and eight-inch pipes discharging from the Grit Pump into the Grit Cyclones And Grit-Dewatering Unit (*June 5*)
- Reinstalled Headworks Sump Pump #P2212 in the lower headworks after its repair (*June 10*)
- Removed debris from the valve seat of the leaking backflow device on the four-inch water line entering the WWTP (*June 11*)
- Drained the Solids Contact Channel to replace eight diffusers (*July 1*)
- Replaced Sodium-Hypochlorite Dosing Pump #1 with a newer-model pump (*July 6*)
- Repaired the drive chain in the Chlorine Contact Tank without draining the Tank (*July 13*)
  - Identified and replaced a badly cracked chain link prior to failure from a small boat placed into the Tank
- Briefly drained the Chlorine Contact Tank to replace a faulty six-inch drain valve (*July 17*)
  - Excavated to expose the valve prior to Tank draining to minimize the time it was offline
  - Pumped the contents of the Chlorine Contact Tank into an empty sludge bed
  - Discontinued flow to the Tank by stopping the Influent Pumps and allowing influent to accumulate in the Trunk Line
    - Reported daily flow using the Effluent Meter because the Influent Metering Flume was surcharged
  - High-pressure washed the interior of the Tank and replaced the drain valve
- Repaired lighting for the roadways within the WWTP including installation of new control circuitry on the automatic lighting system (*August 12*)
- Repaired a water leak in the two-inch potable water line located within the Chlorine Building Storage Area (*August12*)
- Replaced a broken sheer pin on the drive unit for the North Chlorine Tank (*August13*)
- Installed a new skimmer-arm assembly on the Secondary Clarifier (*August 28*)
- Replaced Sodium-Hypochlorite Dosing Pump #3 after a bad diaphragm was discovered (*September 11*)
  - Replaced the supply and discharge tubing and fittings for the pump
- Identified and replaced a faulty diaphragm on Primary Sludge Pump #P3502 (*September 12*)
- Re-examined potential concerns with the efficacy of the disinfection process (*September 7-16*)
  - Identified another increase in the measured density of effluent coliform bacteria (see Figure 2.14)
  - As with the June increase, posited that the coliform bloom was caused by an accumulation of organic solids within the Chlorine Contact Tank
  - Temporarily drained the Contact Tank to inspect and clean it (*September 16*)
    - Pumped the Tank contents to an empty sludge bed
    - Diverted WWTP flow to the grit chamber and Primary Clarifier #2 that had been previously drained in preparation for draining of the Contact Tank
    - Removed an abnormal amount of solids that had accumulated on the floor of the Tank using high-pressure hoses
- Installed a new skimmer arm assembly on the Secondary Clarifier (*September 17*)
- Removed Influent Pump #3 for repair after discovering a small hole in the bottom of the volute at the base of the Pump (*September 30*)
  - Reinstalled the refurbished Pump #3 which contained new seals and bearings and a repaired volute
  - Subsequently, removed the Pump again for repair after a leaking seal was discovered (*October 25*)
  - Reinstalled the refurbished Pump #3 with repairs to the seal on volute (*December 9*)
- Repaired the 120 volt 20 amp GFI circuit breaker used to power the Influent Composite Sampler (*September 25*)
- Installed a new local remote switch on Aeration Air Blower #B5111 (*September 25*)
- Repaired the controls and pendent for the headworks jib crane (*September 25*)
- Repaired spalled concrete on the Chlorine Contact Tank by removing the damaged concrete, epoxying exposed rebar, and installing new concrete (*September*)
- Removed and rebuilt the Waste-Activated Sludge Pump #6511 by installing new seals and bearings (*September*)
- Drained the Secondary Clarifier for inspection and maintenance (*October 14*)

  - Isolated the Secondary Clarifier from WWTP throughput
    - Initially stopped the three Main Influent Pumps and stacked influent within the Influent Trunk Line
    - Filled the previously emptied Aerated Grit Chamber and Primary Clarifier #2 after the Influent Pumps were restarted
    - Stopped the Influent Pumps again as the Grit Chamber and Clarifier approached capacity
    - Reported daily flow using the Effluent Meter because the Influent Metering Flume was surcharged
  - Cleaned the Clarifier and removed approximately one-half meter of debris, plastics, and sand
  - Installed a new seal on the center column of the Return Activated Sludge (RAS) system
  - Cleaned the ports and pipes on the suction arms
- Manually reset the Return Activated Sludge (RAS) blower following a power outage when the blower did not automatically reset and RAS flow ceased, causing elevated TSS and turbidity effluent concentrations (see Figures 2.6 & 2.7; *October 20*)
- Calibrated the zero-flow set-point on the existing Ultrasonic Flow Meter and transducer in the twenty-seven inch Palmer Bowlus Flume by plugging thirty-inch Influent Trunk Line upstream of the Flume (*October 22*)
  - Verified the functionality and calibrations of Flow Meters located on the Primary Sludge Pipes, on the Sludge-Recirculation Pipes for Digesters #2 and #3, and on the Influent Pipe to the Secondary Clarifier.
- Replaced a corroded six-inch check valve, a new sight glass, and associated pipes on Primary Sludge Pump #1 (*October 29*)
- Repaired the heating element and controls used to heat the Sodium-Bisulfite Storage Tank and prevent sodium-bisulfite crystallization at low temperatures (*November 11*)
  - Replaced a faulty fuse, installed a backup fuse, and sealed the control box to prevent entry of off-gassed sodium bisulfite
- Installed a new Ultrasonic Flow Meter and transducer in the twenty-seven inch Palmer Bowlus Flume to update influent flow-measurement technology (*November 18*)
  - Calibrated the Meter's zero-flow set-point by plugging thirty-inch Influent Trunk Line upstream of the Metering Manhole
  - Reprogrammed the newly installed Flow Meter per manufacturer instructions, resulting in the absence of an influent flow reading (*November 30*)
- Drained the Chlorine Contact Tank to address the increase in coliform density caused by an accumulation of organic solids in the Tank (*November 19*)
  - Temporarily drained the Contact Tank
    - Pumped the Tank contents into two empty Sludge Beds
    - Diverted WWTP flow to the Grit Chamber and Primary Clarifier #2 that had been previously drained in preparation for repair work on the Chlorine Contact Tank
  - Discontinued flow to the Tank by stopping the Influent Pumps and allowing influent to accumulate in the Trunk Line
    - Reported daily flow using the Effluent Meter because the Influent Metering Flume was surcharged
  - Removed solids that had accumulated on the floor of the Tank using high-pressure hoses
  - Installed wood fillets along the edges of the south Tank to mitigate solids accumulation along the bottom edges of the Tank that had caused the repeated increases in effluent coliform density
- Repaired the control circuitry on Hot-Water Circulation Pump P9221, which is used in heating the Digesters (*November 23*)
- Repaired the seal-water lines on the Biofilter-Recirculation Pumps (*November 27*)
- Identified a requirement to isolate each of the electrical circuits powering the chlorine-residual analyzers, the hypochlorite and bisulfite pumps, and the sump pumps used to dewater the associated containment area (*December 11*)
  - Operated the sump pump in the sodium-hypochlorite containment area to drain rainwater accumulation
  - Investigated an abnormal chlorine residual and found that the sump pump had tripped the breaker on the electrical circuit that also powers the sodium-hypochlorite and sodium-bisulfite dosing pumps

  - Re-sampled for effluent chlorine after restarting the dosing pumps and found that the prior measurement of 4.5 mg/L, which constituted an exceedance of the 1.07-mg/L maximum daily limit (see Figure 2.13), had declined to undetectable levels
- Drained the Chlorine Contact Tank to further address prior increases in coliform density caused by an accumulation of organic solids in the Tank (*December 17*)
  - Temporarily drained the Contact Tank
    - Pumped the Tank contents into two empty Sludge-Drying Beds
    - Diverted WWTP flow to the Grit Chamber and Primary Clarifier #2 that had been previously drained in preparation for repair work on the Chlorine Contact Tank
  - Discontinued flow to the Tank by stopping the Influent Pumps and allowing influent to accumulate in the Trunk Line
    - Reported daily flow using the Effluent Meter because the Influent Metering Flume was surcharged
  - Removed solids that had accumulated on the floor of the Tank using high-pressure hoses
  - Installed two new flights and adjusted the height of the wear shoes in the north Tank to mitigate solids accumulation along the bottom edges of the Tank that had contributed to repeated prior increases in effluent coliform density
- Mitigated potential problems from a possible future inundation of rainwater into the WWTP in response to long-range forecasts of heavy winter rainfall (*December*)
  - Installed a backwater valve on the Maintenance Shop Drain
  - Prepared for preventing unwanted backflow into the headworks from drains in various treatment components by either plugging the drains, or acquiring covers to be deployed in an emergency
  - Installed solid plates on the openings to the Interstage Pump Station
  - Tested the flood gates protecting the doors to the Motor Control Centers
  - Contracted for the construction of masonry walls around the periphery of the two Biofilters

APPENDIX B

Infaunal Biology

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INFAUNAL INDICES

B.1.1 Species Diversity

The Shannon diversity index (*H'*) (Shannon and Weaver 1949) is the most common diversity index used in 301(h) programs. It measures the relative distribution of individual organisms among the species present in the sample. *H'* increases for broader distributions of individuals among species. If all individuals are of one species then *H'* is 0.00. If each individual organism is a separate species then *H'* is determined by the logarithm of the total number of organisms collected. For other distributions, the diversity index is given by: $H' = -\sum_{j=1}^{S}\left[\left(\frac{n_j}{N}\right)\ln\left(\frac{n_j}{N}\right)\right]$; where: S = total number of species, n_j = number of individuals in the jth species, N = total number of individuals, and ln = natural logarithm (base e). The value of the Shannon index usually falls between 1.5 and 3.5 and only rarely surpasses 4.5 (Margalef 1972).

Some studies have found a decrease in this index in response to pollutant stress in benthic communities. However, this index is ambiguous because it depends on how evenly the organisms are distributed among the species. Consequently, a statistically significant reduction in this index can occur in the absence of anthropogenic (human-induced) stresses.

When randomness in the sample cannot be guaranteed, then the Brillouin index (*h*) is a more appropriate measure of diversity (Pielou 1977). It is calculated using the formula: $h = \frac{\ln(N!) - \sum_{j=1}^{S}\left[\ln(n_j!)\right]}{N}$. It gives a similar measure of diversity although it produces a slightly lower value than the Shannon index when applied to the same data. In contrast to the Shannon index, the Brillouin will vary between samples although the number of species and their proportional abundance remain the same. Because of its dependence on sample size and the increased complexity of its computation, the Brillouin index is more rarely used than the Shannon index.

B.1.2 Evenness

The Pielou evenness index (*J'*) (Pielou 1977) measures how evenly the individual organisms are distributed among the species present in the sample. *J'* increases for more even distributions of individuals among species. If all individuals belong to a single species, then *J'* is indeterminate. If each species is represented by a single organism, then *J'* will be equal to 1.00. For other distributions, the evenness index is given by: $J' = \frac{H'}{\ln S}$; where: S = total number of species, and H' = Shannon-Wiener diversity index. Because this index is derived from the Shannon-Wiener diversity index (*H'*), it is subject to the same limitations.

B.1.3 Species Dominance

Dominance indices increase with decreasing diversity and are heavily weighted toward the most common species in a sample. The best known of these measures is Simpson's index (*C'*) (Simpson 1949; Wittaker 1965). It is related to other diversity and evenness indices but increases with increasing proportions of individuals associated with a few species. If all individuals are of one species, then *C'* is maximum and equal to the maximum dominance of 1.00. If individual organisms are evenly distributed among species

(J'=1.00), then C' asymptotically approaches 0.00 with increasing numbers of individuals. The Simpson dominance measure is given by: $C' = \sum_{j=1}^{S}\left(\frac{n_j}{N}\right)^2$ but for finite communities, the unbiased form is: $C' = \sum_{j=1}^{S}\left(\frac{n_j(n_j-1)}{N(N-1)}\right)$ (Magurran 1988).

An unrelated measure of dominance has been ascribed to Swartz et al. (1985). The Swartz dominance index (*Sw*) is defined as the minimum number of species that account for at least 75% of all individual organisms collected in a sample. In this dominance measure, species are first ranked by the number of individual organisms before summing the number of species that represent a cumulative percent equal to, or first exceeding 75%. This is an inverse measure because higher dominance is reflected in a lower number of species accounting for 75% of the individual organisms. Despite this, it is not subject to many of the limitations that plague the other univariate indices. It is a non-parametric measure that does not assume an underlying distribution of individuals among species.

B.1.4 Infaunal Trophic Index

The Infaunal Trophic Index (*ITI)* (Word 1978) compares the abundance of four soft-bottom benthic assemblages distinguished by feeding behavior. Because the sensitivity or tolerance to organic enrichment in particulate matter differs among the four groups, shifts in group dominance, as reflected in a changing infaunal index, can be indicative of changed or degraded environmental conditions. The *ITI* ranges between 0 and 100. When species in Group I (suspension feeders) and Group II (surface-detritus feeders) dominate, index values are above 58 and sediments are relatively clean. Lower infaunal indices occur when species in Group III (surface deposit feeders) and Group IV (sub-surface detritus feeders) dominate and sediments are high in organics. The *ITI* is computed from: $ITI = 100 - 33.3\left[\frac{G_2 + 2G_3 + 3G_4}{G_1 + G_2 + G_3 + G_4}\right]$; where: G_i = number of individual organisms within the i^{th} trophic group.

B.1.5 Species Richness

The Margalef species richness index (*d*) (Margalef 1951) measures the number of species in a sample relative to the number of individual organisms. *d* strongly increases for increasing number of species and increases only logarithmically for decreasing number of individuals. If only one species is present then *d* is 0.00. For other distributions, the richness index is given by: $d = \frac{S - 1}{\ln N}$. Its applicability to biological communities is dependent on whether specimens are log-normally distributed among the species in a given sample. Such an assumption is not globally applicable to benthic marine communities, and without testing each data set, the richness index is of questionable value.

Table B.1 Station Abundance by Taxa during October 2015

Taxonomic Group	Taxon	Station							Station Total	Percent of Total	Cumu-lative %
		B1	B2	B3	B4	B5	B6	B7			
Echinodermata	*Dendraster excentricus*	638	392	331	368	335	351	373	2788	–	–
Mollusca	*Balcis rutila*	63	11	15	14	95	41	52	291	34.11	34.11
Crustacea	*Rhepoxynius menziesi*	3	7	15	13	5	8	16	67	7.85	41.97
Annelida	*Armandia bioculata*	12	1	5	15	8	8	5	54	6.33	48.30
Crustacea	*Americhilidium shoemakeri*	4	3	3	5	8	16	8	47	5.51	53.81
Annelida	*Magelona sacculata*	1	4	4	5	8	5	20	47	5.51	59.32
Bivalvia	*Tellina modesta*	8	5	8	9	9	2	5	46	5.39	64.71
Mollusca	*Alvania*	7	5	2	5	19	3	5	46	5.39	70.11
Crustacea	Hippolytidae	1	5	4	7	6	10	2	35	4.10	74.21
Crustacea	*Cancer gracilis*	7	5	3	4	4	5	2	30	3.52	77.73
Nemertea	*Cerebratulus californiensis*	3	1	5	4	3	1	2	19	2.23	79.95
Annelida	*Sigalion spinosa*	1	3	–	4	3	3	2	16	1.88	81.83
Annelida	*Apoprionospio pygmaea*	–	1	2	3	2	1	5	14	1.64	83.47
Annelida	*Scoloplos armiger*	5	2	2	–	–	3	1	13	1.52	84.99
Annelida	*Lumbrineris californiensis*	–	3	1	2	3	1	3	13	1.52	86.52
Annelida	*Nephtys caecoides*	2	–	–	–	1	2	5	10	1.17	87.69
Nemertea	*Carinoma mutabilis*	2	2	2	1	–	2	–	9	1.06	88.75
Crustacea	*Portunus xantusii*	1	–	–	2	3	2	1	9	1.06	89.80
Annelida	*Lumbrineris*	5	2	–	–	1	–	–	8	0.94	90.74
Bivalvia	*Tellina bodegensis*	–	–	2	1	2	3	–	8	0.94	91.68
Crustacea	*Lepidopa californica*	–	1	2	–	2	2	–	7	0.82	92.50
Annelida	*Glycinde armigera*	2	2	1	–	–	–	1	6	0.70	93.20
Crustacea	*Foxiphalus xiximeus*	2	–	–	–	1	2	1	6	0.70	93.90
Annelida	*Chaetozone setosa*	1	–	1	2	–	–	2	6	0.70	94.61
Bivalvia	*Cooperella subdiaphana*	2	1	–	–	1	1	–	5	0.59	95.19
Annelida	*Prionospio cirrifera*	3	–	–	–	–	1	–	4	0.47	95.66
Bivalvia	*Clinocardium nuttallii*	1	2	–	1	–	–	–	4	0.47	96.13
Crustacea	*Eohaustorius sencillus*	–	–	1	1	–	1	1	4	0.47	96.60
Annelida	*Notomastus lineatus*	–	1	1	–	–	–	1	3	0.35	96.95
Echinodermata	*Leptosynapta*	–	–	–	1	1	–	1	3	0.35	97.30
Peanut Worms	Sipuncula	2	–	–	–	–	–	–	2	0.23	97.54
Crustacea	*Majoxiphalus major*	1	–	–	–	–	1	–	2	0.23	97.77
Annelida	*Gyptis brevipalpa*	–	1	–	1	–	–	–	2	0.23	98.01
Mollusca	*Nassarius perpinguis*	–	1	–	–	–	1	–	2	0.23	98.24
Annelida	*Phyllodoce*	–	–	–	1	1	–	–	2	0.23	98.48
Bivalvia	*Rochefortia tumida*	–	–	–	1	–	1	–	2	0.23	98.71
Nemertea	*Carinomella lactea*	–	–	–	–	2	–	–	2	0.23	98.94
Annelida	*Phylo felix*	1	–	–	–	–	–	–	1	0.12	99.06
Annelida	*Harmothoe*	–	1	–	–	–	–	–	1	0.12	99.18
Crustacea	Gammaridea	–	–	1	–	–	–	–	1	0.12	99.30
Annelida	*Glycera convoluta*	–	–	–	1	–	–	–	1	0.12	99.41
Platyhelminthes	Polycladida	–	–	–	1	–	–	–	1	0.12	99.53
Phoronida	*Phoronis*	–	–	–	1	–	–	–	1	0.12	99.65
Bivalvia	*Rochefortia grippi*	–	–	–	–	1	–	–	1	0.12	99.77
Annelida	*Dispio uncinata*	–	–	–	–	–	1	–	1	0.12	99.88

Table B.1 Station Abundance by Taxa during October 2015

Taxonomic Group	Taxon	Station B1	B2	B3	B4	B5	B6	B7	Station Total	Percent of Total	Cumulative %
Bivalvia	*Macoma*	–	–	–	–	–	–	1	1	0.12	100.00
Total Number of Individuals		**778**	**462**	**411**	**473**	**524**	**478**	**515**	**3641**		
Total Number of Individuals Excluding *D. Excentricus*		**140**	**70**	**80**	**105**	**189**	**127**	**142**	**853**		

Table B.2 Replicate Sample Abundance by Taxa at Station B1 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Echinodermata	*Dendraster excentricus*	133	110	124	156	115	638	–	–
Mollusca	*Balcis rutila*	6	13	11	11	22	63	45.00	45.00
Annelida	*Armandia bioculata*	1	3	3	2	3	12	8.57	53.57
Bivalvia	*Tellina modesta*	1	4	1	1	1	8	5.71	59.29
Crustacea	*Cancer gracilis*	1	3	–	3	–	7	5.00	64.29
Mollusca	*Alvania*	1	–	3	2	1	7	5.00	69.29
Annelida	*Lumbrineris*	1	–	–	1	3	5	3.57	72.86
Annelida	*Scoloplos armiger*	1	–	–	4	–	5	3.57	76.43
Crustacea	*Americhilidium shoemakeri*	2	1	1	–	–	4	2.86	79.29
Annelida	*Prionospio cirrifera*	1	1	–	–	1	3	2.14	81.43
Crustacea	*Rhepoxynius menziesi*	–	1	1	–	1	3	2.14	83.57
Nemertea	*Cerebratulus californiensis*	–	–	2	1	–	3	2.14	85.71
Crustacea	*Foxiphalus xiximeus*	1	1	–	–	–	2	1.43	87.14
Annelida	*Nephtys caecoides*	1	–	1	–	–	2	1.43	88.57
Bivalvia	*Cooperella subdiaphana*	1	–	–	–	1	2	1.43	90.00
Nemertea	*Carinoma mutabilis*	2	–	–	–	–	2	1.43	91.43
Annelida	*Glycinde armigera*	–	1	–	1	–	2	1.43	92.86
Peanut Worms	Sipuncula	–	–	–	–	2	2	1.43	94.29
Annelida	*Chaetozone setosa*	1	–	–	–	–	1	0.71	95.00
Bivalvia	*Clinocardium nuttallii*	1	–	–	–	–	1	0.71	95.71
Annelida	*Sigalion spinosa*	–	1	–	–	–	1	0.71	96.43
Annelida	*Magelona sacculata*	–	–	1	–	–	1	0.71	97.14
Annelida	*Phylo felix*	–	–	1	–	–	1	0.71	97.86
Crustacea	*Portunus xantusii*	–	–	1	–	–	1	0.71	98.57
Crustacea	*Majoxiphalus major*	–	–	–	1	–	1	0.71	99.29
Crustacea	Hippolytidae	–	–	–	1	–	1	0.71	100.00
Total Number of Individuals		**155**	**139**	**150**	**184**	**150**	**778**		
Total Number of Individuals Excluding *D. Excentricus*		**22**	**29**	**26**	**28**	**35**	**140**		

Table B.3 Replicate Sample Abundance by Taxa at Station B2 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Echinodermata	*Dendraster excentricus*	90	76	73	78	75	392	–	–
Mollusca	*Balcis rutila*	3	2	2	2	2	11	15.71	15.71
Crustacea	*Rhepoxynius menziesi*	1	–	3	2	1	7	10.00	25.71
Crustacea	*Cancer gracilis*	1	1	2	1	–	5	7.14	32.86
Bivalvia	*Tellina modesta*	1	1	2	–	1	5	7.14	40.00
Mollusca	*Alvania*	2	–	2	1	–	5	7.14	47.14
Crustacea	Hippolytidae	3	–	–	1	1	5	7.14	54.29
Annelida	*Magelona sacculata*	–	1	1	2	–	4	5.71	60.00
Annelida	*Lumbrineris californiensis*	2	1	–	–	–	3	4.29	64.29
Annelida	*Sigalion spinosa*	–	1	–	1	1	3	4.29	68.57
Crustacea	*Americhilidium shoemakeri*	–	1	–	1	1	3	4.29	72.86
Bivalvia	*Clinocardium nuttallii*	1	1	–	–	–	2	2.86	75.71
Annelida	*Lumbrineris*	1	1	–	–	–	2	2.86	78.57
Annelida	*Scoloplos armiger*	1	–	–	–	1	2	2.86	81.43
Annelida	*Glycinde armigera*	2	–	–	–	–	2	2.86	84.29
Nemertea	*Carinoma mutabilis*	–	–	–	1	1	2	2.86	87.14
Nemertea	*Cerebratulus californiensis*	–	1	–	–	–	1	1.43	88.57
Bivalvia	*Cooperella subdiaphana*	–	1	–	–	–	1	1.43	90.00
Annelida	*Gyptis brevipalpa*	–	1	–	–	–	1	1.43	91.43
Annelida	*Apoprionospio pygmaea*	–	1	–	–	–	1	1.43	92.86
Annelida	*Notomastus lineatus*	–	–	1	–	–	1	1.43	94.29
Mollusca	*Nassarius perpinguis*	–	–	1	–	–	1	1.43	95.71
Crustacea	*Lepidopa californica*	–	–	1	–	–	1	1.43	97.14
Annelida	*Harmothoe*	–	–	–	1	–	1	1.43	98.57
Annelida	*Armandia bioculata*	–	–	–	–	1	1	1.43	100.00
Total Number of Individuals		**108**	**90**	**88**	**91**	**85**	**462**		
Total Number of Individuals Excluding *D. Excentricus*		**18**	**14**	**15**	**13**	**10**	**70**		

Table B.4 Replicate Sample Abundance by Taxa at Station B3 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Echinodermata	*Dendraster excentricus*	65	63	72	65	66	331	–	–
Mollusca	*Balcis rutila*	2	6	4	1	2	15	18.75	18.75
Crustacea	*Rhepoxynius menziesi*	3	4	2	3	3	15	18.75	37.50
Bivalvia	*Tellina modesta*	1	6	–	–	1	8	10.00	47.50
Nemertea	*Cerebratulus californiensis*	1	2	1	1	–	5	6.25	53.75
Annelida	*Armandia bioculata*	1	–	2	2	–	5	6.25	60.00
Crustacea	Hippolytidae	1	–	3	–	–	4	5.00	65.00
Annelida	*Magelona sacculata*	–	1	–	1	2	4	5.00	70.00
Crustacea	*Cancer gracilis*	1	–	1	1	–	3	3.75	73.75
Crustacea	*Americhilidium shoemakeri*	1	–	–	1	1	3	3.75	77.50

Table B.4 Replicate Sample Abundance by Taxa at Station B3 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Crustacea	*Lepidopa californica*	1	–	1	–	–	2	2.50	80.00
Annelida	*Scoloplos armiger*	1	–	–	–	1	2	2.50	82.50
Mollusca	*Alvania*	1	–	–	–	1	2	2.50	85.00
Annelida	*Apoprionospio pygmaea*	–	2	–	–	–	2	2.50	87.50
Bivalvia	*Tellina bodegensis*	–	–	1	1	–	2	2.50	90.00
Nemertea	*Carinoma mutabilis*	–	–	–	1	1	2	2.50	92.50
Annelida	*Chaetozone setosa*	1	–	–	–	–	1	1.25	93.75
Annelida	*Glycinde armigera*	1	–	–	–	–	1	1.25	95.00
Crustacea	*Eohaustorius sencillus*	–	–	1	–	–	1	1.25	96.25
Annelida	*Lumbrineris californiensis*	–	–	–	–	1	1	1.25	97.50
Annelida	*Notomastus lineatus*	–	–	–	–	1	1	1.25	98.75
Crustacea	Gammaridea	–	–	–	–	1	1	1.25	100.00
Total Number of Individuals		**81**	**84**	**88**	**77**	**81**	**411**		
Total Number of Individuals Excluding *D. Excentricus*		**16**	**21**	**16**	**12**	**15**	**80**		

Table B.5 Replicate Sample Abundance by Taxa at Station B4 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Echinodermata	*Dendraster excentricus*	75	78	75	75	65	368	–	–
Annelida	*Armandia bioculata*	1	3	11	–	–	15	14.29	14.29
Mollusca	*Balcis rutila*	6	3	2	1	2	14	13.33	27.62
Crustacea	*Rhepoxynius menziesi*	1	2	2	4	4	13	12.38	40.00
Bivalvia	*Tellina modesta*	3	1	2	3	–	9	8.57	48.57
Crustacea	Hippolytidae	2	2	–	2	1	7	6.67	55.24
Crustacea	*Americhilidium shoemakeri*	1	1	–	3	–	5	4.76	60.00
Mollusca	*Alvania*	2	–	–	–	3	5	4.76	64.76
Annelida	*Magelona sacculata*	–	1	4	–	–	5	4.76	69.52
Annelida	*Sigalion spinosa*	1	1	–	1	1	4	3.81	73.33
Crustacea	*Cancer gracilis*	1	1	–	1	1	4	3.81	77.14
Nemertea	*Cerebratulus californiensis*	2	1	–	1	–	4	3.81	80.95
Annelida	*Apoprionospio pygmaea*	–	–	3	–	–	3	2.86	83.81
Annelida	*Lumbrineris californiensis*	1	1	–	–	–	2	1.90	85.71
Annelida	*Chaetozone setosa*	1	–	1	–	–	2	1.90	87.62
Crustacea	*Portunus xantusii*	–	–	1	1	–	2	1.90	89.52
Annelida	*Glycera convoluta*	–	–	1	–	–	1	0.95	90.48
Annelida	*Gyptis brevipalpa*	–	–	1	–	–	1	0.95	91.43
Annelida	*Phyllodoce*	–	–	1	–	–	1	0.95	92.38
Bivalvia	*Clinocardium nuttallii*	–	–	–	1	–	1	0.95	93.33

