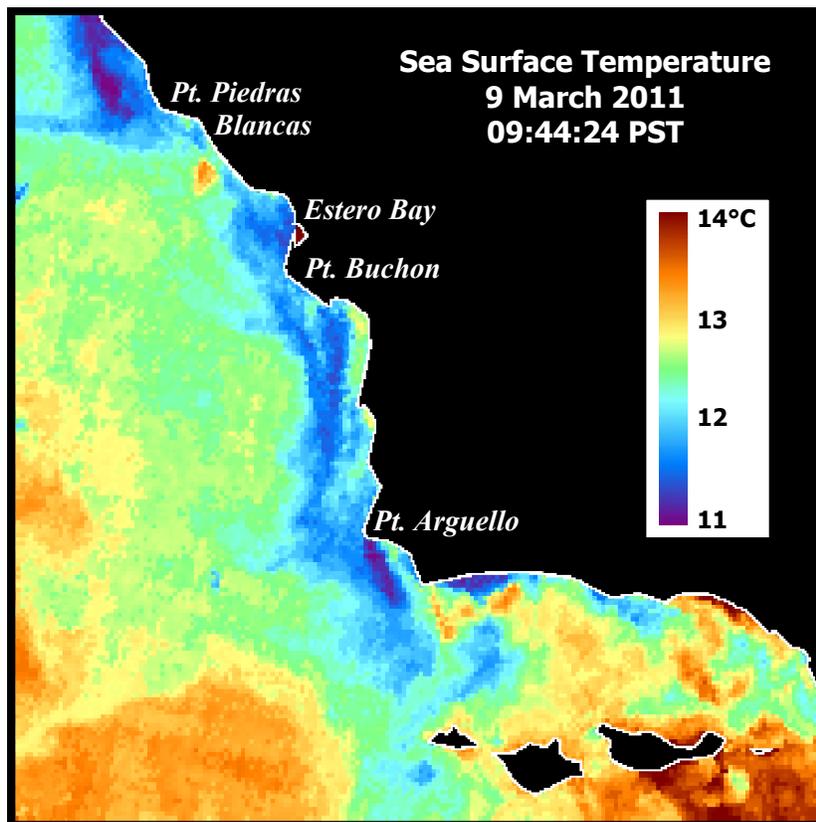


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

FIRST QUARTER RECEIVING-WATER SURVEY MARCH 2011



Marine Research Specialists

3140 Telegraph Rd., Suite A
Ventura, California 93003

**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**

**FIRST QUARTER
RECEIVING-WATER SURVEY**

MARCH 2011

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April 2011

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

29 April 2011

Reference: First Quarter Receiving-Water Survey Report – March 2011

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Wednesday, 9 March 2011. The survey was conducted in accordance with the requirements of the NPDES permit issued to the City and District for discharge of treated wastewater to Estero Bay. The report evaluated compliance with permit limitations and assessed the effectiveness of effluent dispersion during winter oceanographic conditions. Based on report's quantitative analyses of continuous instrumental measurements and qualitative visual observations, the wastewater discharge complied with the receiving-water limitations specified in the permit, and with the objectives of the California Ocean Plan.

The offshore measurements confirmed that the diffuser structure and treatment plant continued to operate at high performance levels. The measurements delineated a diffuse discharge plume containing low organic loads within a highly localized region surrounding the discharge point. Dilution within the plume exceeded expectations based on modeling and outfall design criteria.

Please contact the undersigned if you have questions regarding the attached report.

Sincerely,

Bonnie Luke
Program Manager

(Submitted Electronically)

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.

Mr. Rob Livick
Director of Public Services
City of Morro Bay

Date _____

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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. In March 1985, Region IX of the U.S. Environmental Protection Agency (USEPA) and the Central Coast California Regional Water Quality Control Board (RWQCB) issued the first National Pollutant Discharge Elimination System (NPDES) permit to the MBCSD. The permit incorporated partially modified secondary treatment requirements for the plant's ocean discharge. The permit has been re-issued three times, in March 1993 (RWQCB-USEPA 1993ab), December 1998 (RWQCB-USEPA 1998ab), and January 2009 (RWQCB-USEPA 2009). The March 2011 field survey described in this report was the eighth receiving-water survey conducted under the current permit.

The NPDES discharge permit requires seasonal monitoring of offshore receiving-water quality with quarterly surveys. This report summarizes the results of sampling conducted on 9 March 2011. Specifically, this first-quarter survey captured ambient oceanographic conditions along the central California coast towards the end of the winter season. The survey's measurements were used to assess the discharge's compliance with the objectives of the California Ocean Plan (COP) and the Central Coast Basin Plan (RWQCB 1994) as promulgated by the receiving-water limitations specified in the NPDES discharge permit.

The monitoring objectives were achieved by evaluating empirical tabulations of instrumental measurements and standard field observations. In addition to the traditional, vertical water-column profiles, instrumental measurements were used to generate horizontal maps from high-resolution data gathered by towing a CTD¹ instrument package repeatedly over the diffuser structure. This allowed for a more precise determination of the plume's lateral extent.

SURVEY SETTING

The MBCSD treatment plant is located within the City of Morro Bay, which is situated along the central coast of California halfway between Los Angeles and San Francisco. Effluent is carried from the onshore treatment plant through a 1,450-m long outfall pipe, which terminates at a diffuser structure on the seafloor 827 m from the shoreline within Estero Bay (Figure 1). The diffuser structure extends an additional 52 m toward the northwest from the outfall terminus and consists of 34 ports that are hydraulically designed to create a turbulent ejection jet that rapidly mixes effluent with receiving seawater upon discharge. Currently, six of the diffuser ports are kept closed, thereby improving effluent dispersion by increasing the ejection velocity from the remaining 28 ports distributed along a 42-m section of the diffuser structure.

Following discharge from the diffuser ports, additional turbulent mixing occurs as the buoyant plume of dilute effluent rises through the water column. Most of this buoyancy-induced mixing occurs within a zone of initial dilution (ZID), whose lateral reach in modeling studies extends 15.2 m from the centerline of the diffuser structure. Beyond the ZID, energetic waves, tides, and coastal currents within Estero Bay further disperse the discharge plume within the open-ocean receiving waters. Both vertical hydrocasts and a horizontal tow survey are conducted around the diffuser structure to assess the efficacy of the diffuser, to define the extent of the discharge plume, and to evaluate compliance with the NPDES permit limitations.

¹ Conductivity, temperature, and depth (CTD)



Near the diffuser, prevailing currents generally follow bathymetric contours that parallel the north-south trend of the adjacent coastline. Because of the rapid initial mixing achieved within 15 m of the diffuser structure, impingement of unmixed effluent onto the adjacent coastline, 827 m away, is highly unlikely. Nevertheless, in the event of a failure in the treatment plant's disinfection system, collection and analysis of water samples at the surfzone sampling stations shown in Figure 1 would be conducted to monitor for potential shoreline impacts. These surfzone samples would be analyzed for total and fecal coliform, and enterococcus bacterial densities.

Areas of special concern, such as the Morro Bay National Estuary and the Monterey Bay National Marine Sanctuary, are not affected by the discharge because they are even more distant from the outfall location. For example, the southern boundary of the Monterey Bay National Marine Sanctuary is located 38 km to the north, while the entrance to the Morro Bay National Estuary lies 2.8 km south. The southerly orientation of the mouth of the Bay and the presence of Morro Rock 2 km to the south serve to further limit seawater exchange between the discharge point and the Bay (Figure 1).

SAMPLING LOCATIONS

As shown in Figure 2, the offshore sampling pattern consists of six fixed offshore stations located within 100 m of the outfall diffuser structure. The red ⊕ symbols in the Figure indicate the target locations of the sampling stations (Table 1). The stations are situated at three distances relative to the center of the diffuser structure and lie along a north-south axis at the same water depth (15.2 m) as the center of the diffuser. Depending on the direction of the local oceanic currents at the time of sampling, the discharge may influence one or more of these stations. The up-current stations on the opposite side of the diffuser then act as reference stations. Comparisons of water properties at these antipodal stations quantify departures from ambient seawater properties that help determine compliance with the NPDES discharge permit.

The finite size of the diffuser is an important consideration in the assessment of wastewater dispersion close to the discharge. Although the discharge is considered a "*point source*" for modeling and regulatory purposes, it does not occur at a point of infinitesimal size. Instead, the discharge is distributed along a 42 m section of the seafloor, and, ultimately, the amount of wastewater dispersion at a given point in the water column is dictated by its distance from the closest diffuser port, rather than its distance from the center of the diffuser structure. Therefore, the "*closest approach*" distance can be considerably less than the centerpoint distance normally cited in modeling studies.

Another important consideration for compliance evaluation is the ability to determine the actual location of the measurements. Discerning small spatial separations within the compact sampling pattern only became feasible after the advent of Differential Global Positioning Systems (DGPS). The accuracy of traditional navigation systems such as LORAN or standard GPS is typically ± 15 m, a span equal to half the total width of the ZID itself. DGPS incorporates a second signal from a fixed, land-based beacon that continuously transmits position errors in standard GPS readings to the DGPS receiver onboard the survey vessel. Real-time correction for these position errors provides an extremely stable and accurate offshore navigational reading with position errors of less than 2 m.

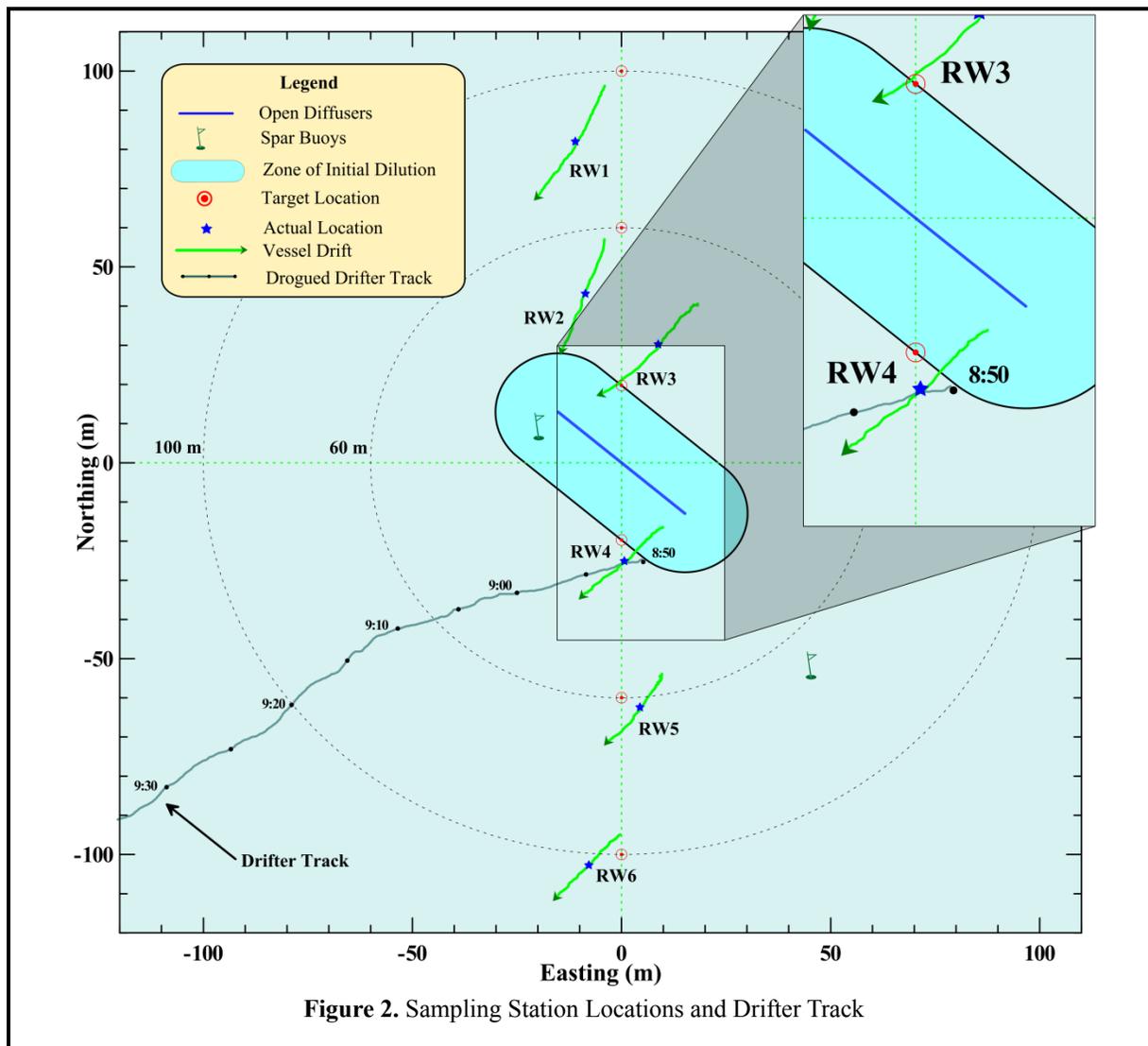


Figure 2. Sampling Station Locations and Drifter Track

Table 1. Target Locations of the Receiving-Water Monitoring Stations

Station	Description	Latitude	Longitude	Center Distance ² (m)	Closest Approach Distance ³ (m)
RW1	Upcoast Midfield	35° 23.253' N	120° 52.504' W	100	88.4
RW2	Upcoast Nearfield	35° 23.231' N	120° 52.504' W	60	49.4
RW3	Upcoast ZID	35° 23.210' N	120° 52.504' W	20	15.0
RW4	Downcoast ZID	35° 23.188' N	120° 52.504' W	20	15.0
RW5	Downcoast Nearfield	35° 23.167' N	120° 52.504' W	60	49.4
RW6	Downcoast Midfield	35° 23.145' N	120° 52.504' W	100	88.4

² Distance to the center of the open diffuser section

³ Distance to the closest open diffuser port

In July 1998, the survey vessel's DGPS navigation system, consisting of a Furuno™ GPS 30 and FBX2 differential beacon receiver, was used to precisely determine the position of the open section of the diffuser structure (MRS 1998) and establish the target locations for the receiving-water monitoring stations shown in Figure 2 and listed in Table 1. Currently, use of two independent DGPS receivers on the survey vessel allows access to two separate land-based beacons for navigational comparison, ensuring extremely accurate and uninterrupted navigational reports.

