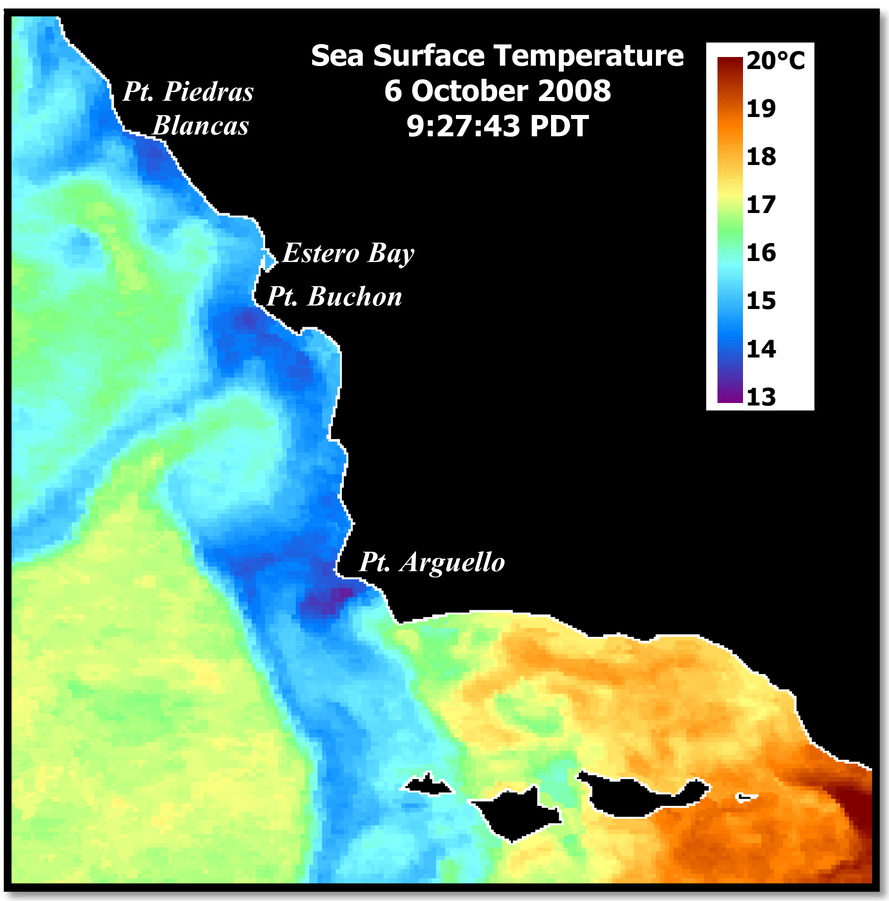
City of Morro Bay and
Cayucos Sanitary District

OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING OCTOBER 2008 SURVEY



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Report to

City of Morro Bay and
Cayucos Sanitary District

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OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING October 2008 SURVEY

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November 2008

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

1 November 2008

Reference: Quarterly Receiving-Water Report – October 2008

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on Tuesday, 7 October 2008. This fourth-quarter survey assessed the effectiveness of effluent dispersion during fall 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 five of the six seawater properties at three of the sixteen sampling stations. Most of these stations were located southeast of the diffuser structure in a direction consistent with plume transport by prevailing currents. The anomalies in four of the six seawater properties were generated by the upward displacement of ambient seawater entrained within the rising effluent plume. Although variations in salinity captured the presence of wastewater constituents, computed dilutions appreciably exceeded those anticipated by modeling and outfall design criteria. All of the measurements were indicative of low organic loading within the discharged wastewater, and of an outfall operating as designed to achieve acceptable effluent dilution levels.

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.

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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 originally issued to the MBCSD in March 1985. The permit was issued by Region IX of the U.S. Environmental Protection Agency (USEPA) and the Central Coast California Regional Water Quality Control Board (RWQCB). Following extensive evaluation processes, the permit has been re-issued twice, once in March of 1993 (RWQCB-USEPA 1993ab) and again in December 1998 (RWQCB-USEPA 1998ab).

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 water-quality monitoring performed on a seasonal basis. The four quarterly surveys are 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 7 October 2008. Specifically, this fourth-quarter survey captures ambient oceanographic conditions along the central California coast during the fall.

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 2008 field survey.

Both monitoring objectives were achieved through an evaluation of the water-column profiles and cross 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 promulgated by the NPDES discharge permit.

The October 2008 field survey was the fortieth water-quality 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 (≤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 recorded by the CTD[1] instrument package. Continuous deployment of the CTD between stations 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 onboard the

[1] 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 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 the 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 of the subsequent water-quality surveys (MRS 2000–2008), including the one described in this report. Moreover, improved navigation, in concert with the denser sampling pattern, more precisely delineated the lateral extent 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 that surrounds the outfall. Additionally, the amplitudes of the discharge-related perturbations can be better determined by the denser sampling pattern. The amplitudes of discharge-related salinity anomalies reflect dilution levels as the effluent plume disperses within receiving waters. These measured dilution factors lend timely insight into the present operational performance of the outfall and diffuser structure. As described in this report, the presence of dilute effluent south of the diffuser structure, which was continuing to undergo turbulent mixing within the moderately stratified water column, was delineated by the data collected during the October 2008 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.[2] 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 a 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.

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, the entrance to the Morro Bay National Estuary lies 2.8 km south of the discharge and 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

[2] 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 Water-Quality Sampling Stations within Estero Bay

discharge (Figure 1). Its presence further restricts the direct exchange of seawater between the discharge point and 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 densities. 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 all resulted from onshore non-point sources rather than the discharge of disinfected wastewater from the MBCSD outfall (MRS 2000–2008).

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 seawater 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.

Six other stations (7 through 12) are 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*" for modeling and regulatory purposes, it does not occur at a point of infinitesimal size. Instead, the discharge is distributed along a 42 m section of the seafloor. 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

Table 1. Target Locations of the Offshore Water-Quality Monitoring Stations

Station	Description	Latitude	Longitude	Closest Approach Distance[1] (m)	Center Distance[2] (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