Table B.5 Replicate Sample Abundance by Taxa at Station B4 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Bivalvia	*Tellina bodegensis*	–	–	–	–	1	1	0.95	94.29
Echinodermata	*Leptosynapta*	–	–	–	–	1	1	0.95	95.24
Nemertea	*Carinoma mutabilis*	–	–	–	–	1	1	0.95	96.19
Crustacea	*Eohaustorius sencillus*	–	–	–	–	1	1	0.95	97.14
Bivalvia	*Rochefortia tumida*	–	–	–	–	1	1	0.95	98.10
Platyhelminthes	Polycladida	–	–	–	–	1	1	0.95	99.05
Phoronida	*Phoronis*	–	–	–	–	1	1	0.95	100.00
Total Number of Individuals		**97**	**95**	**104**	**93**	**84**	**473**		
Total Number of Individuals Excluding *D. Excentricus*		**22**	**17**	**29**	**18**	**19**	**105**		

Table B.6 Replicate Sample Abundance by Taxa at Station B5 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Echinodermata	*Dendraster excentricus*	55	71	79	65	65	335	–	–
Mollusca	*Balcis rutila*	13	27	23	16	16	95	50.26	50.26
Mollusca	*Alvania*	5	3	4	6	1	19	10.05	60.32
Bivalvia	*Tellina modesta*	1	3	2	2	1	9	4.76	65.08
Annelida	*Magelona sacculata*	1	2	1	3	1	8	4.23	69.31
Annelida	*Armandia bioculata*	2	1	–	3	2	8	4.23	73.54
Crustacea	*Americhilidium shoemakeri*	2	–	3	1	2	8	4.23	77.78
Crustacea	Hippolytidae	1	1	1	3	–	6	3.17	80.95
Crustacea	*Rhepoxynius menziesi*	–	3	1	–	1	5	2.65	83.60
Crustacea	*Cancer gracilis*	–	1	–	1	2	4	2.12	85.71
Crustacea	*Portunus xantusii*	–	1	1	1	–	3	1.59	87.30
Annelida	*Lumbrineris californiensis*	–	2	–	1	–	3	1.59	88.89
Annelida	*Sigalion spinosa*	–	3	–	–	–	3	1.59	90.48
Nemertea	*Cerebratulus californiensis*	–	–	1	2	–	3	1.59	92.06
Bivalvia	*Tellina bodegensis*	–	1	–	–	1	2	1.06	93.12
Annelida	*Apoprionospio pygmaea*	–	1	–	–	1	2	1.06	94.18
Crustacea	*Lepidopa californica*	–	1	–	–	1	2	1.06	95.24
Nemertea	*Carinomella lactea*	–	–	–	1	1	2	1.06	96.30
Crustacea	*Foxiphalus xiximeus*	–	1	–	–	–	1	0.53	96.83
Bivalvia	*Cooperella subdiaphana*	–	1	–	–	–	1	0.53	97.35
Annelida	*Lumbrineris*	–	1	–	–	–	1	0.53	97.88
Annelida	*Nephtys caecoides*	–	1	–	–	–	1	0.53	98.41
Bivalvia	*Rochefortia grippi*	–	–	1	–	–	1	0.53	98.94
Echinodermata	*Leptosynapta*	–	–	–	–	1	1	0.53	99.47
Annelida	*Phyllodoce*	–	–	–	–	1	1	0.53	100.00
Total Number of Individuals		**80**	**125**	**117**	**105**	**97**	**524**		
Total Number of Individuals Excluding *D. Excentricus*		**25**	**54**	**38**	**40**	**32**	**189**		

Table B.7 Replicate Sample Abundance by Taxa at Station B6 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Echinodermata	*Dendraster excentricus*	83	61	70	73	64	351	–	–
Mollusca	*Balcis rutila*	6	4	14	7	10	41	32.28	32.28
Crustacea	*Americhilidium shoemakeri*	5	1	4	2	4	16	12.60	44.88
Crustacea	Hippolytidae	3	–	1	6	–	10	7.87	52.76
Annelida	*Armandia bioculata*	2	–	3	–	3	8	6.30	59.06
Crustacea	*Rhepoxynius menziesi*	3	–	3	–	2	8	6.30	65.35
Annelida	*Magelona sacculata*	3	1	1	–	–	5	3.94	69.29
Crustacea	*Cancer gracilis*	–	1	1	1	2	5	3.94	73.23
Mollusca	*Alvania*	1	–	–	2	–	3	2.36	75.59
Annelida	*Sigalion spinosa*	2	1	–	–	–	3	2.36	77.95
Annelida	*Scoloplos armiger*	2	–	1	–	–	3	2.36	80.31
Bivalvia	*Tellina bodegensis*	–	2	–	–	1	3	2.36	82.68
Crustacea	*Portunus xantusii*	1	–	–	1	–	2	1.57	84.25
Bivalvia	*Tellina modesta*	1	–	–	–	1	2	1.57	85.83
Annelida	*Nephtys caecoides*	–	1	1	–	–	2	1.57	87.40
Nemertea	*Carinoma mutabilis*	–	1	–	1	–	2	1.57	88.98
Crustacea	*Lepidopa californica*	–	1	–	1	–	2	1.57	90.55
Crustacea	*Foxiphalus xiximeus*	–	–	1	–	1	2	1.57	92.13
Nemertea	*Cerebratulus californiensis*	1	–	–	–	–	1	0.79	92.91
Crustacea	*Eohaustorius sencillus*	1	–	–	–	–	1	0.79	93.70
Bivalvia	*Rochefortia tumida*	1	–	–	–	–	1	0.79	94.49
Mollusca	*Nassarius perpinguis*	1	–	–	–	–	1	0.79	95.28
Annelida	*Dispio uncinata*	–	1	–	–	–	1	0.79	96.06
Annelida	*Prionospio cirrifera*	–	1	–	–	–	1	0.79	96.85
Annelida	*Lumbrineris californiensis*	–	–	1	–	–	1	0.79	97.64
Annelida	*Apoprionospio pygmaea*	–	–	1	–	–	1	0.79	98.43
Crustacea	*Majoxiphalus major*	–	–	–	1	–	1	0.79	99.21
Bivalvia	*Cooperella subdiaphana*	–	–	–	1	–	1	0.79	100.00
Total Number of Individuals		**116**	**76**	**102**	**96**	**88**	**478**		
Total Number of Individuals Excluding *D. Excentricus*		**33**	**15**	**32**	**23**	**24**	**127**		

Table B.8 Replicate Sample Abundance by Taxa at Station B7 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Echinodermata	*Dendraster excentricus*	72	77	76	75	73	373	–	–
Mollusca	*Balcis rutila*	10	10	9	12	11	52	36.62	36.62
Annelida	*Magelona sacculata*	2	1	10	3	4	20	14.08	50.70
Crustacea	*Rhepoxynius menziesi*	6	1	–	6	3	16	11.27	61.97
Crustacea	*Americhilidium shoemakeri*	1	4	–	2	1	8	5.63	67.61

Table B.8 Replicate Sample Abundance by Taxa at Station B7 during October 2015

Taxonomic Group	Taxon	Replicate 1	2	3	4	5	Total	Percent of Total	Cumulative Percent
Bivalvia	*Tellina modesta*	1	2	2	–	–	5	3.52	71.13
Annelida	*Nephtys caecoides*	–	–	2	1	2	5	3.52	74.65
Annelida	*Armandia bioculata*	–	–	2	1	2	5	3.52	78.17
Mollusca	*Alvania*	4	–	1	–	–	5	3.52	81.69
Annelida	*Apoprionospio pygmaea*	–	–	–	–	5	5	3.52	85.21
Annelida	*Lumbrineris californiensis*	–	1	–	2	–	3	2.11	87.32
Annelida	*Chaetozone setosa*	1	–	1	–	–	2	1.41	88.73
Nemertea	*Cerebratulus californiensis*	1	–	1	–	–	2	1.41	90.14
Crustacea	*Cancer gracilis*	–	–	–	1	1	2	1.41	91.55
Annelida	*Sigalion spinosa*	–	1	–	1	–	2	1.41	92.96
Crustacea	Hippolytidae	–	–	–	–	2	2	1.41	94.37
Annelida	*Scoloplos armiger*	1	–	–	–	–	1	0.70	95.07
Echinodermata	*Leptosynapta*	1	–	–	–	–	1	0.70	95.77
Annelida	*Notomastus lineatus*	1	–	–	–	–	1	0.70	96.48
Crustacea	*Foxiphalus xiximeus*	1	–	–	–	–	1	0.70	97.18
Annelida	*Glycinde armigera*	1	–	–	–	–	1	0.70	97.89
Crustacea	*Eohaustorius sencillus*	–	–	1	–	–	1	0.70	98.59
Crustacea	*Portunus xantusii*	–	–	1	–	–	1	0.70	99.30
Bivalvia	*Macoma*	–	–	–	–	1	1	0.70	100.00
Total Number of Individuals		**103**	**97**	**106**	**104**	**105**	**515**		
Total Number of Individuals Excluding *D. Excentricus*		**31**	**20**	**30**	**29**	**32**	**142**		

Table B.9 Infaunal Indices in Sediment Samples Collected in October 2015

	Parameter[a]	Total Organisms	Identified Organisms	Number of Species	Organisms per Species	Diversity (H')	Brillouin Index (*h*)	Dominance (C')	Dominance (S_w)	Species Richness (d)	Evenness (J')	Infaunal Index (*ITI*)
Station B1	Replicate 1	155	153	14	11	0.69	0.60	0.76	1	2.58	0.26	61
	Replicate 2	139	139	11	13	0.89	0.80	0.64	1	2.03	0.37	45
	Replicate 3	150	147	11	13	0.71	0.63	0.72	1	2.00	0.30	43
	Replicate 4	184	181	10	18	0.64	0.58	0.75	1	1.73	0.28	52
	Replicate 5	150	144	7	21	0.69	0.63	0.66	1	1.21	0.35	33
Station B2	Replicate 1	108	105	10	11	0.71	0.61	0.74	1	1.93	0.31	83
	Replicate 2	90	89	13	7	0.78	0.64	0.73	1	2.67	0.30	67
	Replicate 3	88	86	9	10	0.73	0.62	0.72	1	1.80	0.33	80
	Replicate 4	91	89	9	10	0.62	0.52	0.77	1	1.78	0.28	83
	Replicate 5	85	85	10	9	0.62	0.51	0.78	1	2.03	0.27	56
Station B3	Replicate 1	81	80	13	6	0.93	0.77	0.66	1	2.74	0.36	72
	Replicate 2	84	84	7	12	0.97	0.86	0.58	1	1.35	0.50	86
	Replicate 3	88	88	10	9	0.85	0.73	0.67	1	2.01	0.37	50
	Replicate 4	77	77	10	8	0.76	0.63	0.72	1	2.07	0.33	61
	Replicate 5	81	79	10	8	0.79	0.67	0.70	1	2.06	0.34	83
Station B4	Replicate 1	97	95	12	8	0.97	0.83	0.63	1	2.42	0.39	56
	Replicate 2	95	95	12	8	0.88	0.75	0.68	1	2.42	0.35	45
	Replicate 3	104	103	11	9	1.11	0.98	0.55	2	2.16	0.46	36
	Replicate 4	93	93	11	8	0.91	0.78	0.66	1	2.21	0.38	100
	Replicate 5	84	78	10	8	0.79	0.66	0.70	1	2.07	0.34	94
Station B5	Replicate 1	80	75	7	11	0.90	0.80	0.57	2	1.39	0.46	22
	Replicate 2	125	121	17	7	1.45	1.29	0.40	2	3.34	0.51	74
	Replicate 3	117	113	10	11	0.99	0.90	0.53	2	1.90	0.43	78
	Replicate 4	105	99	12	8	1.28	1.14	0.46	2	2.39	0.51	33
	Replicate 5	97	94	12	8	1.14	1.00	0.51	2	2.42	0.46	47
Station B6	Replicate 1	116	115	15	8	1.27	1.12	0.53	2	2.95	0.47	61
	Replicate 2	76	76	12	6	0.94	0.78	0.65	1	2.54	0.38	67
	Replicate 3	102	102	13	8	1.23	1.08	0.49	2	2.59	0.48	61
	Replicate 4	96	94	10	9	0.94	0.82	0.61	1	1.98	0.41	100
	Replicate 5	88	88	9	10	1.06	0.94	0.55	2	1.79	0.48	50
Station B7	Replicate 1	103	98	12	8	1.08	0.95	0.56	2	2.40	0.44	88
	Replicate 2	97	97	8	12	0.82	0.73	0.64	1	1.53	0.39	83
	Replicate 3	106	105	10	11	1.07	0.96	0.54	2	1.93	0.47	58
	Replicate 4	104	104	10	10	1.08	0.97	0.54	2	1.94	0.47	79
	Replicate 5	105	104	10	10	1.18	1.05	0.51	2	1.94	0.51	65
Mean	Station B1	156	153	10.6	15.1	0.72	0.65	0.70	1.0	1.91	0.31	47
	Station B2	92	91	10.2	9.1	0.69	0.58	0.75	1.0	2.04	0.30	74
	Station B3	82	82	10.0	8.5	0.86	0.73	0.67	1.0	2.05	0.38	71
	Station B4	95	93	11.2	8.3	0.93	0.80	0.64	1.2	2.26	0.39	66
	Station B5	105	100	11.6	9.0	1.15	1.02	0.49	2.0	2.29	0.48	51
	Station B6	96	95	11.8	8.2	1.09	0.95	0.57	1.6	2.37	0.44	68
	Station B7	103	102	10.0	10.3	1.05	0.93	0.56	1.8	1.95	0.46	74
Standard Deviation	Station B1	17	17	2.5	4.0	0.09	0.09	0.05	0.0	0.50	0.05	10.5
	Station B2	9	8	1.6	1.4	0.07	0.06	0.02	0.0	0.37	0.02	12.3
	Station B3	4	4	2.1	2.2	0.09	0.09	0.05	0.0	0.49	0.07	15.0
	Station B4	7	9	0.8	0.6	0.12	0.12	0.06	0.4	0.16	0.05	29.2
	Station B5	18	18	3.6	1.8	0.22	0.20	0.07	0.0	0.72	0.04	24.5
	Station B6	15	15	2.4	1.4	0.16	0.15	0.06	0.5	0.47	0.05	19.0
	Station B7	4	4	1.4	1.4	0.13	0.12	0.05	0.4	0.31	0.04	12.8

Table B.9 Infaunal Indices in Sediment Samples Collected in October 2015

	Parameter[a]	Total Organisms	Identified Organisms	Number of Species	Organisms per Species	Diversity (H')	Brillouin Index (*h*)	Dominance (C')	Dominance (S_w)	Species Richness (d)	Evenness (J')	Infaunal Index (*ITI*)
Station Total	Station B1	778	764	23	33	0.79	0.74	0.71	1	3.31	0.25	47
	Station B2	462	454	22	21	0.78	0.71	0.75	1	3.43	0.25	75
	Station B3	411	408	20	20	0.96	0.90	0.66	1	3.16	0.32	72
	Station B4	473	464	22	21	1.06	0.99	0.63	1	3.42	0.34	54
	Station B5	524	502	21	24	1.25	1.19	0.48	2	3.22	0.41	54
	Station B6	478	475	27	18	1.23	1.15	0.56	2	4.22	0.37	61
	Station B7	515	508	21	24	1.16	1.10	0.55	2	3.21	0.38	71
Survey	**Total**	**3641**	**3575**	**36**	**99**	**1.08**	**1.06**	**0.62**	**1**	**4.28**	**0.30**	**62**

Table B.10 Infaunal Indices excluding *D. excentricus* in Sediment Samples Collected in October 2015

	Parameter[a]	Total Organisms	Identified Organisms	Number of Species	Organisms per Species	Diversity (H')	Brillouin Index (*h*)	Dominance (C')	Dominance (S_w)	Species Richness (d)	Evenness (J')	Infaunal Index (*ITI*)
Station B1	Replicate 1	22	20	13	1.54	2.32	1.72	0.14	8	4.01	0.90	61
	Replicate 2	29	29	10	2.90	1.80	1.45	0.25	4	2.67	0.78	45
	Replicate 3	26	23	10	2.30	1.79	1.38	0.27	5	2.87	0.78	43
	Replicate 4	28	25	9	2.78	1.76	1.39	0.25	4	2.49	0.80	52
	Replicate 5	35	29	6	4.83	0.91	0.72	0.59	1	1.48	0.51	33
Station B2	Replicate 1	18	15	9	1.67	2.08	1.53	0.14	6	2.95	0.95	83
	Replicate 2	14	13	12	1.08	2.46	1.68	0.09	9	4.29	0.99	67
	Replicate 3	15	13	8	1.63	1.99	1.44	0.15	5	2.73	0.96	80
	Replicate 4	13	11	8	1.38	2.02	1.40	0.14	6	2.92	0.97	83
	Replicate 5	10	10	9	1.11	2.16	1.44	0.12	7	3.47	0.99	56
Station B3	Replicate 1	16	15	12	1.25	2.40	1.69	0.10	9	4.06	0.96	72
	Replicate 2	21	21	6	3.50	1.63	1.32	0.22	3	1.64	0.91	86
	Replicate 3	16	16	9	1.78	2.05	1.52	0.15	5	2.89	0.93	50
	Replicate 4	12	12	9	1.33	2.10	1.46	0.14	6	3.22	0.95	61
	Replicate 5	15	13	9	1.44	2.10	1.49	0.14	6	3.12	0.96	83
Station B4	Replicate 1	22	20	11	1.82	2.16	1.63	0.15	6	3.34	0.90	56
	Replicate 2	17	17	11	1.55	2.28	1.68	0.11	7	3.53	0.95	45
	Replicate 3	29	28	10	2.80	1.93	1.55	0.21	5	2.70	0.84	36
	Replicate 4	18	18	10	1.80	2.14	1.61	0.14	6	3.11	0.93	100
	Replicate 5	19	13	9	1.44	2.03	1.44	0.16	6	3.12	0.93	94
Station B5	Replicate 1	25	20	6	3.33	1.19	0.92	0.45	2	1.67	0.66	22
	Replicate 2	54	50	16	3.13	1.88	1.54	0.31	5	3.83	0.68	74
	Replicate 3	38	34	9	3.78	1.27	1.01	0.47	2	2.27	0.58	78
	Replicate 4	40	34	11	3.09	1.85	1.50	0.26	5	2.84	0.77	33
	Replicate 5	32	29	11	2.64	1.69	1.33	0.33	4	2.97	0.71	47
Station B6	Replicate 1	33	32	14	2.29	2.44	1.96	0.10	7	3.75	0.92	61
	Replicate 2	15	15	11	1.36	2.25	1.60	0.13	8	3.69	0.94	67
	Replicate 3	32	32	12	2.67	1.93	1.55	0.23	4	3.17	0.78	61
	Replicate 4	23	21	9	2.33	1.82	1.41	0.22	4	2.63	0.83	100
	Replicate 5	24	24	8	3.00	1.74	1.39	0.24	4	2.20	0.83	50
Station B7	Replicate 1	31	26	11	2.36	1.91	1.50	0.22	5	3.07	0.80	88
	Replicate 2	20	20	7	2.86	1.50	1.17	0.31	3	2.00	0.77	83
	Replicate 3	30	29	9	3.22	1.75	1.42	0.23	4	2.38	0.80	58
	Replicate 4	29	29	9	3.22	1.76	1.43	0.24	4	2.38	0.80	79
	Replicate 5	32	31	9	3.44	1.90	1.57	0.19	5	2.33	0.87	65

Table B.10 Infaunal Indices excluding *D. excentricus* in Sediment Samples Collected in October 2015

	Parameter[a]	Total Organisms	Identified Organisms	Number of Species	Organisms per Species	Diversity (H')	Brillouin Index (*h*)	Dominance (C')	Dominance (S_w)	Species Richness (d)	Evenness (J')	Infaunal Index (*ITI*)
Mean	Station B1	28	25	9.6	2.9	1.71	1.33	0.30	4.4	2.70	0.75	47
	Station B2	14	12	9.2	1.4	2.14	1.50	0.13	6.6	3.27	0.97	74
	Station B3	16	15	9.0	1.9	2.05	1.50	0.15	5.8	2.99	0.94	71
	Station B4	21	19	10.2	1.9	2.11	1.58	0.15	6.0	3.16	0.91	66
	Station B5	38	33	10.6	3.2	1.58	1.26	0.36	3.6	2.72	0.68	51
	Station B6	25	25	10.8	2.3	2.03	1.58	0.18	5.4	3.09	0.86	68
	Station B7	28	27	9.0	3.0	1.76	1.42	0.24	4.2	2.43	0.81	74
Standard Deviation	Station B1	5	4	2.5	1.22	0.51	0.37	0.17	2.5	0.91	0.15	10.5
	Station B2	3	2	1.6	0.28	0.19	0.11	0.02	1.5	0.63	0.02	12.3
	Station B3	3	4	2.1	0.94	0.28	0.14	0.04	2.2	0.87	0.02	15.0
	Station B4	5	6	0.8	0.54	0.13	0.09	0.03	0.7	0.31	0.04	29.2
	Station B5	11	11	3.6	0.41	0.33	0.28	0.09	1.5	0.81	0.07	24.5
	Station B6	7	7	2.4	0.61	0.30	0.23	0.06	1.9	0.67	0.07	19.0
	Station B7	5	4	1.4	0.42	0.17	0.15	0.04	0.8	0.39	0.04	12.8
Station Total	Station B1	140	126	22	5.73	2.05	1.82	0.27	5	4.34	0.66	47
	Station B2	70	62	21	2.95	2.75	2.34	0.08	10	4.85	0.91	75
	Station B3	80	77	19	4.05	2.54	2.22	0.11	8	4.14	0.86	72
	Station B4	105	96	21	4.57	2.64	2.35	0.09	8	4.38	0.87	54
	Station B5	189	167	20	8.35	1.85	1.68	0.34	5	3.71	0.62	54
	Station B6	127	124	26	4.77	2.50	2.23	0.15	7	5.19	0.77	61
	Station B7	142	135	20	6.75	2.17	1.97	0.20	6	3.87	0.73	71
Survey	**Total**	**853**	**787**	**35**	**22.49**	**2.51**	**2.42**	**0.17**	**8**	**5.10**	**0.71**	**62**

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Education

B.S.	Marine Biology, California State University, Long Beach
Certificate	Environmental Studies, California State University, Long Beach
M.S.	Biology, California State University, Long Beach

Credential

Instructor, California Community Colleges
Subjects: Biological Sciences, Marine Sciences, Ecology

Qualifications

Susan Williams is an environmental scientist with over thirty years experience in ecological monitoring and assessment. She has a strong background in natural history and an excellent working knowledge of such varied communities as coastal sage scrub, coastal dunes, wetlands, and marine benthos. Ms. Williams also has training in hazardous materials management, including courses and seminars in CEQA, environmental auditing, and the fate of toxins in the environment. She has an extensive background in biological survey techniques and laboratory methodology.

The postgraduate Environmental Studies Certificate provided interdisciplinary training in economics, public health issues, environmental toxicology, and assessing human impacts on terrestrial and marine environments.

Professional Employment

1989-present. Consultant and Contract Employee. Projects include Shoreline Recovery Study of the Exxon Valdez spill, terrestrial ecological survey of a Superfund site, and various benthic surveys, and environmental education.

1990-present. Interpretive Specialist, City of Ventura (Community Services). As part of the Interpretive Outreach Program, deliver classroom and field presentations on a variety of natural and cultural history topics; program development.

1993 - 1994. Park Ranger (Interpretive Division), Channel Islands National Park. Staff Visitor Center, present programs to school groups and general public, develop public programs (Tidepools, Island Ethnobotany).

1989 - 1994. Part-time Instructor, Oxnard College. Topics taught include Microbiology, Marine Biology, Biology, and Environmental Sciences.

1986 - 1989. Researcher, Battelle Ocean Sciences, Ventura. Laboratory supervisor, task leader for monitoring program, taxonomist, safety officer.

1984 - 1986. Research Scientist, Harbors Environmental Project, University of Southern California. Assessment of the marine environment of Marina Del Rey; monitoring offshore disposal of cannery waste.

1980 - 1986. Assistant Curator, Allan Hancock Foundation, University of Southern California. Responsible for maintaining museum collection of marine animals, processing loans, conducting independent research.

1979 - 1981. Research Associate, Applied Ecology Program, Institute for Marine and Coastal Studies. Investigated impacts of storms on sandy beaches, monitored benthic impacts of electrical generating stations, supervised laboratory.

1975 - 1978. Associate Research Scientist, Department of Biological Sciences, University of Southern California. As part of the Outer Continental Shelf Program, collected and analyzed benthic samples prior to offshore oil exploration.

Miscellaneous

Charter Member, Southern California Association of Marine Invertebrate Taxonomists

Participant, Boys & Girls Club of Ventura Career Fair

Judge, Ventura County Science Fair (2004-present). Assigned categories included Zoology, Botany, and Human Biology, junior division (grades 6-8)

Publications and Technical Reports

Ms.Williams has published 13 papers, ranging from taxonomic works and ecological analyses to articles on environmental issues for the general public.
Detailed list available upon request.

ROY K. KROPP
Senior Research Scientist
Pacific Northwest National Laboratory
Battelle Marine Sciences Laboratory
Sequim, Washington

Education

Ph.D.	Zoology, University of Maryland, 1988
M.S.	Biology, University of Guam, 1982
B.S.	Zoology, San Diego State University, 1978

Qualifications

Dr. Kropp is a specialist in benthic marine ecology, toxicology, and the systematics of crustaceans and mollusks with 21 years of experience. He has served as the principal investigator for or participated in marine environmental surveys in the tropical and boreal Pacific, off California, the Gulf of Mexico, along the Atlantic Coast of the United States, and in the Mediterranean. Currently, Dr. Kropp is the Senior Scientist for Benthic Biology for the Massachusetts Water Resources Authority Monitoring Program. Since matriculating to the Marine Sciences Laboratory from Battelle's Duxbury facility, Dr. Kropp has continued benthic ecological studies, recently completing studies of infaunal communities associated with dredged material disposal sites in Rhode Island Sound and Long Island Sound. He was the technical project manager for the preparation of the Final Environmental Impact Statement being prepared for the Providence River dredging project by the U.S. Army Corps of Engineers and is participating as a benthic ecologist on similar EISs for the designation of disposal sites in Rhode Island Sound and Long Island Sound. Dr. Kropp designed and directed a study to examine the effects of increased summer nutrient loads on nearshore seagrass beds in NW Sardinia by examining changes in plant phenology, motile epifaunal communities, and plant epiphyte loads. Dr. Kropp is a recognized authority on crustacean systematics. He was the crustacean taxonomist for the Sardinian study and served as the crustacean and mollusk taxonomist for studies conducted off California and New England. He was the crustacean taxonomist for the Gulf of Thailand and Sea of Okhotsk programs and has extensive experience in the systematics of Indo-Pacific crustaceans. Dr. Kropp is a Research Associate with the Smithsonian Institution and a Research Affiliate of the University of Guam Marine Laboratory. He has authored or coauthored many journal publications and technical reports.

