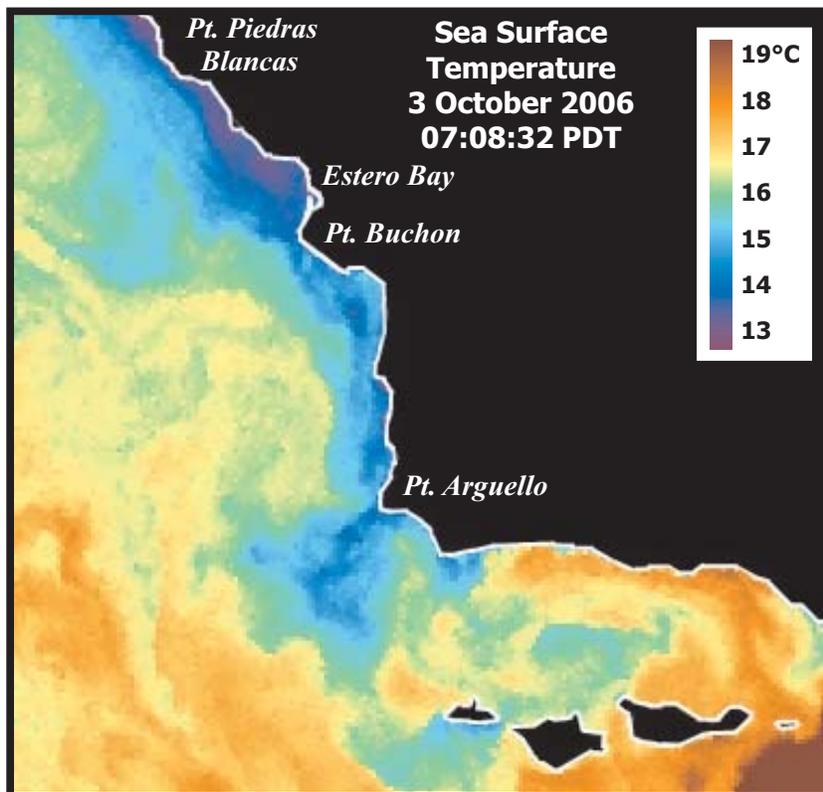


**City of Morro Bay and  
Cayucos Sanitary District**

## **OFFSHORE MONITORING AND REPORTING PROGRAM**

### **QUARTERLY REPORT**

### **WATER-COLUMN SAMPLING OCTOBER 2006 SURVEY**



**Marine Research Specialists**

3140 Telegraph Rd., Suite A  
Ventura, California 93003

**Report to**

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

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

**OFFSHORE MONITORING  
AND  
REPORTING PROGRAM**

**QUARTERLY REPORT**

**WATER-COLUMN SAMPLING  
OCTOBER 2006**

**Prepared by**

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and  
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**October 2006**

# marine research specialists

3140 Telegraph Road, Suite A · Ventura, CA 93003 · (805) 644-1180

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

30 October 2006

**Reference: Quarterly Receiving-Water Report – October 2006**

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on 3 October 2006. This fourth-quarter survey assessed the effectiveness of effluent dispersion during autumn oceanographic conditions. Based on quantitative analyses of continuous instrumental measurements and qualitative visual observations, the wastewater discharge was found to be in compliance with the receiving-water limitations specified in the NPDES discharge permit, and with the objectives of the California Ocean Plan.

High-precision measurements clearly delineated discharge-related perturbations in all six seawater properties at one of the sixteen sampling stations. The station was located near the boundary of the zone of initial dilution. The anomalies in all of the seawater properties, except salinity, were generated by the upward displacement of ambient seawater entrained within the effluent plume. However, dilution levels determined from the salinity anomalies within the discharge plume significantly exceeded those anticipated by modeling and outfall design criteria. Thus, all of the measurements were indicative of low organic loading within the discharged wastewater, and of an outfall operating as designed.

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

Sincerely,

Douglas A. Coats, Ph.D.  
Program Manager

Enclosure (Five Report Copies)

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

---

Mr. Bruce Ambo  
City of Morro Bay

Date \_\_\_\_\_

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## INTRODUCTION

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. A National Pollutant Discharge Elimination System (NPDES) permit, modifying secondary treatment requirements, was issued to the City of Morro Bay and the Cayucos Sanitary District in December 1998 (Permit No. CA0047881). This current permit was issued by Region 9 of the Environmental Protection Agency (EPA) and the Central Coast California Regional Water Quality Control Board (RWQCB-EPA 1998a). The previous permit expired in early 1998. An administrative extension was granted through 11 December 1998 to allow time for review and issuance of the current discharge permit (RWQCB 1998).

As part of the current permit provisions, the previous monitoring program was modified to better evaluate short- and long-term effects of the discharge on receiving waters, benthic sediments, and infaunal communities (RWQCB-EPA 1998b). The program continued to include a requirement for receiving-water-quality monitoring performed on a seasonal basis. Four quarterly surveys were intended to record ambient water properties that approximate winter, spring, summer, and fall conditions. In keeping with seasonal synopses, this quarterly report summarizes the results of water-quality sampling conducted on 3 October 2006. Specifically, this fourth-quarter survey was conducted to capture ambient oceanographic conditions along the central California coast during the autumn season.

The water-quality surveys also provide timely assessments of the performance of the diffuser structure in dispersing wastewater within stratified receiving waters. Any significant, recent damage to the diffuser structure would be revealed by a decline in the level of wastewater dispersion measured in this survey compared to that of prior surveys, and compared to design specifications. As described in this report, no such decline was observed in the October 2006 field survey.

Both monitoring objectives were achieved through an evaluation of the water-column profiles and vertical sections of water-property distributions that are presented in Appendix A. Appendix B tabulates instrumental measurements and standard field observations. These data were used to assess compliance with the objectives of the California Ocean Plan (COP) as specified in the NPDES discharge permit.

The October 2006 field survey was the thirty-second receiving-water survey to be conducted under the monitoring provisions of the current permit. Compared to the previous permit, the number of stations increased from 11 to 16, and the stations were relocated closer ( $\leq 100$  m) to the diffuser structure. Sampling at these more closely spaced stations could only be achieved because of the availability of increased navigational accuracy that resulted from implementation of the differential global positioning satellite (DGPS) system. This system was commissioned during the March 1998 survey (MRS 1998a) and was subsequently employed in the precise determination of the open section of the diffuser structure during a diver survey on 29 September 1998 (MRS 1998bc).

The current sampling design also allowed surveying to be conducted more rapidly than previous surveys by eliminating the requirement for collection of discrete water samples at individual stations. These samples were collected using Niskin bottles, which was time consuming and interrupted the continuity of instrumental measurements collected by the CTD<sup>1</sup> instrument package. Continuous deployment of the

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<sup>1</sup> Conductivity, Temperature, and Depth (CTD) were the original measurements recorded by this standard oceanographic instrument package, but the moniker now connotes an electronic instrument package with a broader suite of probes and sensors capable of *in situ* measurement of dissolved oxygen, transmissivity, and pH.

CTD between stations now provides a more synoptic snapshot of the water properties immediately surrounding the diffuser structure. Consequently, the extent of the effluent plume and the amplitude of its associated water-property anomalies can be more precisely determined. The sensitive sensors in the CTD instrument package are capable of detecting minute changes in water properties. These sensors are described in the Methods Section below.

Surveys conducted prior to 1999 rarely detected the effluent plume because sampling stations were too widely separated to resolve a dilute wastewater signature that is highly localized around the outfall diffuser. With the implementation of the current sampling design in 1999, the presence of well-mixed effluent near the diffuser structure was found in all 32 of the subsequent water-quality surveys (MRS 2000, 2001, 2002, 2003, 2004, 2005, 2006), including the one described in this report. Moreover, improved navigation in concert with the denser sampling pattern more precisely delineated the location of the discharge-related perturbations in seawater properties.

Precision navigation is important for assessing compliance because most receiving-water limitations apply only beyond the narrow zone of initial dilution (ZID) that surrounds the outfall. Additionally, the amplitudes of the effluent-related perturbations can be better determined by the denser sampling pattern. The amplitudes of discharge-related salinity anomalies reveal the details of dilution as the effluent plume disperses within receiving waters. Measured dilution factors lend insight into the current operational performance of the outfall and diffuser structure. As described in this report, the presence of dilute effluent undergoing turbulent mixing close to the diffuser structure was clearly delineated by the data collected during the October 2006 survey.

## STATION LOCATIONS

The water-sampling stations surround the area where effluent is discharged within Estero Bay (Figure 1). The 1,450 m long outfall pipe, which carries the effluent from the onshore treatment plant, terminates at the diffuser structure, which lies on the seafloor approximately 827 m from the shoreline<sup>2</sup>. The diffuser structure itself extends an additional 52 m toward the northwest from the outfall terminus.

Twenty-eight of the 34 available ports discharge effluent along a 42 m section of the diffuser structure. The other six diffuser ports remain closed to improve dispersion by increasing the ejection velocity from the open ports. For a given flow rate, the diffuser ports were hydraulically designed to create an turbulent ejection jet, which serves to rapidly mix effluent with receiving seawater immediately upon discharge. 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 extent in modeling studies is considered to be approximately 15 m from the centerline of the diffuser structure.

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<sup>2</sup> This distance was determined from a navigational survey conducted on 6 July 2005 to benchmark the locations of the current surfzone sampling stations along the shoreline adjacent to the diffuser structure. The beginning of the section of the diffuser structure containing open diffuser ports lies directly offshore surfzone Station C (Figure 1). This closest-approach shoreline position was determined at the water's edge when the tidal level was +2.7 ft, referenced to mean lower low water (MLLW).



**Figure 1.** Regional Setting of Receiving-Water Sampling Stations within Estero Bay

Beyond the ZID, the energetic waves, tides, and coastal currents within Estero Bay further disperse the discharge plume within the open-ocean receiving waters. Areas of special concern, such as sanctuaries and estuaries, are too distant to be affected by the effluent discharge. For example, the southern boundary of the Monterey Bay National Marine Sanctuary is located 38 km to the north, near Cambria Rock. Similarly, although the entrance to the Morro Bay National Estuary lies only 2.8 km south of the discharge, direct seawater exchange between the discharge point and the Bay is restricted by the southerly orientation of the mouth of the Bay, and by the presence of Morro Rock. Morro Rock is the largest physiographic feature of the adjacent coastline and extends into Estero Bay approximately 2 km south of

the point of discharge (Figure 1). Its presence blocks the direct incursion of unmixed wastewater into the Bay.

Near the diffuser, prevailing currents generally follow bathymetric contours, which 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, water samples are regularly collected along the shoreline at the surfzone sampling stations shown in Figure 1. These surfzone samples are analyzed for total and fecal coliform levels. Results of these analyses are reported in monthly operational summaries and in annual reports. The instances of elevated beach coliform levels that are occasionally observed have resulted from onshore non-point sources rather than the discharge of disinfected wastewater from the MBCSD outfall (MRS 2000, 2001, 2002, 2003, 2004, 2005, 2006).

As shown in Figure 2, the water-sampling design consists of 16 fixed offshore stations located within 100 m of the outfall diffuser structure. The target locations of the 16 offshore sampling stations are indicated by the red ⊙ symbols in the Figure. The stations are situated at three distances relative to the center of the diffuser structure in order to capture any discharge-related trends in water properties. Six of the stations lie along a north-south axis at the same water depth (15.2 m) as the center of the diffuser. Stations 3 and 4 are positioned at the upcoast and downcoast boundaries of the ZID, at a distance of 15 m from the closest diffuser ports (Table 1). Stations 2 and 5 are located at nearfield distances (60 m) from the diffuser centroid. Stations 1 and 6 represent midfield stations, and are situated 100 m upcoast and downcoast of the centroid. Depending on the direction of the local oceanic currents at the time of sampling, one or more of these stations could conceivably be influenced by the discharge. Under those circumstances, the midfield station on the opposite side of the diffuser can act as a reference station. Comparisons of water properties at these antipodal stations quantify departures from ambient seawater properties so that compliance with the NPDES discharge permit can be evaluated.

**Table 1.** Description of Receiving-Water Monitoring Stations

Station	Description	Latitude	Longitude	Closest Approach Distance <sup>1</sup> (m)	Center Distance <sup>2</sup> (m)
1	Upcoast Midfield	35° 23.253' N	120° 52.504' W	88.4	100
2	Upcoast Nearfield	35° 23.231' N	120° 52.504' W	49.4	60
3	Upcoast ZID	35° 23.210' N	120° 52.504' W	15.0	20
4	Downcoast ZID	35° 23.188' N	120° 52.504' W	15.0	20
5	Downcoast Nearfield	35° 23.167' N	120° 52.504' W	49.4	60
6	Downcoast Midfield	35° 23.145' N	120° 52.504' W	88.4	100
7	Offshore Midfield	35° 23.199' N	120° 52.570' W	85.8	100
8	Offshore Nearfield	35° 23.199' N	120° 52.544' W	46.7	60
9	Offshore ZID	35° 23.199' N	120° 52.519' W	15.0	23
10	Shoreward ZID	35° 23.199' N	120° 52.489' W	15.0	23
11	Shoreward Nearfield	35° 23.199' N	120° 52.464' W	46.7	60
12	Shoreward Midfield	35° 23.199' N	120° 52.438' W	85.8	100
13	Southwest Nearfield	35° 23.176' N	120° 52.532' W	59.8	60
14	Northwest Nearfield	35° 23.222' N	120° 52.532' W	40.2	60
15	Northeast Nearfield	35° 23.222' N	120° 52.476' W	59.8	60
16	Southeast Nearfield	35° 23.176' N	120° 52.476' W	40.2	60

<sup>1</sup>Distance to the closest open diffuser port.

<sup>2</sup>Distance to the center of open diffuser section.

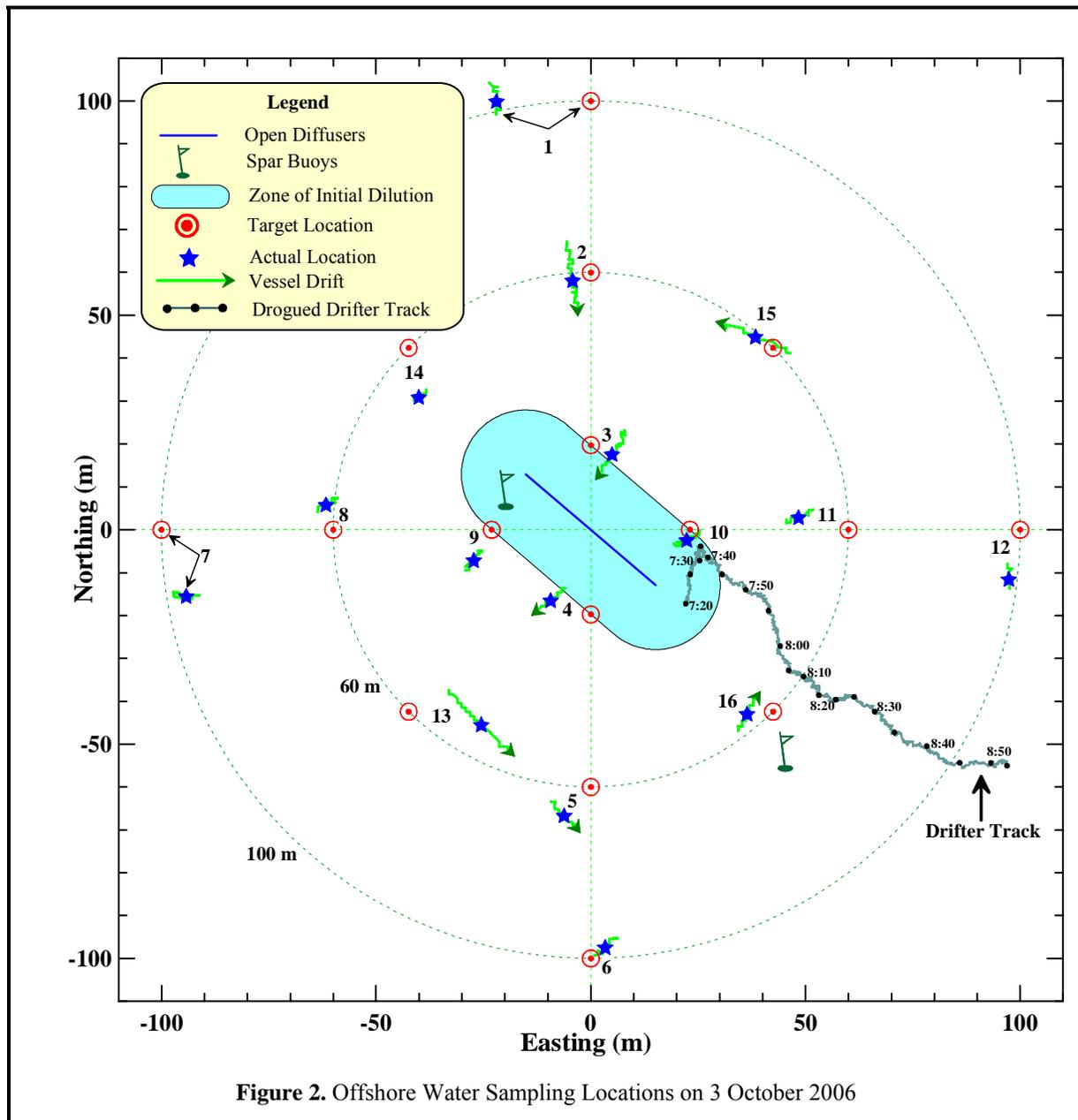


Figure 2. Offshore Water Sampling Locations on 3 October 2006

Six other stations (7 through 12) were aligned along a cross-shore transect in a pattern matching that of the along-shore transect. The remaining four stations (13 through 16) measure the nearfield influence of effluent transported by ocean currents flowing at oblique angles to the bathymetry.

