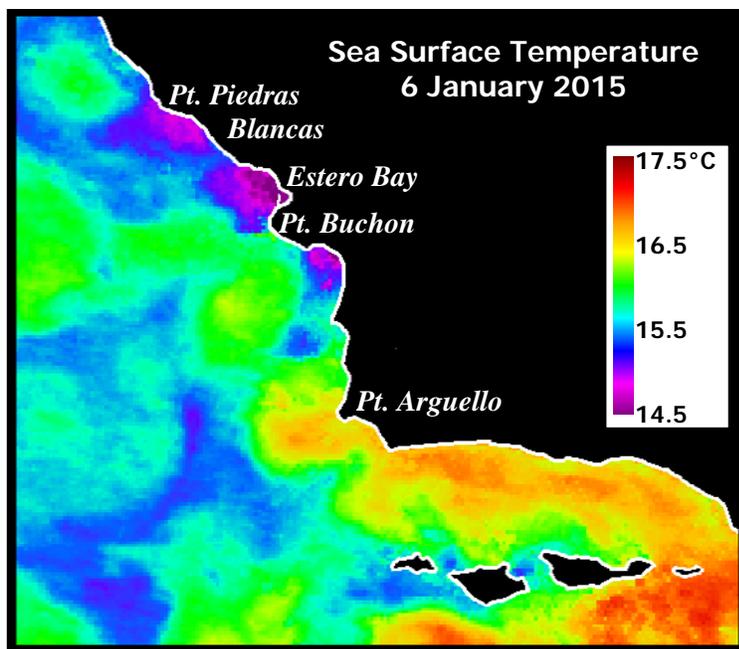


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

FIRST QUARTER RECEIVING-WATER SURVEY JANUARY 2015



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**

JANUARY 2015

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April 2015

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

1 April 2015

Reference: First Quarter Receiving-Water Survey Report – January 2015

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Wednesday, 7 January 2015. 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. Quantitative analyses of continuous instrumental measurements and qualitative visual observations confirm that 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 continue to operate at a high level of performance. 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

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. Bruce Keogh
Wastewater Division Manager
City of Morro Bay

Date 3-31-2015

TABLE OF CONTENTS

LIST OF FIGURES	i
LIST OF TABLES	ii
INTRODUCTION	1
SURVEY SETTING	1
SAMPLING LOCATIONS	3
OCEANOGRAPHIC PROCESSES	7
METHODS	9
<i>Auxiliary Measurements</i>	9
<i>Instrumental Measurements</i>	10
<i>Quality Control</i>	12
RESULTS	12
<i>Auxiliary Observations</i>	12
<i>Instrumental Observations</i>	13
<i>Outfall Performance</i>	19
COMPLIANCE	24
<i>Permit Provisions</i>	25
<i>Screening of Measurements</i>	25
<i>Other Lines of Evidence</i>	28
CONCLUSIONS	30
REFERENCES	31

LIST OF FIGURES

Figure 1. Location of the Receiving-Water Survey Area	2
Figure 2. Station Locations	4
Figure 3. Drogued Drifter Trajectory	7
Figure 4. Tidal Level during the January 2015 Survey	8
Figure 5. Five-Day Average Upwelling Index (m ³ /s/100 m of coastline)	9
Figure 6. CTD Tracklines during the January 2015 Tow Surveys	11
Figure 7. Vertical Profiles of Water-Quality Parameters	18
Figure 8. Horizontal Distribution of Mid-Depth Water-Quality Parameters 8.76 m below the Sea Surface	20
Figure 9. Horizontal Distribution of Shallow Water-Quality Parameters 2.68 m below the Sea Surface	21
Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b	23
Figure 11. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 9b	24

LIST OF TABLES

Table 1.	Target Locations of the Receiving-Water Monitoring Stations	4
Table 2.	Average Position of Vertical Profiles during the January 2015 Survey	6
Table 3.	CTD Specifications.....	10
Table 4.	Standard Meteorological and Oceanographic Observations.....	13
Table 5.	Vertical Profile Data Collected on 7 January 2015	14
Table 6.	Permit Provisions Addressed by the Offshore Receiving-Water Surveys.....	24
Table 7.	Receiving-Water Measurements Screened for Compliance Evaluation.....	26
Table 8.	Compliance Thresholds	28

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 January 2015 field survey described in this report was the twenty-fourth 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 7 January 2015. Specifically, this first-quarter survey captured ambient oceanographic conditions along the central California coast during 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 empirically evaluating 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 delineation 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 dilute effluent within the open-ocean receiving waters. Both vertical hydrocasts and horizontal tow surveys are conducted around the diffuser structure to assess the efficacy of the diffuser, to define the lateral extent of the discharge plume, and to evaluate compliance with the NPDES permit limitations.

¹ Conductivity, temperature, and depth (CTD)



Near the diffuser, prevailing flow generally follows 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 eight 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 between the water properties at these antipodal stations quantify departures from ambient seawater properties caused by the discharge and allow compliance with the NPDES discharge permit to be determined.

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. This "*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.

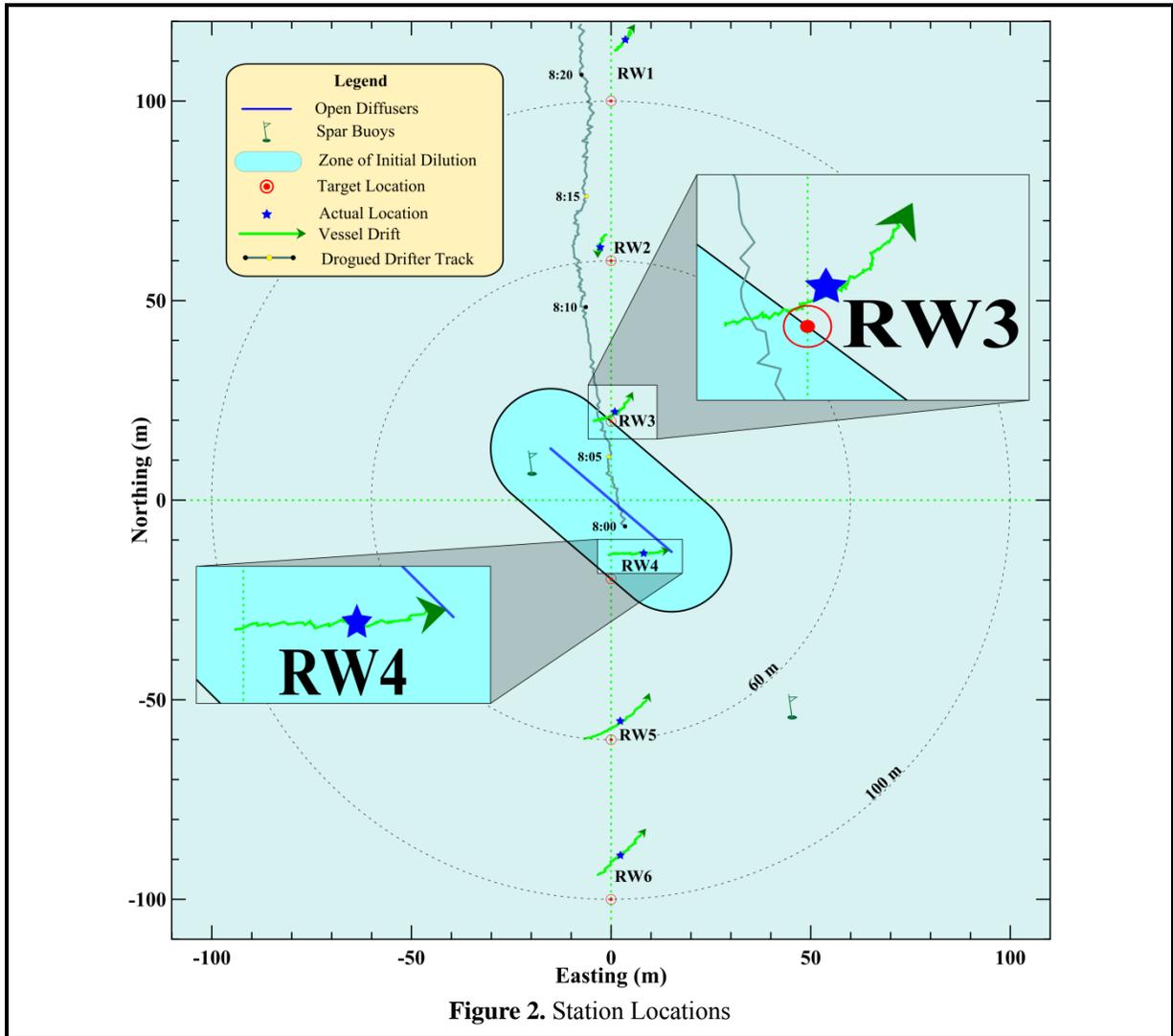


Table 1. Target Locations of the Receiving-Water Monitoring Stations

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

During a diver survey 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. Presently, the use of two independent DGPS receivers onboard 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 downcasts during the January survey were conducted progressing from north to south, beginning with Station RW1. The magnitude of the drift at each of the six stations during the January 2015 survey is apparent from the length of the green tracklines in Figure 2. The tracklines trace the horizontal movement of the CTD as it was lowered to the seafloor at each station. Their lengths and offsets from the target locations reflect the overall station-keeping ability during the January 2015 survey. Although the time it took the CTD to traverse the water column to the seafloor, which averaged 1 min 34 s, was consistent among stations, the lateral distance traversed by the instrument package varied considerably, from as little as 3.7 m at Station RW2, to 18.7 m at Station RW5. At 11.6 m, the average distance among all the stations was slightly greater than that of most prior surveys. At most stations, the direction of the CTD movement was toward the northeast. Although the northward drift component was consistent with the northward transport of the drifter (see drifter track in the figure), the residual momentum of the survey vessel as it approached the stations from the north reduced its influence.

Detailed knowledge of the CTD's location during downcasts is important for the interpretation of the water-quality measurements. Because the target locations for Stations RW3 and RW4 lie along the ZID boundary (red ⊙ symbols in Figure 2), knowledge of the CTD's location during the downcasts at those stations is especially important in the compliance evaluation. This is because the receiving-water limitations specified in the COP only apply to measurements recorded along or beyond the ZID boundary, where initial mixing is assumed complete. For example, during the January 2015 survey, the shallowest measurements at Station RW3 were located within the ZID boundary where receiving-water limitations do not apply (see the upper-right inset in Figure 2). However, most of the deeper data collected during the hydrocast at that station was subject to compliance analysis. In contrast, all of the CTD measurements at Station RW4 were collected within the ZID (see the lower-left inset in Figure 2), and were therefore excluded from the compliance evaluation.

