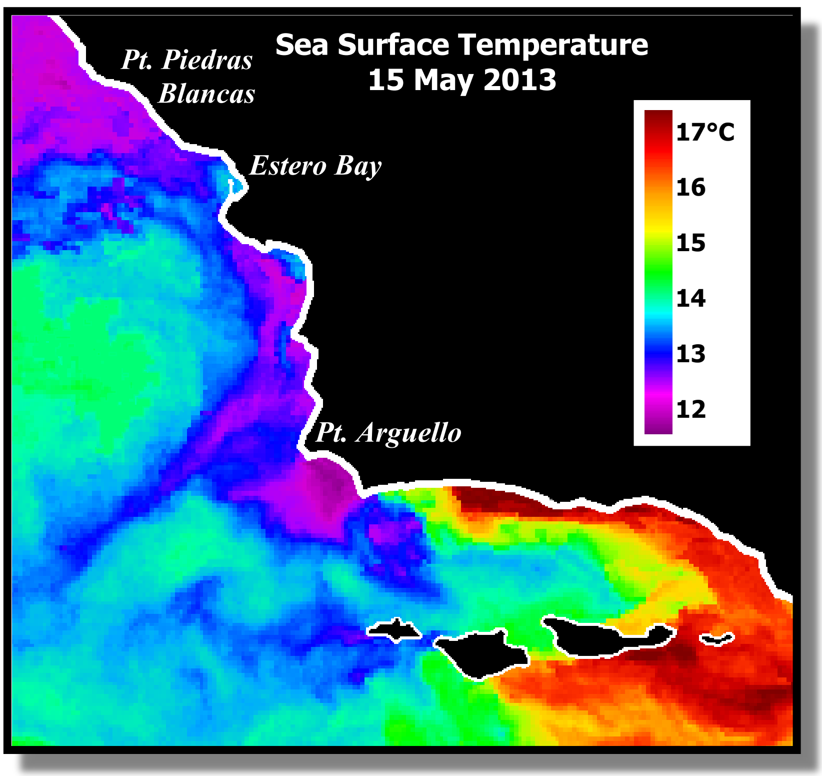
City of Morro Bay and
Cayucos Sanitary District

OFFSHORE MONITORING AND REPORTING PROGRAM

SECOND QUARTER RECEIVING–WATER SURVEY

MAY 2013



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Report to the

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SECOND QUARTER RECEIVING–WATER SURVEY

MAY 2013

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July 2013

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

1 July 2013

Reference: Second Quarter Receiving-Water Survey Report – May 2013

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Thursday, 16 May 2013. 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 continued 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

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.

Bruce Keogh

Mr. Bruce Keogh
Wastewater Division Manager
City of Morro Bay

Date July 1, 2013

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INTRODUCTION

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. In March 1985, Region IX of the U.S. Environmental Protection Agency (USEPA) and the Central Coast California Regional Water Quality Control Board (RWQCB) issued the first National Pollutant Discharge Elimination System (NPDES) permit to the MBCSD. The permit incorporated partially modified secondary treatment requirements for the plant's ocean discharge. The permit has been re-issued three times, in March 1993 (RWQCB-USEPA 1993ab), December 1998 (RWQCB-USEPA 1998ab), and January 2009 (RWQCB-USEPA 2009). The May 2013 field survey described in this report was the seventeenth 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 16 May 2013. Specifically, this second-quarter survey captured ambient oceanographic conditions along the central California coast during the spring 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 CTD[1] 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)

Figure 1. Location of the Receiving-Water Survey Area

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.

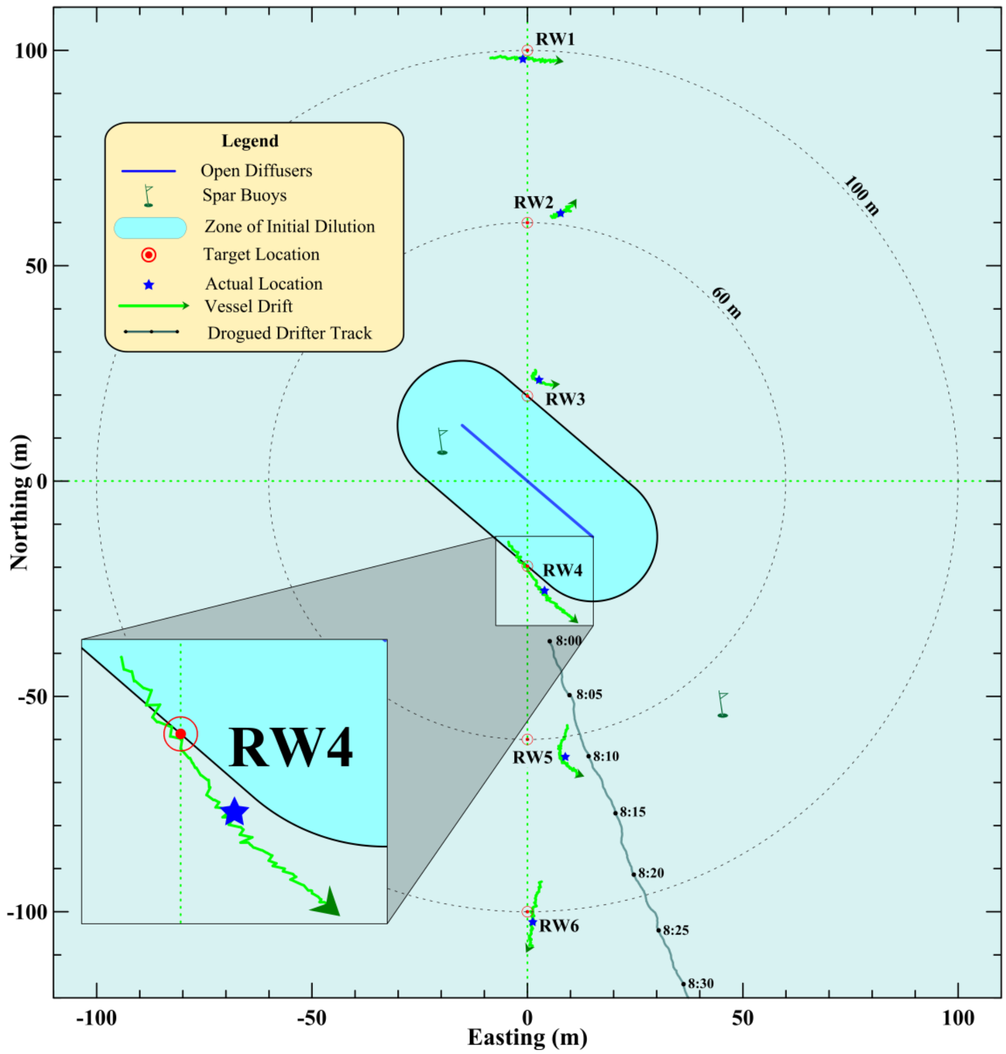

Figure 2. Station Locations

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 metocean[4] conditions, the residual momentum of the survey vessel as it approaches the target locations can create perceptible offsets. Using DGPS however, these offsets can be quantified, and the vessel location can be precisely tracked throughout sampling at each station.

The magnitude of the drift at each of the six stations during the May 2013 survey is apparent from the length of the green tracklines in Figure 2. These tracklines trace the horizontal movement of the CTD as it was lowered to the seafloor at each station. Their lengths and offsets from the target locations reflect the overall station-keeping ability during the May 2013 survey. As seen in Figure 2, drift distance and direction varied widely among the six downcasts. In particular, the 23.7 m drift at Station RW4 was substantially greater than at the other stations, which ranged from 1.9 m (Station RW2) to 15.6 m (Stations RW1 and RW6).

The increased drift distance at Station RW4 resulted from the combined effect of the vessel's residual momentum as it approached the station from the northwest, and the southeastward current and winds that prevailed at the time of the survey. The southeasterly drift component that was evident in the CTD trajectories at several of the stations was consistent with southeastward transport of the drogued drifter by subsurface currents (Figure 3).

During the time it took the CTD to traverse the water column and reach the seafloor at each of the stations, which averaged 1 minute 28 seconds, the instrument package moved an average of 12.2 m. This amount of drift is comparable to most recent surveys, where downcasts have typically been completed in 1 minute 30 seconds with lateral offsets of less than 10 m.

Because the target locations for Stations RW3 and RW4 lie along the ZID boundary (red ⊙ symbols in Figure 2), detailed knowledge of the CTD's location during the downcasts at those stations is particularly 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. During the May 2013 survey, the CTD traversed the ZID boundary at Station RW4 (green line in the inset in Figure 2). As a result, some of the shallowest measurements recorded by the CTD at Station RW4 were located inside the ZID and were not subject to the compliance analysis.

It has not always been possible to determine which measurements were subject to permit limits within hydrocasts near the ZID boundary. 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.

