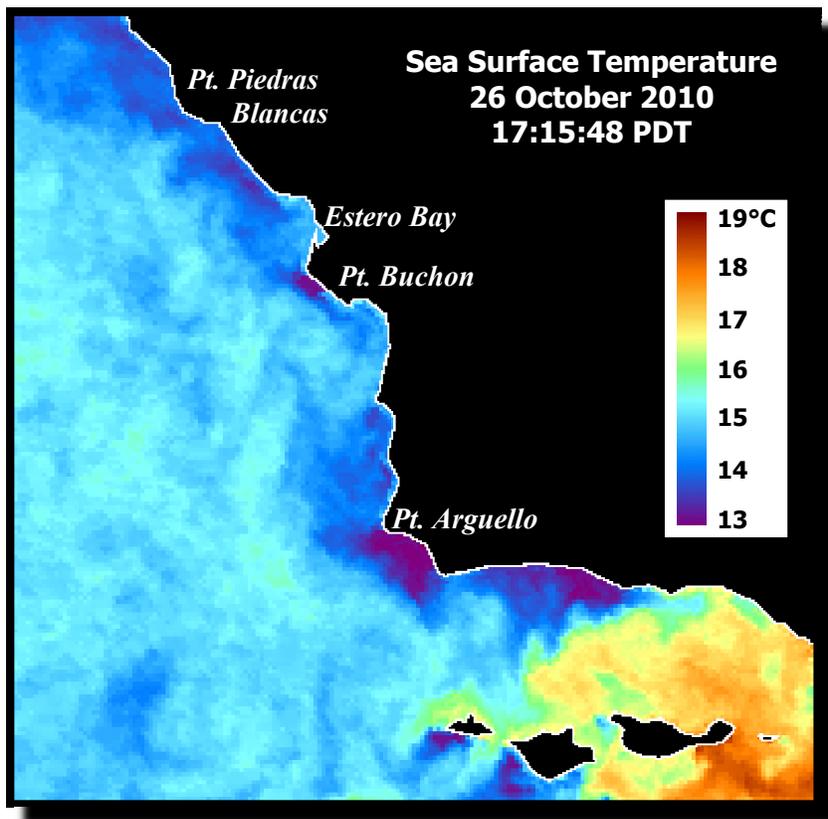


**City of Morro Bay and
Cayucos Sanitary District**

**OFFSHORE MONITORING
AND REPORTING PROGRAM**

**FOURTH QUARTER
RECEIVING-WATER SURVEY
OCTOBER 2010**



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**

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RECEIVING-WATER SURVEY**

OCTOBER 2010

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January 2011

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

31 January 2011

Reference: Fourth Quarter Receiving-Water Survey Report – October 2010

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Thursday, 7 October 2010. 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 fall 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 October 2010 field survey described in this report was the seventh receiving-water survey conducted under the current permit.

Under the NPDES discharge permit, seasonal monitoring of offshore receiving-water quality is conducted on a quarterly basis. This report summarizes the results of sampling conducted on 7 October 2010. Specifically, this fourth-quarter survey captured ambient oceanographic conditions along the central California coast during the fall 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, define the extent of the discharge plume, and evaluate compliance with the NPDES permit limitations.

¹ Conductivity, temperature, and depth (CTD)



Figure 1. Location of the Receiving-Water Survey Area

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.

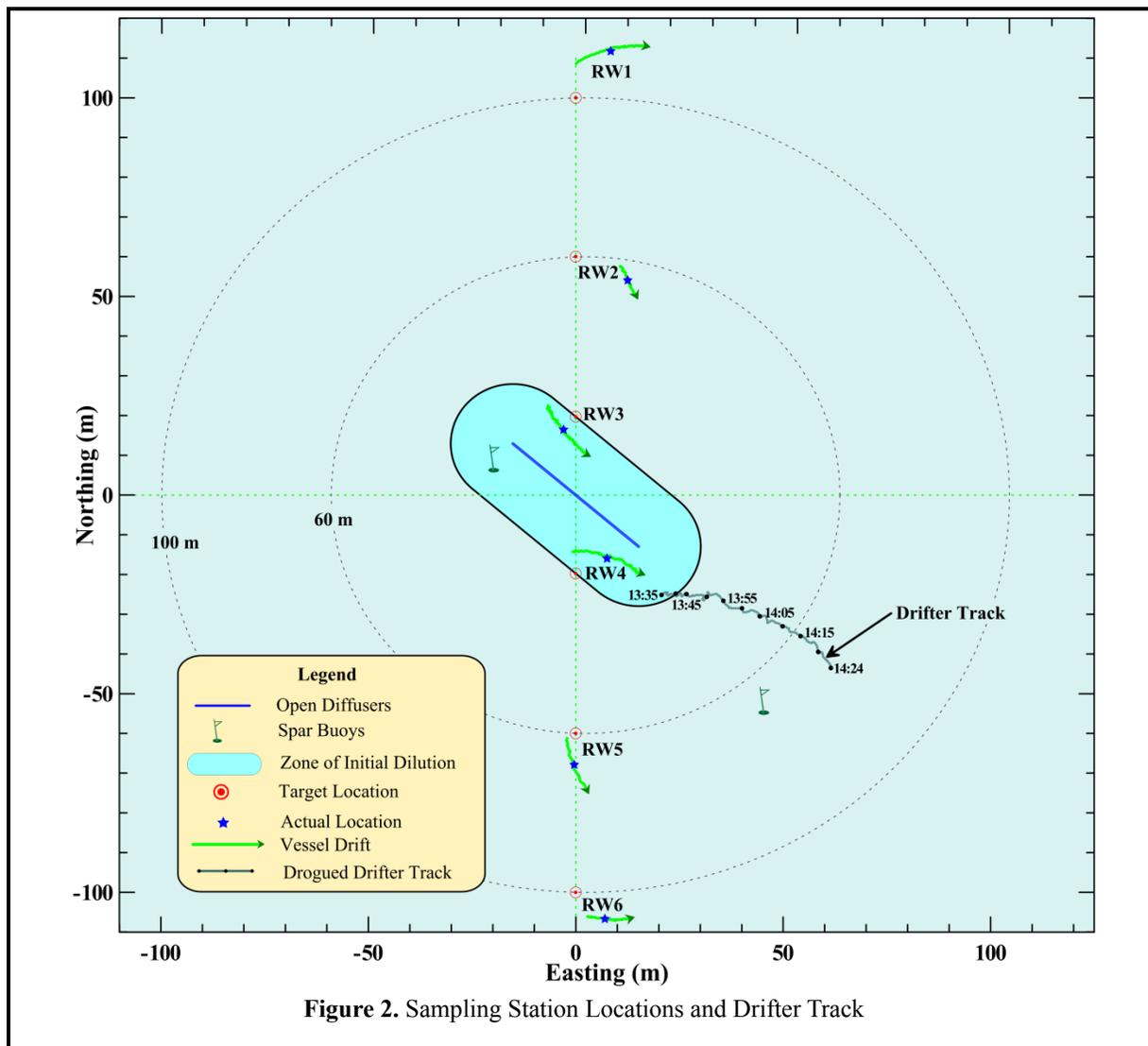


Figure 2. Sampling Station Locations and Drifter Track

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 locate 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 meteocean⁴ 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 October 2010 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 October 2010 survey. During the time it took the CTD to traverse the water column and reach the seafloor, which averaged 1 min 17 s, the instrument package moved an average of 13.4 m, which is fairly typical of most surveys.

The CTD trajectories shown by the tracklines in Figure 2 often reflect complex interactions between surface currents and wind forces that act on the survey vessel during sampling. Generally, winds can move the vessel to a greater degree than current flow. However, the constant but light winds during the October survey were directed toward the southeast, in a direction aligned with the prevailing waves and currents. As a result, the relative influence of these individual processes on vessel drift cannot be determined from the October 2010 survey. Regardless of which was the dominant process, however, vessel drift at all six stations was to the east or southeast. The slight differences among the tracklines also reflect differences in the residual momentum of the survey vessel as it approached each target location. Brief thrust reversals were successful at eliminating the majority of residual vessel momentum prior to initiation of the downcast, allowing winds and currents to also visibly influence vessel transport during each vertical cast.

Although relatively small, and comparable to the survey vessel's 12-m length, lateral drift of the CTD during the vertical hydrocasts can complicate 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 October 2010 survey, none of the measurements recorded at Stations RW3 and RW4 were subject to the limitations because the CTD was within the ZID boundary throughout the entirety of the vertical casts at those stations (Figure 2).

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 requires 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 October 2010 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 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.