Project Experience

- **Soft-Bottom Monitoring Study conducted for Massachusetts Water Resources Authority (MWRA)**. Senior Scientist responsible for technical oversight of benthic monitoring tasks, including directing data analyses and report preparation for study of the response of the Boston Harbor benthos to the abatement of sludge discharge, and for the eventual diversion of effluent to Massachusetts Bay. Assisted in the design and performance of the rapid assessment technique used in the study. Co-principal Investigator of a study to determine the importance of the new outfall site as a recruitment area for juvenile lobsters.
- **Piscataqua River, New Hampshire 301(h) waiver Water Quality and Benthic Community Study**. Principal investigator for the study performed to fulfill requirements of a 301(h) waiver application. Designed the sampling scheme for the study, analyzed ecological and water-quality data, and prepared the interpretive report.
- **Rhode Island Sound and Long Island Sound Infaunal Community Analyses**. Co-Principal Investigator for two studies of infaunal communities in and near dredged material disposal sites for the U.S. Army Corps of Engineers. Performed benthic data analyses and coauthored the technical reports.
- **Effect of Water-Column Nutrients on Seagrass Epifaunal Communities in NW Sardinia, Italy**. Principle Investigator responsible for study design, staff training, study implementation, data analysis and interpretation, and preparation of interpretive report. Study examining the effects of increased summer nutrient loads (related to increased tourism) on nearshore seagrass beds by examining changes in plant phenology, motile epifaunal communities, and epiphyte loads.
- **Environmental Studies in the Gulf of Thailand, Phase I and II** Biology Task Leader for project that investigated the impacts of drilling activities on the benthos. Performed ecological data analysis, wrote biological characterization chapters of the resulting reports.

Roy K. Kropp (Continued)

Other Experience

Monitoring Studies.

Task Leader for a study to determine the abundance of ocean quahogs (*Arctica islandica*) at proposed dredged material disposal sites in Rhode Island Sound. Designed and directed the study. Analyzed quahog abundance and size-frequency data, and prepared an interpretive report.

Biology Task Leader for the Sediment Survey at the (New York) Mud Dump Site and Environs. Responsible for analysis and interpretation of infaunal data collected during 1994. Prepared sections on the benthic community for the draft final report. Contributed sections on the infaunal community and trophic relationships for the draft SEIS.

Task Leader. Statistical design of field sampling and data analysis, interpretation, and write-up for program involving lead shot remediation at Remington Gun Club site.

Biology Task Leader for Environmental Studies in the Sea of Okhotsk. Analyzed infaunal data collected from proposed drilling platform sites. Prepared an interpretive report on the infaunal communities in the study area.

Biology Task Leader for the Region VI (EPA) contaminated sediment study. Analyzed infaunal data from seven ocean dredged material disposal sites in the Gulf of Mexico. Prepared interpretive reports on the communities at each site and provided recommendations for improving the study design.

Scientist for the New York Bight Rapid Benthic Assessment project that concerned the selection of a new site for the disposal of dredge spoils. Conducted epibenthic trawls and sediment grab sampling. Analyzed trawl catches, fish stomach contents, and infauna collected in sediment grabs.

Assistant Program Manager for California OCS Phase II Monitoring Program (CAMP) that established baseline conditions in the Santa Maria Basin prior to the installation of a drilling platform. Principal Investigator studying the life histories of several key infaunal species. Conducted independent study on the incidence of repaired shell damage to gastropods and scaphopods in the study area.

Beach Replenishment Dredging Studies. Principal Investigator for three USACE sand borrow area studies. Responsible for design and ecological analysis for three projects establishing baseline conditions or investigating the effects of dredging in sand borrow areas at Broadkill Beach in Delaware Bay and off Absecon Inlet and Great Egg Harbor, New Jersey.

Toxicological Studies. Project Manager or Senior Scientist for toxicological testing of sediments from the Providence River, New Haven, and Boston Harbor/Weymouth Fore River. These tests were conducted fro the New England Division, Army Corps of Engineers and involved marine species, including *Americamysis bahia* and *Ampelisca abdita*. Responsibilities included overall test planning and supervision, data analyses, and report preparation.

Project Manager for toxicological testing of sediments from Pistol Pont Bar, CT. These tests were conducted fro the New England Division, Army Corps of Engineers and involved freshwater species including *Hyalella azteca*, *Chironomus tentans*, and *Lumbriculus variegatus*.

Project Manager for toxicological testing of synthetic-based drilling muds from the Gulf of Mexico. These tests were conducted fro the American Petroleum Institute and involved a marine species, *Leptocheirus plumulosus*.

Environmental Impact Statements. Project Manager for the preparation of the Final Environmental Impact Statement being prepared for the Providence River dredging project by the US Army Corps of Engineers. Coordinator for activities including response to public comments, re-analysis of fish trawl data to evaluate fishery value of potential disposal sites, directed the development of a statistically valid design of study on lobster populations at disposal sites, directing implementation of the study, designed a dredge survey to sample northern quahog populations in the area to be dredged and wrote the interpretive report, monitored project budgets and tracked deliverable preparation. Information will be used to assist the government in deciding the most appropriate disposal alternative.

Artificial Reef Studies. Benthic Infauna/Epifauna Task Leader for 5-year study for U.S. Army Corps of Engineers (USACE) and Environmental Protection Agency (EPA) Delaware Artificial Reef Study that investigated the feasibility of using artificial reef as compensation for shallow- and deep-water habitat loss. Performed ecological data analysis of epifaunal communities on the reefs and infaunal communities surrounding the reefs, wrote sections

of the report. Designed portions of a study to examine the effects of artificial reef units on the infauna.

NOAA Hydrolab Aquanaut and field assistant for study of artificial reef colonization at Salt River Canyon, St. Croix, U.S. Virgin Islands.

Taxonomist. Crustacean taxonomist for benthic studies conducted in NW Sardinia, Italy.

Identified crustaceans and mollusks collected from Boston Harbor, Massachusetts Bay, and Cape Cod Bay for the MWRA Harbor and Outfall Monitoring Program.

Chief taxonomist for the Environmental Studies in the Gulf of Thailand, Phase I and II project. Identified the crustaceans collected during the study. Directed the establishment of a project-specific voucher collection and edited the documentation for the voucher collection.

Identified crustaceans and mollusks collected from off California for the CAMP program and the Morro Bay/Cayucos Sanitation District 301(h) monitoring program.

Specialist on benthic invertebrates for several baseline monitoring studies conducted in the western Pacific (Micronesia).

Professional Affiliations

Biological Society of Washington
Crustacean Society
Estuarine Research Federation
Pacific Science Association

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APPENDIX C

Sediment Properties: October 2015 Survey

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APPENDIX C

Properties of Sediment Samples Collected during the October 2015 Offshore Survey

Table C.1 Sediment Grab-Sample Collection Record

Station	Sample	Date	Time[1]	Penetration Depth (cm)	Latitude	Longitude	Sediment Type	Sediment[2] Color	Comment
1	Bio 1	10/26/2015	7:57:29	7.0	35° 23.7478' N	120° 52.6822' W	Sand	Lt. Brown	
	Bio 2	10/26/2015	8:01:49	7.5	35° 23.7475' N	120° 52.6823' W	Sand	Lt. Brown	Sediment volume
	Bio 3	10/26/2015	8:16:40	8.3	35° 23.7483' N	120° 52.6827' W	Sand	Lt. Brown	was limited by the
	Bio 4	10/26/2015	8:19:03	8.5	35° 23.7468' N	120° 52.6848' W	Sand	Lt. Brown	presence of large
	Bio 5	10/26/2015	8:21:31	8.5	35° 23.7479' N	120° 52.6843' W	Sand	Lt. Brown	numbers of sizable
	Chem 1	10/26/2015	8:26:06	N/A	35° 23.7478' N	120° 52.6833' W	Sand	Lt. Brown	Sand Dollars in all
	Chem 2	10/26/2015	8:35:23	N/A	35° 23.7493' N	120° 52.6825' W	Sand	Lt. Brown	samples
	Chem 3	10/26/2015	8:41:45	N/A	35° 23.7489' N	120° 52.6820' W	Sand	Lt. Brown	
2	Bio 1	10/26/2015	9:02:20	7.5	35° 23.2958' N	120° 52.5118' W	Sand	Lt. Brown	
	Bio 2	10/26/2015	9:04:31	7.5	35° 23.2953' N	120° 52.5125' W	Sand	Lt. Brown	
	Bio 3	10/26/2015	9:09:21	8.5	35° 23.2949' N	120° 52.5113' W	Sand	Lt. Brown	
	Bio 4	10/26/2015	9:12:43	8.0	35° 23.2968' N	120° 52.5105' W	Sand	Lt. Brown	
	Bio 5	10/26/2015	9:17:01	7.0	35° 23.2969' N	120° 52.5082' W	Sand	Lt. Brown	
	Chem 1	10/26/2015	9:21:26	N/A	35° 23.2979' N	120° 52.5072' W	Sand	Lt. Brown	
	Chem 2	10/26/2015	9:25:59	N/A	35° 23.2980' N	120° 52.5045' W	Sand	Lt. Brown	
	Chem 3	10/26/2015	9:30:20	N/A	35° 23.2976' N	120° 52.5065' W	Sand	Lt. Brown	
3	Bio 1	10/26/2015	9:58:13	8.0	35° 23.2432' N	120° 52.5069' W	Sand	Lt. Brown	
	Bio 2	10/26/2015	10:00:46	7.5	35° 23.2497' N	120° 52.5074' W	Sand	Lt. Brown	
	Bio 3	10/26/2015	10:02:40	8.0	35° 23.2480' N	120° 52.5117' W	Sand	Lt. Brown	
	Bio 4	10/26/2015	10:05:56	8.8	35° 23.2502' N	120° 52.5074' W	Sand	Lt. Brown	
	Bio 5	10/26/2015	10:11:36	7.0	35° 23.2514' N	120° 52.5024' W	Sand	Lt. Brown	
	Chem 1	10/26/2015	10:16:22	N/A	35° 23.2518' N	120° 52.5020' W	Sand	Lt. Brown	
	Chem 2	10/26/2015	10:21:24	N/A	35° 23.2527' N	120° 52.4993' W	Sand	Lt. Brown	
	Chem 3	10/26/2015	10:25:09	N/A	35° 23.2525' N	120° 52.4989' W	Sand	Lt. Brown	
4	Bio 1	10/26/2015	10:37:32	9.0	35° 23.2223' N	120° 52.4957' W	Sand	Lt. Brown	
	Bio 2	10/26/2015	10:39:51	8.5	35° 23.2236' N	120° 52.4925' W	Sand	Lt. Brown	
	Bio 3	10/26/2015	10:42:03	8.0	35° 23.2234' N	120° 52.4916' W	Sand	Lt. Brown	
	Bio 4	10/26/2015	10:44:08	7.0	35° 23.2226' N	120° 52.4934' W	Sand	Lt. Brown	
	Bio 5	10/26/2015	10:46:17	8.5	35° 23.2218' N	120° 52.4915' W	Sand	Lt. Brown	
	Chem 1	10/26/2015	11:04:08	N/A	35° 23.2217' N	120° 52.4913' W	Sand	Lt. Brown	
	Chem 2	10/26/2015	11:09:07	N/A	35° 23.2227' N	120° 52.4929' W	Sand	Lt. Brown	
	Chem 3	10/26/2015	11:13:07	N/A	35° 23.2221' N	120° 52.4932' W	Sand	Lt. Brown	
5	Bio 1	10/26/2015	11:54:50	7.0	35° 23.1891' N	120° 52.5204' W	Sand	Lt. Brown	
	Bio 2	10/26/2015	11:57:21	9.0	35° 23.1890' N	120° 52.5212' W	Sand	Lt. Brown	
	Bio 3	10/26/2015	11:58:52	8.0	35° 23.1898' N	120° 52.5196' W	Sand	Lt. Brown	
	Bio 4	10/26/2015	12:03:04	7.5	35° 23.1893' N	120° 52.5198' W	Sand	Lt. Brown	
	Bio 5	10/26/2015	12:05:10	7.0	35° 23.1899' N	120° 52.5193' W	Sand	Lt. Brown	
	Chem 1	10/26/2015	12:11:17	N/A	35° 23.1907' N	120° 52.5195' W	Sand	Lt. Brown	
	Chem 2	10/26/2015	12:15:36	N/A	35° 23.1903' N	120° 52.5184' W	Sand	Lt. Brown	
	Chem 3	10/26/2015	12:21:19	N/A	35° 23.1900' N	120° 52.5192' W	Sand	Lt. Brown	

[1] Time when the sediment grab was collected (trip time of the grab)

[2] No odors emanating from the sediment samples were noted at any station

Table C.1 Sediment Grab-Sample Collection Record

Station	Sample	Date	Time[1]	Penetration Depth (cm)	Latitude	Longitude	Sediment Type	Sediment[2] Color	Comment
6	Bio 1	10/26/2015	13:18:54	9.0	35° 23.1704' N	120° 52.4986' W	Sand	Lt. Brown	
	Bio 2	10/26/2015	13:20:49	8.3	35° 23.1745' N	120° 52.4962' W	Sand	Lt. Brown	
	Bio 3	10/26/2015	13:24:53	9.0	35° 23.1761' N	120° 52.4961' W	Sand	Lt. Brown	
	Bio 4	10/26/2015	13:26:47	7.5	35° 23.1759' N	120° 52.4962' W	Sand	Lt. Brown	
	Bio 5	10/26/2015	13:28:47	7.5	35° 23.1757' N	120° 52.4951' W	Sand	Lt. Brown	
	Chem 1	10/26/2015	13:38:35	N/A	35° 23.1766' N	120° 52.4949' W	Sand	Lt. Brown	
	Chem 2	10/26/2015	13:42:51	N/A	35° 23.1762' N	120° 52.4954' W	Sand	Lt. Brown	
	Chem 3	10/26/2015	13:46:39	N/A	35° 23.1759' N	120° 52.4969' W	Sand	Lt. Brown	
7	Bio 1	10/26/2015	12:35:04	10.5	35° 23.1230' N	120° 52.4932' W	Sand	Lt. Brown	
	Bio 2	10/26/2015	12:39:36	8.0	35° 23.1239' N	120° 52.4923' W	Sand	Lt. Brown	
	Bio 3	10/26/2015	12:41:33	8.0	35° 23.1235' N	120° 52.4927' W	Sand	Lt. Brown	
	Bio 4	10/26/2015	12:43:26	7.0	35° 23.1236' N	120° 52.4934' W	Sand	Lt. Brown	
	Bio 5	10/26/2015	12:47:14	8.8	35° 23.1234' N	120° 52.4941' W	Sand	Lt. Brown	
	Chem 1	10/26/2015	12:52:07	N/A	35° 23.1242' N	120° 52.4943' W	Sand	Lt. Brown	
	Chem 2	10/26/2015	12:57:33	N/A	35° 23.1228' N	120° 52.4935' W	Sand	Lt. Brown	
	Chem 3	10/26/2015	13:01:26	N/A	35° 23.1244' N	120° 52.4939' W	Sand	Lt. Brown	

Table C.2 Grain-Size Class Distribution

Phi	-2 to -1	-1 to 0	0 to 1	1 to 2	2 to 3	3 to 4	4 to 9	>9
Size (µm)	2000	1000	500	250	125	62.5	62.5 to 2	<2
Class	Gravel	Vry Crs Snd	Crs Sand	Med Snd	Fine Snd	Vry Fine Snd	Silt	Clay
Station 1	0.048%	0.159%	0.417%	1.187%	72.633%	23.436%	1.560%	0.559%
Station 1(d)	0.397%	0.126%	0.227%	0.560%	75.296%	21.279%	1.638%	0.476%
Station 2	0.074%	0.116%	0.244%	1.012%	74.186%	22.600%	1.146%	0.621%
Station 3	0.084%	0.077%	0.253%	0.807%	75.672%	21.607%	1.008%	0.490%
Station 4	0.765%	0.087%	0.150%	0.705%	74.359%	22.475%	1.015%	0.444%
Station 4(d)	0.017%	0.105%	0.202%	1.259%	76.453%	20.756%	0.788%	0.421%
Station 5	0.293%	0.085%	0.309%	1.087%	76.638%	20.141%	0.985%	0.462%
Station 5(d)	0.113%	0.044%	0.105%	0.963%	74.521%	22.747%	0.985%	0.522%
Station 6	0.132%	0.074%	0.128%	0.540%	76.378%	21.459%	0.883%	0.407%
Station 7	0.514%	0.127%	0.213%	0.614%	75.625%	21.514%	0.978%	0.414%

Table C.3 Grain-Size Weight Distribution

	Dry Weight (grams)			Percentage Summary		
Phi	**<-1 to 4**	**>4**		**-2 to -1**	**-1 to 4**	**4 to >9**
Size (µm)	**2000 to 62.5**	**<62.5**		**2000**	**1000 to 62.5**	**<62.5**
Class	**Coarse**	**Fine**	**Total**	**Gravel**	**Sand**	**Mud**
Station 1	115.437	2.499	**117.936**	0.048%	97.833%	2.119%
Station 1(d)	117.098	2.529	**119.627**	0.397%	97.489%	2.114%
Station 2	109.732	1.974	**111.706**	0.074%	98.159%	1.767%
Station 3	117.792	1.792	**119.584**	0.084%	98.417%	1.499%
Station 4	109.303	1.618	**110.921**	0.765%	97.777%	1.459%
Station 4(d)	120.388	1.473	**121.861**	0.017%	98.774%	1.209%
Station 5	116.568	1.712	**118.280**	0.293%	98.260%	1.447%
Station 5(d)	109.050	1.669	**110.719**	0.113%	98.380%	1.507%
Station 6	111.204	1.453	**112.657**	0.132%	98.578%	1.290%
Station 7	116.922	1.651	**118.573**	0.514%	98.093%	1.392%

Table C.4 Grain-Size Statistics

					Percent Coarser than Listed Diameter (µm)				
Station	**Mean (ϕ)**	**σ (ϕ)**	**Skewness (ϕ)**	**Mean (µm)**	**5%**	**16%**	**50%**	**84%**	**95%**
B1	2.80	0.412	0.22	144	215	185	148	109	78
B1(d)	2.78	0.388	0.24	146	210	183	149	112	80
B2	2.79	0.391	0.21	145	212	183	149	111	81
B3	2.78	0.372	0.21	146	209	182	149	113	83
B4	2.78	0.386	0.19	146	214	185	149	112	83
B4(d)	2.76	0.372	0.18	148	214	186	151	115	86
B5	2.75	0.378	0.19	149	216	187	151	116	85
B5(d)	2.79	0.381	0.20	145	210	183	148	112	83
B6	2.78	0.356	0.21	146	205	180	148	114	85
B7	2.77	0.374	0.19	147	211	184	150	114	84

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APPENDIX D

Outfall Inspection Report

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OUTFALL/DIFFUSOR ANNUAL REPORT

NAME OF DISCHARGER MBCSD
NPDES PERMIT # _____

NAME OF DIVER/INSPECTOR Craig Porter / Porter Diving
FIRM & ADDRESS 15730 Morro rd

TELEPHONE # (805) 466-0566

OUTFALL LENGTH 5160 FT. DEPTH OF WATER 50' FT.

DESIGN OF DIFFUSOR (physical dimesions, shape, include sketch)

OF PORTS 34 # PORTS OPEN 28 DIFFUSOR LEVEL? 16" to 4'

END OF DIFUSSOR OPEN?_____ CLOSED? X

OUTFALL MARKED BY BOUYS? YES X NO_____ TYPE SPAR

DIFFUSORS OPERATING AS DESIGNED? YES X NO_____

BREAKS IN OUTFALL LINE NOTED? YES_____ NO X IF YES, DESCRIBE

DESCRIBE PROBLEMS NOTED N/A

CORRECTIVE ACTION NEEDED None

PHYSICAL DESCRIPTION OF ENVIRONMENT AROUND OUTFALL (ie. fish noted, debris, sediments, etc.) Starfish, Sand Dollars, Anemones

DIRECTION OF PLUME IN RELATIONSHIP TO SHORELINE West, parallel to Shoreline

PICTURES TAKEN? YES X video NO _____ (INCLUDE COPIES IF TAKEN)

Ed Mueller
SIGNATURE OF DIVER/INSPECTOR

1-7-15
DATE

Bruce Keogh
SIGNATURE OF DISCHARGER

1-7-15
TITLE

RHS/DIFF. DISC C

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APPENDIX E

Sediment Chemistry: October 2015 Survey
Methods, Results, and QA/QC

Note that the results reported for Stations B6 and B7 were reversed in Appendix E due to mislabeling of sample containers in the field. All results reported elsewhere in this report have been corrected for this reversal. Additionally, small differences between the dry results reported in Appendix E and elsewhere in this report were due to rounding. Dry concentrations in the body of this report were determined directly from the reported moisture content and the as-received concentration.

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Methods

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Table E.1 Summary of Analytical Methods Used for Physicochemical Determinations of Sediment

Parameter	Method	Description	Reference
Biochemical Oxygen Demand 5-Day	5210B	Dissolved Oxygen Probe	6
Total Kjeldahl Nitrogen (TKN)	351.2	Block Digestion/Colorimetry	1
Total Volatile Solids	160.4	Dry ashing/Gravimetry	1
Moisture	160.3	Evaporation/Gravimetry	1
Sediment Grain Size	MRS, 1998	Sieve/Pipette without salt	2,3,4
Aluminum	6010	ICP	5
Arsenic	7060	GFAAS	5
Cadmium	6010	ICP	5
Chromium	6010	ICP	5
Copper	6010	ICP	5
Iron	6010	ICP	5
Lead	7421	CVAAS	5
Mercury	7471	CVAAS	5
Nickel	6010	ICP	5
Silver	272.2	GFAAS	1
Zinc	6010	ICP	5
Oil and Grease	1664	Extraction/Gravimetry	7

CVAAS = Cold Vapor Atomic Absorption Spectrometry
ICP/MS = Inductively Coupled Plasma/Mass Spectrometry
GC = Gas Chromatography
GC/MS = Gas Chromatography/Mass Spectrometry
GFAAS = Graphite Furnace Atomic Absorption Spectrometry

References:

1. U.S. Environmental Protection Agency. 1983. Methods for chemical analysis of water and wastes. EPA-600/4-79-020.
2. Plumb, R.H., Jr. 1981. Procedures for Handling and chemical analysis of sediment and water samples. U.S. Army Corps of Engineer Waterway Experiment Stations, Vicksburg, Miss.
3. Marine Research Specialists. 1998. City of Morro Bay and Cayucos Sanitary District, Offshore Monitoring and Reporting Program, Semiannual Benthic Sampling, October 1997. Prepared for the City of Morro Bay, Morro Bay, CA
4. Coats, D.A., Imamura, E., Fukuyama, A.K., Skalski, J.R., Kimura, S., and J. Steinbeck. 1998. Monitoring of Biological Recovery of Prince William Sound Intertidal Sites Impacted by the *Exxon Valdez* Oil Spill.1997 Biological Monitoring Survey. NOAA Technical Memorandum NOS ORCA NOS OR&R 1.
5. U.S. Environmental Protection Agency. 1986. Test methods for evaluating solid wastes physical/chemical methods. EPA SW-846. 3rd ed., revised.
6. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1998. Standard methods for the examination of water and wastewater (20th Ed.). Washington, DC.
7. U.S. Environmental Protection Agency. 1999. Method 1664 Revision A: N-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated N-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry. February 1999. EPA-821-R-98-002.

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Analytical Results

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BC Laboratories, Inc.
Environmental Testing Laboratory Since 1949

Date of Report: 11/12/2015

Doug Coats

Marine Research Specialists
3140 Telegraph Road, Suite A
Suite A
Ventura, CA 93003-3238

Client Project: [none]
BCL Project: Annual Benthic Sediment Sampling for MBTP
BCL Work Order: 1527173
Invoice ID: B218921

Enclosed are the results of analyses for samples received by the laboratory on 10/26/2015. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Contact Person: Tina Green
Client Services Manager

Authorized Signature

Table of Contents

BC Laboratories, Inc.
Environmental Testing Laboratory Since 1949

Chain of Custody Form

Report To:	
Client: Marine Research Specialists	Project #: Morro Bay Benthic
Attn: Douglas A Coats	Project Name: Offshore Sediment Sampling
Street Address: 3140 Telegraph Rd STE A	Global ID #:
City, State, Zip: Ventura CA 93003	Sampler(s): Douglas Coats
Telephone: (805)218-3662	
Email: Marine@Rain.org	
Work Order #: 15-27173	

Analysis Requested

Comments: PRIOR TO ANALYSIS: HOMOGENIZE EACH SAMPLE IN LAB Remove macrofauna and remnants larger than 0.25 inches Report dry weights and see additional instructions attached

Sample #	Description	Date Sampled	Time Sampled	Moisture 160.3, SM-2540G, or BC	Total Volatile Solids 160.4 or 2540G	BOD 405.1 or SM17-5210B	Total Kjeldahl Nitrogen 351.2	Oil and Grease 413.2 or 1664/HEM	Al, Fe, As, Cd, Cr (total), Cu, Pb, Hg,	Ni, Ag, Zn	Sample Matrix: Soil	Sludge	Drinking Water	Ground Water	Waste Water	Other	TAT Days	Are there any tests with holding times less than or equal to 48 hours? X Yes ☐ NO	Notes
1	Station B1	10/26/15	08:40	X	X	X	X		X	X	X								No O&G at Station B1
2	Station B2		09:26	X	X	X	X	X	X	X	X								
3	Station B3		10:21	X	X	X	X	X	X	X	X								
4	Station B4		11:09	X	X	X	X	X	X	X	X								
5	Station B5		12:16	X	X	X	X	X	X	X	X								
6	Station B6		12:58	X	X	X	X	X	X	X	X								
7	Station B7		13:43	X	X	X	X	X	X	X	X								

CHK BY DISTRIBUTION SUB-OUT

SHORT HOLD

Billing

X Same as Above

Client: _____
Address: _____
City: _____ State: _____ Zip: _____
Attn: _____
PO#: _____

EDF Required? ☐ Yes X No

Send Copy to State of CA? ☐ Yes X No

Sample Disposal

☐ Return to Client X Disposal by lab ☐ Archive Months ___

Special Reporting

☐ QC ☐ EDF ☐ Raw Data

	Relinquished By:	Date	Time	Received by:	Date	Time
1.	Douglas A Coats	10/26/15	1630		10-26-15	1630
2.		10-26-15	2040		10/26/15	2040
3.						

