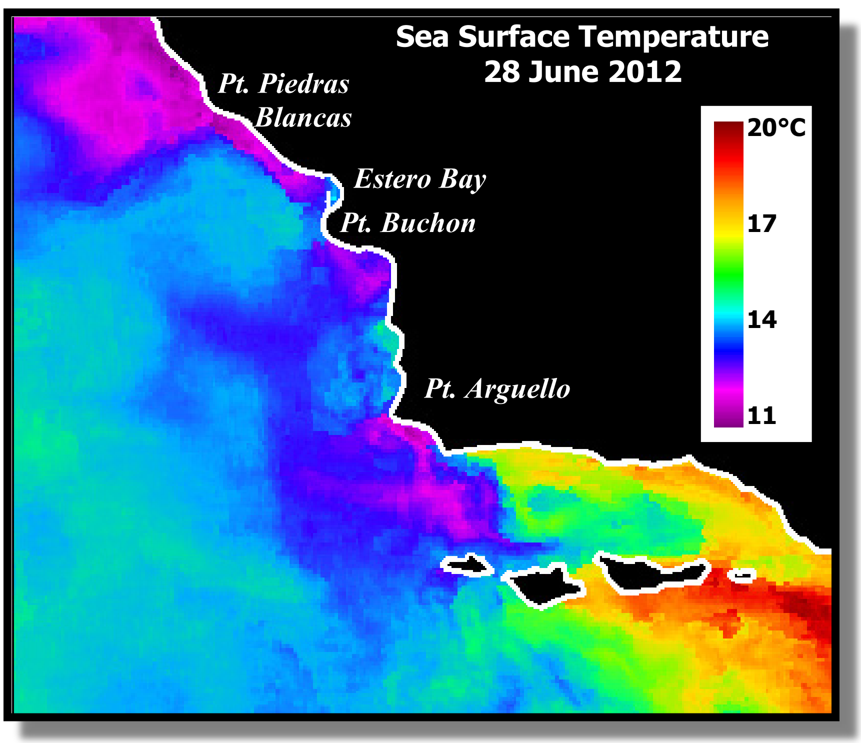
City of Morro Bay and
Cayucos Sanitary District

OFFSHORE MONITORING AND REPORTING PROGRAM

SECOND QUARTER RECEIVING–WATER SURVEY

JUNE 2012



Marine Research Specialists

3140 Telegraph Rd., Suite A
Ventura, California 93003

Report to the

City of Morro Bay and Cayucos Sanitary District

955 Shasta Avenue
Morro Bay, California 93442
(805) 772-6272

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SECOND QUARTER RECEIVING–WATER SURVEY

JUNE 2012

Prepared by

Bonnie Luke
Douglas A. Coats

Marine Research Specialists

3140 Telegraph Rd., Suite A
Ventura, California 93003

Telephone: (805) 644-1180
Telefax: (805) 289-3935
E-mail: Marine@Rain.org

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marine research specialists
3140 Telegraph Road, Suite A • Ventura, CA 93003 • (805) 644-1180

13 July 2012

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

Reference: Second Quarter Receiving-Water Survey Report – June 2012

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Friday, 29 June 2012. 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

(Submitted Electronically)

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

Bruce Keogh

Mr. Bruce Keogh
Wastewater Division Manager
City of Morro Bay

Date July 13, 2012

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 June 2012 field survey described in this report was the thirteenth 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 29 June 2012. Specifically, this second-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 evaluating empirical tabulations of instrumental measurements and standard field observations. In addition to the traditional, vertical water-column profiles, instrumental measurements were used to generate horizontal maps from high-resolution data gathered by towing a CTD[1] instrument package repeatedly over the diffuser structure. This allowed for a more precise determination of the plume's lateral extent.

SURVEY SETTING

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

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

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

Figure 1. Location of the Receiving-Water Survey Area

Near the diffuser, prevailing 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 surfzone sampling stations shown in Figure 1 would be conducted to monitor for potential shoreline impacts. These surfzone samples would be analyzed for total and fecal coliform, and enterococcus bacterial densities.

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

SAMPLING LOCATIONS

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

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

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

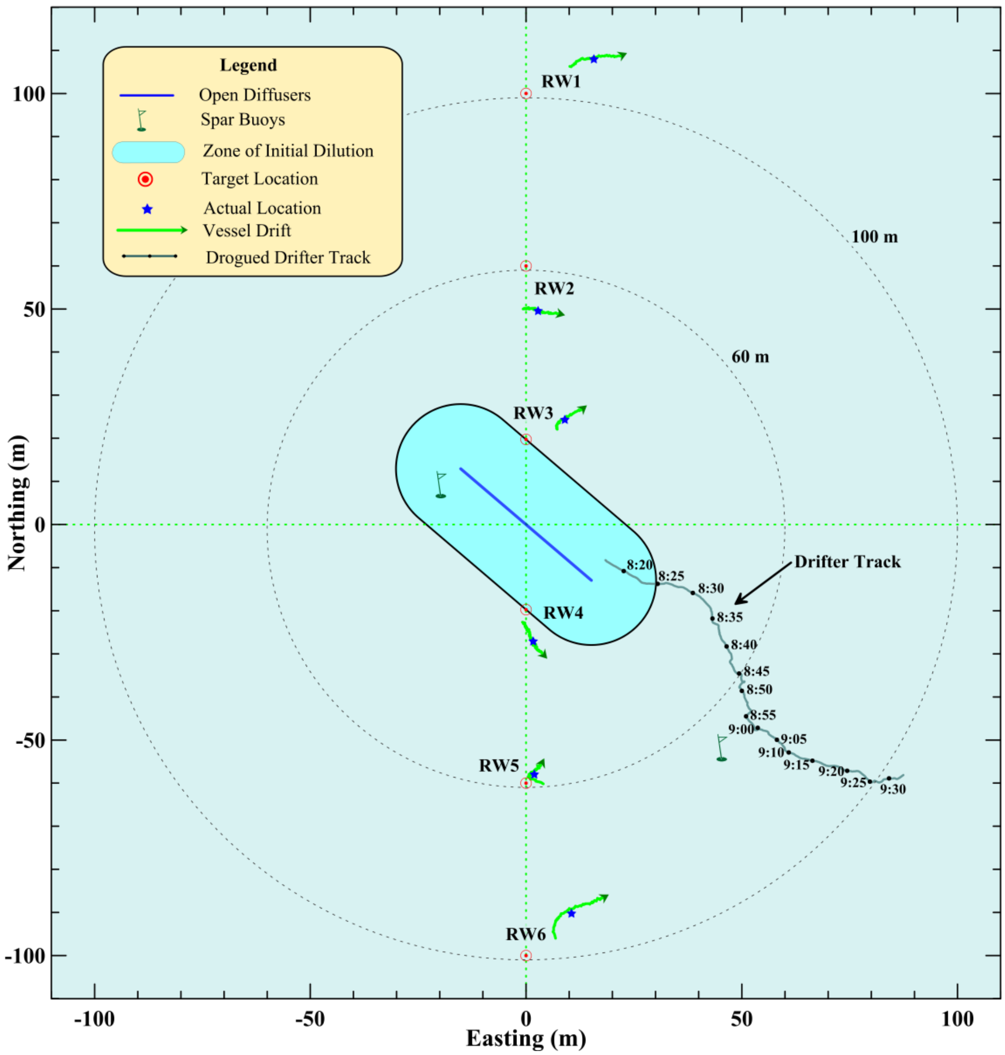

Figure 2. Sampling Station Locations and Drifter Track

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

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

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

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. Currently, use of two independent DGPS receivers on the survey vessel allows access to two separate land-based beacons for navigational comparison, ensuring extremely accurate and uninterrupted navigational reports.

Recording of DGPS positions at one-second intervals allows precise determination of sampling locations throughout the vertical CTD profiling conducted at the six individual stations, as well as during the tow survey. Knowledge of the precise location of individual CTD measurements relative to the diffuser is critical for accurate interpretation of the water-property fields. During vertical-profile sampling, the actual measurement locations rarely coincide with the target coordinates listed in Table 1 because winds, waves, and currents induce unavoidable horizontal offsets (drift). Even during quiescent 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 June 2012 survey is apparent from the length of the green tracklines in Figure 2. These tracklines traced the horizontal movement of the CTD as it was lowered to the seafloor. Their lengths and offsets from the target locations reflect the overall station-keeping ability during the June 2012 survey. During the time it took the CTD to traverse the water column and reach the seafloor, which averaged 1 minute 33 seconds, the instrument package moved an average of 9.2 m. This amount of drift is comparable to that of most prior surveys conducted under similar oceanographic conditions.

The CTD trajectories shown by the tracklines in Figure 2 reflect complex interactions between surface currents, wind forces, and any residual momentum of the survey vessel as it approached each station during the June 2012 survey. For example, the CTD trajectories at all stations had an easterly drift component, which was consistent with southeast transport by the subsurface current measured by the drogue drifter. The northward drift that initially occurred at Stations RW5 and RW6 resulted from the residual momentum of the vessel as it approached these stations from the south. Generally, winds affect the vessel's ability to maintain station to a greater degree than does current flow, however, this was not the case with the June 2012 survey because winds were light throughout the survey.

Assessing compliance at Stations RW3 and RW4, which are closest to the diffuser structure, can be complicated by CTD drift during the downcasts, and by offsets from target sampling locations located on the ZID boundary. This is because the receiving-water limitations specified in the COP only apply to measurements recorded beyond the ZID boundary, where initial mixing is assumed to be complete. Occasionally, CTD data at RW3 or RW4 are unavoidably collected within ZID, and those measurements are not subject to receiving-water limitations. However, during the June 2012 survey, none of the data collected during the vertical hydrocasts was acquired within the ZID boundary (Figure 2).