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

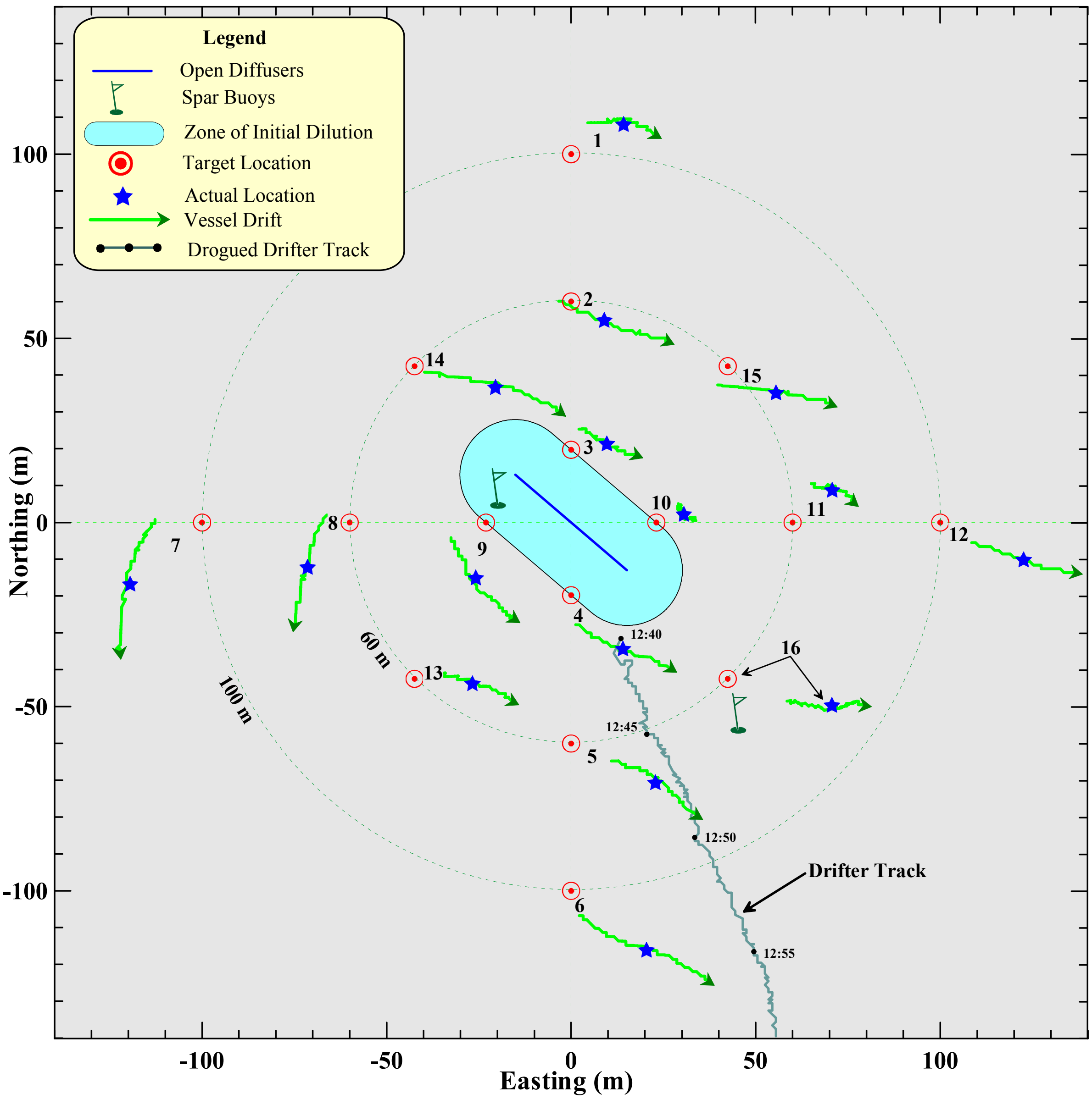

Figure 2. Offshore Water Sampling Locations on 7 October 2008

distance to the center of the diffuser structure. The "*closest approach*" distance can be considerably less than the centerpoint 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. The ability to discern small spatial separations among stations within the compact sampling pattern became feasible only after the advent of DGPS. The accuracy of traditional navigation systems such as LORAN or standard GPS is typically ±15 m, a span equal to half the total width of the ZID itself. 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 interfere with satellite signals, 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 to enhance offshore navigation. 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 extremely stable and accurate offshore navigational readings, 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 recording of DGPS readings allows precise determination of sampling locations throughout the vertical CTD profiling at individual stations. Knowledge of the precise location of individual CTD measurements relative to the diffuser position is crucial for accurate interpretation of the water-property fields. During any given survey, the actual sampling locations rarely 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 upon its approach to 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 a key consideration for compliance evaluations 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 2008 survey is apparent from the length of the green tracklines in Figure 2. These tracklines traced the horizontal location of the CTD instrument package as it was lowered to the seafloor. Their lengths reflect the station-keeping capability during the October 2008 survey. During the time it took the CTD to traverse the water column to the seafloor, which averaged 1 min 16 s, the instrument package moved as much as 39.3 m laterally (Station 6). Overall, however, the drift was 26.1 m when averaged over all the stations. This amount of drift was approximately double that of most surveys for the reasons described below.

The CTD trajectories shown by the green tracklines in Figure 2 reflect the complex interaction between surface currents, wind forces, and residual momentum as the vessel approached each station during the October 2008 survey. Generally, winds affect the vessel's ability to maintain station to a greater degree than does current flow. This made station keeping difficult because, as summarized in Table B–9, wind strength and direction varied substantially throughout the course of the October survey. Light winds from the south prevailed during the very beginning of the survey, but by the latter part of the survey, wind direction had shifted by more than 180 degrees to arrive out of the northwest, and average wind speeds had increased considerably. In contrast to the dramatic shifts in observed wind speed and direction, surface waves and a strong subsurface current were both directed toward the southeast throughout the survey.

Not surprisingly, during the first portion of the October survey (Stations 7 and 8), when winds were light, this southward directed current flow appears to have been the dominant influence on the CTD drift shown in Figure 2. However, as the winds shifted direction to arrive from the east and then from the north and northwest, strengthening as the survey progressed, their increasing influence can be seen in the drift record, most notably at Stations 5, 6, and 14 where the average recorded wind speeds were greatest.

The influence of vessel momentum was also evaluated at each station by examining the vessel's track immediately prior to the downcast. For example, the minimal vessel drift observed at Stations 10 and 11 was due to residual momentum as the vessel approached these stations from the southeast, which counteracted much of the influence of the prevailing flow field.

Drift in the CTD location during the downcasts often complicates the assessment of compliance with discharge limitations at stations close to the diffuser structure because 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 permit limitations apply to conditions after this initial mixing is complete. Although not the case during the October 2008 survey, in most prior surveys the CTD tracks at one or more of the near-field stations crossed the ZID boundary. As such, only the portions of those vertical profiles taken outside the ZID were used to assess compliance in these previous studies while all of the data recorded during the October survey were subject to the receiving-water limitations specified in the NPDES discharge permit.

Nevertheless, the measurements recorded close to the diffuser structure, within the ZID, have lent valuable insight into the outfall's effectiveness at dispersing wastewater. Without measurements recorded close to the diffuser, 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 that is now in use was instituted. Additionally, damaged or broken diffuser ports would be reflected by low dilution rates and measurements of concentrated effluent throughout the ZID.

Surveys prior to 1999 also predated the advent of DGPS. Consequently, the 26-m average drift experienced during sampling at individual stations in the October 2008 survey would not have been fully 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 reporting, and for historical consistency with past surveys, a single sampling location was also reported for each station during the October 2008 survey. The reported sampling locations coincided with the average CTD position 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.