Compliance assessments notwithstanding, measurements acquired 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 three decades, however, demonstrates that it has maintained a consistently high level of effectiveness at effluent dispersal. In fact, without the occasional measurements

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

recorded within the ZID due to vessel drift, the extremely dilute discharge plume might remain undetected within all the vertical profiles collected during a given survey.

For example, the data collected near the end of the downcast at Station RW4 was particularly valuable in that the CTD passed within 22 cm of a diffuser port as it approached the seafloor, passing thru a wastewater ejection jet and capturing mixing conditions almost immediately after discharge (see the green arrow tip in the lower-left inset in Figure 2). This resulted in a measured dilution (48:1) that is the lowest ever recorded in the history of the monitoring program. The associated water-property measurements acquired during this downcast provide unique insight into the efficacy of the diffuser structure’s dispersive capabilities because the measurements captured conditions where wastewater characteristics dominated the discharge plume. Observations of receiving-water properties that clearly reflect the presence of wastewater constituents are extremely rare because the diffuser structure rapidly dilutes them beyond recognition, even very close to the individual diffuser ports. For water properties other than salinity, the small differences in the temperature, turbidity, pH, and dissolved oxygen content between wastewater and ambient seawater quickly disappear with very little dilution.

It has not always been possible to determine which measurements were subject to permit limits among hydrocasts along the ZID boundary. For example, prior to 1999 and before the advent of DGPS, CTD locations could not be determined with sufficient accuracy to establish whether the average station position 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 January 2015 survey also identifies a single sampling location for each station. These average station positions are identified by the blue stars in Figure 2, and are listed in Table 2 along with their distances from the diffuser structure.

Table 2. Average Position of Vertical Profiles during the January 2015 Survey

Station	Time (PST)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ⁵ (m)	Bearing ⁶ (°T)
RW1	8:09:28	8:11:11	35° 23.261' N	120° 52.502' W	104.2	10
RW2	8:16:34	8:18:21	35° 23.233' N	120° 52.506' W	52.0	14
RW3	8:27:06	8:28:31	35° 23.211' N	120° 52.503' W	17.5⁷	41
RW4	8:38:00	8:39:39	35° 23.192' N	120° 52.499' W	4.7⁸	221
RW5	8:44:11	8:45:32	35° 23.169' N	120° 52.502' W	44.2	197
RW6	8:50:19	8:51:48	35° 23.151' N	120° 52.502' W	77.0	190

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 Some of the CTD measurements collected at Station RW3 were located within the ZID boundary (refer to the upper-right inset in Figure 2).

⁸ All of the CTD measurements collected at Station RW4 were located within the ZID boundary (refer to the lower-left inset in Figure 2).

OCEANOGRAPHIC PROCESSES

The trajectory of a satellite-tracked drogued drifter measured oceanic flow throughout the January 2015 survey (Figure 3). Modeled after the curtain-shade design of Davis et al. (1982) and drogued at mid-depth (7 m), a drifter has been deployed during each of the quarterly water column surveys conducted over the past two decades. In this configuration, the oceanic flow field rather than surface wind dictates the drifter's trajectory, providing a good assessment of the plume's movement after discharge.

During the January 2015 survey, the drifter was deployed near the diffuser structure at 8:02 AM, and was recovered at 10:07 AM at a location 858 m to the north-northwest (350°T^9) of its original release point (red dots in Figure 3). The direction and speed of the drifter was relatively uniform throughout its deployment. The rapid but steady flow speed is reflected by the uniform spacing of the green and black dots in Figure 3, which show the drifter's progress at five- and ten-minute intervals. The drifter's average speed of 11.4 cm/s^{10} was nearly double the maximum speeds measured during the prior survey. At the rapid transport rate measured during the January 2015 survey, effluent would have experienced only a brief, two-minute residence time within the ZID. As a result of the rapid speed with which the drifter was carried from the survey area, it was retrieved just after 10:07am, and subsequently redeployed at the ZID mid-way through the horizontal tow survey.

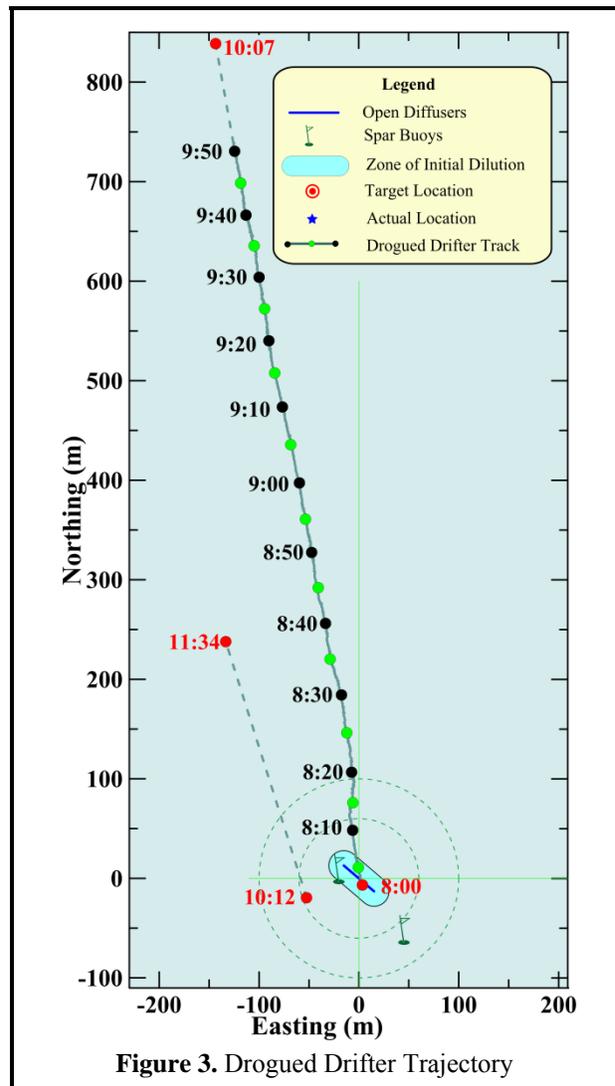


Figure 3. Drogued Drifter Trajectory

Although the deployment and recovery locations of the drifter were accurately determined from the vessel navigation log, drifter positions were only continuously recorded for the first portion of the deployment. After 9:50 AM, the internal lithium battery used for data storage on the drifter experienced a failure that resulted in a loss of subsequent navigational information.¹¹ Drifter movement after this time was estimated from the position of the vessel at the drifter recovery time (dashed green line at the top of Figure 3). The drifter was redeployed within the survey area at 10:12 AM, and was recovered for a second time at 11:34 AM. Based on vessel locations at the deployment and recovery times (dashed green line in the lower left of Figure 3), the drifter traversed a distance of 270 m along a heading similar to the prior

deployment. After 9:50 AM, the internal lithium battery used for data storage on the drifter experienced a failure that resulted in a loss of subsequent navigational information.¹¹ Drifter movement after this time was estimated from the position of the vessel at the drifter recovery time (dashed green line at the top of Figure 3). The drifter was redeployed within the survey area at 10:12 AM, and was recovered for a second time at 11:34 AM. Based on vessel locations at the deployment and recovery times (dashed green line in the lower left of Figure 3), the drifter traversed a distance of 270 m along a heading similar to the prior

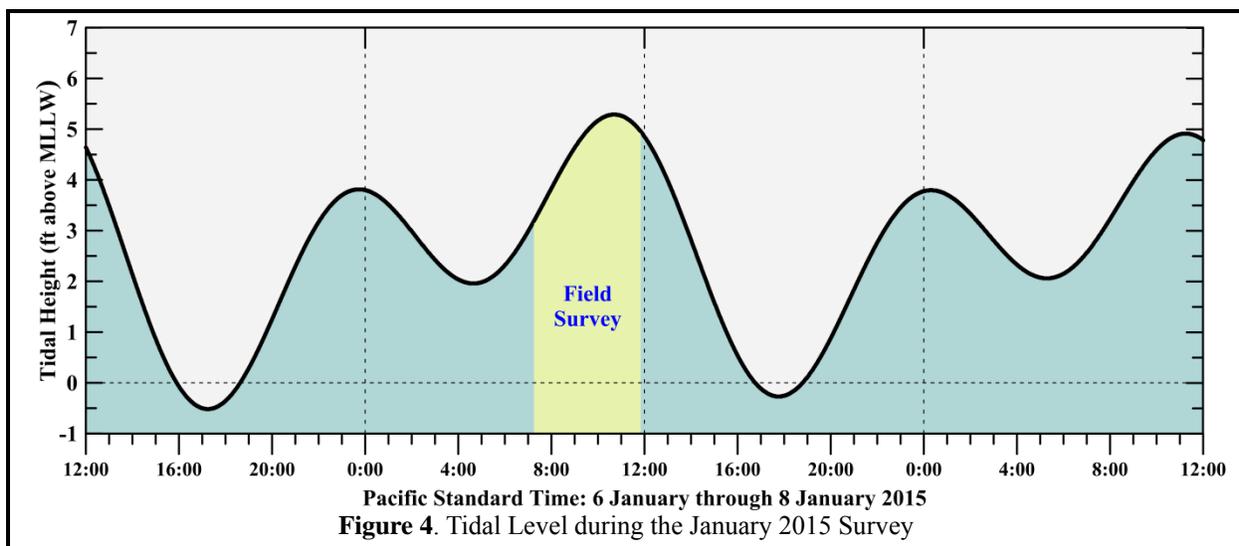
⁹ Direction measured clockwise relative to true (rather than magnetic) north

¹⁰ 0.2221 kt

¹¹ The entire drifter-tracking device will be replaced prior to the next survey to avoid future data loss; the internal lithium battery in the existing device is not user serviceable.

deployment. The second deployment indicates that the prevailing oceanic current had slowed substantially, to only half of the rate observed during the first deployment.

The overall flow direction measured by the drifter was consistent with the flood tide that prevailed during the January 2015 survey (Figure 4). Flood tides normally induce a weak northward (onshore) flow in the survey region. Additionally, the reduced flow speed measured during the drifter's second deployment corresponds with the approach of slack water after high tide at 10:41 AM. However, flow within the survey area is often also affected by other processes, such as wind-generated upwelling, downwelling, or offshore eddies migrating past Estero Bay. These external flow influences are apparent in the complexity of sea-surface temperatures depicted in the satellite image on the cover of this report. The cover image was recorded on the afternoon of 6 January 2015, when skies were clear enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA's polar orbiting satellites.