Determining which measurements are subject to permit limits within hydrocasts near the ZID boundary only became possible after the advent of DGPS. Prior to 1999, CTD locations could not be determined with sufficient accuracy to establish whether a station was located within the ZID, much less how the CTD was moving laterally during the hydrocast. Because of these navigational limitations, sampling was presumed to occur at a single, imprecisely determined, horizontal location. Federal and state reporting of monitoring data still mandates identification of a single position for all of the CTD data collected at a particular station. Thus, for regulatory reporting, and for consistency with past surveys, the June 2012

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

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 June 2012 Survey

Station	Time (PDT) Downcast	Time (PDT) Upcast	Latitude	Longitude	Closest Approach Range[5] (m)	Closest Approach Bearing[6] (ºT)
RW1	9:04:41	9:06:08	35° 23.257' N	120° 52.494' W	100.0	18
RW2	8:59:10	9:00:33	35° 23.226' N	120° 52.502' W	40.9	26
RW3	8:50:05	8:51:28	35° 23.212' N	120° 52.498' W	24.4	41
RW4	8:41:57	8:43:35	35° 23.184' N	120° 52.503' W	19.4	221
RW5	8:34:06	8:35:43	35° 23.168' N	120° 52.503' W	46.9	196
RW6	8:27:22	8:29:13	35° 23.150' N	120° 52.497' W	77.4	183

OCEANOGRAPHIC PROCESSES

The trajectory of a satellite-tracked drogued drifter documented flow generally toward the southeast, albeit with some variability in flow direction (Figure 2). 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 8:17 PDT, and was recovered 1 hour 15 minutes later, at a location 85 m southeast of its initial location (Figure 2). The black dots in Figure 2 show the

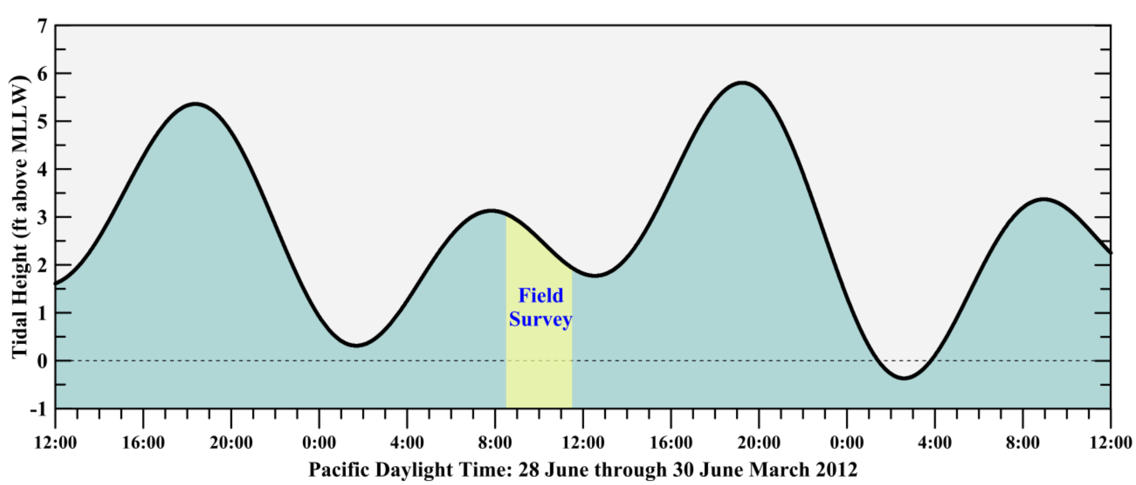

Figure 3. Tidal Level during the June 2012 Survey

[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.

drifter's progress at five-minute intervals, and their non-uniform spacing reflects changes in speed experienced by the drifter as it traveled along its serpentine trajectory. The actual distance traveled along this path was 105 m, at an average speed of 2.3 cm/s, or 0.05 knots. At this low transport rate, it would have taken the plume eleven minutes to traverse the ZID.

The variation in oceanic flow measured by the drifter was consistent with the influence of a slack tide (Figure 3). However, flow within Estero Bay is also often strongly influenced by external processes, such as wind-generated upwelling, downwelling, or the passing of offshore eddies propagating along the coastline. Upwelling, for example, can induce a southerly (offshore) flow in the upper water column, and a northerly (onshore) flow at depth. The ebb flow that prevailed during the latter half of the survey typically produces a weak southwestward flow, which was partially consistent with the drifter path shown in Figure 2.

Upwelling was occurring around the time of the June 2012 survey. Upwelling season normally begins sometime during late March and or early April as shown by the positive (blue) upwelling indices in Figure 4. At the onset of upwelling season, there is a spring transition to more persistent southeastward winds along the central California coast. This transition is initiated by the stabilization of a high-pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive the prevailing northwesterly winds along the central California coast. These prevailing winds move warmer surface waters southward and offshore, allowing deep, cool, nutrient-rich waters to move shoreward and upwell near the coast.

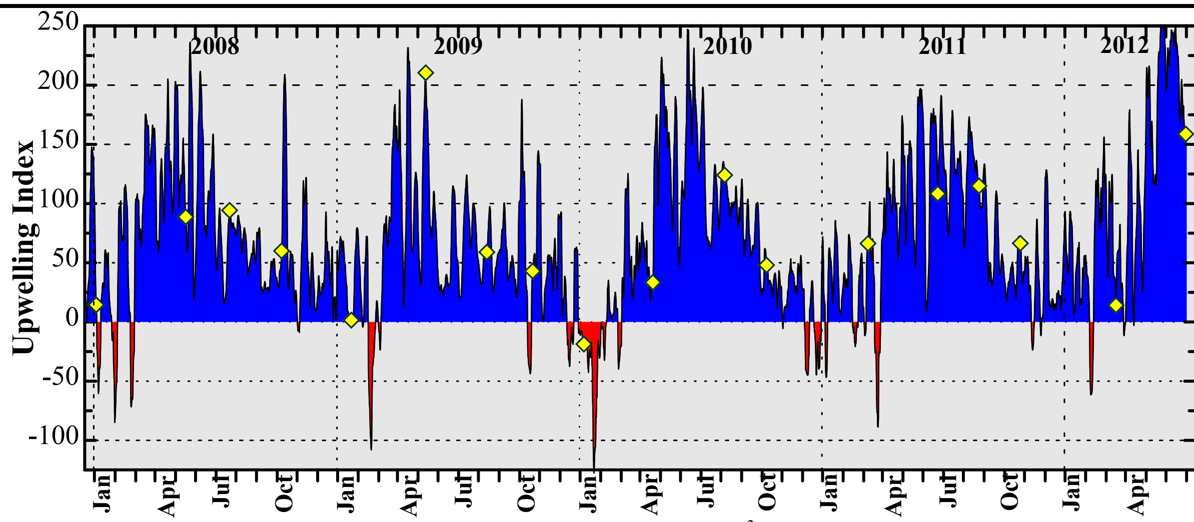

Figure 4. Five-Day Average Upwelling Index ($m^3/s/100$ m of coastline)

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) indices in Figure 4, occur infrequently, and almost exclusively in winter, when passing storms temporarily reverse the normal wind pattern and drive surface waters shoreward. As the surface waters approach the coastline, they downwell, producing nearly uniform seawater properties throughout the water column.

Although winds were mild on the morning of the June 2012 survey, northwesterly winds increased substantially, to 33 knots, by the afternoon. Unusually intense, sustained northwesterly winds prevailed along the central coast throughout the spring. In particular, every day from May 16 through May 31 peak afternoon northwesterly winds at the nearby Diablo Canyon Nuclear Power Plant reached or exceeded 40 mph. [7] These winds produced a tremendous amount of upwelling along the central coast, which is reflected by the unusually large upwelling index immediately prior to the survey (rightmost yellow diamond in Figure 4). This intensive upwelling caused nearshore water temperatures to be depressed below normal levels; although the seawater temperature at Diablo Canyon intake typically averages 11.2˚C degrees during the month of May, the average temperature measured during 2012 was closer to 10.0˚C, more than a degree cooler.

The satellite image on the cover of this report documents the upwelling that prevailed around the time of the June 2012 survey. The image was recorded two days 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. As is apparent in the cover image, the cool, nearshore sea-surface temperatures (<13.0˚C) within Estero Bay were comparable to the near-surface temperatures measured by the CTD during the June 2012 survey.[8]

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on Friday, 29 June 2012. Bonnie Luke of Marine Research Specialists (MRS) was Chief Scientist and collected auxiliary measurements of biological, meteorological, and oceanographic conditions. Dr. Douglas Coats, also of MRS, provided navigational support during the survey. William Skok assisted with deployment and recovery of the CTD and drifter.

Auxiliary Measurements

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

Additionally, at all six stations, a Secchi disk was lowered through the water column to determine its depth of disappearance. Secchi depths provide a visual measure of near-surface turbidity or water clarity. The depth of disappearance is inversely proportional to the average amount of organic and inorganic suspended material along a line of sight in the upper water column. As such, 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.

[7] http://www.sanluisobispo.com/2012/06/09/2099158/windy-spring-really-blew-meteorologist.html
[8] Refer to Table 5 and Figure 6 for receiving-water properties recorded during the vertical hydrocasts.

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 June 2012 survey. This new CTD instrument package was commissioned in May 2011 to replace an older model SBE-19 profiler that was retired from regular use following the June 2011 survey.

The new CTD system offers many advantages over the older unit, which was in service for nearly two decades. The 4 Hz sampling rate[10] on the new instrument collects data at twice the rate of the older unit, allowing much higher spatial resolution for a given tow, or descent rate. In addition, the probes and sensors have a much faster response time, further enhancing the spatial resolution of seawater properties. Lastly, the probes and sensors on the new CTD are more stable and exhibit negligible long-term drift. As a result, and in accordance with the manufacturer's recommendations, the new CTD package does not require calibration of the sensors prior to each field survey.

The six seawater properties used to assess receiving-water quality in this report were derived from the continuously recorded output of the CTD's probes and sensors. Pressure housing limitations confine the CTD to depths less than 680 m (Table 3), which 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 also 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).

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.

[9] 25-cm path length of red (660 nm) light
[10] 0.25-s sampling interval

Transmissivity readings are reported relative to 100% transmission in air. Therefore, transmission in pure water is expected to be 91.3% of the reported values for this transmissometer.