Table 2. Average Position of Vertical Profiles during the October 2010 Survey

Station	Time (PDT)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ⁵ (m)	Bearing ⁶ (°T)
RW1	13:53:32	13:54:42	35° 23.259' N	120° 52.498' W	101.7	13
RW2	13:57:05	13:58:18	35° 23.228' N	120° 52.496' W	49.7	34
RW3	14:00:11	14:01:32	35° 23.208' N	120° 52.506' W	10.7 ⁷	221
RW4	14:03:51	14:05:18	35° 23.190' N	120° 52.499' W	7.1 ⁷	221
RW5	14:07:26	14:08:39	35° 23.162' N	120° 52.504' W	56.9	196
RW6	14:12:07	14:13:27	35° 23.141' N	120° 52.499' W	94.0	185

OCEANOGRAPHIC PROCESSES

The trajectory of a satellite-tracked drogued drifter documented a weak but steady east-southeastward flow during the October 2010 survey (Figure 2). 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. Following the loss of the drifter during the August 2010 survey, a new drifter was constructed for deployment during the October 2010 survey. The current drifter is slightly larger than the original model, but otherwise consistent in its design.

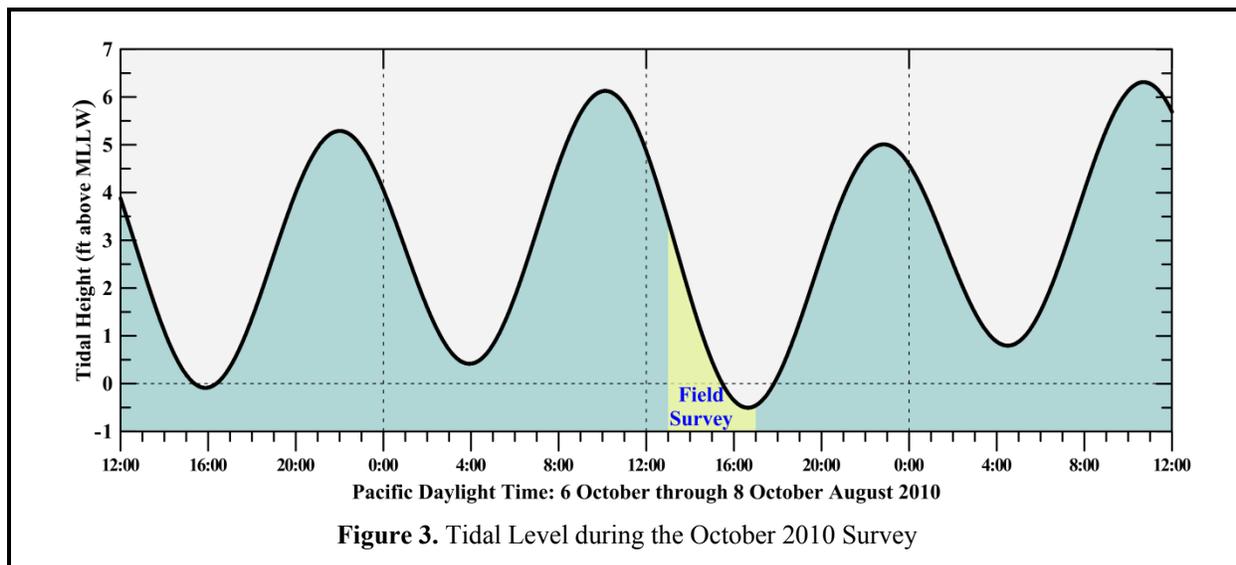
The drifter was deployed just south of the ZID at 13:35 PDT, and was recovered an hour later, at a location 45 m southeast of its deployment location. The black dots in Figure 2 show the drifter’s progress at five-minute intervals. The evenly spaced time stamps reflect the slow, but relatively constant speed of the drifter, which averaged 1.5 cm/s, or 0.03 knots.

Flow was initially directed due east, but at 13:50 PDT, the drifter track acquired a southerly component that was partially consistent with the outgoing (ebb) tide (Figure 3). In the absence of other influences, an ebb tide normally induces a weak southwestward (offshore) flow in the survey region. However, flow is

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.

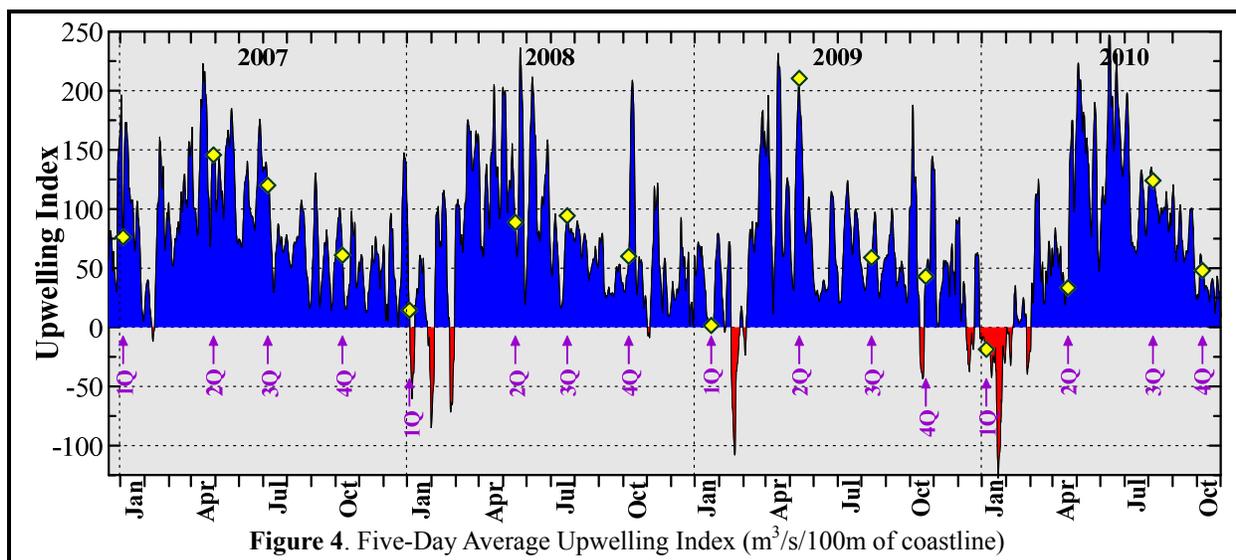
⁷ The CTD casts at stations RW3 and RW4 were located entirely within the ZID boundary.



often also influenced by external processes, such as wind-generated upwelling or passing offshore eddies. Specifically, upwelling also 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 4. 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.

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 4, 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.

Stronger-than-normal winds measurably increased the persistence and strength of upwelling events along the central California coastline during much of 2010. Combined with a rapidly strengthening La Niña condition, this acted to depress seawater temperatures in the region. For example, throughout the summer, seawater temperatures averaged only 12°C at the nearby Diablo Canyon Nuclear Power Plant intake. This is a full two degrees cooler than normal, and represents the lowest average temperature since records started being kept in 1976.⁸

La Niña phenomena are characterized by unusually cold ocean temperatures in the equatorial Pacific. During a La Niña event, high pressure builds in the eastern equatorial Pacific while low pressure develops to the west, producing a stronger equatorial pressure gradient. The easterly trade winds strengthen, causing upwelling off the coastlines of Peru and Ecuador to intensify, and lowering sea surface temperatures throughout the Eastern Pacific Ocean, including along California's central coast.

The satellite image on the cover of this report documents conditions two and a half weeks after the October survey, when skies were clear enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA's polar orbiting satellites. Persistent cloud cover throughout much of the month prevented the acquisition of a satellite image closer to the survey date. Nevertheless, the sea surface temperatures (15°C) depicted in the satellite image were only slightly warmer than the near-surface temperatures measured by the CTD (<14°C) during the October 2010 survey.⁹

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on Thursday, 7 October 2010. 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

⁸ http://www.sanluisobispo.com/2010/08/28/1267200/la_nina_helping_chill_our_summer.html

⁹ Refer to Table 5 and Figure 6 for receiving-water properties recorded during the vertical hydrocasts.

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 October 2010 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	Depth¹⁰	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

¹⁰ Maximum depth limit in meters

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 , 7 ± 0.01 , 8 ± 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 water surface while transiting between adjacent stations.

At 14:13 PDT, following the last vertical profile at RW6, 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 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 5).