Recording of DGPS positions at one-second intervals allows precise determination of sampling locations throughout the vertical CTD profiling conducted at the six individual stations, as well as during the tow survey. Knowledge of the precise location of individual CTD measurements relative to the diffuser is critical for accurate interpretation of the water-property fields. During vertical-profile sampling, the actual measurement locations rarely coincide with the target coordinates listed in Table 1 because winds, waves, and currents induce unavoidable horizontal offsets (drift). Even during quiescent metocean⁴ conditions, the residual momentum of the survey vessel as it approaches the target locations can create perceptible offsets. Using DGPS however, these offsets can be quantified, and the vessel location can be precisely tracked throughout sampling at each station.

The magnitude of the drift at each of the six stations during the March 2011 survey is apparent from the length of the green tracklines in Figure 2. These tracklines trace the horizontal movement of the CTD as it was lowered to the seafloor. Their length and offset from the target locations reflect the overall station-keeping ability during the March 2011 survey. During the time it took the CTD to traverse the water column and reach the seafloor, which averaged 1 min 02 s, the instrument package moved an average of 27.5 m. This amount of drift is approximately double that of most surveys for the reasons described below.

The CTD trajectories shown by the tracklines in Figure 2 reflect complex interactions between surface currents, wind forces, and any residual momentum of the survey vessel as it approached each station during the March 2011 survey. For example, vessel drift at all six stations was to the southwest, in a direction consistent with both the prevailing northeasterly winds and the moderate subsurface current measured by the drogue drifter. Generally, however, winds affect the vessel's ability to maintain station to a greater degree than does current flow. Specifically, the increasingly gusty northeasterly winds (see Table 4) significantly diminished the vessel's station-keeping ability during the March 2011 survey.

Lateral drift of the CTD during the vertical hydrocasts complicates the assessment of compliance with discharge limitations at stations close to the diffuser structure. This is because the receiving-water limitations specified in the COP only apply to measurements recorded beyond the ZID boundary, where initial mixing is assumed to be complete. For example, during the March 2011 survey the deepest measurements from the downcast recorded at Station RW3 and the shallowest measurements recorded at Station RW4 were not subject to the limitations because the CTD was within the ZID boundary during those portions of the vertical casts (Figure 2). Specifically, the measurements collected below a depth of 12.5 m at Station RW3 and all those above 6 m at Station RW4 were acquired while the CTD was within the ZID.

Determining which measurements are subject to permit limits within hydrocasts near the ZID boundary only became possible after the advent of DGPS. Prior to 1999, CTD locations could not be determined

⁴ Meteorological and oceanographic conditions include winds, waves, tides, and currents.

with sufficient accuracy or precision to establish whether a station was located within the ZID, much less how the CTD was moving laterally during the hydrocast. Because of these navigational limitations, sampling was presumed to occur at a single, imprecisely determined, horizontal location. Federal and State reporting of monitoring data still mandates identification of a single position for all of the CTD data collected at a particular station. Thus, for regulatory reporting, and for consistency with past surveys, the March 2011 survey also identifies a single sampling location for each station. These average station positions are shown by blue stars in Figure 2, and are listed in Table 2 with their distances from the

Table 2. Average Position of Vertical Profiles during the March 2011 Survey

Station	Time (PST)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ⁵ (m)	Bearing ⁶ (°T)
RW1	9:22:19	9:23:23	35° 23.243' N	120° 52.511' W	69.3	3
RW2	9:18:28	9:19:30	35° 23.222' N	120° 52.510' W	31.0	12
RW3	9:45:53	9:46:48	35° 23.215' N	120° 52.498' W	28.8 ⁷	41
RW4	9:10:09	9:11:15	35° 23.185' N	120° 52.504' W	18.5 ⁷	221
RW5	9:06:02	9:07:06	35° 23.165' N	120° 52.501' W	50.5	192
RW6	9:01:25	9:02:24	35° 23.143' N	120° 52.509' W	92.6	194

diffuser structure.

Compliance assessments notwithstanding, measurements acquired from within the ZID lend valuable insight into the outfall's effectiveness at dispersing wastewater. For example, low dilution rates and concentrated effluent throughout the ZID would indicate potentially damaged or broken diffuser ports. Analysis of the outfall's operation over the past two decades, however, suggests that it has maintained a high level of effectiveness in effluent dispersal. In fact, without the occasional measurements recorded within the ZID due to CTD drift, the extremely dilute discharge plume might remain undetected within all vertical profiles collected during a given survey.

OCEANOGRAPHIC PROCESSES

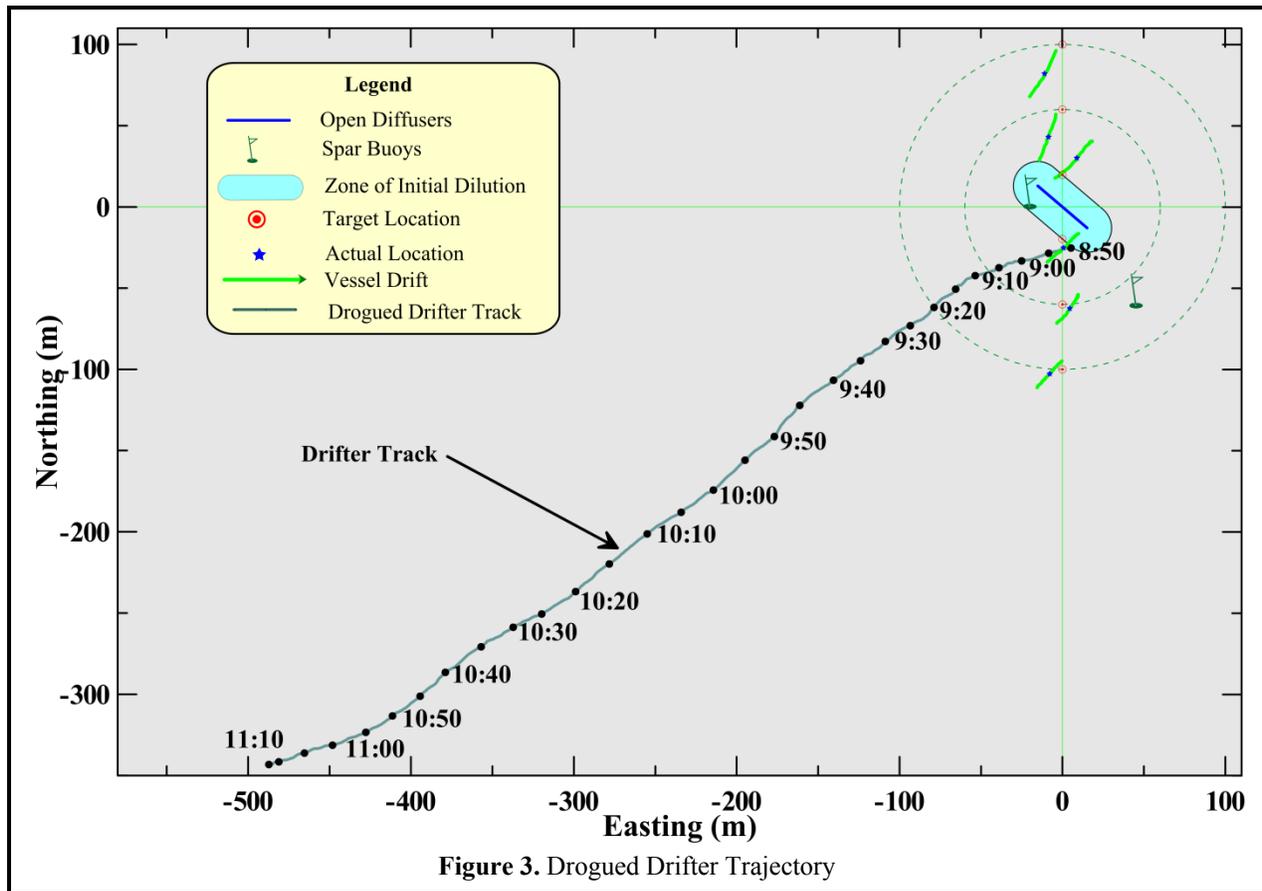
The trajectory of a satellite-tracked drogued drifter documented a steady southwestward flow during the March 2011 survey (Figure 3). Modeled after the curtain-shade design of Davis et al. (1982) and drogued at mid-depth (7 m), a drifter has typically been deployed during each of the quarterly water column surveys conducted over the past decade. In this configuration, the oceanic flow field rather than surface winds dictates the drifter's trajectory, providing a good assessment of the plume's movement following discharge.

The drifter was deployed just south of the ZID at 08:50 PST, and was recovered two hours and twenty minutes later, at a location 586 m southeast of its deployment location. The black dots in Figure 3 show the drifter's progress at five-minute intervals. The uniform spacing of the time stamps reflects the relatively constant speed of the drifter, which averaged 6.9 cm/s, or 0.13 knots. At this speed, the plume would have traversed the ZID in slightly less than four minutes.

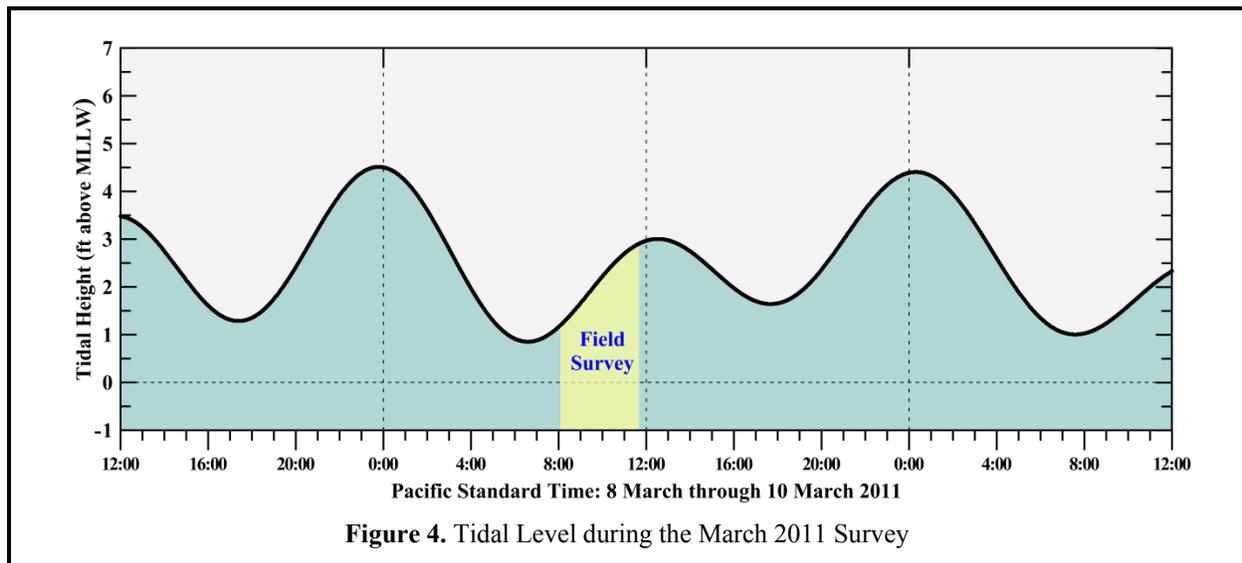
⁵ Distance from the closest open diffuser port to the average profile location.