FLOW FIELD

A satellite-tracked drifter documented the prevailing southeastward flow during the October 2008 survey. The drifter is designed to track the subsurface current, with little influence from the wind. As in past reports, its trajectory is shown by the grey line with black dots in Figure 3. Each dot along the drifter track represents a time span of five minutes. The drogued drifter was deployed near Station 4 at 12:40 PDT and was recovered an hour and thirty-four minutes later, at 14:14 PDT. Throughout the survey, a strong current carried the drifter rapidly southeast, and out of the survey area. During its deployment, the drifter traversed a total of 862 m toward the southeast (153°T) at an average speed of 15.3 cm/s or 0.3 knots.

Table 2. Average Coordinates of Vertical Profiles during the October 2008 Survey

	Time (PDT)				Closest Approach	
Station	**Downcast**	**Upcast**	**Latitude**	**Longitude**	**Range[1](m)**	**Bearing[2](ºT)**
1	13:28:39	13:29:47	35°23.2519' N	120°52.4867' W	99.7	17
2	13:34:02	13:35:13	35°23.2243' N	120°52.4814' W	48.5	30
3	13:38:12	13:39:28	35°23.2050' N	120°52.4932' W	22.6	41
4	13:43:56	13:45:09	35°23.1800' N	120°52.4839' W	21.3	183
5	13:48:27	13:49:40	35°23.1572' N	120°52.4786' W	58.1	172
6	13:52:55	13:54:15	35°23.1344' N	120°52.4785' W	103.2	177
7	12:55:12	12:56:49	35°23.1784' N	120°52.5824' W	108.4	254
8	13:01:11	13:02:28	35°23.1817' N	120°52.5512' W	61.5	246
9	13:05:21	13:06:56	35°23.1848' N	120°52.5102' W	28.1	221
10	13:09:23	13:10:34	35°23.1956' N	120°52.4829' W	21.7	45
11	13:13:24	13:14:35	35°23.1983' N	120°52.4511' W	59.7	69
12	13:17:54	13:19:12	35°23.1939' N	120°52.4142' W	107.5	88
13	14:01:49	14:02:56	35°23.1692' N	120°52.5152' W	50.5	221
14	14:06:56	14:08:14	35°23.2187' N	120°52.5034' W	24.5	347
15	13:23:36	13:24:51	35°23.2195' N	120°52.4578' W	62.9	41
16	13:57:23	13:58:25	35°23.1675' N	120°52.4525' W	66.5	123

[1] Distance from the closest open diffuser port to the average sampling location.
[2] Direction measured clockwise in degrees from true north from the closest diffuser port to the average sampling location.

The flow trajectory measured by the drogued drifter was inconsistent with the incoming flood tide that prevailed during the October 2008 survey (Figure 4). In the absence of other external influences, a flood tide normally induces a weak north northeastward flow in the survey region. However, flow is more often influenced by external processes, such as wind-generated upwelling, or by passing offshore eddies. For example, upwelling normally induces an offshore-directed surface flow toward the south southwest, which is in keeping with the observed southward flow component. However, the slight increase in shoreward drift that became apparent after 1 PM (Figure 3), around the time when the flood tide began increasing in strength (Figure 4), suggests that this too contributed to the observed flow. Thus, during the October 2008 survey, the prevailing southeastward flow measured by the drogue drifter was indicative of both a tidal influence and the moderate upwelling conditions that prevailed during October 2008 (Figure 5).

Cross-shore counter-currents are generated during upwelling conditions when warmer surface waters are driven offshore by the prevailing winds and are replaced by shoreward transport of cooler waters at depth. During the October 2008 survey, these warmer surface waters were restricted to a 6-m surface mixed layer situated above a series of sharp thermoclines that are apparent at most stations in the vertical temperature profiles (red lines in Figures A–1 through A–3). As described below, the drifter was drogued at 7 m, and thus reflected the shoreward transport occurring within the deeper waters below the surface mixed layer.

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 initiated by the stabilization of a high atmospheric pressure field over the northeastern Pacific Ocean.