Initially, the reconfigured CTD package was towed for 45 min at an average depth of 3.4 m,¹¹ and an

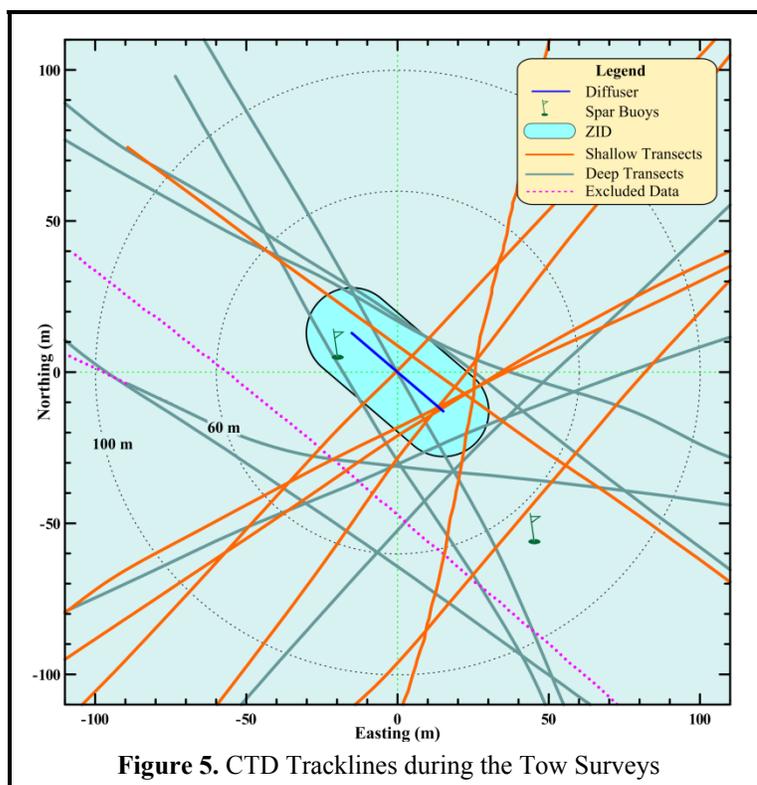


Figure 5. CTD Tracklines during the Tow Surveys

¹¹ Average depth of the seven shallow tow transects evaluated in the compliance analysis. One additional transect was removed from consideration due to a vertical offset in tow depth as described in the *Quality Control* section.

average speed of 1.8 m/s, passing near the diffuser structure eight times. Subsequently, eight additional passes were made with the CTD at an average depth of 8.1 m. During this 39-minute mid-depth-tow, vessel speed averaged 1.7 m/s. At the observed towing speeds and 2 Hz sampling rate, 1.1 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.¹²

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.

First, the entire data set was screened for “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 October 2010 survey.

Preliminary review of the raw CTD data also determined that data recorded during portions of the shallow tow survey were collected at depths that were substantially offset from the remainder of the tow data. Specifically, near the beginning of the fifth shallow tow transect, a large piece of giant kelp (*Macrocystis pyrifera*) became snagged on the CTD apparatus, introducing vertical instability in the subsequent tow transects.

Although the water column was only moderately stratified at the time of the October 2010 survey, reductions in tow depth caused by the snagged kelp resulted in substantial increases in reported temperatures. 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 included. Nevertheless, most of the data collected during tows S5, S6, and S8 were usable because the CTD depth remained below 1 m where a sharp thermocline is apparent in the vertical temperature profiles.¹³ However, during tow S7, the snagged kelp caused the CTD to rise within 1 m of the sea surface, rendering the data from that transect useless. Therefore, all the data from that tow were excluded from the subsequent analysis (shown by the dotted purple line in Figure 5) to avoid introducing erroneous lateral differences in the horizontal property maps.¹⁴ Exclusion of this data did not, however, adversely affect the compliance analysis because the remaining transects adequately covered the survey region and met the permit monitoring requirement of at least five passes near the diffuser structure at each tow depth (orange and green lines in Figure 5).

¹² Figures 7 and 8 present the horizontal maps of seawater properties measured during the October 2010 survey.

¹³ Shown in red in Figure 6 on Page 19

¹⁴ Shown in Figures 7 and 8 on Pages 21 and 22

Similarly, because the overall length of the CTD is close to the 0.5-m standard depth bins used to report the vertical profile data, the ability to compute average values for seawater properties at locations very near the sea surface and seafloor varies depending on how the CTD's depth is influenced by wave and tidal-induced oscillations during its deployment at each station. For example, during the October 2010 survey, data on average seawater properties were not recorded within the shallowest depth bin (0.5 m) at Stations RW5 and RW6 (see Table 5 on Page 16) or within the deepest depth bin (below 15 m) at any station except RW5. Because the spatial coverage of the observations at the very deepest and shallowest depth levels could not adequately quantify horizontal trends, the observations were excluded from the subsequent compliance evaluation.

Additionally, the presence of numerous large egg yolk jellyfish (*Phacellophora camtschatica*) throughout the survey region sporadically impacted the operation of various sensors on the CTD. Particularly during the towed survey, jellies can often become snagged on the CTD or sucked into the CTD pump apparatus. Fortunately, impacts to the CTD sensors from jelly collisions are generally fleeting, and do not require the exclusion of extended segments of data.

Finally, as in the August 2010 survey, lower than average DO concentrations were recorded throughout the water column. Near the sea surface, where seawater is normally saturated through atmospheric equilibration, the highest ambient DO concentrations were only 53% of saturation (5.14 mg/L). DO measurements near the seafloor were similarly depressed, with some measurements dropping slightly below historical lows of approximately 4.5 mg/L (41% saturation). This marks a slight increase from August conditions, when DO concentrations at depth approached 3 mg/L (35% saturation). Although it is normal to find naturally low-oxygen conditions in deep, offshore waters, the occurrence of low-oxygen water so close to shore (on the inner continental shelf, or in less than 50 m of water) is highly unusual.

The extremely large DO offsets that were first noted in August 2010 prompted an investigation into the operation and calibration of the DO sensor to ensure that the measured concentrations were not artifacts of a mechanical malfunction or processing error. However, following the August survey the sensor was confirmed to be working properly through a post-survey calibration. In addition, the saturation endpoints during calibration of the CTD were also independently confirmed with a separate DO sensor, indicating that the data were accurately recorded.

Further analysis indicated that the low ambient DO measurements likely resulted from the unusually prolonged period of strong upwelling that prevailed throughout much of the summer season and persisted well into fall (Figure 4). Typically recognized as the primary driver behind the productive fisheries of the central California coast, the August and October surveys document an extended period of time when upwelling had actually become "too much of a good thing."

As discussed previously, nutrient-rich seawater, brought to the sea surface by upwelling facilitates phytoplankton blooms that produced oxygen and consume carbon dioxide (CO₂). Normally, the northwesterly winds that promote upwelling are not constant. When they intermittently relax, mixing of the waters on the continental shelf takes place, replenishing subsurface waters with oxygen. If this periodic relaxation of the winds does not occur, however, 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 uses up oxygen in nearshore waters. Thus, the intensity and duration of upwelling events that occurred throughout the summer of 2010, led to abnormally low DO levels that persisted into fall and were observed in the water column during the October 2010 survey when DO levels ranged between 40% and 60% of full saturation.

Although the low ambient DO concentrations recorded during both the August and October 2010 surveys were not 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.

RESULTS

The fourth-quarter receiving-water survey was conducted on the afternoon of Thursday, 7 October 2010, following the completion of the annual benthic monitoring survey. The receiving-water survey commenced at 13:35 PDT with the deployment of the drogued drifter. Over the following two and a half hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended just after 16:15 PDT with the recovery of the CTD from its mid-depth-tow configuration. Observations of beneficial use and the collection of required visual observations of the sea surface were unencumbered throughout the survey.

Auxiliary Observations

Although an energetic upper-level low pressure system had moved through the region the previous day producing rainfall totals of between one-half to three-quarters of an inch throughout the county, by the beginning of the October 2010 survey the skies had cleared. Winds were mild, but constant throughout the survey, with average wind speeds, calculated over one-minute intervals, ranging from 2.0 to 5.0 kt, and peak wind speeds ranging from 2.7 to 6.0 kt (Table 4). The swell was out of the northwest with a significant wave height of 3 to 4 feet. Air temperatures were several degrees warmer than average surface-water temperatures, and varied from 15.8°C to 19.8°C.