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

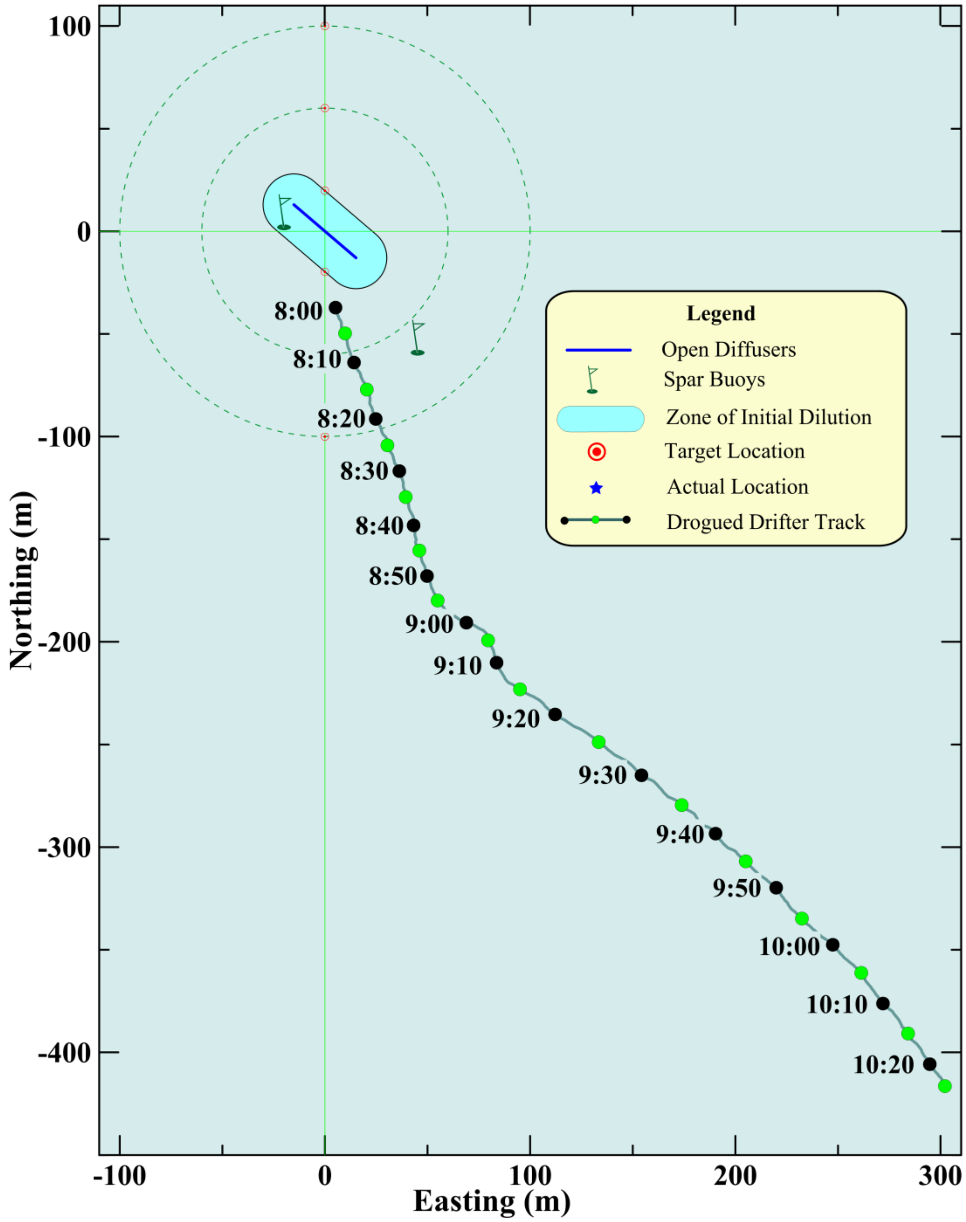

Figure 3. Drogued Drifter Trajectory

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 May 2013 survey also identifies a single sampling location for each station. These average station positions are shown by blue stars in Figure 2, and are listed in Table 2 along with their distances from the diffuser structure.

Table 2. Average Position of Vertical Profiles during the May 2013 Survey

Station	Time (PDT)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range[5] (m)	Bearing[6] (ºT)
RW1	8:07:25	8:08:49	35° 23.252' N	120° 52.505' W	86.3	9
RW2	8:24:28	8:25:56	35° 23.233' N	120° 52.499' W	54.4	25
RW3	8:18:52	8:20:12	35° 23.212' N	120° 52.502' W	19.7	41
RW4	8:28:59	8:30:31	35° 23.185' N	120° 52.501' W	**16.7**[7]	221
RW5	8:34:47	8:36:03	35° 23.164' N	120° 52.498' W	51.4	187
RW6	8:40:37	8:41:52	35° 23.144' N	120° 52.503' W	90.4	189

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 two decades, however, demonstrates that it has maintained a high level of effectiveness in effluent dispersal. In fact, without the occasional measurements recorded within the ZID due to vessel drift, the extremely dilute discharge plume might remain undetected within all vertical profiles collected during a given survey.

OCEANOGRAPHIC PROCESSES

The trajectory of a satellite-tracked drogued drifter documented the oceanic flow during the May 2013 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 decade. In this configuration, the oceanic flow field rather than surface winds dictates the drifter's trajectory, providing a good assessment of the plume's movement after discharge.

The drifter was deployed near the diffuser structure at 8:00 AM, and was recovered at 10:25 AM at a location 482 m from its original release point (Figure 3). Overall, the drifter measured an average flow speed of 5.6 cm/s (0.11 kt). At that transport rate, effluent only had a 4.6-minute residence time within the ZID.

During the first hour of the survey, the drifter traveled swiftly toward the south-southeast (161ºT[8]) at a speed of 4.6 cm/s (0.09 kt). The initial south-southeastward (offshore) flow direction was consistent with the ebb tide that prevailed during the initial (vertical-cast) portion of the May 2013 survey (Figure 4). Additionally, current speed remained relatively constant during this time as shown by the uniform spacing between the green and black dots in Figure 3. The dots show the drifter's progress at five- and ten-minute intervals.

At 9:00 AM, the drifter's movement shifted to a more southeasterly direction (134ºT) and its speed increased to 6.4 cm/s (0.12 kt). This slight change in flow direction and speed coincided with the onset of a slack tide (Figure 4).

5 Distance from the closest open diffuser port to the average profile location.
6 Angle measured clockwise relative to true north from the closest diffuser port to the average profile location.
7 The shallowest CTD measurements at Station RW4 were located within the ZID boundary (refer to the inset in Figure 2).
8 Direction measured clockwise relative to true (rather than magnetic) north

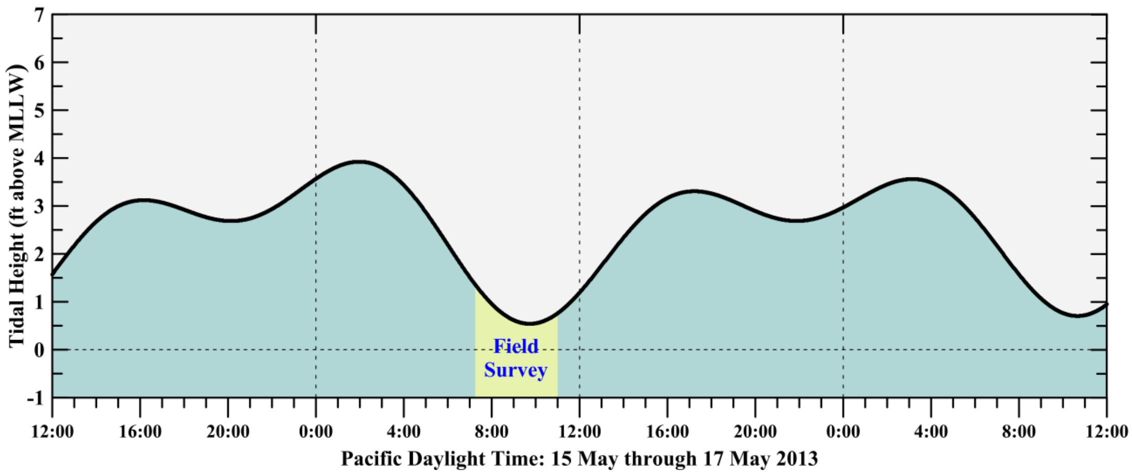

Figure 4. Tidal Level during the May 2013 Survey

Despite the general correspondence between flow direction and tides measured during the May 2013 survey, coastal currents within Estero Bay are often more-strongly influenced by external processes, such as wind-generated upwelling, downwelling, or the passing of offshore eddies propagating along the coastline. For example, during the May 2013 survey, the observed prevailing flow could be largely ascribed to upwelling. Strong upwelling winds that prevailed around the time of the survey (last yellow diamond in Figure 5) induced a southerly (offshore) flow in the upper water column, and a northerly (shoreward) flow close to the seafloor. Upwelling season normally begins sometime during late March and or early April as shown by the positive (blue) upwelling indices in Figure 5. At the onset of upwelling season, there is a transition to more persistent southeastward winds along the central California coast that 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 southward and offshore, allowing deep, cool, nutrient-rich waters to move shoreward and upwell near the coast.