The satellite image revealed relatively uniform sea surface temperatures along the south central coast, varying by less than 3°C throughout the region. In fact, the contrast between the sea-surface temperatures measured in the nearshore waters of Morro Bay (purple) and the offshore waters southwest of Pt. Arguello (green) was less than 1.5°C. Slightly warmer water, delineated by orange shading near Pt. Arguello, was carried northward from the Santa Barbara Channel by the Davidson current.

A cell of high-atmospheric pressure that stagnated over the western United States at the end of 2014 generated light but sustained downslope (Santa Lucia) winds along most of the central coast that persisted through the beginning of 2015. This period of relaxation from the prevailing northwesterly winds allowed the northward-flowing Davidson current to strengthen, and caused a series of downwelling events along the coast (indicated by negative upwelling indices shown in red shading at the right of Figure 5). Downwelling events occur infrequently, and almost exclusively in winter, when Santa Lucia conditions or passing storms drive surface waters shoreward. As these surface waters approach the coastline, they downwell and produce nearly uniform seawater properties throughout the water column.

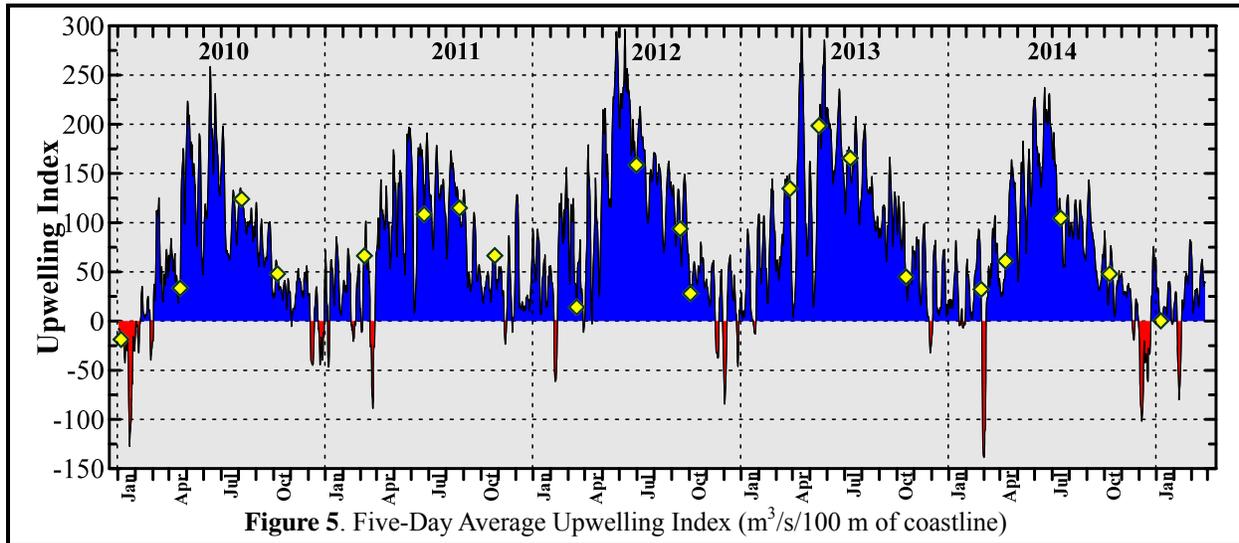


Figure 5. Five-Day Average Upwelling Index ($m^3/s/100$ m of coastline)

Accordingly, the vertically uniform water properties observed during the January 2015 survey were unusual compared to the highly stratified conditions that are normally observed during water-quality surveys. Stratified conditions result from upwelling processes that prevail most of the year along the central coast, as shown by the positive (blue) upwelling indices in Figure 5. Upwelling normally strengthens rapidly sometime during late March and or early April and is initiated by the stabilization of a high-pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive prevailing northwesterly winds along the central California coast. These winds move warmer surface waters southwestward 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 influx of denser water at depth produces a shallow thermocline (<10 m) that is commonly maintained throughout summer and into fall. As a result, some degree of upwelling is almost always present during offshore surveys (yellow diamonds in Figure 5).

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, 7 January 2015. Bonnie Luke of Marine Research Specialists (MRS) supervised deck operations as Chief Scientist, and collected auxiliary measurements of biological, meteorological, and oceanographic conditions. Dr. Douglas Coats, provided data-acquisition and navigational support during the survey. Mr. William Skok served as deckhand and assisted with the 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, Secchi depths measure natural light penetration, which can be limited by suspended particulates generated by plankton blooms, onshore runoff, seafloor sediment resuspension, and wastewater discharge. They are 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-19plusV2 Seacat CTD instrument package collected measurements of conductivity, temperature, light transmittance, dissolved oxygen (DO), pH, and pressure during the January 2015 survey. The six seawater properties used to assess receiving-water quality in this report were derived from the continuously recorded output from the CTD's probes and sensors. Although pressure-housing limitations confine the CTD to depths less than 680 m (Table 3), this is well beyond the maximum depth of the deepest station in the outfall survey.

Table 3. CTD Specifications

Component	Units	Range	Accuracy	Resolution
Housing (19p-1a; Acetron Plastic)	m	0 to 680	—	—
Pump (SBE 5P)	—	—	—	—
Pressure (19p-2h; Strain-Gauge)	dBar	0 to 680	±1.7	± 0.10
Conductivity	Siemens/m	0 to 9	± 0.0005	± 0.00005
Salinity	‰	0 to 58	± 0.004	± 0.0004
Temperature	°C	-5 to 35	± 0.005	± 0.0001
Transmissivity (WETLabs C-Star) ¹²	%	0 to 100	± 0.3	± 0.03
Oxygen (SBE 43)	% Saturation	0 to 120	± 2	—
pH (SBE 18)	pH	0 to 14	± 0.1	—

The precision and accuracy of the various probes, as reported in manufacturer's specifications, are listed in Table 3. 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).

Assessments of all three of the physical parameters (salinity, temperature, and density) helped determine the lateral extent of the effluent plume during the tow phase of the 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-

¹² 25-cm path length of red (660 nm) light

m path. Transmissivity readings are reported relative to 100% transmission in air, so the maximum theoretical transmission in (pure) water is expected to be 91.3%.

Before the first vertical hydrocast at Station RW1, the CTD was held below the sea surface for four minutes. 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 8:54 AM, following completion of the last vertical profile at RW6, the CTD instrument package was brought aboard the survey vessel and reconfigured for horizontal towing with forward-looking probes. The protective cage around the CTD was fitted with a horizontal stabilizer wing and a depth-suppression weight was added to the towline to achieve constant-depth tows. After the reconfigured CTD was deployed, it was towed around and across the ZID at two separate depths, one within the surface mixed layer and one at mid-depth within the thermocline, in accordance with the monitoring requirements of the NPDES discharge permit (Figure 6).

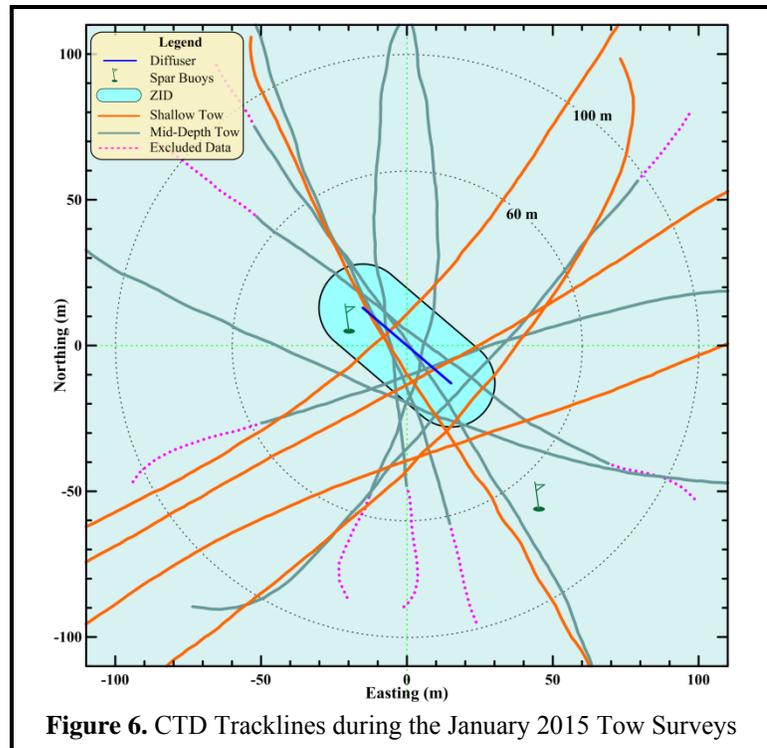


Figure 6. CTD Tracklines during the January 2015 Tow Surveys

Recurring interruption of the data stream from the CTD plagued the shallow tow, resulting in the CTD package being retrieved and redeployed several times during the following two hours as the problem was troubleshot. Although CTD battery voltage readings onboard the survey vessel indicated that they were within specifications, extended operation within cool ocean waters had resulted in additional voltage declines which caused recurring system shutdowns.

After replacing the CTD batteries, the shallow tows were resumed and all subsequent tow data was collected without interruption. However, only five of the fifteen shallow transects that were attempted produced usable data (shown by the orange lines in Figure 6). Although the permit only requires five passes over the ZID, most surveys attempt to collect data from at least eight transects at each depth level. The five usable transects of shallow data were collected at an average depth of 2.7 m, and an average speed of 1.60 m/s. Subsequently, eight additional passes were made with the CTD at an average depth of 8.8 m. During this 25-minute mid-depth tow, vessel speed averaged 1.65 m/s. At the observed towing speeds and the 4 Hz sampling rate, at least 2.4 CTD measurements were collected for each meter traversed. This complies with the permit requirement for minimum horizontal resolution of 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 then processed to produce horizontal maps within the upper and sub-thermocline portions of the water column.¹³

Quality Control

During the vertical-profiling and horizontal-towing phases of the survey, real-time data were monitored for completeness and range acceptability. Although real-time monitoring indicated the recorded properties were complete and within acceptable coastal seawater ranges,¹⁴ subsequent post-processing revealed several events that impacted portions of the data, resulting in the adjustment or exclusion of these data prior to initiating the compliance analysis. For example, review of the tow data revealed that the CTD was tracking at a slightly different depth (>1 m offset) during the initial and final portions of several of the mid-depth tows (purple dotted lines in Figure 6). Depth offsets are typically induced by changes in vessel speed that are instituted to prevent the CTD from colliding with the seafloor during the execution of the turns used to align the vessel between each transect. Because of the complex interaction between turn radius, vessel speed, and CTD depth, the CTD's target depth cannot always be precisely maintained at these times.