⁶ Angle measured clockwise relative to true north from the closest diffuser port to the average profile location.

⁷ Portions of the CTD casts at stations RW3 and RW4 were located within the ZID boundary.



The drifter track was inconsistent with the incoming (flood) tide (Figure 4). In the absence of other influences, a flood tide normally induces a weak northeastward (onshore) flow in the survey region. However, flow is often also influenced by external processes, such as wind-generated upwelling or passing offshore eddies. Specifically, upwelling normally induces a weak southerly flow.



Upwelling season normally begins sometime during late March and or early April as shown by the positive (blue) upwelling indices in Figure 5. At this time, there is a ‘spring’ transition to more persistent southeastward-directed winds along the central California coast. This transition is initiated by the stabilization of a high-pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive the prevailing northwesterly winds along the central California coast. These prevailing winds move warmer surface waters southward and offshore, allowing deep, cool, nutrient-rich waters to move shoreward and upwell near the coast.

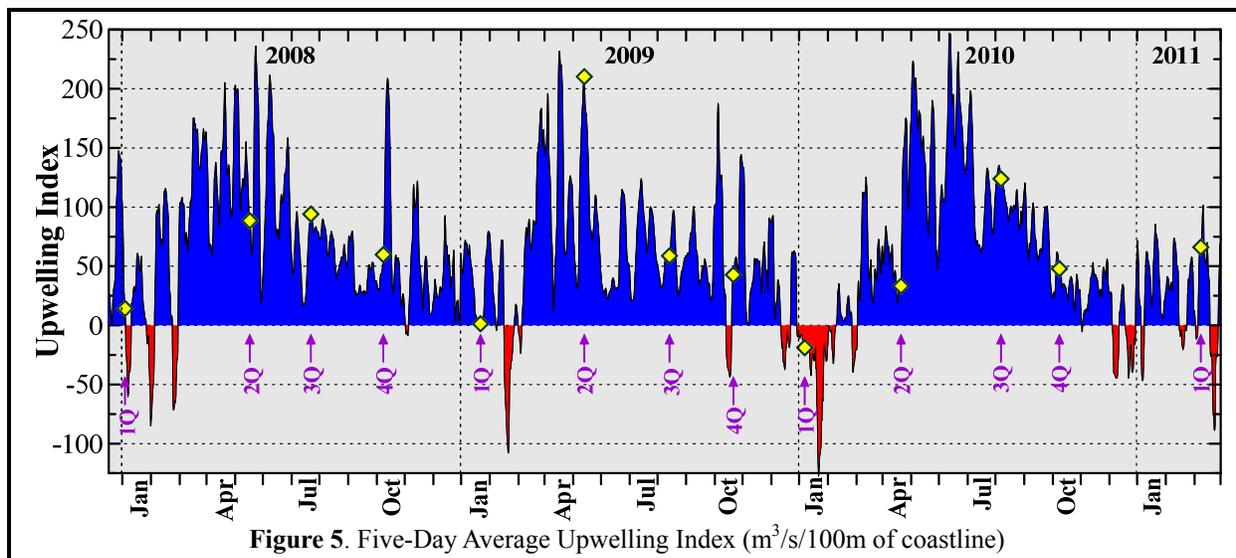


Figure 5. Five-Day Average Upwelling Index ($m^3/s/100m$ of coastline)

The nutrient-rich seawater that is brought to the sea surface near the coast by upwelling enables phytoplanktonic blooms that are the foundation of the productive marine fishery found along the central California coast. The cross-shore flow associated with persistent upwelling conditions also enhances vertical stratification of the water column. The presence of denser water at depth produces a shallow thermocline (<10 m) that is commonly maintained throughout summer and into fall.

In contrast, downwelling events, indicated by the negative (red) indices in Figure 5, occur infrequently, and almost exclusively in winter, when passing storms temporarily reverse the normal wind pattern and drive surface waters shoreward. As the surface waters approach the coastline, they downwell, producing nearly uniform seawater properties throughout the water column.

The satellite image on the cover of this report documents the upwelling that was present on the day of the March 2011 survey, when skies were clear enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA’s polar orbiting satellites. Although winds on the morning of the survey were out of the northeast, strong southeastward winds prevailed along the central California coast in the days leading up to the March 2011 survey, resulting in cooler sea surface temperatures close to the coastline, while farther offshore, surface water temperatures were approximately three degrees warmer. As is apparent in the cover image, the cool, nearshore sea-surface temperatures near $11^{\circ}C$ within Estero Bay were comparable to the near-surface temperatures measured by the CTD during the March 2011 survey.⁸

⁸ Refer to Table 5 and Figure 6 for receiving-water properties recorded during the vertical hydrocasts.

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on Wednesday, 9 March 2011. Bonnie Luke of Marine Research Specialists (MRS) was the Chief Scientist and collected auxiliary measurements of biological, meteorological, and oceanographic conditions. Douglas Coats, also of MRS, provided navigational support during the survey. William Skok assisted with deployment and recovery of the CTD and drifter.

Auxiliary Measurements

Auxiliary measurements and observations were collected during the vertical water-column profiling conducted at each of the six stations. Standard observations of weather and sea conditions, and beneficial uses, were augmented by visual inspection of the sea surface for floating particulates, oil sheens, and discoloration potentially related to the effluent discharge. Other auxiliary measurements collected at each station included wind speeds and air temperatures measured with a handheld Kestrel[®] 2000 Thermo-Anemometer, and oceanic flow measurements made throughout the survey using a drogued drifter.

Additionally, at all six stations, a Secchi disk was lowered through the water column to determine its depth of disappearance. Secchi depths provide a visual measure of near-surface turbidity or water clarity. The depth of disappearance is inversely proportional to the average amount of organic and inorganic suspended material along a line of sight in the upper water column. As such, the Secchi depth measures natural light penetration, which can be limited by increased suspended particulate loads from plankton blooms, onshore runoff, seafloor sediment resuspension, and wastewater discharge. It is also biologically meaningful because the depth of the euphotic zone, where most oceanic photosynthesis occurs, extends to approximately twice the Secchi depth.

Instrumental Measurements

A Sea Bird Electronics SBE-19 Seacat CTD instrument package collected measurements of conductivity, temperature, light transmittance, dissolved oxygen (DO), pH, and pressure at a sampling rate of 2 Hz (0.5-s intervals) at each of the six vertical sampling stations, as well as during the towed survey. A submersible pump 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 column.

The CTD instrument package receives regular maintenance and calibration. After the January 2001 survey, the CTD was returned to the factory for comprehensive testing, repair, and calibration. The DO and pH sensors were returned to the factory in May 2003 and June 2006 for testing and calibration. Because of increasing temporal drift associated with aging DO probes, the DO probe was replaced on both occasions. The CTD system was calibrated at the MRS laboratory prior to the March 2011 survey. The upper-bound DO calibration point at full saturation was established by immersing the CTD in an aerated, temperature-controlled calibration tank. Similarly, a zero-oxygen calibration point was determined by filling the oxygen-sensor plenum with an 8% solution of sodium sulfite (Na₂SO₃). Oxygen calibration coefficients were established through regression analysis of sensor-membrane current and temperature, as recommended by the manufacturer (SBE 1993). As in previous surveys, the calibration coefficients determined by MRS closely corresponded with prior factory calibrations.

The six seawater properties used to assess receiving-water quality in this report were derived from the continuously recorded output of the CTD's probes and sensors. Pressure housing limitations on the combination oxygen/pH sensor confine the CTD to depths less than 200 m (Table 3), which is well beyond the maximum depth of the deepest station in the outfall survey.

Table 3. CTD Specifications

Component	Depth⁹	Units	Range	Accuracy	Resolution
Housing	600	—	—	—	—
Pump	3400	—	—	—	—
Pressure	680	Psia	0 to 1000	± 5.0	± 0.5
Depth	—	Meters	0 to 690	± 3.0	± 0.3
Conductivity	600	Siemens/m	0 to 6.5	± 0.001	± 0.0001
Salinity	600	‰	0 to 38	± 0.006	± 0.0006
Temperature	600	°C	-5 to 35	± 0.01	± 0.001
Transmissivity	2000	%	0 to 100	± 0.1	± 0.025
Dissolved Oxygen	200	mg/L	0 to 21.5	± 0.14	± 0.014
Acidity/Alkalinity	200	pH	0 to 14	± 0.1	± 0.006

The precision and accuracy of the various probes, as reported in manufacturer's specifications, are also listed in the table. Salinity (‰) 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).

All three of the physical parameters (salinity, temperature, and density) helped determine the lateral extent of the effluent plume during the towing phase of the survey. Additionally, during the vertical-profiling phase, they quantified layering, or vertical stratification and stability of the water column, which determines 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 the 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.

During the calibration of the CTD, coefficients for the pH (alkalinity) sensor were determined from a linear regression of output voltage after immersion in four separate buffered solutions of known pH. Buffering solutions with a pH of 4±0.01, 6±0.01, 7±0.01, and 9±0.02 were used to bracket the range of in situ measurements. The SeaTech transmissometer was air calibrated by fitting the voltages recorded with and without blocking of the light transmission path in air, as recommended by the manufacturer (SBE 1989). Algorithms that converted sensor voltage to engineering units during processing of the field data relied on calibration coefficients determined before the survey.

Comparison with the factory calibration of the entire CTD package conducted in December 2001, and the more recent June 2006 replacement and calibration of the DO probe, confirmed the continued accuracy and stability of the temperature, pressure, and conductivity sensors, as well as the operational integrity of the oxygen and pH probes. To correct for a slight drift in the pressure strain gauge since its calibration in 2001, a -0.25 Psia offset was incorporated in the conversion to depth measurements. In addition, slight temporal trends in pH and DO measurements arose from the sensor's ongoing equilibration during the survey. These trends were removed by fitting orthogonal polynomials to the pH and DO time series.

Before initial deployment for the vertical hydrocasts, the CTD was held below the sea surface for a six-minute equilibration period. Subsequently, the CTD was raised to within 0.5 m of the sea surface and profiling commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at all six stations were collected during a single deployment of the CTD package by towing it below the

⁹ Maximum depth limit in meters

water surface while transiting between adjacent stations. Following retrieval of the CTD and preliminary review of the data, the CTD was redeployed and the vertical hydrocast at Station RW3 was repeated (See the Quality Control discussion below).

At 09:25 PST, following the last vertical profile at RW3, the CTD instrument package was brought onboard the survey vessel and fitted with a depth-suppressor wing and horizontal stabilizer. Ducting from the DO plenum to the pump was also disconnected. This configuration allowed the CTD to achieve constant-depth tows with uniform flow across forward-looking probes. The CTD was then towed continuously around and across the ZID at two separate depths in accordance with the receiving-water monitoring requirements of the NPDES discharge permit (Figure 6).

Initially, the reconfigured CTD package was towed for 28 min at an average depth of 5.6 m, and an average speed of 1.5 m/s, passing near the diffuser structure eight times. Subsequently, eight additional passes were made with the CTD at an average depth of 8.3 m.¹⁰ During this 23-minute mid-depth-tow, vessel speed averaged 1.6 m/s. At the observed tows speeds and 2 Hz sampling rate, 1.3 CTD measurements were collected for each meter traversed, which complies with the permit requirement for at least one sample per meter. Contemporaneous navigation fixes recorded onboard the survey vessel were adjusted for CTD setback and aligned with time stamps on the internally recorded CTD data. The resulting data for the six seawater properties were processed to produce horizontal maps within the mid-depth and upper portions of the water column.¹¹

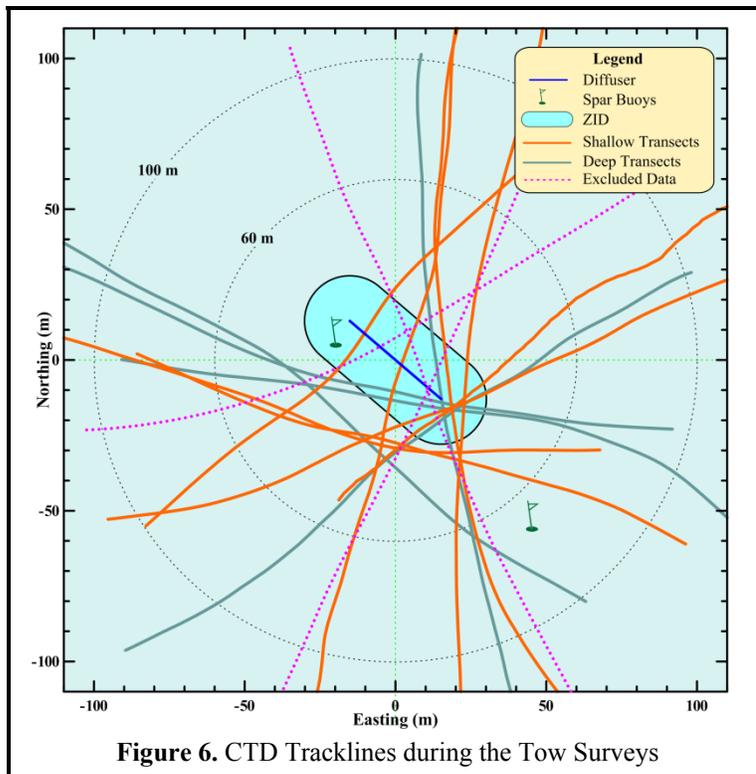


Figure 6. CTD Tracklines during the Tow Surveys

Quality Control

Upon retrieval of the CTD following both the vertical casts and the horizontal tows, the data were downloaded to a portable computer and examined for completeness and range acceptability. Preliminary review revealed several events that impacted portions of the data, resulting in the adjustment or exclusion of these data prior to initiation of the compliance analysis.