BC Laboratories, Inc. 4100 Atlas Court Bakersfield, Ca. 93308 Tel: 800.878.4911 Fax: 661.327.4911

Chain of Custody and Cooler Receipt Form for 1527173 Page 2 of 2

BC LABORATORIES INC. **COOLER RECEIPT FORM** Page 1 Of 1

Submission #: 15-27173

SHIPPING INFORMATION
Fed Ex ☐ UPS ☐ Ontrac ☐ Hand Delivery ☐
BC Lab Field Service ☒ Other ☐ (Specify)_____

SHIPPING CONTAINER
Ice Chest ☒ None ☐ Box ☐
Other ☐ (Specify)_____

FREE LIQUID
YES ☐ NO ☐

Refrigerant: Ice ☒ Blue Ice ☐ None ☐ Other ☐ Comments:

Custody Seals Ice Chest ☐ Intact? Yes ☐ No ☐ Containers ☐ Intact? Yes ☐ No ☐ None ☒ Comments:

All samples received? Yes ☒ No ☐ All samples containers intact? Yes ☒ No ☐ Description(s) match COC? Yes ☒ No ☐

COC Received
☒ YES ☐ NO

Emissivity: 0.98 Container: Clear glass Thermometer ID: 208
Temperature: (A) 0.5 °C / (C) 0.6 °C
Date/Time 10/26/15
Analyst Init KIB 2029

SAMPLE CONTAINERS	SAMPLE NUMBERS 1	2	3	4	5	6	7	8	9	10
QT PE UNPRES										
4oz / 8oz / 16oz PE UNPRES										
2oz Cr^{+6}										
QT INORGANIC CHEMICAL METALS										
INORGANIC CHEMICAL METALS 4oz / 8oz / 16oz										
PT CYANIDE										
PT NITROGEN FORMS										
PT TOTAL SULFIDE										
2oz. NITRATE / NITRITE										
PT TOTAL ORGANIC CARBON										
PT CHEMICAL OXYGEN DEMAND										
PtA PHENOLICS										
40ml VOA VIAL TRAVEL BLANK										
40ml VOA VIAL										
QT EPA 1664										
PT ODOR										
RADIOLOGICAL										
BACTERIOLOGICAL										
40 ml VOA VIAL- 504										
QT EPA 508/608/8080										
QT EPA 515.1/8150										
QT EPA 525										
QT EPA 525 TRAVEL BLANK										
40ml EPA 547										
40ml EPA 531.1										
8oz EPA 548										
QT EPA 549										
QT EPA 8015M										
QT EPA 8270										
8oz / 16oz / 32oz AMBER										
8oz / 16oz / 32oz JAR	A	A	A	A	A	A	A			
SOIL SLEEVE										
PCB VIAL										
PLASTIC BAG										
TEDLAR BAG										
FERROUS IRON										
ENCORE										
SMART KIT										
SUMMA CANISTER										

Comments:
Sample Numbering Completed By: KIB Date/Time: 10/26/15 2045 Rev 20 07/24/2015
A = Actual / C = Corrected
[S:\WPDoc\WordPerfect\LAB_DOCS\FORMS\SAMREC rev 20]

Marine Research Specialists
3140 Telegraph Road, Suite A
Suite A
Ventura, CA 93003-3238

Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Laboratory / Client Sample Cross Reference

Laboratory	Client Sample Information			
1527173-01	**COC Number:**	---	**Receive Date:**	10/26/2015 20:40
	Project Number:	---	**Sampling Date:**	10/26/2015 08:40
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	Station B1	**Lab Matrix:**	Solids
	Sampled By:	---	**Sample Type:**	Soil
1527173-02	**COC Number:**	---	**Receive Date:**	10/26/2015 20:40
	Project Number:	---	**Sampling Date:**	10/26/2015 09:26
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	Station B2	**Lab Matrix:**	Solids
	Sampled By:	---	**Sample Type:**	Soil
1527173-03	**COC Number:**	---	**Receive Date:**	10/26/2015 20:40
	Project Number:	---	**Sampling Date:**	10/26/2015 10:21
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	Station B3	**Lab Matrix:**	Solids
	Sampled By:	---	**Sample Type:**	Soil
1527173-04	**COC Number:**	---	**Receive Date:**	10/26/2015 20:40
	Project Number:	---	**Sampling Date:**	10/26/2015 11:09
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	Station B4	**Lab Matrix:**	Solids
	Sampled By:	---	**Sample Type:**	Soil
1527173-05	**COC Number:**	---	**Receive Date:**	10/26/2015 20:40
	Project Number:	---	**Sampling Date:**	10/26/2015 12:16
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	Station B5	**Lab Matrix:**	Solids
	Sampled By:	---	**Sample Type:**	Soil
1527173-06	**COC Number:**	---	**Receive Date:**	10/26/2015 20:40
	Project Number:	---	**Sampling Date:**	10/26/2015 12:58
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	Station B6	**Lab Matrix:**	Solids
	Sampled By:	---	**Sample Type:**	Soil
1527173-07	**COC Number:**	---	**Receive Date:**	10/26/2015 20:40
	Project Number:	---	**Sampling Date:**	10/26/2015 13:43
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	Station B7	**Lab Matrix:**	Solids
	Sampled By:	---	**Sample Type:**	Soil

Marine Research Specialists
3140 Telegraph Road, Suite A
Suite A
Ventura, CA 93003-3238

Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

BCL Sample ID: 1527173-01 | **Client Sample Name:** Station B1, 10/26/2015 8:40:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Moisture	0	23.1	**%**	**0.05**	**0.05**	**Calc**	ND		1
Total Kjeldahl Nitrogen	160	120	**mg/kg**	**40**	**15**	**EPA-351.2**	ND		2
Volatile Solids	1.78	1.37	**%**	**0.200**	**0.200**	**SM-2540G**	ND		3
Biochemical Oxygen Demand	39	30	**mg/kg**	**10**	**10**	**SM17-5210B**			4
Solids	100	76.9	**%**	**0.05**	**0.05**	**SM-2540G**			5

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	Calc	10/29/15	11/09/15 17:01	AMM	Calc	1	BYJ2691
2	EPA-351.2	10/28/15	10/30/15 12:42	JMH	SC-1	1	BYJ2622
3	SM-2540G	10/29/15	10/29/15 11:30	CAD	MANUAL	1	BYJ2732
4	SM17-5210B	10/27/15	10/27/15 09:15	HPR	YSI-57	0.333	BYK0005
5	SM-2540G	10/28/15	10/28/15 11:30	NW1	TOC2	1	BYJ2583

Marine Research Specialists
3140 Telegraph Road, Suite A
Suite A
Ventura, CA 93003-3238

Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

BCL Sample ID: 1527173-01 | **Client Sample Name:** Station B1, 10/26/2015 8:40:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Arsenic	2.8	2.2	**mg/kg**	**0.50**	**0.17**	**EPA-6020**	ND		1
Cadmium	ND	ND	mg/kg	0.50	0.052	EPA-6010B	ND		2
Chromium	63	48	**mg/kg**	**0.50**	**0.050**	**EPA-6010B**	ND		2
Copper	3.2	2.4	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	ND		2
Lead	2.3	1.8	**mg/kg**	**0.25**	**0.12**	**EPA-6020**	ND		1
Mercury	ND	ND	mg/kg	0.16	0.036	EPA-7471A	ND		3
Nickel	39	30	**mg/kg**	**0.50**	**0.15**	**EPA-6010B**	ND		2
Silver	ND	ND	mg/kg	0.25	0.051	EPA-6020	ND		1
Zinc	17	13	**mg/kg**	**2.5**	**0.087**	**EPA-6010B**	0.23		2
Aluminum	6400	4900	**mg/kg**	**5.0**	**1.2**	**EPA-6010B**	ND		2
Iron	9800	7500	**mg/kg**	**5.0**	**1.7**	**EPA-6010B**	3.2		2

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6020	10/28/15	10/29/15 02:21	GPD	PE-EL2	1	BYJ2549
2	EPA-6010B	10/27/15	10/27/15 13:43	JRG	PE-OP2	0.943	BYJ2415
3	EPA-7471A	10/28/15	10/28/15 14:22	MEV	CETAC1	1.025	BYJ2505

Marine Research Specialists
3140 Telegraph Road, Suite A
Suite A
Ventura, CA 93003-3238

Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

BCL Sample ID: 1527173-02 | **Client Sample Name:** Station B2, 10/26/2015 9:26:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Oil and Grease	ND	ND	mg/kg	50	25	EPA-1664A HEM	ND		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-1664A HEM	10/28/15	10/28/15 08:00	MAM	MAN-SV	0.998	BYJ2722

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

BCL Sample ID: 1527173-02 | **Client Sample Name:** Station B2, 10/26/2015 9:26:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Moisture	0	23.3	**%**	**0.05**	**0.05**	**Calc**	ND		1
Total Kjeldahl Nitrogen	160	130	**mg/kg**	**40**	**15**	**EPA-351.2**	ND		2
Volatile Solids	2.31	1.77	**%**	**0.200**	**0.200**	**SM-2540G**	ND		3
Biochemical Oxygen Demand	34	26	**mg/kg**	**10**	**10**	**SM17-5210B**			4
Solids	100	76.7	**%**	**0.05**	**0.05**	**SM-2540G**			5

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	Calc	10/29/15	11/09/15 17:01	AMM	Calc	1	BYJ2691
2	EPA-351.2	10/28/15	10/30/15 12:44	JMH	SC-1	1	BYJ2622
3	SM-2540G	10/29/15	10/29/15 11:30	CAD	MANUAL	1	BYJ2732
4	SM17-5210B	10/27/15	10/27/15 09:15	HPR	YSI-57	0.333	BYK0005
5	SM-2540G	10/28/15	10/28/15 11:30	NW1	TOC2	1	BYJ2583

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

BCL Sample ID: 1527173-02 | **Client Sample Name:** Station B2, 10/26/2015 9:26:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Arsenic	3.9	3.0	**mg/kg**	**0.50**	**0.17**	**EPA-6020**	ND		1
Cadmium	ND	ND	mg/kg	0.50	0.052	EPA-6010B	ND		2
Chromium	50	38	**mg/kg**	**0.50**	**0.050**	**EPA-6010B**	ND		2
Copper	3.6	2.7	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	ND		2
Lead	2.4	1.9	**mg/kg**	**0.25**	**0.12**	**EPA-6020**	ND		1
Mercury	ND	ND	mg/kg	0.16	0.036	EPA-7471A	ND		3
Nickel	48	37	**mg/kg**	**0.50**	**0.15**	**EPA-6010B**	ND		2
Silver	ND	ND	mg/kg	0.25	0.051	EPA-6020	ND		1
Zinc	17	13	**mg/kg**	**2.5**	**0.087**	**EPA-6010B**	0.23		2
Aluminum	6100	4700	**mg/kg**	**5.0**	**1.2**	**EPA-6010B**	ND		2
Iron	10000	7800	**mg/kg**	**5.0**	**1.7**	**EPA-6010B**	3.3		2

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6020	10/28/15	10/29/15 02:49	GPD	PE-EL2	0.971	BYJ2549
2	EPA-6010B	10/27/15	10/27/15 13:45	JRG	PE-OP2	0.971	BYJ2415
3	EPA-7471A	10/28/15	10/28/15 14:25	MEV	CETAC1	1.008	BYJ2505

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

BCL Sample ID: 1527173-03 | **Client Sample Name:** Station B3, 10/26/2015 10:21:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Oil and Grease	ND	ND	mg/kg	50	25	EPA-1664A HEM	ND		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-1664A HEM	10/28/15	10/28/15 08:00	MAM	MAN-SV	0.990	BYJ2722

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

BCL Sample ID: 1527173-03 | **Client Sample Name:** Station B3, 10/26/2015 10:21:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Moisture	0	22.6	**%**	**0.05**	**0.05**	**Calc**	ND		1
Total Kjeldahl Nitrogen	180	140	**mg/kg**	**40**	**15**	**EPA-351.2**	ND		2
Volatile Solids	2.35	1.82	**%**	**0.200**	**0.200**	**SM-2540G**	ND		3
Biochemical Oxygen Demand	33	26	**mg/kg**	**10**	**10**	**SM17-5210B**			4
Solids	100	77.4	**%**	**0.05**	**0.05**	**SM-2540G**			5

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	Calc	10/29/15	11/09/15 17:01	AMM	Calc	1	BYJ2691
2	EPA-351.2	10/28/15	10/30/15 12:46	JMH	SC-1	1	BYJ2622
3	SM-2540G	10/29/15	10/29/15 11:30	CAD	MANUAL	1	BYJ2732
4	SM17-5210B	10/27/15	10/27/15 09:15	HPR	YSI-57	0.333	BYK0005
5	SM-2540G	10/28/15	10/28/15 11:30	NW1	TOC2	1	BYJ2583

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

BCL Sample ID: 1527173-03 | **Client Sample Name:** Station B3, 10/26/2015 10:21:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Arsenic	3.8	2.9	**mg/kg**	**0.50**	**0.17**	**EPA-6020**	ND		1
Cadmium	ND	ND	mg/kg	0.50	0.052	EPA-6010B	ND		2
Chromium	51	40	**mg/kg**	**0.50**	**0.050**	**EPA-6010B**	ND		2
Copper	3.6	2.8	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	ND		2
Lead	2.5	1.9	**mg/kg**	**0.25**	**0.12**	**EPA-6020**	ND		1
Mercury	ND	ND	mg/kg	0.16	0.036	EPA-7471A	ND		3
Nickel	52	40	**mg/kg**	**0.50**	**0.15**	**EPA-6010B**	ND		2
Silver	ND	ND	mg/kg	0.25	0.051	EPA-6020	ND		1
Zinc	18	14	**mg/kg**	**2.5**	**0.087**	**EPA-6010B**	0.23		2
Aluminum	6200	4800	**mg/kg**	**5.0**	**1.2**	**EPA-6010B**	ND		2
Iron	10000	8000	**mg/kg**	**5.0**	**1.7**	**EPA-6010B**	3.2		2

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6020	10/28/15	10/29/15 02:52	GPD	PE-EL2	0.952	BYJ2549
2	EPA-6010B	10/27/15	10/27/15 13:55	JRG	PE-OP2	0.952	BYJ2415
3	EPA-7471A	10/28/15	10/28/15 14:27	MEV	CETAC1	1.025	BYJ2505

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

BCL Sample ID: 1527173-04 | **Client Sample Name:** Station B4, 10/26/2015 11:09:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Oil and Grease	ND	ND	mg/kg	50	25	EPA-1664A HEM	ND		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-1664A HEM	10/28/15	10/28/15 08:00	MAM	MAN-SV	0.992	BYJ2722

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

BCL Sample ID: 1527173-04 | **Client Sample Name:** Station B4, 10/26/2015 11:09:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Moisture	0	23.2	**%**	**0.05**	**0.05**	**Calc**	ND		1
Total Kjeldahl Nitrogen	180	140	**mg/kg**	**40**	**15**	**EPA-351.2**	ND		2
Volatile Solids	2.54	1.95	**%**	**0.200**	**0.200**	**SM-2540G**	ND		3
Biochemical Oxygen Demand	40	31	**mg/kg**	**10**	**10**	**SM17-5210B**			4
Solids	100	76.8	**%**	**0.05**	**0.05**	**SM-2540G**			5

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	Calc	10/29/15	11/09/15 17:01	AMM	Calc	1	BYJ2691
2	EPA-351.2	10/28/15	10/30/15 12:39	JMH	SC-1	1	BYJ2622
3	SM-2540G	10/29/15	10/29/15 11:30	CAD	MANUAL	1	BYJ2732
4	SM17-5210B	10/27/15	10/27/15 09:15	HPR	YSI-57	0.333	BYK0005
5	SM-2540G	10/28/15	10/28/15 11:30	NW1	TOC2	1	BYJ2583

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

BCL Sample ID: 1527173-04 | **Client Sample Name:** Station B4, 10/26/2015 11:09:00AM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Arsenic	3.7	2.8	**mg/kg**	**0.50**	**0.17**	**EPA-6020**	ND		1
Cadmium	ND	ND	mg/kg	0.50	0.052	EPA-6010B	ND		2
Chromium	52	40	**mg/kg**	**0.50**	**0.050**	**EPA-6010B**	ND		2
Copper	3.7	2.9	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	ND		2
Lead	2.4	1.9	**mg/kg**	**0.25**	**0.12**	**EPA-6020**	ND		1
Mercury	ND	ND	mg/kg	0.16	0.036	EPA-7471A	ND		3
Nickel	55	42	**mg/kg**	**0.50**	**0.15**	**EPA-6010B**	ND		2
Silver	ND	ND	mg/kg	0.25	0.051	EPA-6020	ND		1
Zinc	18	14	**mg/kg**	**2.5**	**0.087**	**EPA-6010B**	0.23		2
Aluminum	6300	4800	**mg/kg**	**5.0**	**1.2**	**EPA-6010B**	ND		2
Iron	11000	8100	**mg/kg**	**5.0**	**1.7**	**EPA-6010B**	3.1		2

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6020	10/28/15	10/29/15 02:56	GPD	PE-EL2	0.971	BYJ2549
2	EPA-6010B	10/27/15	10/27/15 13:57	JRG	PE-OP2	0.935	BYJ2415
3	EPA-7471A	10/28/15	10/28/15 14:29	MEV	CETAC1	0.992	BYJ2505

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

BCL Sample ID: 1527173-05 | **Client Sample Name:** Station B5, 10/26/2015 12:16:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Oil and Grease	ND	ND	mg/kg	50	25	EPA-1664A HEM	ND		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-1664A HEM	10/28/15	10/28/15 08:00	MAM	MAN-SV	0.996	BYJ2722

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

BCL Sample ID: 1527173-05 | **Client Sample Name:** Station B5, 10/26/2015 12:16:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Moisture	0	23.2	**%**	**0.05**	**0.05**	**Calc**	ND		1
Total Kjeldahl Nitrogen	170	130	**mg/kg**	**40**	**15**	**EPA-351.2**	ND		2
Volatile Solids	2.33	1.79	**%**	**0.200**	**0.200**	**SM-2540G**	ND		3
Biochemical Oxygen Demand	40	31	**mg/kg**	**10**	**10**	**SM17-5210B**			4
Solids	100	76.8	**%**	**0.05**	**0.05**	**SM-2540G**			5

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	Calc	10/29/15	11/09/15 17:01	AMM	Calc	1	BYJ2691
2	EPA-351.2	10/28/15	10/30/15 12:47	JMH	SC-1	0.962	BYJ2622
3	SM-2540G	10/29/15	10/29/15 11:30	CAD	MANUAL	1	BYJ2732
4	SM17-5210B	10/27/15	10/27/15 09:15	HPR	YSI-57	0.333	BYK0005
5	SM-2540G	10/28/15	10/28/15 11:30	NW1	TOC2	1	BYJ2583

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

BCL Sample ID: 1527173-05 | **Client Sample Name:** Station B5, 10/26/2015 12:16:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Arsenic	3.6	2.8	**mg/kg**	**0.50**	**0.17**	**EPA-6020**	ND		1
Cadmium	ND	ND	mg/kg	0.50	0.052	EPA-6010B	ND		2
Chromium	53	41	**mg/kg**	**0.50**	**0.050**	**EPA-6010B**	ND		2
Copper	3.6	2.8	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	ND		2
Lead	2.3	1.8	**mg/kg**	**0.25**	**0.12**	**EPA-6020**	ND		1
Mercury	ND	ND	mg/kg	0.16	0.036	EPA-7471A	ND		3
Nickel	49	38	**mg/kg**	**0.50**	**0.15**	**EPA-6010B**	ND		2
Silver	ND	ND	mg/kg	0.25	0.051	EPA-6020	ND		1
Zinc	18	14	**mg/kg**	**2.5**	**0.087**	**EPA-6010B**	0.24		2
Aluminum	6400	4900	**mg/kg**	**5.0**	**1.2**	**EPA-6010B**	ND		2
Iron	10000	8000	**mg/kg**	**5.0**	**1.7**	**EPA-6010B**	3.4		2

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6020	10/28/15	10/29/15 02:59	GPD	PE-EL2	0.952	BYJ2549
2	EPA-6010B	10/27/15	10/27/15 13:53	JRG	PE-OP2	1	BYJ2415
3	EPA-7471A	10/28/15	10/28/15 14:35	MEV	CETAC1	0.962	BYJ2505

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

BCL Sample ID: 1527173-06 | **Client Sample Name:** Station B6, 10/26/2015 12:58:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Oil and Grease	ND	ND	mg/kg	50	25	EPA-1664A HEM	ND		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-1664A HEM	10/28/15	10/28/15 08:00	MAM	MAN-SV	0.992	BYJ2722

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

BCL Sample ID: 1527173-06 | **Client Sample Name:** Station B6, 10/26/2015 12:58:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Moisture	0	28.2	**%**	**0.05**	**0.05**	**Calc**	ND		1
Total Kjeldahl Nitrogen	150	110	**mg/kg**	**40**	**15**	**EPA-351.2**	ND		2
Volatile Solids	2.00	1.44	**%**	**0.200**	**0.200**	**SM-2540G**	ND		3
Biochemical Oxygen Demand	43	31	**mg/kg**	**7.5**	**7.5**	**SM17-5210B**			4
Solids	100	71.8	**%**	**0.05**	**0.05**	**SM-2540G**			5

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	Calc	10/29/15	11/09/15 17:01	AMM	Calc	1	BYJ2691
2	EPA-351.2	10/28/15	10/30/15 12:48	JMH	SC-1	0.926	BYJ2622
3	SM-2540G	10/29/15	10/29/15 11:30	CAD	MANUAL	1	BYJ2732
4	SM17-5210B	10/27/15	10/27/15 09:15	HPR	YSI-57	0.250	BYK0005
5	SM-2540G	10/28/15	10/28/15 11:30	NW1	TOC2	1	BYJ2583

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

BCL Sample ID: 1527173-06 | **Client Sample Name:** Station B6, 10/26/2015 12:58:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Arsenic	3.4	2.4	**mg/kg**	**0.50**	**0.17**	**EPA-6020**	ND		1
Cadmium	ND	ND	mg/kg	0.50	0.052	EPA-6010B	ND		2
Chromium	48	34	**mg/kg**	**0.50**	**0.050**	**EPA-6010B**	ND		2
Copper	3.2	2.3	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	ND		2
Lead	2.2	1.6	**mg/kg**	**0.25**	**0.12**	**EPA-6020**	ND		1
Mercury	ND	ND	mg/kg	0.16	0.036	EPA-7471A	ND		3
Nickel	44	31	**mg/kg**	**0.50**	**0.15**	**EPA-6010B**	ND		2
Silver	ND	ND	mg/kg	0.25	0.051	EPA-6020	ND		1
Zinc	17	12	**mg/kg**	**2.5**	**0.087**	**EPA-6010B**	0.23		2
Aluminum	6000	4300	**mg/kg**	**5.0**	**1.2**	**EPA-6010B**	ND		2
Iron	9700	7000	**mg/kg**	**5.0**	**1.7**	**EPA-6010B**	3.2		2

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6020	10/28/15	10/29/15 03:03	GPD	PE-EL2	1	BYJ2549
2	EPA-6010B	10/27/15	10/27/15 13:59	JRG	PE-OP2	0.962	BYJ2415
3	EPA-7471A	10/28/15	10/28/15 14:38	MEV	CETAC1	0.992	BYJ2505

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

BCL Sample ID: 1527173-07 | **Client Sample Name:** Station B7, 10/26/2015 1:43:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Oil and Grease	ND	ND	mg/kg	50	25	EPA-1664A HEM	ND		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-1664A HEM	10/28/15	10/28/15 08:00	MAM	MAN-SV	0.988	BYJ2722

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

BCL Sample ID: 1527173-07 | **Client Sample Name:** Station B7, 10/26/2015 1:43:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Moisture	0	25.4	**%**	**0.05**	**0.05**	**Calc**	ND		1
Total Kjeldahl Nitrogen	150	110	**mg/kg**	**40**	**15**	**EPA-351.2**	ND		2
Volatile Solids	2.20	1.64	**%**	**0.200**	**0.200**	**SM-2540G**	ND		3
Biochemical Oxygen Demand	37	28	**mg/kg**	**10**	**10**	**SM17-5210B**			4
Solids	100	74.6	**%**	**0.05**	**0.05**	**SM-2540G**			5

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	Calc	10/29/15	11/09/15 17:01	AMM	Calc	1	BYJ2691
2	EPA-351.2	10/28/15	10/30/15 12:49	JMH	SC-1	0.962	BYJ2622
3	SM-2540G	10/29/15	10/29/15 11:30	CAD	MANUAL	1	BYJ2732
4	SM17-5210B	10/27/15	10/27/15 09:15	HPR	YSI-57	0.333	BYK0005
5	SM-2540G	10/28/15	10/28/15 11:30	NW1	TOC2	1	BYJ2583

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Ventura, CA 93003-3238

Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

BCL Sample ID: 1527173-07 | **Client Sample Name:** Station B7, 10/26/2015 1:43:00PM

Constituent	Dry Basis Result	As Recvd Result	Units	PQL	MDL	Method	MB Bias	Lab Quals	Run #
Arsenic	3.6	2.7	**mg/kg**	**0.50**	**0.17**	**EPA-6020**	ND		1
Cadmium	ND	ND	mg/kg	0.50	0.052	EPA-6010B	ND		2
Chromium	51	38	**mg/kg**	**0.50**	**0.050**	**EPA-6010B**	ND		2
Copper	3.4	2.5	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	ND		2
Lead	2.3	1.7	**mg/kg**	**0.25**	**0.12**	**EPA-6020**	ND		1
Mercury	ND	ND	mg/kg	0.16	0.036	EPA-7471A	ND		3
Nickel	49	36	**mg/kg**	**0.50**	**0.15**	**EPA-6010B**	ND		2
Silver	ND	ND	mg/kg	0.25	0.051	EPA-6020	ND		1
Zinc	18	13	**mg/kg**	**2.5**	**0.087**	**EPA-6010B**	0.24		2
Aluminum	6100	4600	**mg/kg**	**5.0**	**1.2**	**EPA-6010B**	ND		2
Iron	10000	7500	**mg/kg**	**5.0**	**1.7**	**EPA-6010B**	3.3		2

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6020	10/28/15	10/29/15 03:06	GPD	PE-EL2	0.943	BYJ2549
2	EPA-6010B	10/27/15	10/27/15 14:01	JRG	PE-OP2	0.980	BYJ2415
3	EPA-7471A	10/28/15	10/28/15 14:40	MEV	CETAC1	1.025	BYJ2505

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Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

Quality Control Report - Method Blank Analysis

Constituent	QC Sample ID	MB Result	Units	PQL	MDL	Lab Quals
QC Batch ID: BYJ2722						
Oil and Grease	BYJ2722-BLK1	ND	mg/kg	50	25	

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Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

Quality Control Report - Laboratory Control Sample

Constituent	QC Sample ID	Type	Result	Spike Level	Units	Percent Recovery	RPD	Control Limits Percent Recovery	Control Limits RPD	Lab Quals
QC Batch ID: BYJ2722										
Oil and Grease	BYJ2722-BS1	LCS	701.60	796.41	mg/kg	88.1		59 - 117		

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Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

EPA Method 1664

Quality Control Report - Precision & Accuracy

Constituent	Type	Source Sample ID	Source Result	Result	Spike Added	Units	RPD	Percent Recovery	Control Limits RPD	Control Limits Percent Recovery	Lab Quals
QC Batch ID: BYJ2722	Used client sample: N										
Oil and Grease	DUP	1524843-26	ND	ND		mg/kg			30		
	MS	1524843-26	ND	778.77	791.67	mg/kg		98.4		56 - 111	
	MSD	1524843-26	ND	667.33	794.82	mg/kg	15.4	84.0	30	56 - 111	

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

Quality Control Report - Method Blank Analysis

Constituent	QC Sample ID	MB Result	Units	PQL	MDL	Lab Quals
QC Batch ID: BYJ2622						
Total Kjeldahl Nitrogen	BYJ2622-BLK1	ND	mg/kg	40	15	
QC Batch ID: BYJ2691						
Moisture	BYJ2691-BLK1	ND	%	0.05	0.05	
QC Batch ID: BYJ2732						
Volatile Solids	BYJ2732-BLK1	ND	%	0.133	0.133	
QC Batch ID: BYK0005						
Biochemical Oxygen Demand	BYK0005-BLK1	ND	mg/kg	0.98	0.98	

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Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

Quality Control Report - Laboratory Control Sample

Constituent	QC Sample ID	Type	Result	Spike Level	Units	Percent Recovery	RPD	Control Limits Percent Recovery	Control Limits RPD	Lab Quals
QC Batch ID: BYJ2622										
Total Kjeldahl Nitrogen	BYJ2622-BS1	LCS	436.84	400.00	mg/kg	109		90 - 110		
QC Batch ID: BYK0005										
Biochemical Oxygen Demand	BYK0005-BS1	LCS	199.39	198.00	mg/kg	101		85 - 115		

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Chemical Analysis

Quality Control Report - Precision & Accuracy

Constituent	Type	Source Sample ID	Source Result	Result	Spike Added	Units	RPD	Percent Recovery	Control Limits RPD	Control Limits Percent Recovery	Lab Quals
QC Batch ID: BYJ2583	Used client sample: Y - Description: Station B1, 10/26/2015 08:40										
Solids	DUP	1527173-01	76.920	76.510		%	0.5		20		
QC Batch ID: BYJ2622	Used client sample: Y - Description: Station B4, 10/26/2015 11:09										
Total Kjeldahl Nitrogen	DUP	**1527173-04**	**141.28**	**155.46**		**mg/kg**	**9.6**		**20**		
	MS	**1527173-04**	**141.28**	**583.70**	**400.00**	**mg/kg**		**111**		**90 - 110**	**Q03**
	MSD	**1527173-04**	**141.28**	**576.10**	**400.00**	**mg/kg**	**1.3**	**109**	**20**	**90 - 110**	
QC Batch ID: BYJ2732	Used client sample: Y - Description: Station B1, 10/26/2015 08:40										
Volatile Solids	DUP	1527173-01	1.3700	1.3600		%	0.7		20		
QC Batch ID: BYK0005	Used client sample: Y - Description: Station B3, 10/26/2015 10:21										
Biochemical Oxygen Demand	DUP	1527173-03	25.620	23.383		mg/kg	9.1		20		