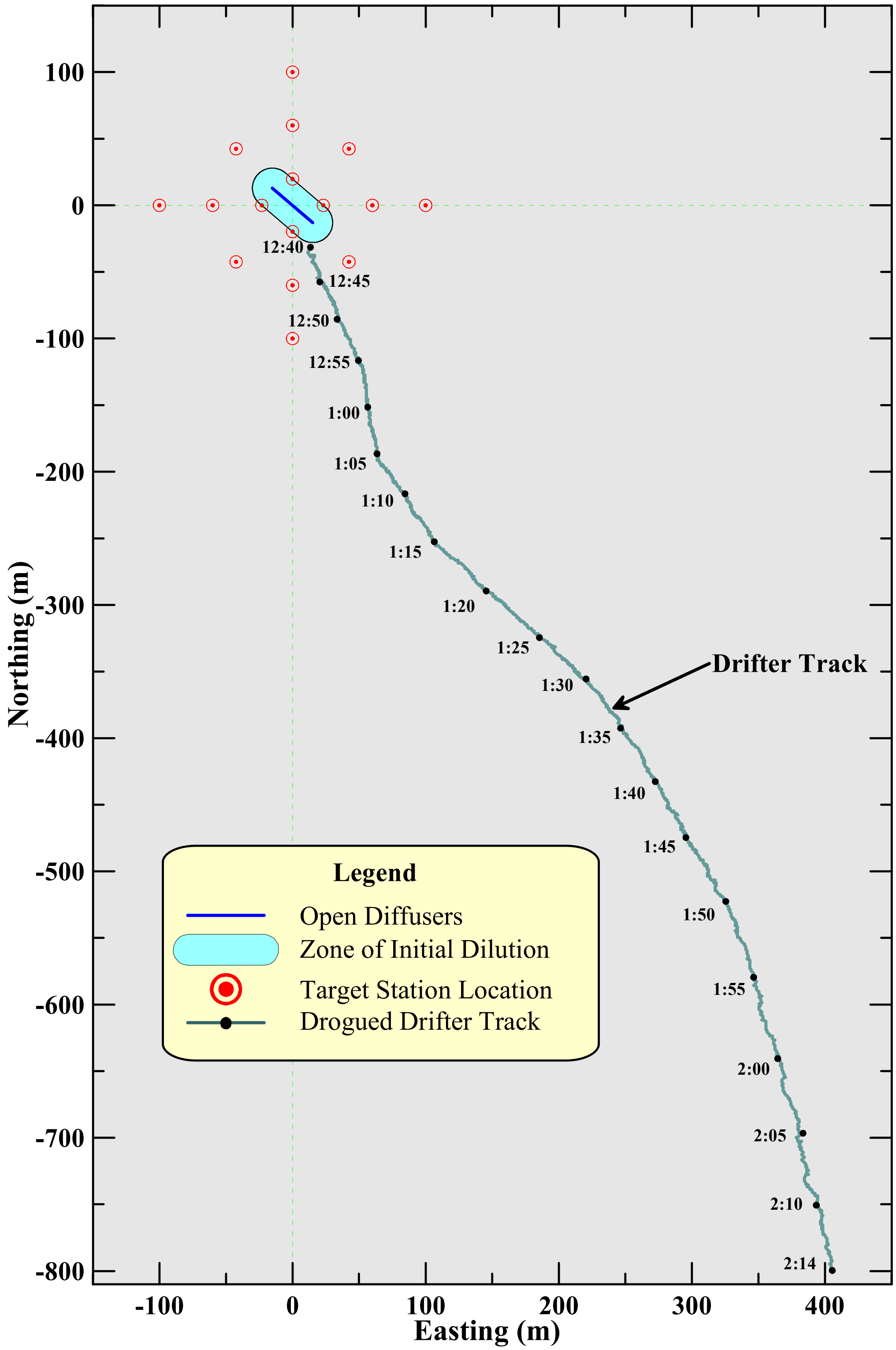

Figure 3. Drifter Trajectory on 7 October 2008

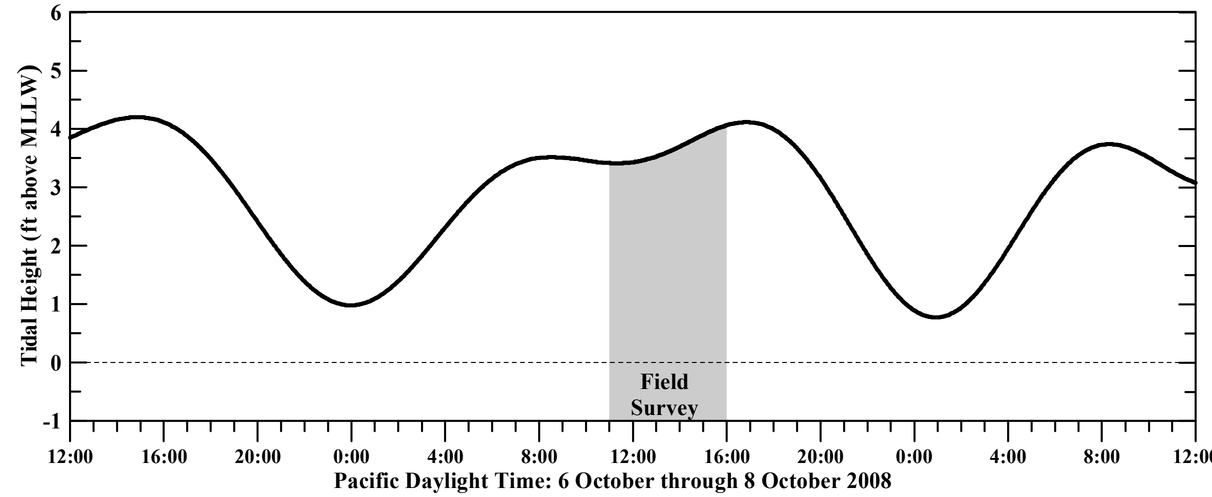

Figure 4. Estero Bay Tidal Level during the Field Survey of October 2008

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. The spring upwelling conditions in 2008 began in early March, and were particularly sustained and intense through the month of July (Figure 5).

Following a period of relaxation during much of August and September, winds strengthened along the central California coast again during early October 2008, resulting in cooler sea-surface temperatures close to the coastline at the time of the survey. The satellite image on the cover of this report depicts this cooler coastal water, with temperatures near 14°C, in dark blue. Farther offshore, surface water temperatures were as much as three degrees warmer, as delineated by the areas with yellow shading. The image also depicts another characteristic of upwelling, wherein jets of cooler coastal water extend

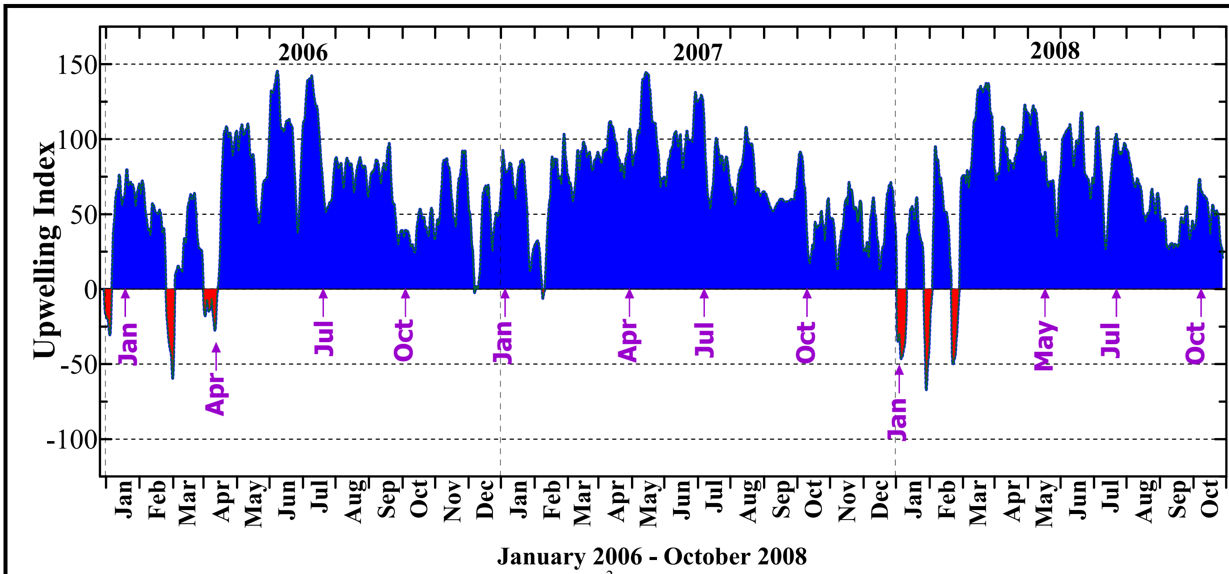

Figure 5. 30-Day Running Mean Upwelling Index ($m^3/s/100m$ of coastline) Offshore Estero Bay with the Dates of the Quarterly Water-Quality Surveys Indicated

offshore at major promontories, such as Point Piedras Blancas, Point Buchon, and Point Arguello. These features reflect the offshore transport of cool surface waters that were upwelled near the coast.

The image was recorded one day before the survey when skies were clear enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA's polar orbiting satellites. The cool, upwelling-induced temperatures present within Estero Bay, where the October 2008 survey was conducted, were consistent with the near-surface temperatures measured by the CTD during the survey, which averaged 14.4°C (Table B–1 in Appendix B).

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 7 October 2008. Dr. Douglas Coats of Marine Research Specialists (MRS) was the Chief Scientist while Captain Mark Tognazzini supervised vessel operations and Mr. William Skok acted as marine technician. Ms. Bonnie Luke and Mr. Tyler Eck, both of MRS provided general scientific support, collecting auxiliary measurements of meteorological and oceanographic conditions throughout the survey. These included Secchi depth measurements and standard observations for weather, sea conditions, and water clarity as recorded in Table B–9. Wind speeds and air temperatures were measured with a Kestrel® 2000 Thermo-Anemometer. These auxiliary observations were collected contemporaneously with the rapid water-column profiling that was conducted at each station using a CTD instrument package.