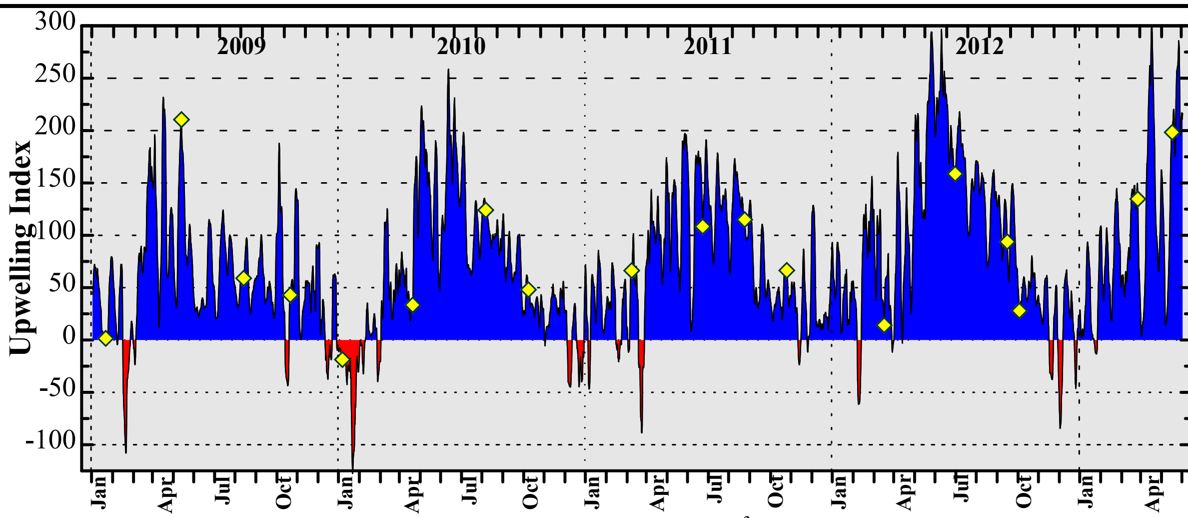

Figure 5. Five-Day Average Upwelling Index ($m^3/s/100$ m of coastline)

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

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

The satellite image on the cover of this report documents the influence of upwelling on sea-surface temperatures immediately prior to the May 2013 survey. The image was recorded the day before the survey, when skies were clear enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA's polar orbiting satellites. The distinctive thermal signature of upwelling is apparent in the cover image, with a band of cooler nearshore sea-surface temperatures shown in purple (<12˚C) along the central coast. As is common during upwelling, these cooler waters are typically transported offshore by the cross-shore flow that occurs at major promontories, such as Point Arguello.

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on Thursday, 16 May 2013. 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. William Skok assisted with deployment and recovery of the CTD and drifter. Mr. Neza Chavira, a Grade II operator at the WWTP, was onboard to observe the survey activities and assist in the CTD deployment and recovery.

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 increased suspended particulate loads from 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 May 2013 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	ºC	–5 to 35	± 0.005	± 0.0001
Transmissivity (WETLabs C-Star)[9]	%	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-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 8:42 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 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

[9] 25-cm path length of red (660 nm) light

and across the ZID at two separate depths, one at mid-depth below the thermocline and one within the surface mixed layer, in accordance with the monitoring requirements of the NPDES discharge permit (Figure 6).

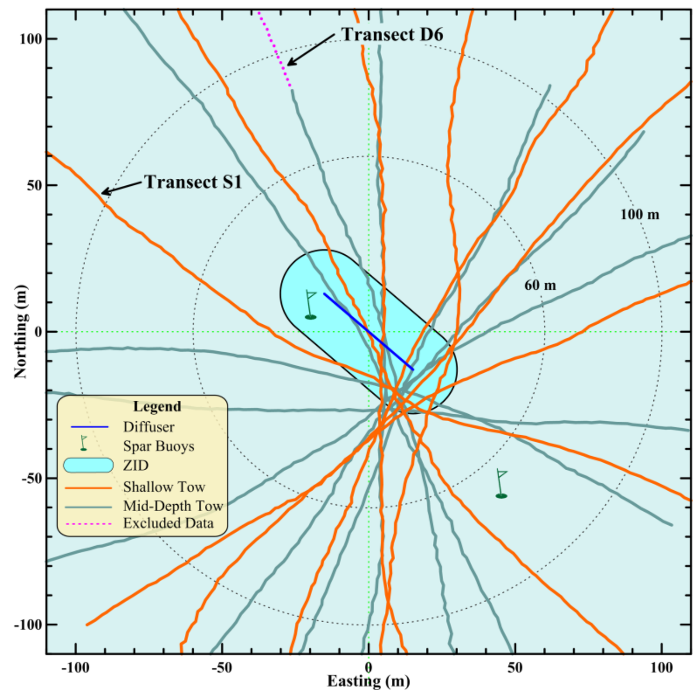

Figure 6. CTD Tracklines during the May 2013 Tow Surveys

Initially, the reconfigured CTD package was towed for 34 minutes at an average depth of 2.52 m, and an average speed of 1.85 m/s, passing over, or near the diffuser structure seven times. Subsequently, eight additional passes were made with the CTD at an average depth of 8.34 m. During this 33-minute mid-depth tow, vessel speed averaged 2.18 m/s. At the observed towing speeds and the 4 Hz sampling rate, at least 1.8 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.[10]

Quality Control

During the vertical-profiling and horizontal-towing phases of the survey, real-time data were monitored for completeness and range acceptability. For example, the data demonstrated that the CTD failed to reach the seafloor during the initial vertical cast at Station RW2. Therefore, after completing the vertical cast at Station RW3, the vertical cast at Station RW2 was repeated. Although real-time monitoring indicated the balance of the recorded properties were complete and within acceptable coastal seawater ranges,[11] subsequent post-processing revealed several events that impacted portions of the data, resulting in the adjustment or exclusion of these data prior to initiation of the compliance analysis. For example, review of the tow data revealed that the CTD was tracking at a slightly different depth (>1 m offset) during the latter portion of the mid-depth tow along Transect D6 (purple dotted line in Figure 6).

This depth offset was induced by changes in vessel speed that were 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.

[10] Figures 7 and 8 later in this report

[11] 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.

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 stratified, as was the case during the May 2013 survey.

The exclusion of the small portion of Transect D6 did not, however, adversely affect the compliance analysis because the remaining transects adequately covered the 100-m survey area surrounding the diffuser structure. Specifically, the remaining data, shown by the solid orange and blue-green lines in Figure 6, met the permit monitoring requirement of at least five passes near the diffuser structure at each tow depth.

In addition to the removal of all measured properties within a limited section of Transect D6, four individual transmissivity measurements were excised from data collected during the first shallow transect (S1). These data represented large (17%), but short-lived (1-second) reductions in transmissivity that arise when the CTD encounters a piece of floating kelp or other debris which briefly blocks the transmissometer's light path. In contrast, when the plume signature is observed in the transmissivity record, the changes are gradual, of limited amplitude, and can be in either direction relative to average water clarity depending on whether the deep seawater entrained at depth is more or less turbid than mid-depth seawater. In fact, during the May 2013 survey, ambient seawater clarity was higher near the seafloor, and when entrained within the rising effluent plume, it resulted in plume signature characterized by increased transmissivity in the upper water column. In addition, the anomalously low transmissivity measurements were located 100 m from the outfall in the northwest quadrant of the survey area (near the tip of the arrow extending from the *Transect S1* label in Figure 6). That location is well upstream of the southward plume transport path that was determined by the drifter trajectory and documented by the CTD measurements of the other seawater properties (Figure 3).

RESULTS

The second-quarter receiving-water survey was conducted on the morning of Thursday, 16 May 2013. The receiving-water survey commenced at 8:00 AM with the deployment of the drogued drifter. Over the following two and a half hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended at 10:25 AM with the retrieval of the drogued drifter. Collection of required visual observations of the sea surface was unencumbered throughout the survey.

Auxiliary Observations

On the morning of 16 May 2013, the sky was overcast, and it remained so throughout the survey. Light and variable northwesterly winds prevailed during the morning. Average wind speeds, calculated over one-minute intervals, ranged from 0.8 kt to 1.4 kt (Table 4). Similarly, peak wind speeds ranged from 1.6 kt to 2.5 kt. The swell was out of the northwest with a significant wave height of between 3 and 5 feet. Air temperatures remained fairly constant throughout the survey, averaging 13.3°C.

The 3 m Secchi depths recorded during the May 2013 survey reflected the presence of a restricted 6-m euphotic zone that did not extend through even half of the water column at any station (Table 4). Thus, although much less turbid seawater was present at depth, the Secchi measurements only captured the low water clarity that was present within the 4-m thick surface mixed layer. The reduced seawater clarity within the mixed layer near the sea surface was caused by increased planktonic densities that arose because of upwelling. During upwelling, nutrients carried upward into the euphotic zone are assimilated by phytoplankton, whose populations increase and, along with their associated zooplanktonic predators, their elevated densities can reduce the transmittance of ambient light.

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location[12] Latitude	Longitude	Diffuser Distance (m)	Time (PDT)	Air (°C)	Cloud Cover (%)	Wind Avg (kt)	Wind Max (kt)	Wind Dir (from) (°T)	Swell Ht/Dir (ft/°T)	Secchi Depth (m)
RW1	35° 23.246' N	120° 52.488' W	84.1	8:10:08	12.7	100	1.0	1.8	NW	3-5 NW	3.0
RW2	35° 23.229' N	120° 52.490' W	55.8	8:15:28	13.5	100	0.8	1.7	NW	3-5 NW	3.0
RW3	35° 23.212' N	120° 52.494' W	27.6	8:21:31	13.7	100	0.9	1.7	NW	3-5 NW	3.0
RW4	35° 23.178' N	120° 52.492' W	26.1	8:31:56	13.5	100	1.1	2.5	NW	3-5 NW	3.0
RW5	35° 23.163' N	120° 52.496' W	53.9	8:37:13	12.7	100	1.4	2.5	NW	3-5 NW	3.0
RW6	35° 23.140' N	120° 52.503' W	97.1	8:43:13	13.5	100	1.1	1.6	NW	3-5 NW	3.0

Communication with plant personnel and subsequent review of effluent discharge properties on the day of the survey, confirm that the treatment process was performing nominally at time of the survey. The 0.846 million gallons of effluent discharged on 16 May had a temperature of 20°C, a suspended-solids concentration of 54 mg/L, and a pH of 7.5. Biochemical oxygen demand (BOD) measured in an effluent sample collected six days before the survey was 48 mg/L.