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Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

Quality Control Report - Method Blank Analysis

Constituent	QC Sample ID	MB Result	Units	PQL	MDL	Lab Quals
QC Batch ID: BYJ2415						
Cadmium	BYJ2415-BLK1	ND	mg/kg	0.50	0.052	
Chromium	BYJ2415-BLK1	ND	mg/kg	0.50	0.050	
Copper	BYJ2415-BLK1	ND	mg/kg	1.0	0.050	
Nickel	BYJ2415-BLK1	ND	mg/kg	0.50	0.15	
Zinc	**BYJ2415-BLK1**	**0.24125**	**mg/kg**	**2.5**	**0.087**	**J**
Aluminum	BYJ2415-BLK1	ND	mg/kg	5.0	1.2	
Iron	**BYJ2415-BLK1**	**3.3508**	**mg/kg**	**5.0**	**1.7**	**J**
QC Batch ID: BYJ2505						
Mercury	BYJ2505-BLK1	ND	mg/kg	0.16	0.036	
QC Batch ID: BYJ2549						
Arsenic	BYJ2549-BLK1	ND	mg/kg	0.50	0.17	
Lead	BYJ2549-BLK1	ND	mg/kg	0.25	0.12	
Silver	BYJ2549-BLK1	ND	mg/kg	0.25	0.051	

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Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

Quality Control Report - Laboratory Control Sample

Constituent	QC Sample ID	Type	Result	Spike Level	Units	Percent Recovery	RPD	Control Limits Percent Recovery	Control Limits RPD	Lab Quals
QC Batch ID: BYJ2415										
Cadmium	BYJ2415-BS1	LCS	9.4414	10.000	mg/kg	94.4		75 - 125		
Chromium	BYJ2415-BS1	LCS	97.939	100.00	mg/kg	97.9		75 - 125		
Copper	BYJ2415-BS1	LCS	96.629	100.00	mg/kg	96.6		75 - 125		
Nickel	BYJ2415-BS1	LCS	100.35	100.00	mg/kg	100		75 - 125		
Zinc	BYJ2415-BS1	LCS	98.153	100.00	mg/kg	98.2		75 - 125		
Aluminum	BYJ2415-BS1	LCS	499.73	500.00	mg/kg	99.9		75 - 125		
Iron	BYJ2415-BS1	LCS	508.64	500.00	mg/kg	102		75 - 125		
QC Batch ID: BYJ2505										
Mercury	BYJ2505-BS1	LCS	0.78720	0.80000	mg/kg	98.4		80 - 120		
QC Batch ID: BYJ2549										
Arsenic	BYJ2549-BS1	LCS	25.238	25.000	mg/kg	101		75 - 125		
Lead	BYJ2549-BS1	LCS	25.964	25.000	mg/kg	104		75 - 125		
Silver	BYJ2549-BS1	LCS	10.404	10.000	mg/kg	104		75 - 125		

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Total Concentrations (TTLC)

Quality Control Report - Precision & Accuracy

Constituent	Type	Source Sample ID	Source Result	Result	Spike Added	Units	RPD	Percent Recovery	Control Limits RPD	Control Limits Percent Recovery	Lab Quals
QC Batch ID: BYJ2415	Used client sample: N										
Cadmium	DUP	1527082-01	ND	ND		mg/kg			20		
	MS	1527082-01	ND	8.6886	10.000	mg/kg		86.9		75 - 125	
	MSD	1527082-01	ND	8.5689	10.000	mg/kg	1.4	85.7	20	75 - 125	
Chromium	DUP	1527082-01	25.249	27.916		mg/kg	10.0		20		
	MS	1527082-01	25.249	112.63	100.00	mg/kg		87.4		75 - 125	
	MSD	1527082-01	25.249	114.42	100.00	mg/kg	1.6	89.2	20	75 - 125	
Copper	DUP	1527082-01	15.980	15.861		mg/kg	0.7		20		
	MS	1527082-01	15.980	108.92	100.00	mg/kg		92.9		75 - 125	
	MSD	1527082-01	15.980	107.42	100.00	mg/kg	1.4	91.4	20	75 - 125	
Nickel	DUP	1527082-01	34.087	34.632		mg/kg	1.6		20		
	MS	1527082-01	34.087	118.99	100.00	mg/kg		84.9		75 - 125	
	MSD	1527082-01	34.087	119.78	100.00	mg/kg	0.7	85.7	20	75 - 125	
Zinc	DUP	1527082-01	45.114	44.921		mg/kg	0.4		20		
	MS	1527082-01	45.114	127.96	100.00	mg/kg		82.8		75 - 125	
	MSD	1527082-01	45.114	128.03	100.00	mg/kg	0.1	82.9	20	75 - 125	
Aluminum	DUP	**1527082-01**	**9441.1**	**9093.7**		**mg/kg**	**3.7**		**20**		
	MS	**1527082-01**	**9441.1**	**12326**	**500.00**	**mg/kg**		**577**		**75 - 125**	**A03**
	MSD	**1527082-01**	**9441.1**	**12652**	**500.00**	**mg/kg**	**2.6**	**642**	**20**	**75 - 125**	**A03**
Iron	DUP	**1527082-01**	**15631**	**15490**		**mg/kg**	**0.9**		**20**		
	MS	**1527082-01**	**15631**	**17992**	**500.00**	**mg/kg**		**472**		**75 - 125**	**A03**
	MSD	**1527082-01**	**15631**	**17333**	**500.00**	**mg/kg**	**3.7**	**340**	**20**	**75 - 125**	**A03**
QC Batch ID: BYJ2505	Used client sample: N										
Mercury	DUP	**1527207-01**	**ND**	**ND**		**mg/kg**			**20**		
	MS	**1527207-01**	**ND**	**1.0105**	**0.81967**	**mg/kg**		**123**		**80 - 120**	**Q03**
	MSD	**1527207-01**	**ND**	**0.92984**	**0.81967**	**mg/kg**	**8.3**	**113**	**20**	**80 - 120**	
QC Batch ID: BYJ2549	Used client sample: Y - Description: Station B1, 10/26/2015 08:40										
Arsenic	DUP	1527173-01	2.1708	2.2928		mg/kg	5.5		20		
	MS	1527173-01	2.1708	26.914	25.000	mg/kg		99.0		75 - 125	
	MSD	1527173-01	2.1708	26.887	25.000	mg/kg	0.1	98.9	20	75 - 125	
Lead	DUP	1527173-01	1.7665	1.7372		mg/kg	1.7		20		
	MS	1527173-01	1.7665	25.286	25.000	mg/kg		94.1		75 - 125	
	MSD	1527173-01	1.7665	25.400	25.000	mg/kg	0.4	94.5	20	75 - 125	
Silver	DUP	1527173-01	ND	ND		mg/kg			20		
	MS	1527173-01	ND	9.8732	10.000	mg/kg		98.7		75 - 125	
	MSD	1527173-01	ND	9.8915	10.000	mg/kg	0.2	98.9	20	75 - 125	

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Reported: 11/12/2015 16:19
Project: Annual Benthic Sediment Sampling for MBTP
Project Number: [none]
Project Manager: Doug Coats

Notes And Definitions

J	Estimated Value (CLP Flag)
MDL	Method Detection Limit
ND	Analyte Not Detected
PQL	Practical Quantitation Limit
A03	The sample concentration is more than 4 times the spike level.
Q03	Matrix spike recovery(s) is(are) not within the control limits.

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APPENDIX F

Laboratory Quality Assurance and Quality Control Plans

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APPENDIX F

Quality Assurance/Quality Control

Government organizations and respected contract research facilities now require specific Quality Assurance Programs and Plans for all scientific research efforts. Marine Research Specialists (MRS), without exception, abides by these requirements and has integrated Quality Assurance procedures in their normal course of scientific investigations. We pride ourselves on excellence and objectivity in research, and we support that pride with Quality Assurance and Quality Control procedures, which are documented by SOP's. These procedures have been developed through the years in support of major environmental programs for clients such as the U.S. Environmental Protection Agency, U.S. Department of Commerce (NOAA), and the U.S. Department of the Interior.

The quality assurance procedures for work undertaken in this program meet all MRS requirements for assuring the reliability of monitoring and measurement data. This level of QA/QC is also applicable to all subcontractors working on this monitoring program under the direction of MRS. The procedures form an integrated program for assuring complete, accurate, precise, and representative data under defined requirements. Our general quality assurance requirements are discussed below.

Program Management. The basis of any sound QA/QC program resides with the Program Manager, Dr. D.A. Coats. He ensures that monitoring program activities, client-approved changes in scope, and progress are well documented throughout the duration of the monitoring program. He also ensures that specific QA/QC documentation such as field observation logs, sampling logs (separate logs are maintained for water, sediment and infauna samples), and sample transfer forms are properly and accurately recorded and maintained. It is important to note that each and all samples maintain unique sample codes throughout the sample collection, analyses, and reporting phases of the monitoring program.

Dr. Coats also conducts QA/QC reviews of our subcontractors, BC Laboratories, Monterey Bay Analytical Services, Vista Analytical Laboratories, Weck Laboratories, and Aquatic Testing Laboratories, to ensure that their QA/QC procedures are adhered to. They are promptly notified of any deviation and the need for corrective action.

Field Sampling. All field sampling equipment is calibrated according to manufacturer's specifications. Logs are maintained for the SBE-19plusV2 CTD System with the number of casts and cast locations recorded. Calibration results are also recorded into the log. Periodically, the CTD is returned to the manufacturer for a complete bench testing and calibration. The CTD was factory calibrated and fully tested at the Sea Bird Testing Facility in January 2015.

The Van Veen sediment grab sampler and subsamplers are cleaned with noncontaminating solvents between all collections of sediment chemistry samples. The solvents include methanol for the removal of organics and de-ionized water and HCl for the removal of metals. The grab sampler and sediment subsamplers such as scoops, are coated with noncontaminating Dykor® to limit contamination of chemistry samples from the sampling equipment. Similarly, all sediment sample containers are pre-cleaned and acid washed accorded to USEPA specifications. The grab sampler was recoated with Dykor® in September 1999.

Laboratory Analysis. QA/QC procedures are also used in the MRS laboratory for grain-size analysis and sorting benthic infauna samples. A minimum of 10 percent of all samples sorted by any one technician are resorted by another technician. The level of sorting error must not exceed five percent (i.e. the sample residue that is resorted by another technician must not contain more than five percent of the total number of organisms contained in the original sample). Additionally, all samples sorted by a technician who is in

the process of being trained are subject to quality control inspection. A technician is considered a trained sorter if they pass quality control inspection in five consecutive samples. Ms. Bonnie Luke is currently the lead technician for MRS for both grain-size analysis and benthic sample sorting.

Independent QA/QC Audit. In addition to the QA/QC auditing performed by the Program Manager, an independent semi-random audit on project performance is conducted by Dr. Douglas A. Coats. Dr. Coats reviews all reports for completeness, thoroughness, accurateness, and errors. He also performs periodic unannounced audits on monitoring program status and additionally, calls or meets independently with the Public Works Department's project officer for an evaluation of our performance.

Subcontracted Laboratories. The Quality Assurance guidelines and methods for subcontractor laboratories are too voluminous to include in this annual report but can be accessed by contacting each laboratory directly. The following version of the Quality Assurance Manual for the MBCSD WWTP includes a list of updates to the Operation and Maintenance Manual that were instituted during 2015.

Operation and Maintenance Manual
2015 Updates
Volumes 1 and 2

O&M Updates

- Created Activity Hazards Analysis (AHA) and Pre-Task Plan (PTP) Assessment Program
- Developed and modified the SOP for draining the Chlorine Contact Tank – 4 times
- Stormwater Pollution Prevention Program sampling procedures
- Biofilter Work Order SOP
- Update the Open-up forms
- Influent Meter download SOP
- Modify High Flow/ Flood Response Plan
- Update the Heat Illness Prevention Program
- Digester #1 start-up procedure and gas monitoring forms
- Update the Emergency Chemical Spill Response Plan
- Developed a SOP for draining the secondary clarifier

Hazard Analysis Developed for the Following Procedures

- Draining the Chlorine Contact Tank
- Pulling the WAS Pumps
- Draining the Secondary Clarifier
- Plugging the Influent Trunk Line for Calibration of the Influent Meter
- Removal and Installation of the Main Influent Pumps
- Loading Trucks when Hauling Biosolids
- Excavation for Pipe Repairs

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2015

Morro Bay / Cayucos Wastewater Treatment Plant

LABORATORY QUALITY ASSURANCE MANUAL

Updated 2-13-15

Bruce Keogh, Lab Director _____ Date: _____

TABLE OF CONTENTS

INTRODUCTION

The Morro Bay – Cayucos Wastewater Treatment Plant Laboratory provides analytical services for the Morro Bay – Cayucos Wastewater Treatment Plant located at 160 Atascadero Road, the mailing address is: 955 Shasta Ave, Morro Bay, CA 93442

The laboratory analyzes samples of wastewater effluent, influent and sludge on a daily, weekly or monthly basis for physical parameters. Microbiological samples are analyzed daily, weekly and monthly.

The laboratory only analyzes samples from the Morro Bay – Cayucos Wastewater Treatment Plant. The laboratory does not accept samples for analysis from outside sources.

There are currently three positions in the laboratory, the Laboratory Director and two Laboratory Analysts.

III. INFLUENT MONITORING REQUIREMENTS

A. Monitoring Location M-INF

1. The Discharger shall monitor representative samples[1] of influent to the treatment plant at M-INF as follows:

Parameter	Units	Sample Type	Minimum Frequency of Sampling/Analysis
Daily Flow	MG	Metered	Daily
Maximum Daily Flow	MGD	Metered	Daily
Mean Daily Flow	MGD	Calculated	Monthly
BOD_5 (20°C)	mg/L	24-hr Composite	Weekly
Suspended Solids	mg/L	24-hr Composite	Weekly

2. Effluent flow metering shall be reported in place of influent flow metering when the flume is surcharged.

IV. EFFLUENT MONITORING REQUIREMENTS

A. Monitoring Location M-001

The Discharger shall monitor representative effluent samples (downstream of any in-plant return flows or disinfection units) at M-001, as follows:

Parameter	Units	Sample Type	Minimum Frequency of Sampling/Analysis
Total Chlorine Residual	mg/L	Grab	Daily
Chlorine Usage	lbs/day	Recorded	Daily
Total Coliform	MPN	Grab	5 days/week[2]
Temperature	°C	Grab	5 days/week[1]
Turbidity	NTU	Grab	5 days/week[1]
BOD_5 (20°C)	mg/L	24-hr Composite	Weekly[1]
Suspended Solids	mg/L	24-hr Composite	Weekly[1]
pH	pH units	Grab	Weekly[1]
Settleable Solids	mL/L	Grab	Weekly
Grease and Oil	mg/L	Grab	Weekly
Chronic toxicity[3]	TUc	24-hr Composite	Semiannually (Jan/July)

[1] Influent samples shall be corrected to compensate for in-plant return flows.
[2] Sampling shall be arranged so that each day of the 7-day week is represented, at least once, each month, or every two months for weekly sampling. For samples collected five times per month, at least one sample shall be taken weekly, and sampling should be arranged so that each day of the 7-day week is represented, at least once, every two months.

Parameter	Units	Sample Type	Minimum Frequency of Sampling/Analysis
Ammonia (as N)	mg/L	Grab	Monthly
Nitrate (as N)	mg/L	Grab	Semiannually (Jan/July)
Urea (as N)	mg/L	Grab	Semiannually (Jan/July)
Ortho-Phosphate (as P)	mg/L	Grab	Semiannually (Jan/July)
Dissolved Silica (SiO_2)	mg/L	Grab	Semiannually (Jan/July)

PROTECTION OF MARINE AQUATIC LIFE

Parameter	Units	Type of Sample	Minimum Frequency of Sampling/Analysis	Minimum Levels[3] (µg/L)
Arsenic	mg/L	24-hr. Composite	Semi-annually	All methods contained in Table II-3 of 2005 Ocean Plan, with exception to the Direct Current Plasma method
Cadmium	mg/L	" "	" "	" "
Chromium(Hex)[4]	mg/L	" "	" "	" "
Copper	mg/L	" "	" "	" "
Lead	mg/L	" "	" "	" "
Mercury	µg/L	" "	" "	" "
Nickel	mg/L	" "	" "	" "
Selenium	mg/L	" "	" "	" "
Silver	mg/L	" "	" "	" "
Zinc	mg/L	" "	" "	" "
Cyanide	mg/L	" "	" "	" "
Phenolic Compounds	mg/L	Grab	Annually	See Table II-2 of 2005 Ocean Plan

[3] See MRP Section V, *Whole Effluent Toxicity Testing Requirements*, below.
[3] Minimum Levels (taken from Appendix II of the 2001 California Ocean Plan) represent the lowest quantifiable concentration in a sample based on the proper application of method-specific analytical procedures and the absence of matrix interferences.

The Discharger must instruct their laboratory to establish calibration standards so that the Minimum Level is the lowest calibration standard. At no time is the Discharger to use analytical date derived from extrapolation beyond the lowest point in the calibration curve.

The Discharger must report with each sample result the reported Minimum Level and the laboratory's current Method Detection Limit (MDL).

Discharger must report analytical results using the following protocols:

1. Sample results greater than or equal to the reported Minimum* Level must be reported "as measured" by the laboratory (i.e., the measured chemical concentration in the sample).
2. Sample results less than the reported Minimum Level, but greater than or equal to the laboratory's MDL, must be reported as "Detected, but Not Quantified", or DNQ. The laboratory must write the estimated chemical concentration of the sample next to DNQ as well as the words "Estimated Concentration" (may be shortened to "Est. Conc.").
3. Sample results less than the laboratory's MDL must be reported as "Not Detected", or ND.

[4] Discharger may at their option meet this limitation as total chromium limitation.

(non-chlorinated)				
Chlorinated Phenolics	mg/L	" "	" "	" "
Endosulfan[5]	µg/L	24-hr. Composite	" "	0.01
Endrin	µg/L	" "	" "	0.01
HCH[6]	µg/L	" "	" "	See Table II-4 of 2005 Ocean Plan
Radionuclide	pCi/L	" "	" "	–

[5] Endosulfan shall mean the sum of endosulfan-alpha and -beta and endosulfan sulfate.
[6] HCH shall mean the sum of the alpha, beta, gamma (lindane), and delta isomers of hexachlorocyclohexane.

QUALITY ASSURANCE OBJECTIVES

The role of the analytical laboratory is to provide qualitative and quantitative data to be used in decision-making. To be valuable, the data must accurately describe the characteristics or the concentration of constituents in the sample submitted to the laboratory. In many cases, an approximate answer or incorrect result is worse than no answer at all, because it will lead to faulty interpretations.

Decisions made using data from water and wastewater are far reaching. Water quality standards are set to establish satisfactory conditions for a given water use. The laboratory data define whether that condition is being met and whether the water can be used for its intended purpose. If the laboratory results indicate a violation of the standard, action is required on the part of pollution control authorities. With the present emphasis on legal action and social pressures to abate pollution, the analyst should be aware of his or her responsibility to provide laboratory results that are a reliable description of the sample. Furthermore, the analyst must be aware of his or her professional competence, the procedures he or she has used and the reported values may be used and challenged in court. To satisfactorily meet this challenge, the laboratory data must be backed up by an adequate program to document the proper control and application of all of the factors in which affect the result.

In wastewater analyses, the laboratory data define the treatment plant influent, the status of the steps in the treatment process and the final load imposed upon the water resources. Decisions on process changes, plant modification and even the construction of a new facility are based upon the results of laboratory analysis.

Research investigations in water pollution control rest upon a firm base of laboratory data. The final result sought can usually be described in numerical terms. The progress of the research and the alternative pathways available are generally evaluated on the basis of laboratory data. The value of the research effort will depend on the validity of laboratory results.

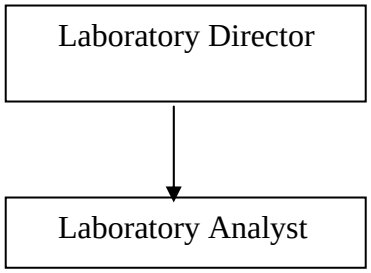
Because of the importance of laboratory analyses and the resulting actions that they produce, a program to ensure the reliability of the data is essential. It is recognized that all analysts practice quality control to varying degrees, depending somewhat upon their training, professional pride and awareness of the importance of the work they are doing. An established, routine control program applied to every analytical test is important in assuring the reliability of the final results. **Note:** Document analysis training and occasionally perform split samples to document analysis trainee proficiency.

The Quality Control Program in the laboratory has two primary functions. First, the program should monitor the reliability or truth of the results reported. It should continually provide an answer to “How good or true are the results submitted?” This phase may be a “measurement of quality.” The second function is the control of the quality in order to meet the program requirements for reliability. For example, the processing of spiked samples is the measurement of quality, while the use of analytical grade reagents is a control measure. Just as each analytical method has a rigid protocol, so the quality control associated with that test must also involve definite required steps to monitor and assure that the result is correct. Ideally, all of the variables, which can affect the final answer should be considered, evaluated and controlled.

PROGRAM ORGANIZATION AND RESPONSIBILITY

The responsibility for the Quality Control Program lies with the Laboratory Director who collects, interprets and reviews all the data from various quality control measures taken in the laboratory. It is the responsibility of this Quality Control official to make sure that each analyst in the laboratory is performing their duties of quality control measures and proper documentation of sample collection, preservation and analyses. It is therefore requested that all laboratory employees read this Quality Assurance Manual and become familiar with all the quality control terminology, methodology and procedures. Without exception, the final responsibility for the reliability of the analytical results rest with the Laboratory Director.

The Morro Bay – Cayucos Wastewater Treatment Plant Laboratory is organized as follows:



Responsibilities for each position in the Morro Bay – Cayucos Wastewater Treatment Plant Laboratory are as follows:

Laboratory Director

The managerial, administrative and supervisory level position for the laboratory is responsible for the planning, implementation and supervision of the laboratory testing and water quality control programs to comply with local, State and Federal standards. Supervisory duties include making assignments of work, setting priorities, training and inspecting work, selection of employees, preparing performance evaluations and recommending recognition and disciplining of subordinates.

Laboratory Analyst

The chemist level position for the laboratory is responsible for the physical, chemical and biological testing of water, wastewater and sludge. Additional responsibilities include sampling and cleaning and preparing laboratory glassware. Analyses include pH, turbidity, total chlorine residual, suspended solids, BOD, oil & grease, volatile acids, alkalinity and total and fecal coliforms. Assisting in the training and supervision of other laboratory analysts, assigning, instructing, monitoring and correcting work.

LABORATORY GENERAL PROCEDURES

There are some standard operating procedures that all laboratories have to ensure that procedures are performed the same way by each analyst and are a form of Quality Control.

Glassware

1. After dumping sample, rinse with water and apply FL70 detergent located at sink. Scrub or brush unit until all of sample has been removed from glassware. Glassware should then be rinsed at least three times with hot water. After rinsing with tap water, rinse again with DI water. Dry glassware is ready for use. **Note**: if there is a change in the formulation used or a change in the method of washing glassware; an inhibitory residue test must be performed.

2. Broken, cracked or chipped glassware is to be discarded.

Sample Custody

1. Sample bottles are labeled either prior to sampling by the lab or during sampling by the sampler.

2. Chain of Custody sheets, filled out completely, must accompany all samples sent to other laboratories for analysis.

3. A copy of Chain of Custody sheets are kept in a separate file in the laboratory file cabinet.

Quality Control

1. Use volumetric glassware and pipettes for all analyses.

2. Label all reagents with name, date and expiration.

3. Record all temperatures of lab equipment on a daily basis.

4. Keep the laboratory bench-tops, floors and instruments neat and clean.

5. Double check your calculations or have them checked by another analyst.

6. Standards should reflect a high and low value, with the sample close to the middle standard.

7. Re-run any questionable sample results to verify your analyses.

Safe Practices

1. Be familiar with the Material Safety Data Sheets (MSDS) for any chemical you are working with.
2. Do not pipette liquids by mouth.
3. Wear safety glasses when working with strong acids or bases.
4. Wear a lab coat or apron when working in the lab.
5. Use the fume hood to vent hazardous materials.
6. Wipe up any spills on the floors or counter tops immediately.
7. If a large chemical spill occurs use the chemical spill kit.
8. Know where the eyewash, extinguishers and showers are located.
9. No eating, drinking or smoking is allowed in the lab.
10. Wear gloves and then wash hands after working with sewage, sludge, coliform bacteria or any chemical.
11. Clean up your glassware from your work area when done and wipe counters.
12. Return any chemicals used to the chemical storage area.
13. Try to predict any safety hazards you will encounter before performing a task.
14. Inform the supervisor of any accident or injury immediately.

PREVENTATIVE MAINTENANCE

Since instrumentation is heavily relied upon in the laboratory it must be kept clean and well maintained. A computerized work order program, Datastream MP2 Access, is used to schedule and record all preventative maintenance procedures performed on turbidimeters, dissolved oxygen meters, composite samplers, ovens, autoclave, water-baths, analytical balances and pH meters. Calibration records of all instruments are also kept in the appropriate folders in the laboratory file cabinet.

Distilled Water: Distilled water is used in the laboratory for dilutions and final rinsing of glassware. We currently use bottled, distilled water from Crystal Springs. The water quality is tested and assured from the distributor, a copy of the results, are located in the laboratory file cabinet.

Analytical Balances: The laboratory balances are cleaned and serviced annually by a balance technician.

Temperature Logs: Temperature logs are kept on all ovens, incubators, refrigerators and water baths. Temperatures are recorded twice daily or when in use. Thermometers are compared annually against a certified National Bureau of Standards thermometer and recorded on the temperature logs. Thermometers are also labeled with any corrective factor.

Composite Samplers: Composite samplers have tubing for the sample line and the peristaltic pump. This tubing needs to be cleaned as needed due to algae growth. The tubing must be replaced when cracked or worn. Desiccant, inside the control box of the sampler needs to be changed whenever indicator turns pink.

Turbidimeter: The Hach 2100N Turbidimeter needs to be cleaned and serviced per the manufacturer's recommendations.

SYSTEM AUDITS

The laboratory participates annually in the National Pollutant Discharge Elimination System (NPDES) DMR-QA Laboratory Performance Evaluation sponsored by the U.S. Environmental Protection Agency. The samples are purchased from a list of accredited providers and the samples are analyzed along with the lab's regular samples and the results are reported. The accredited provider submits a report to the laboratory and the USEPA that notes whether sample results were acceptable or unacceptable. Any sample result receiving a not acceptable report requires a letter of corrective action be submitted to the State coordinator for USEPA within the specified time period.

The laboratory applies for certification with the California State Department of Health Services every two years as part of their Environmental Laboratory Accreditation Program (ELAP). The laboratory participates in Water Pollution Laboratory Performance Evaluation Studies (WP) for chemistry and microbiological samples on an annual basis. The samples are purchased from a list of accredited providers and the samples are analyzed along with the lab's regular samples and the results are reported. The accredited provider submits a report to the laboratory and to ELAP that notes whether sample results were acceptable or unacceptable. Any sample result receiving a not acceptable report requires a letter of corrective action be submitted to ELAP within the specified time period.

An additional requirement for the State Department of Health Services ELAP certification is a site visit and inspection of the laboratory every two years. The results of the visit and any deficiencies noted are sent back to the lab to be corrected.

SAMPLING POINTS AND TECHNIQUES

Sampling is a very important part of analysis. It should always be done with great consistency at the same point and the same technique should always be employed to ensure a representative sample. Because of the importance of this subject sample, it is necessary to have outlined procedure and set points for obtaining various samples for analysis.

Sample containers can greatly affect the constituent to be determined. Cations can absorb readily on some plastics and glassware. Metal or aluminum foil cap liners can interfere with metals analyses. How the sample containers are washed and cleaned are also a significant factor in quality control.