An important consideration in the assessment of wastewater dispersion close to the discharge is the finite size of the diffuser. Although the discharge is considered a ‘point source,’ it does not occur at a point of infinitesimal size. Instead, the discharge is distributed along a 42 m section of the seafloor. Because of this distributed discharge, the amount of wastewater dispersion at a given point in the water column is dictated by its distance to the closest diffuser port, rather than its distance to the center of the diffuser

structure. Because of this distributed seafloor source, the ‘*closest approach*’ distance is considerably less than the centerline distance normally cited in modeling studies (Table 1).

Another important consideration for compliance evaluation is the ability to determine the actual location of the measurements. Station positioning within the compact sampling pattern specified in the current permit became feasible only after the advent of DGPS. The accuracy of traditional navigation systems such as LORAN or standard GPS is typically  $\pm 15$  m, a span equal to the total width of the ZID itself. Prior to 2 May 2000, standard commercial GPS receivers were not allowed to be perfectly accurate by law; and a built-in error system called Selective Availability (SA) was encoded into GPS transmissions. SA could introduce a misreading of up to 100 m, although it altered most measurements by less than 30 m. After May 2000, SA was turned off and the accuracy of standard GPS receivers improved substantially, with horizontal position errors that are now typically less than 10 m.

Even so, extreme atmospheric conditions and physiographic obstructions can still cause satellite signals to bounce around, leading to errors in position beyond those that were previously introduced by SA. These other errors are greatly reduced with the Differential GPS (DGPS) system that was first implemented by the U.S. Coast Guard. DGPS incorporates a second signal from a nearby, land-based beacon. Because the beacon is fixed at a known location, the position error in the reading from the GPS satellites can be precisely calculated at any given time. This correction is continuously transmitted to the DGPS receiver onboard the survey vessel and provides an extremely stable and accurate offshore navigation reading, typically with position errors of less than 2 m.

At the beginning of 1998, the survey vessel F/V *Bonnie Marietta* was fitted with a Furuno™ GPS 30 and FBX2 differential beacon receiver. This navigational system was used on 29 July 1998 to precisely locate the position of the open section of the diffuser structure (MRS 1998b) and establish the new target locations for the receiving-water monitoring stations shown in Figure 2 and listed in Table 1. The survey vessel is now fitted with two independent DGPS receivers to allow access to two separate land-based beacons for navigational intercomparison, which ensures extremely accurate and uninterrupted navigational reports.

Frequent DGPS navigational reports allow precise determination of sampling locations during the vertical CTD profiling at individual water-quality stations. Knowledge of the precise location of the actual sampling measurements relative to the diffuser position is crucial for accurate interpretation of the water-property fields. During any given survey, the actual sampling locations do not coincide with the exact target coordinates listed in Table 1. Winds, waves, and currents induce offsets during sampling. Equally important are the offsets caused by the residual momentum of the survey vessel as it approaches the target locations. Using DGPS, these offsets can be resolved and the vessel location can be precisely tracked throughout sampling at each station. This is an important consideration because vertical profiling conducted at an individual station can cover a large horizontal distance relative to the ZID.

The magnitude of the horizontal drift that occurred at each of the stations during the October 2006 survey is apparent in Figure 2 from the length of the green tracklines. These tracklines trace the horizontal location of the CTD instrument package as it was lowered to the seafloor. Their lengths reflect the relative station-keeping difficulty experienced during the October 2006 survey. The moderate drift of the CTD instrument package that occurred during the October 2006 survey was due to the limited wind and current conditions that prevailed at the time. The prevailing metocean conditions are reflected by the light winds reported in Table B-8 and the slow drifter movement shown by the drifter track in Figure 2. Nevertheless, the CTD tracklines at some of the stations (2, 3, 13 and 15) reveal perceptible lateral drift that resulted from residual vessel momentum as it approached the target location and the CTD was deployed. During

the time it took the CTD to traverse the water column to the seafloor, which averaged 1 min 30 s, the instrument package moved an average of 8.8 m laterally.

At stations close to the diffuser structure, this horizontal drift in the position of the CTD complicates the assessment of compliance with discharge limitations. Receiving-water limitations specified in the COP only apply to measurements recorded beyond the ZID boundary. Within the ZID, rapid turbulent mixing associated with the momentum of the effluent jet and the rise of the buoyant plume is expected, and the limitations apply to conditions after this initial mixing is complete. Specifically, during the October 2006 survey, the vertical profiles at Stations 3, 4, and 10 traversed the boundary of the ZID (Figure 2). Thus, strictly speaking, only a portion of the data recorded during these casts was subject to the receiving-water limitations specified in the NPDES discharge permit. Additionally, almost all of the measurements recorded at Station 10 were not subject to receiving-water limitations because the CTD was well within the ZID boundary throughout most of the vertical cast.

Compliance assessments notwithstanding, measurements recorded close to the diffuser structure within the ZID lend valuable insight into the outfall's effectiveness at dispersing wastewater during the October 2006 survey. Damaged or broken diffuser ports would be reflected by low dilution rates and measurements of concentrated effluent throughout ZID. Without measurements recorded within the ZID, the discharge plume might go undetected. This was the case in nearly every water-quality survey conducted prior to 1999, before the denser sampling pattern now in use was instituted.

Surveys prior to 1999 also predated the advent of DGPS. Consequently, the 8.8 m average drift experienced during sampling at individual stations in the October 2006 survey would not have been resolved with the navigation available prior to 1999. In fact, before 1999 sampling was presumed to occur at a single, imprecisely determined, horizontal location near each station. Federal and State reporting of monitoring data still depends on identification of a single position for all of the CTD data collected at a particular station. Thus, for regulatory and historical consistency with past surveys, a single reportable sampling location was also determined for each station during the October 2006 survey. These positions were based on the average locations shown for each station by the blue stars in Figure 2. The average positions are also listed in Table 2, along with their distance from the diffuser structure. However, based on the foregoing discussion, the distance between the average station position and the ZID does not determine whether all the measurements at that station are subject to the receiving-water objectives in the discharge permit. For example, the 16.6 m and 18.6 m closest-approach distances specified for Stations 3 and 4 would suggest that all of the data at those stations were collected outside of the ZID. In reality, as shown by the green tracklines in Figure 2, the deeper measurements at Station 3 were recorded well within the ZID, where water-quality limitations do not apply.

The vessel drift indicated by the green tracklines in Figure 2 was dictated by the complex interactions between surface currents, wind forces, and residual momentum as the vessel approached each station. As summarized in Table B-8, winds were light and variable, but were generally offshore throughout the survey. However, these winds, combined with oceanic currents oriented in the opposite direction (flow toward the east), appear to have had little influence on the overall net drift at each station. Instead, the residual momentum of the vessel as it approached each station largely dictated the drift observed during the survey. The influence of vessel momentum became apparent in an examination of the vessel tracklines recorded before each downcast was conducted. Although these portions of vessel track are not shown in Figure 2, the approach direction was consistent with that of the vessel drift recorded throughout each CTD cast.

Table 2. Average Coordinates of Vertical Profiles during the October 2006 Survey

Station	Time (PDT)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range <sup>1</sup> (m)	Bearing <sup>2</sup> (°T)
1	7:32:21	7:33:56	35° 23.253' N	120° 52.519' W	87.4	355
2	7:36:01	7:37:41	35° 23.230' N	120° 52.507' W	46.6	14
3	7:39:21	7:40:54	35° 23.209' N	120° 52.501' W	<b>16.6<sup>3</sup></b>	41
4	7:43:45	7:45:21	35° 23.190' N	120° 52.510' W	<b>18.6<sup>3</sup></b>	221
5	7:47:19	7:48:48	35° 23.163' N	120° 52.508' W	57.8	202
6	7:51:08	7:52:36	35° 23.146' N	120° 52.502' W	85.2	188
7	7:56:24	7:57:59	35° 23.191' N	120° 52.566' W	84.1	250
8	8:00:18	8:02:09	35° 23.202' N	120° 52.545' W	47.1	261
9	8:04:43	8:06:05	35° 23.195' N	120° 52.522' W	23.1	221
10	8:09:15	8:10:37	35° 23.198' N	120° 52.489' W	<b>12.8<sup>3</sup></b>	41
11	8:12:54	8:14:35	35° 23.201' N	120° 52.472' W	36.8	64
12	8:16:38	8:17:53	35° 23.193' N	120° 52.440' W	82.2	89
13	8:27:56	8:29:24	35° 23.174' N	120° 52.521' W	51.1	221
14	8:23:32	8:24:55	35° 23.216' N	120° 52.530' W	30.8	306
15	8:20:23	8:21:35	35° 23.223' N	120° 52.479' W	59.2	41
16	8:32:03	8:33:27	35° 23.176' N	120° 52.480' W	36.7	145

<sup>1</sup> Distance from the closest open diffuser port. Observations collected within the ZID shown in bold

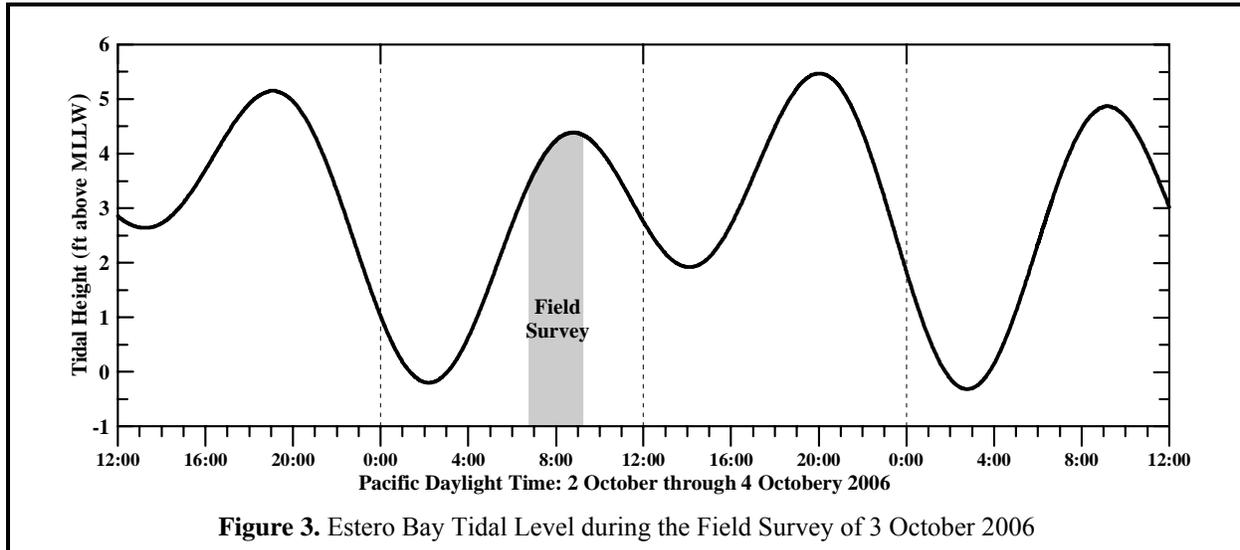
<sup>2</sup> Direction measured clockwise in degrees from true north from the closest diffuser port to the actual sampling location.

<sup>3</sup> Portions of the CTD (Conductivity-Temperature-Depth) cast were within the ZID boundary.

The moderate, eastward current flow that prevailed during the October 2006 survey was documented by a satellite-tracked drifter, whose path is shown by the grey line with black dots in Figure 2. This drifter is designed to track the subsurface current, with little influence from the wind. Each dot along the drifter trackline represents a time span of five minutes. The drogued drifter was deployed just southeast of the center of the diffuser structure at 07:20 PDT. The drifter was recovered an hour and a half later, at 08:53 PDT. Initially, for the first fifteen minutes after deployment, it traveled 14 m toward the north-northeast at a speed of 1.6 cm/s or 0.03 knots. However, at 07:35 PDT, it changed direction and traveled 88 m toward the southeast (126°T) at an average speed of 1.9 cm/s or 0.04 knots. Toward the end of its track, the drifter took a more easterly course. This slight change in direction coincided with the peak flood tide, which occurred at 08:47 PDT as documented in Table B-8 and Figure 3.

The eastward flow component measured by the drogued drifter is consistent with the flood tide that prevailed throughout the survey (Figure 3). In the absence of external influences, a flood tide normally induces a weak northeastward flow in the survey region. However, flow is also often influenced by external processes, such as wind-generated upwelling. The mild upwelling conditions that prevailed prior to, and during the survey are apparent in the satellite image on the cover of this report as areas of dark blue shading near the coast. The satellite image was recorded during the survey, indicating that skies were clear enough for sea-surface temperatures to be measured by infrared sensors on NOAA's polar orbiting satellite, despite the presence of a diffuse cloud cover that was noted aboard the survey vessel (Table B-8).

The mild upwelling event that occurred around the time of the October 2006 survey was largely responsible for the moderate water-column stratification, evident around in the vertical profiles collected with the CTD (Figures A-1 through A-3 in Appendix A). Upwelling season normally begins sometime during late March and or early April when there is a "spring transition" to more persistent southward-



directed winds along the Central California Coast. This transition is marked by the stabilization of a high atmospheric pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive the prevailing northwesterly winds along the Central Coast. These prevailing winds move surface waters southward and offshore. To replace these coastal surface waters, deep, cool, nutrient-rich waters upwell near the coast as delineated on the cover of this report. At the time of the survey, the satellite image shows cool ( $14^{\circ}\text{C}$ ) sea-surface temperatures were present within Estero Bay, while temperatures farther offshore exceeded  $17^{\circ}\text{C}$  (yellow and orange) over much of the south-central coast. The lower Estero Bay temperatures represented in the satellite image were consistent with the near-surface temperatures measured by the CTD during the survey, which averaged  $13.97^{\circ}\text{C}$  (Table B-1 in Appendix B). The image also exhibits another upwelling characteristic, namely, a jet of cold coastal water (blue) extending offshore at Point Arguello. This jet reflects the offshore transport of upwelled water that occurs mostly at major promontories along the coast.

The nutrient-rich seawater that is brought to the sea surface near the coast by upwelling enables phytoplanktonic blooms that are the foundation of the productive marine fishery found along the central California coast. The cross-shore flow associated with persistent upwelling conditions also enhances vertical stratification of the water column. The presence of denser water at depth produces a shallow (<10 m) thermocline that is commonly maintained throughout summer and into the fall. In contrast, winter oceanographic conditions are generally characterized by vertically uniform conditions. Not only is there little cross-shore transport during winter, but intense winds generated by passing local storm fronts, and large waves produced by distant Pacific storms, generally result in a vertically well mixed water column.

## METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 3 October 2006. Dr. Douglas Coats and Ms. Bonnie Luke of Marine Research Specialists (MRS) provided scientific support. Captain Mark Tognazzini supervised vessel operations, while Mr. Bob Silva acted as marine technician. Secchi depth measurements and standard observations for weather, seas, water clarity/coloration, and the presence of any odors, floating debris, and oil and grease were recorded during the survey (Table B-8). Wind speeds and air temperatures were measured

with a Kestrel<sup>®</sup> 2000 Thermo-Anemometer. These ancillary observations were collected during the rapid water-column profiling that was conducted at each station using a CTD instrument package.