During the May 2013 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. Small numbers of Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), and western gulls (*Larus occidentalis*) were noted transiting the survey area. Additionally, several southern sea otters (*Enhydra lutris nereis*) and California sea lions (*Zalophus californianus*) were observed inside the mouth of Morro Bay during transit to and from the survey site. A lone, adult sea lion and three common dolphins (*Delphinus capensis*) were observed briefly at the survey site. Although low clouds and fog restricted visibility during the first half of the survey, pedestrians and equestrians were visible along Atascadero State beach during the latter half of the survey. Additionally, several recreational and sport-fishing vessels were observed transiting the survey area.

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 May 2013 survey reflect the presence of a highly stratified water column indicative of upwelling conditions within Estero Bay (Figure 5).

Upwelling of varying intensity occurs most of the year along the central California coast, with the strongest upwelling winds beginning in March or April and extending through the summer. 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 a small vertical distance. Under highly stratified conditions, isotherms crowd together to form a density interface that restricts the vertical transport of the effluent plume, inhibiting the vertical exchange of nutrients and other water properties, and reducing the initial dilution of the effluent plume.

Although winds were mild on the morning of the survey, sustained northwesterly strong winds prevailed both in the days prior to the survey, and during the afternoon on the day of the survey (Figure 5), resulting in intense upwelling. As a result, the vertical profiles exhibit a sharply defined transition between the 3-m

[12] 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 16 May 2013

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		12.859	12.994	11.402	12.231	12.937		33.729	33.726	33.612	33.698	33.736
1.5	13.083	12.850	13.030	11.958	12.381	12.848	33.731	33.727	33.731	33.675	33.721	33.733
2.0	12.947	12.829	12.957	12.217	12.401	12.675	33.723	33.725	33.725	33.701	33.719	33.724
2.5	12.835	12.700	12.820	12.139	12.064	12.443	33.722	33.724	33.719	33.690	33.683	33.717
3.0	12.676	12.440	12.637	11.843	11.749	12.242	33.719	33.721	33.718	33.673	33.664	33.702
3.5	12.419	12.281	12.378	11.611	11.577	12.023	33.720	33.721	33.714	33.688	33.667	33.681
4.0	11.989	11.966	11.990	11.588	11.554	11.741	33.696	33.699	33.684	33.692	33.678	33.665
4.5	11.896	11.850	11.896	11.572	11.554	11.572	33.717	33.715	33.707	33.691	33.685	33.679
5.0	11.838	11.842	11.817	11.535	11.546	11.547	33.726	33.726	33.719	33.701	33.689	33.691
5.5	11.817	11.816	11.796	11.506	11.536	11.542	33.733	33.729	33.729	33.728	33.693	33.698
6.0	11.719	11.763	11.765	11.506	11.528	11.543	33.730	33.732	33.732	33.724	33.699	33.720
6.5	11.681	11.733	11.709	11.502	11.529	11.547	33.735	33.735	33.731	33.725	33.704	33.738
7.0	11.643	11.646	11.673	11.518	11.529	11.536	33.736	33.736	33.736	33.731	33.707	33.745
7.5	11.612	11.609	11.605	11.549	11.521	11.494	33.738	33.739	33.736	33.714	33.716	33.748
8.0	11.579	11.575	11.585	11.531	11.510	11.458	33.740	33.742	33.740	33.713	33.737	33.751
8.5	11.571	11.556	11.577	11.513	11.514	11.443	33.742	33.746	33.741	33.724	33.730	33.753
9.0	11.558	11.541	11.561	11.472	11.500	11.421	33.745	33.748	33.742	33.748	33.742	33.753
9.5	11.544	11.532	11.550	11.474	11.477	11.409	33.747	33.749	33.745	33.753	33.750	33.754
10.0	11.544	11.529	11.539	11.482	11.466	11.401	33.748	33.750	33.747	33.752	33.753	33.755
10.5	11.538	11.519	11.536	11.484	11.460	11.388	33.749	33.750	33.748	33.752	33.753	33.755
11.0	11.532	11.512	11.525	11.482	11.454	11.383	33.749	33.751	33.749	33.752	33.754	33.756
11.5	11.533	11.508	11.515	11.458	11.449	11.380	33.749	33.751	33.749	33.753	33.754	33.756
12.0	11.525	11.505	11.506	11.448	11.447	11.379	33.749	33.751	33.750	33.754	33.754	33.756
12.5	11.521	11.502	11.495	11.436	11.429	11.366	33.750	33.751	33.750	33.754	33.754	33.756
12.0	11.520	11.497	11.490	11.435	11.408	11.354	33.749	33.751	33.750	33.755	33.754	33.756
12.5	11.519	11.497	11.490	11.435	11.408	11.348	33.750	33.751	33.751	33.755	33.755	33.756
14.0	11.518	11.496	11.487	11.435	11.399	11.346	33.750	33.751	33.751	33.755	33.755	33.756
14.5	11.518	11.495	11.487	11.435	11.398	11.353	33.749	33.751	33.751	33.755	33.756	33.757
15.0	11.519	11.497	11.487	11.434	11.405	11.352	33.749	33.751	33.751	33.755	33.756	33.757
15.5			11.488	11.435	11.418	11.362			33.751	33.755	33.756	33.757

Table 5. Vertical Profile Data Collected on 16 May 2013 (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		25.437	25.408	25.622	25.534	25.426		8.218	8.241	7.976	8.085	8.191
1.5	25.393	25.436	25.404	25.568	25.523	25.441	8.266	8.216	8.255	7.985	8.109	8.198
2.0	25.414	25.439	25.414	25.539	25.518	25.468	8.253	8.212	8.258	8.027	8.110	8.184
2.5	25.435	25.464	25.436	25.545	25.554	25.508	8.211	8.206	8.261	8.067	8.092	8.149
3.0	25.464	25.512	25.471	25.588	25.598	25.535	8.198	8.179	8.234	8.062	8.060	8.124
3.5	25.515	25.542	25.518	25.643	25.633	25.561	8.156	8.140	8.189	8.026	8.027	8.097
4.0	25.578	25.585	25.569	25.650	25.646	25.601	8.122	8.112	8.145	8.008	8.004	8.067
4.5	25.612	25.620	25.605	25.653	25.651	25.643	8.082	8.089	8.091	7.997	7.986	8.037
5.0	25.630	25.630	25.629	25.667	25.656	25.657	8.063	8.065	8.070	7.987	7.983	8.015
5.5	25.640	25.637	25.640	25.694	25.661	25.664	8.053	8.057	8.053	7.981	7.980	8.001
6.0	25.655	25.649	25.648	25.690	25.667	25.680	8.042	8.048	8.043	7.976	7.979	7.995
6.5	25.667	25.657	25.658	25.692	25.671	25.693	8.030	8.038	8.036	7.971	7.978	7.992
7.0	25.675	25.674	25.669	25.693	25.673	25.701	8.020	8.026	8.028	7.971	7.976	7.989
7.5	25.682	25.683	25.682	25.674	25.681	25.711	8.011	8.015	8.019	7.972	7.975	7.985
8.0	25.689	25.691	25.688	25.677	25.699	25.720	8.006	8.007	8.011	7.974	7.974	7.979
8.5	25.692	25.698	25.691	25.689	25.693	25.724	8.002	7.997	8.007	7.977	7.971	7.972
9.0	25.697	25.702	25.694	25.715	25.705	25.729	7.997	7.989	8.002	7.970	7.972	7.968
9.5	25.701	25.705	25.698	25.718	25.716	25.732	7.991	7.983	7.998	7.966	7.969	7.964
10.0	25.702	25.706	25.702	25.717	25.720	25.734	7.984	7.978	7.992	7.964	7.967	7.960
10.5	25.704	25.708	25.703	25.716	25.721	25.736	7.978	7.975	7.983	7.963	7.964	7.958
11.0	25.705	25.710	25.706	25.717	25.723	25.737	7.976	7.972	7.981	7.965	7.964	7.956
11.5	25.705	25.711	25.708	25.721	25.724	25.738	7.972	7.970	7.977	7.965	7.962	7.953
12.0	25.706	25.711	25.710	25.724	25.724	25.738	7.968	7.969	7.972	7.961	7.960	7.952
12.5	25.708	25.712	25.713	25.726	25.728	25.740	7.968	7.967	7.971	7.958	7.959	7.952
12.0	25.707	25.713	25.714	25.727	25.732	25.743	7.964	7.967	7.969	7.956	7.955	7.951
12.5	25.708	25.713	25.714	25.727	25.733	25.744	7.965	7.964	7.966	7.954	7.956	7.949
14.0	25.708	25.713	25.714	25.727	25.734	25.745	7.964	7.964	7.965	7.954	7.953	7.948
14.5	25.708	25.713	25.714	25.727	25.735	25.744	7.965	7.963	7.965	7.953	7.952	7.948
15.0	25.708	25.713	25.714	25.727	25.733	25.744	7.963	7.963	7.964	7.952	7.950	7.948
15.5			25.714	25.727	25.731	25.742			7.960	7.952	7.956	7.948