All samples should be refrigerated while they are being transported to the laboratory. If the samples cannot be analyzed immediately they should be refrigerated and analyzed as soon as possible. The following page contains our guidelines for sample containers, preservative used and the holding times for most of the samples we take for analysis by the Morro Bay – Cayucos Wastewater Treatment Plant laboratory or a contract laboratory.

It is essential to ensure sample integrity from collection to data reporting. This includes the ability to trace possession and handling of the sample from the time of collection through analysis and final disposition. This is referred to as chain of custody and is important in the event of litigation involving the analytical results. Where litigation is not involved, chain of custody procedures are useful for routine control of sample flow. Samples that come into the laboratory on a daily basis do not need a chain of custody, but are logged into the laboratory workbook.

A sample is considered to be under a person's custody if it is in the individual's physical possession, in the individual's sight, secured in a tamper proof way by that individual or is secured in an area restricted to authorized personnel.

All composite samples of final effluent should be collected from the refrigerated automatic composite sampler currently located on top of Air Release Structure or ARS. The sampler should be pre-set according to manufacturer instructions located in the filing cabinet in the laboratory. The effluent grab samples are obtained from the air relief structure, located downstream from the chlorine contact chamber.

If bacteriological samples are needed from the plant final effluent then samples should be collected at the discharge end of the chlorine contact chamber, using sterile sample bottles containing sodium thiosulfate, which de-chlorinates the sample.

Composite influent samples are taken at the headworks and again a refrigerated automatic composite sampler is employed for obtaining the influent composite samples.

Digester sludge samples are obtained at the valve manifold for each digester. They are all marked and samples can be obtained from any elevation desired. Close attention should be given to flushing the line by opening the valve and letting the old sludge in the line to run for at least two minutes. Then grab the sample.

Grab samples of mixed liquor suspended solids and return activated sludge are obtained at the south end of the solids contact channel and in the return sludge box respectively on the top of the secondary clarifier.

Samples of primary clarifiers are obtained by holding a beaker or container close to the weirs, where the primary process water is being discharged over the weirs. Samples of trickling filters are collected at the wet well next to them.

City of Morro Bay Wastewater Treatment Plant
CHAIN OF CUSTODY

Project Name:	**Date:**
Project Manager:	**Page:** _____ **of** _____
City of Morro Bay Wastewater Treatment Plant	**Special Instructions:**
160 Atascadero Road	
Morro Bay, CA 93442	
Phone: 805.772.6274	

Sample I.D.	Date	Time	Analysis Requested	Remarks

Relinquished/ Received By:	Date	Time	Firm/City	Signature

Container and Preservative Guide

ANALYSIS GROUP	Required Volume	Container/Preservative	Holding Time	Notes
General Mineral, Physical, Inorganics	2L	Qt/P/UNP	NO3: 48hrs	
		250/AG/UNP	ODOR: 24hrs, pH: 15min	
		250/P/NaOH		pH>12
		500/P/HNO3		pH<2
General Mineral / Irrigation Minerals	1L	Qt/P/UNP	NO3: 48hrs pH: 15min	
		250/P/HNO3	pH: 15min	pH<2
Storm Water	2L	L/AG/H2SO4		pH<2
		Qt/P/UNP	pH: 15min	
Inorganics	1L	8oz/P/UNP	NO3: 48hrs	
		250/P/HNO3		pH<2
General Physical	250ml	250/AG/UNP	ODOR: 24hrs	
NITROGEN FORMS				
Total Nitrogen Package	500ml	8oz/P/UNP	48 hours	
		8oz/P/H2SO4		pH<2
Total Nitrogen Series	500ml	8oz/P/UNP	48 hours	
		8oz/P/H2SO4		pH<2
TKN	250ml	8oz/P/H2SO4	28 Days	pH<2
Nitrate	250ml	8oz/P/UNP	48 Hours	
Nitrite	250ml	8oz/P/UNP	48 Hours	
Nitrate & Nitrite	250ml	8oz/P/UNP	48 Hours	
Ammonia	250ml	8oz/P/H2SO4	28 Days	pH<2
Ammonia (low DL)	250ml	250/P/UNP	24 Hours	GLASS OK
BACTERIA				
Bacti (Drinking Water)	100ml	BJ	24 Hours	
Bacti (Waste Water)	100ml	BJ	8 Hours	
METALS				
Total Metal	250ml	250/P/HNO3	6 Months	pH<2
Dissolved Metal	250ml	250/P/HNO3	6 Months	pH<2, FILTER WITHIN 15min
Mercury	250ml	250/P/HNO3	28 Days	pH<2
CAM 17	250ml	250/P/HNO3	6 Months	pH<2
Copper / Lead (Tap water)	1L	1L/P/HNO3	6 Months	pH<2 (first draw)
Chromium, Hexavalent	250ml	250/P/UNP	24 Hours	28 Day Hold Time w/ (NH4)2SO4 (Sub)
Boron	250ml	250/P/HNO3	6 Months	pH<2

NOTE: If Highlighted, Check pH with pH paper

- BACTERIA

  Recreational Waters hold time is 6 hours.

Container and Preservative Guide

COMMON ANALYSIS	Required Volume	Container/Preservative	Holding Time	Notes
Color	50ml	8oz/P/UNP	48 Hours	GLASS OK
Odor	250ml	250/G/UNP	24 Hours	
DO	250ml	250/P/UNP	15 Minutes	GLASS OK
Electrical Conductivity	100ml	250/P/UNP	28 Days	GLASS OK
pH	50ml	8oz/P/UNP	15 Minutes	GLASS OK
Total Solids	250ml	8oz/P/UNP	7 Days	GLASS OK
Total Dissolved Solids	250ml	8oz/P/UNP	7 Days	GLASS OK
Total Suspended Solids	1/5 Gall	1/2G/P/UNP	7 Days	GLASS OK, 1L MINIMUM (clean sample)
Settleable Solids	1/5 Gall	1/2G/P/UNP	48 Hours	GLASS OK
Total Organic Carbon (TOC)	100ml	2x VOA/HCl	28 Days	pH<2 (if we perform in house)
Turbidity	100ml	250/P/UNP	48 Hours	GLASS OK
Acidity	100ml	250/P/UNP	14 Days	
Alkalinity	100ml	100/P/UNP	14 Days	GLASS OK
Alpha Chlorophyl	1L	L/AG/UNP	48 Hours	
BOD, cBOD	1/5 Gall	1/2G/P/UNP	24-48 Hours	GLASS OK
Chloride	100ml	250/P/UNP	28 Days	GLASS OK
Chlorine Residual	100ml	2x VOA/UNP	15 Minutes	
COD	50ml	250/P/H2SO4	28 Days	pH<2, GLASS OK
Cyanide, Amenable CN	250ml	250P/NaOH	14 Days	pH>12, 24hr HT if sulfide is present
Fluoride	100ml	250/P/UNP	28 Days	GLASS OK
Hardness	250ml	250/P/HNO3	6 Months	pH<2
MBAS (Surfactants)	250ml	250/P/UNP	48 Hours	GLASS OK
Oil & Grease	1L	L/AG/H2SO4	28 Days	pH<2, *2 EXTRA EVERY 20 FOR QC
Phenols (420.1)	500ml	500/AG/H2SO4	28 Days	pH<2
Ortho Phosphate	100ml	250/P/UNP	48 Hours	FILTER WITHIN 15min
Total Phosphorous	100ml	250/P/H2SO4	28 Days	pH<2
Sulfate	100ml	250/P/UNP	28 Days	
Sulfide	100ml	250/P/NaOH & Zn Acetate	7 Days	pH 9-11
Sodium	250ml	250/P/HNO3	6 Months	pH<2

NOTE: If Highlighted, Check Cl2, pH, & Sulfide
NOTE: If Highlighted, Check pH
NOTE: If Highlighted, Check pH & Cl2

Container and Preservation Guide: Volatile & Semi Volatile Analysis

NOTE: Front office does not open VOA containers: they are checked by Analyst when performing test

VOLATILE ORGANICS

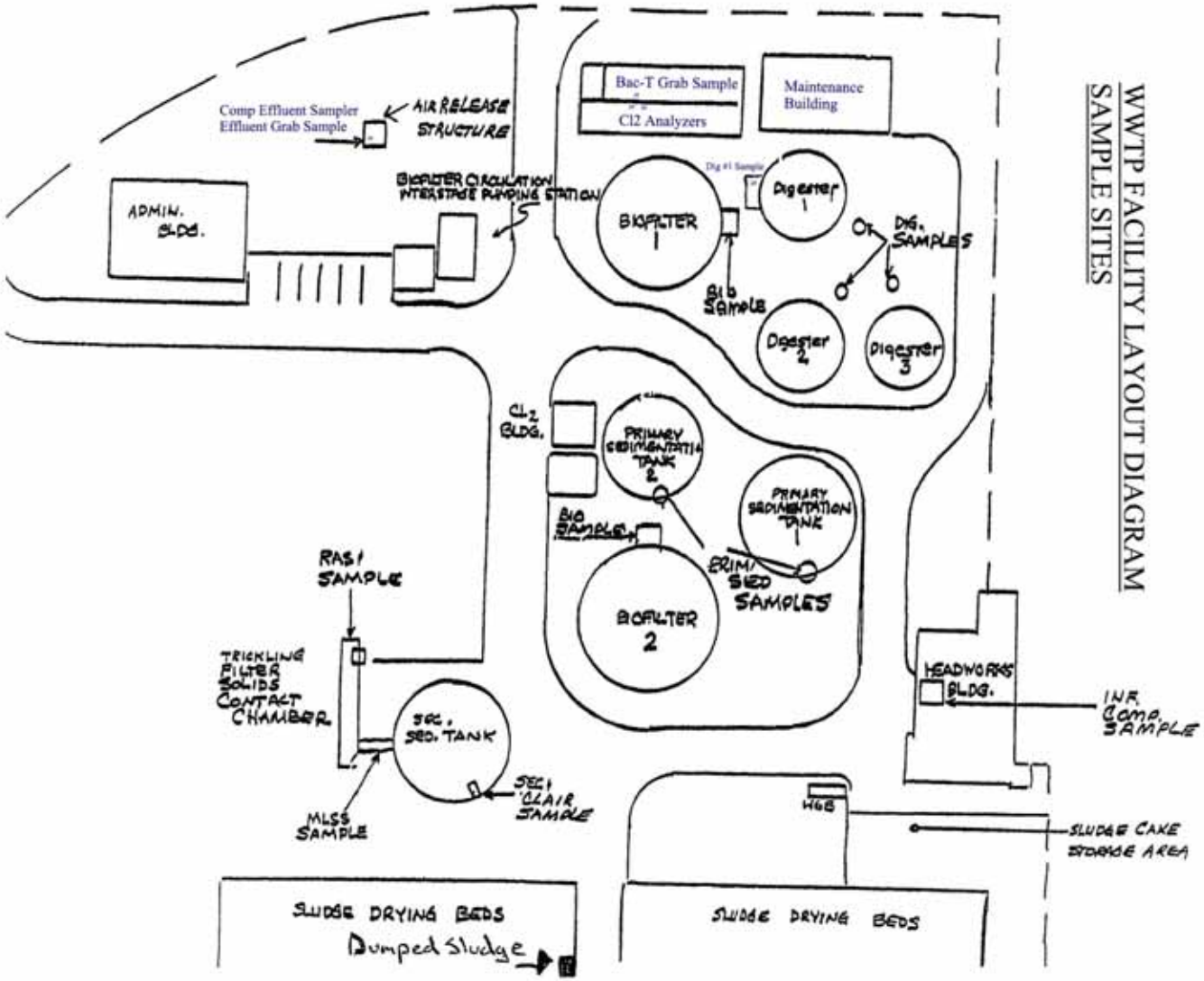
VOC (8260) or VOC & THPg by 8260	250ml	4x VOA/HCl	14 Days	pH<2
524.2 (Chlorinated Drinking Water)	250ml	4x VOA/HCl & Ascorbic Acid	14 Days	pH<2 HCL to be added after filling sample
TTHM'S	100ml	2x VOA/Ascorbic Acid	14 Days	
Methanol/ Ethanol (8015)	120ml	3xVOA/HCl	14 Days	pH<2
VOC (8260) & TPHg (8015)	250ml	6xVOA/HCl	14 Days	pH<2
VOC/ THPg Solids	4oz	4oz Jar (no preservative)	14 Days	
VOC/ THPg Encore	15g	3x 5g Encore samples	14 Days	Sample to be frozen within 48hrs

SEMI-VOLATILE ORGANICS

SVOC (8270)	1L	L/AG/UNP	7 Days	*2 EXTRA EVERY 20 FOR QC
TPH Diesel / Motor Oil (8015)	1L	L/AG/UNP	7 Days	*2 EXTRA EVERY 20 FOR QC
Pest/PCB (8081/8082)	1L	L/AG/UNP	7 Days	*2 EXTRA EVERY 20 FOR QC
~~VOC/ TPHg~~ Solids	8oz	8oz Jar (no preservative)	14 Days	

NOTE: If Highlighted, Check CL2 with KI/Starch paper

WWTP FACILITY LAYOUT DIAGRAM
SAMPLE SITES



ANALYTICAL METHODS

The following methods are used by the Morro Bay – Cayucos Wastewater Treatment Plant Laboratory and taken from Standard Methods for the Examination of Water and Wastewater, 22nd Edition.

Analysis	Method No.
pH	SM4500-H+B
Turbidity	SM2130B
Total Chlorine Residual	SM4500-C1 G
Total Suspended Solids	SMSM2540D
BOD	SMSM5210B
Total Coliform	SM9221B
Volatile Acid	SM5560C
Alkalinity	SM2320A
Settleable Solids	SM2540F

CALIBRATION PROCEDURES AND FREQUENCY

All laboratory instruments are to be calibrated prior to or during use. Instruments require calibration, standardization and informed observation to work accurately.

- The pH meter is calibrated daily during lab open up using pH 4, 7, 8 and 10 buffers. Refer to the standard operating procedures (SOP) for pH. pH 8 is used for a control check.

- The turbidimeter is checked daily against secondary standards and calibrated quarterly using primary standards. Refer to the standard operating procedures (SOP) for the turbidimeter.

- The analytical balances are calibrated annually by an independent company (Wine Country Balance, Sonoma, CA). Refer to the standard operating procedures (SOP) for the balances.

DATA REDUCTION, VALIDATION AND REPORTING

Standard Methods 22nd Edition, Pages 1-6 to 1-14 Section 1020 A-B

Significant Figures

A significant figure is a digit that denotes the amount of the quantity in the particular decimal place in which it stands. Reported analytical values should contain only significant figures. A value is made up of significant figures when it contains all digits known to be true and on the last digit in doubt. For example, if a value is reported as 18.8 mg/L, the 18 must be firm while the 0.8 is somewhat uncertain, but presumably better than one of the values 0.7 or 0.9 would be.

The number zero may or may not be a significant figure depending on the situation. Final zeros after a decimal point are always meant to be significant figures. Zeros before a decimal point with non-zero digits preceding them are significant. With no preceding non-zero digit, a zero before the decimal point is not significant. If there are no non-zero digits preceding a decimal point, the zeros after the decimal point but preceding other non-zero digits are not significant. These zeros only indicate the position of the decimal point.

Rounding Off

Round off by dropping digits that are not significant. If the digit 6, 7, 8, or 9 is dropped, increase the preceding digit by one unit. If the digit 1, 2, 3, or 4 is dropped, do not alter the preceding digit. If the digit 5 is dropped, increase the preceding digit by one if it is an odd number, or keep it unchanged if it is an even number.

Calculations

As a practical operating rule, round off the result of a calculation in which several numbers are multiplied or divided to as few significant figures as are present in the factor with the fewest significant figures. When numbers are added or subtracted, the number that has the fewest decimal places, not necessarily the fewest significant figures, puts the limit on the number of places that justifiably may be carried in the sum or difference.

Data Validation

The data is reviewed and checked by the analyst. The analyst will review all raw data and calculations to insure that the QC criteria, has been met. The raw data, sample run sheet and all other paperwork associated with the job are kept in the individual analyses notebooks for supervisor review. If the data is acceptable, then a report will be generated by the Laboratory supervisor.

The review of the data will include the following checks:

- Were the correct samples analyzed for the correct analyses as documented on the chain of custody form?
- Was the instrument properly calibrated?
- Was the holding time of the samples prior to analysis within acceptable limits?
- Are results calculated correctly after dilutions?

If there is a question to the validity of the analyses, then the sample is re-run by the analyst to verify. If the results are still in question after the second analyses, then they are declared invalid and the sampler is contacted to provide a second sample to the laboratory. All final reports are reviewed and signed by the Laboratory Director. All NPDES and EPA reports to the Regional Water Quality Control Board are also reviewed and signed by the Lab Director. All lab data sheets are kept and stored at the wastewater treatment plant.

MAINTENANCE OF LABORATORY SUPPLIES

Standard Methods 22nd Edition, Page 9-8 Section 9020 B-4

Monitoring Pure Water Quality

At this time, laboratory distilled water (DI water) is purchased from an independent company (Crystal Springs). Copies of analysis of purchased water are requested from the company. Copies of the monthly and annual analytical results are on file in the laboratory file cabinet. To perform analysis for quality of purified water used in bacteriological testing, refer to Standard Methods 22nd Edition, Page 1-46 to 1-48 Section 1080 A-C

*** Note: Remember to check and compare Crystal Spring's Report to the Micro checklist for quality assurance.**

GLASSWARE CLEANING

Standard Methods 22nd Edition, Pages 9-10 to 9-11 Section 9020 B-5

Before each use, examine glassware and discard items with chipped edges or etched inner surfaces. Particularly examine screw-capped dilution bottles and flasks for chipped edges that could leak and contaminate the sample, analyst and area. Inspect glassware after washing for excessive water beading, stains and cloudiness and rewash if necessary. Replace glassware with excessive writing if marking cannot be removed. Either cover glassware or store glassware with its bottom up to prevent dust from settling in.

Procedure

1. Glassware soap is made by using 25% FL70 with DI water.
2. After dumping sample, rinse with water and apply FL70 detergent located at sink.
3. Scrub or brush unit until all of sample has been removed from glassware.
4. Glassware should then be rinsed three times with hot water.
5. After rinsing with tap water, rinse again with DI water.
6. Dry glassware is ready for use.

* **Note: A glassware inhibitory residue test** will be performed on initial use of washing compound, when there is a change in formulation used or a change in the method of washing of reusable culture tubes, pipettes, flasks, graduated cylinders, beakers, blenders, funnels, etc.

  A glassware inhibitory residue test was last performed on 9 Feb 05
  by: Bio Screen Testing

pH Spot Check

Because some cleaning solutions are difficult to remove completely, spot-check batches of clean glassware for pH reaction, especially if soaked in alkali or acid.

Procedure

On a monthly basis, test clean glassware by adding a few drops of 0.04% bromthymol blue (BTB) or other pH indicator and observe the color reaction. BTB should be blue – green (in the neutral range). Record results on pH check form.

Crystal Springs Distilled Water Report

The Morro Bay/Cayucos Wastewater Treatment Plant Laboratory received the latest available Crystal Springs Distilled Water Report on 2/9/15. The report is attached to the Laboratory QA Manual due to the length of the report (66 pages).

pH SPOT CHECK

Date	Beaker	Acid / Neutral / Base	Initials
Acid = Yellow	**Neutral = Green**	**Base = Blue**	

LAB EQUIPMENT AND INSTRUMENTATION

Standard Methods 22nd Edition, Pages 9-7 to 9-10 Section 9020 B-4

Analytical Balance & Top Load Balance (Mettler Toledo New Classic MS)

1. Balance must have a readability of 0.1 mg.
2. Balance is checked daily for accuracy using ASTM class I weights
3. **Note:** a minimum of 2 traceable weights that bracket our lab's weighing needs are to be used; we consistently use 4 weights 0.2, 0.5, 1.0 and 10.0g.
4. Data recording on daily scale record sheet located on the refrigerator.
5. All reference weights will be re-certified if damaged, corroded or every 5 years.
6. Service contract for internal maintenance control on the analytical and top load balance is completed annually by Wine Country Balance, Sonoma, CA.
7. The analytical balance is located on a granite table for stability.
8. Use plastic tipped forceps when handling weights.

Portable Balance (Ohaus Adventurer Pro)

The portable top load balance will be checked at least monthly and before each use, using ASTM 1.0, 10.0 and 100.0 gram weights (minimum of three traceable weights that bracket our labs weighing needs) and recorded on the portable balance calibration sheet. The portable balance is located on the east stainless steel countertop.

Incubators

1. Our incubator is of sufficient size for our workload.
2. Our incubator unit has an internal temperature monitoring device and maintains a temperature of 35ºC ± 0.5º C.
3. Any temperature corrections must be noted on the daily incubator record sheet located on the side of our unit and on the thermometers.
4. Temperatures must be recorded twice each day of use, with readings at least 4 hours apart.
5. Clean and sanitize incubators as needed.

Thermometers

Normally, temperature measurements may be made with a mercury filled Celsius thermometer certified by National Institute of Standards and Technology (NIST) or one meeting the requirements of NBS Monograph SP 250. As a minimum, the thermometer should have a scale marked for every 0.5ºC with markings etched on the capillary glass (see specific equipment for scaling). The thermometer should have a minimal thermal capacity to permit rapid equilibration. Annually, check the thermometer against a precision thermometer certified by NIST. Thermometers must be labeled with the date of calibration and applicable correction factor. The data will be recorded on the applicable temperature sheets. NIST thermometers shall be replace every 5 years.

Scale Calibration

Class I weights used #1_____ #2_____ #3_____ #4_____

Date	Scale off in grams				Operator	Date	Scale off in grams				Operator
	#1	#2	#3	#4			#1	#2	#3	#4	

C:\Documents and Settings\Administrator\My Documents\Lab\Lab Forms\Scale Calibration.doc

EQUIPMENT TEMPERATURE RECORD
(CELCIUS)

MONTH _____ YEAR _____ Correction Date/Diff _____ - _____

EQUIPMENT _____ CERTIFIED THERMOMETER # _____ +/- _____

Name	Times		Temp C°	Date	Name	Times		Temp C°	Date
	1st	2nd				1st	2nd		

C:\Documents and Settings\Administrator\My Documents\Lab\Lab Forms\Equipment Temperature Record.doc

AUTOCLAV

Standard Methods 22nd Edition, Page 9-9 Section 9020 B-4

1. Our autoclave is sufficient for our workload and pressure cookers are not being used.
2. Our autoclave has an internal heat source, digital read-out, temperature gauge with sensor in exhaust, pressure gauges and an operational safety valve.
3. Our autoclave maintains sterilization temperature during cycle and completes the entire cycle within 42 minutes when 15 minute sterilization period is used. Runtimes will vary when longer sterilization periods are used.
4. For quality control, the automatic timing device is checked quarterly for accuracy with another accurate timing device. Results are recorded on the Control Test Data sheet in the lab data book and corrections are to be noted on log sheet and autoclave time temperature sheet.
5. For quality control, the autoclave has a temperature registering device and is used weekly to check the sterilization temperature of 121º ±2º C. Total runtime results are printed from the autoclave, dated, initialed and stored in the lab file cabinet.
6. A heat indicating tape is used to identify items that have been sterilized.
7. Routine maintenance of the autoclave includes cleaning of drain screen and visual inspection of the door seals on a weekly basis. The autoclave shall be inspected and calibrated per manufactures specs. Keep reports on file.
8. Spore ampules are used monthly as bioindicators to confirm sterilization. Results are recorded on the Control Test data sheet in the lab data book.
9. Contaminated test materials must be autoclaved at 121ºC for at least 30 minutes.

Autoclave records must include:

1. Date
2. Contents
3. Time in and out
4. Total exposure/cycle time
5. Sterilization time
6. Sterilization temperature
7. Initial of technician

AUTOCLAVE RECORD SHEET

DATE	CONTENTS	TIME IN/OUT		TOTAL EXPOSURE / CYCLE TIME	STERILIZATION TIME	TEMP	OPERATOR INITIALS

LAB OPEN UP

I. Procedures to open Lab

1. Check Temp of Bacti Incubator (35°C ± 0.5°C)
2. Check Oven Temp (103 - 105°C)
3. Check BOD Incubator Temp (20°C ± 1.0ºC)
4. Check Refrigerator Temp (0 - < 5.0° C)
5. Check the Calibration of Turbidimeter (see instructions)
6. Calibrate the pH meter (see instructions)
7. Check Calibration on the Scale (see instructions)

II. Other Open-up Duties

A. Read Plant Bac T Test.

1. Monday – Friday
2. Saturday – Sunday (Once a month sliding schedule)

B. Calibrate the Chlorine Residual Meters (every morning)

C. Set-up daily glassware

1. Three 50 ml. Beakers (pH calibration)
2. Two 250 ml. Graduated cylinders (Comp Eff. Susp. Solids Test)
3. One 25 ml. Graduated cylinder (MLSS)
4. One 250 ml. Graduated cylinder (Secondary Susp. Solids Test)
5. Two 100 ml. Graduated cylinders (Composite Influent) BOD
6. One 250 ml. Beaker (Inf. pH Test)
7. One 250 ml. Beaker (Eff. pH. Test)
8. Two 250 ml. Beakers (Composite Influent & Effluent) BOD
9. Six 50 ml. Beakers (Inf. & Eff. pH Tests)
10. One 1000 ml. Imhoff Cone (Eff. Settleable Solids Test)
11. One 1000 ml. Imhoff Cone (Inf. Settleable Solids Test) BOD
12. One Turbidity Tube (NTU Test)
13. Two Glass Vials (CL2 Test)
14. One 10 ml. Graduated cylinder (RAS Susp. Solids Test)
15. One 1000 ml. Graduated cylinder (SVI Test)

III. Weigh Suspended Solids Filters

1. Two Composite Effluent
2. One MLSS
3. One Secondary Effluent
4. One RAS
5. Two Composite Influent (BOD)
6. Three Primary Effluent (Tuesdays)

COLIFORM

Standard Methods 22nd Edition, Pages 9-65 to 9-74 Section 9221 A–E

Equipment

Pipettes – 10ml, 5ml, and 1ml
Durham tube (glass viles)
Test tubes with aluminum caps
Wire loop
35º C incubator

Broths

LTB, BGB

Procedure

1. Make up and sterilize as on label of broth. Note: make up 1 liter of broth for approx. 80 tubes
2. Put 10ml of broth in a test tube containing inverted Durham tube using the automatic dispenser
3. Put aluminum caps on
4. Sterilize using autoclav

Sterilize capped test tubes containing the media for not more than 15 minutes. The autoclav is preset to maintain a temperature of 121º C at 15 lbs. of pressure. All that is required to operate the autoclav is to fill the chamber with DI water to the marked point, close the door and set the timer for the desired length of time. Make sure that when sterilizing the test tube containing broth media, the exhaust selector switch is in slow (liquid mode).

To sterilize pipettes, after rinsing with DI water and drying, place them in the stainless steel cylindrical storage case by the oven. Close the top and place them in the autoclav. Sterilize for 30 minutes at 121ºC and 15lbs of pressure. Log actual time in and time out. (must be < 45 mins. Total)

The Bacti sample bottles are also sterilized in the same manner as for pipettes except for samples containing residual chlorine. 1ml = 2 drops of 1% sodium thiosulfate is placed in the jar prior to sterilization. At least one bottle from each batch or lot of bottles shall be tested for sterility with TSB media incubated at 35°C for 24 hours and checked for growth. The results will be recorded on a bottle sterility data sheet.

Store sterilized sample bottles in cabinet # 47 on the east wall.

Note: We are currently supplied with pre-sterilized sodium thiosulfate tablet added Bacti bottles.