### *Ancillary Measurements*

At all stations, a Secchi disk was lowered through the water column to determine its depth of disappearance (Table B-8). Secchi depths provide a visual measure of near-surface turbidity or water clarity. The depth of disappearance is inversely proportional to the average amount of organic and inorganic suspended material along a line of sight in the upper water column. As such, the Secchi depth measures natural light penetration, which can be limited by increased suspended particulate loads from plankton blooms, onshore runoff, seafloor resuspension, and wastewater discharge. It is also of biological significance because the depth of the euphotic zone, where most oceanic photosynthesis occurs, extends to approximately twice the Secchi depth. With the exception of Station 4, the average Secchi depth of 7.5 m, measured during the October 2006 survey reflects the presence of a comparatively deep euphotic zone, extending nearly to the seafloor. The presence of such a deep euphotic zone is fairly typical of mild upwelling conditions, but does not occur under stronger upwelling conditions. When strong upwelling conditions prevail, increased primary production, namely, increased plankton density, markedly decreases light transmissivity within the upper water column. However, during the October 2006 survey, only a slight (<10%) reduction in light transmissivity in the upper water column (above 5 m) was observed (light blue lines in Figures A-1 through A-3).

Secchi depths are less precise than measurements recorded by the transmissometer mounted on the CTD instrument package. For example, the visibility of the disk, and hence its depth of disappearance, depends on the amount of natural light available at the time of the measurement. Thus, the Secchi depth reading can artificially change by as much as 0.5 m depending on whether the sample is taken on the sunny or shady side of the boat. Moreover, a temporal drift in the measurements can be introduced as the sun rises in the sky while the survey progresses. Nevertheless, Secchi depth measurements reflect general turbidity levels within the upper portion of the water column, including waters within a meter of the sea surface where, because of the physical size of the CTD package, the transmissometer cannot record turbidity.

During the October 2006 survey, a satellite-tracked drifter was deployed near the open section of the diffuser structure. The drifter was drogued at mid-depth (7 m) using the curtain-shade design of Davis et al (1982). In this configuration, the drifter's trajectory was largely dictated by the oceanic flow field rather than by surface winds. The times and precise positions of the drifter deployment and recovery were recorded to determine the overall strength and direction of plume transport during the October 2006 sampling effort. In addition, the October 2006 survey was the eighth MBCSD survey to record the drifter position throughout its deployment. In the past, the average ambient flow velocity during each survey was estimated solely from the deployment and recovery positions. However, during the October 2006 survey, the added satellite-tracking capability revealed a significant change in the flow direction, as documented by the path of the drifter shown in Figure 2. Drifter data collected in most prior surveys lacked information on this and other short-term flow fluctuations that can occur during the course of a survey.

### *Instrumental Measurements*

Vertical water-column profiling was conducted using an electronic instrument package equipped with a number of probes and sensors. A Sea Bird Electronics SBE-19 Seacat CTD package was used to collect profiles of conductivity, salinity, temperature, light transmittance, dissolved oxygen (DO), pH, density, and pressure at each station. A submersible pump on the CTD continuously flushed water through the conductivity cell and oxygen plenum at a constant rate, independent of the CTD's motion through the

water column. After the October 2001 survey, the CTD was returned to the factory for full testing, repair, and calibration. Temporal drifts in the oxygen and alkalinity readings during the October 2001 survey indicated that the sensitivity of these probes had degraded because of an accumulation of marine growth. During the factory repair, the pH probe was replaced and the electrolyte in the oxygen sensor was refurbished. The entire CTD system was then recalibrated at the factory. Upon return of the instrument, the transmissivity, dissolved oxygen, and pH sensors were recalibrated at the MRS laboratory. Calibration coefficients determined at the factory and by MRS were nearly identical, and confirmed the accuracy and stability of the refurbished sensors.

The DO and pH sensors were again returned to the factory in May 2003 and in June 2006 for testing and recalibration. Because of increasing temporal drift associated with the aging DO probe, it was replaced on both occasions with a new DO probe. As is the case before all surveys, the CTD system was recalibrated at the MRS laboratory prior to the October 2006 survey. Calibration at upper-bound DO concentrations was established by immersing the CTD in an aerated, temperature-controlled calibration tank. In addition to oxygen readings at full saturation, a zero-oxygen calibration point was determined by filling the oxygen-sensor plenum with an 8% solution of sodium sulfite ( $\text{Na}_2\text{SO}_3$ ). Oxygen calibration coefficients were determined by regression analysis of sensor-membrane current and temperature, as recommended by the manufacturer (SBE 1993). As with prior factory calibrations, pre-cruise calibration coefficients determined by MRS closely corresponded to those determined by the factory.

Prolonged equilibration times of the pH sensor have been an ongoing challenge, requiring removal of temporal trends in the pH data collected in most surveys, even those following the 2001 pH-sensor replacement. Laboratory tests conducted in conjunction with pre-cruise calibrations have demonstrated that the equilibration time is reduced if the sensor is immersed in water prior to deployment. This was accomplished during the October 2006 survey by attaching a water-filled hose to the sensor during transit to the survey area. Immediately prior to deployment, the hose was removed. Although this procedure did not entirely eliminate the temporal offsets, it markedly reduced their amplitude. The required pH adjustments were small, and did not exceed 0.23 pH units.

During the pre-cruise calibration, coefficients for the pH (alkalinity) sensor were determined from a linear regression of output voltage after immersion in three separate buffered solutions of known pH. Buffering solutions with a pH of  $4 \pm 0.01$ ,  $7 \pm 0.01$ , and  $10 \pm 0.02$  were used to bracket the range of in situ measurements. The SeaTech transmissometer was air calibrated by fitting the voltages recorded with and without blocking of the light transmission path in air, as recommended by the manufacturer (SBE 1989). Revised calibration coefficients determined prior to the survey were used in the algorithms that converted sensor voltage to engineering units when the field data were processed. Comparison with the factory calibration of the entire CTD package that was conducted in December 2001, and the more recent June 2006 replacement and calibration of the DO probe, confirmed the continued accuracy and stability of the temperature, pressure, and conductivity sensors, as well as the operational integrity of the oxygen and pH probes.

Six seawater properties were used to assess receiving-water quality in this report. They were derived from the continuously recorded output from the probes and sensors on the CTD. Pressure housing limitations on the combination oxygen/pH sensor confine the CTD to depths less than 200 m (Table 3), which is well beyond the maximum depth of the deepest station in the outfall survey. 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 (Siemens/m) measurements. Density was derived from contemporaneous temperature ( $^{\circ}\text{C}$ ) and salinity data. It was expressed as 1000 times the specific gravity minus one, which is a unit of sigma-T ( $\sigma_t$ ).

**Table 3. Instrumental Specifications for CTD Profiler**

<b>Component</b>	<b>Depth<sup>1</sup></b>	<b>Units</b>	<b>Range</b>	<b>Accuracy</b>	<b>Resolution</b>
Housing	600	—	—	—	—
Pump	3400	—	—	—	—
Pressure	680	Psia	0 to 1000	± 5.0	± 0.5
Depth	—	Meters	0 to 690	± 3.0	± 0.3
Conductivity	600	Siemens/m	0 to 6.5	± 0.001	± 0.0001
Salinity	600	‰	0 to 38	± 0.006	± 0.0006
Temperature	600	°C	-5 to 35	± 0.01	± 0.001
Transmissivity	2000	%	0 to 100	± 0.1	± 0.025
Dissolved Oxygen	200	mg/L	0 to 21.5	± 0.14	± 0.014
Acidity/Alkalinity	200	pH	0 to 14	± 0.1	± 0.006

<sup>1</sup> Maximum depth limit in meters

All three of these physical parameters (salinity, temperature, and density) were used to determine the lateral extent of the effluent plume. Additionally, they define the layering (vertical stratification – stability) of the receiving waters, which determines the behavior and dynamics of the wastewater as it mixes with seawater within the ZID. Data on three remaining seawater properties, consisting of light transmittance (water clarity), hydrogen-ion concentration (acidity/alkalinity – pH), and dissolved oxygen (DO), further characterize receiving waters, and were used to assess compliance with water-quality criteria. Light transmittance was measured as a percentage of the initial intensity of a transmitted beam of light detected at the opposite end of a 0.25 m path. Increased transmittance indicates increased water clarity and decreased turbidity.

Before deployment at the initial station, the CTD was held below the sea surface for a six-minute equilibration period. Subsequently, the CTD was raised to within 1.0 m of the sea surface and profiling commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at multiple stations were collected during a single successful deployment of the CTD package by towing it below the water surface while transiting between adjacent stations. The October 2006 survey was the first survey in which all of the data was collected during a single deployment of the CTD. As a result, a more contemporaneous dataset was collected at the sixteen stations. Two CTD deployments were used in prior surveys because of uncertainties about exceeding data recording capacity and battery life. Upon retrieval of the CTD, the profile data were downloaded to a portable computer and examined for completeness and range acceptability.

### *Temporal Trends in the pH Sensor*

The pH sensor exhibited a temporal drift during the October 2006 survey. Perceptible drift in pH measurements has been consistently observed in prior water-quality surveys as the result of ongoing sensor equilibration during profiling. Prolonged exposure to the atmosphere between surveys results in the largest offsets and can also affect the dynamic range of the measurements. During past surveys, smaller equilibration offsets have been observed when the CTD was redeployed after being brought onboard to download data during the middle of the survey. Use of a single deployment during the October 2006 survey obviated the need for mid-survey adjustments for pH drift. Previous attempts to further mitigate sensor drift have included prolonging the soak time of the CTD after deployment below the sea surface prior to profiling. Soak times in excess of six minutes at the beginning of a survey were found to reduce but not entirely eliminate sensor drift. During the October 2006 survey, a tube filled with seawater

was placed around the pH sensor while in transit to the survey site to limit atmospheric exposure of the probe prior to deployment. This technique was successful at further ameliorating sensor drift.

Temporal drift in the pH sensor was responsible for perceptibly lower pH measurements at stations occupied during the initial stages of the CTD deployment. Beginning with Station 1, where the offset was -0.225 pH units, equilibration-related reductions in pH became steadily smaller as the survey progressed sequentially from Station 2 (-0.178 pH) through Station 12 (-0.002 pH). The pH measurements collected at the last four stations did not exhibit a perceptible offset. The magnitude of the pH offset at the twelve previous stations was determined by comparing pH values recorded at the sea surface with the surface pH measured at the last four stations, after the sensor had fully equilibrated.

Removal of the artificial pH trend was important because it was large compared to reported accuracy and precision of the probe, and because the offsets masked a very slight discharge-related anomaly that only became apparent when corrected pH values at the same depth were compared at adjacent stations. The artificial pH reduction (-0.225 pH) at the beginning of the deployment was more than double the instrumental accuracy ( $\pm 0.1$  pH) reported by the probe manufacturer (Table 3). Equilibration-related offsets only became smaller than the instrumental resolution ( $\pm 0.006$  pH) after Station 10 (-0.004 at Station 11). Before correction, equilibration-related offsets created marked artificial differences between the pH measured at adjacent stations. These appear as strong lateral gradients at the first few stations in Table B-7. The artificial spatial gradient was large enough at Stations 1 and 2 to be statistically significant, as reflected in Table B-7 by the values listed in bold typeface and enclosed in a box. Table B-6 lists the pH data after removal of the temporal trend. As a result of trend removal, a slight discharge-related pH anomaly (-0.044 pH) became apparent at Station 4, as shown in the bottom frame of Figure A-5. It also revealed a larger pH anomaly near the seafloor at Station 2 that was unrelated to the discharge. However, only the Station-2 anomaly was found statistically significant after trend removal, as indicated by the bolded and boxed entries in Table B-6.

## RESULTS

The fourth-quarter water-quality survey began on Tuesday, 3 October 2006, at 07:20 PDT with the deployment of the drogued drifter. Subsequently, all water-column measurements were collected as required by the NPDES monitoring program (Table 2 and B-8). Sunrise was at 06:59 PDT and skies were partly cloudy throughout the survey, which ended at 09:00 PDT when infaunal sampling was initiated as part of the benthic monitoring program. Winds were light and variable throughout the survey. Average wind speeds, calculated over one-minute intervals, ranged from approximately 0.2 kt to 1.5 kt, with peak speeds ranging from 0.5 kt to 2.4 kt. Additionally, a 1-2 ft swell moved through the survey area from the west. Atmospheric visibility was greater than 2 nM along the ocean surface owing to the absence of low-lying fog. As a result, Morro Rock and the shoreline remained visible throughout the survey. Air temperatures increased from 11.5°C to 13.3°C as the survey progressed. The surface seawater temperature (13.9°C) in the survey area was slightly higher than the average air temperature, but was consistent with coastal sea-surface temperatures within Estero Bay recorded by the satellite image shown on the cover of this report.

The discharge plume was not readily visible near the sea surface at any time during the survey. Throughout the survey, there was also no visual evidence of floating particulates, oil and grease, or seawater discoloration associated with the discharge.

### *Beneficial Use*

During the October 2006 survey, observations of beneficial use demonstrated that the coastal waters in the outfall vicinity continued to be utilized by wildlife and for recreation. Large numbers of California brown pelicans (*Pelecanus occidentalis californicus*), western gulls (*Larus occidentalis*), Heermann's gulls (*Larus heermanni*), Pelagic cormorants (*Phalacrocorax pelagicus*), and Brandt's cormorants (*Phalacrocorax penicillatus*) were observed transiting through the survey area. Additionally, six California Least terns (*Sterna Antillarum Browni*) were observed foraging near the ZID, while several sooty shearwater (*Puffinus griseus*) and a lone Common murre (*Uria aalge*) were observed in transit closer to Morro Rock.

In addition to bird life, a single southern sea otter (*Enhydra lutris*) was observed swimming approximately 100 m north of the area throughout the survey. The sea otter was not seen to dive. Four other otters were seen within Morro Bay harbor, and one otter was observed near Morro Rock during transit to the survey site. Sea otters are a federally and state-protected species. Since the arrival of a raft of 30 to 40 sea otters just north of Port San Luis was observed in 1974 (Gotshall et al., 1984), they have become increasingly prevalent in the vicinity of Estero Bay (Gotshall et al., 1986). Sea otters feed almost entirely on macroinvertebrates (Ebert, 1968; Estes et al., 1981; Riedman and Estes, 1990) and the southward expansion of the sea otter is firmly correlated, chronologically and geographically, with the demise of the abalone fishery in the region (Morro Group, Inc. 1999). Additionally, a total of five California sea lions (*Zalophus californianus*) were observed in the area during the survey. The sea lions were seen transiting through the area, with two of them making repeated dives. One sea lion's efforts were accompanied by those of several pelicans and a persistent gull.

Several vessels were observed during the course of the survey, including three small recreational fishing boats, which followed the survey vessel out of the bay before transiting to locations further offshore. Additionally, the bait vessel F/V Billy Boy, which is based in Morro Bay, was observed during the first portion of the survey transiting approximately 100 m inshore of the survey area. A few pedestrians were seen utilizing Atascadero Beach during the survey. No other evidence of beneficial use of the receiving waters was noted during the survey.

### *Ambient Seawater Properties*

Data collected during the October-2006 survey reflect the classical, stratified conditions that are indicative of upwelling. Upwelling results in an influx of dense, cold, saline water at depth and often leads to a sharp thermocline, halocline, and pycnocline where temperature, salinity, and density change rapidly over short vertical distances. Under stratified conditions, isotherms crowd together to form a thermocline that restricts the vertical transport of the effluent plume and reduces its dispersion.

Weak, but perceptible, upwelling-induced vertical gradients are plainly evident throughout the water column in the vertical profiles of Figures A-1 through A-3. A thermocline, where temperature steadily decreases with increasing depth, is evident in all but one of the vertical profiles shown in Figures A-1 through A-3 (red lines). The thermocline at Station 4 was much stronger and was limited to a narrow depth region between 1 m and 2.5 m (middle right frame of Figure A-1). As described in the following sections, the presence of the effluent discharge plume altered the vertical structure of the water column at that station. However, at the other stations, most ambient seawater properties exhibited vertical stratification nearly identical to that of the thermal structure. For example, the shape of the temperature profile at any given station is closely reflected in the profiles of dissolved oxygen (dark blue lines), and to a lesser extent, in the profiles of pH (olive-colored lines). Similarly, the steady decreases in temperature,

DO, and pH with depth are mirrored by a pycnocline where density (black lines) steadily increases with depth. Thus, upwelling-induced stratification dictated the vertical structure of all ambient seawater properties except salinity (green lines) and transmissivity (light-blue lines).