Table 5. Vertical Profile Data Collected on 16 May 2013 (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		9.850	10.851	7.903	8.339	9.615		69.742	66.382	81.394	73.022	68.951
1.5	9.796	9.629	9.926	8.174	7.895	8.237	69.360	66.135	65.912	80.405	70.464	67.035
2.0	9.536	9.099	9.227	7.649	7.103	8.002	69.512	68.697	65.792	77.606	70.420	66.242
2.5	8.709	7.848	8.303	6.974	6.585	7.570	69.881	69.259	65.102	71.801	72.073	69.512
3.0	7.975	7.710	7.673	6.400	6.323	7.112	69.954	72.981	66.538	74.728	77.459	72.163
3.5	6.999	7.161	7.061	6.586	6.459	6.611	73.063	74.422	68.273	81.202	80.060	73.635
4.0	7.254	7.182	7.194	6.505	6.476	6.429	74.851	75.198	73.597	86.161	82.639	76.463
4.5	7.226	7.246	7.169	6.470	6.473	6.486	79.862	78.646	76.437	86.029	83.855	80.935
5.0	7.219	7.167	7.161	6.363	6.442	6.504	83.790	84.828	81.937	85.211	84.143	83.816
5.5	6.943	7.064	7.150	6.372	6.439	6.565	85.855	84.265	84.792	84.877	84.773	85.268
6.0	6.897	7.027	7.006	6.362	6.446	6.579	86.057	85.126	86.601	85.218	85.279	85.608
6.5	6.836	6.771	6.893	6.455	6.436	6.516	88.311	86.020	86.946	84.860	85.296	85.800
7.0	6.786	6.762	6.693	6.516	6.421	6.240	89.180	86.961	87.921	84.843	85.445	86.896
7.5	6.715	6.634	6.713	6.452	6.404	6.198	90.169	90.173	89.724	84.871	85.437	86.583
8.0	6.724	6.508	6.730	6.362	6.404	6.196	90.403	89.990	89.956	85.622	85.369	85.746
8.5	6.590	6.433	6.644	6.229	6.353	6.133	90.623	89.070	90.009	85.692	85.778	85.212
9.0	6.466	6.406	6.538	6.293	6.268	6.143	90.425	86.529	90.763	84.990	85.656	85.083
9.5	6.485	6.411	6.486	6.316	6.247	6.118	87.916	84.811	89.918	84.534	85.508	85.445
10.0	6.468	6.384	6.517	6.319	6.258	6.094	86.807	84.295	88.487	84.680	85.173	85.875
10.5	6.422	6.366	6.411	6.338	6.200	6.094	85.745	83.914	86.285	84.468	84.716	85.676
11.0	6.434	6.361	6.407	6.225	6.220	6.072	85.195	84.181	85.604	84.592	84.832	85.978
11.5	6.421	6.363	6.379	6.198	6.203	6.089	84.932	84.226	85.209	84.784	84.810	86.064
12.0	6.394	6.343	6.353	6.174	6.134	6.056	84.467	84.256	84.822	84.799	84.884	86.001
12.5	6.406	6.336	6.342	6.165	6.101	6.042	84.262	84.288	84.825	84.640	85.004	86.086
12.0	6.395	6.346	6.357	6.174	6.127	6.028	84.361	84.206	84.768	84.667	85.159	86.549
12.5	6.403	6.317	6.340	6.164	6.102	6.041	84.272	84.022	84.802	84.560	85.583	86.826
14.0	6.368	6.315	6.335	6.164	6.106	6.036	84.235	84.248	84.619	84.499	85.704	86.915
14.5	6.385	6.333	6.341	6.169	6.118	6.047	83.891	84.129	84.694	84.220	85.827	87.061
15.0	6.384	6.320	6.328	6.156	6.114	6.053	83.737	84.061	84.752	84.290	85.582	87.161
15.5			6.322	6.162	6.110	6.043			84.213	83.932	85.755	87.230

deep surface mixed layer and the nearly uniform seawater properties that were present at depths below 7 m (Figure 7). In particular, all seawater properties except transmissivity exhibit steadily increasing or decreasing values throughout the subsurface transition zone. At the southern stations of RW4, RW5, and RW6 (Figure 7def), the upward displacement of deeper ambient seawater that was entrained within the rising effluent plume further compressed this vertical transition zone.

Within the transition zone, temperature (red lines), DO (dark blue lines), and pH (olive-colored lines) decrease with depth and reflect the effects of upwelling during the days prior to the survey. These decreases are mirrored by a pycnocline, where density (black lines), and to some extent salinity (green lines) steadily increase with depth. These vertical changes reflect the transition to colder, saltier, nutrient-rich but oxygen-poor watermass that migrated shoreward along the seafloor as part of the upwelling process. This offshore watermass moved shoreward to replace nearshore surface waters that were driven offshore by the prevailing northwesterly winds. Because this deep offshore watermass had not been in recent direct contact with the atmosphere, biotic respiration and decomposition had depleted its DO levels (dark blue lines). Additionally, at depth, biotic respiration and decomposition produced carbon dioxide (CO_2), and in its dissolved state, the increased concentration of carbonic acid appears as a concomitant decline in pH (olive-colored lines).

Meanwhile, within the surface mixed layer, nutrient-rich seawater brought to the sea surface by the recent upwelling facilitated phytoplankton blooms that produced oxygen, consumed carbon dioxide (CO_2), and decreased water clarity (light blue lines). The presence of plankton within the surface mixed layer caused a large, 25% decrease in transmissivity at the sea surface compared to mid-depth.

The degree of vertical stratification within the survey area is important for understanding the dynamics of the effluent dispersion at the time of the survey. For example, when the water column is strongly stratified during upwelling events, the rising plume can become trapped at depth within the water column, thereby limiting its full capacity for dilution. However, even with the strong stratification present at the time of the May 2013 survey, the plume's buoyancy was still sufficient to carry it briefly to the sea surface within a localized area immediately south of the diffuser structure near Station RW4 (Figure 7d).

The plume's presence at the sea surface was confirmed by the CTD measurements acquired during the downcast at Station RW4 as well as by visual observation of the near-surface waters during deployment of the Secchi disk at that station. However, by the time the Secchi depth was measured at that station, the vessel had already drifted beyond the localized surface-plume signature, and accordingly, the recorded measurements did not capture the increased light penetration cause by the presence of the less-turbid plume waters.

Similarly, although the plume's signature was not readily apparent at the sea surface in the vertical profiles at Stations RW5 and RW6 (Figure 7ef), its presence was evident immediately below the surface in the vertically compressed transition zone. All three of these stations were located to the south of the diffuser structure and generally along the May 2013 plume transport path delineated by the drogued drifter (Figure 3).

The influence of ambient seawater entrained within the rising effluent plume at the three southerly stations is particularly apparent in the transmissivity profiles (light blue lines). In contrast, stations to the north (RW1, RW2, and RW3; Figure 7abc), which were located upstream of the plume's influence, all exhibited a distinct mid-depth maximum in transmissivity near 8.5 m. This mid-depth transmissivity maximum was largely eliminated at the southern stations as the rising plume caused seawater properties to become nearly uniform over most of the water column.