For example, initial review of the raw CTD data from the vertical casts showed that the vertical cast at Station RW3 did not reach the seafloor. During the downcast at that station, the CTD snagged the line holding the northwestern outfall marker buoy, which prevented its continued descent through the water

¹⁰ Average depth of the five mid-depth tow transects evaluated in the compliance analysis. Three additional transects were removed from consideration due to a vertical offset in tow depth as described in the *Quality Control* section.

¹¹ Figures 8 and 9 present the horizontal maps of seawater properties measured during the March 2011 survey.

column. Therefore, the vertical cast at Station RW3 was repeated at 9:45AM, just prior to the beginning of the towed survey. However, the data reported in Table 4 reflects the ambient meteorological and oceanographic conditions that were present at 9:14AM, when the original vertical cast was conducted. Nevertheless, ambient meteorological and oceanographic conditions did not change substantially over the intervening half hour, with the exception that wind speeds continued to increase, further diminishing the vessel's station-keeping ability.

Quality control review of tow survey data also determined that portions of the deep tow survey were collected at depths that were substantially shallower than the remainder of deep tow data. Specifically, slightly increased vessel speeds caused significantly decreased tow depths during three of the deep tow transects. Since the significance of potential discharge-related anomalies is evaluated by comparing the amplitudes of measurements acquired at the same depth level, the ability to resolve anomalies with statistical certainty is compromised when data from different levels are combined, particularly when the water column is stratified as was the case during the March 2011 survey. Because of their depth offsets, data collected during Transects D1, D5, and D7 were incompatible with the rest of the deep tow data, and were excluded from the subsequent analysis to avoid introducing erroneous lateral differences in the horizontal property maps.¹² Exclusion of these transects, shown by the dotted purple lines in Figure 6, did not, however, adversely affect the compliance analysis because the remaining transects adequately covered the survey region. The remaining transects, shown by the solid orange and blue lines in Figure 6, also met the permit monitoring requirement of at least five passes near the diffuser structure at each tow depth.

Additional quality-control screening of the vertical profile data found that variation in total water depth due to passing waves, along with differences in how long the CTD is allowed to pause within the deepest bin, created differences in the maximum depth measured at individual stations. For example, during the March 2011 survey, data on average seawater properties were not recorded the below 15 m at any station except RW5, while Station RW3 only had reliable data down to 14 m (Table 5). Although the bin-averages at the remaining five stations were sufficient to determine lateral variation from 14 m to 15 m, the inconsistent spatial coverage of the observations at 15.5 m could not adequately quantify horizontal trends, the observations at the deepest depth were excluded from the subsequent compliance evaluation.

Further quality-control screening eliminated erroneous "salinity spikes." When the CTD crosses a sharp thermocline, the mismatch between the locations of the conductivity and the temperature probes on the CTD results in the sensors sampling parcels of water with entirely different properties, thereby creating erroneous spikes in computed salinity. This is particularly common with data obtained at shallow depths, where entrainment of ambient waters by the rising effluent plume has 'squeezed' the thermocline, making it sharper. Low-pass filtering of the time series of tow data and vertical smoothing of the profile data effectively mitigated the influence of salinity spikes that resulted from the moderate vertical stratification present during the March 2011 survey.

Finally, unusually low ambient DO concentrations first documented in August 2010, were again recorded throughout the March 2011 survey (MRS 2011). During the March 2011 survey, where surface seawater is normally saturated through atmospheric equilibration, ambient DO concentrations were only 60% of saturation, while DO measurements near the seafloor were correspondingly depressed, achieving concentrations that were only 50% of saturation. Although well below normal levels, the March 2011 DO concentrations represent a substantial increase over the conditions documented in the previous two surveys when DO concentrations at depth had declined to 35% (August 2010) and 40% saturation

¹² Shown in Figures 8 and 9 on Pages 22 and 23

(October 2010). Although it is normal to find naturally low-oxygen conditions in deep, offshore waters, the occurrence of low-oxygen water so close to shore was highly unusual.

Analysis of the extremely low ambient DO measurements during the latter half of 2010 demonstrated that they were the direct result of an unusually prolonged period of strong upwelling associated with a strong La Niña event. La Niña conditions prevailed throughout much of the summer season and persisted well into fall of 2010 (Figure 5). The previous two receiving water surveys captured the affect of the extended period of continuous upwelling on dissolved oxygen levels. Specifically, intense and sustained upwelling eventually became “too much of a good thing.” Without the periodic relaxation of the northwesterly winds that drive upwelling, mixing of the waters on the continental shelf cannot take place, and oxygen is prevented from reaching and replenishing the subsurface waters. Meanwhile, the dense blooms of phytoplankton spurred by upwelling die and fall to the seafloor, where their decomposition further depletes oxygen levels in the nearshore waters.

The intensity and duration of upwelling events that occurred throughout the summer and fall of 2010, led to abnormally low DO levels that persisted through winter and were observed in the water column during the March 2011 survey. Although the low ambient DO concentrations that have been recorded since the summer of 2010 are not the result the result of the discharge, and therefore not of direct compliance interest, such phenomena are pertinent for establishing the natural variation in ambient water quality within Estero Bay. They also demonstrate how perfunctory application of fixed numerical limits on DO and pH from the Basin Plan can lead to an erroneous conclusion of noncompliance when ambient receiving waters already range beyond those limits (see the discussion of LOE#05 in the Compliance Section).

RESULTS

The first-quarter receiving-water survey began on Wednesday, 9 March 2011, at 08:50 PST with the deployment of the drogued drifter. Over the following two hours and twenty minutes, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended just after 11:10 PST with the recovery of the drifter. Observations of beneficial use and the collection of required visual observations of the sea surface were unencumbered throughout the survey.

Auxiliary Observations

On the morning of 9 March 2011, skies were clear, with moderate but increasingly gusty winds. Average wind speeds, calculated over one-minute intervals, ranged from 6.0 kt at the beginning of the survey to 12.2 kt toward the end of the vertical profiling phase (Table 4). Similarly, peak wind speeds increased from 7.3 to 20.3 kt. The swell was out of the northwest with a significant wave height of 3 to 4 feet. Air

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location ¹³		Diffuser Distance (m)	Time (PST)	Air (°C)	Cloud Cover (%)	Wind Avg (kt)	Wind Max (kt)	Wind Dir (from) (°T)	Swell Ht/Dir (ft/°T)	Secchi Depth (m)
	Latitude	Longitude									
RW1	35° 23.245' N	120° 52.513' W	71.5	9:22:47	15.9	0	11.1	13.8	NE	3-4/NW	6.0
RW2	35° 23.222' N	120° 52.506' W	32.1	9:18:54	16.0	0	12.2	20.3	NE	3-4/NW	6.0
RW3	35° 23.207' N	120° 52.503' W	11.9	9:14:26	15.3	0	10.3	12.3	NE	3-4/NW	7.0
RW4	35° 23.184' N	120° 52.510' W	26.6	9:10:52	15.8	0	10.8	13.2	NE	3-4/NW	8.0
RW5	35° 23.167' N	120° 52.505' W	47.9	9:06:34	15.9	0	6.0	7.3	NE	3-4/NW	6.0
RW6	35° 23.143' N	120° 52.517' W	96.4	9:02:09	15.9	0	6.0	8.0	NE	3-4/NW	6.0

¹³ Locations are the vessel positions at the time the Secchi depths were measured. They may depart from the CTD profile locations listed in Table 2.

temperatures were several degrees warmer than average surface-water temperatures, and varied from 15.8°C to 16.0°C.

The 6-m Secchi depths recorded at most stations during the March 2011 survey indicated a moderate level of ambient water clarity (Table 4). The Secchi depths reflected the presence of a 12-m euphotic zone that spanned most of the 16-m water column. Although several small pieces of the biofilm that lines the interior surfaces of the outfall pipe were observed suspended within the water column near Station RW3, there was no evidence during the survey of floating particulates, oil sheens, or any discoloration of the sea surface associated with wastewater-related constituents. Communication with plant personnel during the survey and subsequent review of effluent discharge properties, confirm that the treatment process was performing nominally at the time of the survey.

During the March 2011 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. Wildlife sightings during the survey were dominated by a large body of several hundred sooty shearwaters (*Puffinus griseus*). Every year, millions of these migratory seabirds arrive from distant breeding grounds in New Zealand and Chile to forage in the highly productive waters of the California Current. They generally begin to arrive in California waters in March and stay throughout the summer. Smaller numbers of Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), western gulls (*Larus occidentalis*), and California brown pelicans (*Pelecanus occidentalis californicus*) were also noted occasionally transiting the survey area. Within the confines of the harbor mouth, a common murre (*Uria aalge*) and several western grebes (*Aechmophorus occidentalis*) were also present. Marine mammal observations included one southern sea otter (*Enhydra lutris nereis*) near the outfall site, and several rafts of otters within the mouth of the harbor.

Beach usage by pedestrians was observed during the March 2011 survey; however, no fishing vessels or surfers were observed in the nearshore waters on the morning of the survey.

Instrumental Observations

Data collected during vertical profiling were processed in accordance with standard procedures (SCCWRP 2002), and are collated within 0.5-m depth intervals in Table 5. Data collected during the March 2011 survey reflect the presence of a moderately stratified water column indicative of upwelling conditions. Upwelling conditions prevail most of the year along the central California coast, generally beginning in March or April, and extend through the fall months. Upwelling results in an influx of dense, cold, saline water at depth and often leads to a sharp thermocline, halocline, and pycnocline where temperature, salinity, and density change rapidly over short vertical distances. Under highly stratified conditions, isotherms crowd together to form a density interface that restricts the vertical transport of the effluent plume, inhibiting the vertical exchange of nutrients and other water properties, and reducing dispersion.

Upwelling-induced gradients are evident in the vertical profiles of seawater properties shown in Figure 7 as decreases in temperature (red lines), DO (dark blue lines), and pH (gold lines) with increasing depth. These decreases are mirrored by a pycnocline and halocline where density (black lines) and salinity (green line) steadily increase with depth. Specifically, the profiles exhibit a vertical transition zone between a relatively uniform, near-surface mixed layer and a colder, clearer, saltier, nutrient-rich but more oxygen-poor water mass at depth.