Auxiliary Measurements

At all stations, a Secchi disk was lowered through the water column to determine its depth of disappearance (Table B–9). 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. Secchi depths ranged between 6.5 m and 7.5 m during the October 2008 survey, reflecting the presence of a euphotic zone that extended to a depth of 13 m or greater at all stations, and spanned the entire water column at stations 1, 11, and 12. This unusually deep euphotic zone is not typical of upwelling conditions when increased primary productivity normally results in decreased light transmissivity in the upper water column.

Secchi depths provide less precise measures of light transmittance than 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 readings 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 survey vessel. To minimize the influence of variations in ambient light, attempts were made to measure Secchi depths in a consistent manner. However, changes in vessel orientation during the hydrocasts may have artificially reduced Secchi depths by 0.5 m at Stations 10, 14, and 15 due to partial shading of the sea surface by the vessel superstructure (Table B–9). Additionally, temporal drift in the measurements can be introduced as the sun rises in the sky, or as cloud cover changes. Nevertheless, Secchi depth measurements reflect general turbidity levels within the majority 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 2008 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 2008 sampling effort. In addition, the October 2008 survey was the fifteenth MBCSD survey to record the drifter position continuously throughout its deployment, rather than merely calculating the average flow velocity solely from the vessel position at the time of the drifter's deployment and recovery. Knowledge of the drifter trajectory throughout its deployment is of interest because it can reveal vagaries in the drifter's trajectory and speed that would otherwise go unnoticed. In particular, the slightly serpentine drifter path that was observed in the October 2008 survey (Figure 3) reflects the aforementioned tidal influence with increasing shoreward transport after 1:05 PM. As the drifter approached shallower waters at 1:30 PM, it turned southward again to follow local isobaths that parallel the shoreline.

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.

The CTD instrumentation receives regular maintenance and calibration. After the January 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 January 2001 survey indicated that the sensitivity of these probes had degraded because of an accumulation of marine growth. During the factory repair, both the pH probe and the electrolyte in the oxygen sensor were replaced. The entire CTD system was then calibrated 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 calibration. 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 2008 survey. In addition, as part of routine maintenance, the oxygen probe's membrane and electrolyte solution were replaced prior to calibration. The upper-bound DO calibration point at full saturation was established by immersing the CTD is 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 (Na_2SO_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.

The six seawater properties used to assess receiving-water quality in this report 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 readings, which are reported in Siemens/m. Density was derived from

Table 3. Instrumental Specifications for CTD Instrumentation Package

Component	Depth[1]	Units	Range	Accuracy	Resolution
Housing	600	—	—	—	—
Pump	3400	—	—	—	—
Pressure	680	Psia	0 to 1000	± 5.0	± 0.5
Depth	—	Meters	0 to 690	± 3.0	± 0.3
Conductivity	600	Siemens/m	0 to 6.5	± 0.001	± 0.0001
Salinity	600	‰	0 to 38	± 0.006	± 0.0006
Temperature	600	ºC	–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

[1] Maximum depth limit in meters

contemporaneous temperature (°C) and salinity data. It was expressed as 1000 times the specific gravity minus one, which is a unit of sigma-T (σ_t).

All three of the physical parameters (salinity, temperature, and density) were used to determine the lateral extent of the effluent plume. Additionally, they quantified the layering, or vertical stratification and stability of the water column, 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 characterized 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.

During the pre-cruise calibration, coefficients for the pH (alkalinity) sensor were determined from a linear regression of output voltage after immersion in five separate buffered solutions of known pH. Buffering solutions with a pH of 4±0.01, 6±0.01, 7±0.01, 9±0.01, and 10±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). The revised calibration coefficients 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.

Before deployment at the initial station, the CTD was held below the sea surface for a ten 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 all the stations were collected during single deployment of the CTD package by towing it below the water surface while transiting between adjacent stations. 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 DO and pH Sensors

The DO and pH sensors exhibited slight temporal drift during the October 2008 survey. Perceptible drift in the pH measurements has been consistently observed in prior water-quality surveys as the result of ongoing sensor equilibration during profiling. In contrast, drift in the DO sensor is normally imperceptible except during surveys when the range in the ambient DO field is small, as was the case during the October 2008 survey. For the pH sensor, 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 were also 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 2008 survey obviated the need for mid-survey adjustments for pH drift.

Previous additional attempts to mitigate sensor drift have included prolonging the soak time of the CTD prior to profiling. For the October 2008 survey, a soak time of ten minutes at the beginning of the survey was found to reduce, but not entirely eliminate sensor drift. Additionally, a tube filled with seawater was placed around the pH sensor for several hours prior to the survey to limit atmospheric exposure of the probe prior to deployment. This technique has been successful at further ameliorating sensor drift.

Temporal drift in the DO and pH sensors was responsible for slight, but perceptibly lower measurements at stations occupied during the initial stages of the CTD deployment. Beginning with Station 7, where the respective DO and pH offsets were –0.12 mg/L and –0.0141 pH units, equilibration-related reductions became steadily smaller as the survey progressed. The magnitudes of the offsets for each station were determined by fitting a piecewise continuous linear trend to values recorded near the sea surface, and computing the difference between the fitted values and values measured near the end of the survey, when the sensors had fully equilibrated.

Removal of artificial DO and pH trends is important because drift can potentially mask smaller-amplitude, discharge-related anomalies. The artificial pH reduction (–0.0141 pH) measured at the beginning of the CTD deployment is smaller than the instrumental accuracy (± 0.1 pH), but is more than twice as large as the instrumental resolution (±0.006 pH) reported by the probe manufacturer (Table 3). Similarly, the initial DO reduction (–0.12 mg/L) is close to the sensor's reported accuracy (±0.14 mg/L). Before correction, equilibration-related offsets at Stations 7 through 12 affected the amplitude of discharge-related anomalies and confounded the associated statistical tests for significance. Temporal detrending removed these instrumental anomalies. For example, the statistically significant reduction in pH near 16 m at Station 8, as highlighted in Table B–7, was an artifact of sensor drift that was eliminated after temporal detrending was applied (Table B–6).

RESULTS

The fourth-quarter water-quality survey began on Tuesday, 7 October 2008, at 12:40 PDT with the deployment of the drogued drifter. Subsequently, all water-column measurements were collected as required by the NPDES monitoring program (Tables 2 and B–9). Skies were clear and sunny throughout the survey, which ended at 14:14 PDT with the retrieval of the drogue drifter. Atmospheric visibility was clear along the ocean surface, with Morro Rock and the shoreline remaining visible throughout the survey. Sunset was at 18:38 PDT, well after sampling was completed.

Average wind speeds, calculated over one-minute intervals, varied widely over the course of the October 2008 survey. Average speeds ranged from 3.2 kt to 13.9 kt and corresponding peak-wind speeds ranged from 7.5 kt to 17.2 kt (Table B–9). This large variance in wind speeds occurred in conjunction with a the directional shift, strengthening as the survey progressed, as summarized in Table B–9. Light winds from the southeast prevailed at the beginning of the survey; however, by the latter part of the survey, the wind direction had shifted by almost 180 degrees.