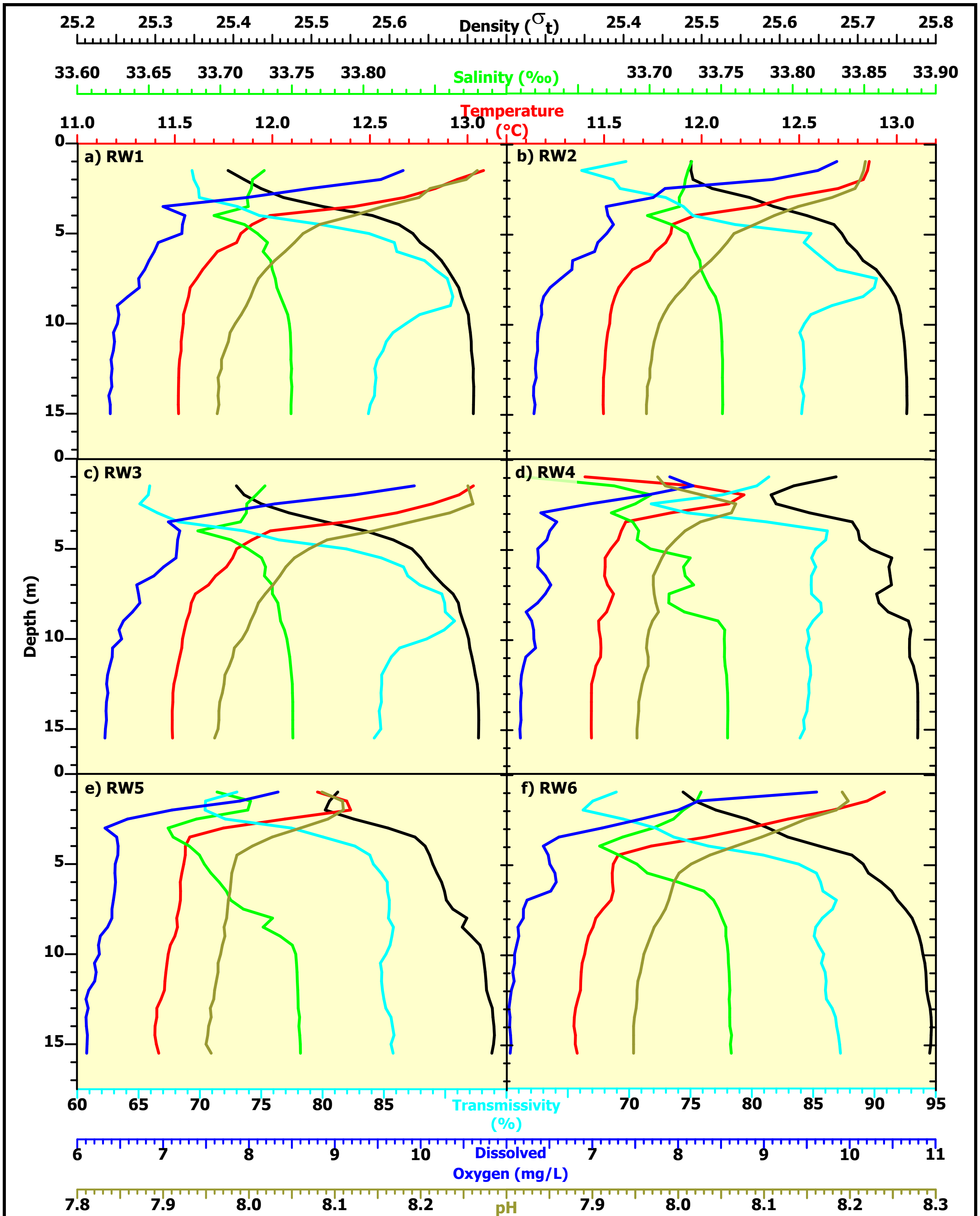

Figure 7. Vertical Profiles of Water-Quality Parameters

The effluent plume acquires deep watermass properties because it rapidly entrains bottom seawater shortly after discharge. 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 acquired at the seafloor. These deep seawater properties become apparent as a signature of the buoyant effluent plume when they are juxtaposed against the ambient seawater characteristics in the upper water column.

It is clear that the anomalies in seawater properties in the upper water column at the three southern stations were caused by entrainment rather than the presence of wastewater constituents because the offsets in their properties were consistent with the vertical differences in ambient seawater. For example, the increased transmissivity, and decreased temperature, pH, and DO measured within the anomalies were comparable to the ambient seawater properties found near the seafloor (Figure 7def). Additionally, for some properties the offsets were opposite of the changes that would be caused by wastewater particulates. Specifically, wastewater discharged on the day of the survey was much warmer (20°C) than the receiving seawater (<13°C), and thus the presence of warmer wastewater constituents could not have induced the negative thermal signature observed in the upper water column at these stations. Entrainment of cool bottom seawater is the only mechanism that could have created a plume that was cooler than the surrounding ambient seawater within the upper water column.

Additionally, 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 requirements restrict attention to water-quality changes caused solely by the presence of wastewater constituents. Nevertheless, these anomalies provide useful tracers of the diffuse effluent plume after the completion of the initial dilution process.

The post-ZID disposition of the effluent plume is particularly apparent in the horizontal maps created from the tow data (Figures 8 and 9). At mid-depth, the presence of wastewater constituents, as indicated by lower salinity, is generally limited to a small area near the ZID boundary that lies southwest of the diffuser structure (Figure 8b). Entrainment anomalies, however, are apparent in all the other water properties, and tend to extend further to the southwest than the more compact salinity footprint (Figure 8acdef). The effects of entrainment are particularly apparent within the region of increased water clarity (Figure 8d). Note that the scale is reversed in the transmissivity map and the colored region represents increased water clarity.

Similarly, the scale is reversed in the mid-depth density map (Figure 8c). The colored region in this figure coincides with the plume signature and contains water that is denser than the surrounding seawater at 8.3 m. This indicates that plume was negatively buoyant at that location and that buoyancy forces would not be expected to contribute to the plume's further rise within the water column, although the upward momentum of the rising plume may have continued to carry it to shallower depths.

Accordingly, close to the sea surface (Figure 9), there was no plume signature apparent in the horizontal maps. Instead, small fluctuations in seawater properties are randomly distributed throughout the survey area with little or no spatial coherence among the properties, particularly with respect to the distribution of salinity (Figure 9b). The absence of a well-defined entrainment signature near the sea surface indicates that the plume was largely located below the 2.5 m tow depth, and that the shallow tow survey did not capture the transient localized surfacing of the plume that was apparent in the vertical profile collected earlier at Station RW4 (Figure 7d).

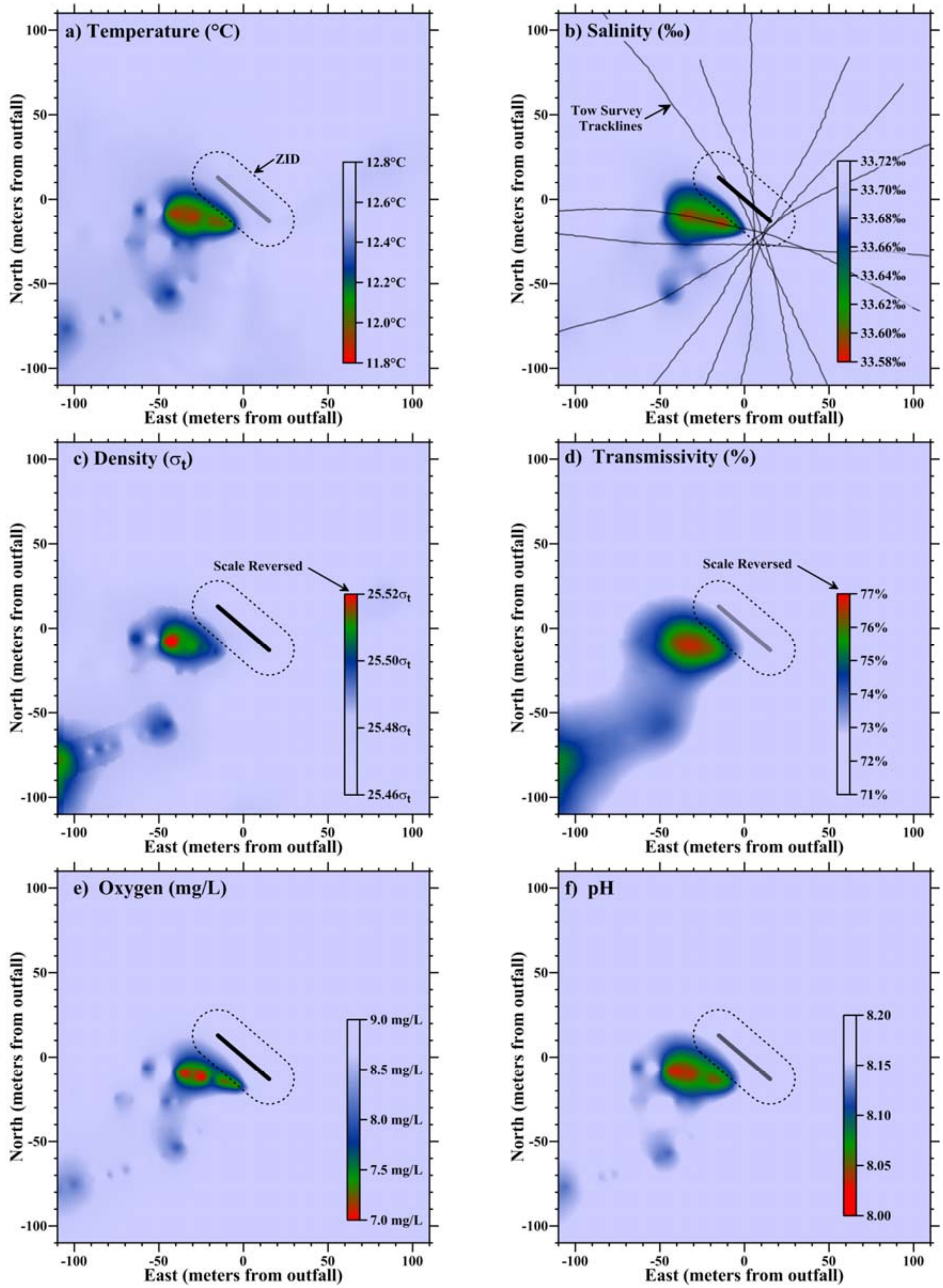

Figure 8. Horizontal Distribution of Mid-Depth Water-Quality Parameters 8.3 m below the Sea Surface