Because the discharge-related anomalies used in the compliance analysis are identified 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 depth levels are combined in the horizontal maps. This is particularly true when the water column is highly stratified, although this was not the case during the January 2015 survey. Nevertheless, portions of the January mid-depth transects were excluded to conform to historical protocols, and because their exclusion did not adversely affect the compliance analysis. The remaining data adequately covered the 100-m survey area surrounding the diffuser structure.

RESULTS

The first-quarter receiving-water survey was conducted on the morning of Wednesday, 7 January 2015. The receiving-water survey commenced at 8:02 AM with the deployment of the drogued drifter. Over the following 3.5 hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended at 11:34 AM with the retrieval of the drogued drifter. Collection of the required visual observations of the sea surface was unencumbered throughout the survey.

Auxiliary Observations

On the morning of 7 January 2015, skies were clear, with light northeasterly winds. Average wind speeds, calculated over one-minute intervals, ranged from 0.6 kt to 2.3 kt (Table 4). Similarly, peak wind speeds ranged from 1.0 kt to 3.2 kt. The swell was out of the northwest with a significant wave height of two feet. Air temperatures remained nearly constant throughout the survey, averaging 16.5°C, and were two degrees warmer than the 14.5°C sea-surface temperatures.

¹³ Figures 8 and 9 later in this report

¹⁴ Field sampling protocols employed during the survey generally followed the field operations manual for the Southern California Bight Study (SCBFMC 2002), which includes CTD cast-acceptability ranges listed in Table 2 of the manual.

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location ¹⁵		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° 23.264' N	120° 52.502' W	107.9	8:12:47	16.2	0	0.7	1.0	NE	1-2 NW	10.0
RW2	35° 23.232' N	120° 52.501' W	52.5	8:19:38	16.5	0	0.8	1.2	NE	1-2 NW	9.0
RW3	35° 23.221' N	120° 52.496' W	39.0	8:29:49	16.6	0	0.6	1.1	NE	1-2 NW	7.5
RW4	35° 23.192' N	120° 52.493' W	2.5	8:41:23	16.7	0	2.3	3.1	NE	1-2 NW	9.5
RW5	35° 23.177' N	120° 52.489' W	28.1	8:47:02	16.7	0	1.6	2.0	NE	1-2 NW	7.5
RW6	35° 23.167' N	120° 52.488' W	47.7	8:53:52	16.3	0	2.2	3.2	NE	1-2 NW	8.5

The ≥ 7.5 m Secchi depths recorded during the January 2015 survey reflected the presence of a 15-m euphotic zone that was projected to extend throughout the water column (Table 4). The unusually high seawater clarity measured by Secchi depth measurements within the upper water column actually extended to the seafloor, as indicated by the elevated transmissivities that were recorded throughout the water column. Transmissivity measurements exceeded 87% everywhere except where the CTD passed through an ejection jet near the seafloor at Station RW4. During the survey, no evidence of floating particulates, oil sheens, or any discoloration of the sea surface was visually observed that might be related to the presence of wastewater constituents. However, an area of reduced capillary wave formation was briefly observed within the ZID during the survey. This surface-boil feature is a physical manifestation of the rising effluent plume that is often the only indication that the plume has risen to the surface rather than being trapped at depth.

Communication with plant personnel and subsequent review of effluent discharge properties on the day of the survey, confirmed that the treatment process was performing nominally at time of the survey. The 0.927 million gallons of effluent discharged on 7 January had a temperature of 19°C, a suspended-solids concentration of 31.6 mg/L, and a pH of 7.4. The biochemical oxygen demand (BOD) of the effluent measured on the following day, 8 January, was 54 mg/L.

During the January 2015 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. Small numbers of California brown pelicans (*Pelecanus occidentalis*), Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), western grebes (*Aechmophorus occidentalis*), royal terns (*Thalasseus maximus*), and western gulls (*Larus occidentalis*) were all observed transiting the survey area. Southern sea otters (*Enhydra lutris nereis*) and buffleheads (*Bucephala albeola*) were observed inside the mouth of Morro Bay and just outside the harbor breakwater during transit to the survey site. A lone sea otter was also observed inshore of the survey area during the tow survey. Pedestrians and paddle boarders were visible along Atascadero State beach and the nearshore waters throughout 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 January 2015 survey reflect weakly stratified conditions indicative of the prevailing downwelling

¹⁵ Locations are the vessel positions at the time the Secchi depths were measured. These typically depart slightly from the CTD profile locations listed in Table 2.

Table 5. Vertical Profile Data Collected on 7 January 2015

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
1.0		13.911	13.940	13.955	13.954	13.953		33.320	33.331	33.378	33.378	33.377
1.5	13.878	13.915	13.942	13.954	13.959	13.953	33.347	33.325	33.343	33.378	33.378	33.377
2.0	13.878	13.914	13.945	13.954	13.955	13.949	33.347	33.323	33.350	33.379	33.378	33.377
2.5	13.877	13.913	13.950	13.956	13.953	13.945	33.349	33.324	33.357	33.379	33.378	33.377
3.0	13.877	13.934	13.939	13.959	13.957	13.946	33.353	33.354	33.345	33.378	33.378	33.377
3.5	13.877	13.959	13.942	13.959	13.955	13.947	33.355	33.380	33.350	33.378	33.378	33.377
4.0	13.875	13.961	13.958	13.959	13.952	13.948	33.356	33.380	33.373	33.378	33.378	33.378
4.5	13.868	13.962	13.957	13.959	13.951	13.948	33.370	33.380	33.370	33.378	33.378	33.377
5.0	13.870	13.961	13.942	13.959	13.951	13.949	33.369	33.379	33.347	33.378	33.378	33.377
5.5	13.865	13.962	13.949	13.959	13.952	13.948	33.377	33.379	33.359	33.378	33.378	33.377
6.0	13.865	13.962	13.961	13.958	13.952	13.947	33.378	33.378	33.377	33.378	33.378	33.378
6.5	13.869	13.964	13.959	13.958	13.953	13.946	33.378	33.380	33.373	33.378	33.378	33.378
7.0	13.871	13.964	13.938	13.958	13.954	13.946	33.378	33.380	33.343	33.378	33.378	33.378
7.5	13.869	13.964	13.933	13.960	13.953	13.946	33.378	33.380	33.340	33.378	33.378	33.378
8.0	13.869	13.964	13.952	13.959	13.944	13.946	33.378	33.380	33.365	33.378	33.378	33.378
8.5	13.871	13.965	13.957	13.959	13.943	13.945	33.378	33.380	33.379	33.378	33.379	33.378
9.0	13.869	13.964	13.947	13.958	13.940	13.945	33.378	33.380	33.378	33.378	33.379	33.378
9.5	13.868	13.964	13.943	13.954	13.938	13.945	33.378	33.380	33.378	33.378	33.379	33.378
10.0	13.867	13.962	13.949	13.953	13.939	13.944	33.378	33.379	33.379	33.378	33.379	33.378
10.5	13.866	13.944	13.939	13.954	13.939	13.943	33.378	33.379	33.378	33.378	33.379	33.378
11.0	13.866	13.931	13.929	13.953	13.939	13.935	33.378	33.378	33.378	33.378	33.379	33.378
11.5	13.866	13.918	13.927	13.951	13.941	13.934	33.378	33.378	33.378	33.378	33.379	33.378
12.0	13.866	13.910	13.927	13.936	13.942	13.934	33.378	33.378	33.378	33.378	33.379	33.378
12.5	13.866	13.900	13.925	13.906	13.936	13.933	33.378	33.377	33.378	33.377	33.379	33.378
13.0	13.866	13.890	13.920	13.908	13.919	13.923	33.378	33.377	33.378	33.378	33.378	33.378
13.5	13.867	13.868	13.916	13.901	13.912	13.913	33.378	33.376	33.378	33.378	33.378	33.378
14.0	13.866	13.866	13.915	13.898	13.898	13.908	33.379	33.377	33.378	33.378	33.378	33.378
14.5	13.865	13.866	13.912	13.891	13.890	13.906	33.379	33.377	33.378	33.378	33.378	33.378
15.0	13.866	13.865	13.880	13.883	13.883	13.905	33.379	33.377	33.376	33.378	33.378	33.378
15.5	13.866	13.865	13.868	13.875	13.882	13.902	33.379	33.378	33.377	33.375	33.378	33.378
16.0	13.865	13.865	13.866	13.930	13.881	13.900	33.380	33.378	33.378	33.017	33.378	33.378
16.5		13.864	13.867	13.983	13.879	13.900		33.379	33.378	32.719	33.378	33.378
17.0			13.868	13.908	13.878	13.900			33.378	33.159	33.378	33.378
17.5				13.875						33.350		

Table 5. Vertical Profile Data Collected on 7 January 2015 (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
1.0		24.908	24.910	24.943	24.943	24.943		8.142	8.142	8.149	8.147	8.148
1.5	24.935	24.911	24.919	24.944	24.942	24.943	8.141	8.141	8.143	8.148	8.148	8.148
2.0	24.935	24.909	24.924	24.944	24.943	24.944	8.141	8.141	8.143	8.148	8.148	8.148
2.5	24.937	24.910	24.928	24.943	24.943	24.945	8.140	8.141	8.143	8.147	8.148	8.147
3.0	24.940	24.929	24.921	24.943	24.943	24.945	8.141	8.142	8.143	8.148	8.148	8.148
3.5	24.941	24.943	24.924	24.942	24.943	24.944	8.141	8.144	8.144	8.148	8.148	8.148
4.0	24.943	24.943	24.939	24.942	24.944	24.944	8.141	8.145	8.145	8.149	8.147	8.148
4.5	24.955	24.943	24.936	24.942	24.944	24.944	8.141	8.146	8.145	8.148	8.147	8.148
5.0	24.954	24.943	24.922	24.943	24.944	24.944	8.141	8.146	8.146	8.148	8.148	8.148
5.5	24.961	24.943	24.930	24.943	24.944	24.944	8.142	8.148	8.145	8.148	8.148	8.148
6.0	24.962	24.942	24.941	24.943	24.944	24.944	8.143	8.147	8.146	8.148	8.147	8.148
6.5	24.961	24.943	24.939	24.943	24.944	24.945	8.143	8.148	8.146	8.148	8.147	8.148
7.0	24.961	24.943	24.920	24.943	24.943	24.945	8.143	8.147	8.146	8.148	8.149	8.147
7.5	24.961	24.943	24.918	24.942	24.944	24.945	8.143	8.147	8.146	8.148	8.148	8.148
8.0	24.961	24.943	24.934	24.942	24.946	24.945	8.143	8.147	8.144	8.148	8.148	8.147
8.5	24.961	24.942	24.943	24.943	24.946	24.945	8.143	8.148	8.145	8.148	8.148	8.147
9.0	24.961	24.943	24.945	24.943	24.947	24.945	8.144	8.148	8.146	8.147	8.148	8.148
9.5	24.961	24.943	24.946	24.944	24.947	24.945	8.143	8.148	8.145	8.147	8.148	8.148
10.0	24.962	24.943	24.945	24.944	24.947	24.945	8.143	8.147	8.146	8.147	8.147	8.148
10.5	24.962	24.946	24.947	24.944	24.947	24.946	8.144	8.148	8.147	8.147	8.148	8.148
11.0	24.962	24.948	24.948	24.944	24.947	24.947	8.143	8.147	8.146	8.147	8.147	8.148
11.5	24.962	24.951	24.949	24.944	24.947	24.948	8.143	8.147	8.146	8.148	8.146	8.148
12.0	24.962	24.952	24.949	24.947	24.947	24.948	8.143	8.147	8.147	8.148	8.147	8.147
12.5	24.962	24.954	24.949	24.953	24.948	24.948	8.143	8.147	8.147	8.147	8.148	8.146
13.0	24.962	24.956	24.950	24.953	24.951	24.950	8.143	8.146	8.146	8.147	8.146	8.146
13.5	24.962	24.960	24.951	24.954	24.952	24.952	8.143	8.146	8.146	8.147	8.146	8.146
14.0	24.962	24.961	24.951	24.955	24.955	24.953	8.143	8.145	8.147	8.146	8.146	8.146
14.5	24.962	24.961	24.952	24.956	24.957	24.953	8.143	8.144	8.146	8.146	8.146	8.146
15.0	24.962	24.961	24.957	24.958	24.958	24.953	8.143	8.144	8.146	8.146	8.145	8.146
15.5	24.963	24.961	24.960	24.957	24.958	24.954	8.142	8.145	8.146	8.145	8.145	8.144
16.0	24.963	24.962	24.961	24.669	24.958	24.954	8.141	8.144	8.143	8.143	8.145	8.145
16.5		24.962	24.961	24.428	24.959	24.955		8.143	8.143	8.130	8.144	8.145
17.0			24.961	24.784	24.959	24.955			8.141	8.123	8.144	8.145
17.5				24.938						8.132		