DO concentrations were highest near the sea surface where atmospheric equilibration and upwelling-induced photosynthesis saturated the seawater with oxygen. Near the sea surface, direct, gaseous exchange with the overlying atmosphere combined with increased primary productivity to produce high DO concentrations. Nutrient-rich seawater brought to the sea surface by upwelling enabled phytoplanktonic blooms that produced oxygen and consumed carbon dioxide (CO<sub>2</sub>). The associated increase in planktonic biomass near the sea surface resulted in the slightly reduced water clarity that is evident in the vertical profiles of light transmittance (light-blue lines in Figures A-1 through A-3). As the ratio of respiration to photosynthesis increased with depth, there was an increase in dissolved CO<sub>2</sub> (carbonic acid) and a concomitant decline in pH, reflecting the slightly more acidic nature of the seawater. These processes account for the decline in pH (olive-colored lines) with increasing depth that is apparent in all but one of the vertical profiles shown in Figures A-1 through A-3. The pH profile at Station 2 (upper right frame of Figure A-1) exhibited an unusual localized maximum above the seafloor near 14 m. It is also apparent in the vertical section shown in the bottom frame of Figure A-5. As described in the following sections, this localized increase in pH at depth was unrelated to the discharge, but its origin remains unclear.

Upwelling-induced cross-shore transport also influenced the vertical distribution of seawater properties. Near the seafloor, upwelling transported cold, dense seawater onshore to replace nearshore surface waters that were driven offshore by prevailing winds. The undersaturated DO found at depth was a clear indicator of the deep offshore origin of this watermass. Deep offshore waters are undersaturated in oxygen because they have not had direct contact with the atmosphere for long periods of time, and biotic respiration and decomposition have slowly depleted the dissolved-oxygen levels. Similarly, slightly elevated salinity immediately above the seafloor is indicative of waters that originate in the Southern California Bight and are carried northward by the Davidson undercurrent. These waters differ from the relatively fresh surface water associated with the southward-flowing California Current. Accordingly, the vertical salinity profiles measured during the October 2006 survey consistently exhibited slightly higher salinities at depth (green lines in Figures A-1 through A-3).

In contrast to the other water properties, transmissivity also exhibited a marked reduction immediately above the seafloor at all stations except Station 4 (light blue lines in Figure A-1 through A-3). The distinctive decrease in transmissivity within a thin layer immediately above the seafloor indicates the presence of a bottom nepheloid layer (BNL), which is a widespread phenomenon on continental shelves (Kuehl et al. 1996). Thus, the increased turbidity observed within the BNL during the October 2006 survey was caused by the presence of naturally occurring particulates formed from light-weight flocs of detritus. This detritus is easily suspended by oscillatory bottom currents generated by passing surface gravity waves.

### *Lateral Variability*

The influence of the effluent discharge can be best identified from localized anomalies in seawater properties, particularly salinity. In contrast to the vertical profiles, discharge-related anomalies become especially apparent in the vertical sections when seawater properties from the same depth level are compared at adjacent stations. Accordingly, the vertical salinity section in the top frame of Figure A-4 shows the influence of the discharge at Stations 4, 5, and 6. Discharge-related anomalies in other seawater properties are only apparent at Station 4 in Figures A-4 and A-5. Note that for these other water

properties, the shallow discharge-related anomalies at Station 4 had the same characteristics as ambient seawater at depth. This contrasts with the isolated salinity anomalies in the top frame of Figure A-4, which do not exhibit a clear connection to the ambient seafloor properties.

Different processes generated these two sets of discharge-related anomalies. The shallow, non-salinity anomalies at Station 4 became apparent because deep, naturally-occurring water properties had been entrained in the discharge plume and displaced upward into the water column where the surrounding seawater characteristics differed. In contrast, the salinity anomalies at Stations 4, 5, and 6 could only have been caused by the characteristics of the effluent itself. Both of these types of anomalies became apparent only through a comparison of seawater properties measured at the same depth level at adjacent stations. Because of this, the analysis of lateral variability in seawater properties forms the basis for assessments of water-quality impacts.

In particular, the significance of each potential discharge-related anomaly was statistically evaluated by comparing its amplitude to the natural background variability. Each observation at a particular station was compared with the observations from other stations at the same depth level. Measurements recorded within 10 m of the sea surface were compared with other measurements at the same depth level below the sea surface. However, deeper measurements were compared with other measurements recorded at the same height above the sloping seafloor. This is done because deep seawater properties tend to parallel the sloping seafloor rather than the horizontal sea surface.

The statistical significance of departures from ambient seawater properties was computed from the raw CTD data listed in Tables B-1 through B-7. First, anomalies from mean conditions were computed by subtracting a particular measurement from the average of all other measurements at the same depth level, whether measured relative to the sea surface or the seafloor. Natural variability was then estimated from the standard deviation of all measurements (excluding the one in question) for a given seawater parameter (e.g., salinity). Statistically significant anomalies were those that departed from mean conditions by more than the 95% confidence interval determined from the standard deviation and number of observations used to compute the average. Statistically significant departures from ambient conditions are highlighted in Tables B-1 through B-7 by bolded values enclosed in boxes.

Temperature (Table B-1), salinity (Table B-2), and pH (Table B-5) were the only seawater properties that exhibited statistically significant anomalies in the October 2006 data. This contrasts with other surveys where significant anomalies in other water properties are occasionally found (MRS, 2006). However, the lack of statistical significance in other seawater anomalies during the October 2006 survey was not necessarily because the amplitudes of the anomalies were smaller than in other seasons. In fact, discharge-related density, DO, and transmissivity anomalies are visually apparent at Station 4 in the vertical sections of Figures A-4 and A-5. However, the amplitudes of these anomalies were not large relative to the variability in ambient water properties and consequently, they were not found to be statistically significant. Because the natural spatial variability in most seawater properties was large during the October-2006 survey, particularly in the vertical direction, the amplitude of the anomalies would need to be proportionally larger in order to be reliably resolved on a statistical basis. Thus, statistical significance is a function of the overall variability during a given survey because it is more difficult to reliably discern small differences in a noisy field of measurements than in a more uniform field.

The origin of the statistically significant pH anomaly that extends 3.5 m above the seafloor at Station 2 remains unclear, but it was probably unrelated to the discharge for two fundamental reasons: isolation and location. First, the pH anomaly was isolated and did not coincide spatially with an anomaly in any other seawater property, particularly a salinity anomaly. Because salinity provides the greatest contrast between

the salty receiving water and the relatively fresh wastewater, salinity anomalies have always been associated with discharge-related perturbations. In contrast, the pH of wastewater is close to that of seawater. After dilution, one would not expect to see discharge-induced differences in pH without a much larger concomitant difference in salinity. Second, the pH anomaly was located upstream of the diffuser structure and the intervening Station 3, which lies between the anomaly and the discharge, did not exhibit a pH anomaly (bottom frame of Figure A-5). Also, at 07:37 PDT, when the anomalous pH measurements were recorded near the seafloor at Station 2 (Table 2), flow was toward the southeast (Figure 2), in a direction nearly opposite of the northerly location of Station 2 relative to the diffuser. Although earlier transport was toward the north, Stations 4, 5, 6, and 16 all revealed the presence of the discharge plume (Table 4). These stations were located on the opposite side of the diffuser structure, and were aligned in a downstream direction that was consistent with the southeastward flow conditions that prevailed at that time. Data at Station 4 was collected only six minutes after the downcast was completed at Station 2.

Furthermore, the statistical significance of the deep pH anomaly at Station 2 may have been an artifact of the correction that was applied to account for sensor equilibration. Namely, rapid ongoing sensor equilibration during the CTD cast at Station 2 was probably incompletely accommodated by the single correction factor (0.178 pH) that was applied to the entire pH profile at Station 2. The Station-2 correction factor was based on temporal trends in surface pH, and may have been too large for the actual offset at depth after the sensor had a chance to further equilibrate during its one-minute 40-second descent to the seafloor. Statistical significance notwithstanding, the shape of the pH profile at Station 2, particularly with regard to the localized pH increase above seafloor, departed from that of all the other stations.

This suggests the possibility that the increased pH near the seafloor at Station 2 was also an artifact of the natural variability in ambient seawater. The presence of statistically significant anomalies that are unrelated to the discharge is expected. From the definition of a 95% confidence level, one ‘*significant*’ departure out of every 20 measurements should occur by chance alone. With 517 measurements examined for each of the six parameters, it would not be surprising if a few departed from the mean by an amount more than the 95% confidence interval. Moreover, when multiple hypotheses are being tested (*i.e.*, one for each observation), the error rate for each individual test should be adjusted to achieve the overall experimentwise error rate of 5% (95% confidence). By definition, this error rate is the probability that one or more of the hypothesis tests would incorrectly find a significant difference when none exists. Thus, without correcting for repeated hypothesis testing, the individual tests are conservative and “*significant*” departures will be found more often than if a single test were being performed at the 95% confidence level.

### *Discharge-Related Perturbations*

During the October 2006 survey, five distinct perturbations in seawater properties were unequivocally related to the discharge (Perturbations P1 through P5 in Table 4). A discharge-related perturbation is a group of anomalies in one or more seawater properties that are spatially contiguous at a particular station. The vertical distribution of seawater properties within and below the perturbations lends insight into which of the two discharge processes were responsible for generating a particular anomaly. As indicated in Table 4, only the salinity anomalies reflected the presence of dilute wastewater, while the anomalies in other water properties were generated by entrainment of ambient seawater within the rising effluent plume. The mechanism that produces discharge-related anomalies is an important consideration when assessing the discharge’s compliance with the receiving-water objectives of the COP, and the requirements of the NPDES permit.

**Table 4. Discharge-Related Water-Property Anomalies<sup>a</sup>**

<b>Perturbation<sup>b</sup></b>	<b>Station</b>	<b>Depth Range</b>	<b>Depth of Extremum</b>	<b>Property</b>	<b>Magnitude</b>	<b>Process</b>
P1 Dilution $\geq$ 375:1	4	1.5 to 10.0 m	<b>8.0 m</b>	<b>Salinity</b>	<b>-0.089 ‰</b>	Effluent
		1.5 to 12.0 m	<b>2.5 m</b>	<b>Temperature</b>	<b>-0.55 °C</b>	Entrainment
		2.0 to 5.0 m	3.0 m	Density	+0.059 $\sigma_t$	Entrainment
		1.0 to 6.5 m	3.0 m	Transmissivity	+5.4 %	Entrainment
		1.5 to 14.0 m	2.5 m	Dissolved Oxygen	-0.7 mg/L	Entrainment
		3.0 to 12.5 m	4.0 m	pH	-0.044	Entrainment
P2 Dilution $\geq$ 412:1	5	4.5 to 6.0 m	<b>5.0 m</b>	<b>Salinity</b>	<b>-0.081 ‰</b>	Effluent
P3 Dilution $\geq$ 668:1	5	10.0 to 11.5 m	<b>11.0 m</b>	<b>Salinity</b>	<b>-0.050 ‰</b>	Effluent
P4 Dilution $\geq$ 498:1	6	8.0 to 10.0 m	<b>9.0 m</b>	<b>Salinity</b>	<b>-0.067 ‰</b>	Effluent
P5 Dilution $\geq$ 668:1	16	2.0 to 6.0 m	<b>3.0 m</b>	<b>Salinity</b>	<b>-0.050 ‰</b>	Effluent

<sup>a</sup> Anomalies shown in bold type were statistically significant

<sup>b</sup> Perturbations are composed of a group of spatially consistent anomalies in several different seawater properties (P1) or were laterally adjacent to other perturbations and located along the path of plume transport (P2, P3, P4, and P5)

The anomalies in salinity could not have been generated by the movement of ambient seawater alone. The top frame of Figure A-4 shows that the anomalously low salinity observed in the upper water column at Stations 4, 5, and 6 was vertically isolated, and far lower than the salinity of the ambient seawater at depth. In contrast, the corresponding temperature, density, transmissivity, DO and pH anomalies at Station 4 were not vertically isolated, and supported concentrations that were comparable to the range of properties within ambient seawater at depth.

Furthermore, the character of the non-salinity anomalies in Perturbation P1 was not consistent with the properties of effluent constituents. For example, the temperature within the anomaly was 0.55°C lower than surrounding seawater, the direction opposite of what would be expected from the presence of warmer, wastewater constituents. Similarly, turbidity associated with effluent particulates would be expected to induce a localized reduction in transmissivity, yet the transmissivity within the anomaly was actually 5.4% higher than the surrounding seawater. Increased transmissivity could only have been generated by the upward displacement of deep, ambient seawater that was naturally low in turbidity. Movement of low turbidity water into the upper water column at Station 4 was independently corroborated by the 2 m increase in Secchi depth that was observed there (Table B-8). When the 9.5-m Secchi depth was first recorded at Station 4, a second confirmatory Secchi cast was performed because the initial measurement was so unusual compared to that of other stations. It was only after the transmissivity data from the CTD was analyzed, that the reason for the increase in light penetration at Station 4 became apparent. Namely, naturally low turbidity seawater at depth had been entrained in the rising effluent plume and was located close to the sea surface (top frame of Figure A-5).

### *Initial Dilution Computations*

The amplitude of negative salinity anomalies at Stations 4, 5, 6, and 16 lends insight into effectiveness of the outfall at dispersing effluent and, ultimately, compliance with the receiving-water objectives of the COP and NPDES discharge permit. The critical initial dilution applicable to the MBCSD outfall was

conservatively estimated to be 133:1 (Tetra Tech 1992). This estimate was based on worst-case modeling using highly stratified conditions where the trapping of the plume below the thermocline limited the mixing achieved during the plume's buoyant rise through the water column. The dispersion modeling determined that, after initial mixing was complete, 133 parts of ambient water would have mixed with each part of wastewater. The modeling predicted that this dilution would be achieved after the plume rose only 9 m from the seafloor, whereupon it would become trapped below a thermocline and spread laterally with no further substantive dilution. A 9-m rise translates into a trapping depth 6.4 m below the sea surface.

However, as described below, dilutions computed from salinity anomalies observed during the October 2006 survey demonstrated that the effluent plume actually achieved a far higher dilution (>375:1) at depths (8 m) well below the predicted trapping depth (6.4 m). The conservative nature of the dilution ratio determined from 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 listed in the COP (SWRCB 1997) using the 133:1 dilution ratio determined from the modeling. Use of a higher critical dilution ratio would relax the stringent end-of-pipe effluent limitations that were thought to be necessary in order to meet Ocean-Plan standards.

End-of-pipe limitations on contaminant concentrations within effluent were based on the definition of dilution (Fischer et al. 1979), where the concentration of a particular contaminant in effluent is given by:

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

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

The actual dilution achieved by the outfall can also be computed from Equation 1 using 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. Specifically, the salinity concentration in effluent is negligible so  $C_e$  is eliminated in Equation 1 and the dilution ratio ( $D$ ) can be computed from the salinity anomaly ( $A = C_o - C_s$ ) as:

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

where:  $D$  = the dilution ratio of the volume of seawater mixed with effluent,  
 $C_o$  = the salinity of the effluent-seawater mixture after dilution by  $D$ ,  
 $C_s$  = the background seawater salinity (approximately 32.9‰), and  
 $A = C_o - C_s$  = the salinity anomaly.

The resulting computed dilutions during the moderately stratified conditions of the October 2006 survey demonstrate that the modeled dilution factors were significantly more conservative than those actually achieved by the discharge. Specifically, minimum dilutions computed from the largest salinity anomalies observed at Stations 4, 5, 6, and 16 all exceeded 375:1 at depths well below the sea surface (Table 4). The largest discharge-induced salinity anomaly (-0.089‰) was recorded 8 m below the sea surface at Station

4 (Perturbation P1). Based on Equation 2, this translates to a dilution that was nearly three times higher than the dilution predicted by modeling at a trapping depth that was 1.6 m shallower than the observed anomaly. Moreover, this discharge-related salinity anomaly, as well as anomalies in other seawater properties at this station, extended to within 1 m of the sea surface. This indicates that during the moderately stratified conditions of the October 2006 survey, the plume did not fully reach buoyant equilibrium within the water column, but probably extended to the sea surface without trapping. Both the high dilution computed at depth, and the absence of trapping, indicate that the modeling was conservative with regard to the performance of the diffuser during the October 2006 survey.

Accordingly, smaller-amplitude discharge-related salinity anomalies were recorded well beyond the ZID at Stations 5, 6, and 16 (Perturbations P2 through P5). The largest of these anomalies ( $-0.081\text{‰}$ ) was observed at a depth of 5 m at Station 5 where the effluent had been diluted 412-fold. At this point, discharge-related anomalies in other seawater properties that were apparent at Station 4 had long-since dissipated. This was the case even though the anomalies in the other seawater properties at Station 4 were generated by the upward displacement of ambient seawater rather than the presence of effluent constituents. By the time the plume reached more distant stations (Station 6 and Station 16) it had been diluted nearly 500-fold (Perturbations P4 and P5). This is nearly four-times the dilution level predicted by the modeling. These dilution computations demonstrate that, during the October 2006 survey, the outfall was performing better than designed, and was rapidly diluting effluent more than 375-fold just beyond the boundary of the ZID at Station 4. Consequently, COP receiving-water objectives were easily met by the chemical concentration limits promulgated by the NPDES discharge permit issued to the MBCSD.