Table 5. Vertical Profile Data Collected on 9 March 2011

Depth (m)	Temperature (°C)						Salinity (‰)					
	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6
0.5				10.498	10.839	10.834				33.598	33.603	33.612
1.0	10.821	10.810	10.805	10.486	10.810	10.832	33.606	33.608	33.601	33.594	33.611	33.610
1.5	10.821	10.802	10.789	10.503	10.775	10.823	33.606	33.607	33.602	33.608	33.617	33.611
2.0	10.825	10.786	10.780	10.504	10.729	10.816	33.606	33.609	33.606	33.609	33.623	33.614
2.5	10.820	10.781	10.767	10.481	10.716	10.813	33.607	33.608	33.595	33.609	33.620	33.616
3.0	10.817	10.773	10.734	10.499	10.714	10.804	33.607	33.608	33.590	33.613	33.623	33.617
3.5	10.821	10.776	10.661	10.506	10.712	10.802	33.606	33.609	33.576	33.612	33.627	33.617
4.0	10.817	10.769	10.606	10.480	10.713	10.798	33.606	33.608	33.589	33.613	33.628	33.617
4.5	10.807	10.774	10.601	10.458	10.715	10.762	33.607	33.607	33.594	33.602	33.628	33.621
5.0	10.770	10.775	10.631	10.466	10.716	10.737	33.609	33.611	33.588	33.604	33.629	33.626
5.5	10.760	10.697	10.609	10.474	10.706	10.723	33.604	33.607	33.603	33.604	33.629	33.629
6.0	10.723	10.663	10.447	10.477	10.683	10.686	33.608	33.594	33.592	33.605	33.627	33.637
6.5	10.629	10.615	10.382	10.473	10.611	10.639	33.618	33.608	33.593	33.606	33.640	33.642
7.0	10.619	10.602	10.342	10.494	10.592	10.567	33.628	33.610	33.605	33.610	33.638	33.656
7.5	10.588	10.563	10.337	10.498	10.529	10.516	33.638	33.613	33.609	33.636	33.661	33.665
8.0	10.542	10.542	10.298	10.491	10.500	10.479	33.649	33.619	33.622	33.661	33.664	33.675
8.5	10.506	10.518	10.261	10.498	10.478	10.452	33.661	33.637	33.638	33.661	33.668	33.677
9.0	10.487	10.469	10.251	10.490	10.472	10.433	33.664	33.664	33.653	33.666	33.668	33.679
9.5	10.436	10.423	10.246	10.481	10.450	10.425	33.674	33.673	33.659	33.670	33.673	33.681
10.0	10.407	10.409	10.245	10.473	10.429	10.415	33.674	33.676	33.670	33.672	33.678	33.681
10.5	10.357	10.394	10.248	10.462	10.424	10.389	33.685	33.676	33.686	33.674	33.680	33.686
11.0	10.319	10.331	10.252	10.438	10.417	10.348	33.665	33.696	33.702	33.680	33.680	33.694
11.5	10.296	10.263	10.252	10.399	10.413	10.326	33.676	33.689	33.704	33.692	33.679	33.703
12.0	10.245	10.230	10.217	10.331	10.398	10.302	33.705	33.700	33.712	33.717	33.683	33.703
12.5	10.235	10.224	10.201	10.256	10.332	10.247	33.713	33.710	33.713	33.722	33.690	33.711
13.0	10.236	10.221	10.196	10.226	10.324	10.227	33.715	33.716	33.716	33.715	33.695	33.720
13.5	10.236	10.218	10.195	10.219	10.261	10.226	33.718	33.720	33.723	33.717	33.699	33.720
14.0	10.236	10.215	10.197	10.221	10.233	10.226	33.718	33.722	33.725	33.716	33.709	33.721
14.5	10.238	10.216		10.224	10.230	10.232	33.720	33.723		33.716	33.717	33.720
15.0	10.240	10.216		10.224	10.235	10.245	33.720	33.725		33.717	33.719	33.723
15.5					12.695						33.602	

Table 5. Vertical Profile Data Collected on 9 March 2011 (continued)

Depth (m)	Density (σ_t)						pH					
	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6
0.5				25.772	25.716	25.725				7.556	7.580	7.588
1.0	25.722	25.726	25.721	25.771	25.728	25.723	7.590	7.583	7.585	7.553	7.584	7.588
1.5	25.722	25.726	25.725	25.779	25.739	25.725	7.587	7.583	7.583	7.555	7.586	7.588
2.0	25.721	25.731	25.729	25.780	25.751	25.729	7.589	7.583	7.583	7.555	7.586	7.588
2.5	25.723	25.731	25.723	25.783	25.751	25.731	7.589	7.583	7.583	7.552	7.586	7.588
3.0	25.723	25.732	25.725	25.783	25.754	25.733	7.589	7.583	7.583	7.550	7.586	7.589
3.5	25.722	25.732	25.727	25.782	25.757	25.734	7.589	7.583	7.583	7.552	7.581	7.586
4.0	25.723	25.733	25.746	25.787	25.758	25.734	7.588	7.583	7.579	7.552	7.581	7.585
4.5	25.725	25.731	25.751	25.783	25.758	25.744	7.589	7.583	7.577	7.551	7.581	7.584
5.0	25.734	25.734	25.741	25.783	25.758	25.752	7.587	7.583	7.571	7.550	7.581	7.584
5.5	25.731	25.744	25.757	25.781	25.760	25.757	7.584	7.583	7.569	7.549	7.581	7.585
6.0	25.741	25.740	25.776	25.781	25.762	25.770	7.584	7.577	7.570	7.549	7.581	7.582
6.5	25.741	25.759	25.788	25.783	25.785	25.782	7.582	7.572	7.570	7.550	7.580	7.581
7.0	25.725	25.763	25.805	25.782	25.787	25.805	7.576	7.568	7.564	7.550	7.575	7.577
7.5	25.760	25.772	25.809	25.802	25.816	25.821	7.570	7.565	7.556	7.550	7.571	7.573
8.0	25.804	25.781	25.826	25.823	25.823	25.835	7.565	7.561	7.548	7.550	7.566	7.568
8.5	25.820	25.799	25.844	25.822	25.830	25.842	7.561	7.558	7.543	7.553	7.563	7.563
9.0	25.826	25.828	25.858	25.826	25.831	25.847	7.557	7.557	7.538	7.555	7.559	7.559
9.5	25.842	25.844	25.863	25.831	25.839	25.850	7.556	7.552	7.533	7.555	7.558	7.556
10.0	25.848	25.849	25.872	25.834	25.847	25.851	7.552	7.549	7.532	7.555	7.555	7.555
10.5	25.864	25.851	25.884	25.837	25.849	25.860	7.549	7.547	7.529	7.555	7.555	7.555
11.0	25.855	25.877	25.896	25.846	25.850	25.873	7.546	7.543	7.528	7.555	7.555	7.549
11.5	25.868	25.884	25.897	25.863	25.850	25.884	7.540	7.539	7.528	7.555	7.555	7.550
12.0	25.899	25.898	25.910	25.894	25.856	25.888	7.536	7.535	7.532	7.555	7.553	7.547
12.5	25.907	25.906	25.913	25.910	25.873	25.904	7.534	7.533	7.533	7.555	7.550	7.546
13.0	25.909	25.912	25.916	25.910	25.866	25.914	7.529	7.529	7.532	7.551	7.547	7.541
13.5	25.910	25.916	25.921	25.913	25.892	25.915	7.528	7.524	7.528	7.548	7.545	7.537
14.0	25.911	25.918	25.923	25.912	25.905	25.915	7.524	7.524	7.528	7.540	7.537	7.534
14.5	25.912	25.918		25.912	25.911	25.913	7.522	7.519		7.536	7.535	7.529
15.0	25.912	25.920		25.912	25.912	25.913	7.519	7.519		7.532	7.531	7.529
15.5					25.370						7.398	

Table 5. Vertical Profile Data Collected on 9 March 2011 (continued)

Depth (m)	Dissolved Oxygen (mg/L)						Transmissivity (%)					
	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6
0.5				5.100	5.620	5.727				77.736	76.872	76.301
1.0	5.524	5.567	5.538	5.051	5.652	5.720	76.029	76.806	75.819	77.807	76.760	76.179
1.5	5.532	5.573	5.549	5.070	5.618	5.713	76.120	76.897	76.297	77.675	76.480	76.154
2.0	5.531	5.562	5.545	5.063	5.582	5.704	76.180	76.918	76.330	77.785	76.070	76.052
2.5	5.531	5.552	5.518	5.058	5.566	5.708	76.122	76.856	76.304	77.450	75.692	74.807
3.0	5.533	5.547	5.456	5.066	5.557	5.699	76.268	77.012	76.490	77.851	75.812	75.755
3.5	5.533	5.550	5.400	5.074	5.556	5.698	76.261	76.962	76.849	77.919	75.955	75.963
4.0	5.530	5.540	5.338	5.045	5.551	5.693	76.403	76.947	77.102	77.741	75.767	75.966
4.5	5.514	5.555	5.330	5.005	5.561	5.663	76.466	76.959	77.300	78.107	75.945	76.113
5.0	5.481	5.523	5.345	5.008	5.559	5.633	76.661	76.914	77.324	78.163	75.946	76.070
5.5	5.456	5.452	5.266	5.012	5.528	5.612	76.756	77.138	77.139	78.313	76.013	76.410
6.0	5.389	5.375	5.136	5.014	5.460	5.579	76.789	77.641	77.582	78.083	78.048	76.478
6.5	5.290	5.333	5.036	5.016	5.375	5.511	77.208	77.589	78.282	78.378	79.750	77.252
7.0	5.225	5.286	4.974	5.024	5.303	5.373	77.518	77.729	78.183	78.250	80.736	79.097
7.5	5.207	5.229	4.927	5.045	5.250	5.279	76.683	78.082	78.281	78.748	80.466	80.081
8.0	5.178	5.184	4.885	5.057	5.193	5.216	75.113	78.281	77.786	79.160	80.114	80.140
8.5	5.126	5.150	4.828	5.049	5.153	5.144	76.842	78.027	79.233	79.201	80.687	80.979
9.0	5.066	5.090	4.791	5.051	5.122	5.092	77.657	80.819	79.472	79.141	81.109	82.371
9.5	4.991	5.010	4.772	5.045	5.082	5.069	81.200	83.054	79.970	79.191	81.510	82.668
10.0	4.926	4.970	4.765	5.026	5.053	5.031	82.896	82.734	80.381	79.561	81.563	82.526
10.5	4.859	4.931	4.755	5.009	5.027	4.981	82.999	83.072	81.865	79.832	82.015	82.162
11.0	4.801	4.863	4.759	4.963	4.997	4.938	83.784	83.085	83.570	81.389	82.394	82.592
11.5	4.755	4.791	4.735	4.915	4.978	4.896	83.244	84.552	83.910	82.467	82.384	82.645
12.0	4.719	4.750	4.720	4.847	4.937	4.847	81.394	84.507	83.713	82.996	82.404	83.100
12.5	4.682	4.714	4.697	4.773	4.884	4.797	78.663	83.042	84.249	83.858	82.480	82.924
13.0	4.659	4.680	4.679	4.714	4.837	4.754	77.399	81.556	83.348	82.276	83.386	80.559
13.5	4.632	4.645	4.653	4.676	4.782	4.714	76.970	81.035	80.819	80.644	83.207	79.391
14.0	4.618	4.638	4.644	4.654	4.739	4.696	75.762	79.419	79.054	79.948	81.666	79.292
14.5	4.592	4.637		4.639	4.714	4.703	73.577	77.126		79.687	79.822	77.830
15.0	4.582	4.628		4.638	4.705	4.663	72.802	76.108		79.051	77.864	74.447
15.5					4.538						75.947	

At the time of the March 2011 survey, the fundamental vertical structure of seawater characteristics was comparable to other upwelling periods. Near the seafloor, upwelling had transported cold, dense seawater (red and black lines in Figure 7) onshore to replace nearshore surface waters that were driven offshore by prevailing winds. These deep offshore waters had not been in recent direct contact with the atmosphere, and biotic respiration and decomposition had depleted their DO levels (dark blue lines). In contrast to the relatively fresh surface waters associated with the southward-flowing California Current, however, the slightly elevated salinity (green lines in Figure 6) within 5 m of the seafloor was indicative of waters that originate in the Southern California Bight and had been carried northward by the Davidson Undercurrent.

Nutrient-rich seawater brought to the sea surface by upwelling facilitates phytoplankton blooms that produced oxygen and consumed carbon dioxide (CO₂). With depth, the rate of respiration to photosynthesis increases, resulting in a corresponding increase in dissolved CO₂ (carbonic acid) and a concomitant decline in pH (olive-colored lines). Additionally, the associated increases in primary productivity generated by upwelling also typically result in a slight reduction in water clarity (light-blue lines) near the sea surface compared to mid-depth. Closer to the seafloor, decreased water clarity arises from detritus resuspended above the seafloor within the benthic nepheloid layer. Sandwiched between these turbid layers at the base of the thermocline, the clear seawater within the deep watermass is apparent as a distinct maximum in transmissivity.

The influence of the discharge can be seen in the vertical profiles recorded at both Station RW3 and Station RW4 (Figure 7cd). Typically, the presence of dilute wastewater appears as a sharp reduction in salinity and density at depth. However, no such signature was apparent at either station indicating that the buoyant effluent plume was quickly being diluted beyond recognition as it rose through the water column. In contrast, because of the natural vertical stratification at the time of the survey, ambient seafloor water properties were entrained within the rising plume and were juxtaposed with differing mid-water properties, thereby creating a plume signature associated with discharge dynamics rather than wastewater.