Table 5. Vertical Profile Data Collected on 7 January 2015 (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
1.0		7.805	7.827	7.865	7.868	7.865		89.111	88.239	88.062	87.778	88.065
1.5	7.754	7.807	7.867	7.869	7.877	7.849	91.143	88.953	88.212	88.218	87.940	88.052
2.0	7.753	7.800	7.843	7.881	7.872	7.872	91.198	88.942	88.310	88.221	87.922	88.069
2.5	7.759	7.876	7.837	7.869	7.861	7.869	91.251	88.926	88.355	88.244	88.099	88.103
3.0	7.765	7.921	7.862	7.875	7.879	7.859	91.450	88.994	88.383	88.165	88.031	88.035
3.5	7.752	7.903	7.894	7.883	7.857	7.862	91.530	88.854	88.479	88.117	87.960	88.023
4.0	7.768	7.897	7.858	7.873	7.858	7.862	91.540	88.626	88.446	88.024	87.975	88.033
4.5	7.767	7.910	7.834	7.870	7.859	7.858	91.576	88.601	88.384	87.962	88.118	88.080
5.0	7.777	7.901	7.874	7.867	7.870	7.864	91.590	88.540	88.177	87.971	88.098	88.036
5.5	7.773	7.900	7.897	7.855	7.857	7.850	92.159	88.548	88.372	87.888	88.109	88.053
6.0	7.770	7.900	7.871	7.880	7.868	7.870	92.466	88.556	88.364	87.933	87.954	88.108
6.5	7.778	7.902	7.829	7.853	7.868	7.866	92.372	88.574	88.315	87.833	88.030	88.062
7.0	7.771	7.903	7.837	7.861	7.855	7.871	92.331	88.602	88.271	87.798	88.093	88.000
7.5	7.776	7.900	7.870	7.878	7.848	7.866	92.375	88.612	88.326	87.841	88.002	88.005
8.0	7.793	7.903	7.847	7.874	7.849	7.862	92.292	88.593	88.391	87.740	88.078	88.059
8.5	7.769	7.910	7.832	7.869	7.848	7.862	92.356	88.500	88.373	87.811	88.717	88.092
9.0	7.785	7.879	7.856	7.856	7.872	7.854	92.339	88.622	88.441	87.793	88.580	88.122
9.5	7.789	7.899	7.858	7.874	7.846	7.859	92.263	88.601	88.585	87.729	88.721	88.120
10.0	7.784	7.864	7.839	7.862	7.852	7.849	92.211	88.648	88.858	87.908	88.813	88.190
10.5	7.796	7.837	7.836	7.869	7.856	7.833	92.326	88.782	88.910	87.955	88.736	88.141
11.0	7.783	7.828	7.833	7.860	7.857	7.842	92.295	89.441	88.963	88.096	88.642	88.216
11.5	7.774	7.833	7.826	7.825	7.854	7.824	92.323	89.664	89.444	88.194	88.601	88.333
12.0	7.799	7.824	7.837	7.820	7.839	7.845	92.317	89.907	89.667	88.153	88.594	88.458
12.5	7.785	7.806	7.826	7.818	7.819	7.818	92.280	90.183	89.670	88.769	88.649	88.431
13.0	7.765	7.752	7.811	7.832	7.815	7.801	92.294	90.454	89.747	89.858	89.193	88.527
13.5	7.786	7.782	7.833	7.820	7.803	7.803	92.289	91.059	89.766	89.820	89.680	88.818
14.0	7.835	7.783	7.811	7.821	7.784	7.796	92.329	91.524	89.759	89.902	89.826	89.087
14.5	7.805	7.787	7.762	7.813	7.781	7.781	92.286	91.576	90.090	90.122	90.016	89.216
15.0	7.808	7.795	7.773	7.791	7.798	7.791	92.258	91.805	90.206	90.324	90.150	89.155
15.5	7.837	7.795	7.781	7.622	7.785	7.786	92.307	91.815	90.891	90.511	90.193	89.194
16.0	7.822	7.803	7.781	7.576	7.783	7.807	92.252	91.808	91.222	90.671	90.278	89.137
16.5		7.806	7.773	7.729	7.757	7.790		91.735	91.428	86.304	90.207	89.165
17.0			7.793	7.743	7.748	7.774			91.385	77.608	90.137	89.174
17.5				7.835						83.381		

conditions (Figure 5). Downwelling events are typically rare and brief compared to the upwelling conditions that prevail most of the time along the central California coast.

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 small vertical distances. Highly stratified waters inhibit vertical exchange of nutrients and other water properties, and can reduce dilution of materials introduced by seafloor point sources, such as ocean outfalls. In contrast, downwelling does not generate significant vertical variations in cross-shore flow, and thus does not result in strongly stratified waters that are resistant to vertical motion. During downwelling conditions, the discharge plume often rises all the way to the sea surface rather than becoming trapped at depth. Such was the case during the January 2015 survey.

Although very weak, some vertical structure is apparent in the vertical profiles at Stations RW5 and RW6, which were unaffected by the discharge plume due to their southerly (upstream) location relative to the diffuser structure. Weak vertical gradients are apparent as a slight decrease in pH (gold lines in Figure 7ef), temperature (red lines), and DO (dark blue lines) within increasing depth. Meanwhile, transmissivity (light blue lines) exhibits a slight increase in depth. However, the differences between surface and bottom measurements were exceedingly small and approached the limits of instrumental accuracy (Table 5).

While differences between surface and bottom temperature (0.075°C), DO (0.097 mg/L), and transmissivity (-2.2%) were marginally resolved, the vertical changes in pH (0.0032), salinity (-0.0007), and density (-0.016σ_t) were too small to be reliably resolved by the CTD's probes (Table 3).

The degree of vertical stratification within the receiving seawater is also important for understanding the dynamics of the effluent dispersion at the time of the survey. For example, when the water column is strongly stratified by upwelling, the rising plume can become trapped at depth within the water column, thereby limiting its full capacity for dilution. This was not the case during the January 2015 survey when the nearly uniform ambient receiving waters allowed the plume to rise unimpeded to the sea surface. Accordingly, a localized surface expression of the plume (surface boil) was visually observed during the survey, and comparatively large salinity reductions are readily apparent at, and immediately below the sea surface in the vertical profiles at the northern (downstream) Stations RW1, RW2, and RW3 (green lines in Figure 7abc). In contrast to these obvious plume-related salinity anomalies near the sea surface, the plume signature was not readily apparent in the other water properties because the small differences between wastewater and seawater rapidly dissipated after discharge.

When the water column is stratified, even when the presence of dilute effluent is not readily apparent in other water properties, they frequently exhibit excursions in conjunction with salinity anomalies. These excursions are not, however, caused by the presence of wastewater constituents as in the case of salinity anomalies. Instead, they reflect the presence of ambient seawater that becomes entrained within the rising effluent plume shortly after its discharge near the seafloor. Close to the seafloor, intense mixing is driven by the momentum of the effluent's ejection from the individual diffuser ports. Subsequent turbulent mixing caused by rise of the plume through the water column is less intense, and as a result, the dilute effluent plume tends to retain the ambient seawater properties it acquires at the seafloor. These deep seawater properties can become apparent as a signature of the buoyant effluent plume when they are juxtaposed against the ambient seawater characteristics in the mid and upper water column. These entrainment-generated anomalies are only apparent, however, when the water column is sufficiently stratified to cause a perceptible contrast between the shallow and deep ambient seawater properties. When there is little contrast between seawater properties near the seafloor and in the upper water column, as was the case during the January 2015 survey, the signatures of such entrainment anomalies become imperceptible.