## **DISCUSSION**

Sampling during the October 2006 survey indicated that the wastewater discharge was in compliance with the receiving-water limitations specified in the NPDES permit, and with the water-quality objectives of the COP (SWRCB 1997) and the Central Coast Basin Plan (RWQCB 1994). Specifically, there were no particulates of sewage origin seen floating on the ocean surface at any of the stations sampled during the October 2006 water-quality survey, and the discharge complied with all quantitative limits on seawater properties.

Although discharge-related changes in all six water properties were observed during the October 2006 survey, the changes were either not statistically significant, were measured within the boundary of the ZID, or resulted from the displacement of ambient seawater rather than the presence of effluent constituents. Receiving-water limitations only apply to statistically significant changes caused by the presence of effluent constituents beyond the margin of the ZID. The limitations do not apply to measurements within the ZID because the discharged wastewater is still undergoing rapid initial mixing with the surrounding seawater. This was the case for the shallow anomalies associated with Perturbation P1. Those measurements were collected within the ZID at the beginning of the CTD cast at Station 4, as the vessel drifted southwestward across the boundary of the ZID (Figure 2).

Other than salinity, the thermal anomaly at Station 4 was the only discharge-related change in seawater properties that was found to be statistically significant. It was observed near the sea surface at Station 4. However, because it reflects a localized decrease in seawater temperature, it could only have been generated by the upward displacement of ambient seawater, rather than the presence of warmer wastewater constituents. None of the anomalies associated with Perturbation P1, other than salinity and temperature, were statistically significant. Moreover, as with the thermal anomaly, they were also generated by the upward displacement of ambient seawater. As such, discharge limitations, such as those

for DO concentrations, do not apply because the changes were not induced by the discharge of oxygen-demanding materials. Although the discharge-related salinity anomalies at Stations 5, 6, and 16 were statistically significant, there are no restrictions on the alteration of this seawater property. In any regard, the amplitudes of the observed salinity deviations were very small compared to the temporal variability in salinity that occurs within this coastal region.

### *Outfall Performance*

Small anomalies in salinity indicated the presence of dilute wastewater at Stations 4, 5, 6, and 16. These high-precision observations demonstrated that the diffuser structure was operating better than predicted by modeling, and that the discharged wastewater experienced high levels of dilution both within and beyond the ZID. A dilution of 375:1 was determined from the salinity anomaly located at mid-depth at Station 4. This is well above the minimum critical dilution of 133:1 specified in the NPDES permit. The statistically significant salinity anomalies at the other stations were even smaller in amplitude. They indicate that wastewater had been diluted more than 400-fold, which is three times higher than the 133:1 dilution used in the NPDES permit to establish end-of-pipe concentration limits on effluent constituents. Thus, with the higher dilution ratio that was determined from actual measurements during the October-2006 survey, contaminant concentrations within the wastewater could have been more than three times the limits specified in the NPDES discharge permit, and the receiving-water objectives of the California Ocean Plan (COP) would still have been achieved.

### *NPDES Permit Limits*

The seawater properties measured during the October 2006 survey were statistically evaluated for compliance with the pertinent receiving-water limitations promulgated by the NPDES discharge permit and the COP. Specifically, the permit and COP state that the discharge shall not cause the occurrence of the following conditions.

1. *Natural light to be significantly reduced at any point outside the initial dilution zone as the result of the discharge of waste*
2. *The dissolved oxygen concentration outside the zone of initial dilution to fall below 5.0 mg/L or to be depressed more than 10 percent from that which occurs naturally*
3. *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*
4. *Temperature of the receiving water to adversely affect beneficial uses*

The COP (SWRCB 1997) further defines a ‘significant’ difference as ‘...a statistically significant difference in the means of two distributions of sampling results at the 95 percent confidence level.’ For each observation in Tables B-1 through B-7, the statistical significance of departures from mean conditions at a given depth level were determined with an analysis of variance that compares a single observation with the mean of a larger set of samples (Sokal and Rohlf 1997, p228; Ury 1976). Although 15 independent hypothesis tests were performed at each depth level, no Bonferroni adjustment to the error rate was included, so the tests are conservative. Specifically, Bonferroni adjustment indicates that the actual confidence level for the overall null hypothesis test for differences in properties is higher, around 99.7%, rather than the 95% level that applies to a single test. The standard deviation that was applied in the tests was determined from the entire data set to reflect the full range in ambient properties, including vertical variations.

### *Light Transmittance*

Based on the statistical analysis, there no stations where significant reductions in instrumentally recorded light transmittance were found (Table B-5). On the contrary, the discharge-induced transmissivity anomaly observed at Station 4, albeit not statistically significant, represented a 5.4% increase in light transmittance. The increase in ambient light transmittance at Station 4 was independently corroborated by the 2-m increase in Secchi depth recorded at that station. This discharge-related increase in light penetration was generated by the upward displacement of ambient low-turbidity seawater at depth rather than the presence of wastewater particulates. As such, it did not represent a significant “...reduction in the transmittance of natural light...” generated “...as the result of the discharge of waste” (SWRCB 1997).

### *Dissolved Oxygen*

Although it is not explicitly stated in the NPDES discharge permit, the COP specifies that the DO limitation only applies to reductions that occur “...as a result of the discharge of oxygen demanding waste materials.” Clearly, then, the DO limitation does not apply to reductions in DO caused by the movement of ambient waters, regardless of whether or not they were induced by the physics of the discharge. None of the DO anomalies was significant, and the only discharge-related DO reduction (Perturbation P1 at Station 4) was generated by the entrainment of ambient seawater. Therefore, it was not subject to the limitations. Even so, the amplitude of that DO anomaly was so small (-0.7 mg/L) that it did not constitute a statistically significant deviation from the norm. This would have to be the case because the anomaly was created by the upward movement of ambient seawater that is naturally depleted in oxygen at depth, and therefore, was comparable to observed background concentrations. Regardless, all of the DO measurements complied with the numerical limits specified in the permit. Specifically, none of the DO concentrations measured during the October 2006 survey fell below the 5-mg/L minimum specified in the Basin Plan and the NPDES discharge permit. In fact, none of the 517 measurements collected during the October-2006 survey fell below 6.1 mg/L. In addition, the discharge-related reduction at Station 4 was too small to be considered “...depressed more than 10 percent from that which occurs naturally,” given that the measured concentration of 6.74 mg/L within the anomaly was higher than the 6.22-mg/L average concentration of ambient seawater near the seafloor.

### *pH*

As with the DO anomaly, the discharge-related pH anomaly found near the sea surface at Station 4 fully complies with the requirements of the discharge permit. It was not statistically significant (Tables 4 and B-6), and was generated by the upward displacement of ambient seawater. Although the pH (8.046) within the anomaly was 0.044 pH units lower than the average pH of seawater at 4 m, it was higher than the average pH of ambient seawater (8.021) just above the seafloor. Consequently, it cannot be considered changed by ‘...more than 0.2 pH units from that which occurs naturally.’ In fact, pH remained between 7.99 and 8.11 in all 517 measurements, and thus all of the measurements were within 0.12 pH units of one another, and also complied with the lower (7.0 pH) and upper (8.3 pH) bounds on discharge-induced pH changes.

In fact, the only statistically significant pH anomaly was detected above the seafloor at Station 2. However, that anomaly was not associated with the discharge for several reasons. First, it did not coincide with anomalies in other seawater properties, particularly salinity. Second, its location was spatially disconnected from the discharge point because another station (Station 3) that was located between Station 2 and the discharge did not exhibit a pH anomaly. Finally, the statistical significance of the pH anomaly at Station 2 may have been an artifact of an excessive adjustment to the temporal drift in the pH

sensor. The adjustment was based on surface measurements prior to the downcast at Station 2, and therefore, did not account for ongoing sensor equilibration that continued to occur during the 1 min 40 s descent to the seafloor. However, regardless of whether the pH anomaly at Station 2 was discharge related or statistically significant, or whether it was merely an artifact of natural variability, its amplitude of 0.067 pH units remained well within the allowed range of 0.2 pH units, and was in compliance with the numerical limitations specified in the discharge permit.

### *Temperature and Salinity*

At -0.55°C, the statistically significant discharge-related thermal anomaly at Station 4 was far too small to adversely affect beneficial uses. The slightly depressed temperature of 13.32°C was comparable to average temperatures measured 3.5 m above the seafloor, and higher than temperatures measured closer to the seafloor. As such, the amplitude of the anomaly was only about half as large as the 1.1°C range in temperature observed during the survey due to naturally occurring vertical stratification. It was also much smaller than the 5°C range in sea-surface temperature found all along the central coast at the time of the survey, as shown in the satellite image on the cover of this report.

Although salinity anomalies provide the best tracer of discharged effluent, their actual amplitude (<0.1‰) was small compared to seasonal and spatial differences in salinity that occur along the south-central California coast. For example, in 2005, the difference in average salinity between the April and July survey was six times higher (0.64‰). In any regard, the observed ranges in both the measured temperature (1.1°C) and salinity (0.15‰) across all data collected during the October 2006 survey were too small to be considered harmful to marine biota or deleterious to beneficial uses.

### *Conclusions*

All of the measurements recorded during the October 2006 survey complied with the receiving-water limitations specified in the NPDES discharge permit. Other than salinity, the discharge-related anomalies that were found near the ZID boundary southeast of the diffuser structure at Station 4 were caused by upward displacement of ambient seawater rather than the presence of dilute effluent. At that point, effluent had been diluted at least 375-fold, and any perceptible trace of anomalous wastewater characteristics, other than low salinity, had long since disappeared. Beyond the ZID, at Stations 5, 6, and 16, dilution levels were more than three-times those predicted by modeling. These measurements confirm that the diffuser structure and the outfall were operating better than would be expected from the modeling.

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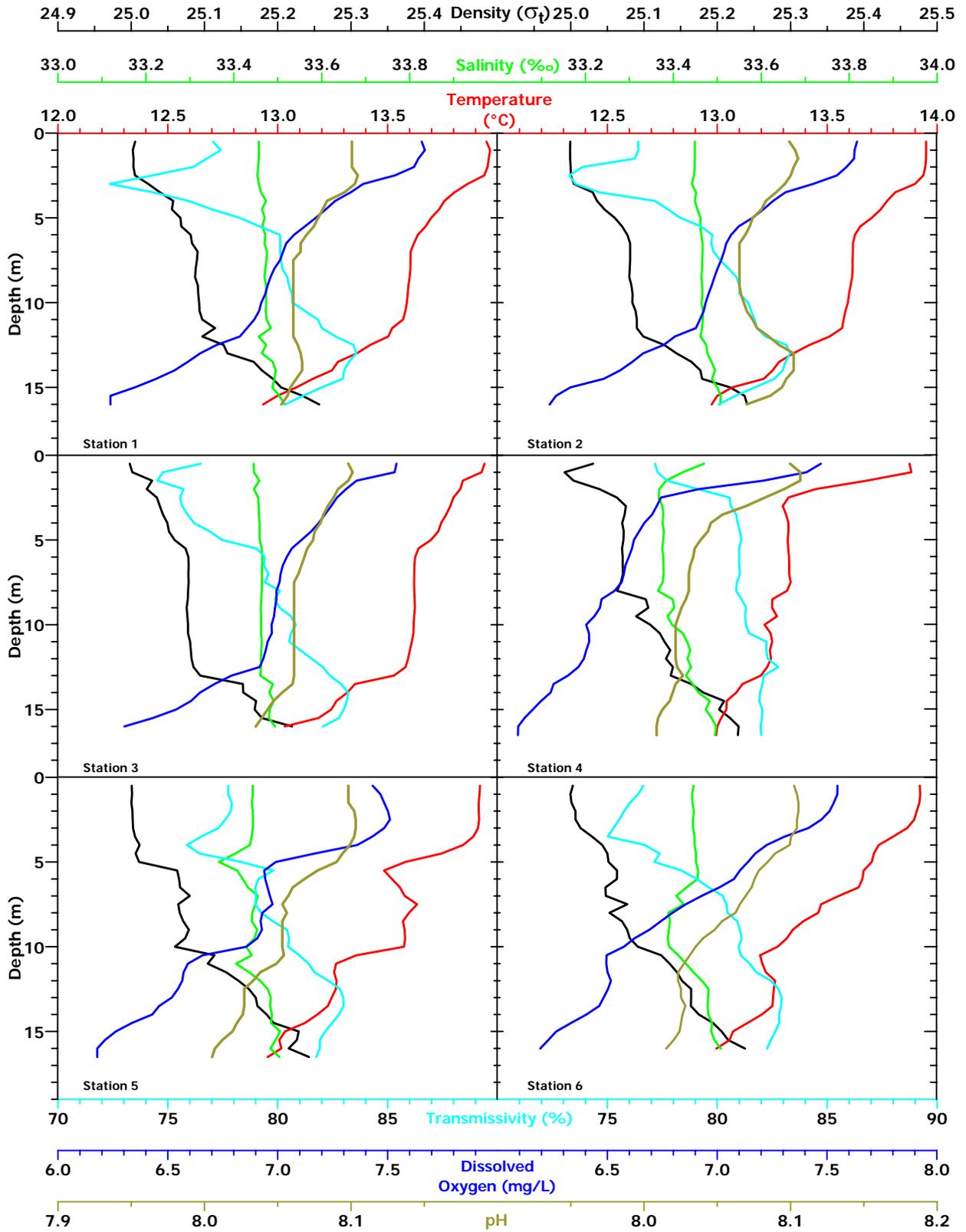
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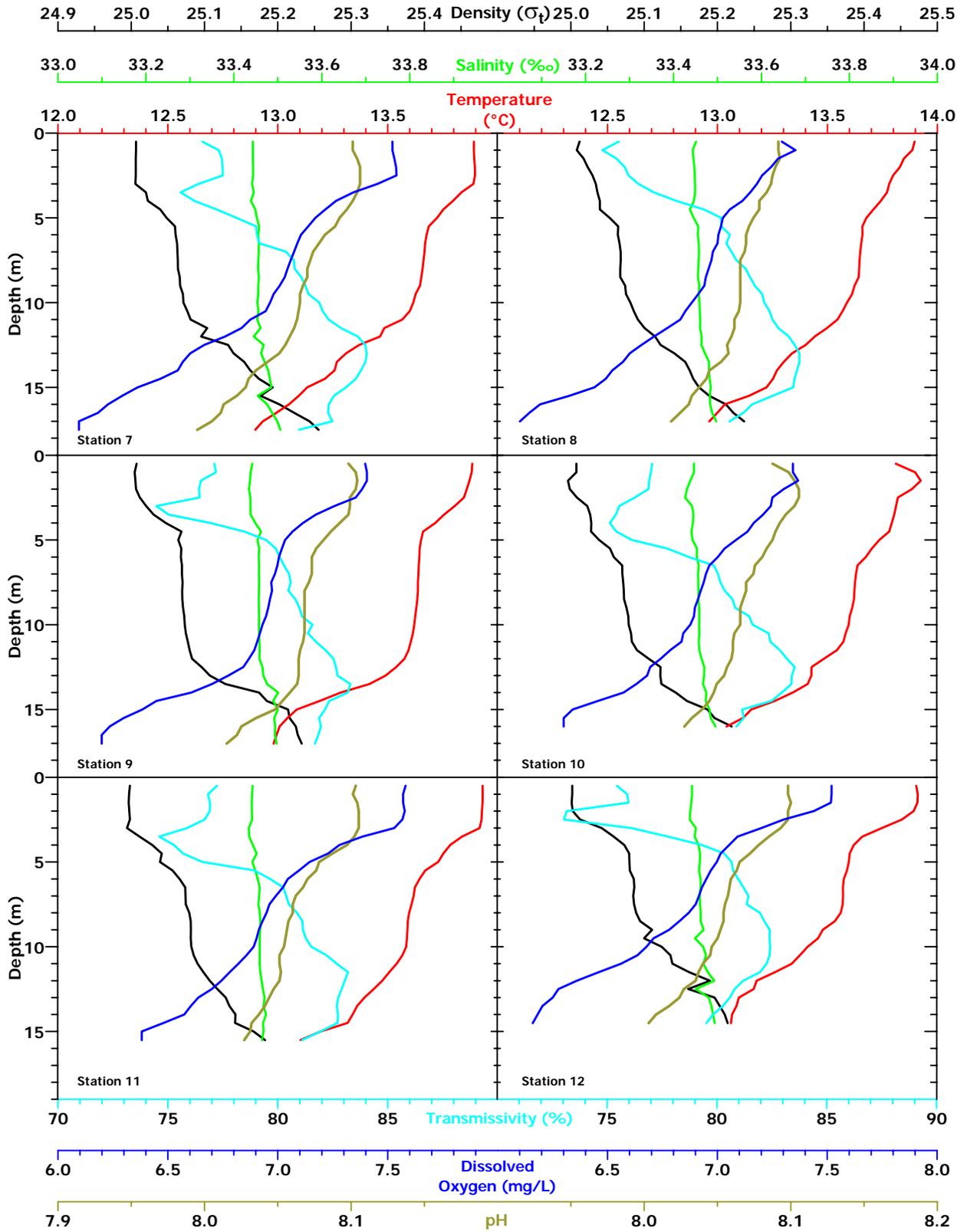
*APPENDIX A*