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location ¹⁵		Diffuser Distance (m)	Time (PDT)	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° 23.259' N	120° 52.491' W	103.5	13:55:10	19.3	10	2.0	3.3	NW	3-4/NW	6.0
RW2	35° 23.227' N	120° 52.498' W	45.6	13:58:02	17.4	10	3.1	3.7	NW	3-4/NW	6.0
RW3	35° 23.207' N	120° 52.502' W	13.7	14:00:54	17.2	10	2.2	2.7	NW	3-4/NW	6.0
RW4	35° 23.188' N	120° 52.503' W	13.2	14:04:19	19.8	10	2.4	3.3	NW	3-4/NW	5.0
RW5	35° 23.163' N	120° 52.502' W	54.9	14:07:55	16.3	10	3.1	4.6	NW	3-4/NW	6.0
RW6	35° 23.143' N	120° 52.499' W	90.2	14:12:33	15.8	10	5.0	6.0	NW	3-4/NW	6.0

The 6-m Secchi depths recorded at most stations during the October 2010 survey indicated a moderate level of ambient water clarity (Table 4). The Secchi depths reflected the presence of a 12-m euphotic zone that extended most of the 16-m water column. Additionally, there was no evidence of wastewater-related floating particulates, oil sheens, or discoloration of the sea surface observed at any of the stations during vertical profiling, or at any other time during the survey. 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 October 2010 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. As usual, wildlife sightings during the

¹⁵ Locations are the vessel positions recorded at the time the Secchi depth was measured and may depart from the CTD profile locations listed in Table 2.

survey were dominated by Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), and western gulls (*Larus occidentalis*). California brown pelicans (*Pelecanus occidentalis californicus*) were also noted occasionally transiting the survey area. Marine mammal observations included several California sea lions (*Zalophus californianus*), and a southern sea otter (*Enhydra lutris nereis*). As noted previously, numerous egg yolk jellyfish (*Phacellophora camtschatica*) were also present in the waters of Estero bay during the October 2010 water column survey. These large jellyfish have bells up to 60 cm (2 ft) in diameter and clusters of tentacles reaching 6 meters (20 ft) long. They feed mostly on smaller jellyfish and other gelatinous zooplankton.

As stated previously, although conditions on the day of the survey were generally sunny and fair, a rapidly moving low-pressure system had passed through the region on the preceding afternoon and evening depositing approximately half an inch of rain locally. Not surprisingly, beach usage by pedestrians was limited during the October 2010 survey. Additionally, no fishing vessels or surfers were observed in the nearshore waters on the afternoon 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 October 2010 survey reflect the presence of a mildly 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 extending 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 6 as decreases in temperature (red lines), DO (dark blue lines), and pH (gold lines) with increasing depth. These decreases are mirrored by a pycnocline where density (black lines) steadily increases with depth. Specifically, the profiles reflect the vertical juxtaposition of a near-surface mixed layer and a colder, clearer, nutrient-rich but more oxygen-poor water mass at depth. Normally, upwelling induces a sharp interface between the two water masses, but the wind and wave action from the energetic upper-level low which had passed through the region the previous afternoon and evening had eroded much of this interface and the vertical gradients extended throughout most of the water column.

Nevertheless, at the time of the October 2010 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 6) 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, 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). Normally, the associated increases in primary productivity generated by upwelling also result in a slight reduction water clarity (light-blue lines) near the sea surface compared to waters at depth; however, wind and wave action from the previous day's storm had mixed near-surface waters downward into the water column. The quick-moving storm contributed approximately one-half to three quarters of an inch of precipitation to the Morro Bay area. The effects of the sudden influx of freshwater from the storm can be seen in the generally lower salinities recorded within the upper water column (above 6 m) at each of the six sampling stations.

The influence of the discharge plume can be seen in the vertical profiles recorded at both Station RW3 and Station RW4 (Figure 6cd). The plume appears at Station RW4 as a sharp reduction in salinity and density near 10 m. However, with only mild stratification present in the water column to inhibit mixing, the buoyant plume was rapidly diluted beyond recognition as it continued to rise through the water column. In the vertical profiles at both stations, entrainment of bottom waters by the rising effluent plume can be seen to visibly compress the thermocline (red line) and reduce the thickness of the overlying surface mixed layer. Specifically, DO, pH, and temperature at Station RW4 were slightly, but perceptibly lower throughout the upper half of the water column, compared to the other stations. The differing mid-depth seawater characteristics at Station RW4 were consistent with plume's entrainment and upward transport of ambient seawater properties within the seafloor watermass, which was denser, cooler, clearer, more oxygen-depleted, and more acidic than naturally occurring waters within the upper water column.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the October 2010 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 slightly above the mid-depth (8.1 m) tow survey and below the shallow (3.4 m) tow survey conducted on 7 October 2010.

Table 5. Vertical Profile Data Collected on 7 October 2010

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					13.775	13.680					33.580	33.594
1.0	13.779	13.568	13.984	13.667	13.920	13.776	33.565	33.548	33.556	33.543	33.566	33.522
1.5	13.723	13.610	13.926	13.638	13.918	13.784	33.553	33.540	33.569	33.532	33.556	33.546
2.0	13.599	13.495	13.651	13.411	13.802	13.756	33.533	33.527	33.586	33.461	33.539	33.543
2.5	13.490	13.396	13.288	13.151	13.685	13.684	33.464	33.517	33.528	33.442	33.534	33.525
3.0	13.291	13.204	13.227	13.067	13.559	13.543	33.476	33.507	33.527	33.497	33.517	33.509
3.5	13.123	13.103	13.640	13.039	13.379	13.427	33.495	33.521	33.509	33.483	33.494	33.509
4.0	13.104	13.088	13.475	12.984	13.187	13.382	33.544	33.533	33.481	33.467	33.489	33.485
4.5	13.147	13.128	13.323	12.970	13.099	13.275	33.568	33.560	33.454	33.479	33.495	33.529
5.0	13.142	13.165	13.149	12.934	13.069	13.212	33.577	33.572	33.485	33.486	33.513	33.527
5.5	13.131	13.154	13.016	12.955	13.078	13.234	33.577	33.577	33.487	33.515	33.528	33.560
6.0	13.106	13.135	13.019	13.015	13.114	13.229	33.572	33.576	33.513	33.536	33.549	33.560
6.5	13.083	13.119	13.059	13.036	13.132	13.186	33.564	33.577	33.486	33.547	33.569	33.558
7.0	13.069	13.114	12.994	13.082	13.150	13.147	33.567	33.576	33.501	33.547	33.566	33.557
7.5	13.064	13.096	13.010	13.103	13.142	13.098	33.568	33.581	33.531	33.551	33.560	33.563
8.0	13.053	13.085	13.059	13.113	13.096	13.087	33.571	33.582	33.579	33.548	33.572	33.566
8.5	13.046	13.084	13.079	13.102	13.086	13.073	33.571	33.581	33.582	33.548	33.570	33.571
9.0	13.035	13.073	13.081	13.080	13.075	13.069	33.574	33.581	33.581	33.554	33.576	33.573
9.5	13.014	13.065	13.083	13.062	13.072	13.068	33.577	33.582	33.581	33.534	33.578	33.573
10.0	13.005	13.051	13.084	12.976	13.068	13.063	33.578	33.580	33.581	33.406	33.581	33.576
10.5	13.001	13.037	13.082	12.872	13.068	13.050	33.580	33.581	33.580	33.442	33.582	33.574
11.0	12.972	13.009	13.067	12.868	13.035	13.037	33.588	33.581	33.580	33.470	33.583	33.567
11.5	12.902	12.954	13.014	12.867	12.944	12.944	33.588	33.582	33.573	33.489	33.585	33.572
12.0	12.861	12.898	12.971	12.823	12.902	12.939	33.591	33.588	33.576	33.512	33.578	33.566
12.5	12.809	12.798	12.926	12.761	12.859	12.826	33.604	33.599	33.584	33.510	33.582	33.588
13.0	12.766	12.762	12.814	12.751	12.757	12.735	33.606	33.602	33.594	33.508	33.594	33.598
13.5	12.744	12.745	12.759	12.742	12.731	12.738	33.609	33.603	33.592	33.555	33.598	33.597
14.0	12.737	12.737	12.736	12.731	12.723	12.718	33.609	33.605	33.601	33.585	33.597	33.600
14.5	12.735	12.726	12.732	12.727	12.684	12.698	33.608	33.605	33.603	33.583	33.606	33.600
15.0			12.722	12.704	12.677	12.698			33.605	33.585	33.603	33.594
15.5					12.695						33.602	