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

At 09:07 PDT, following the last vertical profile at RW1, 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 retrieval of the drifter, the CTD was deployed and towed around and across the ZID at two separate depths, one within the surface mixed layer and one below the thermocline, in accordance with the monitoring requirements of the NPDES discharge permit (Figure 5).

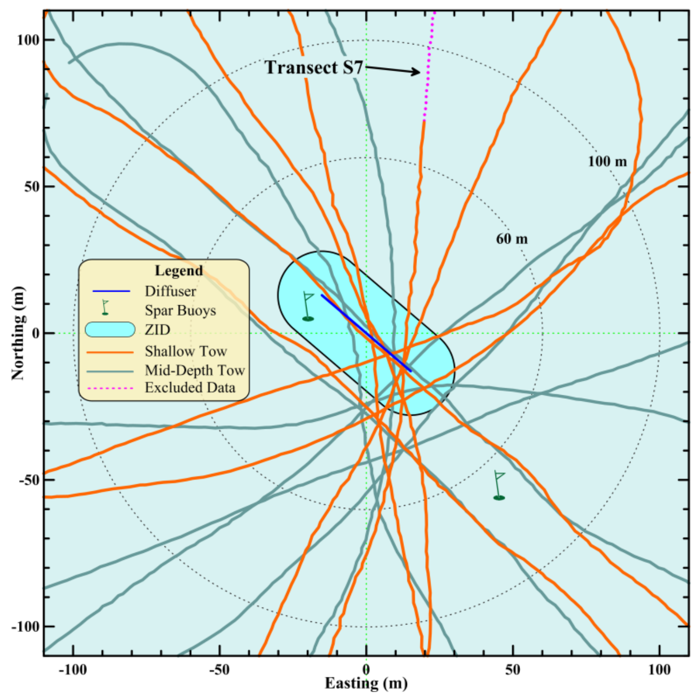

Figure 5. CTD Tracklines during the June 2012 Tow Surveys

Initially, the reconfigured CTD package was towed for 34 minutes at an average depth of 5.83 m, and an average speed of 1.76 m/s, passing over, or near the diffuser structure eight times. Subsequently, eight additional passes were made with the CTD at an average depth of 8.37 m. During this 37-minute mid-depth-tow, vessel speed averaged 1.79 m/s. At the observed towing speeds and a 4 Hz sampling rate, 2.2 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.[11]

Quality Control

Upon retrieval of the CTD following the tow survey, water-quality data were examined for completeness and range acceptability. Real-time monitoring revealed that the recorded seawater properties were complete and within acceptable coastal seawater ranges.[12]

[11] Figures 7 and 8 present the horizontal maps of seawater properties measured during the tow-survey portion of the field survey.
[12] Field sampling protocols employed during the March 2012 survey generally followed the field operations manual for the

Subsequent post-processing of the data review revealed several events that impacted portions of the data, resulting in the adjustment or exclusion of these data prior to initiation of the compliance analysis. For example, review of the tow data revealed that the CTD was tracking at a slightly shallower depth during latter portion of the shallow tow along transect S7 (purple dotted line in Figure 5). Specifically, slight increases in vessel speed resulted in tow depths that were more than 0.4 m shallower than average.

While this depth offset appears small, it created artificial horizontal differences in the combined data set because of vertical gradients associated with the upwelling-induced stratification present in the water column at the time of the survey. Because discharge-related anomalies 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 levels are combined, particularly when the water column is moderately stratified, as was the case during the June 2012 survey.

Because of their depth offsets, data collected during that portion of the tow survey were incompatible with the rest of the tow data, and were excluded from the subsequent analysis to avoid introducing erroneous lateral differences in the horizontal property maps.[13] Exclusion of this portion of transect S7 did not, however, adversely affect the compliance analysis because the remaining transects adequately covered the survey region, and because the excluded data were well north of the diffuser structure in a location opposite the direction of the prevailing flow. The remaining transects, shown by the solid orange and blue lines in Figure 5, met the permit monitoring requirement of at least five passes near the diffuser structure at each tow depth.

Similarly, quality-control screening of the vertical profile data was required because the length of the CTD is close to the 0.5-m standard depth bins used to report the vertical profile data. Because of the CTD's size, the ability to compute average values for seawater properties at locations very near the sea surface and seafloor varies depending on how the CTD's reported depth is influenced by temporal differences in sea-surface height caused by wave and tidal-induced oscillations during its deployment at each station. For example, during the June 2012 survey, data on average seawater properties was not reported within the deepest depth bin (16.5 m) except at Station RW4.[14] Because this isolated observation within the deepest depth bin cannot quantify a horizontal trend, it was excluded from the subsequent compliance evaluation.

In addition, eight transmissivity observations were excluded because they were impacted by brief encounters with salps (Salpidae sp.). Salps are barrel-shaped, free-floating tunicates that move by pumping water through their gelatinous bodies and feed on the phytoplankton filtered from the pumped seawater. Substantial numbers of salp colonies were visually observed floating in the water column during the June 2012 survey. Two separate one-second reductions in transmissivity were ascribed to blockage of the transmissometer path during encounters with the floating salps during the tow survey.

RESULTS

The second-quarter receiving-water survey was conducted on the morning of Friday, 29 June 2012. The receiving-water survey commenced at 08:17 PDT with the deployment of the drogued drifter. Over the following three hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended at 10:58 PDT with the retrieval of the CTD from its mid-depth-tow configuration. The collection of required visual observations of the sea surface was unencumbered throughout the survey, although, as during the March 2012 survey, fog obscured views of both the

Southern California Bight Study (SCBFMC 2002), which includes CTD cast-acceptability ranges in Table 2 of the manual.

[13] Figures 7 and 8

[14] Refer to Table 5

shoreline and Morro Rock during the first hour of the survey, restricting observations of beneficial uses during that time to within a quarter mile of the survey vessel.

Auxiliary Observations

On the morning of 29 June 2012, skies were initially overcast, with light northwesterly winds. Skies began to clear after 09:00 PDT, however fog rolled back in at the end of the survey as the boat was returning to the dock. Average wind speeds, calculated over one-minute intervals, ranged from 1.0 kt to 2.5 kt (Table 4). Similarly, peak wind speeds ranged from 1.5 kt to 3.4 kt. The swell was out of the northwest with a significant wave height of three feet. Air temperatures increased from 12.2°C to 20.2°C due to increased insolation as the skies cleared during the survey.

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location[15] Latitude	Location[15] 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	25° 22.260' N	120° 52.478' W	112.8	9:07:25	15.5	100	2.5	2.7	NW	3 NW	4.0
RW2	25° 22.228' N	120° 52.492' W	51.4	9:01:42	19.8	100	1.5	2.5	NW	3 NW	4.0
RW3	25° 22.217' N	120° 52.490' W	28.7	8:52:48	20.2	100	1.0	1.5	NW	3 NW	4.0
RW4	25° 22.185' N	120° 52.491' W	14.2	8:45:12	15.5	100	1.7	2.6	NW	3 NW	5.0
RW5	25° 22.169' N	120° 52.497' W	42.1	8:27:08	12.2	100	2.4	2.4	NW	3 NW	4.0
RW6	25° 22.152' N	120° 52.480' W	76.7	8:21:09	12.5	100	2.0	2.5	NW	3 NW	3.0

The 3-to-4 m Secchi depths recorded during the June 2012 survey reflected the presence of a shallow 6-to-8 m euphotic zone that spanned only about half the extent of the 15.5-m water column (Table 4). The limited water clarity in the upper water column was associated with upwelling, which carries nutrients upward into the euphotic zone where phytoplankton populations assimilate them and increase in abundance. Increased phytoplankton densities, along with their associated zooplanktonic predators, reduce the transmittance of ambient light during upwelling events. In contrast, the observed 1-m increase in Secchi depth at Station RW4 reflected the presence of the discharge plume as it approached the sea surface at this location. The reduced particulate load within the discharge plume compared to the surrounding ambient waters was due to the entrainment and upward transport of clearer seawater at depth.

Despite the limited visibility in the upper water column, salps and biofilm particulates were visually apparent during the survey. Although small pieces of biofilm, which lines the interior surfaces of the outfall pipe, were observed suspended within the water column near Station RW3, there was no evidence during the survey of floating particulates, oil sheens, or any discoloration of the sea surface associated with wastewater-related constituents. As previously mentioned, strings of salp colonies were observed throughout the survey area.

Communication with plant personnel during the survey, and subsequent review of effluent discharge properties, confirm that the treatment process was performing nominally at the time of the survey. The 1.354 million gallons of effluent discharged on the day of the survey had a temperature of 21°C a suspended-solids concentration of 22 mg/L, and a pH of 7.6. Biochemical oxygen demand (BOD) measured in an effluent sample five days before the survey was 59.6 mg/L.

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

During the June 2012 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. Observations of the adjacent beach and Morro Rock were restricted during the majority of the June 2012 survey due to fog; however small numbers of Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), western gulls (*Larus occidentalis*), and California brown pelicans (*Pelecanus occidentalis californicus*) were noted transiting the survey area. Several small recreational fishing boats were also observed offshore during the survey. During the vertical tow portion of the survey, a solitary juvenile pelican and a sooty shearwater (*Puffinus griseus*) approached and followed the boat closely for approximately 20 minutes looking for fishing scraps and offal. Just prior to the beginning of the towed survey, a fisherman caught a halibut directly offshore of 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 June 2012 survey reflect the presence of a moderately stratified water column indicative of upwelling conditions that prevailed in the two months prior to, and during the survey. 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 short 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.

Winds were mild on the morning of the June 2012 survey, although the upwelling signature of the strong, sustained winds during the prior few days was readily apparent in the vertical structure in seawater characteristics. Nevertheless, water-column stratification was only about half the level typically found at the onset of intense upwelling, when a sharply defined thermocline is formed within the upper water column in the survey area. When upwelling winds are sustained and exert their influence over an extended period, however, the wind-mixed surface layer deepens, and the thermocline extends offshore and below the maximum water depth within the survey area. This was the case during the June 2012 survey, namely, the main upwelling-induced thermocline was deeper than the maximum depth in the survey area. Likewise, the increased turbidity found within the upper water column also resulted from longer-term upwelling processes that had prevailed throughout spring, generating increased primary productivity and high planktonic densities throughout the region.