GENERAL SCHEME OF LABORATORY TESTING
FOR DETECTION OF COLIFORM GROUP IN WATER

Standard Methods 22nd Edition, Pages 9-65 to 9-74 Section 9221 A–E

Presumptive Test/Confirmation Test

Inoculation of lactose broth

Gas produced = presumed evidence of coliforms Examination continued	**No Gas** = coliform not present
CONFIRMED TEST – Transfer made from lactose broth tubes to the following:	
BGLB or Brilliant green lactose broth (this medium inhibits the growth of lactose fermenters other than coliforms; thus gas formation in the BGLB medium constitutes a confirmed test: i.e. coliforms present.	**Eosin-mehylene agar (EMB).** Coli-aerogenes organisms produce characteristic colonies; Escherichia: small colonies, dark, almost black centers, with greenish metallic sheen. Enterobacter: large, pinkish colonies, dark centers, rarely show metallic sheen. Presence of typical colonies constitutes a confirmed test: i.e. coliforms present.
Completed Test The most typical colonies are selected from EMB plate. (if BGLB used in confirm test, it is first streaked to EMB) and inoculated into :	
Lactose broth (coliforms produce gas).	Ager slant (gram stain prepared from growth; coliforms are gram-negative, nonsporulating bacilli (rod shaped).

Fermentation of lactose broth and demonstration of gram-negative, nonsporulating bacilli constitutes a positive completed test demonstrating the presence of some member of coliform group in the volume of sample examined.

* **Note**: A Completed Test must be run quarterly or 1 Test for every 10% of positive tubes and results are to be logged in Lab Log Sheet. A Completed Test must be run if there are two or more confirmed positive tubes.

LTB solutions setup:

10.0 ml LTB II	O	O	O	O	O
1.0 ml LTB	O	O	O	O	O
0.1 ml LTB	O	O	O	O	O

CONFIRMED TEST
BRILLIANT GREEN BILE (BGB)

Standard Methods 22nd Edition, Pages 9-65 to 9-74 Section 9221 A–E

LTB broths plus the sample with dilution indicated are positioned in the tray (in the big incubator) as shown below:

10.0 ml LTB II	O	O	O	O	O
1.0 ml LTB	O	O	O	O	O
0.1 ml LTB	O	O	O	O	O

Any positive (gas production) LTB tube either at 24 hrs or 48 hrs is transferred to BGB. The BGB tubes replace the LTB tubes in the same spot.

Example

1. Burn loop in Bunsen burner flame till glowing orange
2. Air cool 10-15 seconds
3. Dip loop in a positive LTB tube about 3mls under surface and rotate tube. Pull out loop full of culture and transfer to BGB or BGLB (try not to pick up scum off the surface of culture)
4. Repeat 1, 2, & 3

MEDIA QC POSITIVE / NEGATIVE CONTROL

Standard Methods 22nd Edition, Pages 9-2 to 9-32 Section 9020A-9050C

Rehydrate Culti – Loops

E-coli, *Staphylococcus aureus*: using blood agar (TSA with sheep blood).

Procedure

The film in each loop is made of a gelatin formulation. To rehydrate the film, the loop must come in contact with both warmth and moisture. To open: cut open the end of the foil packet as indicated on the label.

Direct Streak Method

1. Warm appropriate plated media to 35º C
2. Remove red sheath from the loop (*E-coli*, *staph*)
3. Lay the loop flat on the warm agar surface for 10 – 15 seconds, pressing gently onto the surface of the media. Re-hydration of the loop will appear as a clear "bead of moisture" upon lifting the loop from the agar surface. **Note:** The black film does not have to completely dissolve from the loop for growth of the organism to occur.

After Incubation of 24 to 48 hours at 35ºC the *S.Aureus*, *E-Coli* plates will be ready for use as positive/negative controls.

*** Note:** Store in the refrigerator after incubation.

Using a sterile inoculation loop transfer the appropriate bacteria to the prepared broths.

LTB/BGB

E-Coli as a positive control
Staph aureus as a negative control

Once the bacteria are transferred, LTB and BGB broth will be incubated at 35º C ± 0.5ºC for 24 to 48 hours. Log results in lab book.

TRIGGERED MONITORING PROCEDURES

(Permit – required)

1. When the Plant Bacti sample shows signs of violation I.E. (tubes are 5-5-5 positive) in the LTB broth, first or second day. Call lab personnel at Abalone Coast Bacteriology (805-595-1080) to notify them that we have a possible TME (Triggered Monitoring Event). This gives them time to prepare for the volume of samples we will bring their lab over the next four days. Continue running the sample in question as usual.

2. When the Plant Bacti confirms positive (5-5-5) in the BGB broth follow these steps.

    A. Notify ACB (Abalone Coast Bacteriology) samples are on their way
    B. Collect Beach Bacti samples as you normally would
    C. Complete the Beach Bacti Survey Form as you normally would
    D. Complete Chain of Custody
    E. Plant Bacti should be run in conjunction with Beach Bacti

        1. Date
        2. Time of each sample
        3. Sampler
        4. Test required

3. These procedures should be followed during the four-day event. If a second high Bacti occurs these will extend sampling.

OCEAN SAMPLES

Standard Methods 22nd Edition, Pages 9-65 to 9-74 Section 9221 A–E

Procedure

1. (5) double strength tubes of LTB broth inoculated with 10.0ml of sample (double strength = double in concentration).
2. (5) single strength tubes of broth inoculated with 1.0ml of sample.
3. (5) single strength tubes of broth inoculated with 0.1ml of sample.

*** Note: the hold times for recreational waters is 6 hrs.**

These tubes are then incubated in 35º C incubator by the east wall and checked at the end of 24 hours and 48 hours. The results are entered in the laboratory log-book. At the end of 24 hours, transfer with transfer loop the positive tubes (gas production constitutes a positive result) to BLGB broth and E.C. broth at the same time. Incubate BGLB medium in 35º C. Production of gas at the end of 24 hrs or 48 hrs constitutes a confirmed test, i.e. coliforms are present. Incubate the E.C. broth in water bath at 45º C for 24 hrs. Gas production constitutes a positive test, i.e. fecal coliform is present. If, at the end of 24 hrs, the E.C broth yields a negative result (no gas production), it constitutes a negative test, i.e. fecal coliform is not present. The E.C. tubes are then discarded.

Positive (*Escherichia Coli*) and negative (*Enterobacter aerogenes*) controls must be run whenever sample tubes are placed in the water bath for determination of fecal Coliform. Results are to be recorded on the water bath positive/negative control data sheet and beach survey form.

Please note that the transfer loop is sterilized by heat (a Bunsen burner); it's placed in the flame and needs to glow bright orange then taken out and air cooled before using it for transfer. If a sizzling sound is produced when dipping the loop in the medium that is an indication that the loop has not been given enough time to cool.

Note: Contract lab will be used after triggered monitoring.

QUALITY CONTROLS

Autoclave Bacillus Stearothermophilus			Bact-T Bottle/Pipette Sterile Check Media Type (TSB)			
Date	Pos Control	Neg Control	Date	Bottles by numbers	Pipettes Pos/Neg	Bottles Pos/Neg
Cl2 Low range standard solution						
Standard mg/l	Results	Date				

Completed Test						Autoclave Timer/Temp		
Date		Growth Yes/No	LTB Pos/Neg	BGB Pos/Neg	EC Pos/Neg	Date	Temp	Time Corrections
Bacti	Setup							

TOTAL SUSPENDED SOLIDS

Standard Methods 22nd Edition, Page 2-66 Section 2540 D

Background

Total suspended solid (non-filterable residue) is the material retained on a standard glass fiber filter after filtration of a well-mixed sample.

Equipment

- Vacuum source (on the bench top)
- Buchner Funnel and 1000 ml. vacuum flask (by the north sink)
- Filter paper (glass microfibril) 9 cm (located in drawer)
- Oven 103°-105º C (north wall)
- Analytical Balance (north wall)
- Desiccators (by oven)

Procedure

The filtration is achieved by vacuum. The filter paper (located in drawer) is first washed with distilled water (three 20 ml. portions) and place in the 103°-105ºC oven for one hour to dry and then transferred to the desiccators to cool for 15-30 mins. (Use forceps for handling the filter paper). Weigh the filter paper and record in the lab log book. Measure the desired volume of sample with a graduated cylinder and pass through the filter (vacuum filtration). This is achieved with the use of a Hirsh Funnel. When washing the filter paper, a Buchner Funnel is employed.

Dry the filter paper in the oven (103°-105º C) for one hour or more and cool in the desiccators to balance temperature. Weigh as before and record the values in the lab log-book. Composite influent and effluent samples must be averaged between the two samples (of the same kind) when weighed. A second weighing should be done on all samples tested. If a deviation of 5% or more from the previous weight is noted, than a third weighing is necessary. The weight measurements are done by the analytical balance and weights are recorded to the nearest 0.1 mg. i.e. 1.2345 grams. Calculate the Relative Percent Difference on the Comp Effluent Suspended Solids test and log on the worksheet. This is done every Friday.

Calculation

Mg. total non-filterable residue $PPM = \frac{(a-b) \times 100}{\text{Sample volume, ml.}}$

A= weight of filter paper + residue in mg. and
B= weight of filter paper, mg.

*** Note:** 1.00 gr. = 1000 mg

Morro Bay / Cayucos WWTP

Suspended Solids Record

Date	Sample I.D.	Volume	Tare Weight	Comb. WT. 1	Comb. WT. 2	1 & 2 Ave.	WT. Mg/L	Average Mg/L

C:\Documents and Settings\Administrator\My Documents\Lab\Lab Forms\Suspended Solids Record Sheet.doc

RPD Calculations: (A - B) = ____ = X 100 =

BIOLOGICAL OXYGEN DEMAND (BOD)

Standard Methods 22nd Edition, Pages 5-1 to 5-9, Sections 5010A-B, 5020A-B and 5210A-B

Background

Biochemical Oxygen Demand (BOD) is an empirical test that is used to determine the relative oxygen requirements of wastewater effluents and polluted waters. The test measures the oxygen required for the biochemical degradation (degradation by living organisms) of organic materials (pollutants that can be used as food for living organisms).

There are also some inorganic materials that would oxidize and therefore increase the oxygen consumption. These materials are mostly sulfides (s-2) and ferrous iron (Fe+2). A reduced form of nitrogen, like ammonia, would also use the oxygen to become oxidized (nitrogenous demand).

Nitrogenous demand can be prevented by the use of an inhibitor such as:
2-chloro-6 (trichloromethlyle) pyridine (TCMP).

Equipment

- Dissolved oxygen meter HACH, HQ40d (on the bench top)
- BOD bottles (cabinet under incubator)
- Plastic caps (located in drawer)
- Glass bottle caps (cabinet under incubator)

Reagents

BOD nutrient buffer pillows (Hach, BOD nutrient buffer pillows)

Locations

Compositor at headworks (influent) and upper chlorine contact chamber area (effluent).

Procedure

Please note that these procedures are only applicable at Morro Bay/Cayucos WWTP Lab.

A. Preparations of dilution water:

Use one BOD nutrient buffer pillow for three liters of DI water, usually six liters of dilution water is made. Shake bottle to mix buffer and DI water. Check to ensure that the dissolved oxygen concentration is at least 7.5 mg/L; if not, aerate the dilution water by shaking the bottle for a few minutes or use organic-free filtered air.

B. Dilution Techniques:

* Note: Composite influent and effluent samples both need to be at a pH range between 6.0 and 8.0. This is accomplished by placing the samples on our pH meter and titrating the sample with either sulfuric acid solution to reduce the pH to 8.0, if pH is lower than 6.0, titrate with sodium hydroxide to increase pH to proper range.

Use three dilutions for each sample in duplicate (two of each) and a blank for each set of analyses. Composite final effluent samples usually require 25, 20 and 15 ml. of sample per BOD bottle with a .5ml secondary effluent seed. Raw samples require 5, 4 and 3 ml. per BOD bottle. The seed duplicate requires 1 ml. of Secondary Effluent. (**<u>*Note</u>:** these dilutions may be changed as needed.) Use a pipette for all measurements.

After all the samples are measured and put in BOD bottles fill the bottles with dilution water to the top and make sure that there are no air bubbles trapped in the bottles. The air bubbles can be withdrawn by tapping the side of the bottle with a glass or metal rod.

HACH HQ 40D

Calibration Instructions

Step #1. Probe should already be in a water saturated BOD bottle (½ full).
Step #2. Turn the unit on. The button is located above the HACH logo.
Step #3. Turn the stirrer on. The button is located on top of the probe itself.
Step #4. Now press the blue calibration button.

The display will read the following:
"Dry probe. Place in water saturated air and press read"

* The probe should already be in the water-saturated air from step # 1

Step #5. Now press read.

The display will read the following:
"100% Calibration complete"

Step #6. Next you will press the done button.

The display will read the following:
"Calibration summary"

Step #7. Now press the store button. Your HACH 40d meter is now ready for use. You will run the BOD test with the same procedures as in the SOP.

Step #8. Turn off stirrer.

Step #9. Place the probe into BOD sample bottle and turn stirrer on. Now press the read button. In the upper left corner of the display it will show the meter is stabilizing. When the lock appears your reading is ready.

Step #10. Repeat for each sample bottle.

Step #11. Record all readings on the BOD Calculations Sheet.

HACH HQ 40D METER

BOD Test

How to Run (*Note: Bottle numbers will vary)

1. After calibrating your HACH, HQ 40d meter you are ready to begin your readings. Place the probe into Blank bottle # 122, wait for meter to lock. Then read. # 137 is the second blank. Log the readings on BOD sheet.
2. Now do the rest of the BOD bottles the same way. In this order. Bottles # 137, # 130, # 110, # 127, # 123, # 104, # 126, # 135, # 98. Remember there are two dilutions of 1ml seed.
3. After your last bottle. Turn the unit off then rinse the probe CAREFULLY no higher the 1" from the bottom. Replace probe into holder.

*** Note:** the oxygen content of all samples bottles (other than the blanks) should be at least 1 mg/L. Furthermore, a depletion of 2 mg/L of DO is desirable and the DO uptake in the blanks should not be more than 0.2 mg/L and preferably not more than 0.1 mg/L.

To prevent loss of oxygen during incubation, the DO must be reduced to saturation at 20º C by bringing the sample to about 20º C in partially filled bottle while agitating by vigorous shaking or by aerating with clean, filtered compressed air. During the BOD setup, initial DO should not be over 9.0mg/L.

Calculations

By subtracting final DO from initial DO, the depletion of oxygen is obtained, and since there are duplicate bottles, this depletion is averaged.

$$\text{BOD mg/L} = \frac{\text{In} - \text{Out} - (\text{seed factor}) \times 300\text{mL}}{\text{mL of sample}}$$

BOD TEST SET-UP

1. Collect the composite samples from the Influent and Effluent Samplers.
2. Be sure the pH of both the samples are between 6.0 and 8.0, if not adjust the samples with Sulfuric Acid Solution to reduce pH or Sodium Hydroxide to increase; adjust to 7.0 – 7.2 pH (log on form the ml. used) also check for CL2. Dechlorinate with Sodium Thiosulfate as required.
3. Place the composite effluent sample on the stirrer. Stir while you pipette the sample into BOD bottles.
4. Use a 25 ml. Pipette to pipette the samples into the BOD bottles (see the bottle diagram for dilutions).
5. Start with composite effluent bottles # 130 & # 110, pipette 25 ml. of composite effluent into each bottle. Add .5ml Sec Eff. seed.
6. Next bottles are composite effluent bottles # 127 & 123, pipette 20 ml. of composite effluent into each bottle. Add .5ml Sec Eff. seed.
7. Next bottles are Comp Eff. Bottles # 90 & 91, pipette 15ml of Comp Eff. into each bottle. Add .5ml of Sec Eff. seed.
8. Now place the composite influent on the stirrer. Stir while you pipette the sample into the BOD bottles.
9. Next bottles are the composite influent bottles # 104 & 126, pipette 5 ml. of comp influent into each bottle.
10. Next bottles are the composite influent bottles # 135 & 98, pipette 4ml. of composite influent into each bottle.
11. Next bottles are the Comp Inf. Bottles # 50 & 51, pipette 3ml. into each bottle.
12. Next add 1ml of Sec Eff. to bottles # 52 & 53 these are your seed bottles.
13. The next two bottles are the blanks. These bottles contain no sample at all. These are bottles # 122 & 137.
14. Now we fill each BOD bottle with BOD Nutrient H2O. Start with the Blanks # 122 & # 137. Fill each bottle to mid way between the neck and the top. Do not over flow.

    Composite effluent # 130 & # 110
    Composite effluent # 127 & # 123
    Composite effluent # 90 & # 91
    Composite influent # 104 & # 126
    Composite influent # 135 & # 98
    Composite influent # 50 & # 51
    Seed (Sec Eff) # 52 & # 53

15. Samples in the bottles are now ready to run (see instructions Hach HQ 40D, pages 45 & 46).

BOD BOTTLE SET-UP

COMP EFF #130
25 ML. FINAL
0.5 ML SEED

COMP EFF #110
25 ML. FINAL
0.5 ML SEED

COMP EFF #127
20 ML. FINAL
0.5 ML SEED

COMP EFF #123
20 ML. FINAL
0.5 ML SEED

COMP EFF #90
15 ML. FINAL
0.5 ML SEED

COMP EFF #91
15 ML. FINAL
0.5 ML SEED

COMP INF #104
5 ML. FINAL
NO SEED

COMP INF #126
5 ML. FINAL
NO SEED

COMP INF #135
4 ML. FINAL
NO SEED

COMP INF #98
4 ML. FINAL
NO SEED

COMP INF #50
3 ML. FINAL
NO SEED

COMP INF #51
3 ML. FINAL
NO SEED

SEED #102
SECONDARY EFF
1 ML

SEED #72
SECONDARY EFF
1 ML

BLANKS #122
ML. NONE

BLANKS #137
ML. NONE

MORRO BAY/CAYUCOS WAST VATER TREATMENT PLANT

BOD RECORD (mg/L, 5 Day, 20°C)

DATE, TIME[1], INITIALS	BOTTLE NUMBER	SAMPLE DESCRIPTION	AMT (mL)	INITIAL D.O. (mL)	FINAL D.O. (mL)	AVERAGE TOTAL	BOD mg/L	REMARKS[2]
DATE, TIME[1], INITIALS	BOTTLE NUMBER	SAMPLE DESCRIPTION	AMT (mL)	INITIAL D.O. (mL)	FINAL D.O. (mL)	AVERAGE TOTAL	BOD mg/L	REMARKS[2]

[1] Time at start of incubation

[2] Include Time Sampler On and period of collection

pH RANGE OF SAMPLES, 6 - 8

BLANK D.O.. Should not drop more than .2 mg/L

D.O. in samples should drop at least 2.0 mg/L with at least 1.0 mg/L remaining @ 5 days.

BOD RECORD

GLUCOSE-GLUTAMIC ACID OR GGA

Standard Methods 22nd Edition, Pages 5-8 to 5-9 Section 5210 B-6

Background

A Glucose-Glutamic Acid (GGA) check must be conducted monthly to assure dilution water quality, seed effectiveness, and analytical technique. Because the BOD test is a bioassay, its results can be influenced greatly by the presence of toxicants or by use of a poor seeding material. The widely accepted BOD standard is a mixture of glucose and glutamic acid. Increasing increments (1, 2, 3 and 4 ml) of a BOD standard are added to the BOD bottles, which are then filled with seeded dilution water and incubated at 20 degrees Celsius for 5 days. The amount of Dissolved Oxygen remaining after 5 days is plotted against the volume of standard used and the best straight line through the accepted points drawn.

Equipment

- Dissolved Oxygen Meter HACH HQ 40d
- BOD bottles
- BOD caps (glass and plastic required)
- Reagent Water
- Glucose-Glutamic Acid bottles (3-4)

Procedure

The day before a GGA setup the nutrient water must be made (see QA manual under BOD setup). Use two pillows of nutrient for six liters of DI water. Shake lightly and place in 20 degrees Celsius Incubator. Always remember to warm up the DO meter for at least ½ hour and calibrate. After setting up 12 bottles in pairs, add the Glucose Glutamic solution in increments of 4, 3, 2, and 1 ml. The seed bottles will contain 1 ml each of Secondary Effluent, while all other bottles (except blanks) need .5ml of Secondary Effluent seed. Blanks do not require Glucose or Seed. Fill bottles with nutrient DI water so there is enough water that when the stopper is inserted, all air is dispersed leaving no bubbles in the bottle. After all bottles are filled to near the top, begin your DO read on each bottle, always remembering to start with the cleanest sample and work towards the dirtiest sample. Do not forget to use a plastic cap on each bottle after the stopper is placed in the bottle. Log initial DO in Lab book and place samples in 20 degree Celsius incubator for 5 days and reread DO. Complete math and check for discrepancies.

Note: Document that the GGA test is within limits every time test is performed. Log on worksheet. Passing results: 198 ± 30.5 mg/l

WINKLER METHOD

5-day BOD

Winkler Method Procedure (*Note: Bottle numbers will vary)

1. Follow the instructions as you would set up a normal BOD Test (see the BOD Set-up steps 1-12 and the bottle set-up pgs.)
2. Once all of the bottles are set-up. Place all of the final bottles into the BOD Incubator for the 5-day incubation period. These bottles are as follows, # 130, # 127, # 104, # 135, #122 and #102
3. Now take the Initial bottles and arrange them from left to right.
   # 137 # 110 # 123 # 126 # 98 #72
4. While leaving the stopper in the bottles tip the water out of the water seal.
5. Now remove the stoppers from all of the bottles.
6. Start with package #1 Manganous Sulfate powder pillow and empty into each BOB Bottle left to right.
7. Add package #2 Alkaline Iodine-Azide reagent powder pillow to each BOD bottle left to right.
8. Now replace the stoppers. Invert all of the bottles 3 times to mix.
9. Let the Floc settle ½ way in the bottles. Then invert again 3 times.
10. Let the Floc settle ½ way again.
11. Replace the stoppers and tip the water out of the water seal again.
12. Remove the stoppers again.
13. Replace the stoppers and tip the water out of the water seals. Invert the bottles 3 times to mix (color should be dark yellow).
14. Now add container #3 Sulfamatic Acid powder pillow to each BOD bottle from left to right.
15. Each sample has a matching Erlenmeyer flask, from left to right fill to the 200 ml. line with the proper sample.
16. Now with bottle # 4 Starch Indicator Solution. From left to right with a new 5 ml. pipette. Pipette 1 ml. into each Erlenmeyer flask (the color should be Dark Dark Blue).
17. Now your samples are ready to titrate with Sodium Thiosulfate Solution. Bottle # 5.
18. Place your first bottle on the stirrer and stir. This bottle will be # 137 the BLANK.
19. With bottle # 5 Sodium Thiosulfate Solution. Take a new 5 ml. Pipette and slowly pipette into the stirring flask. It will begin to change color from dark to light Blue until it is clear. The last drop titrated producing the clear sample is the end point. If it took 8.5 ml. Your mg/l reading is the same 8.5 mg/l O2. Log on the BOD form.
20. With the same Pipette repeat steps 18 – 19 on the rest of the bottles # 110, # 123, # 126, # 98.
21. Calculations are the same as with the meter.
22. Note the same procedures for the final bottles are the same.

pH METER CALIBRATION

Orion Model 310

Procedure for pH Meter Calibration

1. Fill (1) 50 ml. Beaker with pH 7 Buffer, fill (1) 50 ml. Beaker with pH 10 Buffer and fill (1) 50 ml. Beaker with pH 8.

2. Place the pH 7 Buffer on the stirrer and stir. Insert the pH probe.

3. Now press the mode button to turn the unit on.

4. Next press the Cal. Button to start the Calibration process. The meter will flash the SLP & percentage on the screen. Usually 97.5 – 103.0 or so.

5. Next 7-10 will appear on the screen. Push the YES button to accept this range. If 4 – 7 appears, hit the up arrow to get the 7-10 range.

6. The meter at this time will show 7.01 or so, (LOG THIS ON pH CAL. FORM.) then the meter will lock on 7.0 and the ready light will go on. Press the Yes button to accept.

7. Remove the probe from the 7 Buffer and lightly wipe off. Now place the 10 Buffer on the stirrer and stir. Insert the pH probe.

8. The unit at this time will show a reading climbing to 10.00, then will lock on to 10.01 and the ready light will go on. Hit the YES button to accept.

9. At this time a new SLP percentage will show. About 97.5-103.0% or so. Log the SLP percentage on the pH Cal Form.
10. Check the pH Meters accuracy with PH. 8 Buffer. Log on form.
11. The pH meter is now ready for use.
12. WHEN NOT IN USE STORE THE PROBE IN THE # 7 BUFFER.
13. Remember when running the pH Test on the Inf & Eff samples you must run three duplicates of each of the Inf & Eff samples in separate 50 ml Beakers.

pH

Please refer to Standard Methods 22nd Edition, Pages 4-92 to 4-95 Section 4500 H+ B

Equipment (Orion model 310 pH meter)

Procedure

Before making measurements with a pH meter, one must make sure that the meter is calibrated. Each day of use, the pH will be calibrated with 2 buffers (4&7 or 7&10). The buffers must be dated and buffer type documented on our daily logs each time a calibration is made or changed. Accuracy and scale graduations must be within ±0.1 units and the electrode must be maintained as per manufacturer's instructions. The calibration procedure is in the LAB TEST PROCEDURES BOOK located on shelf above computers.

In general, four types of buffers are used (pH 7.00, pH 4.00, pH 8.00 and pH 10.00, located in chemical cabinet). Fill one 50 ml beaker with pH 7.00 buffer, one with 10.00 pH buffer and one with 8.00 pH. Place the 7.00 buffer on the stirrer and stir. Insert the pH probe into the beaker then press the mode button to turn unit on. Next press the CAL. Button to start the calibration process. The meter will flash SLP (at this point the up arrow may need to be pressed to bring the slope to 7-10 range) then briefly a percentage number. After the slope is seen on the meter push the YES button to accept this range. The meter will show a reading *at or near 7.00.* Log this reading on pH Calibration sheet located on BOD incubator. The meter will then lock onto the 7.00 reading and the ready light will be displayed. At this point, press the YES button locking in the 7.00 pH part of the CAL. Remove probe from 7.00 pH buffer beaker and replace with 10.00 pH buffer (on stirrer). Be sure to wipe the electrode with a clean Kim Wipe to remove 7.00 pH buffer. Insert probe into pH 10.00 and stir. Leave electrode in 10.0 pH buffer until the unit reads exactly 10.01 and the ready light is visible. Hit the Yes button, and a new SLP percentage will show (approx. 97.5 – 103.0% or so). Check the meter using the pH 8.0 buffer and log the reading on the pH Calibration Sheet. The pH meter is now ready for use.

Notes

1. Make sure the electrode is thoroughly rinsed with DI water after each use or between measurements of different samples.
2. Do not touch or damage the electrode tip. It is very sensitive and great care should be taken when analysis is performed.
3. Record all reading in lab log book and initial the entries.
4. When testing a lower pH range, for instance, during a grease and oil test, the pH meter must be recalibrated to the 4-7 range by simply pressing the down arrow during initial calibration.
5. Always stir the sample during use of the pH meter.
6. For additional info refer to pH instruction handbook located above the computer desk.
7. Remember when running a PH. Test on the Inf & Eff samples you must run three PH. Test for each Inf & Eff samples.

pH Calibration

Date	Initials	Temp.	pH was	Cal. to pH	pH 8	Buffers used – exp. date	Slope
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	
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						7____ 8 ____ 10 ____	
						7____ 8 ____ 10 ____	

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DETERMINATION OF RESIDUAL CHLORINE IN WASTEWATER
SIMPLIFIED FIELD TEST

Refer to Standard Methods 22nd Edition, Pages 4-69 to 4-70 Section 4500-CI G

Equipment

1. LaMotte 1200 Colorimeter
2. 10ml Sample Cell
3. Sample bottle
4. DI water
5. DPD pillows (reagents)
6. 2.5ml & 7.5ml Eppendorf pipetters

Procedure

To get an accurate reading a dilution will be necessary for this test. Collect a sample of the wastewater or water to be tested in a clean sample bottle. Add 2.5 ml of sample to your 10 ml sample cell. Then add 7.5 ml of DI water to the sample cell.

*** NOTE:** this is your diluted sample used for the test at a ratio of 4:1. In general, this dilution factor will change depending on the strength of CL2 in your sample as the residual meter does not exceed 9.9mg/l.