Table 5. Vertical Profile Data Collected on 7 October 2010 (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					25.136	25.091					7.522	7.501
1.0	25.124	25.154	25.074	25.130	25.096	25.091	7.518	7.499	7.528	7.475	7.525	7.513
1.5	25.126	25.139	25.097	25.127	25.088	25.108	7.527	7.503	7.531	7.484	7.525	7.516
2.0	25.136	25.153	25.167	25.118	25.099	25.112	7.531	7.504	7.533	7.486	7.528	7.516
2.5	25.105	25.165	25.196	25.156	25.120	25.113	7.532	7.504	7.530	7.482	7.528	7.516
3.0	25.155	25.196	25.207	25.216	25.132	25.129	7.532	7.505	7.506	7.472	7.524	7.516
3.5	25.203	25.227	25.110	25.210	25.151	25.153	7.528	7.498	7.526	7.466	7.522	7.515
4.0	25.244	25.239	25.121	25.209	25.185	25.143	7.520	7.490	7.523	7.461	7.511	7.511
4.5	25.254	25.252	25.131	25.221	25.207	25.198	7.511	7.485	7.513	7.456	7.497	7.504
5.0	25.262	25.254	25.189	25.233	25.227	25.210	7.509	7.486	7.492	7.452	7.490	7.500
5.5	25.265	25.260	25.218	25.251	25.237	25.231	7.513	7.497	7.477	7.451	7.486	7.505
6.0	25.265	25.263	25.237	25.256	25.246	25.232	7.514	7.507	7.465	7.451	7.486	7.511
6.5	25.264	25.267	25.208	25.260	25.258	25.239	7.516	7.514	7.461	7.456	7.493	7.516
7.0	25.269	25.268	25.233	25.251	25.253	25.246	7.513	7.518	7.458	7.469	7.499	7.516
7.5	25.271	25.275	25.253	25.250	25.249	25.260	7.513	7.518	7.457	7.478	7.507	7.514
8.0	25.276	25.277	25.281	25.246	25.268	25.265	7.508	7.513	7.470	7.488	7.506	7.505
8.5	25.277	25.277	25.279	25.248	25.268	25.272	7.507	7.512	7.480	7.492	7.502	7.499
9.0	25.281	25.279	25.278	25.257	25.275	25.274	7.507	7.508	7.483	7.494	7.499	7.494
9.5	25.288	25.281	25.277	25.245	25.278	25.274	7.505	7.506	7.485	7.494	7.495	7.492
10.0	25.291	25.283	25.277	25.163	25.280	25.277	7.503	7.504	7.487	7.490	7.493	7.490
10.5	25.293	25.287	25.277	25.211	25.281	25.279	7.503	7.502	7.488	7.479	7.493	7.489
11.0	25.305	25.292	25.279	25.234	25.288	25.276	7.498	7.498	7.488	7.458	7.491	7.484
11.5	25.319	25.304	25.285	25.249	25.308	25.298	7.496	7.495	7.487	7.450	7.487	7.480
12.0	25.329	25.319	25.296	25.275	25.311	25.294	7.493	7.491	7.481	7.444	7.475	7.469
12.5	25.350	25.347	25.311	25.286	25.322	25.334	7.485	7.485	7.474	7.432	7.466	7.458
13.0	25.359	25.357	25.340	25.286	25.352	25.359	7.477	7.477	7.466	7.418	7.453	7.443
13.5	25.366	25.361	25.350	25.324	25.360	25.358	7.462	7.463	7.445	7.412	7.441	7.428
14.0	25.367	25.364	25.361	25.349	25.361	25.364	7.451	7.450	7.431	7.406	7.429	7.418
14.5	25.367	25.366	25.364	25.349	25.375	25.368	7.437	7.436	7.422	7.404	7.421	7.410
15.0			25.367	25.355	25.374	25.363			7.410	7.401	7.411	7.403
15.5					25.370						7.398	

Table 5. Vertical Profile Data Collected on 7 October 2010 (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					5.105	5.271					72.863	71.588
1.0	5.244	5.258	5.200	4.935	5.182	5.328	72.124	72.737	72.482	71.963	72.040	71.868
1.5	5.211	5.220	5.212	4.897	5.153	5.321	71.745	72.650	71.908	72.099	71.762	71.567
2.0	5.149	5.182	5.094	4.784	5.120	5.321	72.570	72.772	72.023	72.299	72.457	72.093
2.5	5.088	5.115	5.016	4.738	5.086	5.243	72.372	72.470	72.543	72.225	72.501	71.954
3.0	5.043	5.061	5.019	4.765	5.020	5.199	73.335	72.910	72.421	72.160	72.899	72.597
3.5	5.047	5.083	5.172	4.737	4.947	5.168	73.282	72.867	72.369	72.483	72.636	73.067
4.0	5.123	5.136	5.114	4.743	4.932	5.149	72.258	72.535	72.337	72.321	72.860	73.545
4.5	5.206	5.234	5.057	4.735	4.934	5.207	70.556	71.661	72.692	71.980	72.803	72.433
5.0	5.222	5.296	5.014	4.737	4.963	5.224	69.960	70.393	72.724	71.941	72.590	71.566
5.5	5.209	5.310	4.990	4.781	5.000	5.296	70.533	70.704	72.371	72.509	72.857	71.475
6.0	5.196	5.309	5.012	4.847	5.075	5.307	70.513	71.582	72.549	72.330	71.949	71.468
6.5	5.183	5.283	4.997	4.874	5.120	5.307	71.309	71.230	71.955	72.324	71.884	71.761
7.0	5.177	5.263	4.976	4.914	5.145	5.287	71.807	71.353	72.372	71.572	71.802	72.092
7.5	5.186	5.251	5.076	4.944	5.129	5.241	71.843	72.168	72.380	71.697	72.406	72.857
8.0	5.171	5.244	5.136	4.953	5.092	5.227	72.044	72.202	71.984	71.497	71.812	72.976
8.5	5.166	5.241	5.140	4.955	5.080	5.216	72.818	72.036	71.984	72.282	71.142	72.908
9.0	5.146	5.235	5.139	4.952	5.077	5.208	73.190	72.243	71.781	72.419	72.080	72.551
9.5	5.123	5.219	5.149	4.888	5.071	5.199	73.339	72.465	71.551	72.418	71.142	72.857
10.0	5.114	5.212	5.152	4.739	5.055	5.172	73.496	72.428	71.357	72.044	72.882	72.722
10.5	5.099	5.183	5.140	4.681	5.034	5.128	72.693	72.501	71.446	72.335	72.593	73.429
11.0	5.054	5.146	5.110	4.691	4.966	5.072	73.910	73.739	71.904	73.185	73.172	73.579
11.5	4.998	5.088	5.055	4.687	4.882	4.985	73.812	74.183	73.846	73.693	75.100	75.420
12.0	4.944	5.023	5.007	4.619	4.844	4.939	74.936	74.713	75.340	72.846	75.684	75.284
12.5	4.897	4.926	4.955	4.554	4.769	4.832	74.887	75.135	75.259	73.642	75.844	75.697
13.0	4.836	4.880	4.847	4.524	4.691	4.746	75.867	75.553	74.808	73.659	75.848	75.880
13.5	4.797	4.837	4.776	4.510	4.654	4.708	75.299	75.150	74.773	74.435	76.265	75.897
14.0	4.760	4.809	4.740	4.494	4.623	4.671	75.461	74.864	74.871	75.100	75.882	75.806
14.5	4.738	4.764	4.720	4.468	4.585	4.635	74.457	74.261	74.739	75.148	76.033	75.350
15.0			4.682	4.434	4.549	4.592			73.132	75.294	74.906	75.953
15.5					4.538						75.947	