Air temperatures were inversely correlated with wind speed, with the lowest air temperatures recorded near the end of the survey when winds from the northwest were strongest. Air temperatures ranged between 16.9°C and 27.0°C during the survey. Measured air temperatures were substantially warmer than the upwelling-influenced sea-surface temperatures observed at the time of the survey (14.4°C, Table B–1). Ambient sea state during the survey was fairly calm, but showed a combined influence from the increasing winds and a 4 ft to 6 ft swell arriving from the west-northwest.

No evidence of the discharge plume was visible near the sea surface or within the water column at any time during the survey. Accordingly, there was no visual evidence of floating particulates, oil and grease, or seawater discoloration associated with the discharge.

Beneficial Use

During the October 2008 survey, observations of beneficial use demonstrated that the coastal waters within Estero Bay continued to be utilized by wildlife and for recreation. Due to the advanced hour at which the survey took place, compared to previous surveys, more human uses of the beach and nearshore waters were observed, while fewer observations of foraging seabirds were noted. Small numbers of California brown pelicans (*Pelecanus occidentalis californicus)*, and western gulls (*Larus occidentalis*) were observed during transit to and from the survey area, and during the course of the survey. Pelagic and Brandt's cormorants (*Phalacrocorax*), which nest on Morro Rock, were also observed. Several pairs of least terns were (*Sternula antillarum brownii*) observed foraging in the survey area. Least terns are opportunistic feeders found in relatively shallow, nearshore waters. Southern sea otters (*Enhydra lutris*) and California sea lions (*Zalophus californianus*) were observed within the confines of the harbor, though none were seen during the survey itself. However, over the course of the survey, more than 50 pedestrians and several kayakers were observed utilizing the beach and nearshore waters north of Morro Rock.

Ambient Seawater Properties

Data collected during the October 2008 survey documented a moderately-stratified water column produced by the upwelling conditions present at the time of the survey. Upwelling results in an influx of dense, cold, saline water at depth that normally leads to a sharp thermocline, halocline, and pycnocline where temperature, salinity, and density change rapidly over short vertical distances. Under heavily stratified conditions, isotherms crowd together to form a thermocline that restricts the vertical transport of the effluent plume and reduces its dispersion.

Although the contrast between seawater properties at the sea surface and sea floor was large during the October 2008 survey, the moderate upwelling conditions did not generate a sharply defined thermocline. Instead, the vertical gradient in seawater properties was distributed throughout the water column below the 6-m deep mixed layer (Figures A–1 through A–3). Nevertheless, the vertical changes in all six of the ambient seawater properties were consistently indicative of upwelling-induced stratification. For example, the shape of the temperature profile (red line) at individual stations closely matched the shape of the DO profile (dark blue line), and to a lesser extent, the pH profile (olive-colored line). Similarly, the general decrease in temperature, DO, and pH with increasing depth was mirrored by the density profile (black lines), with its steady increase with depth below approximately 6 m. Although not as consistent as density, salinity (green line) and transmissivity (light-blue line) also exhibit a general increase with depth below the mixed layer.

At some stations, the vertical differential was largely produced by two distinct thermoclines, one immediately below the mixed layer, and another immediately above the seafloor. Double thermoclines are rare and usually arise when an especially cold and dense watermass moves shoreward within a thin layer above the seafloor. This benthic watermass is often associated with increased turbidity from surficial sediments resuspended by the turbulence generated by bottom currents. This particle-rich bottom nepheloid layer (BNL) is a widespread phenomenon on continental shelves (Kuehl et al. 1996) and has occasionally seen during other offshore water-quality surveys conducted for the MBCSD.

Regardless of the presence of sub-layers at depth, the large vertical contrast in ambient seawater properties observed during the October 2008 survey resulted from the juxtaposition of two very different watermasses. The uniform watermass near the sea surface was subjected to wind- and wave-induced stirring which mixed its seawater properties uniformly throughout the surface mixed layer. Its properties were also influenced by insolation, which warmed the seawater; by rapid oxygen equilibration with the overlying atmosphere, which saturated the seawater with DO; and by primary production (photosynthesis) by phytoplankton that thrive on the nutrients that were brought close to the surface by upwelling, which increased the near-surface turbidity and pH.

In contrast, the characteristics of the watermass within and below the thermocline reflected its deeper, offshore origins. Upwelling moved this cold, dense, watermass shoreward from great depths to replace the nearshore surface waters that were driven offshore by southeastward directed winds. At depth, DO concentrations were comparatively low because photosynthesis was largely limited to the upper portions of the euphotic zone, and because biotic respiration and decomposition had slowly depleted oxygen levels in the deep watermass during the period since its contact with the atmosphere. Biotic respiration and decomposition also produced dissolved CO_2 (carbonic acid), which resulted in measurably lower pH (more acidic) levels within the watermass.

The slightly higher salinity associated with the deep watermass arises from its origins in the Southern California Bight. These saline waters are carried northward below the sea surface by the Davidson Undercurrent. In contrast, surface salinity within Estero Bay is largely influenced by the diffuse, southward-flowing California Current, which represents the eastern limb of the clockwise-flowing gyre that covers much of the North Pacific Ocean. Before turning south to form the California Current, sub-arctic surface water is carried along at high latitudes where it is exposed to high precipitation and low evaporation. As a result, the surface waters of the California Current are characterized by a seasonably stable low salinity (32‰ to 34‰). Thus, the overall vertical contrast in salinity reflected by the green lines in Figures A–1 through A–3 results from this difference in watermass origin, with low salinity seawater carried south from northern latitudes by the California Current in the upper mixed layer, and more saline waters that originated to the south at depth.

Interpretation of the shape of the vertical profiles of salinity at some stations is complicated by distinctive zigzags that are not evident in other seawater properties. In some cases, the amplitude of these isolated zigzags is as large as the overall salinity contrast between the two watermasses. These salinity spikes do not reflect actual conditions but are instrumental artifacts that arise when the CTD crosses a sharp thermal interface. Some of the larger erroneous salinity spikes also manifest themselves in the vertical density profiles (black lines). Unless properly identified, salinity spikes can be misinterpreted as the signature of the effluent plume, which is characteristically low in salinity.

For example, the large spike at 7 m at Station 5 is particularly apparent in the salinity profile shown by the green line in the bottom left frame of Figure A–1. Its amplitude was large enough to also influence the corresponding density measurement, shown by the black line in this figure. The spiking resulted in a reported salinity measurement that was significantly lower than the average ambient salinity at that depth (bold number surrounded by a thick box in Table B–2). An even larger spike was generated by the rising effluent plume at Station 9, where it compressed the deep thermocline. A series of large spikes in both density and salinity (black and green lines in the middle left frame of Figure A–2) occurred as a result of the especially sharp vertical temperature gradient between 13 m and 15 m. Consequently, the negative salinity anomalies generated between 13 m and 14 m were statistically significant (Table B–2) and the large, spike-induced modification of the reported salinity measurements at that location overwhelmed any small salinity reductions that may have been associated with the presence of dilute wastewater.