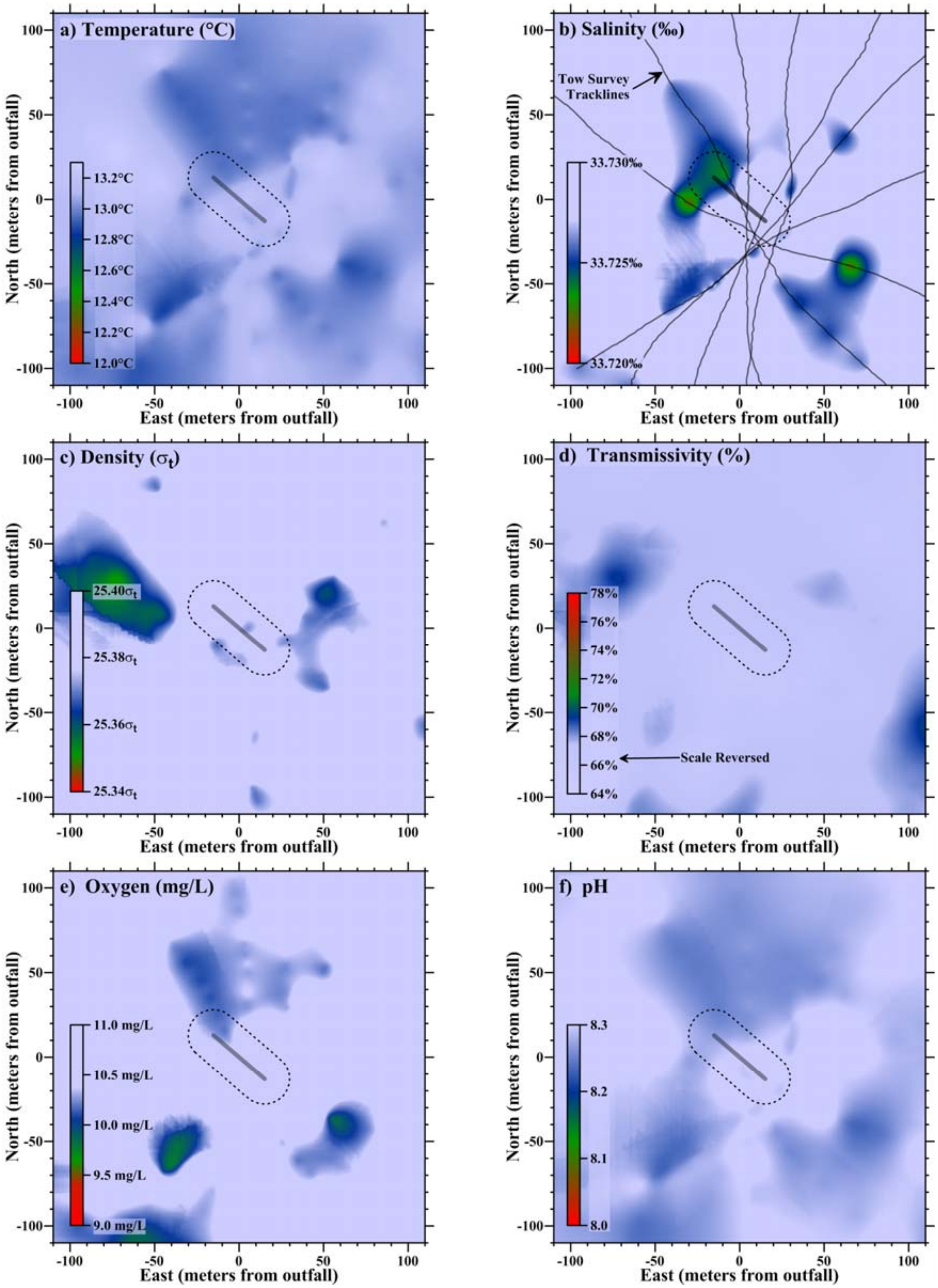

Figure 9. Horizontal Distribution of Shallow Water-Quality Parameters 2.5 m below the Sea Surface

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the May 2013 survey, and dilutions anticipated from modeling studies that were codified in the discharge permit through limits imposed on effluent constituents. Specifically, the critical initial dilution applicable to the MBCSD outfall was conservatively estimated to be 133:1 (Tetra Tech 1992). That is, dispersion modeling estimated that, at the conclusion of the minimum expected initial mixing, 133 parts of ambient seawater would have mixed with each part of wastewater.

The 133:1 dilution estimate was based on worst-case modeling under highly stratified conditions, where trapping of the plume below a strong thermocline would curtail the 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, observed dilution levels during the May 2013 survey were higher than the conservative model prediction, at depths greater than the trapping depth predicted by modeling, and where measured initial-dilution levels would be expected to be much lower than the 133:1 of 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.

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

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

By rearranging Equation 1, the actual dilution achieved by the outfall can be determined from measured seawater anomalies. This measured dilution can then be compared with the critical dilution factor determined from modeling. Salinity is an especially useful tracer because it directly reflects the magnitude of ongoing dilution. Wastewater-induced patches of lower salinity were apparent in the upper water column in the vertical profiles measured at Stations RW4, RW5, and RW6 (green lines in Figure 7def), and near the diffuser structure in the mid-depth tow-survey map (Figure 8b). These localized salinity anomalies document mixing processes within the effluent plume shortly after it emanated from a diffuser port and rose through the water column.

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:

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

The salinity concentration within MBCSD effluent (C_e)[13] 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, lower effluent dilution at a given location within receiving waters is directly mirrored by a larger salinity reduction.

The lowest salinity (33.58‰) measured during the May 2013 survey was recorded 20.1 m from the diffuser structure at a depth of 8.9 m during the fourth transect of the mid-depth tow survey (red shading in Figure 8b). This measured salinity corresponds to a 0.146‰ reduction below the mean ambient salinity of 33.726‰ that was measured at the same depth level, but well beyond the influence of the discharge. From Equation 2, that salinity anomaly corresponds to a dilution of 223-fold (Figure 10). This is 68% higher than 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater.

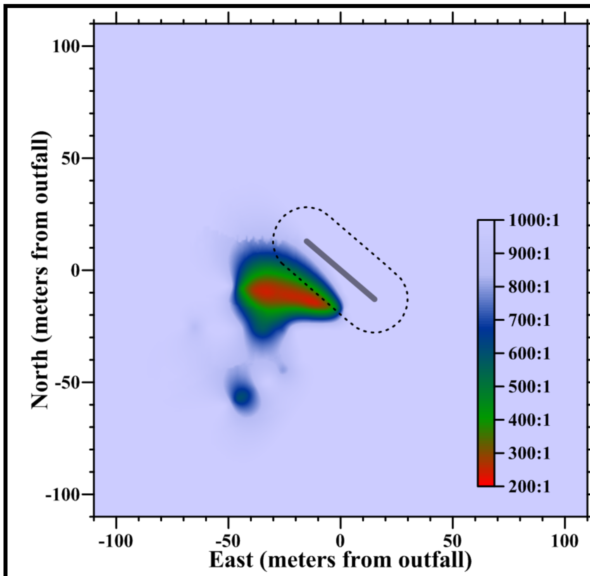

Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b

In addition, the lowest dilution was measured at an 8.9-m depth, which was 2.5 m below 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 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 far more efficiently than predicted by the modeling.

The dilution computations demonstrate that, during the May 2013 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 223-fold immediately after discharge, and well before completion of the initial-dilution process. The measured dilution levels throughout the survey easily exceeded 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.

[13] Wastewater samples have an average salinity of 0.995‰.

Consequently, during the May 2013 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.

COMPLIANCE

This section evaluates compliance with the water-quality limits listed in the NPDES permit (Table 6). The limitations themselves are based on criteria in the COP, the Central Coast Basin Plan, and other state and federal policies that were designed to protect marine life and beneficial uses of ocean waters. 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 applied to the May 2013 data demonstrate that the MBCSD discharge complied with the NPDES discharge permit. Moreover, although observations within the ZID are not subject to compliance evaluations, they often meet the prescribed limits because actual dilution levels routinely exceed the conservative design specifications assumed in the discharge permit. Thus, the quantitative evaluation described in this section documents an outfall and treatment process that was performing at a high level during the May 2013 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. As described previously, no floating wastewater materials, oil, grease, or discoloration of the sea surface were observed during the May 2013 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.

Natural variation in seawater properties is driven by a variety of oceanographic processes. These processes determine the range in ambient seawater properties caused by natural spatial variation within the survey region at a given time (e.g., vertical stratification), and by temporal variations caused by seasonal and interannual influences (e.g., El Niño and La Niña). Of particular interest are upwelling and downwelling processes that not only determine average properties at a given time, but also the degree of water-column stratification, or spatial variability, present during any given survey.

Screening of Measurements

Evaluating whether any of the 12,922 CTD measurements collected during the May 2013 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 apply; 2) changes due to the presence of wastewater particulates; and 3) changes large enough to be reliably detected against the backdrop of natural variation. The measurements that make it through the screening process, if any, can then be compared with Basin-Plan numerical limits and COP allowances. The following subsection 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 provided in the following description of the three screening steps.

Table 7. Receiving-Water Measurements Screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer No	Answer Yes[14]	*Parameter*
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	*1,298*	*11,624*	All
Wastewater Constituents	2. Did the beyond-ZID measurement coincide with a quantifiable salinity anomaly (≤550:1 dilution level) indicating the presence of detectable wastewater constituents?	*11,491*	*133*	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?	*133*	*0*	Temperature
		133	*0*	Transmissivity
		133	*0*	DO
		133	*0*	pH

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

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 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 May 2013 dataset eliminated 1,298 of the original 12,922 receiving-water observations from further consideration because they were collected within the ZID (Table 7, Question 1). The remaining 11,624 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 almost never observed in any seawater property other than salinity, except very close (<1 m) to a diffuser port and within its ejection jet.