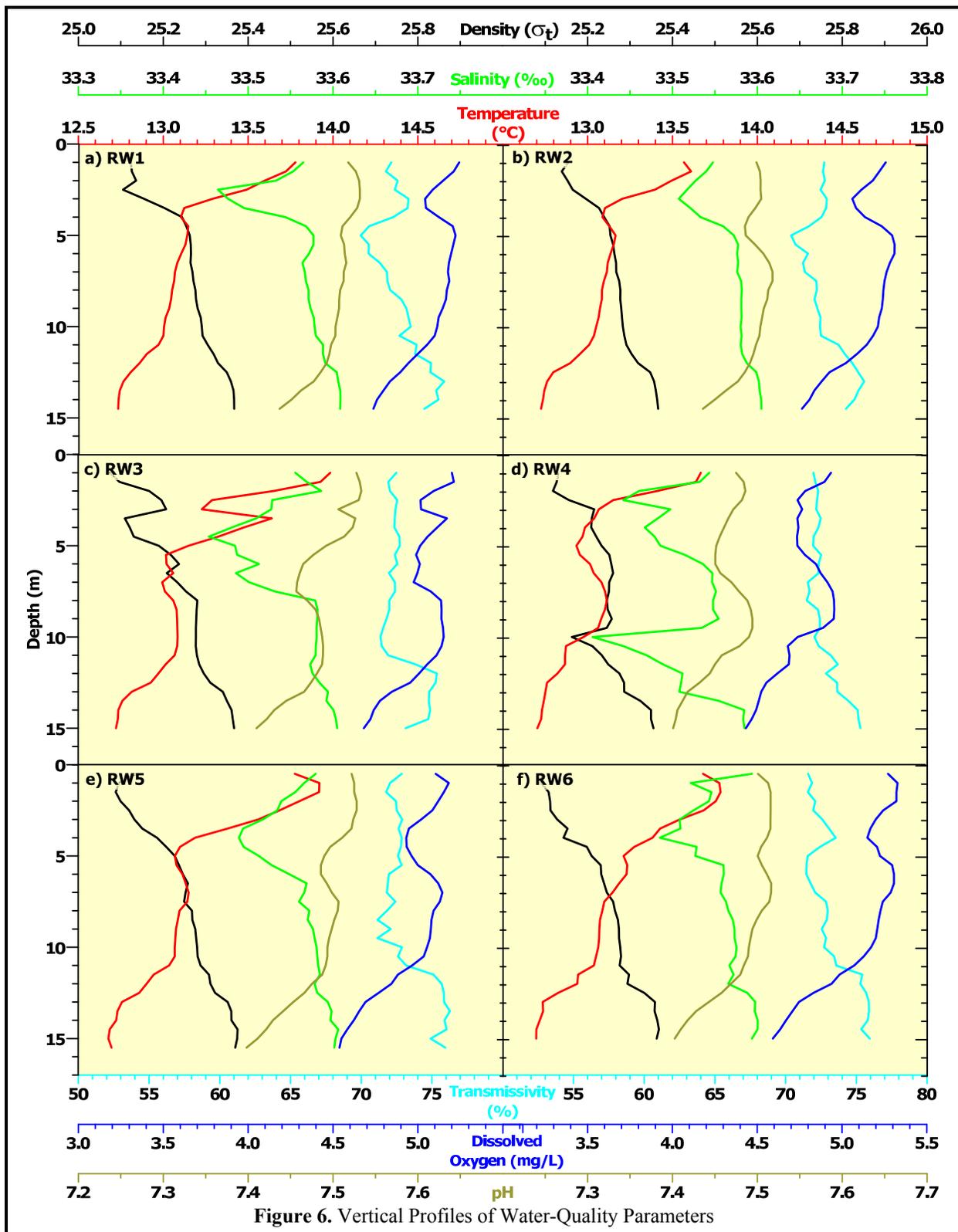


Figure 6. Vertical Profiles of Water-Quality Parameters

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 7b and 8b). 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.

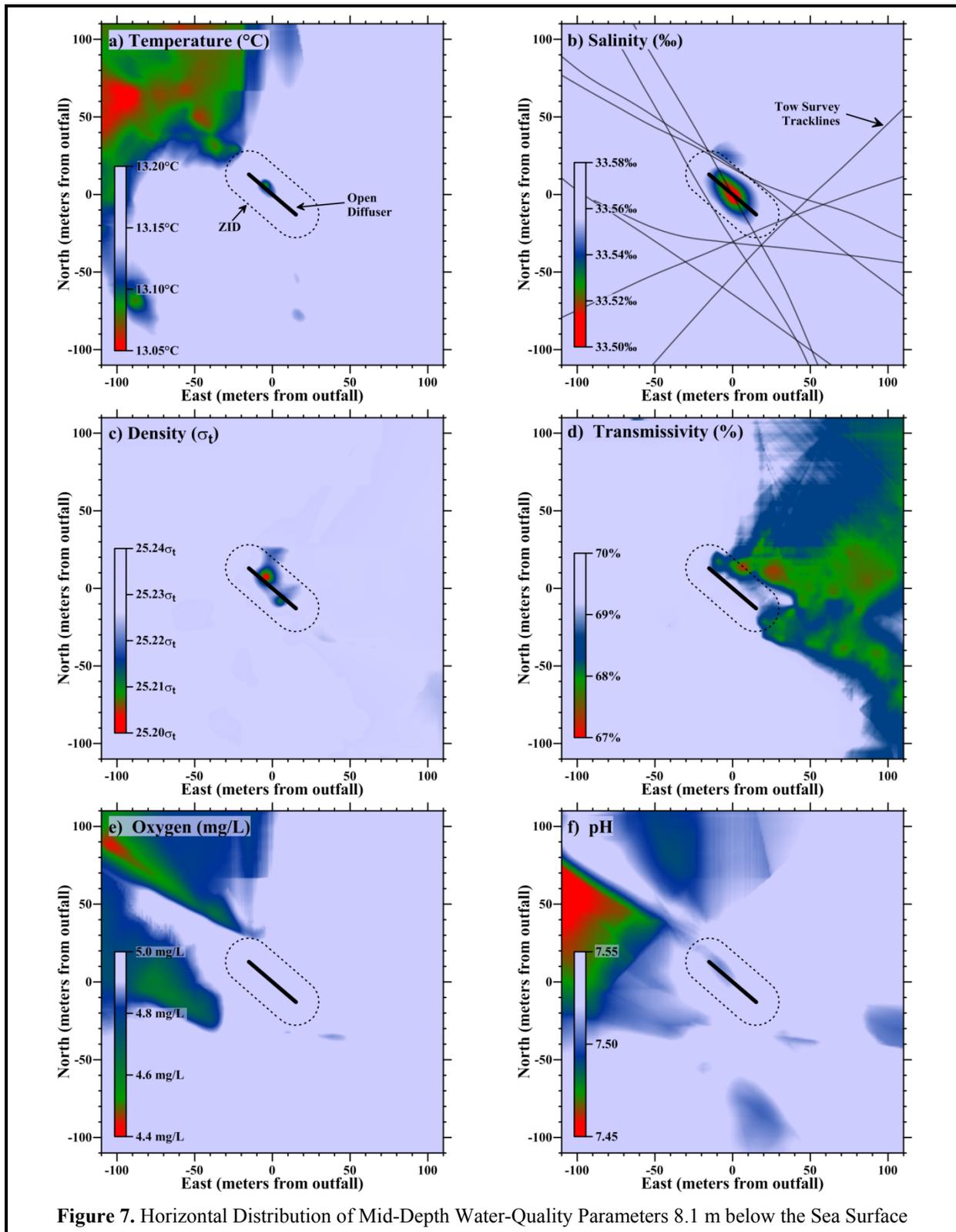
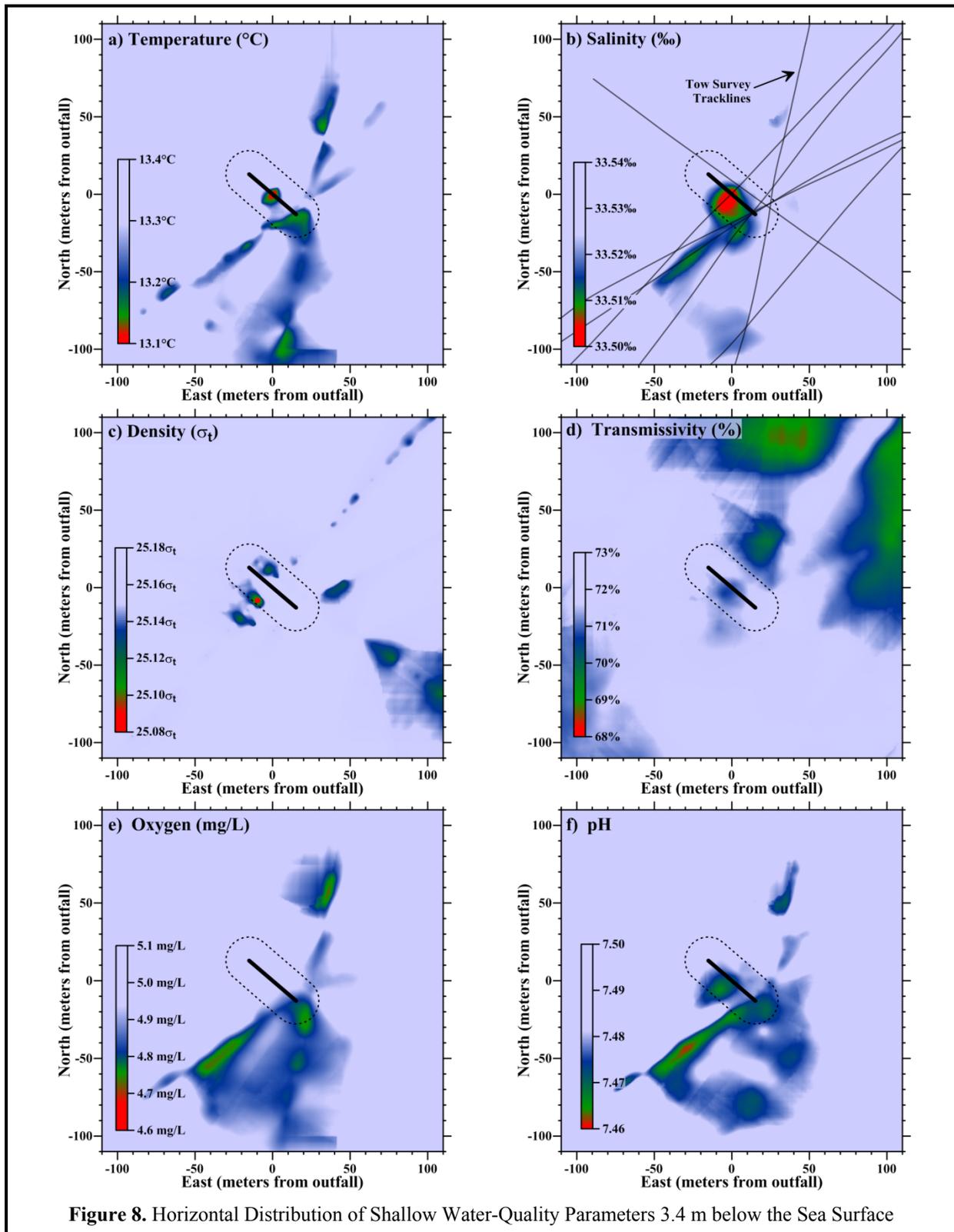