The level of vertical stratification within the survey area is important for understanding the dynamics of the effluent plume dispersion at the time of the survey. For example, when the water column is highly stratified, the rising plume can become trapped at depth within the water column, limiting dilution. However, the the moderate water-column stratification during the June 2012 survey was not large enough to trap the effluent plume below the sea surface. This is apparent from a comparison of the nearly straight vertical-profiles at Station RW4 and the profiles at the other five stations (Figure 6d). The RW4 profiles reflect the entrainment and upward transport of near-bottom seawater within the rising effluent plume.

Although the uniformity of the profiles at Station RW4 compared to the other stations is striking, the vertical gradient in ambient seawater properties at the other stations during the June 2012 survey was not particularly large. For example, vertical temperature differences at the onset of strong upwelling typically exceed 2°C within the survey area, while the temperature difference between surface and bottom waters during the June 2012 survey was only 1°C (Figure 6ab).

Table 5. Vertical Profile Data Collected on 29 June 2012

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	12.279	12.257	12.294	11.465		12.221	22.794	22.788	22.800	22.726		22.787
1.5	12.222	12.216	12.264	11.474	12.175	12.205	22.791	22.788	22.790	22.722	22.782	22.786
2.0	12.228	12.269	12.164	11.475	12.106	12.285	22.792	22.787	22.780	22.724	22.772	22.785
2.5	12.288	12.218	12.052	11.470	12.072	12.227	22.786	22.785	22.774	22.727	22.772	22.780
2.0	12.179	12.101	11.894	11.465	12.074	12.125	22.781	22.779	22.771	22.721	22.772	22.776
2.5	12.092	11.975	11.777	11.466	12.074	12.052	22.782	22.774	22.772	22.722	22.772	22.775
4.0	11.987	11.886	11.712	11.467	12.072	11.955	22.780	22.784	22.765	22.725	22.771	22.762
4.5	11.924	11.824	11.671	11.465	12.067	11.895	22.790	22.787	22.772	22.722	22.771	22.760
5.0	11.898	11.814	11.676	11.452	12.021	11.724	22.777	22.792	22.779	22.726	22.765	22.744
5.5	11.879	11.812	11.694	11.424	11.819	11.592	22.789	22.795	22.785	22.754	22.724	22.752
6.0	11.852	11.808	11.704	11.421	11.649	11.556	22.794	22.797	22.788	22.756	22.757	22.766
6.5	11.824	11.772	11.711	11.422	11.542	11.560	22.795	22.796	22.790	22.756	22.776	22.779
7.0	11.790	11.728	11.718	11.425	11.524	11.558	22.795	22.799	22.796	22.755	22.795	22.782
7.5	11.755	11.661	11.696	11.424	11.527	11.549	22.798	22.799	22.798	22.754	22.800	22.791
8.0	11.688	11.628	11.648	11.422	11.529	11.522	22.798	22.801	22.801	22.756	22.804	22.791
8.5	11.645	11.610	11.618	11.421	11.514	11.497	22.799	22.802	22.802	22.759	22.806	22.786
9.0	11.586	11.577	11.582	11.427	11.522	11.462	22.799	22.802	22.802	22.755	22.807	22.788
9.5	11.551	11.529	11.552	11.441	11.524	11.450	22.802	22.804	22.802	22.752	22.807	22.794
10.0	11.506	11.497	11.515	11.426	11.524	11.441	22.804	22.806	22.806	22.762	22.807	22.797
10.5	11.482	11.481	11.487	11.412	11.522	11.441	22.806	22.807	22.806	22.792	22.807	22.800
11.0	11.465	11.472	11.474	11.287	11.509	11.451	22.807	22.808	22.808	22.807	22.807	22.805
11.5	11.461	11.462	11.467	11.275	11.480	11.462	22.808	22.809	22.809	22.812	22.808	22.809
12.0	11.455	11.460	11.459	11.287	11.472	11.456	22.809	22.810	22.809	22.809	22.810	22.810
12.5	11.445	11.444	11.451	11.292	11.465	11.448	22.810	22.811	22.811	22.807	22.811	22.809
12.0	11.429	11.424	11.442	11.290	11.454	11.414	22.811	22.812	22.812	22.808	22.812	22.808
12.5	11.290	11.299	11.419	11.271	11.407	11.277	22.812	22.812	22.812	22.812	22.812	22.812
14.0	11.258	11.270	11.285	11.268	11.288	11.269	22.815	22.815	22.814	22.812	22.814	22.815
14.5	11.225	11.246	11.240	11.268	11.261	11.262	22.816	22.817	22.817	22.814	22.816	22.817
15.0	11.229	11.240	11.228	11.261	11.260	11.252	22.817	22.818	22.818	22.816	22.817	22.818
15.5	11.229	11.222	11.228	11.258	11.256	11.250	22.818	22.818	22.818	22.816	22.817	22.819
16.0		11.222	11.228	11.254	11.265	11.249		22.819	22.819	22.816	22.818	22.819
16.5				11.254						22.817		

Table 5. Vertical Profile Data Collected on 29 June 2012 (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	25.580	25.580	25.601	25.700		25.586	8.169	8.180	8.126	7.984		8.160
1.5	25.586	25.588	25.599	25.702	25.610	25.588	8.176	8.181	8.156	7.985	8.122	8.157
2.0	25.587	25.596	25.610	25.704	25.615	25.591	8.179	8.181	8.155	7.986	8.126	8.155
2.5	25.591	25.604	25.627	25.699	25.622	25.597	8.178	8.181	8.144	7.984	8.117	8.152
2.0	25.609	25.622	25.654	25.702	25.621	25.612	8.174	8.174	8.122	7.985	8.115	8.142
2.5	25.626	25.641	25.677	25.704	25.621	25.628	8.168	8.158	8.098	7.986	8.112	8.122
4.0	25.644	25.666	25.684	25.706	25.621	25.626	8.152	8.124	8.075	7.985	8.112	8.109
4.5	25.664	25.679	25.697	25.704	25.622	25.645	8.129	8.112	8.056	7.984	8.112	8.089
5.0	25.658	25.686	25.701	25.709	25.624	25.664	8.106	8.094	8.045	7.982	8.110	8.068
5.5	25.671	25.688	25.702	25.726	25.640	25.696	8.091	8.080	8.029	7.981	8.095	8.026
6.0	25.680	25.691	25.702	25.729	25.689	25.712	8.079	8.072	8.027	7.980	8.060	8.015
6.5	25.684	25.697	25.704	25.728	25.724	25.722	8.071	8.064	8.027	7.979	8.022	8.007
7.0	25.692	25.707	25.707	25.727	25.740	25.727	8.061	8.057	8.026	7.977	8.005	8.001
7.5	25.701	25.720	25.712	25.727	25.744	25.724	8.052	8.046	8.025	7.976	8.001	7.998
8.0	25.714	25.727	25.724	25.729	25.749	25.728	8.045	8.028	8.028	7.976	7.998	7.994
8.5	25.722	25.722	25.721	25.721	25.752	25.740	8.027	8.022	8.022	7.975	7.996	7.991
9.0	25.724	25.729	25.727	25.727	25.751	25.748	8.028	8.027	8.018	7.974	7.996	7.988
9.5	25.742	25.748	25.742	25.724	25.751	25.755	8.018	8.022	8.014	7.974	7.994	7.980
10.0	25.752	25.755	25.752	25.722	25.751	25.759	8.011	8.016	8.010	7.972	7.992	7.974
10.5	25.758	25.759	25.758	25.760	25.752	25.762	8.005	8.008	8.002	7.972	7.992	7.972
11.0	25.762	25.762	25.762	25.777	25.754	25.762	8.000	8.004	7.997	7.971	7.992	7.974
11.5	25.764	25.765	25.764	25.782	25.761	25.764	7.992	8.001	7.992	7.966	7.989	7.978
12.0	25.766	25.766	25.765	25.778	25.762	25.766	7.990	7.995	7.989	7.964	7.987	7.981
12.5	25.768	25.769	25.768	25.776	25.765	25.767	7.987	7.992	7.987	7.962	7.986	7.976
12.0	25.772	25.774	25.770	25.777	25.768	25.772	7.985	7.990	7.986	7.964	7.981	7.972
12.5	25.780	25.779	25.775	25.782	25.776	25.782	7.981	7.986	7.984	7.959	7.974	7.960
14.0	25.788	25.786	25.782	25.785	25.782	25.786	7.971	7.982	7.979	7.956	7.966	7.952
14.5	25.792	25.792	25.792	25.785	25.788	25.789	7.962	7.974	7.966	7.952	7.957	7.948
15.0	25.795	25.792	25.794	25.788	25.789	25.791	7.952	7.969	7.956	7.952	7.949	7.942
15.5	25.795	25.795	25.794	25.789	25.790	25.792	7.945	7.959	7.948	7.951	7.946	7.941
16.0		25.796	25.795	25.790	25.789	25.792		7.952	7.944	7.949	7.944	7.929
16.5				25.790						7.948		