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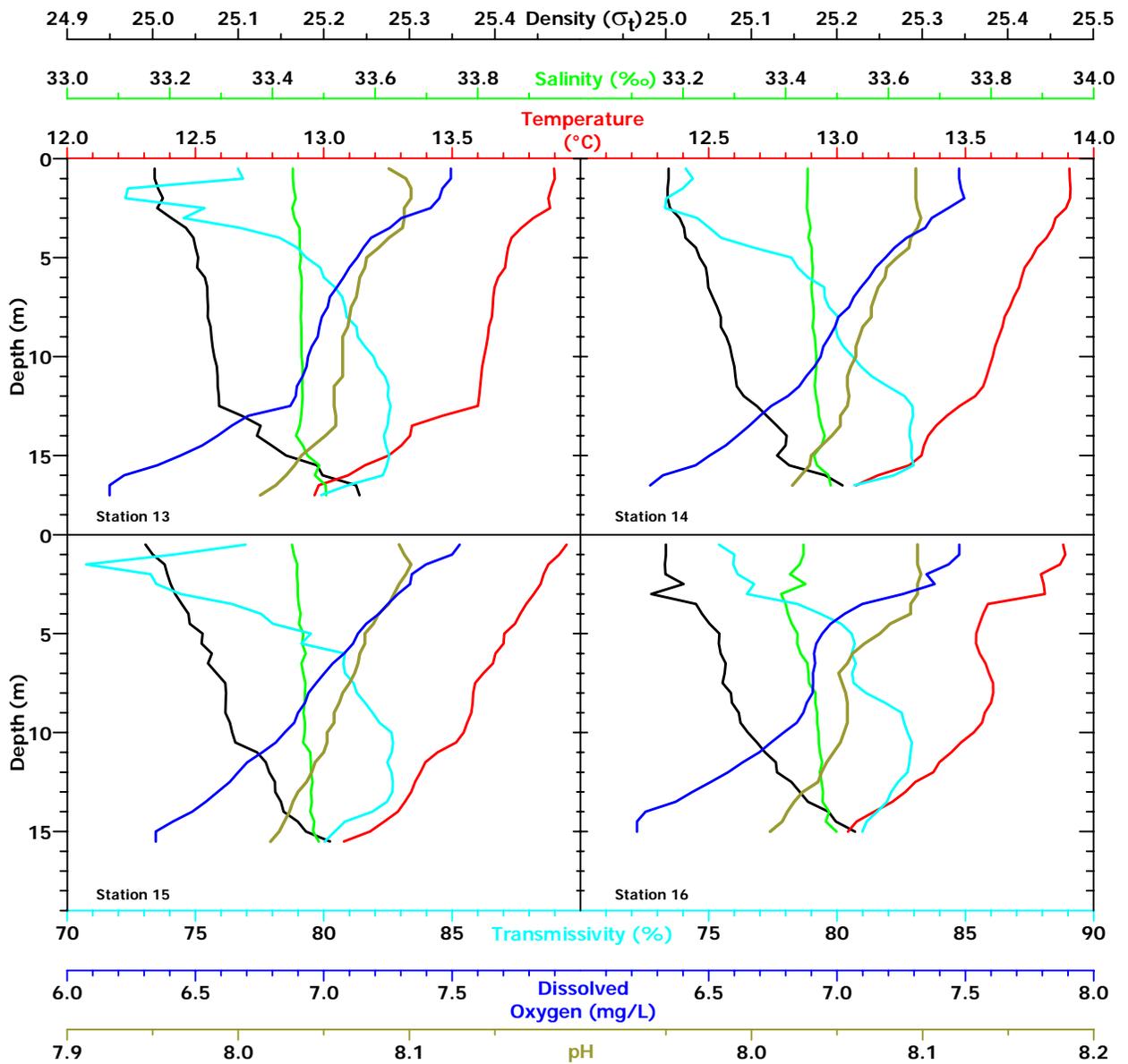
*Water Quality Profiles and Vertical Sections*



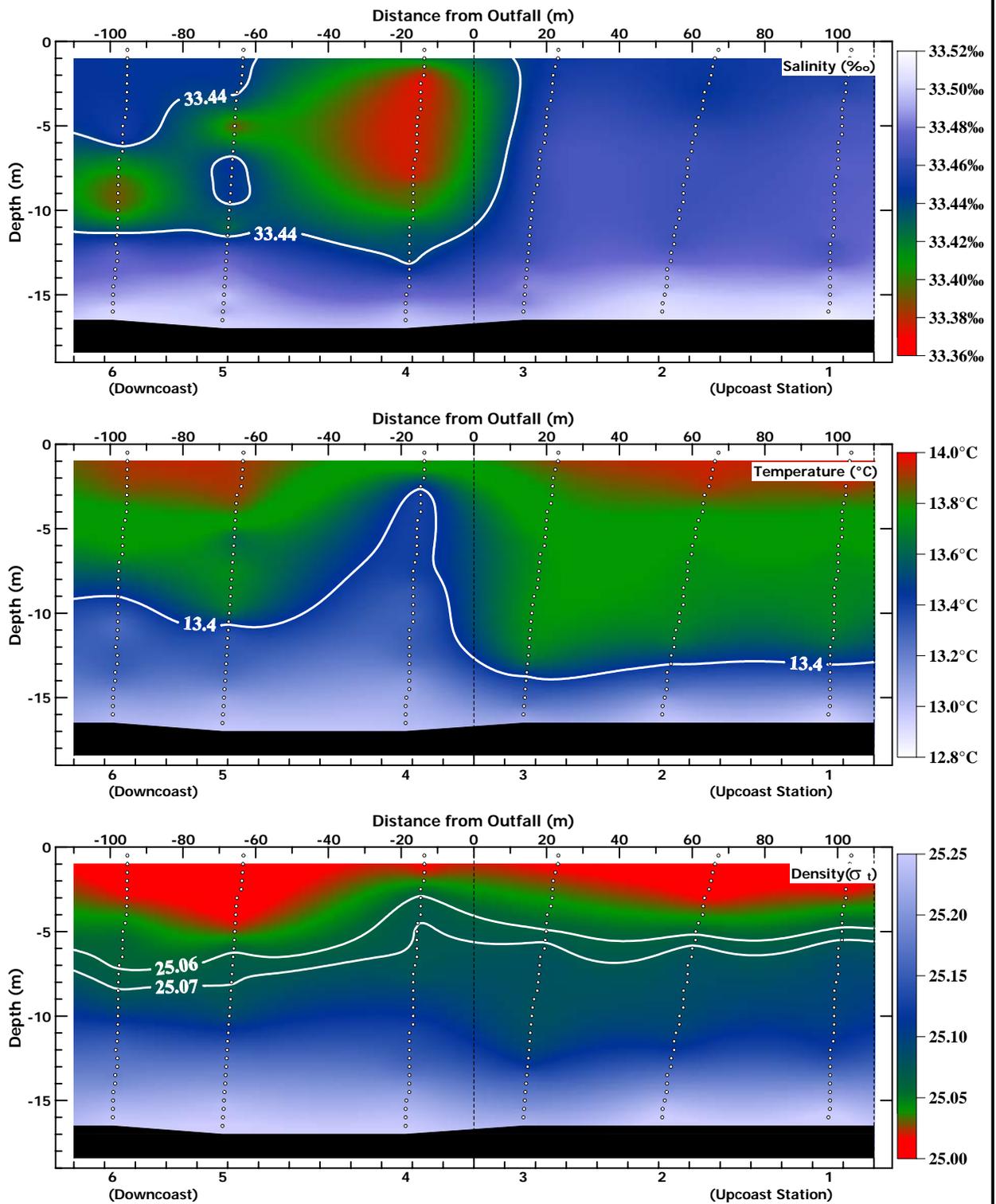
**Figure A-1.** Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 3 October 2006



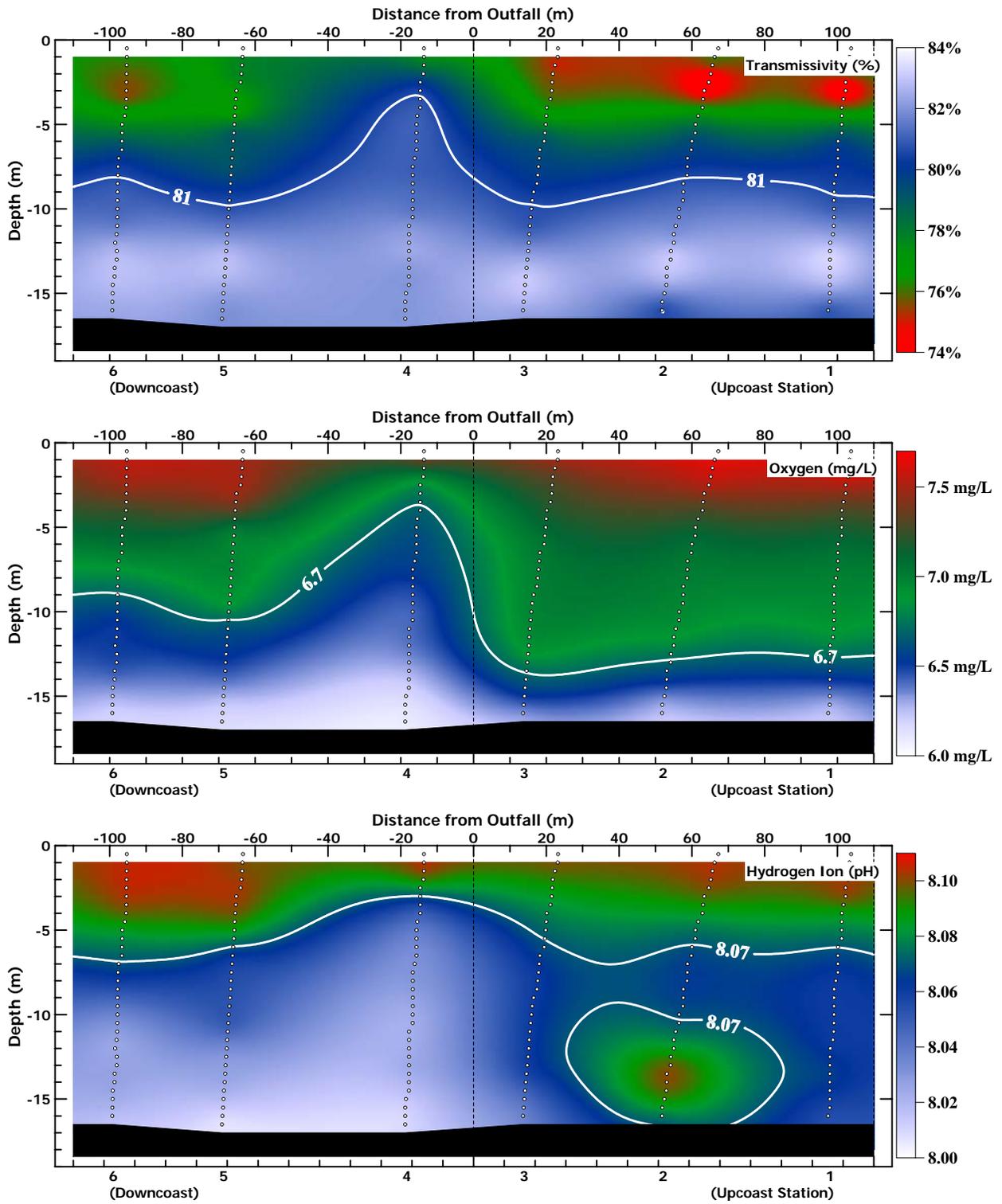
**Figure A-2.** Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 3 October 2006



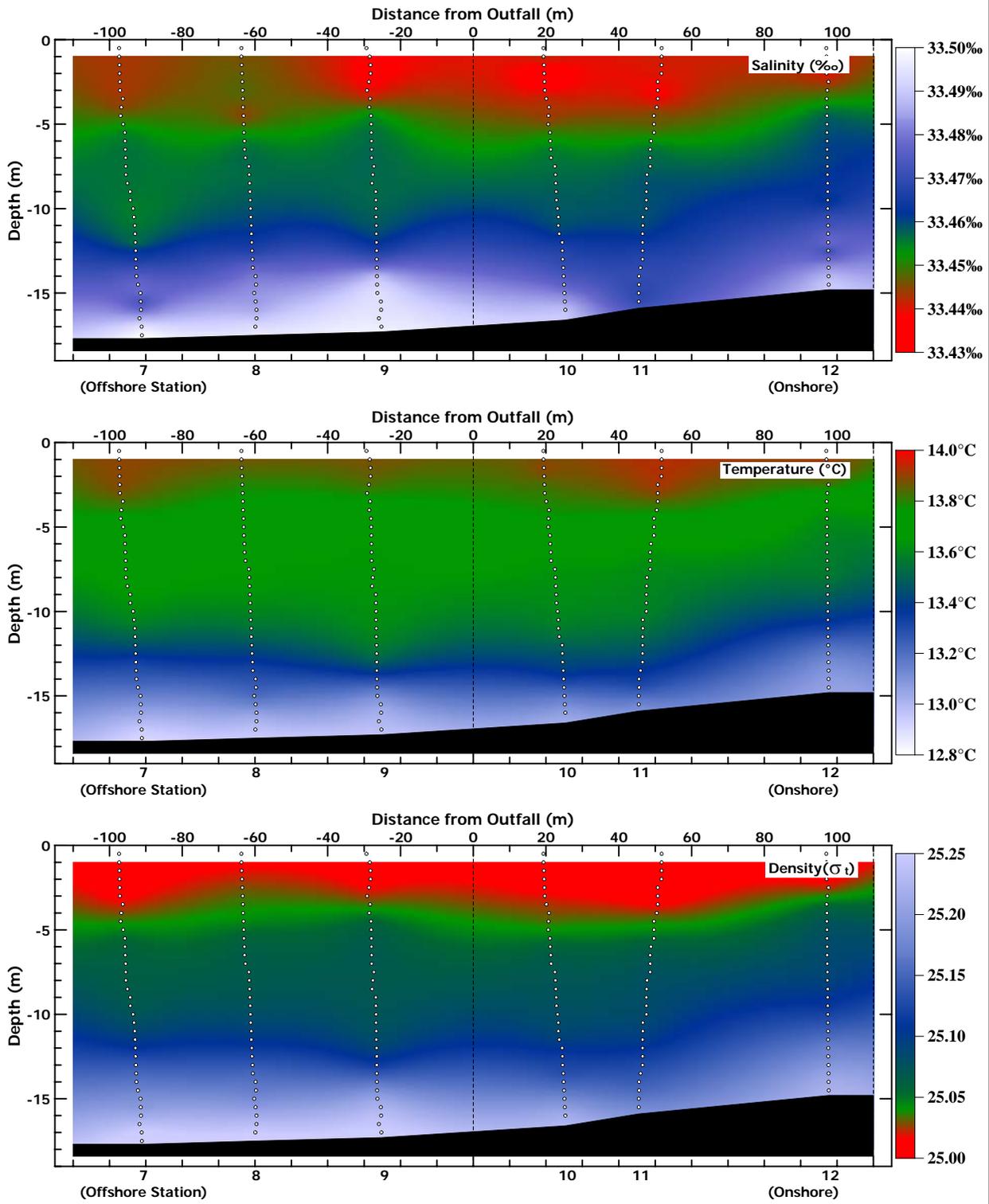
**Figure A-3.** Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 3 October 2006