For example, throughout the upper half of the water column at Station RW4, when the CTD was within the ZID, DO (dark blue line), pH (gold line), and temperature (red line) were noticeably lower than at other stations, while transmissivity (light blue line) and density (black line) were slightly higher (Figure 7d). The differing upper water column characteristics at Station RW4 were consistent with the plume's entrainment and upward transport of ambient seawater properties within the deep, seafloor watermass. This deep water mass was denser, cooler, clearer, more oxygen-depleted, more acidic, and saltier than the naturally occurring waters within the upper water column. The increased water clarity within the upper water column at Station RW4 was also reflected in its markedly increased Secchi depth (Table 4). Increased water clarity is opposite of the change that would be induced by the presence of turbid wastewater particulates, further indicating that the changes seen in the upper water column at Station RW4 resulted from vertical entrainment processes.

The discharge-related signature at Station RW4 extended to the sea surface, indicating that the plume had risen to the sea surface before completing the initial dilution process. Thus, despite the moderate stratification that prevailed at the time of the survey, the plume had not become trapped at depth as predicted by plume modeling. In contrast, the entrainment signature evident within the vertical profiles at

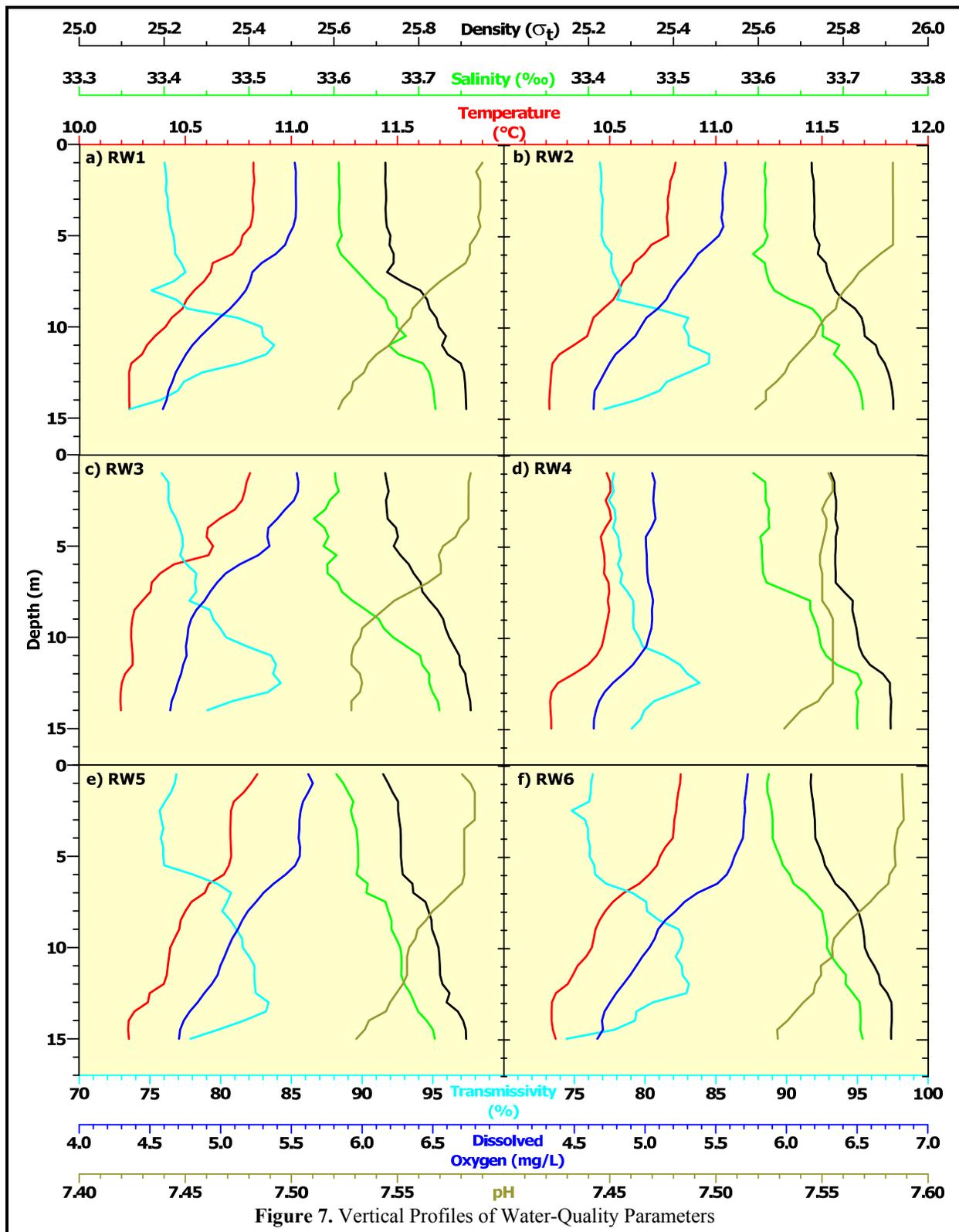


Figure 7. Vertical Profiles of Water-Quality Parameters

Station RW3 was restricted to mid depth, indicating that the hydrocast had captured the plume while it was continuing to rise within the water column. Specifically, upward excursion of lower DO, pH and temperature is apparent between 5 and 10 m at Station RW3 (Figure 7c). Again, however, the anomalous mid-depth properties at Station RW3 are consistent with the upward transport of ambient bottom water rather than the presence of wastewater particulates. Although not as deep as at Station RW4, the Secchi depth of 7 m recorded in the vicinity of the RW3 hydrocast, was 1 m deeper than at stations beyond the influence of the plume (Table 4).

Also, the plume signature at Station RW3 was located northeast of the diffuser structure, in a direction opposite of the prevailing near-surface current measured by the drifter (Figure 2). This indicates that flow within the deep water mass was shoreward, in opposition with the offshore flow within the upper water column. Strongly sheared flows, and even vertical counter currents are a hallmark of stratified conditions. During the March 2011 survey, the deep shoreward flow initially transported the plume toward the northeast (Station RW3), but as the plume rose farther in the water column, strong southwestward flow moved the plume offshore, resulting in its arrival at the sea surface at Station RW4.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the March 2011 survey, and dilutions anticipated from modeling studies that were codified in the discharge permit through limits imposed on effluent constituents. Specifically, the critical initial dilution applicable to the MBCSD outfall was conservatively estimated to be 133:1 (Tetra Tech 1992). That is, dispersion modeling estimated that, at the conclusion of the minimum expected initial mixing, 133 parts of ambient seawater would have mixed with each part of wastewater.

The 133:1 dilution estimate was based on worst-case modeling under highly stratified conditions, where trapping of the plume below a strong thermocline would curtail the buoyant mixing normally associated with turbulence generated by the plume's rise through the water column. Additionally, the modeling assumed quiescent oceanic flow conditions, thereby restricting initial mixing processes to the ZID. Under those conditions, the modeling predicted that a 133:1 dilution would be achieved after the plume rose only 9 m from the seafloor, whereupon it would become trapped. A 9-m rise at the MBCSD outfall translates into a trapping depth that is 6.4 m below the sea surface, just above the mid-depth (8.3 m) tow survey and slightly below the shallow (5.6 m) tow survey conducted on 9 March 2011.

The conservative nature of the critical initial dilution determined from the modeling is an important consideration because it was used to specify permit limitations on chemical concentrations in wastewater discharged from the treatment plant. These end-of-pipe effluent limitations were back calculated from the receiving-water objectives in the COP (SWRCB 2005) using the projected 133-fold dilution determined from the modeling. Use of a higher critical dilution would relax the stringent end-of-pipe effluent limitations thought necessary to meet COP objectives after initial dilution is complete.

End-of-pipe limitations on contaminant concentrations within discharged wastewater were based on the definition of dilution (Fischer et al. 1979). From the mass-balance of a conservative tracer, the concentration of a particular chemical constituent within effluent before discharge (C_e) can be determined from Equation 1.

$$C_e \equiv C_o + D(C_o - C_s) \quad \text{Equation 1}$$

where: C_e = the concentration of a constituent in the effluent,
 C_o = the concentration of the constituent in the ocean after dilution by D (*i.e.*, the COP receiving-water objective),
 D = the dilution expressed as the volumetric ratio of seawater mixed with effluent, and
 C_s = the background concentration of the constituent in ambient seawater.

By rearranging Equation 1, the actual dilution achieved by the outfall can be determined from measured seawater anomalies. This measured dilution can then be compared with the critical dilution factor determined from modeling. Salinity is an especially useful tracer because it directly reflects the magnitude of ongoing dilution. Wastewater-induced patches of lower salinity are apparent near the ZID in the tow-survey maps (Figures 8b and 9b). These localized salinity anomalies reflect the presence of dilute wastewater within the effluent plume as it rose and spread within the water column.

Because the salinity concentration in effluent is negligible, C_e is eliminated in Equation 1 and the dilution ratio (D) can be computed from the salinity anomaly ($A = C_o - C_s$) as:

$$D = \frac{-C_o}{(C_o - C_s)} \equiv \frac{-C_o}{A} \quad \text{Equation 2}$$

where: D = the dilution ratio of the volume of seawater mixed with effluent,
 C_o = the salinity of the effluent-seawater mixture after dilution by D ,
 C_s = the background seawater salinity (approximately 33.8‰), and
 $A = C_o - C_s$ = the salinity anomaly.

The lowest salinity (33.611‰) measured during the March 2011 survey was recorded within the ZID at a depth of 8.2 m during Transect D4 of the deep tow survey (Figure 8b). The measured salinity corresponds to a wastewater-induced reduction of -0.068‰ below the mean ambient salinity of 33.679‰ that was measured at the same depth level well beyond the influence of the discharge. It documents the presence of wastewater that has been diluted 492-fold. This is nearly four times the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater. In addition, the measurement was recorded below the 6.4-m trapping depth assumed in modeling, and well below the sea surface where the plume ultimately completed the initial dilution process during the March 2011 survey.