Table 5. Vertical Profile Data Collected on 29 June 2012 (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	8.672	8.591	8.565	5.888		8.540	72.605	72.222	70.686	84.667		68.090
1.5	8.660	8.546	8.077	5.882	7.974	8.512	70.250	70.496	69.990	84.567	70.105	68.940
2.0	8.555	8.421	7.601	5.844	7.809	8.264	70.278	70.468	70.170	84.499	70.652	68.622
2.5	8.217	7.982	7.076	5.840	7.842	8.012	70.146	70.020	69.807	84.292	71.815	68.225
2.0	8.102	7.296	6.682	5.852	7.840	7.726	71.120	70.106	71.509	84.442	72.294	68.629
2.5	7.608	7.204	6.587	5.829	7.827	7.296	70.109	69.790	75.107	84.460	72.185	69.492
4.0	7.411	6.962	6.490	5.848	7.811	7.214	70.288	70.876	78.100	84.682	71.819	69.842
4.5	7.219	6.962	6.545	5.807	7.699	6.798	71.107	72.264	79.169	84.262	71.227	71.220
5.0	7.205	6.972	6.594	5.780	6.995	6.199	72.461	74.116	80.259	84.589	71.562	72.527
5.5	7.114	6.924	6.626	5.775	6.222	6.165	74.840	74.589	79.787	84.827	72.772	77.294
6.0	7.022	6.777	6.622	5.776	6.162	6.219	75.492	76.482	79.242	85.265	77.278	81.089
6.5	6.814	6.621	6.646	5.787	6.146	6.211	75.114	76.520	79.007	85.289	80.968	82.267
7.0	6.710	6.455	6.560	5.772	6.192	6.201	76.275	77.264	79.092	85.227	82.929	82.081
7.5	6.549	6.275	6.248	5.782	6.182	6.115	76.886	80.006	78.778	85.404	84.171	82.251
8.0	6.465	6.228	6.247	5.772	6.129	6.046	78.141	81.166	80.140	85.479	84.492	82.650
8.5	6.242	6.249	6.255	5.784	6.165	5.946	80.872	82.228	81.541	85.058	84.699	84.167
9.0	6.182	6.120	6.187	5.804	6.152	5.902	81.645	82.786	82.587	85.702	84.551	84.275
9.5	6.072	6.028	6.099	5.784	6.152	5.871	82.091	82.648	82.962	85.678	84.892	85.220
10.0	6.065	6.002	6.012	5.759	6.127	5.892	84.261	84.202	82.461	85.426	84.768	85.612
10.5	5.982	5.982	5.964	5.647	6.089	5.949	85.105	85.200	84.627	85.222	84.857	85.669
11.0	5.968	5.922	5.947	5.590	6.026	6.025	85.880	85.209	85.224	85.506	84.585	85.757
11.5	5.922	5.922	5.941	5.651	6.021	5.992	86.209	85.741	85.597	86.124	84.707	85.720
12.0	5.888	5.907	5.945	5.682	5.995	5.959	85.886	86.208	85.686	87.121	85.044	85.482
12.5	5.864	5.844	5.925	5.659	5.949	5.859	86.241	86.118	85.817	87.159	85.429	85.871
12.0	5.656	5.784	5.809	5.544	5.759	5.578	86.421	85.697	85.521	87.109	85.256	86.580
12.5	5.597	5.624	5.690	5.548	5.688	5.610	86.722	86.185	85.797	87.259	85.664	87.297
14.0	5.461	5.507	5.421	5.546	5.522	5.589	86.565	86.482	86.067	87.289	86.945	87.405
14.5	5.298	5.518	5.416	5.501	5.551	5.521	88.159	87.896	87.664	87.245	87.477	87.540
15.0	5.265	5.429	5.291	5.506	5.524	5.512	88.582	88.259	88.485	87.586	87.459	87.825
15.5	5.271	5.440	5.264	5.509	5.587	5.504	88.698	88.452	88.647	87.260	87.978	87.855
16.0		5.452	5.281	5.501	5.569	5.507		88.569	88.478	87.722	88.007	88.096
16.5				5.505						88.215		

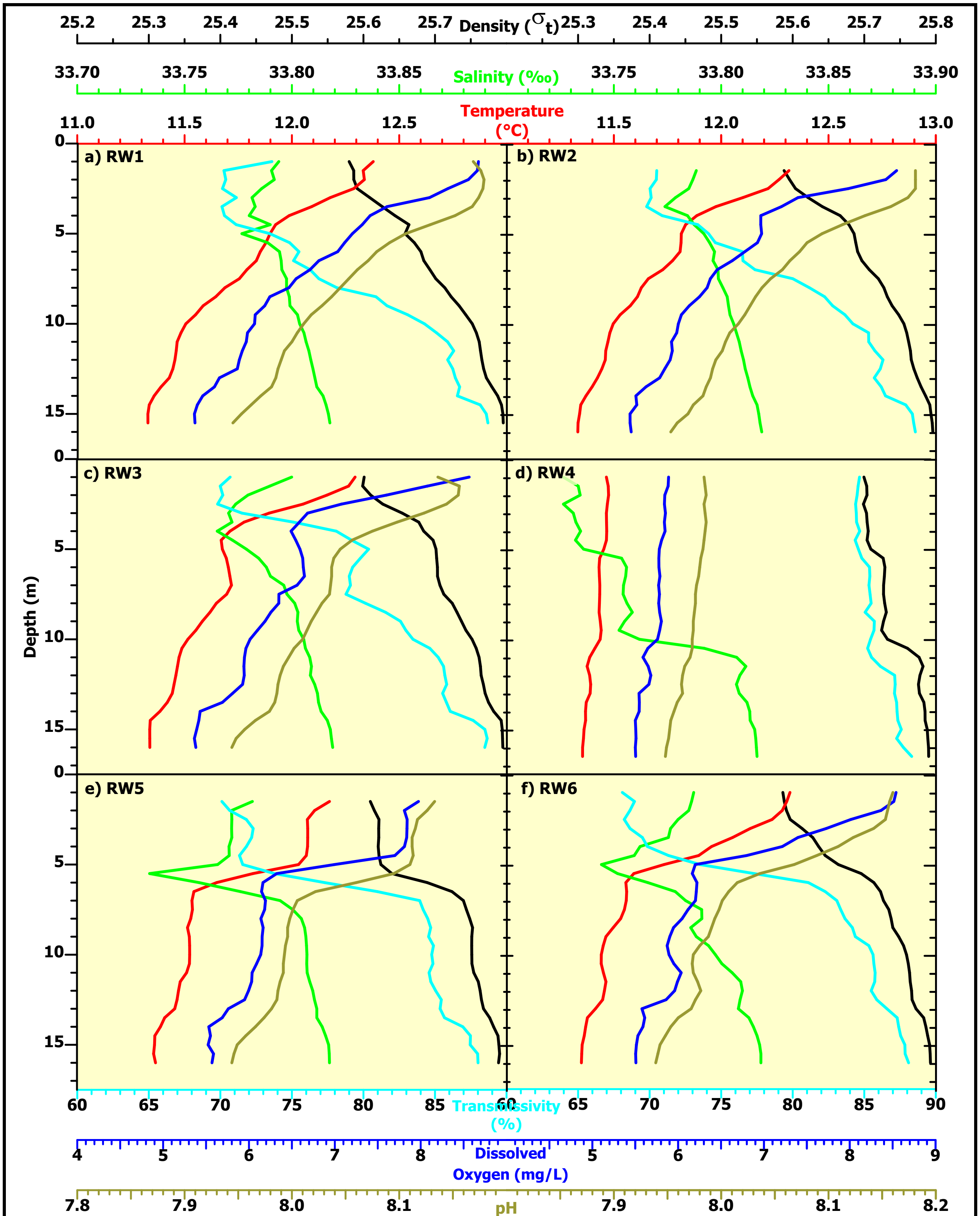

Figure 6. Vertical Profiles of Water-Quality Parameters

Moderate upwelling-induced gradients in ambient seawater properties are apparent as decreases in temperature (red lines), DO (dark blue lines), and pH (gold lines) with increasing depth below 3 m in Figures 6ab. These decreases are mirrored by a pycnocline and halocline, where density (black lines) and salinity (green line) steadily increase with depth. Specifically, the profiles exhibit a gradual vertical transition between a very thin, relatively uniform, near-surface mixed layer and a colder, saltier, nutrient-rich but oxygen-poor water mass that migrated shoreward along the seafloor in response to upwelling processes. Although the effluent plume extended to the sea surface at Station RW4 (Figure 6d), most of the dilute effluent was trapped below the sea surface near 5 m, where it can be seen to have spread laterally to Stations RW3, RW5, and RW6 (Figures 6cef).

In contrast to the salinity profile at RW4, which exhibits an anomalously low salinity from the sea surface down to 10 m, the profiles at Stations RW5 and RW6 (Figure 6ef) exhibit a sharply defined subsurface reduction in salinity that tracked the plume as it spread below the sea surface near 5 m. The plume's influence is also apparent in the more sharply defined thermocline (red lines), and the vertical gradients in DO (dark blue lines), pH (gold lines), transmissivity (light blue lines), and density (black lines) at Stations RW3, RW5, and RW6 (Figures 6cef) as compared to the unaffected Stations RW1 and RW2 (Figures 6ab). The sharply defined vertical gradients at RW3, RW5, and RW6 were caused when the rising effluent plume entrained ambient seawater at depth and transported it upward in the water column where it compressed the thermocline within a limited layer between 4 m and 6 m.

The ambient vertical structure within the survey area, and its associated influence on plume dynamics, are consistent with standard models of cross-shore transport during upwelling. Along the seafloor, upwelling transported cold, dense seawater (red and black lines in Figure 6ab) onshore to replace nearshore surface waters that were driven offshore by prevailing winds. These deep offshore waters had not been in recent direct contact with the atmosphere, and biotic respiration and decomposition had depleted their DO levels (dark blue lines). Additionally, in contrast to the relatively fresh surface waters associated with the southward-flowing California Current, the slightly elevated salinity at depth (green lines in Figure 6) was indicative of waters that originated in the Southern California Bight and had been carried northward by the Davidson Undercurrent.

Nutrient-rich seawater brought to the sea surface by upwelling facilitates phytoplankton blooms that produce oxygen, consume carbon dioxide (CO_2), and decrease water clarity. With increasing depth, respiration increases relative to photosynthesis, resulting in a corresponding increase in dissolved CO_2 (carbonic acid) and a concomitant decline in pH (olive-colored lines). Steadily increasing respiration with increasing depth also depleted DO concentrations near the seafloor relative to the sea surface (dark-blue lines).