In the next step, use Kimwipe to clean sample cell and place sample cell into meter. Upon insertion, close the hatch and turn the meter on. Then, hold the "zero" button down until "BLA" appears. The meter is now zeroed. Remove sample and pour reagent (currently using DPD pillow) into sample. Allow reagent to dissolve completely, use Kimwipe to clean sample cell, insert the sample cell into the machine and press read. The resulting display will show the CL2 concentration. This number would then be multiplied by 4 to counteract the dilution factor. Example: meter reads 1.90 mg/l – times by 4 = 7.6 mg/l. Log all results in lab book. **Note:** you must run a duplicate test on the daily sample.

For further information please look in the LaMonte 1200 colorimeter handbook located in the meter storage box or for more general info, Standard Methods 22nd Edition, Pages 4-58 to 4-65 Section 4500-CI.

Low Range Standard Solution

Cl2

When to use this test?

A. When you question your results during Cl2 meter calibration.
B. When you question the validity of your test kit.
C. Quarterly

1. Fill the 10 ml. vial in the Cl2 test kit with 9.9 ml. distilled water using a 5 ml. pipette with 0.1 ml. subdivisions.
2. Next snap open the Low Range Standard ampule and pipette 0.1 ml. into the vial bringing the volume to 10 mls.
3. Now you're ready to zero out the Cl2 test kit. Place the 10 ml. vial into the test kit and zero as you normally would.
4. Now add the 10 ml. DPD pillow to the vial and wait 1 minute for free Chlorine, Three minutes for Total Chlorine; our lab tests for Total Chlorine.
5. Your results should be as follows with the current standard (each standard is different).

   0.1 = .277 mg/l
   0.2 = .554 mg/l
   0.3 = .831 mg/l
   0.4 = 1.108 mg/l

   This is the formula to calculate the new standard (Standards change with new lot)

   C 1 = Concentration of sample standard, V 1 = volume .1 ml., V 2 = 10 ml.

$$\frac{C\,1 \times V\,1}{V\,2} = C\,2$$

6. This test is performed to test procedures and accuracy; remember that a bad or incorrectly taken sample will be inaccurate.

TURBIDIMETER

Standard Methods 22nd Edition Pages 2-12 to 2-14 Sections 2130 A-B

Calibrating

When data is used is used for USEPA reporting, recalibrate at least every 90 days or as stipulated by the regulating authority. Refer to section 3.2 “calibration” in the Hach 2100N Turbidimeter instrument manual. Furthermore, the turbidimeter will be calibrated using a primary or secondary standard before each use. A quarterly crosscheck should be made using a primary standard. Also, our turbidimeter is on a quarterly work order for calibration and we are using primaries for this check. New primary standards are ordered annually.

Calibration Procedure for the Hach 2100N Turbidimeter

1. Fill a clean sample cell to the line (approx 30 ml) with dilution water.
2. Wipe the cell clean and apply a thin film of silicone oil.
3. Place the sample cell into the cell holder and close the cell cover.
4. Press the CAL key. The SO annunciator lights. The NTU value of the dilution water used in the previous water used in the pervious calibration is displayed.
5. Press ENTER key. The instrument display counts down from 60 to 0 and then makes a measurement. This result is stored and used to compensate for the turbidity of the dilution water.
6. The instrument automatically increments to the next standard, displays the expected NTU value and the S1 annunciator lights. Remove the sample cell from the cell holder.
7. Fill a clean sample cell to the line with well mixed, 20 NTU Formazin standard. Wipe the cell clean and apply a thin film of silicone oil to the surface. Place it into the cell holder, and close the cell cover. Press ENTER key. The instrument display counts down from 60 to 0 and then makes a measurement. The display automatically increments to the next standard, the display shows 200.0 NTU and the S2 annunciator lights. Remove the sample cell from the instrument.
8. Fill a clean sample cell to the line with well-mixed 200 NTU Formazin standard, and complete the same steps used in # 7. This time the S3 light will show.
9. Fill a clean sample cell to the line with well-mixed 1000 NTU Formazin standard, and complete the same steps used in # 7. This time the S4 light will show.
10. Fill a clean sample cell to the line with well-mixed 4000 NTU Formazin standard, and complete the same steps used in # 7. This time the S0 light will show, and the previously measured value of the dilution water is displayed.
11. Press the CAL key. The instrument makes calculations based on the new calibration data, stores the new calibration and returns the instrument to the measurement mode.

Reviewing the calibration sequence

Press the CAL key and then use the UP ARROW key to scroll through the standard to review calibration data currently in effect. Press the UNITS/EXIT key to return to the operating mode without altering the current calibration data.

> **<u>* Note</u>:** reassign new values to the Gelex standards each time the instrument is calibrated with Formazin. Formazin is the primary standard and Gelex is the secondary standard.

<u>Formazin is known to cause cancer so use extreme caution when handling</u>

Error Codes are located on the Hach 2100N Turbidimeter Quick reference guide located in the drawer under the meter itself.

Hach 2100N Turbidimeter Test Procedure

1. Collect a representative sample in a clean container. Fill the sample cell to the line. Take care to handle the sample cell by the top. Cap the sample cell. Our turbidimeter is designed to stay on 24hrs a day. If machine is ever turned off refer to Quick Reference Guide, step 1 in procedures.
2. Hold the sample by the cap, and wipe to remove water spots and finger prints with a clean Kim Wipe.
3. Apply a thin bead of silicone oil from the top to the bottom of the cell, just enough to coat the cell with a thin layer of oil. Using the oiling cloth provided, spread the oil uniformly. Then, wipe off the excess. The cell should appear nearly dry with little or no visible oil.
4. Place the sample cell in the instrument cell compartment and close the cell cover.
5. Select manual or automatic ranging by pressing the RANGE key.
6. Select the appropriate SIGNAL AVERAGING setting (on or off) by pressing the SIGNAL AVERAGE key.
7. Select the appropriate RATIO setting (on or off) by pressing RATIO key. **<u>NOTE</u>:** Values greater than 40 NTU require ratio on.
8. Select the appropriate measurement unit by pressing the UNITS/EXIT key (NTU is our standard).
9. Read and record the results in the lab book.

For any other references please look in the HACH 2100N Turbidimeter manual or Quick reference guide or Standard Methods 22nd Edition, Pages 2-12,2-14 Sections 2130 A-B

Turbidity Meter Calibration

Standards used #1_____ #2_____ #3_____ #4_____ Date: _____

New standards #1_____ #2_____ #3_____ #4_____ Date: _____

Date	Meter off by NTU's				Operator	Date	Meter off by NTU's				Operator
	#1	#2	#3	#4			#1	#2	#3	#4	

SETTLEABLE SOLIDS

Refer to Standard Methods 22nd Edition, Pages 2-67 to 2-68 Section 2540 F

Description

Settleable Solids of sewage is the volume of suspended matter that settles to the bottom of a tank or compartment designed for the collection of the settleable material. The determination for settleable solids is made by allowing one liter of the sewage to stand for one hour in an Imhoff cone, and reading directly from the graduations of the cone the volume of the suspended matter that settled to the bottom. The result represents the settleable solids, in milliliters per liter.

Purpose

The determination of settleable solids in sewage is valuable as showing how much suspended matter can be or has been removed by sedimentation. To measure visibly the efficiency of a sedimentation process, tests for settleable solids are made on the influent and effluent of the settling basin or compartment. The difference between the settleable solids of the influent and effluent gives the settleable solids removed. The percent of the solids removed may now be calculated by dividing the volume of the solids removed, by the volume of the settleable solids of the influent and then multiplying by 100.

Equipment

Imhoff Cones.
Rack for holding Imhoff cones.
Glass stirring rod or wire.

Test Procedure

1. Thoroughly mix the sewage sample by shaking and immediately fill an Imhoff cone to the Liter mark.
2. Record the time that the cone is filled. Time = _____.
3. Allow the waste sample to settle for 45 minutes.
4. Gently spin the cone to facilitate settling of material adhering to the side of the cone.
5. After one hour, record the number of mL/L of settleable solids in the Imhoff cone. Make allowance for voids among the settled material.
6. Record the settleable solids as mL/L or milliliters per Liter

			Sample
Settleable solids, Influent	= _____	mL/L	10.0
Settleable solids, Effluent	= _____	mL/L	0.5
Settleable solids, Removal	= _____	mL/L	9.5

Example

If one liter of raw sewage or influent contains 10.0 ml of settleable solids, it should be possible to remove most of this in the primary settling system. If the effluent contains 0.5 ml per liter, it is possible to calculate the efficiency of removal by using this formula:

$$\% \text{ Efficiency} = \frac{(\text{ml influent}) - (\text{ml effluent})}{(\text{ml influent})} \times 100$$

$$= \frac{10.0 - 0.5}{10.0} \times 100 = 95\% \text{ removal}$$

It should also be possible to check the maximum volume of sludge to be pumped out of settling tanks. For example, if one liter, equaling 1,000 ml of sewage, contains 10.0 ml of settleable solids, 1,000,000 gallons of sewage should not contain over 10,000 gallons of sludge. Generally, sludge compacts by a factor of two or three and therefore this volume will be smaller by half or more. Instead of pumping 10,000 gallons, then, the volume would probably be closer to 5,000 gallons or less.

VOLATILE ACIDS TEST

DISTILLATION METHOD

Standard Methods 22nd Edition, Pages 5-59 to 5-61 Sections 5560 A-C

General Discussion

Digestion is the process wherein anaerobic organisms, concentrated in a digester tank, decompose the waste organic materials in sludge into simple more stable and non-offensive compounds.

The groups of bacteria work to digest sludge. First, saprophytic bacteria will break down the large organic molecules present in the form of proteins, fats and carbohydrates into simpler organic acids, containing six atoms of carbon or less. Second, methane producing bacteria will further break down these acids, called volatile acids, into methane and carbon dioxide. When the rate of the acids produced equals the rate of acid breakdown with methane production, alkaline digestion progresses satisfactorily. When the process of digestion is upset, the volatile acid level rises rapidly. This condition is usually caused by the sudden inactivity of the methane producing bacteria and the continued production of volatile acids by the saprophytic bacteria. When this occurs, the volatile acid level tends to climb by accumulation. Methane bacteria are much more sensitive to environmental changes in a digester. Sudden variations in digester temperature, pH, feed rate, or the introduction of undesirable waste material easily affect them, curtailing their normal functions.

Purpose

The volatile acids test measures the acid content in sludge. This test measures the organic fatty acids produced during digestion, which are water soluble and can be distilled, such as formic, acetic, propionic, butyric, valeric and caproic acids. This information is valuable in maintaining digester control. Volatile acid levels below 300 ppm are desirable. Values greater than 1000 ppm are probably indicative of a serious problem. If the acids increase and continue to build up, this test will usually correct this condition, although other factor such as digester temperature, gas production and raw sludge solids concentration should also be checked.

The straight distillation method will be described. This method is simple and requires little equipment. However, because of the continuously changing conditions in the distillation flask it may give slightly high results. Digested sludge liquor is separated from the solids by centrifugation; a measured volume of the supernatant liquor is then acidified to convert the buffered acids into an acid form. These acids are then distilled and titrated with 0.1 normal sodium hydroxide from which the acid content may be determined. If a centrifuge is not available, the liquor may be separated from the solids by filtering the sludge through coarse paper, such as a paper towel place in a funnel.

Equipment

Glassware needed:

Graduated Cylinder 100 ml. (3)
Erlenmeyer flask 1000 ml.
Pipette 1 ml. 1/100
Flask 225 ml.
Filter w/ 90mm SS filter
Filter Flask w/ hose
Glass beads

Chemicals needed:

H2SO4 Sulfuric Acid Conc.
Phenol Indicator
Sodium Hydroxide
Celite Filter Aid

Procedure

1. Place about 200 ml of sludge into the (4) centrifuge bottles and centrifuge for about 15 minutes and then pour into flask, add 4 spoons of Celite Filter Aid and then filter sample through coarse paper.
2. Measure 100 ml of the supernatant sludge liquor or filtrate into the distillation flask.
3. Add 5 ml concentrated sulfuric acid.
4. Add 100ml DI water to make a total volume of 205ml
5. Connect the flask to distillation apparatus.
6. Discard first 15mls of distilled supernatant to clean distiller.
7. Collect 150 ml of the distilled material in an Erlenmeyer flask.
8. Titrate distillate with 0.1 N Sodium Hydroxide (NaOH).

    a) Add several drops of phenolphthalein indicator.
    b) While stirring, add from a pipette, standard (0.1 N) sodium hydroxide until the first pink coloration that persists on a standing short time.

    * Note: this color should disappear on standing for several mins.
    Ml of NaOH used = _____
9. Calculation of the volatile acids = if 100 ml of sludge sample is taken, then Volatile acid in mg/L = (ml of standard NaOH used) x 86.5.
10. Record results of test. Volatile acids = _____mg/L.
11. Sample calculation:
    Ml of Standard NaOH used = 2.0ml

Volatile acids, mg/L = (ml Std. NaOH used) x 86.5
Volatile acids, mg/L = 2.0 x 86.5 = 173 ppm

Precautions

1. The sludge sample must be representative of the digester. The sample line should be allowed to run for a few minutes before the sample is taken. The sample temperature should be as warm as the digester itself.

2. The sample for the volatile acids test should not be taken immediately after charging the digester with raw sludge. Should this be done, the raw sludge may short circuit to the withdrawal point and result in the withdrawal of raw sludge rather than digested sludge. Therefore, after the raw sludge has been fed into the tank, the tank should be well mixed by re-circulation or other means before a sample is taken.

3. If a digester is performing well with low volatile acids and then if one sample should unexpectedly and suddenly give a high value, say over 300 ppm of volatile acids, do not become alarmed. The high result may be caused by a poor, non-representative sample of raw sludge instead of digested sludge. Resample and retest. The second test will probably give a more normal value.
   However, continued high values of volatile acids will usually mean that corrective measures should be taken, such as reducing the feed rate, reseeding from another digester, maintaining optimum temperatures, or cleaning the tank of grit and scum.

4. Be sure that the cooling water is running through the condenser.

5. Be sure that the H2SO4 has been added before distillation begins. If the solution is alkaline, the volatile acids exist as ammonium salts and will not distill over.

6. Be certain to distill only 165 ml of condensate. Additional distilling beyond 165ml may cause serious errors and very high results, instead of correct answers, for the excess sulfuric acid may start to fume and distill over.

ALKALINITY

Standard Methods 22nd Edition, Pages 2-34 to 2-36 Sections 2320 A-B

Equipment

Graduated cylinder 50ml
Beaker 80ml
5ml Pipette
H2SO4 solution
pH meter
DI water

For sampling points and techniques please refer to pages 14 - 15.

Procedure

*** Note**: the pH meter must be recalibrated to the proper range of 4-7 for this particular test. Refer to pH page for step-by-step instructions.

1. Take the 50ml graduated cylinder and add 45ml D.I. water.

2. Pour the 45ml D.I. water into 80ml beaker.

3. Take 5ml pipette and add 5ml of digester supernatant, which has been separated from the sludge sample during the volatile acid test (both tests are run at the same time). This will bring the total amount of sample in the beaker to 50ml (5ml of supernatant and 45ml D.I. water).

4. Grab another clean 5 ml pipette and fill with sulfuric acid solution to 5 ml. Place sample on stirrer and insert pH probe. While stirring, titrate the sample using your sulfuric acid solution until the pH meter reaches 4.30 pH, which usually requires multiple fillings of the pipette.

5. When 4.30 PH is reached, add up the total ml of sulfuric acid solution applied to reach 4.30 pH. Multiply the sulfuric acid used in ml by 200 and this is the alkalinity.

6. Log results in laboratory log sheet.

VOLATILE ACID & ALKALINITY RESULTS

DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200
DATE:	pH:	V.A.	ALK.	Ratio:
DIGESTER T.F. #	TEMP. °F		x 86.5	x 200

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VOLATILE MATTER / MOISTURE

Refer to Standard Methods 22nd Edition, Pages 2-67 Section 2540 E

General Discussion

A well-mixed sample is evaporated in a weighed dish and dried to a constant weight in an oven at 103º to 105º C. The increase in weight over that of the empty dish represents the total solids. The results may not represent the weight of actual dissolved and suspended solids in wastewater samples.

Equipment

Porcelain dish
Furnace
Desiccators
Drying oven
Analytical balance

Procedure

Remove a crucible from the oven and allow it to cool to scale temperature in desiccators. Weigh the empty crucible to establish a tare weight and log on sheet. Pour a representative sample into pre weighed, fully cooled crucible approximately one third full and weigh immediately. Log weight on Sludge Moisture/Volatile Solids log sheet and place the crucible in the oven (103º-105ºC). Allow crucible to stay in the oven overnight, thus removing any moisture from the sample. Remove and cool to scale temperature in desiccators. Sample is now ready to be placed in the muffle furnace at 500º ±50ºC for 15 to 20 minutes thus burning off all volatile matter leaving only inorganic material. Remove carefully (HOT) and place in desiccators until it is cooled to scale temperature. Weigh and record results in log sheet. Perform calculations on log sheet to determine percent moisture and percent volatile solids.

Digester / Primary # Crucible # Date	◯	◯	◯	◯
Weight of Dish & Wet Sludge				
Weight of Dish				
Weight of Wet Sludge				
Weight of Dish & Wet Sludge				
Weight of Dish & Dry Sludge				
Loss in Weight				
Moisture = (Loss in Weight) Multiplied by 100 & Divided by the (Weight of Wet Sludge)	%	%	%	%
Solids (100% - Moisture)	%	%	%	%

Volatile Content

Weight of Dish & Dry Solids				
Weight of Dish				
Weight of Dry Solids				
Weight of Dish & Dry Solids				
Weight of Dish & Ash				
Loss in Weight				
Volatile Matter = (Loss in Weight) Multiplied by 100 & Divided by the (Weight of Dry Solids)	%	%	%	%

Comments:

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M ENDO AGAR LES

Preparation

1. First take 51g of M Endo Agar LES powder and suspend into1000 ml. (L) of distilled H2O. **Note:** we divide both figures by 4 to avoid waste.

2. Using the hot plate bring the powder and distilled H2O to a boil. This will be obvious, as purple foam will begin to rise. Remove from the heat.

3. At this point pour the hot liquid into two (10) Petri dishes. Replace covers.

4. Place all Petri dishes in BOD incubator over night to cool and solidify.

5. M Endo Agar LES is now ready to use. Store the Petri dishes in the refrigerator. The prepared Petri dishes are good for two weeks.

*** Note**: be careful not to contaminate Petri dishes.

COMPLETED TEST

1. Take Petri dish out of the incubator and place it on the counter in front of you.

2. Get a confirmed positive Brilliant Green Bile test tube and place it in front of you at the counter.

3. Set up the Bunsen burner to sterilize the inoculation loop.

4. Sterilize the inoculation loop. Hold in flame until loop glows red.

5. After the loop has cooled dip the loop into the positive BGB test tube.

6. Then take the loop while removing the cover of the Petri dish scratching the m Endo Agar LES Petri dish as shown below. (**Note**: only dip the loop once into the BGB test tube.)

7. Replace cover of the Petri dish and place in the Bac T incubator for 24 hrs. A green growth should be present.

8. After 24 hrs. remove Petri dish from incubator. Get one each a test tube of LTB, LTBII & BGB and place it in front of you.

9. With a flame-sterilized loop scratch the growth on the Petri dish to inoculate the BGB test tube, and then do the same for the LTB & LTBII test tubes.

10. Place LTB, LTBII and BGB test tubes into the Bac T incubator for 24-48 hrs. All test tubes should be positive.

*** Note:** The Completed Test is run once a week or 1 Test for every 10% of positive tubes.

ACTUAL COMPLETED TEST
PETRI DISH

Morro Bay / Cayucos WWTP
Update Standard Procedures
2004

1. According to Standard Methods 18th Edition, all thermometers will be certified annually. Correction to thermometers and monitoring will documented as needed.

2. SOP glass cleaning/ inhibitory residue test

3. pH 10 buffer to be ordered, see pH page.

4. Calibration of our media scale using 1g, 10g, 100g, monthly. New forms for scale calibrations and calibration for each use.

5. Autoclave 16 min on dial

6. H20 bath pump / agitator, fully immersed thermometer (as of Dec 1,2004 "our unit is equipped").

7. Autoclave heat tape.

8. Heater block < 15 kill on spores (monthly spore check).

9. TSB on all bottles/ Document procedures to track bottles. Corrected December 1, 2004 on form on side of Bac-t incubator and pipettes.

10. 30 minutes for Bact -T sterilization after cleaning.

11. Pipette calibrated by weight.

12. Spot check for PH reaction on glassware / media preparation. Refer to Standard Methods 18th Edition.

13. Control Bact – T SOP from Remel Inc.

14. Pos/neg control while H20 bath in use. Log on beach form.

15. BOD H20 to be aerated for no longer than 1 hour

16. Freon Blank for grease & oil / bottle of 90ml freon. QC blank test

Morro Bay / Cayucos WWTP
Update Standard Procedures
2001

1. According to Standard Methods the thermometer used to monitor the incubator must have increments of .5 degree C or less. See 9030 B.12.

2. According to Standard Methods the incubator must be monitored at least twice daily. See 9020B, Sec. 2p, page 9-5.

3. According to Standard Methods all thermometers used for microbiology tests must be cross-checked against a certified thermometer twice per year. See 9020B, Sec. 2.a, Page 9-4.

4. Turbidimeter will be calibrated using a primary or secondary standard before each use. A quarterly crosscheck should be made using a primary standard.

5. pH Meter will be calibrated and logged each day.

6. When running a BOD test the samples will be tested and treated for CL2 and pH, before analysis. If necessary, adjust the samples to the proper pH range of 6.5-7.5. Per Standard Methods 18th edition, samples can be adjusted with a solution of sulfuric acid (H2SO4) or sodium hydroxide (NaOH) of such strength that the quantity of reagent does not dilute the sample by more than 0.5%.

7. When calculating the results of a BOD test, per Standard Methods 18th edition, the following formulas will be used:

   The formula for calculating the BOD when the dilution water is not seeded:

$$\text{BOD, mg/L} = \frac{D1-D2}{P}$$

   The formula for calculating the BOD where dilution water is seeded:

$$\text{BOD, mg/L} = \frac{(D1 - D2) - (B1 - B2)f}{P}$$

   Where:

   D1= DO of diluted sample immediately after preparation, mg/L,
   D2= DO of diluted sample after 5 day incubation at 20°C, mg/L,
   P= decimal volumetric fraction of sample used,
   B1= DO of seed control before incubation, mg/L,
   B2= DO of seed control after incubation, mg/L,

   Because the seed material is added directly to sample or to seed control bottles:
   f= (volume of seed in diluted sample)/(volume of seed in seed control)

8. A Glucose-Glutamic Acid (GGA) check should be conducted monthly to assure dilution water quality, seed effectiveness and analytical technique. See 5210B, 4.c.

9. Non-filterable residue analysis by method 2540D in Standard methods, 18th edition, the gravimetric method requires drying the sample at 103-105° C, for one hour. Cool in desiccators to balance temperature and weigh. Repeat cycle of drying and cooling, desiccating and weighing until a constant weight is obtained or until weight change is less than 4% of the previous weighing or 0.5mg, whichever is less.

9. When performing analysis for total and fecal coliform using the multiple tube fermentation technique (9221), if the results do not appear on Table 9221.IV. MPN Index and Confidence Limits (page 9-50, Standard Methods, 18th Edition), the MPN can be calculated using the formula listed on page 9-50 of Standard Methods 18th Edition. The results should be rounded to the nearest whole number and be reported as such.

UPDATES MADE TO QC MANUAL

Item updated	Date	
Modify BOD for seed	3/30/06	
Change composite effluent sample site from CL2 chamber to ARS	3/30/06	
QC check form - added area to log CL2 low range test	3/30/06	
Add sections for Glucose Glutamic Acid QC Test for BOD	1/29/07	
Add sections for Winkler Method – 5 day BOD setup	1/29/07	
Add Sections for 5 Day BOD setup	1/29/07	
All sections updated from Standard Methods 18th to 20th Edition	20 Nov 07	
Deleted all pages concerning Oil and Grease	20 Nov 07	
Added reminder to check and compare Crystal Springs report to micro check list	20 Nov 07	
Add Autoclave, inspect and calibrate by certified Technician annually	20 Nov 07	
Add Coliform group, one completed test for every 10% positive	20 Nov 07	
Add actual time in and out of Autoclave	20 Nov 07	
Media QC add refrigerate after incubation	20 Nov 07	
Ocean samples add hold times 6 hours	20 Nov 07	
VA Test changed DI and Distillant vol's.	20 Nov 07	
Update all standard method references to 20th edition	12/21/07	
Update table of contents	12/21/07	
Removal of Beach Bac T and all related pages	3/16/09	
Removal of Fecal QC related pages	3/16/09	
Removal of the Oil/ Grease Test and QC	3/16/09	
Update Table of Contents	3/16/09	
Document that the GGA test is within limits every time test is performed.	3/16/10	
Calculate the Relative Percent Difference on Comp Eff SS test and log. (Fridays)	3/16/10	
Document analysis training and perform split samples to document analysis trainee proficiency.	3/16/10	
Triggered Monitoring Procedures added to table of contents	3/22/10	
Update Laboratory Quality Assurance Manual – Consolidate into one file	5/11/11	
Removal of H20 Bath Temperature	6/21/12	
Addition of BOD Bottles	6/21/12	
Addition to run pH check with 8.0 standard	6/21/12	
Addition to run three pH samples for each Inf. & Eff. samples	6/21/12	
Addition to run duplicate test samples on residual chlorine	6/21/12	
STAFF THOUROULY REVIEW AND UPDATE LAB QA MANAUL (3.5 hrs.)	2/(4-6)/15	
Change all references to refer to the Standard Methods 22nd Edition	2/13/15	
Remove Fire Blanket and add Eyewash	2/13/15	
Add pH 8 to calibration procedures used for control check	2/13/15	
Add procedure for checking glassware prior to use and the proper FL70 dilution	2/13/15	
Move the DI Water Report to the back of the QA Manual (report is 66 pages)	2/13/15	
Add location of the analytical and portable balances	2/13/15	
Change minimum weights to 2 and that we consistently check calibration with 4	2/13/15	
Add use plastic tipped forceps when handling weights	2/13/15	
Update the models of the balances	2/13/15	
Add clean and sanitize incubator as needed	2/13/15	
Add NIST certified thermometers are good for 5 years	2/13/15	
Change 0.2 to 0.5C as a minimum for general purposed; see specific equipment	2/13/15	
Autoclave – add digital readout, total run-time and calibration per manufacturer specs	2/13/15	
Add additional glassware and filters to the Lab Open-up procedure	2/13/15	
Add LTB setup chart to the Presumptive/Confirmation Bacti Test	2/13/15	
Add that a contract lab will be used for Ocean Bacti samples	2/13/15	

Add that Triggered Monitoring is permit-required	2/13/15	
Remove E-aerogenes and add E-coli to the Media QC check	2/13/15	
Update Quality Control Form to add dates to the Completed Test	2/13/15	
Change Suspended Solids to read Total Suspended Solids	2/13/15	
Update the Winkler Method for use of reagent pillows	2/13/15	
Change the slope percentage to approximately 97.5 – 103%	2/13/15	
Add column to pH calibration form for the pH 8 control check	2/13/15	
Add use of Eppendorf pipettes to the Chlorine Residual Test	2/13/15	
Add perform Quarterly to the Low Range Standard Solution Test	2/13/15	
Add that new Primary Standards are ordered annually for the Turbidimeter	2/13/15	
Change milliliters to mL/L on the Settleable Solids Test	2/13/15	
Change volatile acid high level from 1000 to 300 ppm	2/13/15	
Add 4 spoons of Celite Filter Aid to the Volatile Acids Test	2/13/15	
Update procedure for the preparation on M Endo Agar Les	2/13/15	
Update the Table of Contents	2/13/15	

Bruce Keogh, Lab Director _____ Date: _____