**Figure A-4.** Along-Shore Transects of Salinity, Temperature, and Density on 3 October 2006



**Figure A-5.** Along-Shore Transects of Transmissivity, Oxygen, and pH on 3 October 2006



**Figure A-6.** Cross-Shore Transects of Salinity, Temperature, and Density on 3 October 2006

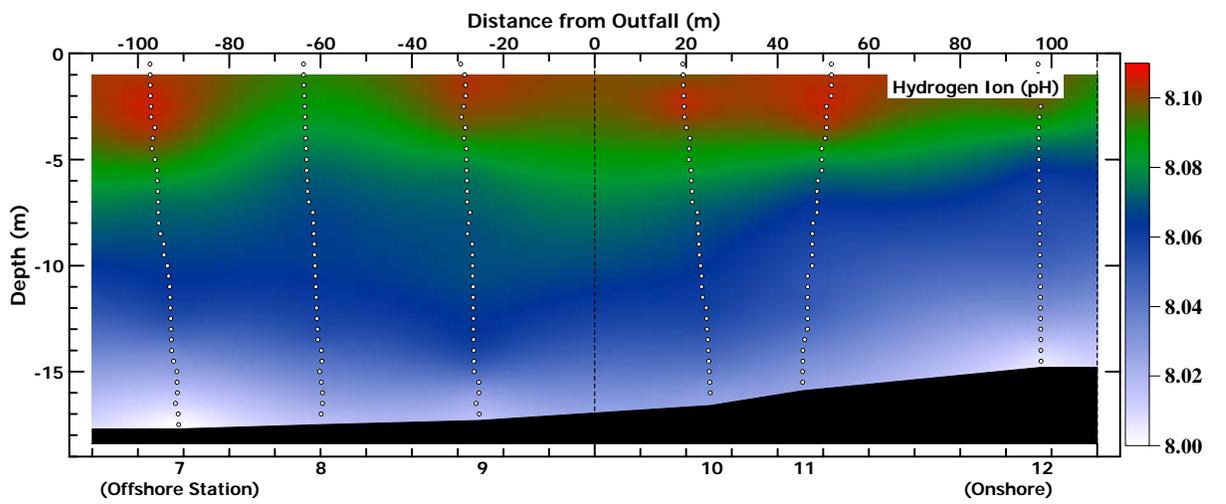
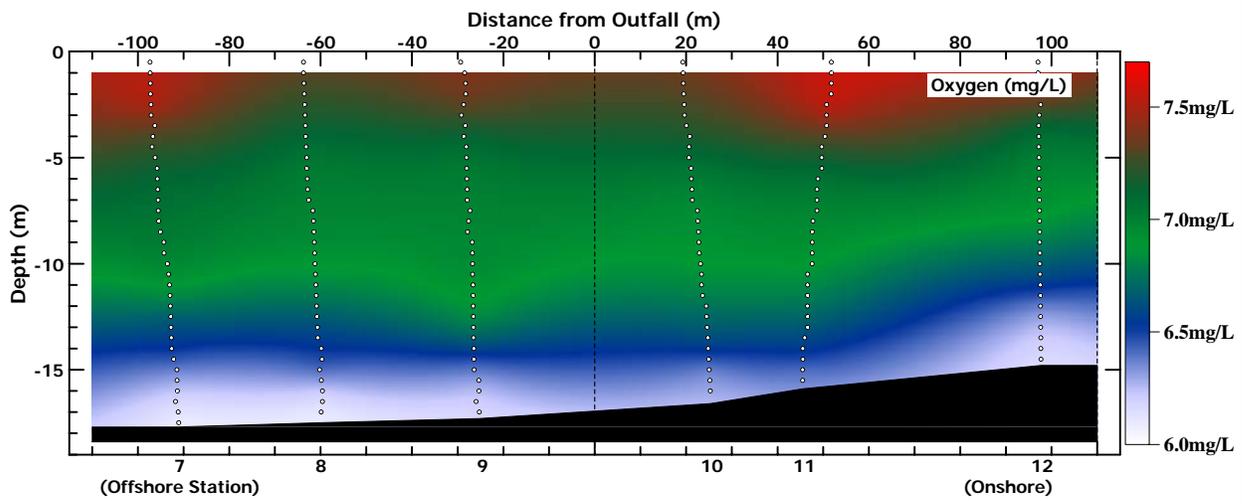
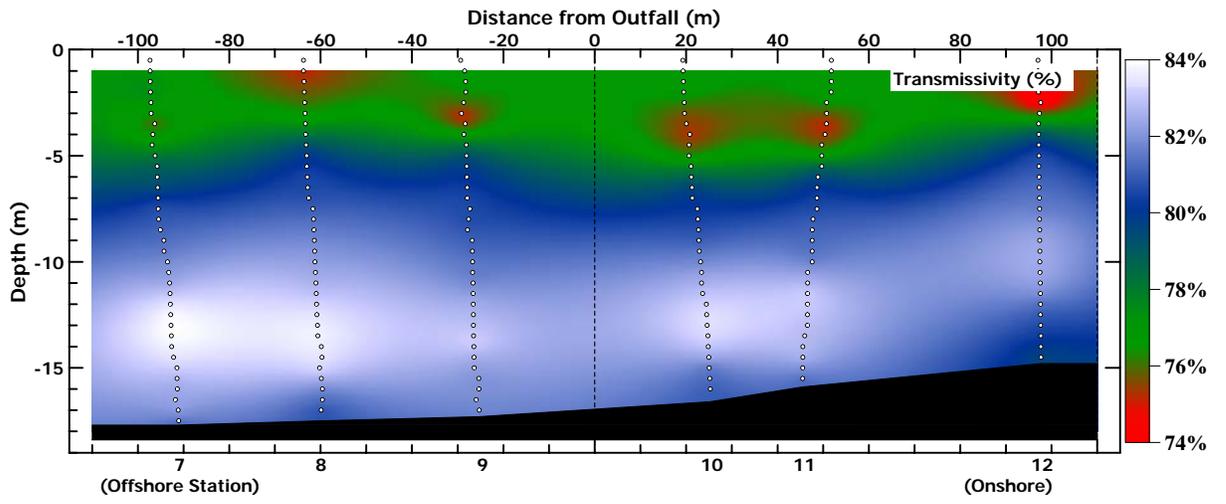


Figure A-7. Cross-Shore Transects of Transmissivity, Oxygen, and pH on 3 October 2006

***APPENDIX B***

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***Tables of Profile Data and Standard Observations***

**Table B-1. Seawater Temperature<sup>1</sup> on 3 October 2006**

Depth (m)	Temperature (°C)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<b>0.5</b>	13.95	13.95	13.94	13.87	13.92	13.92	13.89	13.90	13.88	13.81	13.93	13.90	13.90	13.91	13.95	13.88
<b>1.0</b>	13.97	13.95	13.93	13.88	13.92	13.92	13.89	13.89	13.88	13.90	13.93	13.91	13.90	13.91	13.92	13.89
<b>1.5</b>	13.96	13.95	13.84	13.68	13.91	13.92	13.89	13.85	13.87	13.92	13.93	13.91	13.89	13.91	13.87	13.87
<b>2.0</b>	13.95	13.95	13.83	13.45	13.91	13.91	13.90	13.83	13.86	13.88	13.93	13.89	13.87	13.91	13.86	13.79
<b>2.5</b>	13.94	13.94	13.80	<b>13.32</b>	13.92	13.90	13.90	13.80	13.85	13.82	13.93	13.84	13.88	13.89	13.84	13.80
<b>3.0</b>	13.86	13.90	13.79	<b>13.30</b>	13.91	13.86	13.89	13.78	13.80	13.81	13.92	13.75	13.82	13.85	13.82	13.81
<b>3.5</b>	13.80	13.81	13.77	13.31	13.89	13.80	13.84	13.77	13.76	13.80	13.84	13.66	13.77	13.84	13.79	13.59
<b>4.0</b>	13.76	13.77	13.74	13.32	13.84	13.73	13.80	13.74	13.72	13.79	13.78	13.62	13.73	13.82	13.77	13.57
<b>4.5</b>	13.73	13.74	13.73	13.32	13.75	13.71	13.75	13.71	13.66	13.78	13.75	13.60	13.72	13.78	13.74	13.55
<b>5.0</b>	13.70	13.70	13.70	13.32	13.58	13.70	13.72	13.68	13.65	13.74	13.73	13.60	13.71	13.76	13.70	13.54
<b>5.5</b>	13.67	13.65	13.64	13.32	13.48	13.67	13.69	13.66	13.65	13.70	13.67	13.59	13.71	13.73	13.70	13.54
<b>6.0</b>	13.64	13.63	13.63	13.33	13.52	13.66	13.68	13.66	13.64	13.67	13.64	13.57	13.68	13.72	13.67	13.56
<b>6.5</b>	13.62	13.62	13.62	13.33	13.56	13.64	13.67	13.65	13.64	13.64	13.62	13.57	13.67	13.71	13.66	13.58
<b>7.0</b>	13.60	13.62	13.62	13.33	13.58	13.55	13.67	13.65	13.64	13.63	13.62	13.57	13.66	13.69	13.62	13.59
<b>7.5</b>	13.60	13.62	13.62	13.33	13.63	13.47	13.66	13.65	13.64	13.63	13.61	13.57	13.66	13.67	13.59	13.61
<b>8.0</b>	13.60	13.62	13.62	13.32	13.60	13.46	13.66	13.64	13.64	13.62	13.60	13.56	13.65	13.65	13.58	13.61
<b>8.5</b>	13.60	13.61	13.62	13.25	13.57	13.39	13.65	13.64	13.63	13.62	13.59	13.53	13.64	13.64	13.58	13.60
<b>9.0</b>	13.59	13.61	13.62	13.25	13.58	13.34	13.65	13.62	13.63	13.61	13.59	13.48	13.64	13.63	13.57	13.58
<b>9.5</b>	13.59	13.60	13.62	13.27	13.58	13.32	13.63	13.61	13.63	13.60	13.59	13.46	13.63	13.62	13.56	13.56
<b>10.0</b>	13.59	13.59	13.62	13.22	13.58	13.27	13.62	13.59	13.62	13.60	13.58	13.41	13.62	13.61	13.54	13.53
<b>10.5</b>	13.58	13.58	13.62	13.24	13.36	13.20	13.60	13.57	13.61	13.58	13.57	13.38	13.62	13.59	13.52	13.48
<b>11.0</b>	13.57	13.57	13.61	13.25	13.27	13.20	13.57	13.55	13.61	13.57	13.54	13.34	13.61	13.58	13.44	13.45
<b>11.5</b>	13.52	13.57	13.60	13.24	13.26	13.22	13.48	13.50	13.59	13.54	13.51	13.26	13.61	13.57	13.40	13.40
<b>12.0</b>	13.50	13.51	13.59	13.24	13.27	13.26	13.47	13.44	13.58	13.48	13.48	13.18	13.61	13.54	13.38	13.38
<b>12.5</b>	13.42	13.42	13.58	13.23	13.26	13.26	13.37	13.40	13.54	13.43	13.44	13.16	13.60	13.48	13.36	13.30
<b>13.0</b>	13.36	13.35	13.53	13.20	13.25	13.25	13.31	13.34	13.49	13.43	13.39	13.10	13.46	13.43	13.34	13.27
<b>13.5</b>	13.27	13.28	13.35	13.12	13.23	13.25	13.27	13.30	13.42	13.41	13.36	13.09	13.34	13.39	13.32	13.22
<b>14.0</b>	13.25	13.25	13.32	13.09	13.18	13.20	13.26	13.27	13.29	13.34	13.34	13.07	13.34	13.35	13.29	13.14
<b>14.5</b>	13.16	13.21	13.27	13.04	13.12	13.14	13.21	13.25	13.19	13.26	13.32	13.06	13.30	13.34	13.24	13.08
<b>15.0</b>	13.08	13.07	13.24	13.04	13.03	13.07	13.13	13.22	13.09	13.15	13.19		13.25	13.33	13.18	13.04
<b>15.5</b>	13.00	13.00	13.19	13.02	13.01	13.06	13.10	13.14	13.04	13.12	13.10		13.16	13.28	13.08	
<b>16.0</b>	12.93	12.97	13.03	13.00	13.02	13.00	13.05	13.03	13.01	13.04			13.09	13.16		
<b>16.5</b>				12.99	12.95			12.99	13.00	12.99			12.98	13.07		
<b>17.0</b>								12.93	12.96	12.98			12.96			
<b>17.5</b>								12.90								

<sup>1</sup> Values enclosed in boxes were significantly lower than the mean of other temperature measurements at the same distance below the sea surface.

Table B-2. Salinity<sup>1</sup> on 3 October 2006

Depth (m)	Salinity (‰)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	33.457	33.449	33.445	33.470	33.443	33.446	33.443	33.451	33.442	33.447	33.443	33.442	33.440	33.443	33.438	33.434
1.0	33.458	33.449	33.446	33.421	33.443	33.443	33.443	33.444	33.438	33.447	33.441	33.442	33.440	33.443	33.442	33.434
1.5	33.457	33.449	33.458	<b>33.383</b>	33.441	33.443	33.443	33.446	33.437	33.438	33.441	33.441	33.442	33.442	33.448	33.427
2.0	33.456	33.449	33.446	<b>33.368</b>	33.443	33.447	33.444	33.448	33.435	33.431	33.441	33.438	33.446	33.442	33.448	33.408
2.5	33.454	33.447	33.455	<b>33.366</b>	33.444	33.444	33.444	33.448	33.438	33.426	33.442	33.437	33.439	33.441	33.449	33.439
3.0	33.457	33.442	33.457	<b>33.375</b>	33.443	33.445	33.441	33.449	33.438	33.442	33.434	33.451	33.443	33.445	33.449	<b>33.391</b>
3.5	33.462	33.452	33.457	<b>33.377</b>	33.441	33.448	33.446	33.449	33.438	33.445	33.435	33.448	33.453	33.449	33.451	33.400
4.0	33.473	33.449	33.459	<b>33.376</b>	33.437	33.448	33.439	33.446	33.449	33.444	33.443	33.457	33.454	33.444	33.455	33.404
4.5	33.464	33.455	33.459	<b>33.379</b>	33.404	33.452	33.449	33.437	33.462	33.441	33.452	33.461	33.453	33.450	33.452	33.412
5.0	33.470	33.462	33.459	<b>33.377</b>	<b>33.366</b>	33.451	33.452	33.446	33.454	33.443	33.442	33.460	33.456	33.450	33.460	33.423
5.5	33.465	33.461	33.464	<b>33.375</b>	33.408	33.457	33.457	33.456	33.458	33.453	33.449	33.458	33.453	33.453	33.458	33.422
6.0	33.472	33.464	33.465	<b>33.377</b>	33.421	33.454	33.456	33.456	33.457	33.453	33.454	33.461	33.457	33.452	33.465	33.429
6.5	33.470	33.467	33.465	<b>33.377</b>	33.432	33.430	33.457	33.457	33.458	33.458	33.459	33.462	33.457	33.450	33.457	33.442
7.0	33.476	33.466	33.464	<b>33.378</b>	33.455	33.407	33.457	33.458	33.457	33.456	33.458	33.460	33.456	33.452	33.460	33.444
7.5	33.475	33.466	33.464	<b>33.376</b>	33.449	33.424	33.456	33.457	33.458	33.456	33.456	33.461	33.456	33.454	33.464	33.445
8.0	33.472	33.466	33.464	<b>33.365</b>	33.442	<b>33.389</b>	33.455	33.456	33.457	33.457	33.459	33.462	33.455	33.455	33.464	33.458
8.5	33.470	33.464	33.463	<b>33.398</b>	33.441	<b>33.393</b>	33.457	33.456	33.457	33.457	33.460	33.462	33.456	33.452	33.463	33.458
9.0	33.474	33.466	33.462	<b>33.402</b>	33.453	<b>33.390</b>	33.456	33.459	33.457	33.459	33.460	33.469	33.456	33.457	33.461	33.461
9.5	33.474	33.466	33.462	<b>33.387</b>	33.447	<b>33.387</b>	33.456	33.458	33.457	33.459	33.459	33.449	33.456	33.458	33.463	33.461
10.0	33.474	33.464	33.462	<b>33.397</b>	33.428	<b>33.391</b>	33.454	33.459	33.457	33.458	33.459	33.468	33.457	33.459	33.463	33.464
10.5	33.473	33.467	33.462	33.421	33.441	33.411	33.456	33.460	33.458	33.459	33.459	33.474	33.459	33.460	33.460	33.464
11.0	33.475	33.467	33.464	33.431	<b>33.405</b>	33.429	33.453	33.461	33.458	33.458	33.459	33.468	33.459	33.458	33.474	33.467
11.5	33.485	33.466	33.463	33.439	33.435	33.446	33.461	33.461	33.459	33.459	33.460	33.478	33.458	33.457	33.475	33.471
12.0	33.457	33.462	33.462	33.432	33.460	33.465	33.445	33.464	33.458	33.464	33.463	33.493	33.459	33.459	33.475	33.467
12.5	33.473	33.475	33.462	33.440	33.477	33.480	33.468	33.463	33.465	33.470	33.466	33.451	33.458	33.463	33.478	33.470
13.0	33.464	33.477	33.460	33.429	33.485	33.479	33.462	33.471	33.467	33.470	33.470	33.480	33.456	33.465	33.475	33.473
13.5	33.488	33.487	33.489	33.444	33.483	33.478	33.470	33.481	33.476	33.467	33.468	33.486	33.453	33.469	33.477	33.472
14.0	33.496	33.495	33.481	33.457	33.487	33.479	33.478	33.481	33.501	33.475	33.473	33.490	33.446	33.476	33.474	33.485
14.5	33.493	33.488	33.491	33.483	33.485	33.488	33.482	33.482	33.490	33.473	33.467	33.494	33.459	33.470	33.482	33.478
15.0	33.488	33.500	33.482	33.474	33.505	33.486	33.486	33.485	33.500	33.482	33.468		33.468	33.455	33.479	33.499
15.5	33.503	33.508	33.480	33.487	33.495	33.494	33.454	33.483	33.492	33.484	33.464		33.491	33.461	33.490	
16.0	33.516	33.506	33.494	33.498	33.483	33.508	33.476	33.483	33.494	33.496			33.483	33.484		
16.5				33.495	33.503			33.487	33.488	33.494			33.504	33.488		
17.0								33.499	33.497	33.497			33.505			
17.5								33.506								

<sup>1</sup> Values enclosed in boxes were significantly lower than the mean of other salinity measurements at the same distance below the sea surface.