Although the plume reached the sea surface during the June 2012 survey at Station RW4, there was no visual evidence of its presence within the upper water column at the time of the survey. On rare occasions when the effluent plume is visually evident near the sea surface, it typically appears as a diffuse increase in turbidity within the ZID. However, during the June 2012 survey, the dilute effluent plume was actually less turbid than the surrounding ambient seawater near the sea surface. As a result, the Secchi depth at Station RW4, where the plume reached the surface, was 1 m deeper, indicating increased light transmission within the plume (Table 4). Accordingly, higher transmissivities were measured near RW4 during the shallow tow survey (Figure 8d). Reductions in temperature, DO, pH, and a weak salinity signature (Figure 8aef) were also apparent along the southern boundary of the ZID during the shallow tow survey (Figure 8b).

Salinity and density data collected during the mid-depth tow also confirm the presence of the plume signature near the southern boundary of the ZID (Figure 7bc). The southerly offset in the plume anomalies in both the shallow and mid-depth tows was consistent with the southerly flow component measured by the drifter trajectory (Figure 2). However, the location of the anomalies in temperature, transmissivity, DO, and pH measured during the mid-depth tow (Figures 7adef) were offset 66 m to the southwest of the density and salinity anomalies measured during the mid-depth tow.

The absence of a perceptible salinity anomaly that coincided with the location of the observed temperature, transmissivity, DO, and pH anomalies demonstrates that wastewater constituents had already been diluted beyond recognition by the time they reached this location (Figure 7b). The observed temperature, transmissivity, DO, and pH anomalies were legacies left by the plume mixing process. The lateral anomalies in these four seawater properties were created when near-bottom seawater was entrained within the effluent plume shortly after discharge. At that point, the diluted wastewater plume acquired the ambient seawater characteristics of the bottom water, namely, its low temperature, turbidity, DO, and pH. As these seawater properties were carried upward through the water column by the rising effluent plume, they were juxtaposed against the differing ambient seawater properties in the upper water column. The legacy of these entrainment anomalies can be particularly long-lived and can remain apparent well after completion of the initial dilution process when wastewater constituents have been dispersed beyond recognition. Regardless, such anomalies are irrelevant to the receiving-water compliance analysis because it is restricted to changes caused solely by the presence of wastewater constituents and excludes changes caused by the relocation of ambient seawater.

It is clear that these entrainment anomalies were not caused by the presence of wastewater constituents because the offsets in their properties were consistent with the vertical differences in ambient seawater and, for some properties, the offsets were opposite of the changes that would be expected to be caused by wastewater. Specifically, the increased transmissivity and lower temperature, DO, and pH measured within the entrainment anomalies in Figures 7adef fell within the range of ambient seawater properties found at depths below 8.4 m (Figure 6ab). In contrast, wastewater discharged on the day of the survey was much warmer (21°C) than receiving seawater (<12.4°C), and could not have induced the thermal signature observed within the entrainment anomaly because it was cooler than the surrounding seawater. Similarly, the observed increase in transmissivity (water clarity) could not have been caused by wastewater particulates because their presence would decrease transmissivity, not increase it.

Additional insights into plume dynamics during the June 2012 survey are evident in the density distribution (Figures 7c and 8c). The mid-depth tow captured the signature of the effluent plume near the ZID boundary as it was continuing to rise within the water column. This is apparent from the negative density anomaly in Figure 7c, which shows that the surrounding seawater had a higher density than the plume itself at a depth of 8.4 m. Because the plume was positively buoyant at this depth, it would be expected to continue to rise within the water column and continue the initial mixing process. The shallow tow, however, did not exhibit a strong density anomaly associated with the plume (Figure 8c). This indicates that the plume had achieved neutral buoyancy near a depth of 5.8 m. Although the plume began to spread laterally near that depth, the plume's initial upward momentum continued to carry much of the plume past its neutral-equilibrium depth until it reached the sea surface (Figure 6d).

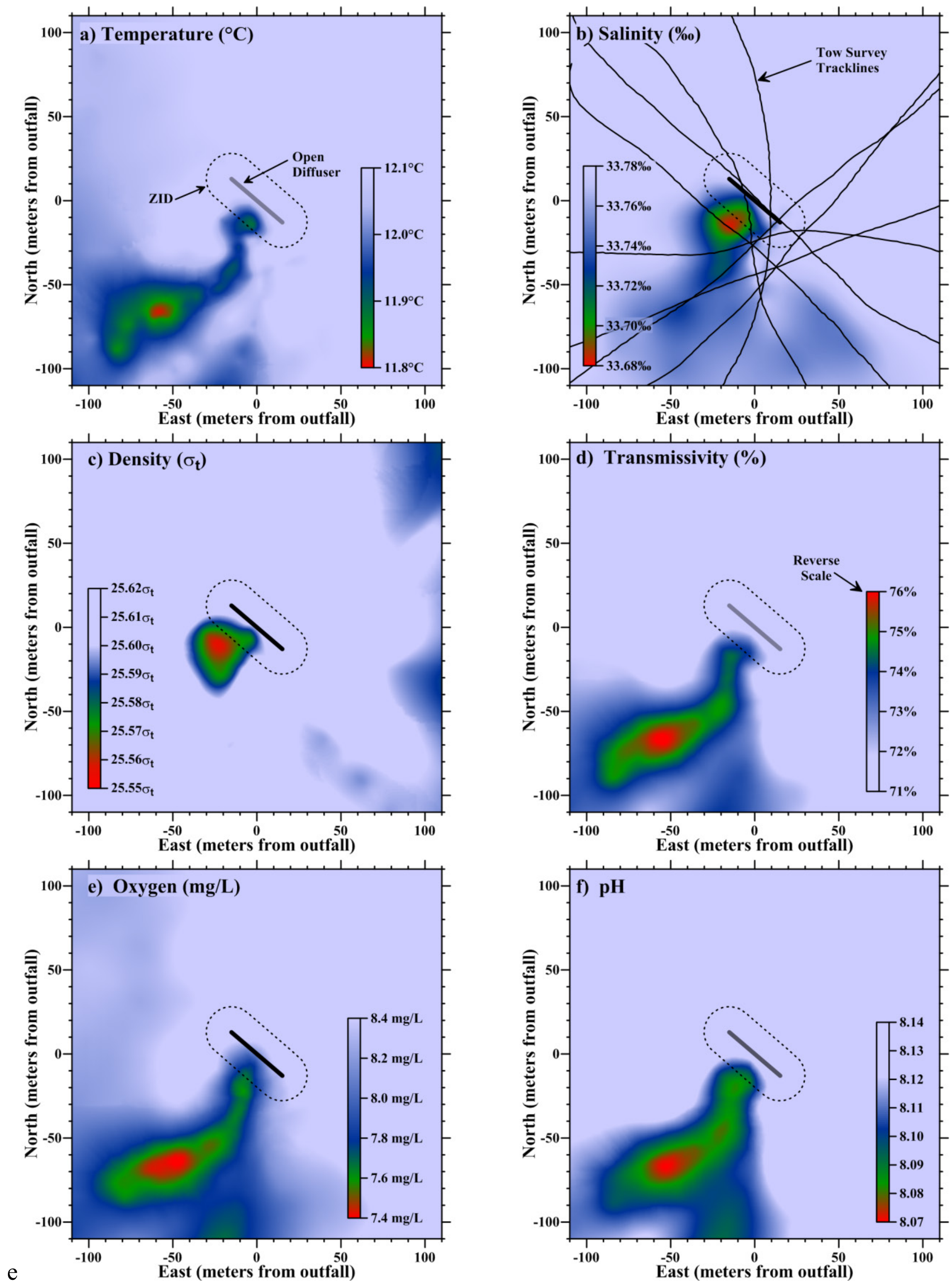

Figure 7. Horizontal Distribution of Mid-Depth Water-Quality Parameters 8.4 m below the Sea Surface