As with the salinity profiles, the vertical variation in transmissivity departed from that of the other seawater properties, namely, it exhibited a distinct decline just above the seafloor at most stations. As described above, this decline was associated with increased turbidity within the BNL that was caused by the resuspension 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. Its presence is not apparent at some stations because the thickness of this thin BNL is variable, and the deepest CTD measurements did not always penetrate into the BNL.

Lateral Variability

The influence of the effluent discharge can be best identified from localized anomalies in seawater properties, particularly salinity. In contrast to the isolated vertical profiles, discharge-related anomalies become especially apparent in vertical cross-sections, which highlight differences in seawater properties at adjacent stations. Accordingly, the salinity sections in the top frames of Figure A–4 and A–6 show the influence of the discharge at Stations 4 and 9. Vertical sections of most other seawater properties exhibit discharge-related anomalies at the same locations. However, in contrast to salinity anomalies, which tend to be vertically isolated, anomalies in other seawater properties have characteristics similar to the ambient seawater at depth. Anomalies were generated when this deep ambient seawater became entrained in the discharge plume and was displaced upward into the water column where the surrounding seawater characteristics presented a lateral contrast. Thus, these other anomalies were not generated by the presence of dilute wastewater particulates, but by the upward displacement of ambient seawater at depth.

The cross-sections show that under the stratified conditions that were present during the October 2008 survey, both entrainment-generated and wastewater-induced anomalies became apparent when seawater properties measured at the same depth level were compared at adjacent stations. Because of this, the analysis of lateral variability in seawater properties forms the basis for assessments of water-quality impacts in this report. 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. For example, 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. These different depth references are used 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–8. 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, which is 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–8 by bold typeface enclosed in boxes.

Based on those statistical hypothesis tests, significant departures from mean conditions were found to occur in only two of the six seawater properties measured, namely, salinity and transmissivity. Out of the 481 salinity observations, only eight represented statistically significant departures from ambient conditions (Table B–2). Additionally, of the eight statistically significant salinity anomalies, only the anomalies at Stations 9 and 13 (Perturbations P2 and P3 in Table 4) were actually related to the presence of dilute effluent. However, the measurements at these stations, along with the remaining statistically significant anomalies, were impacted by salinity spiking. Salinity spiking is a common occurrence in CTD measurements collected within the upper-ocean thermocline, and spiking is routinely observed in MBCSD surveys conducted when the water column is well stratified (MRS 2001–2008). As alluded to in the previous section, salinity spikes are artificially introduced when the CTD instrument package crosses a sharp thermal interface. Salinity is computed from conductivity and temperature readings from probes that do not measure the same water parcel because the sensors are physically separated on the CTD instrument package. In addition, the sensors do not have the same response times. Consequently, when passing though sharp thermal gradients, the mismatch between the recorded conductivity and temperature measurements results in erroneous spikes in computed salinity. The sharper the thermal gradient, the larger the salinity spike. Although the spikes usually manifest as negative (low) salinity anomalies, positive anomalies can also occur, as documented by the statistically significant positive anomalies highlighted in italic font in Table B–2 at Stations 6 and 7. Because wastewater is far lower in salinity than seawater, these positive salinity anomalies could not have been induced by presence of dilute effluent.

As described above, these and other erroneous salinity spikes are apparent as zigzag patterns in the vertical profiles (green lines in Figures A–1 through A–3). However, these profiles reflect smoothed versions of the actual individual CTD measurements, and the spikes were actually larger and more localized than depicted in the figures. The figures and tables presented in this report were based on CTD measurements averaged over 0.5-m depth intervals. Although not shown here, high-resolution vertical profiles of raw temperature and salinity data were reviewed for evidence of salinity spiking. Spikes in the high-resolution profiles were apparent as highly localized outliers in salinity that occurred within the limited regions of the thermocline where the temperature changed abruptly. However, because the sharp thermal interfaces were generally less than 0.5 m thick, the salinity spikes appear as weaker, vertically distributed zigzag features in the lower-resolution salinity profiles included in this report.

Even without salinity spiking, the presence of statistically significant fluctuations unrelated to the discharge is expected from the nature of statistical hypothesis testing itself. From the definition of a 95% confidence level, one "*significant*" departure out of every 20 measurements should occur by chance alone. With 481 measurements examined for each of the parameters, it would not be surprising if a random 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 experiment-wise 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 experiment-wise 95% confidence level.

The statistical significance of the transmissivity anomalies near the seafloor at Station 8 (Table B–5) was an artifact of natural variations in the thickness of the BNL. Statistical tests for lateral differences in transmissivity near the seafloor randomly identified these three, vertically contiguous anomalies as significant because of the presence of a sharply defined BNL. The lateral transmissivity differences observed at Station 8 occurred because the turbidity interface associated with the BNL extended farther above the seafloor at that station than at adjacent stations.

Table 4. Discharge-Related Water-Property Anomalies[a]

Perturbation[b]	Station	Depth Range	Depth of Extremum	Property	Magnitude	Mechanism
P1 Dilution ≥ 597	4	8.0 to 12.0 m	10.0 m	Salinity	–0.056 ‰	Effluent
		6.5 to 9.0 m	7.0 m	Temperature	–0.24 ºC	Entrainment
		7.0 to 12.0 m	9.0 m	Transmissivity	–1.54 %	Entrainment
		6.0 to 10.0 m	8.5 m	DO	–0.23 mg/L	Entrainment
		7.5 to 12.0 m	10.0 m	pH	–0.022	Entrainment
P2 Dilution Indeterminate[c]	9	11.5 to 14.5 m	**13.0 m**	**Salinity**	**–0.097 ‰**[d]	Effluent/Spike
		12.5 to 15.0 m	14.0 m	Transmissivity	–2.49 %	Entrainment
P3 Dilution Indeterminate[c]	13	10.0 to 13.5 m	**12.0 m**	**Salinity**	**–0.064 ‰**[d]	Effluent/Spike
		11.0 to 12.5 m	12.5 m	Transmissivity	–1.38 %	Entrainment

[a] Anomalies shown in bold type were statistically significant.
[b] Perturbations are composed of a group of spatially coincident anomalies in several different seawater properties.
[c] The dilution could not be computed because the salinity anomaly was artificially increased by a large salinity spike in the instrumental measurements (see the discussion in the text).
[d] The reported amplitude of these negative salinity anomalies were artificially increased by salinity spiking.