Figure 7. Horizontal Distribution of Mid-Depth Water-Quality Parameters 8.1 m below the Sea Surface



The lowest salinity (33.406‰) measured during the October 2010 survey was recorded at a depth of 10 m during the vertical profile taken at Station RW-4.

The measured salinity corresponds to a wastewater-induced reduction of -0.169‰ below the mean ambient salinity of 33.575‰ 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 by more than 197-fold. This is 48% higher than the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater.

Moreover, the measurement was made shortly after the effluent was discharged from the diffuser ports and before the rising plume experienced substantial additional dilution generated by buoyancy-induced turbulence. At that time, the CTD was only 5.4 m from the nearest diffuser port; the profile captured the plume shortly after discharge as it was continuing to undergo intense initial mixing within the ZID.

Given the relatively limited stratification present during the October survey, trapping of the plume at depth would not be expected. Consequently, as seen in the salinity cross sections of the towed survey (Figure 7b and Figure 8b), the plume diluted rapidly within the water column as it rose to the surface. In fact, using Equation 2 to recast the salinity distribution shown in Figure 7b, resulted in the delineation of an extremely weak plume signature with dilutions exceeding 500-fold that was entirely restricted to the ZID (dark-blue, green, and red areas in Figure 9). By the time the plume had migrated 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.

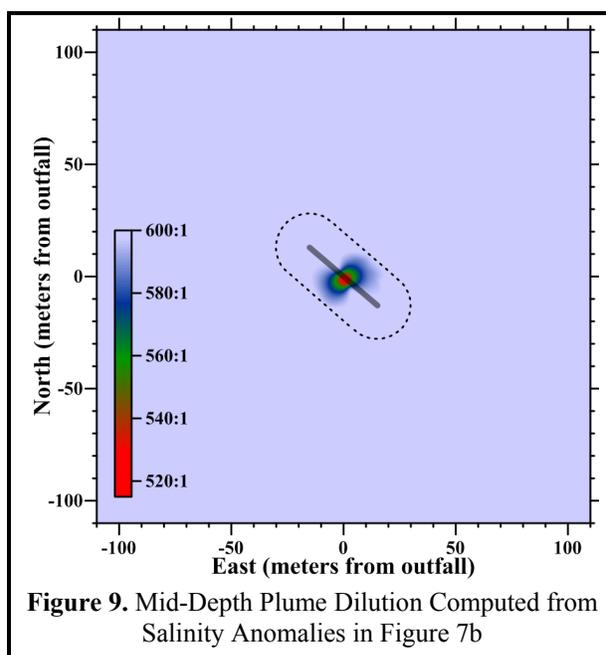


Figure 9. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 7b

The high-resolution salinity measurements collected during both the vertical profiles and the horizontal tows demonstrate that the modeled dilution factor (133:1) was significantly more conservative than that actually achieved by the discharge. Even close to a discharge point and 3.6 m below the 6.4-m trapping depth assumed in modeling, the plume had achieved dilution levels (>197:1) well in excess of critical initial dilution modeling (133:1). Upon rising to the level of the mid-depth tow (8.1 m), the plume was still below the modeling-determined trapping depth but had already achieved dilution levels in excess of 500-fold (Figure 9). There again, the plume was still within the ZID and had yet to reach buoyant equilibrium. In the moderately stratified conditions of the October survey, the plume continued to rise within the water column, overshooting the modeled trapping depth, and at the 3.4-m depth of the shallow tow, achieved dilutions exceeding the limiting resolution 600-fold.

The dilution computations demonstrate that, during the October 2010 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 197-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 October 2010 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 the compliance of the MBCSD discharge with the water-quality permit limits listed in the NPDES permit. 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.

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, their proximity to the ZID, and their amplitude compared to the natural variation in range found in ambient waters. 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 October 2010 data demonstrate that the MBCSD discharge fully complied with the NPDES discharge permit. Moreover, although observations within the ZID are not subject to compliance evaluations, they often still meet the permitted limits because dilution levels regularly exceed the conservative design specifications assumed in the discharge permit. The quantitative evaluation described in this section documents an outfall and treatment process that was exceeding design expectations during October 2010.

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.

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

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 October 2010 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, the numeric limits P5 and P6 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 between discharge-related changes that arise from the presence of wastewater constituents, which are subject to a compliance evaluation, and changes that arise from the upward movement of ambient seawater, which are specifically excluded from the compliance evaluation.

Lines of Evidence

Evaluating whether any of the 5,543 CTD measurements collected during the October 2010 survey exceeded a permit limit is 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, or other anthropogenic influences (e.g. dredging or oil spills).

Because of this complexity, both a tiered approach and abductive inference were applied to “*multiple-lines-of evidence*” (LOE) to evaluate compliance. Specifically, each receiving-water observation is screened for compliance by evaluating the measurement using the series of questions (lines of evidence) outlined in Table 7. Sequential (tiered) application of the initial three lines of evidence (final column in Table 7) serves to both eliminate excursions unrelated to the discharge, and highlight potential non-compliance events.

Any remaining measurements are then evaluated collectively (LOE#04 through LOE#06) to arrive at a “best explanation” 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 the concurrences. A best explanation approach serves to limit the uncertainty associated with each individual CTD measurement and provide a more robust compliance assessment. The detailed analysis described below demonstrates that all of the 5,543 CTD measurements collected during the October 2010 survey complied with receiving-water limitations, and that all documented excursions either occurred within the ZID where mixing was still ongoing, or were the result of natural processes unrelated to the discharge.

Table 7. Receiving-Water Measurements screened for Permit Compliance based on Lines of Evidence

LOE	Topic Addressed	Screening Questions	Answer		
			No ¹⁶	Yes ¹⁷	
<i>Tiered Evaluation</i>					
01	Anomaly Location	Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	530	5,013	
02	Salinity Association	Did the measurement coincide with a quantifiable salinity anomaly ($\leq 550:1$ dilution level) indicating the presence of detectable wastewater constituents?	5,013	0	
03	Transport Direction	Was the measurement collected downstream of the prevailing flow path?	na	na ¹⁸	
<i>Abductive Inference Evaluation</i>					
			No	Yes	Parameter
04	Outside Natural Range of Variation	Did the seawater properties associated with the measurement depart significantly from the natural range in ambient seawater variability present at the time of the survey?	na	na	all
05	Numerical Limits	Did the measurement's DO or pH exceed Basin-Plan numerical limits?	na	na	DO <5 mg/L
			na	na	7.0 > pH >8.3
			na	na	pH
06	Directional Offset	Was the observed offset in the seawater property consistent with the expected difference between wastewater and receiving-water properties?	na	na	Temperature
			na	na	Transmissivity
			na	na	DO

¹⁶ Number of CTD observations eliminated from further consideration by the specific LOE.

¹⁷ Number of CTD observations of potential compliance interest remaining after application of this and previous LOEs.

¹⁸ Application of LOE #01 and LOE #02 alone established that all of the measurements complied with discharge requirements. Therefore, application of LOE #03 through LOE #06 was not required, although they provide additional lines-of-evidence supporting compliance and are discussed briefly in the text.