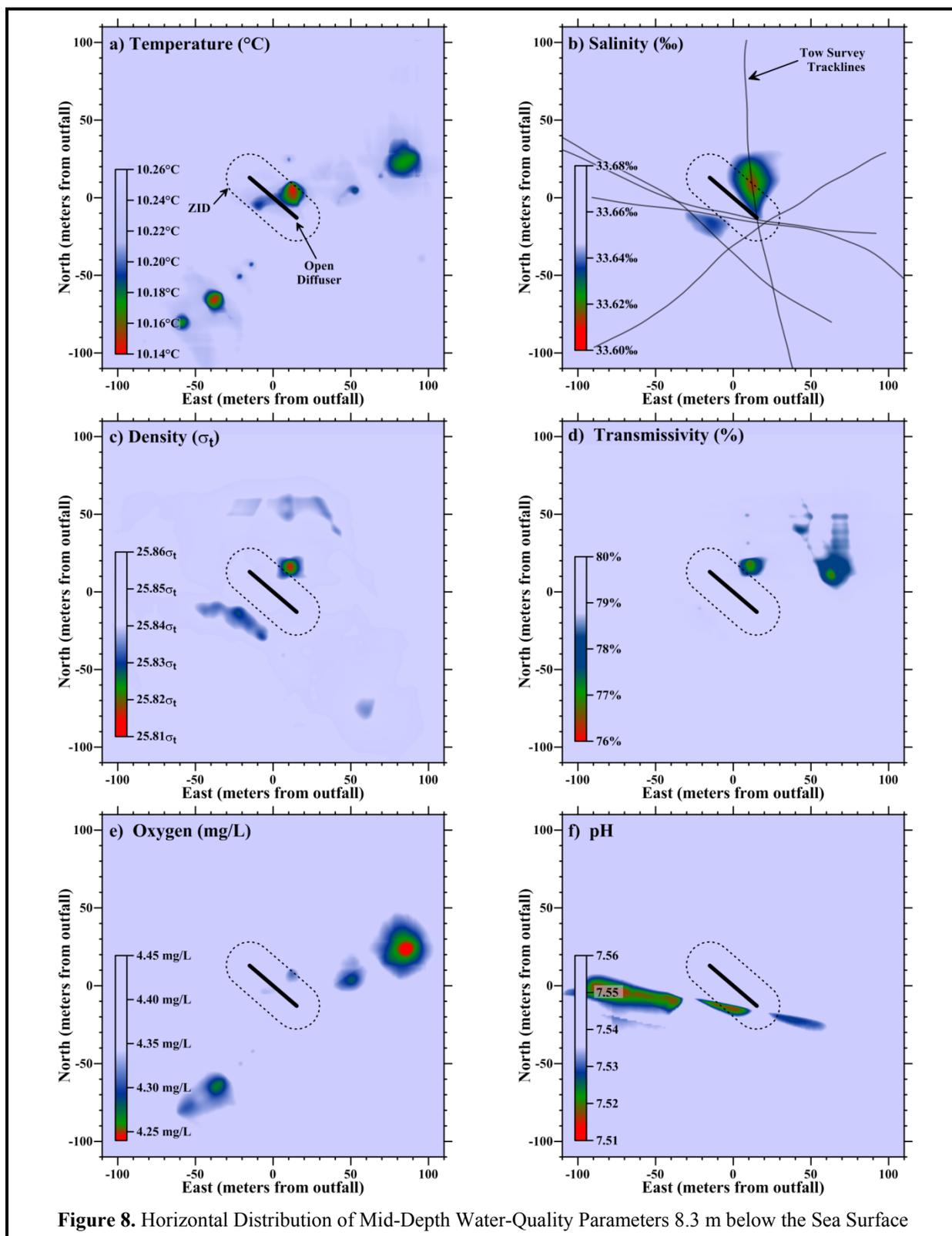
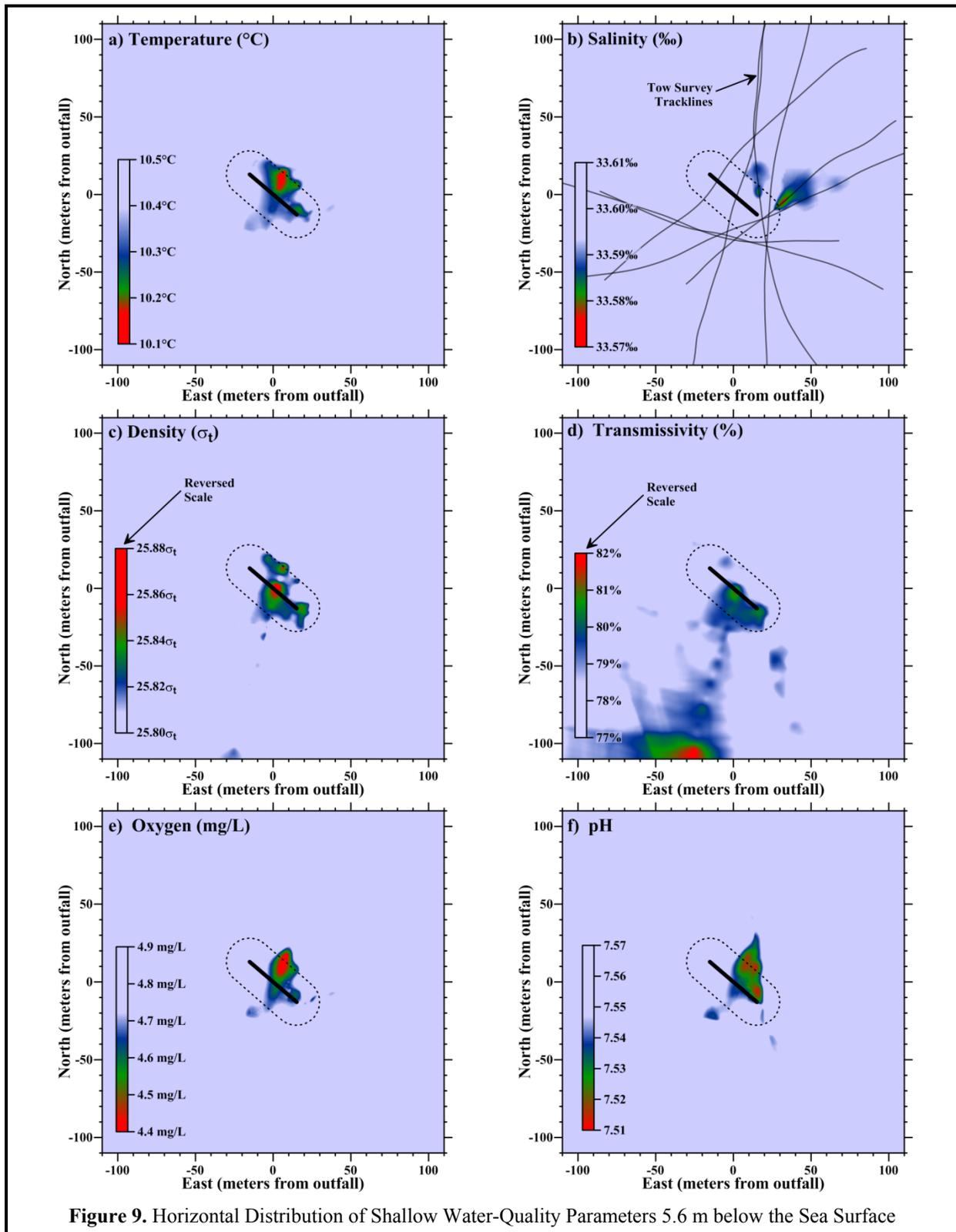


Figure 8. Horizontal Distribution of Mid-Depth Water-Quality Parameters 8.3 m below the Sea Surface



At that depth, the plume was still being transported to the northeast, and lower-dilution portions of the plume extended beyond the ZID, as shown by the shading in the salinity field of Figure 8b. In addition, these data were collected near the base of the thermocline where seawater properties were close to those of the deep water mass. Consequently, there was negligible lateral contrast in entrained seawater properties, and no definitive anomalies were apparent in other seawater properties (Figures 8acdef). Specifically, DO and pH did not exhibit anomalies that coincided with the salinity minimum, and the slightly reduced temperature, density, and transmissivity (Figures 8acd) that coincided with the salinity minimum were comparable to other, apparently random fluctuations observed at that depth level in those seawater properties.

Thus, the general absence of a clear plume signature resulted both from the low contrast with entrained bottom waters, and from the high wastewater dilution associated with the salinity anomaly (Figure 10). At dilution levels near 500-fold, any perceptible change caused by the presence of wastewater constituents would have long since dissipated.

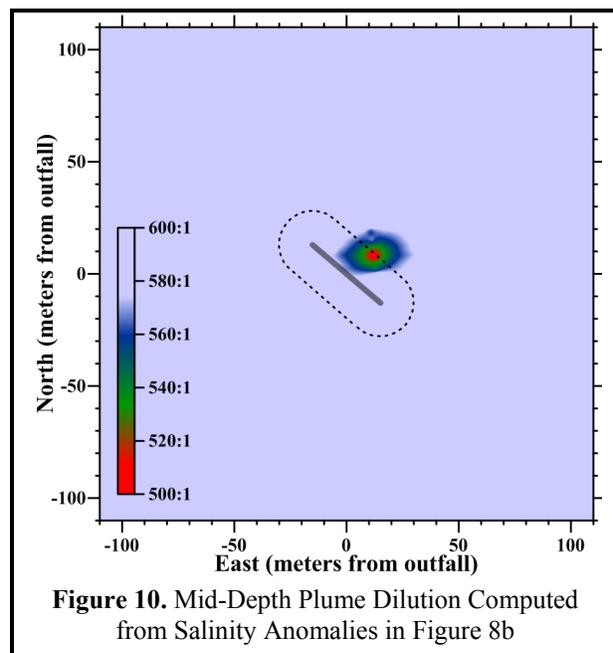


Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b

By the time the plume had risen the short distance to the shallow tow depth, dilutions exceeded 600-fold and the plume signature could not be reliably discerned against the backdrop of existing natural salinity variations (Figure 9b). However, entrainment-related anomalies in other seawater properties became apparent because the contrast between seawater properties within the deep watermass and the shallow properties was greater. In particular, an entrainment-generated plume signature was apparent in localized reductions in temperature, DO, and pH (Figures 9aef). More importantly, the positive density anomaly (Figure 9c) associated with these entrainment features indicates that the plume was negatively buoyant. Nevertheless, the momentum of the rising plume continued to carry it upward as it drifted toward the southwest until it eventually reached the sea surface near Station RW4. The negative density anomaly in Figure 9c demonstrates that rising plume had overshot its equilibrium depth, and had actually become 'heavier' than the surrounding water. However, at that depth, the plume was continuing to mix due to slowly damped vertical oscillations within the nearly uniform mixed layer.

The high-resolution measurements collected during both the vertical profiles and the horizontal tows demonstrate that that the plume was undergoing complex initial mixing processes within and beyond the ZID. Although the plume was not trapped below the sea surface, it achieved dilution levels well in excess of the critical initial dilution (133:1) assumed to occur at a 6.4-m trapping depth. Even 1.9 m below this trapping depth, and within the ZID, the plume had achieved dilution levels nearly four times higher than those predicted by the modeling. Upon rising slightly higher to the 5.6-m level of the shallow tow mid-depth tow, the plume had achieved dilution levels in excess of 600-fold.

The dilution computations demonstrate that, during the March 2011 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 495-fold well within the ZID and before completion of the initial-dilution process. This dilution level exceeds the 133:1 critical dilution used to establish end-of-pipe permit limitations on contaminant concentrations within wastewater discharged from the MBCSD treatment plant. Consequently, during the March 2011 survey, the COP receiving-water

objectives were being easily met by the limits on chemical concentrations within discharged wastewater that are promulgated by the NPDES discharge permit issued to the MBCSD.

COMPLIANCE

This section evaluates compliance with the water-quality permit limits listed in the NPDES permit (Table 6). The limitations themselves are based on criteria in the COP, the Central Coast Basin Plan, and other state and federal policies that were designed to protect marine life and beneficial uses of ocean waters.

Table 6. Permit Provisions Addressed by the Offshore Receiving-Water Surveys

Limit #	Limit
P1	Floating particles or oil and grease to be visible on the ocean surface
P2	Aesthetically undesirable discoloration of the ocean surface
P3	Temperature of the receiving water to adversely affect beneficial uses
P4	Significant reduction in the transmittance of natural light at any point outside the ZID
P5	The DO concentration outside the zone of initial dilution to fall below 5.0 mg/L or to be depressed more than 10% from that which occurs naturally
P6	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

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 permit thresholds. Specifically, the quantitative analyses described in this section focus on water-property excursions caused by the presence of wastewater constituents beyond the ZID 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.

The results of these analyses applied to the March 2011 data demonstrate that the MBCSD discharge complied with the NPDES discharge permit. 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 discharge permit. Thus, the quantitative evaluation described in this section documents an outfall and treatment process that was performing at a high level during.

Permit Provisions

The offshore receiving-water surveys are designed to assess compliance with objectives dealing with undesirable alterations to six physical and chemical characteristics of seawater. Specifically, the permit states that wastewater constituents within the discharge shall not cause the limits listed in Table 6 to be exceeded.

The first two receiving-water limits, P1 and P2, rely on qualitative visual observations for compliance evaluation. As described previously, no floating wastewater materials, oil, grease, or discoloration of the sea surface were observed during the March 2011 survey.

Compliance with the remaining four receiving-water limitations is quantitatively evaluated through a comparison of instrumental measurements and the specific numerical limits listed in the NPDES permit. For example, in P5 and P6, the fixed numeric limits on absolute values of DO (>5 mg/L) and pH (7.0 to 8.3) can be directly compared with field measurements within the dilute wastewater plume. However,

both P5 and P6 also contain narrative limits, which arise from 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.

Natural variation in seawater properties is driven by the oceanographic processes described previously. Those 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, which are subject to a compliance evaluation, from changes that arise because of the upward movement of ambient seawater, which are specifically excluded from the compliance evaluation.

Screening of Measurements

Evaluating whether any of the 4,025 CTD measurements collected during the March 2011 survey exceeded a permit limit can be a complex process. For example, although apparently significant excursions in an individual seawater property may be related to the presence of wastewater constituents, they may also result from instrumental errors, natural processes, entrainment of ambient bottom waters in the rising effluent plume, statistical uncertainty, ongoing initial mixing within and beyond the ZID, or other anthropogenic influences (e.g. dredging or oil spills).

Because of this complexity, measurements were first screened to determine whether numerical limits on individual seawater properties apply (Table 7). The screening procedure sequentially applies three questions 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. The following subsection provides additional lines-of-evidence that demonstrate compliance with numerical permit limits independent of the screening process. However, the screening process described in this section unequivocally eliminated all of the CTD measurements

Table 7. Receiving-Water Measurements Screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer		Parameter
		No	Yes ¹⁴	
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	441	3,584	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?	3,579	5	All
Natural Variation	3. Did seawater properties associated with any measurement depart significantly from the expected range in ambient seawater properties at the time of the survey?	5	0	Temperature
		5	0	Transmissivity
		5	0	DO
		5	0	pH

¹⁴ Number of CTD observations of potential compliance interest based on this screening question

collected during the March 2011 survey from further compliance analysis. The rationale for eliminating observations from further compliance analysis is provided in the following three screening steps.