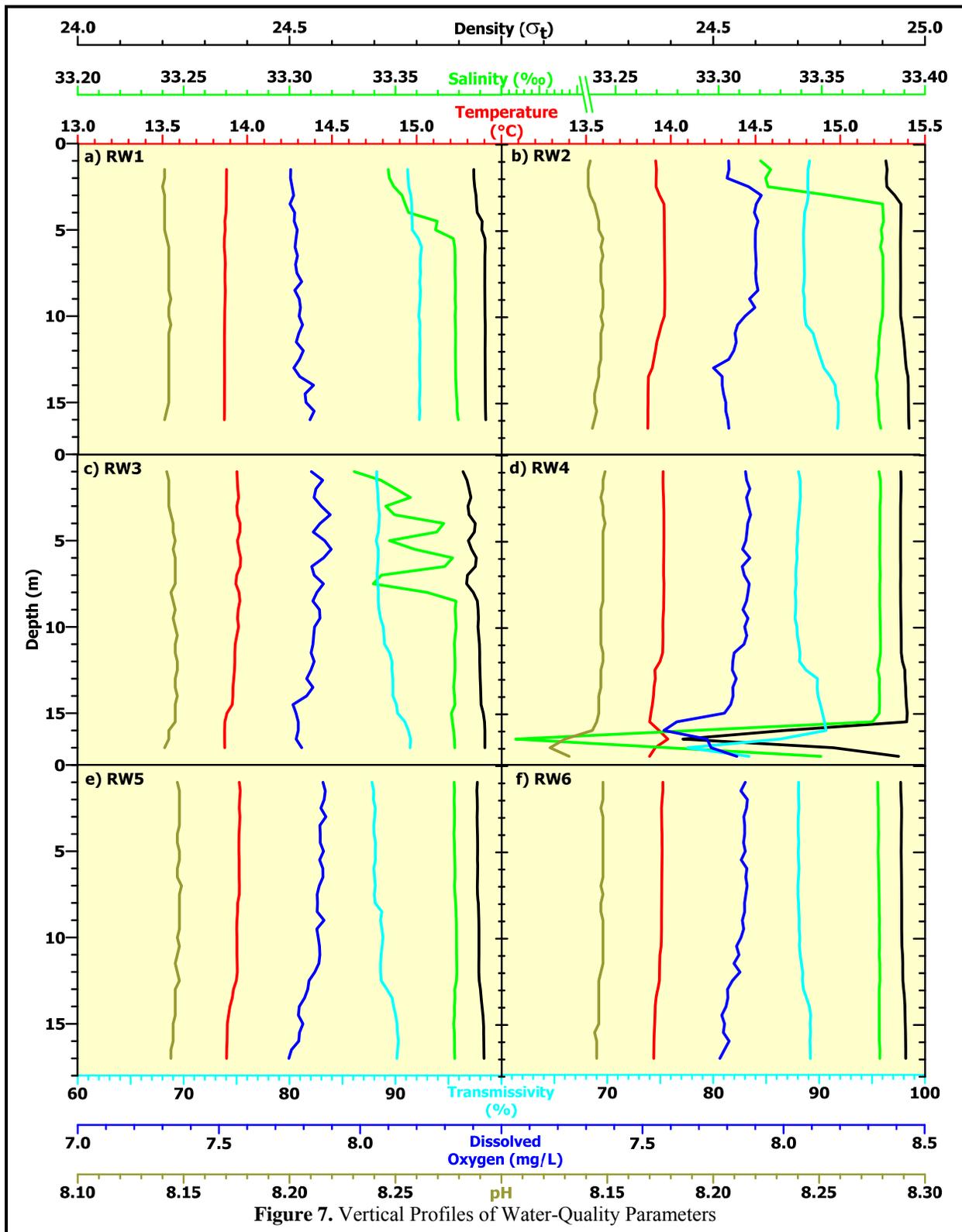


Figure 7. Vertical Profiles of Water-Quality Parameters

During stratified conditions, entrainment-generated anomalies associated with the plume typically dominate the horizontal maps produced by the tow surveys. However, the general absence of discernible contrast in ambient seawater properties within the water column during the January 2015 survey allowed small perturbations directly associated with the presence of dilute wastewater to become apparent in some of the water properties (Figures 8 and 9). For example, the slight transmissivity and pH reductions visible in Figure 8df, that coincided with the plume's mid-depth salinity signature (Figure 8b), could not have been generated by entrainment processes. Transmissivity within ambient seawater was greater near the seafloor, so the observed transmissivity reduction could only have been generated by turbidity associated with the presence of wastewater particulates within the discharge plume. Similarly, the 0.01 reduction in pH was undoubtedly the result of the presence of dilute wastewater, which has a much lower pH (7.4) upon discharge. In contrast, temperature and DO excursions (Figure 8ae) do not coincide spatially with the plume's salinity signature, indicating that any perceptible differences between wastewater and seawater that were present in these properties prior to discharge, had dissipated by this point in the dilution process. Additionally, the negative density anomaly associated with the plume (Figure 8c) indicates that the plume was buoyant and rising within the water column. Thus, the mid-depth tow captured the initial dilution process before it was complete.

Density data from the shallow tow indicate that the plume remained buoyant as it approached the sea surface (Figure 9c), demonstrating that the plume did not become trapped at depth, and that the initial dilution process continued until the plume reached the sea surface where it began to spread laterally. As with the deeper tow data, the reduction in transmissivity (Figure 9d) that coincided with the plume's shallow salinity signature (Figure 9b) was indicative of turbidity associated with the presence of wastewater particulates. Reductions in shallow pH, on the other hand, were exceedingly small and did not coincide spatially with the plume signature (Figure 9f). In contrast to the mid-depth tow data, entrainment anomalies in temperature and DO (Figure 9ae) became apparent as differences between the uplifted water from the seafloor and the surrounding shallow seawater became greater. Although small, the observed 0.03 mg/L reduction in DO near the sea surface (Figure 9e) could have been easily generated by upward plume transport of ambient seawater from the seafloor, where DO concentrations were 0.097 mg/L lower. Similarly, the 0.03°C drop in near-surface plume temperature (Figure 9a) could have been easily generated by entrainment of ambient bottom water, which was 0.075°C colder, but would not have been generated by the presence of warmer wastewater constituents.

The legacies of entrainment anomalies can be particularly long-lived, remaining apparent within the water column well after completion of the initial dilution process. However, such anomalies are irrelevant to the receiving-water compliance assessment because the permit restricts attention to water-quality changes caused solely by the presence of wastewater constituents rather than a simple relocation of ambient seawater. Nevertheless, these anomalies provide useful tracers of the diffuse effluent plume after the completion of the initial dilution process.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the January 2015 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.

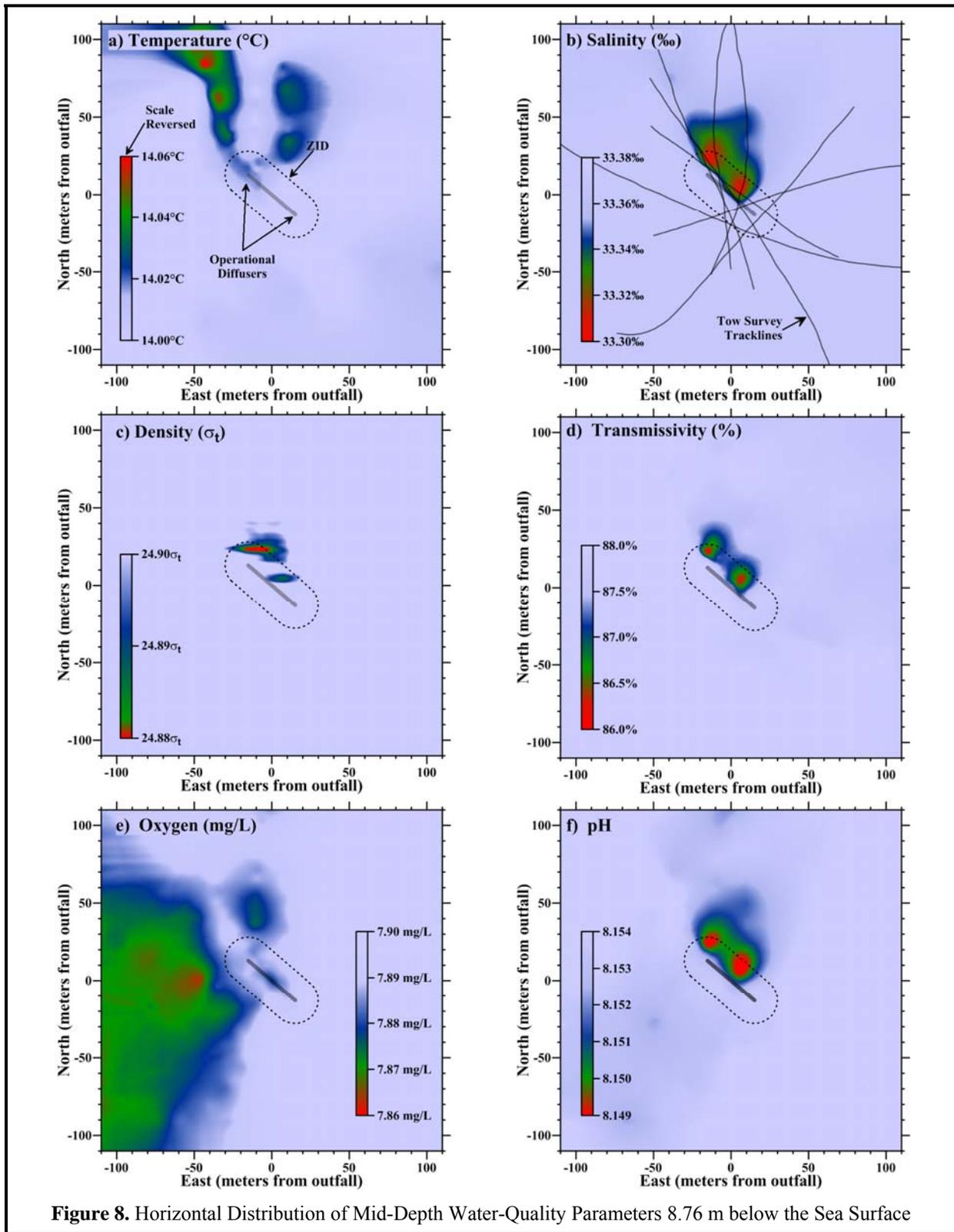
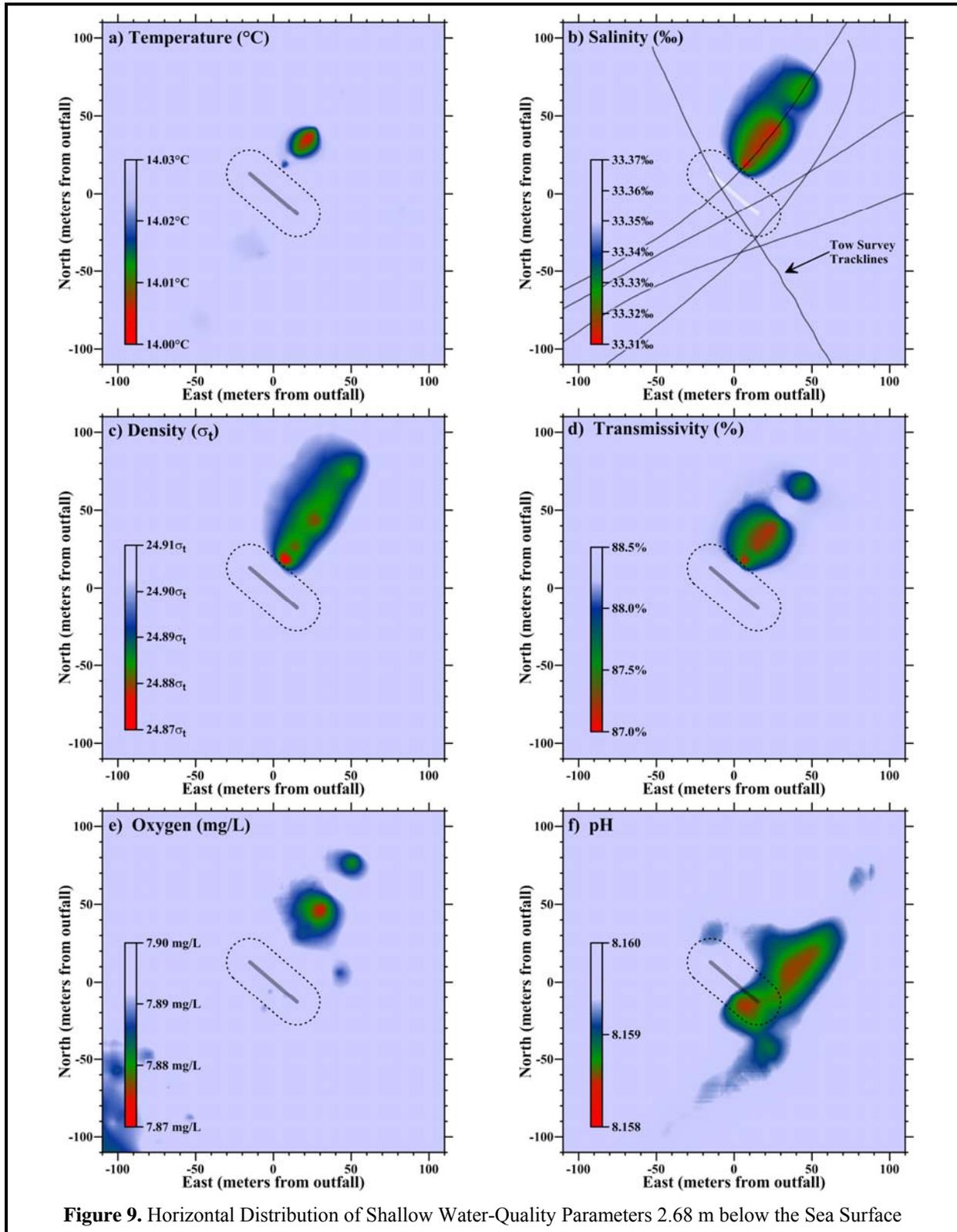