In fact, negative salinity anomalies are the only consistent indicator of the presence of wastewater constituents within receiving 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 powerful 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 reliability 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 shown in Figures 8b and 10, discharge-related salinity anomalies measured during the survey were largely restricted to a localized area just outside the southwest boundary of the ZID. One-hundred-thirty-three measurements had significant reductions in salinity that unequivocally identified the presence of dilute wastewater constituents beyond the ZID. The remaining 11,491 observations that were measured outside the ZID during the May 2013 survey did not have salinity reductions that were greater than 0.062‰ (Table 7).

3. Natural Variation: An integral part of the compliance analysis is determining whether a particular anomalous measurement resulted from the presence of wastewater constituents, or whether it simply became apparent because ambient seawater was relocated (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 columns of Table 8). These natural-variability ranges were used to identify significant departures from ambient conditions that could be indicative of adverse discharge-related effects on water quality. The same five-year database used to establish the 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 (± 0.094). These were combined with 95th percentiles determined from the May 2013 ambient seawater data, to establish time-specific natural-variability thresholds in a manner analogous to COP Appendix VI. The

Table 8. Compliance Thresholds

Water Quality Property	95% Confidence Bound[15]	95th Percentile[16,17]	Natural Variability Threshold[18]	COP Allowance[19]	Basin Plan Limit[20]	Extremum[21]
Temperature (ºC)	0.82	12.92	>13.74	—	—	≤13.33
Transmissivity (%)	-10.2	66.4	<56.2	—	—	≥58.0
DO (mg/L)	-1.38	6.33	<4.95	<4.45	<5.00	≥6.03
pH (minimum)	-0.094	7.964	<7.870	<7.670	<7.000	≥7.948
pH (maximum)	0.094	8.250	>8.344	>8.544	>8.300	≤8.331

15 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.

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

17 The 95th-percentile quantifies natural variability in seawater properties during the May 2013 survey, and was determined from vertical-profiles data unaffected by the discharge.

18 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 May 2013 survey. They do not include the COP allowances specified in the column to the right.

19 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.*"

20 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 the upper-bound objective 8.3, which applies to most beneficial uses was implemented in the MBCSD discharge permit.

21 Maximum or minimum value measured during this survey

percentiles were determined from May 2013 vertical profile data, excluding measurements potentially affected by the discharge.

Temperature, transmissivity, and DO concentrations associated with the 133 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 CTD measurements collected during the May 2013 survey from further consideration. In fact, all of the documented excursions in these properties were the result of physical processes unrelated to the presence of wastewater constituents, namely, entrainment of near-bottom seawater within the rising effluent plume. During periods when the water column is stratified, such as during the May 2013 survey, ambient seawater properties near the seafloor differ from those within the rest of the water column, and their juxtaposition within the rising plume appears as lateral anomalies within the upper water column.

As discussed previously, all of the anomalies in seawater properties that coincided with the salinity anomalies in Figures 7def and 8b were consistent with the upward displacement of ambient bottom water rather than with the presence of the effluent plume. Additionally, even if the presence of wastewater particulates had contributed to the measured decreases in DO and pH, their influence would still have been well within the natural range of the ambient seawater properties at the time of the survey. Consequently, their influence on water quality would not be considered environmentally significant.

Other Lines of Evidence

Several additional lines of evidence further support the conclusion that all the CTD measurements collected during the May 2013 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 May 2013 survey.

Insignificant Thermal Impact: Although there are no explicit numerical objectives for discharge-related decreases in temperature, a numerical limit can be established for thermal excursions that is based on the 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 13.74°C in Table 8). However, none of the 12,922 CTD measurements collected during the May 2013 survey exceeded 13.33°C (last column in Table 8). In fact, as mentioned previously, because the effluent entrained cooler bottom water shortly after discharge, the rising plume actually had a lower temperature than most of the surrounding seawater (Figure 8a).

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, because natural light is restricted to the euphotic zone, which extends to approximately twice the Secchi depth, the limit on transmissivity reductions during the May 2013 survey only applied to measurements recorded above 6 m (twice the maximum ambient Secchi depth listed in Table 4). As stated previously, no exceedance occurred during the May 2013 survey. Additionally, the presence of a restricted euphotic zone resulting from upwelling means that even if the presence of wastewater particulates had caused a substantial reduction in transmissivity below 6 m, it would not have been a violation of permit conditions because turbidity at that depth had no effect on the penetration of natural light.

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). As discussed previously, the reduced temperatures observed in conjunction with the effluent plume (Figure 8a) could not have been generated by the presence of warmer wastewater constituents. Similarly, the increased transmissivity observed near the sea surface at Stations RW4 and RW5 (Figure 7de) and at depth (Figure 8d) in conjunction with the plume could not have been generated by an increased wastewater particulate load. In both cases, the directional offsets were opposite of receiving-water impacts expected from the presence of 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 16 May 2013 was 54 mg/L. After dilution by 223-fold, which was the lowest dilution measured during the survey, the effluent suspended-solids concentration would have the reduced ambient transmissivity by only 1.4%. This small potential decrease in transmissivity was overwhelmed by the 6% increase caused by the entrainment and upward displacement of relatively clear ambient seawater near the seafloor (Figure 8d).

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, 48-mg/L BOD measured within the plant's effluent several days prior to 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.

COP Allowances: The COP does not explicitly require that wastewater-induced changes remain within the ranges in natural variation listed in the third 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 7.670 during the May 2013 survey (fourth column of Table 8). This value is well below the lowest pH measurement of 7.948 recorded during the May 2013 survey (last column of Table 8). Similarly, the lowest DO concentration measured during the survey (6.03 mg/L) was well above both the lower range in natural variation (4.95 mg/L) and the 10% compliance threshold promulgated by the COP (4.45 mg/L).

Natural Variability within and beyond the ZID: Although the permit limits only apply to changes in DO, pH, temperature, and transmissivity beyond the ZID, examination of measurements within the ZID frequently provides additional valuable insight into the potential for adverse effects on water quality. However, during the May 2013 survey, salinity was the only seawater property that consistently exhibited a perceptible difference from ambient conditions. Regardless of their association with the effluent salinity signature or their proximity to the diffuser structure, none of the 12,922 temperature, DO, and pH observations exceeded the thresholds of natural variability specified in Table 8.

Non-Discharge-Related Exceedances of Basin-Plan Limits: Permit provisions P5 and P6 (Table 6) combine receiving-water objectives from both the COP and the Basin Plan with regard to DO and pH limitations. 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).

While all 12,922 DO values measured during the May 2013 survey remained well above the Basin Plan's minimum acceptable concentration (5 mg/L), the same was not true for the pH measurements. Although all of the observed pH concentrations fell within the ambient range measured at the time of the survey, and therefore complied with the COP portion of the permit provision, 20% (2,578) of the observations ranged above the 8.3 maximum Basin-Plan pH threshold. Thus, perfunctory application of the Basin Plan's pH threshold in a compliance analysis of the May 2013 dataset could lead to the incorrect conclusion that the discharge had caused unacceptable increases in pH. However, this could not be the case because effluent pH was lower than that of the receiving seawater on the day of the survey. Moreover, none of the 2,578 elevated pH measurements coincided with the presence of wastewater constituents as determined by low salinities.

In fact, seawater with pH exceeding the 8.3 Basin Plan limit is not unusual within the coastal waters offshore California. This is apparent from the published range-acceptability criteria that are used to assess the validity of CTD data in this monitoring program and that categorize pH values ranging up to 8.5 as typical for this area.[22] Although it was not the case for the May 2013 survey, measurements of naturally occurring DO concentrations below the 5-mg/L Basin-Plan minimum have been observed in a number of past MBCSD receiving-water surveys. Clearly, DO and pH variations beyond their respective fixed limits were simply not envisioned within coastal waters when the Basin Plan was promulgated in 1972. The fixed Basin Plan limits were largely designed for discharges to onshore surface waters, where there is little natural variation in pH and DO within the receiving waters.

Natural oceanographic processes, such as upwelling, regularly cause the DO and pH of the ambient receiving water surrounding the MBCSD outfall to range beyond the Basin Plan limits. In contrast to the Basin Plan limits, the COP recognizes the potential for inherent variation in the receiving-water characteristics and specifies limits on excursions in these two water properties relative to background levels present at the time of the survey. Because the COP receiving-water objectives are designed to be adequately protective of the marine environment, application of the fixed Basin Plan limits to the same receiving-water characteristics already covered by the COP is not only redundant but inappropriate. For these reasons, the Basin Plan limits have been recommended for removal from future MBCSD discharge permits (MRS 2011, 2012, and 2013).

[22] The field operations manual for the Southern California Bight Study (SCBFMC 2002)

CONCLUSIONS

The quantitative screening analysis demonstrated that all measurements recorded during the May 2013 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 May 2013 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.

Shortly after discharge, the outfall was achieving dilution levels in excess of 223-fold, which substantially exceeds the critical dilution levels predicted by design modeling. This lowest dilution level was observed within the submerged discharge plume, and before the initial dilution process was complete. As the plume was carried rapidly southward by the prevailing current it continued to rise through the water column, achieving dilution levels exceeding 400-fold. Lastly, all of the auxiliary observations collected during the May 2013 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 perform at levels exceeding design expectations.

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