Anomaly 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 in the water column. The COP also 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, modeling used to establish the MBCSD critical initial dilution of 133:1 assumes completion of dilution within a standard regulatory mixing distance, which is equal to the 15.2-m water depth of the discharge. For the purposes of screening receiving-water data for compliance, this conservative 15.2-m ZID-distance threshold is used in LOE#01 to restrict attention to post-dilution observations. Application of LOE#01 to the original 5,543 receiving-water observations eliminated 530 receiving-water observations from further consideration because they were collected within the ZID (Table 7). This left 5,013 observations that were measured outside the ZID and were carried forward in the compliance analysis.

Presence of Wastewater Constituents

In recognition of the fact that anomalies can result from the upward movement of ambient seawater entrained within the buoyant effluent plume, the MBCSD discharge permit restricts application of the numerical receiving-water limits to excursions caused by the presence of wastewater constituents (LOE#02). As specified in the COP, this confines the compliance analysis to changes caused “*as the result of the discharge of waste.*”

Salinity provides a powerful tracer of dilute wastewater that is unrivaled by the other seawater properties. In fact, analyses conducted on quarterly receiving-water surveys over the last decade have demonstrated that negative salinity anomalies are the only consistent indicator of the presence of wastewater constituents within receiving waters; the presence of a distinct salinity minimum provides *de facto* evidence of the presence of wastewater constituents. In contrast, the direct influence of dilute wastewater is rarely observed in any other seawater property, except very close (<1 m) to a diffuser port and within its ejection jet.

As described previously, 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 at least 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.

Application of LOE#02 restricts attention to excursions in temperature, light transmittance, DO, and pH that are related to the presence of wastewater constituents. Specifically, application of LOE#02 eliminates extremely small salinity reductions (<0.062‰) that would not result in discernable changes in other seawater properties. During the October 2010 survey, 21 low-salinity observations were identified as potentially being caused by the presence of wastewater constituents. However, each of these was recorded within the ZID where receiving-water limits do not apply because initial mixing is still taking place (LOE#01). Of the 5,013 observations that were measured outside the ZID (LOE#01) during the October 2010 survey, none had reductions in salinity that were greater than 0.062‰, therefore, application of LOE#02 effectively eliminated all 5,013 measurements from further compliance interest (Table 7).

Transport Direction

The drogued drifter documented weak, mid-level flow to the east and southeast during the October 2010 survey. Since the plume signature is usually located downstream of the diffuser structure, pursuant to LOE#03, excursions in receiving-water properties found in locations inconsistent with the path of drogued drifter are generally excluded from further evaluation. Specifically, LOE#03 excludes measurements that lie within a conservatively designed 180° arc centered at the furthest location along the ZID boundary, opposite (upstream of) the prevailing flow direction measured at the time of the survey.

Because application of LOE #01 and LOE #02 had already established that no remaining measurements were of compliance interest, application of LOE #03 was superfluous. Nevertheless, application of LOE#03 would have excluded a total of 1,195 upstream observations from the compliance evaluation. Likewise, application of LOEs#04 through #06 to the data from the October 2010 survey were also unnecessary, although each are discussed briefly in the following sections.

Natural Variability

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 the compliance evaluation under LOE#04.

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.

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 (± 0.094). These were combined with 95th percentiles determined from the October 2010 ambient seawater data, to establish natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from October 2010 vertical profile data, excluding measurements potentially affected by the discharge, specifically all of the measurements recorded at Stations RW3 and RW4 which were acquired within the ZID where ongoing mixing is expected.

Although no CTD observations were identified as requiring further investigation during the tiered evaluation (LOE#01 through LOE#03), none of the original 5,543 observations exceeded the thresholds of natural variability for temperature, DO, pH, or transmissivity established by LOE#04 and specified in Table 8. Thus, even though 21 measurements had salinity reductions that were clearly associated with presence of wastewater constituents undergoing additional initial mixing within the ZID, they were too dilute to induce water-quality changes perceptibly different from the variation in natural conditions.

Table 8. Thresholds of Natural Variation

Water Quality Property	Basin Plan Limit ¹⁹	COP Allowance ²⁰	Natural Variability Threshold ²¹	95 th Percentile ^{22,23}	95% Confidence Bound ²⁴
Temperature (°C)	—	—	>14.59	13.77	0.82
Transmissivity (%)	—	—	<61.0	71.2	-10.2
DO (mg/L)	<5.0	-10%	<3.24	4.62	-1.38
pH (minimum)	<7.0	-0.2	<7.317	7.412	-0.094
pH (maximum)	>8.3	0.2	>7.622	7.528	0.094

Exceedance of Numerical Limits

The NPDES permit specifies finite numerical limits for pH and DO measurements (P5 and P6 in Table 6) that are based on Basin Plan objectives for ocean waters. These numeric limits require that the discharge not cause DO measurements to be reduced below 5 mg/L, or cause pH measurements to be either below 7.0 units or above 8.3 units.

Pursuant to LOE#05, the pH within all 5,543 of the observations remained well within the acceptable range. In contrast, 2,090 (38%) of the DO concentration observations were below the 5 mg/L threshold specified in the Basin Plan (Table 8). However, these DO excursions did not constitute a violation of the permit provision because, as outlined by the natural variability thresholds generated for LOE#04, the recorded DO concentrations were consistent with the oxygen levels of ambient receiving waters in Estero Bay at the time of the survey. As discussed previously, the marked and prolonged periods of upwelling that predominated throughout the summer and early fall of 2010, led to depleted oxygen levels within the nearshore environment and resulted in the unusually low ambient DO concentrations measured in both the August and October receiving-water surveys.

Directional Offset

The final line of evidence normally used to assess compliance with the permit limits and objectives is an evaluation of the directional offset of the water properties of the CTD measurements (Table 7). Analysis of the directional offset of CTD measurements is useful because wastewater and receiving-seawater properties vary from one another in several predictable ways. For example, upon discharge, wastewater is

¹⁹ Permit limits P5 and P6 (Table 6) include specific numerical values promulgated in the RWQCB Basin Plan (1994) in addition to changes relative to natural conditions specified in the COP.

²⁰ The discharge permit, in accordance with the COP, allows excursions in seawater properties that depart from natural conditions by specified amounts. DO cannot be “depressed more than 10% from that which occurs naturally,” and pH cannot be “changed more than 0.2 units from that which occurs naturally.”

²¹ 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 October 2010 survey. They do not include the COP allowances specified in the column to the left.

²² 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.”

²³ The 95th-percentile quantifies natural variability in seawater properties during the October 2010 survey, and was determined from vertical profiles excluding RW3 and RW4 where there were possible influences from the discharge.

²⁴ 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.

fresher, warmer, and lighter than the ambient receiving waters of Estero Bay. Under most conditions, wastewater is also more turbid than the receiving waters. As such, the presence of wastewater constituents will reduce the salinity, density, and transmissivity of the receiving seawater (negative offset), while temperature will be increased (positive offset).

Based on effluent properties measured at the treatment plant during the October 2010 survey, dilute wastewater would have induced a decrease in receiving-water transmissivity, and an increase in temperature. At the time of the October 2010 survey, effluent pH (7.6) measured at the treatment plant was slightly higher than the pH of the ambient receiving-waters (7.5). Therefore, the presence of wastewater constituents would also be expected to increase pH (positive offset).

Meanwhile, oxygen-demanding material within effluent is assumed to depress DO relative to receiving waters although this rarely occurs in the open ocean. Nevertheless, depression of DO concentrations below 5 mg/L, or below 10% from that which occurs naturally are of compliance concern (P5 in Table 6). Historically, effluent DO shortly after discharge has been found to be higher than that of deep receiving waters because of the effluent's recent atmospheric contact and its lack of oxygen-demanding material. The MBCSD treatment process routinely removes 80% or more of the organic material, as demonstrated by the low, 48-mg/L biochemical oxygen demand (BOD) measured within an effluent sample collected from the treatment plant two days after the October 2010 survey. In the absence of tangible influence from effluent BOD, wastewater constituents would actually be expected to cause a DO increase in subsurface receiving waters (positive offset) within Estero Bay. This is because the effluent has been oxygenated by recent contact with the atmosphere, whereas receiving waters at depth are typically depleted in DO, particularly during periods of pronounced upwelling.

CONCLUSIONS

All measurements recorded during the October 2010 survey complied with the receiving-water limitations specified in the NPDES discharge permit, and were within natural variability that prevailed at the time of the survey. The presence of dilute wastewater constituents was delineated from salinity anomalies within a discharge plume that was localized within the ZID.

Immediately after discharge, the outfall was achieving dilution levels in excess of 197-fold, which exceeded the critical dilution levels predicted by design modeling. Additionally, throughout the water column, computed dilution levels outside the ZID achieved dilutions in excess of 600-fold. Lastly, all of the auxiliary observations collected during the October 2010 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 October 2010 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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