Figure 8. Horizontal Distribution of Mid-Depth Water-Quality Parameters 8.76 m below the Sea Surface



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 additional buoyant mixing normally experienced during 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, ceasing to rise further in the water column, and spread laterally with no further dilution occurring. A 9-m rise at the MBCSD outfall translates into a trapping depth that is 6.4 m below the sea surface. As described below, however, the dilution levels observed during the January 2015 survey were much higher than the 133:1 predicted by the modeling, and were measured at depths greater than the trapping depth predicted by the modeling.

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. Application 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. The regions of slightly lower salinity apparent northeast of the diffuser structure in both of the tow-survey maps (Figures 8b and 9b) were induced by the presence of dilute wastewater. These salinity anomalies document mixing processes within the effluent plume shortly after discharge, and as it subsequently rose through the water column and approached the sea surface.

These salinity anomalies measure the magnitude of wastewater dilution at these various stages of the initial mixing process. By rearranging Equation 1, the dilution ratio (D) can be computed from the salinity anomaly ($A = C_o - C_s$) as:

$$D \equiv \frac{(C_e - C_o)}{(C_o - C_s)} \propto A^{-1} \quad \text{Equation 2}$$

The salinity concentration within MBCSD effluent (C_e)¹⁶ is generally small compared to that of the receiving seawater and, after dilution by more than 133-fold, the salinity of the effluent-seawater mixture is close to ambient salinity. Consequently, to a close approximation, dilution levels are inversely proportional to the amplitude of the salinity anomaly. Thus, a lower effluent dilution at a given location within the receiving waters is directly mirrored by a larger salinity reduction.

The lowest salinity (32.72‰) measured during the January 2015 survey was recorded during the vertical hydrocast at Station RW4 (green line in Figure 7d), and provided a rare glimpse into effluent mixing dynamics immediately after discharge and within the turbulent ejection jet emanating from a single diffuser port. CTD data is not normally collected this close to the diffuser structure; however, as the CTD approached the seafloor below 15.5 m, it happened to pass directly through an effluent ejection jet before finally reaching the seafloor at a depth of 17.5 m. The strongest effluent signature was located 1.0 m above the seafloor both because the buoyant jet rapidly carries the plume upward in the water column shortly after discharge, and because the diffuser ports themselves are slightly elevated above the seabed.

The measurements collected within the ejection jet lend valuable insight into dilution levels achieved shortly after discharge. The recorded salinity was 0.66‰ below the mean ambient salinity of 33.38‰ that was measured at the same depth level, but well beyond the influence of the discharge (Table 5). Based on Equation 2, this unusually close-in measurement indicated that wastewater had been diluted 48-fold almost immediately after discharge, and well before the initial-dilution process was complete. Nevertheless, the measured dilution at that point was already one-third as high as the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater after completion of the initial-dilution process.

As the momentum of the ejection jet dissipated and the buoyant plume rose within the water column, turbulent mixing continued to dilute the wastewater. Accordingly, salinity data collected during the mid-depth tow demonstrated that the wastewater had been diluted by at least 228-fold by the time the dilute wastewater had risen 8.7 m to a depth level of 8.8 m (Figure 10). At that point, wastewater dilution was 70% higher than the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater.

In addition, this dilution was measured 2.4 m deeper than the 6.4-m trapping depth identified in the modeling that established the 133:1 minimum dilution ratio. According to the conservative modeling results, dilution levels would be expected to be much less than 133:1 at that depth level. Instead, the much higher dilutions measured during the mid-depth tow indicate that the diffuser structure was dispersing the effluent more efficiently than predicted by the modeling, well before the completion of the initial dilution process. As the plume rose 6 m higher in the water column, to where the shallow tow was conducted, dilution levels exceeded

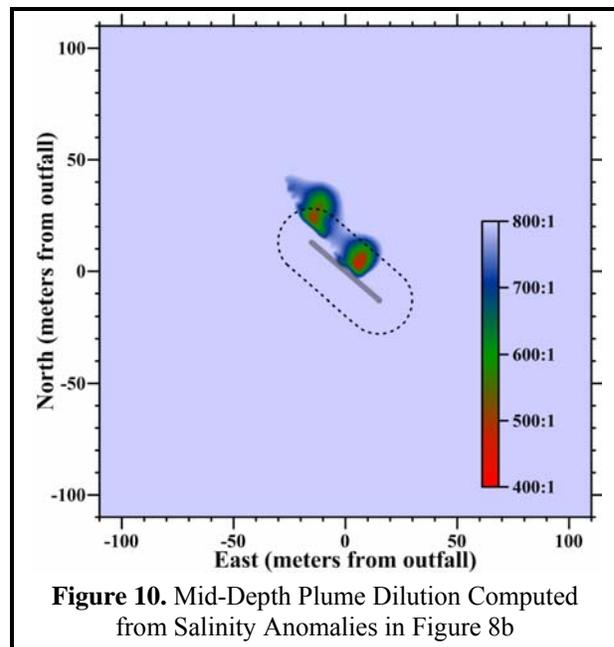


Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b

¹⁶ Wastewater samples have an average salinity of 0.995‰.

485-fold (Figure 11). Thus, near the completion of the initial dilution process, the discharge was achieving rates at least 3.6 times higher than those predicted by the modeling.

Overall, the dilution computations show that, during the January 2015 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 48-fold almost immediately after discharge. After rising through only part of the water column, and well before completion of the initial-dilution process, the buoyant plume had achieved dilutions easily exceeding the 133:1 critical initial dilution used to establish end-of-pipe permit limitations on contaminant concentrations within wastewater discharged from the MBCSD treatment plant. After completion of the initial dilution process, effluent had been diluted at least 485-fold. This demonstrates that, during the January 2015 survey, the COP receiving-water objectives were being met by the limits on chemical concentrations within discharged wastewater that are promulgated by the NPDES discharge permit issued to the MBCSD.

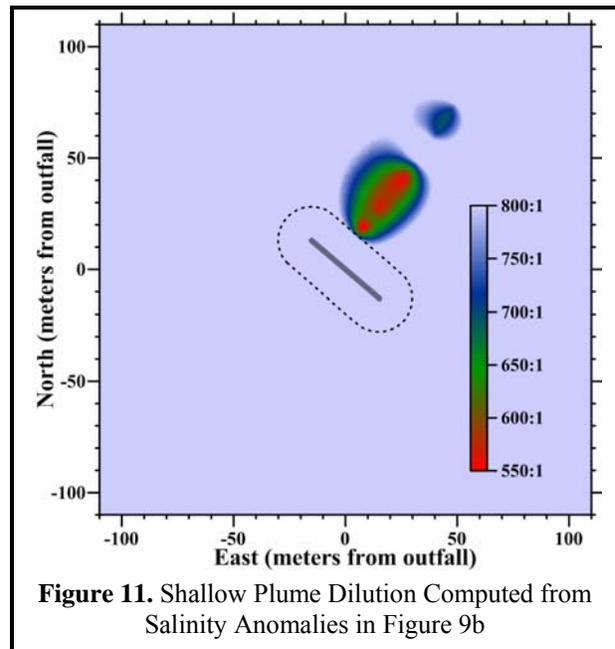


Figure 11. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 9b

COMPLIANCE

This section evaluates compliance with the water-quality limitations listed in the NPDES permit (Table 6). The limits 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 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.

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 results of these analyses of the January 2015 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 met the prescribed limits because actual dilution levels routinely exceeded 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 the January 2015 survey.

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. Compliance was demonstrated by the absence of floating wastewater materials, oil, grease, or discoloration of the sea surface during the January 2015 survey. Compliance with the remaining four receiving-water limitations is quantitatively evaluated through a comparison between instrumental measurements and 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 beyond the ZID. However, both P5 and P6 also contain narrative limits, which originate in the COP, and define unacceptable water-quality impacts as “*significant*” excursions beyond those that occur “*naturally*.” Quantitative evaluation of these limits requires a further comparison of field measurements with numerical thresholds that reflect the natural variation in transmissivity, DO, and pH within the receiving waters surrounding the outfall.