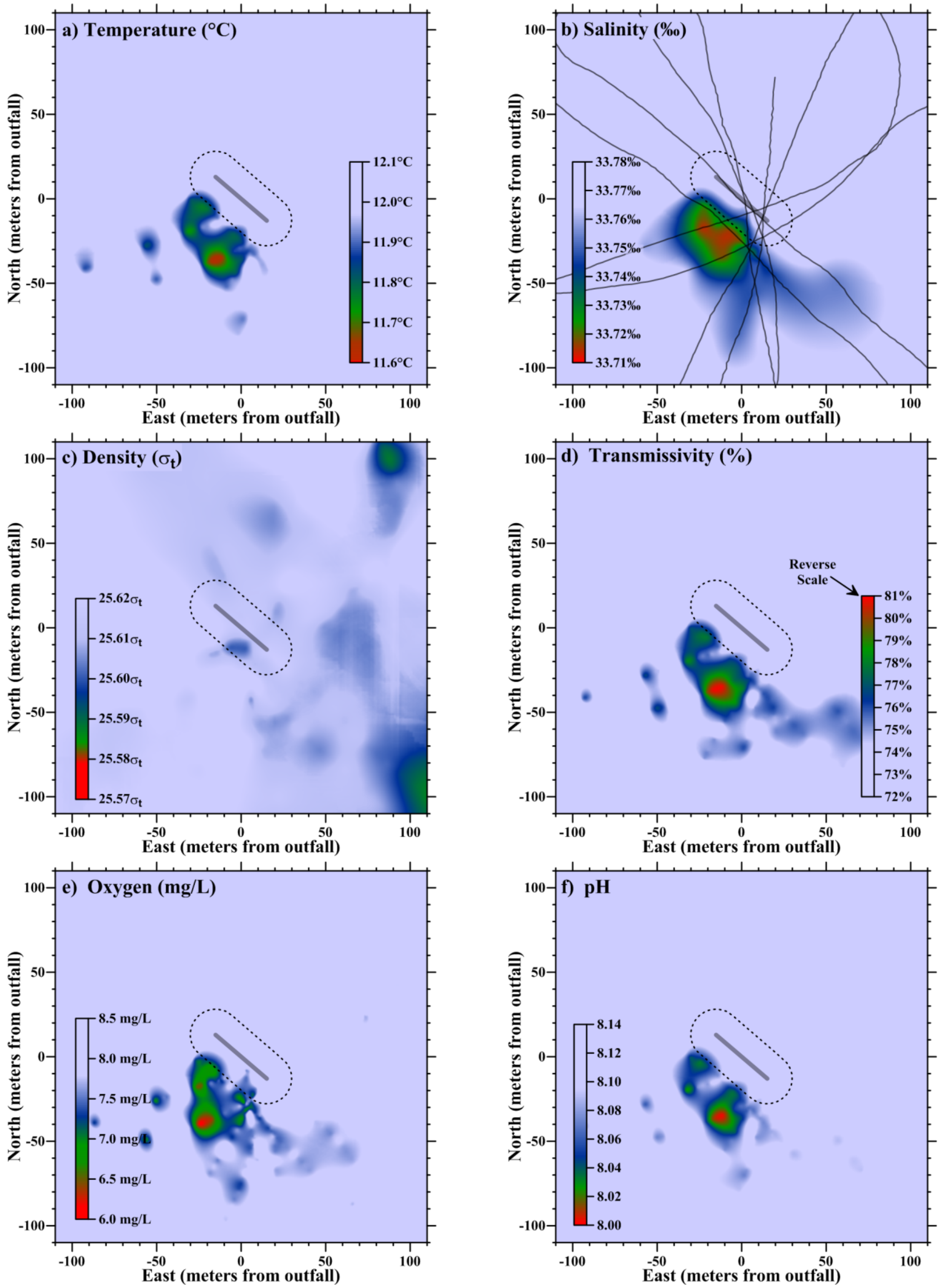

Figure 8. Horizontal Distribution of Shallow Water-Quality Parameters 5.8 m below the Sea Surface

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the June 2012 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 with 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, spread laterally, and cease to rise in the water column and dilute further. 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 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. Use of a higher critical dilution would relax the stringent end-of-pipe effluent limitations thought necessary to meet COP objectives after initial dilution is complete.

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

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

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 near the ZID boundary in the tow-survey maps (Figures 7b and 8b) and above 11 m in the vertical profiles measured at Stations RW3 through RW6 (green lines in Figure 6cdef). These localized salinity anomalies reflect the presence of dilute wastewater within the effluent plume as it rose through the water column and reached the sea surface.

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)[16] is generally small compared to that of the receiving seawater and, after dilution by more than 100-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, reduced effluent dilution at a given location within receiving waters is directly reflected by a larger amplitude salinity anomaly.

The lowest salinity (33.681‰) measured during the June 2012 survey was recorded 21.8 m from the diffuser structure at a depth of 8.1 m during the seventh transect of the deep tow survey (red shading in Figure 7b). This measured salinity corresponds to a 0.101‰ reduction below the mean ambient salinity of 33.782‰ that was measured at the same depth level, but well beyond the influence of the discharge. The salinity anomaly documents the presence of wastewater that has been diluted 321-fold (Figure 9). This is nearly two-and-a-half times the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater.

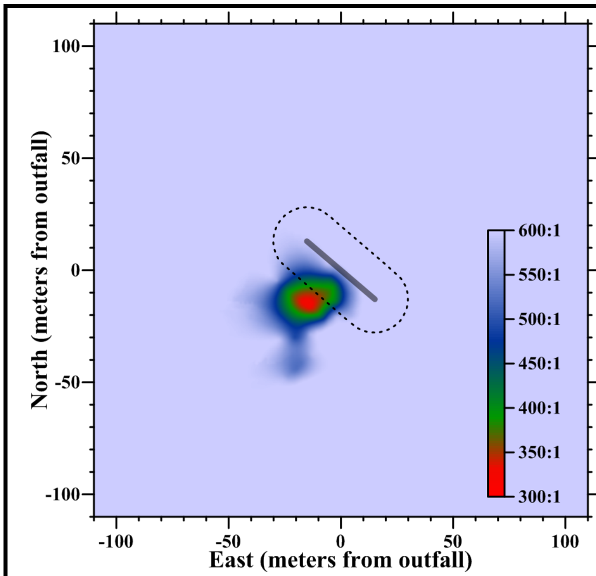

Figure 9. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 7b

In addition, the lowest dilution was measured at a depth below the trapping depth identified in the modeling that established the 133:1 minimum dilution ratio. As a result, dilution levels would be expected to be less than 133:1. 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.

In addition, the mid-depth survey captured the plume signature as the plume was continuing to undergo initial dilution during its ascent through the water column. As described previously, the negative density anomaly associated with this plume measurement (Figure 7c) demonstrated that the plume was buoyant at this location. Additional dilution would result from the turbulence generated by the plume's subsequent rise through the rest of the water column. Consequently, dilution levels well in excess of 321-fold would be expected at the completion of initial dilution when the plume achieved neutral equilibrium.

[16] Wastewater samples collected during March 2012 had an average salinity of 0.995‰.

Accordingly, minimum dilution levels observed within the shallow tow survey all exceeded 450-fold (Figure 10).

The dilution computations demonstrate that during the June 2012 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 321-fold shortly after discharge, and after completion of the initial-dilution process, dilutions exceeded 450-fold. These measured dilution levels were well in excess of 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. Consequently, during the June 2012 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.

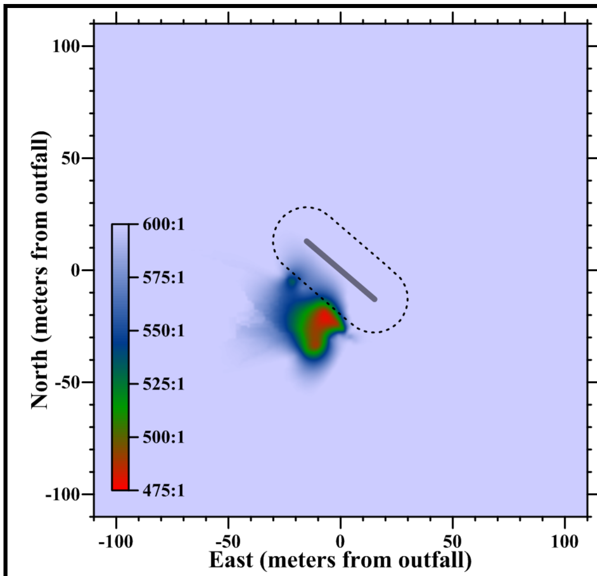

Figure 10. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 8b

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 June 2012 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 June 2012 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 June 2012 survey.

Compliance with the remaining four receiving-water limitations is quantitatively evaluated through a comparison of instrumental measurements and the specific numerical limits listed in the NPDES permit. For example, in P5 and P6, the fixed numeric limits on absolute values of DO (>5 mg/L) and pH (7.0 to 8.3) can be directly compared with field measurements within the dilute wastewater plume 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. An accurate characterization of stratification helps distinguish discharge-related changes that arise from the presence of wastewater constituents, which are subject to a compliance evaluation, from changes that arise because of the upward movement of ambient seawater, which are specifically excluded from the compliance evaluation.

Screening of Measurements

Evaluating whether any of the 14,354 CTD measurements collected during the June 2012 survey exceeded a permit limit can be a complex process. For example, although apparently significant excursions in an individual seawater property may be related to the presence of wastewater constituents, they may also result from instrumental errors, natural processes, entrainment of ambient bottom waters in the rising effluent plume, statistical uncertainty, ongoing initial mixing within and beyond the ZID, or other anthropogenic influences (e.g., dredging or oil spills).

Because of this complexity, measurements were first screened to determine whether numerical limits on individual seawater properties apply (Table 7). The screening procedure sequentially applies three questions to restrict attention to: 1) the oceanic area where permit provisions apply; 2) changes due to the presence of wastewater particulates; and 3) changes large enough to be reliably detected against the backdrop of natural variation. The 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

Table 7. Receiving-Water Measurements Screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer No	Answer Yes[17]	*Parameter*
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	*1,196*	*13,158*	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?	*12,904*	*254*	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?	*254*	*0*	Temperature
		254	*0*	Transmissivity
		254	*0*	DO
		254	*0*	pH

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.

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 June 2012 dataset eliminated 1,196 of the original 14,354 receiving-water observations from further consideration because they were collected within the ZID (Table 7, Question 1). The remaining 13,158 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 water. Wastewater salinity is negligible compared to that of the receiving seawater, so the presence of a distinct salinity minimum provides *de facto* evidence of the presence of wastewater constituents. Because of the large contrast between the nearly fresh wastewater and the salty receiving water, salinity provides a powerful tracer of dilute wastewater that is unrivaled by other

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

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. 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 7b and 8b, discharge-related salinity anomalies were largely restricted to the southwest boundary of the ZID. Two-hundred-fifty-four measurements had significant reductions in salinity that unequivocally identified the presence of dilute wastewater constituents beyond the ZID. The remaining 12,904 observations that were measured outside the ZID during the June 2012 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 numeric permit limits.

A statistical analysis of receiving-water data previously collected around the outfall was used to establish the range of variability in natural conditions surrounding the outfall (first three columns of Table 8). These ranges in natural variability were used to identify significant departures from ambient conditions that could be indicative of adverse discharge-related effects on water quality. The same five-year database used to establish the natural within-survey salinity variation discussed previously was also used to establish one-sided 95% confidence bounds on transmissivity (-10.2%), temperature (+0.82°C), DO (-1.38 mg/L), and pH (± 0.094). These were combined with 95th percentiles determined from the June 2012 ambient seawater data, to establish time-specific natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from June 2012 vertical profile data, excluding measurements potentially affected by the discharge.