Table B-6. Detrended<sup>1</sup> pH<sup>2</sup> on 3 October 2006

Depth (m)	Hydrogen Ion Concentration (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	8.101	8.099	8.098	8.100	8.098	8.102	8.101	8.092	8.098	8.088	8.103	8.098	8.088	8.096	8.094	8.097
1.0	8.101	8.103	8.101	8.107	8.098	8.104	8.101	8.092	8.103	8.099	8.101	8.098	8.098	8.096	8.097	8.097
1.5	8.101	8.105	8.098	8.107	8.098	8.105	8.104	8.093	8.104	8.103	8.104	8.100	8.101	8.096	8.101	8.097
2.0	8.101	8.102	8.091	8.096	8.102	8.105	8.106	8.090	8.103	8.106	8.105	8.098	8.101	8.096	8.098	8.099
2.5	8.105	8.100	8.088	8.083	8.103	8.104	8.106	8.088	8.099	8.106	8.105	8.098	8.097	8.097	8.094	8.097
3.0	8.103	8.096	8.084	8.070	8.103	8.104	8.106	8.087	8.099	8.103	8.105	8.093	8.097	8.099	8.091	8.097
3.5	8.096	8.090	8.081	8.054	8.102	8.100	8.104	8.084	8.098	8.097	8.102	8.085	8.096	8.097	8.088	8.093
4.0	8.084	8.083	8.079	8.046	8.099	8.099	8.101	8.079	8.092	8.093	8.097	8.078	8.088	8.093	8.082	8.093
4.5	8.081	8.080	8.075	8.044	8.094	8.089	8.097	8.079	8.086	8.090	8.087	8.072	8.082	8.092	8.079	8.081
5.0	8.078	8.074	8.074	8.039	8.090	8.084	8.092	8.075	8.081	8.088	8.078	8.065	8.075	8.085	8.074	8.075
5.5	8.075	8.072	8.070	8.035	8.077	8.078	8.089	8.072	8.076	8.084	8.076	8.063	8.074	8.079	8.074	8.066
6.0	8.070	8.069	8.068	8.034	8.068	8.075	8.082	8.070	8.073	8.081	8.070	8.059	8.071	8.078	8.071	8.059
6.5	8.066	8.065	8.066	8.032	8.060	8.073	8.078	8.070	8.073	8.076	8.067	8.058	8.070	8.074	8.070	8.056
7.0	8.066	8.065	8.064	8.031	8.057	8.069	8.074	8.069	8.073	8.075	8.062	8.057	8.069	8.072	8.068	8.051
7.5	8.061	8.065	8.061	8.031	8.053	8.065	8.072	8.066	8.071	8.070	8.060	8.055	8.066	8.070	8.065	8.053
8.0	8.061	8.065	8.061	8.031	8.056	8.062	8.070	8.066	8.068	8.070	8.060	8.054	8.065	8.070	8.061	8.055
8.5	8.061	8.065	8.061	8.029	8.053	8.053	8.070	8.066	8.068	8.068	8.057	8.054	8.064	8.065	8.059	8.056
9.0	8.061	8.065	8.061	8.026	8.053	8.048	8.067	8.066	8.068	8.066	8.056	8.052	8.061	8.063	8.056	8.056
9.5	8.061	8.066	8.061	8.024	8.053	8.040	8.065	8.066	8.068	8.066	8.055	8.050	8.061	8.061	8.056	8.056
10.0	8.061	8.068	8.061	8.022	8.053	8.035	8.065	8.066	8.068	8.066	8.054	8.046	8.061	8.061	8.052	8.054
10.5	8.061	8.070	8.061	8.022	8.054	8.031	8.064	8.065	8.068	8.062	8.051	8.045	8.061	8.058	8.052	8.052
11.0	8.061	8.074	8.061	8.022	8.049	8.027	8.063	8.062	8.067	8.061	8.051	8.040	8.061	8.056	8.050	8.048
11.5	8.061	8.077	8.061	8.022	8.038	8.023	8.061	8.062	8.065	8.061	8.052	8.037	8.056	8.056	8.045	8.044
12.0	8.061	8.085	8.061	8.022	8.033	8.023	8.058	8.060	8.064	8.060	8.051	8.035	8.056	8.057	8.043	8.041
12.5	8.064	8.092	8.061	8.023	8.027	8.025	8.055	8.057	8.064	8.057	8.047	8.027	8.056	8.056	8.040	8.039
13.0	8.066	<b>8.102</b>	8.061	8.027	8.027	8.025	8.051	8.058	8.064	8.055	8.044	8.024	8.057	8.052	8.035	8.030
13.5	8.067	<b>8.102</b>	8.060	8.022	8.027	8.028	8.043	8.053	8.063	8.050	8.041	8.017	8.057	8.052	8.032	8.025
14.0	8.067	<b>8.102</b>	8.053	8.020	8.026	8.026	8.035	8.045	8.058	8.048	8.037	8.008	8.051	8.047	8.030	8.021
14.5	8.063	<b>8.097</b>	8.047	8.018	8.022	8.025	8.030	8.043	8.053	8.045	8.032	8.003	8.044	8.041	8.027	8.018
15.0	8.059	<b>8.094</b>	8.043	8.013	8.019	8.024	8.028	8.038	8.048	8.040	8.031		8.037	8.035	8.024	8.011
15.5	8.057	<b>8.086</b>	8.039	8.010	8.012	8.020	8.022	8.033	8.035	8.033	8.027		8.033	8.034	8.019	
16.0	8.053	<b>8.070</b>	8.035	8.009	8.007	8.015	8.013	8.031	8.025	8.028			8.028	8.029		
16.5				8.009	8.005			8.011	8.025	8.022				8.022	8.024	
17.0								8.005	8.019	8.015				8.013		
17.5								7.995								

<sup>1</sup> Measured pH levels were corrected for temporal drift to account for ongoing equilibration of the pH sensor.

<sup>2</sup> Values enclosed in boxes were significantly higher than the mean of other pH measurements at the same distance above the seafloor.

Table B-7. Uncorrected pH<sup>1</sup> on 3 October 2006

Depth (m)	Alkalinity (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	<b>7.876</b>	<b>7.921</b>	7.997	8.021	8.046	8.057	8.069	8.064	8.077	8.074	8.099	8.096	8.088	8.096	8.094	8.097
1.0	<b>7.876</b>	<b>7.925</b>	8.000	8.028	8.046	8.059	8.069	8.064	8.082	8.085	8.097	8.096	8.098	8.096	8.097	8.097
1.5	<b>7.876</b>	<b>7.927</b>	7.997	8.028	8.046	8.060	8.072	8.065	8.083	8.089	8.100	8.098	8.101	8.096	8.101	8.097
2.0	<b>7.876</b>	<b>7.924</b>	7.990	8.017	8.050	8.060	8.074	8.062	8.082	8.092	8.101	8.096	8.101	8.096	8.098	8.099
2.5	<b>7.880</b>	<b>7.922</b>	7.987	8.004	8.051	8.059	8.074	8.060	8.078	8.092	8.101	8.096	8.097	8.097	8.094	8.097
3.0	<b>7.878</b>	<b>7.918</b>	7.983	7.991	8.051	8.059	8.074	8.059	8.078	8.089	8.101	8.091	8.097	8.099	8.091	8.097
3.5	<b>7.871</b>	<b>7.912</b>	7.980	7.975	8.050	8.055	8.072	8.056	8.077	8.083	8.098	8.083	8.096	8.097	8.088	8.093
4.0	<b>7.859</b>	<b>7.905</b>	7.978	7.967	8.047	8.054	8.069	8.051	8.071	8.079	8.093	8.076	8.088	8.093	8.082	8.093
4.5	<b>7.856</b>	<b>7.902</b>	7.974	7.965	8.042	8.044	8.065	8.051	8.065	8.076	8.083	8.070	8.082	8.092	8.079	8.081
5.0	<b>7.853</b>	<b>7.896</b>	7.973	7.960	8.038	8.039	8.060	8.047	8.060	8.074	8.074	8.063	8.075	8.085	8.074	8.075
5.5	<b>7.850</b>	<b>7.894</b>	7.969	7.956	8.025	8.033	8.057	8.044	8.055	8.070	8.072	8.061	8.074	8.079	8.074	8.066
6.0	<b>7.845</b>	<b>7.891</b>	7.967	7.955	8.016	8.030	8.050	8.042	8.052	8.067	8.066	8.057	8.071	8.078	8.071	8.059
6.5	<b>7.841</b>	<b>7.887</b>	7.965	7.953	8.008	8.028	8.046	8.042	8.052	8.062	8.063	8.056	8.070	8.074	8.070	8.056
7.0	<b>7.841</b>	<b>7.887</b>	7.963	7.952	8.005	8.024	8.042	8.041	8.052	8.061	8.058	8.055	8.069	8.072	8.068	8.051
7.5	<b>7.836</b>	<b>7.887</b>	7.960	7.952	8.001	8.020	8.040	8.038	8.050	8.056	8.056	8.053	8.066	8.070	8.065	8.053
8.0	<b>7.836</b>	<b>7.887</b>	7.960	7.952	8.004	8.017	8.038	8.038	8.047	8.056	8.056	8.052	8.065	8.070	8.061	8.055
8.5	<b>7.836</b>	<b>7.887</b>	7.960	7.950	8.001	8.008	8.038	8.038	8.047	8.054	8.053	8.052	8.064	8.065	8.059	8.056
9.0	<b>7.836</b>	7.887	7.960	7.947	8.001	8.003	8.035	8.038	8.047	8.052	8.052	8.050	8.061	8.063	8.056	8.056
9.5	<b>7.836</b>	7.888	7.960	7.945	8.001	7.995	8.033	8.038	8.047	8.052	8.051	8.048	8.061	8.061	8.056	8.056
10.0	<b>7.836</b>	7.890	7.960	7.943	8.001	7.990	8.033	8.038	8.047	8.052	8.050	8.044	8.061	8.061	8.052	8.054
10.5	<b>7.836</b>	7.892	7.960	7.943	8.002	7.986	8.032	8.037	8.047	8.048	8.047	8.043	8.061	8.058	8.052	8.052
11.0	<b>7.836</b>	7.896	7.960	7.943	7.997	7.982	8.031	8.034	8.046	8.047	8.047	8.038	8.061	8.056	8.050	8.048
11.5	<b>7.836</b>	7.899	7.960	7.943	7.986	7.978	8.029	8.034	8.044	8.047	8.048	8.035	8.056	8.056	8.045	8.044
12.0	<b>7.836</b>	7.907	7.960	7.943	7.981	7.978	8.026	8.032	8.043	8.046	8.047	8.033	8.056	8.057	8.043	8.041
12.5	<b>7.839</b>	7.914	7.960	7.944	7.975	7.980	8.023	8.029	8.043	8.043	8.043	8.025	8.056	8.056	8.040	8.039
13.0	<b>7.841</b>	7.924	7.960	7.948	7.975	7.980	8.019	8.030	8.043	8.041	8.040	8.022	8.057	8.052	8.035	8.030
13.5	<b>7.842</b>	7.924	7.959	7.943	7.975	7.983	8.011	8.025	8.042	8.036	8.037	8.015	8.057	8.052	8.032	8.025
14.0	<b>7.842</b>	7.924	7.952	7.941	7.974	7.981	8.003	8.017	8.037	8.034	8.033	8.006	8.051	8.047	8.030	8.021
14.5	<b>7.838</b>	7.919	7.946	7.939	7.970	7.980	7.998	8.015	8.032	8.031	8.028	8.001	8.044	8.041	8.027	8.018
15.0	<b>7.834</b>	7.916	7.942	7.934	7.967	7.979	7.996	8.010	8.027	8.026	8.027		8.037	8.035	8.024	8.011
15.5	<b>7.832</b>	7.908	7.938	7.931	7.960	7.975	7.990	8.005	8.014	8.019	8.023		8.033	8.034	8.019	
16.0	<b>7.828</b>	7.892	7.934	7.930	7.955	7.970	7.981	8.003	8.004	8.014			8.028	8.029		
16.5				7.930	7.953		7.979	7.997	8.001				8.022	8.024		
17.0							7.973	7.991	7.994				8.013			
17.5							7.963									

<sup>1</sup> Values enclosed in boxes were significantly lower than the mean of other measurements at the same depth.

**Table B-8. Ancillary Observations recorded during the Receiving-Water Survey on 3 October 2006**

Station	Location		Diffuser Distance (m)	Time (PDT)	Air Temperature (°C)	Cloud Cover (%)	Wind Avg (kt)	Wind Max (kt)	Wind Dir (from) (°T)	Swell Ht/Dir (ft/°T)	Secchi Depth (m)
	Latitude	Longitude									
1	35° 23.250' N	120° 52.514' W	95.9	07:33:26	11.8	60	0.5	1.0	ESE	1-2/W	7.0
2	35° 23.229' N	120° 52.505' W	54.6	07:36:29	12.0	60	0.4	0.7	ESE	1-2/W	7.0
3	35° 23.207' N	120° 52.505' W	15.6	07:40:02	11.5	60	0.8	1.3	ESE	1-2/W	7.0
4	35° 23.186' N	120° 52.513' W	26.6	07:44:46	12.2	60	0.2	0.5	ESE	1-2/W	9.5
5	35° 23.163' N	120° 52.506' W	66.5	07:47:47	11.7	60	1.5	2.3	ESE	1-2/W	8.0
6	35° 23.144' N	120° 52.507' W	101.5	07:51:48	12.0	60	0.9	1.5	ESE	1-2/W	7.5
7	35° 23.195' N	120° 52.565' W	93.0	07:57:00	12.3	50	0.6	1.2	ESE	1-2/W	7.5
8	35° 23.199' N	120° 52.544' W	59.5	08:00:43	12.6	50	0.6	1.1	ESE	1-2/W	7.5
9	35° 23.199' N	120° 52.520' W	24.5	08:05:07	12.3	50	1.4	2.2	ESE	1-2/W	8.5
10	35° 23.202' N	120° 52.486' W	28.0	08:10:22	12.6	50	1.4	2.4	ESE	1-2/W	7.5
11	35° 23.199' N	120° 52.467' W	56.5	08:13:23	12.8	50	1.1	1.3	ESE	1-2/W	7.5
12	35° 23.194' N	120° 52.437' W	102.8	08:17:32	12.8	50	1.4	1.8	ESE	1-2/W	7.0
13	35° 23.171' N	120° 52.519' W	56.4	08:28:47	13.3	50	0.9	1.1	ESE	1-2/W	8.0
14	35° 23.219' N	120° 52.532' W	56.8	08:24:08	12.8	50	1.0	1.2	ESE	1-2/W	7.0
15	35° 23.223' N	120° 52.485' W	53.7	08:21:08	13.0	50	0.2	0.8	ESE	1-2/W	7.5
16	35° 23.179' N	120° 52.475' W	58.3	08:33:30	13.3	50	0.6	0.9	ESE	1-2/W	7.5

There was no visual expression of the effluent plume at the sea surface. Neither odors nor debris of sewage origin were observed at any time during the survey.

Tidal Conditions (Pacific Daylight Time)

Low Tide: 02:11 -0.20 ft  
 High Tide: 08:47 4.39 ft  
 Low Tide: 14:05 1.92 ft  
 High Tide: 20:01 5.47 ft