As described previously, natural variation in seawater properties can result from a variety of oceanographic processes. These processes establish 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.

Screening of Measurements

Evaluating whether any of the 7,947 CTD measurements collected during the January 2015 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 discharges 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 pertain; 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 measurements that remain after completing the screening process can then be compared with Basin-Plan numerical limits and COP allowances.

Table 7. Receiving-Water Measurements Screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer		Parameter
		No	Yes ¹⁷	
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	1,219	6,728	All
Wastewater Constituents	2. Did the beyond-ZID measurement coincide with a quantifiable salinity anomaly ($\leq 550:1$ dilution level) indicating the presence of detectable wastewater constituents?	6,664	64	All
Natural Variation	3. Did seawater properties associated with the wastewater measurements depart significantly from the expected range in ambient seawater properties at the time of the survey?	64	0	Temperature
		64	0	Transmissivity
		64	0	DO
		64	0	pH

The last subsection of this section provides additional lines-of-evidence that demonstrate compliance with numerical permit limits independent of the screening process. The rationale for evaluating observations for compliance analysis is presented in the following description of the 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 currents often transport the plume well 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 January 2015 dataset eliminated 1,219 of the original 7,947 receiving-water observations from further consideration because they were collected within the ZID (Table 7, Question 1). The remaining 6,728 observations 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 rarely observed in any seawater property other than salinity, except very close (<1 m) to a diffuser port and within its ejection jet. Data collected during the January 2015 mid-depth tow provided a rare glimpse of wastewater-induced anomalies that only became apparent because ambient seawater properties were exceptionally uniform at the time of the survey.

¹⁷ Number of remaining CTD observations of potential compliance interest based on this screening question

In general, however, negative salinity anomalies are the only consistent indicator of the presence of wastewater constituents within receiving waters. 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 definitive tracer 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 determine the amount of dilution achieved by initial mixing. 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 reliably detected within receiving waters is 0.062‰. This represents a dilution level of 542-fold. Salinity reductions that are smaller than 0.062‰ cannot be reliably discerned against the backdrop of natural variation and would not result in discernible changes in other seawater properties. Eliminating those measurements from further evaluation restricts attention to excursions in temperature, light transmittance, DO, and pH that are potentially related to the presence of wastewater constituents.

As discussed previously, the lowest salinities measured during the January survey were recorded near a diffuser port and well within the ZID boundary. Within the water column, the lowest salinities were recorded northeast of the diffuser structure during the course of the tow surveys. Numerous other detectable reductions in salinity were contiguous to these minima, and together they unequivocally delineated the presence of dilute wastewater constituents within a well-defined region. About half (64) of these measurements were located beyond the ZID boundary and had salinity reductions large enough to indicate the presence of wastewater constituents; namely, had dilutions less than 550:1 (Table 7). The remaining 6,664 observations that were measured outside the ZID during the January 2015 survey did not have salinity reductions that were greater than the 0.062‰ detection level.

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 (upward) 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 the numeric permit limits.

A statistical analysis of receiving-water data previously collected around the outfall was used to establish the range in natural conditions surrounding the outfall (first three data columns of Table 8). These ambient-variability ranges were used to identify significant departures from natural conditions that could be indicative of adverse discharge-related effects on water quality. The same five-year database used to establish the 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 (-1.38 mg/L), and pH (\pm 0.094). These were combined with 95th percentiles determined from the January 2015 ambient seawater data, to establish time-specific natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from January 2015 vertical profile data collected at Stations RW5 and RW6, and the upper portion of RW4, thereby excluding measurements potentially affected by the discharge.

Table 8. Compliance Thresholds

Water Quality Property	95% Confidence Bound ¹⁸	95 th Percentile ^{19,20}	Natural Variability Threshold ²¹	COP Allowance ²²	Basin Plan Limit ²³	Extremum ²⁴
Temperature (°C)	0.82	13.96	>14.78	—	—	≤14.16
Transmissivity (%)	-10.2	87.9	<77.7	—	—	≥77.6
DO (mg/L)	-1.38	7.77	<6.39	<5.75	<5.00	≥7.58
pH (minimum)	-0.094	8.143	<8.049	<7.849	<7.000	≥8.123
pH (maximum)	0.094	8.148	>8.242	>8.442	>8.300	≤8.173

Temperature, transmissivity, pH, and DO concentrations associated with the 64 remaining measurements of potential compliance interest were all well within their respective ranges of natural variability (Table 7, Question 3). As such, the screening process unequivocally eliminated all of the remaining CTD measurements collected during the January 2015 survey from further consideration.

Other Lines of Evidence

Several additional lines of evidence further support the conclusion that all the CTD measurements collected during the January 2015 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 that accounts for both discrepancies and concurrences among multiple lines of evidence. 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 at the time of the January 2015 survey.

Insignificant Thermal Impact: Although there are no explicit numerical objectives for discharge-related increases in temperature, a numerical limit can be established for thermal excursions that is based on the

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 remaining observations for each of the six seawater properties accurately quantified the inherent uncertainty in defining the range in natural conditions.

¹⁹ 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.”

²⁰ The 95th-percentile quantifies natural variability in seawater properties during the January 2015 survey, and was determined from vertical-profiles data unaffected by the discharge.

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 left and are specific to the January 2015 survey. They do not include the COP allowances specified in the column to the right.

²² 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.”

²³ 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. The Basin Plan upper-bound pH objective for ocean waters is 8.5, but a more-stringent upper-bound objective of 8.3, which applies to individual beneficial uses, was implemented in the MBCSD discharge permit.

²⁴ Maximum or minimum value measured during this survey

requirement that they not adversely affect beneficial uses (P3 in Table 6). Increases in temperature caused by the discharge of warm wastewater constituents could be deemed to adversely affect beneficial uses if they exceeded the natural temperature range observed at the time of the survey (i.e. exceeded 14.78°C in Table 8). However, none of the 7,947 CTD measurements collected during the January 2015 survey exceeded 14.16°C (last column in Table 8). Additionally, as mentioned previously, because the effluent entrained cooler bottom water shortly after discharge, the rising plume actually exhibited a slightly lower temperature than the surrounding seawater in the upper water column (Figure 9a).

Limited Ambient 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. However, only one of the transmissivity measurements collected during the January 2015 survey fell below the 77.7% minimum compliance threshold.

The lowest transmissivity measured during the survey was 77.6% and was recorded near the seafloor at Station RW4 (light blue line in Figure 7d). This isolated measurement was collected extraordinarily close to the diffuser structure and within the ejection jet emanating from a single diffuser port. As discussed previously, this low transmissivity was caused by the presence of wastewater particulates that increased turbidity within a highly localized region of comparatively concentrated effluent. The fact that the screening process identified this low transmissivity as departing from natural variability, demonstrates the robustness of the compliance analysis. However, the anomaly was measured well within the ZID where these kinds of excursions are allowed during the initial dilution process. Moreover, it was measured at a depth of 16.5 m, where little ambient light penetrates.

Directional Offset: 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 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). These directional offsets were observed in conjunction with the measurements collected within the ejection jet (Figure 7d). However, as discussed previously, the reduced temperatures observed in conjunction with the shallow effluent plume (Figure 9a) could not have been generated by the presence of warmer wastewater constituents.

Insignificant Wastewater Particulate Loads: Another independent line of evidence demonstrates that the discharge of wastewater particulates could not have contributed materially to turbidity within the dilute effluent plume. The suspended-solids concentration measured onshore, within the effluent, prior to discharge from the WWTP on 7 January 2015 was only 31.6 mg/L. Measurements within the ejection jet at Station RW4 demonstrate that the effluent had only been diluted 48-fold. At this low dilution, the effluent particulate loads would have reduced ambient transmissivity by at least 5%, which is comparable to the observed decrease. Within the rising plume at mid-depth, the 228-fold dilution would have reduced ambient transmissivity by only 1%, which is also comparable to the decrease observed during the mid-depth tow (Figure 8d). After approaching the completion of the initial dilution process however, when effluent had achieved dilutions exceeding 485-fold, the 0.5% expected transmissivity reduction due to the presence of wastewater particulates was negligible compared to natural fluctuations in transmissivity.

Similarly, the MBCSD discharge could not have contributed materially to the observed DO fluctuations. The MBCSD treatment process routinely removes 80% or more of the organic material, as demonstrated by the low, 54-mg/L BOD measured within the plant's effluent on the day following the survey. That

small amount of BOD would have induced a DO depression of no more than 0.022 mg/L after dilution (MRS 2002). In fact, in the absence of tangible BOD influence, wastewater discharge 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 due to the lack of atmospheric equilibration. However, this was not the case for DO measurements collected within the ejection jet during the January 2015 survey (dark blue line in Figure 7d). In the absence of stratification, the ambient seawater at depth was not depleted in oxygen.

COP Allowances: The COP does not explicitly require that wastewater-induced changes remain within the ranges in natural variation listed in the third data column of Table 8, even though these ranges were conservatively used in the data screening process described in the previous subsection. Consideration of these COP allowances in the receiving-water limits provides an additional level of confidence in the compliance evaluation.

For pH, the COP and the discharge permit allow changes up to 0.2 pH units from natural conditions, bringing the minimum allowed pH to 7.849 during the January 2015 survey (fourth data column of Table 8). This limiting value is significantly less than the lowest pH measurement of 8.123 recorded during the January 2015 survey (last column of Table 8). Similarly, the lowest DO concentration measured during the survey (7.58 mg/L) was well above both the lower range in natural variation (6.39 mg/L) and the 10% compliance threshold promulgated by the COP (5.75 mg/L).

Excursions remained within the fixed 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. As described previously, 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). Nevertheless, all of the January 2015 survey measurements complied with the Basin-Plan limits, including the more-restrictive limit on maximum pH.

CONCLUSIONS

The quantitative screening analysis demonstrated that all measurements recorded during the January 2015 survey complied with the receiving-water limitations specified in the NPDES discharge permit. This conclusion was further strengthened by other lines of evidence supporting compliance with the discharge permit. Specifically, although discharge-related changes in seawater properties were observed during the January 2015 survey, the changes were either not of significant magnitude (i.e., they were within the natural range of variability that prevailed at the time of the survey), 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.

As the dilute effluent plume rose through the water column and approached the completion of the initial dilution process, measured dilutions levels reached 485-fold. This measured dilution level far exceeds levels that were predicted by modeling and that were incorporated in the discharge permit as limits on contaminant concentrations within effluent prior to discharge. Lastly, all of the auxiliary observations collected during the January 2015 survey demonstrated that the discharge complied with the narrative receiving-water limits in the discharge permit and the COP. Together, these observations demonstrate that the treatment process, diffuser structure, and the outfall continue to surpass design expectations.

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