Temperature, transmissivity, and DO concentrations associated with the 254 remaining measurements of potential compliance interest all remained 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 June 2012 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 June 2012 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 in the upper water column. As discussed previously, all of the anomalies in seawater properties that coincided with the salinity

Table 8. Compliance Thresholds

Water Quality Property	95% Confidence Bound[18]	95th Percentile[19,20]	Natural Variability Threshold[21]	COP Allowance[22]	Basin Plan Limit[23]	Extremum[24]
Temperature (ºC)	0.82	12.28	>13.10	—	—	≤12.57
Transmissivity (%)	-10.2	70.0	<59.8	—	—	≥65.3
DO (mg/L)	-1.38	5.44	<4.06	<3.65	<5.00	≥5.36
pH (minimum)	-0.094	7.948	<7.854	<7.654	<7.000	≥7.939
pH (maximum)	0.094	8.169	>8.263	>8.463	>8.300	≤8.208

anomalies in Figures 7 and 8 were consistent with the upward displacement of ambient bottom water rather than with the presence of the effluent plume. Even if the presence of wastewater particulates had contributed to the measured decreases in DO and pH within the plume, their influence would have been well within the natural range in ambient seawater properties at the time of the survey. Consequently, their influence on water quality cannot be considered environmentally significant.

Other Lines of Evidence

In addition to the analysis provided above, several additional lines of evidence support the conclusion that all the CTD measurements collected during the June 2012 survey complied with permit limits P3 through P6 in Table 6. In combination, these lines of evidence provide the "best explanation" of the origin and significance of individual measurements using abductive inference (Suter 2007). This process, which has been used to implement sediment-quality guidelines for California estuaries (SWRCB 2009), emphasizes a pattern of reasoning which accounts for both the discrepancies among multiple lines of evidence as well as concurrences. A best explanation approach serves to limit the uncertainty associated with each individual CTD measurement and provide a more robust compliance assessment. Together, these lines of evidence significantly strengthen the conclusion that the discharge fully complied with the permit during the June 2012 survey.

Natural Variability within 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

[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 June 2012 survey, and was determined from vertical profiles at Stations RW1 and RW2 that were not influenced 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 June 2012 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 the upper-bound objective 8.3, which applies to most beneficial uses was implemented in the MBCSD discharge permit.

[24] Maximum or minimum value measured during this survey

provides additional valuable insight into the potential for adverse effects on water quality beyond the ZID. During the June 2012 survey, salinity was the only seawater property that exhibited a perceptible difference from ambient conditions. Regardless of their association with the effluent salinity signature, none of the 14,354 temperature, DO, pH, or transmissivity observations exceeded the thresholds of natural variability specified in Table 8. This includes measurements collected within the ZID that were clearly associated with the presence of wastewater constituents, but were eliminated from further compliance consideration by the first screening question in Table 7.

Insignificant Thermal Impact: Although there are no explicit numerical objectives for discharge-related decreases in temperature, a numerical limit can be established for thermal excursions, which are not allowed to adversely affect beneficial uses (P3 in Table 6). Increases in temperature caused by the discharge of warm wastewater constituents would not be deemed to adversely affect beneficial uses if they remained within the natural temperature range at the time of the survey (less than 13.10°C in Table 8). Such was the case for all 14,354 CTD measurements collected during the June 2012 survey; none of the measured temperatures exceeded 12.57°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 the surrounding seawater (Figures 7a and 8a).

Insignificant Wastewater Particulate Loads: The discharge of wastewater particulates on 29 June 2012 did not contribute materially to turbidity within the dilute effluent plume. The suspended-solids concentration measured onshore within the effluent prior to discharge from the WWTP was 22 mg/L. After dilution by 321-fold, which was the lowest dilution measured during the survey, the effluent TSS concentration would have the reduced ambient transmissivity by only 0.4%. 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, 59.6-mg/L BOD measured within the plant's effluent around the time of 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 constituents 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 subsections. 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 7.654 during the June 2012 survey. This value is well below the lowest pH measurement of 7.939 recorded during the June 2012 survey (last column of Table 8). Similarly, the lowest DO concentration measured during the survey (5.36 mg/L) was well above both the lower range in natural variation (4.06 mg/L) and the 10% compliance threshold promulgated by the COP (3.65 mg/L).

CONCLUSIONS

The statistical screening analysis quantitatively demonstrated that all measurements recorded during the June 2012 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. Although the presence of dilute wastewater constituents was delineated from salinity anomalies within a discharge plume, all the associated seawater properties were within the natural variability that prevailed at the time of the survey.

Immediately after discharge, the outfall was achieving dilution levels in excess of 321-fold, which substantially exceeded the critical dilution levels predicted by design modeling. As the plume rose through the water column it was transported slowly toward the south, becoming more and more diffuse, and achieving dilution levels exceeding 450-fold. Lastly, all of the auxiliary observations collected during the June 2012 survey demonstrated that the discharge complied with the narrative receiving-water limits in the discharge permit and COP. All of these observations demonstrated that the treatment process, diffuser structure, and the outfall continue to perform at levels exceeding design expectations.

Although discharge-related changes in seawater properties were observed during the June 2012 survey, the changes were either not of significant magnitude, were measured within the boundary of the ZID where initial mixing is still expected to occur, or were not directly caused by the presence of wastewater constituents within the water column.

REFERENCES

Davis, R.E., J.E. Dufour, G.J. Parks, and M.R. Perkins. 1982. Two Inexpensive Current-Following Drifters. Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California. SIO Reference No. 82-28. December 1982.

Fischer, H.B., E.J. List, R.C.Y. Koh, J. Imberger, and N.H. Brooks. 1979. Mixing in Inland and Coastal Waters. New York: Academic Press, 482 p.

Kuehl, S.A., C.A. Nittrouer, M.A. Allison, L. Ercilio, C. Faria, D.A. Dukat, J.M. Jaeger, T.D. Pacioni, A.G. Figueiredo, and E.C. Underkoffler 1996. Sediment deposition, accumulation, and seabed dynamics in an energetic fine-grained coastal environment. *Continental Shelf Research*, 16: 787-816.

Marine Research Specialists (MRS). 1998. City of Morro Bay and Cayucos Sanitary District, Offshore Monitoring and Reporting Program, Semiannual Benthic Sampling Report, April 1998 Survey. Prepared for the City of Morro Bay, CA. July 1998.

Marine Research Specialists (MRS). 2002. City of Morro Bay and Cayucos Sanitary District, Supplement to the 2002 Renewal Application For Ocean Discharge Under NPDES Permit No. Prepared for the City of Morro Bay and Cayucos Sanitary District, Morro Bay, CA. July 2002.

Marine Research Specialists (MRS). 2011. City of Morro Bay and Cayucos Sanitary District, Offshore Monitoring and Reporting Program, 2010 Annual Report. Prepared for the City of Morro Bay, California. March 2011.

[City of] Morro Bay and Cayucos Sanitary District (MBCSD). 2010. The City of Morro Bay-Cayucos Wastewater Treatment Plant Monthly Operations Summary, March 2011.

Regional Water Quality Control Board (RWQCB) - Central Coast Region. 1994. Water Quality Control Plan (Basin Plan) Central Coast Region. Available from the RWQCB at 81 Higuera Street, Suite 200, San Luis Obispo, California. 148p. + Appendices.

Regional Water Quality Control Board (RWQCB) - Central Coast Region and the Environmental Protection Agency (USEPA) – Region IX. 1992a. Waste Discharge Requirements (Order No. 92-67) and Authorization to Discharge under the National Pollutant Discharge Elimination System (Permit No. CA0047881) for City of Morro Bay and Cayucos Sanitary District, San Luis Obispo County.

Regional Water Quality Control Board (RWQCB) - Central Coast Region and the Environmental Protection Agency (USEPA) – Region IX. 1992b. Monitoring and Reporting Program No. 92-67 for City of Morro Bay and Cayucos Sanitary District, San Luis Obispo County (Permit No. CA0047881).

Regional Water Quality Control Board (RWQCB) - Central Coast Region and the Environmental Protection Agency (USEPA) – Region IX. 1998a. Waste Discharge Requirements (Order No. 98-15) and National Pollutant Discharge Elimination System (Permit No. CA0047881) for City of Morro Bay and Cayucos Sanitary District, San Luis Obispo County. 11 December 1998.

Regional Water Quality Control Board (RWQCB) - Central Coast Region and the Environmental Protection Agency (USEPA) – Region IX. 1998b. Monitoring and Reporting Program No. 98-15 for City of Morro Bay and Cayucos Sanitary District, San Luis Obispo County. 11 December 1998.

Regional Water Quality Control Board (RWQCB) - Central Coast Region and the Environmental Protection Agency (EPA) – Region IX. 2009. Waste Discharge Requirements (Order No. R2-2008-0065) and National Pollutant Discharge Elimination System (Permit No. CA0047881) for the Morro Bay and Cayucos Wastewater Treatment Plant Discharges to the Pacific Ocean, Morro Bay, San Luis Obispo County. Effective 1 March 2009.

Sea-Bird Electronics, Inc. (SBE) 1989. Calculation of M and B Coefficients for the Sea-Tech Transmissometer. Application Note No. 7, Revised September 1989.

Sea-Bird Electronics, Inc. (SBE) 1992. SBE 12/22/22/20 Dissolved Oxygen Sensor Calibration and Deployment. Application Note No. 12-1, rev B, Revised April 1992.

Southern California Bight Field Methods Committee (SCBFMC). 2002. Field Operation Manual for Marine Water-Column, Benthic, and Trawl monitoring in Southern California. Technical Report 259. Southern California Coastal Water Research Project. Westminster, CA. March 2002.

State Water Resources Control Board (SWRCB). 2005. Water Quality Control Plan, Ocean Waters of California, California Ocean Plan. California Environmental Protection Agency. Effective February 14, 2006.

State Water Resources Control Board (SWRCB). 2009. Water Quality Control Plan for Enclosed Bays and Estuaries – Part 1 Sediment Quality. California Environmental Protection Agency. Effective August 22, 2009. sed_qlty_part1.pdf [Accessed 02/26/10].

Suter II, Glenn, W. 2007. Ecological risk assessment, 2nd edition. U. S. Environmental Protection Agency, Cincinnati, Ohio. CRC.

Tetra Tech. 1992. Technical Review City of Morro Bay, CA Section 201(h) Application for Modification of Secondary Treatment Requirements for a Discharge into Marine Waters. Prepared for the U.S. Environmental Protection Agency, Region IX, San Francisco, CA by Tetra Tech, Inc., Lafayette, CA. February 1992.