1. 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 strong currents can 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 March 2011 dataset eliminated 441 of the original 4,025 receiving-water observations from further consideration because they were collected within the ZID (Table 7). As described previously, some of the remaining 3,584 observations were collected within the buoyant effluent plume as it continued mixing beyond the ZID; however, for initial for screening purposes, all of these measurements were carried forward in the compliance analysis.

2. Presence of Wastewater Constituents: The MBCSD discharge permit 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 anomalies that arise from the movement of ambient seawater entrained in the effluent plume. Analyses conducted on quarterly receiving-water surveys over the last 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, salinity provides a powerful tracer of dilute wastewater that is unrivaled by other seawater properties. Other properties do not exhibit such a large contrast and, as such, their wastewater signatures dissipate rapidly upon discharge with very little mixing. Wastewater’s lack of salinity, however, provides a powerful marker that allows the presence of effluent constituents to be identified even after dilution many times greater than the 133-fold critical initial dilution assumed in the discharge permit.

As described in the previous section, wastewater-induced reductions in salinity can be used to directly determine the amount of dilution achieved by initial mixing. Wastewater’s lack of salinity allows the presence of effluent constituents to be identified within receiving seawater well beyond the 133-fold critical initial dilution assumed in the discharge permit. Based on statistical analyses of the natural variability in salinity readings measured near the outfall over a five-year period between 2004 and 2008, the smallest reduction in salinity that can be reliability detected within receiving waters is 0.062‰. This represents a dilution level of 542-fold. Reductions that are smaller than 0.062‰, cannot be reliably discerned against the backdrop of natural variation and would not result in discernable changes in other seawater properties. Eliminating those measurements from further compliance evaluation restricts attention to excursions in temperature, light transmittance, DO, and pH that are related to the presence of wastewater constituents. During the March 2011 survey, only 17 low-salinity observations were identified as potentially being caused by the presence of wastewater constituents. However, 12 of these were recorded within the ZID where receiving-water limits do not apply because initial mixing was still taking

place. Of the 3,584 observations that were measured outside the ZID during the March 2011 survey, only five had reductions in salinity that were greater than 0.062‰ (Table 7).

3. Natural Variation: An integral part of the compliance analysis is determining whether a particular anomalous measurement resulted from the presence of wastewater constituents, or whether it simply became apparent because ambient seawater was relocated by the plume. If the measurement does not significantly depart from the natural range in ambient seawater properties at the time of the survey, then it is difficult to ascribe the departure to the presence of wastewater constituents. Thus, quantifying the natural variability around the outfall is necessary for determining whether a particular observation warrants comparison with numeric permit limits.

A statistical analysis of receiving-water data previously collected around the outfall was used to establish the range of variability in natural conditions surrounding the outfall (Table 8). These ranges in natural variability were used to identify significant departures from ambient conditions that could be indicative of adverse discharge-related effects on water quality.

Table 8. Thresholds for Significant Departures from Natural Conditions

Water Quality Property	Natural Variability Threshold¹⁵	95th Percentile^{16,17}	95% Confidence Bound¹⁸
Temperature (°C)	>11.64	10.82	0.82
Transmissivity (%)	<65.6	75.8	-10.2
DO (mg/L)	<3.27	4.65	-1.38
pH (minimum)	<7.434	7.528	-0.094
pH (maximum)	>7.682	7.588	0.094

The same five-year database used to establish the natural within-survey salinity variation discussed previously was also used to establish one-sided 95% confidence bounds on transmissivity (-10.2%), temperature (+0.82°C), DO (-1.4 mg/L), and pH (\pm 0.094). These were combined with 95th percentiles determined from the March 2011 ambient seawater data, to establish natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from March 2011 vertical profile data, excluding measurements potentially affected by the discharge, specifically the measurements recorded at Stations RW3 and RW4 which were acquired within the ZID where ongoing mixing is expected.

Temperature, transmissivity, DO, and pH values associated with the remaining five measurements of compliance interest all remained within their respective ranges of natural variability (Table 7). Consequently, all 4,025 CTD measurements collected during the March 2011 survey complied with the receiving-water limitations specified in the MBCSD discharge permit because all documented excursions either occurred within the ZID where mixing was still ongoing, or were the result of physical processes unrelated to the presence of wastewater constituents.

¹⁵ Thresholds represent limits on wastewater-induced changes to receiving-water properties that significantly exceed natural conditions as specified in the discharge permit and COP. They are determined from the sum of columns to the right and are specific to the March 2011 survey. They do not include the COP allowances specified in the column to the left.

¹⁶ The COP (Appendix I, Page 27, SWRCB 2005) defines a “significant” difference as “a statistically significant difference in the means of two distributions of sampling results at the 95% confidence level.” Accordingly, COP effluent analyses (Step 9 in Appendix VI, Page 42, Ibid.) are based “the one-sided, upper 95% confidence bound for the 95th percentile.”

¹⁷ The 95th-percentile quantifies natural variability in seawater properties during the March 2011 survey, and was determined from vertical profiles excluding RW3 and RW4 where there were possible influences from the discharge.

¹⁸ The one-sided confidence bound is used to measure the ability to reliably estimate percentiles within surveys as a whole. They were determined from an analysis of the variability in ambient water-quality data collected during 20 quarterly surveys conducted between 2004 and 2008. Although water-quality observations potentially affected by the presence of wastewater constituents were excluded from the analysis, more than 9,200 observations for each of the six seawater properties accurately quantify the inherent uncertainty in defining the range in natural conditions.

Other Lines of Evidence

In addition to the analysis provided above, several additional lines of evidence support the conclusion that all the CTD measurements collected during the March 2011 survey complied with permit limits P3 through P6 in Table 6. In combination, these lines of evidence provide the “best explanation” of the origin and significance of individual measurements using abductive inference (Suter 2007). This process, which has been used to implement sediment-quality guidelines for California estuaries (SWRCB 2009), emphasizes a pattern of reasoning which accounts for both the discrepancies among multiple lines of evidence as well as concurrences. A best explanation approach 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 permit during the March 2011 survey.

Natural Variability in other Seawater Properties: Although the permit limits only apply to changes in DO, pH, temperature and transmissivity, a comparative evaluation of changes in the remaining seawater properties (salinity, density) frequently provides additional valuable insight into the origins of any variations observed during a particular survey. For example, during the March 2011 survey, salinity was the only seawater property that exhibited a perceptible difference from ambient conditions. As discussed previously, none of the original 4,025 CTD observations exceeded the thresholds of natural variability for temperature, DO, pH, or transmissivity specified in Table 8. This includes measurements collected within the ZID and close to the outfall that were eliminated from further compliance consideration by the first screening question in Table 7. However, even though 12 measurements from inside the ZID had salinity reductions that were clearly associated with presence of wastewater constituents, each of these were too dilute to induce water-quality changes in the other properties that were perceptibly different from natural conditions at the time of the survey (Screening Question 2 in Table 7).

Insignificant Thermal Impact: Although there are no explicit numerical objectives for discharge-related decreases in temperature, a numerical limit can be established for the narrative limit on thermal excursions, which are not allowed to adversely affect beneficial uses (P3 in Table 6). Increases in temperature caused by the discharge of warm wastewater constituents would not adversely affect beneficial uses as long as they remain within the natural temperature range at the time of the survey (11.64°C in Table 8). Such was the case for all 4,025 CTD measurements collected during the March 2011 survey. In fact, because effluent entrained cold bottom water shortly after discharge, the rising plume actually had a lower temperature than the surrounding water (Figure 9a).

Light Penetration: As with temperature, there are no explicit numerical objectives for discharge-related decreases in transmissivity. However, the COP narrative objective (P4) limiting significant reductions in the transmission of natural light can also be translated into a numerical objective. Specifically, because the COP does not specify an allowance beyond natural conditions, the same threshold on ambient transmissivity variations listed in Table 8 can be interpreted to constitute a numerical limit. Because natural light is restricted to the euphotic zone, which extends to approximately twice the Secchi depth, the limit on transmissivity reductions applied to measurements above 12 m during the March 2011 survey (twice the ambient Secchi depth listed in Table 4). Regardless, the March 2011 survey data met the requirement of the COP narrative objective (P4) that there be no significant reduction in the transmittance of natural light at any point outside the ZID because none of the applicable transmissivity measurements was below 65.6% (Table 8).

Insignificant Wastewater Particulate Loads: The discharge of wastewater particulates on 9 March 2011 did not contribute materially to turbidity within the dilute effluent plume. The suspended-solids concentration measured onshore within effluent prior to discharge was 26 mg/L. After dilution by 492-fold, which was the lowest dilution measured during the survey, the effluent TSS concentration would

have the reduced ambient transmissivity by only 0.4%. Instead, shortly after discharge, wastewater mixed with relatively clear seawater within the deep watermass. As the plume moved upward into the more turbid waters within the mixed layer, plume transmissivities were actually higher than the surrounding waters. This accounts for the increased Secchi depths measured at Stations RW3 and RW4 (Table 4), and demonstrates that the discharge process was locally increasing the penetration of natural light rather than decreasing it, as restricted in the permit.

Non-Discharge-Related Exceedances of Basin-Plan Limits: Permit provisions P5 and P6 (Table 6) combine receiving-water objectives from both the COP and the Basin Plan with regard to DO and pH limitations. The COP requires that DO concentrations outside the ZID not be depressed more than 10% from that which occurs naturally, and restricts pH measurements to those within 0.2 units of that which occurs naturally. In contrast, the Basin-Plan's fixed numerical limits do not provide specific guidance as to how they might change in response to widespread changes in oceanographic conditions unrelated to the discharge. Specifically, the fixed numerical limits restrict DO concentrations outside the ZID to no less than 5 mg/L (P5 in Table 6), and pH levels to the 7.0-to-8.3 range (P6). While pH within all 4,025 of the CTD observations measured during the March 2011 survey remained well within the acceptable range, the same was not true for the DO measurements. Although all of the observed DO concentrations were within the ambient range measured at the time of the survey, and therefore complied with the COP portion of the permit provision, more than half (2,537 or 63%) of the observations were below the 5 mg/L Basin-Plan threshold.

The low DO concentrations resulted from the the most intense La Niña event to occur off the California coast in over 35 years (MRS 2011). The associated unrelieved upwelling depleted oxygen levels within the nearshore environment, and resulted in background DO concentrations well below the monitoring program's previously documented historical lows of 4.5 mg/L. As discussed previously, unusually low ambient DO concentrations were also documented during both the August and October 2010 receiving-water surveys.

Unfortunately, naturally occurring DO concentrations below 5 mg/L were simply not envisioned within coastal waters when the Basin Plan was promulgated in 1972. However, because the NPDES permit applies the Basin-Plan DO limit (P5) only when excursions are caused by the presence of wastewater constituents, none of the low DO concentrations measured during the March 2011 survey were subject to the limit. At the time of the survey, oxygen-demanding material within effluent could not have perceptibly depleted DO concentrations within receiving waters. This is because the MBCSD treatment process routinely removes 80% or more of the organic material, as demonstrated by the, 72-mg/L biochemical oxygen demand (BOD) measured within an effluent sample collected from the treatment plant on the day following the March 2011 survey. That small amount of BOD would induce a DO depression of no more than 0.023 mg/L after dilution (MRS 2003), which was insignificant compared to the natural variability during the March 2011 survey. In fact, in the absence of tangible BOD influence, wastewater would actually be expected to increase DO within subsurface receiving waters, rather than decrease it. 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, particularly during periods of pronounced upwelling. As expected, effluent DO concentrations measured shortly after discharge have typically been found to be higher than those of the deep receiving waters.

CONCLUSIONS

The statistical screening analysis quantitatively demonstrated that all measurements recorded during the March 2011 survey complied with the receiving-water limitations specified in the NPDES discharge permit. This conclusion was further strengthened by a wide variety of other lines of evidence supporting

compliance with the discharge permit. Although the presence of dilute wastewater constituents was delineated from salinity anomalies within a discharge plume that was localized near and within the ZID, all the associated seawater properties were within natural variability that prevailed at the time of the survey

Immediately after discharge, the outfall was achieving dilution levels in excess of 492-fold, which exceeded the critical dilution levels predicted by design modeling. Additionally, throughout the water column, computed dilution levels outside the ZID typically achieved dilutions in excess of 600-fold. Lastly, all of the auxiliary observations collected during the March 2011 survey demonstrated that the discharge complied with the narrative receiving-water limits in the discharge permit and COP. All of these observations demonstrated that the treatment process, diffuser structure, and the outfall continue to perform at levels exceeding design expectations.

Although discharge-related changes in seawater properties were observed during the March 2011 survey, the changes were either not of significant magnitude, were measured within the boundary of the ZID where initial mixing is still expected to occur, or were not directly caused by the presence of wastewater constituents within the water column.

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