Discharge-Related Perturbations

Despite the confounding influence of salinity spiking and the influence of BNL variations during the October 2008 survey, three distinct perturbations in seawater properties were unequivocally related to the discharge (Perturbations P1, P2, and P3 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 respective perturbations were observed at Stations 4, 9, and 13. Further evidence that the discharge was influencing seawater properties at these stations is provided by their proximity to, and their southerly location relative to the diffuser structure (Figure 2). The southeasterly drifter trajectory (Figure 2) indicates that portions of the hydrocasts at these stations would be in the path of plume transport, with Station 4 lying directly in the transport path. The weaker discharge-related Perturbations P2 and P3 were only observed in deepest portion of the hydrocasts at Stations 9 and 13. The CTD moved laterally more than 20 m to the east as it was lowered through the water column at these stations. Accordingly, only the deepest, most eastward measurements at these Stations captured the effluent signature on the westernmost portion of the plume.

As discussed above, the vertical distribution of seawater properties within and below the perturbations lends insight into which of two discharge processes were responsible for generating a particular anomaly. Anomalies identified with an “Effluent” mechanism in Table 4 were induced by the presence of dilute wastewater constituents, while the “Entrainment” mechanism indicates that the anomalies were generated by the upward displacement of ambient seawater that was entrained within the rising effluent plume. Effluent-induced anomalies only occur when the contrast between the properties of wastewater and seawater are large enough to remain apparent after rapid initial dilution. Because of the large difference between wastewater and seawater salinity, wastewater-induced anomalies are usually only apparent in that field alone, as was the case in the October 2008 survey.

Similarly, entrainment-generated anomalies are only apparent when the water column is well stratified, and the juxtaposition of deep seawater properties carried upward in the rising effluent plume provides a contrast with shallower seawater properties. Again, this was the case for the anomalies in all other seawater properties identified in the October 2008 survey, but particularly for transmissivity. The presence of a thin BNL containing markedly more turbid seawater was responsible for the transmissivity anomalies observed within all three perturbations (Table 4). In fact, within the weaker perturbations (P2 and P3), transmissivity was the only property with an entrainment signature. A substantial amount of mixing with ambient bottom water occurs within the turbulent discharge jets shortly after discharge. During the October 2008 survey, these turbulent jets mixed effluent with the substantially more turbid seawater contained within the BNL. As the plume rose through the water column, this entrained seawater formed a discernable lateral contrast with the high clarity ambient seawater above the BNL.

Entrainment-generated anomalies in seawater properties other than transmissivity were observed within Perturbation P1 because it was shallower than the other perturbations, and because the vertical gradients in those properties were more gradual than the sharp transmissivity interface at the margin of the BNL. The diffuse effluent plume had to travel farther upward in the water column for lateral contrasts in temperature, DO, and pH to become apparent. The signature of these entrainment-generated anomalies is apparent as an upward bowing of mid-depth isopleths at Station 4 in the middle frame of Figure A–4, and in the middle and bottom frames of Figure A–5. Their signature contrasts sharply with the vertically isolated nature of effluent-induced salinity anomalies shown in the top frames of Figure A–4 and A–6.

Initial Dilution Computations

The amplitude of the discharge-related negative salinity anomalies lends insight into the 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 under highly stratified conditions where trapping of the plume below the thermocline limited the mixing achieved during the buoyant plume's 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 beneath a thermocline and spread laterally with no further substantive dilution. A 9-m rise translates into a trapping depth that is 6.4 m below the sea surface.

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 objectives.

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

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

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.

By rearranging Equation 1, the actual dilution achieved by the outfall can also be determined from measured seawater anomalies. This measured dilution can then be compared with the critical dilution factor determined from modeling. Salinity is an especially useful tracer because it directly reflects the magnitude of ongoing dilution. 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:

$$D = \frac{-C_o}{\left(C_o - C_s\right)} \equiv \frac{-C_o}{A} \qquad \textbf{Equation 2}$$

where: D = the dilution ratio of the volume of seawater mixed with effluent,
C_o = the salinity of the effluent-seawater mixture after dilution by D,
C_s = the background seawater salinity (approximately 33‰), and
$A = C_o - C_s$ = the salinity anomaly.

The magnitudes of the observed salinity anomalies within the perturbations were used in Equation 2 to compute the actual dilution levels associated with the perturbations (left column of Table 4). No dilution level was computed for Perturbations P2 and P3 at Stations 9 and 13 because high resolution salinity data showed that severe spiking confounded the estimation of the magnitude of the anomalies, and rendered the dilution computation untenable. Disregarding the influence of salinity spiking, and perfunctorily applying Equation 2 to the reported salinity anomaly within Perturbation P2 (–0.097‰), results in a computed dilution (344:1) that still far exceeds the minimum initial dilution predicted by modeling. In reality, however, the salinity anomaly measured at Station 4 (–0.056‰) provides a more-accurate measure of dilution (>597:1) because this station was located closer to the diffuser structure (21 m) and directly in the path of plume transport, and there was no evidence of salinity spiking within the anomaly.

DISCUSSION

The dilution computations demonstrate that, during the October 2008 survey, the outfall was performing far better than designed, and was rapidly diluting effluent more than 597-fold just outside of the ZID area. This dilution level is four-and-a-half times greater than the 133:1 critical dilution used to establish end-of-pipe permit limitations on contaminant concentrations within wastewater discharged from the MBCSD treatment plant. Consequently, during the October 2008 survey, COP receiving-water objectives were being easily met by the chemical concentration limits promulgated by the NPDES discharge permit issued to the MBCSD.

Accordingly, receiving-water measurements collected during the October 2008 survey demonstrated that the wastewater discharge was in compliance with the numerical 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 2008 water-quality survey, and the discharge complied with all quantitative limits on seawater properties.

Receiving-water limitations only apply to statistically significant changes caused by the presence of effluent constituents beyond the ZID boundary. Although discharge-related changes in five of the six water properties were observed during the October 2008 survey, most resulted from the displacement of ambient seawater rather than the presence of effluent constituents. Moreover, none of the discharge-related anomalies were large enough to be considered statistically significant departures from mean conditions. The measurements collected during the October 2008 survey demonstrated that the receiving-water limitations were being met at mid-depth, just beyond the boundary of the ZID (Perturbation P1). Moreover, the discharge-related anomalies in temperature, transmissivity, DO, and pH recorded at that location were all generated by the upward displacement of ambient seawater, rather than the presence of dilute effluent. This is an important consideration because seawater limitations promulgated in the COP restrict attention to changes caused by the presence of waste materials, not the movement of ambient seawater.

NPDES Permit Limits

The seawater properties measured during the October 2008 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–8, the statistical significance of departures from mean conditions at a given depth level were determined with an analysis of variance that compared 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

Statistical analysis revealed a significant reduction in instrumentally recorded light transmittance at one of the sixteen monitoring stations during the October 2008 survey (highlighted in the box in Table B–5). This anomaly was not the result of the presence of turbid effluent, however, as it occurred near the seafloor at Station 8, which is located offshore (west) of the diffuser structure, and is isolated from the path of the southeastward plume transport (Figure 2). Thus, the observed decreases in transmissivity were not generated "*…as the result of the discharge of waste*" (SWRCB 1997). Instead, this anomaly probably represents a random increase in the thickness of the BNL at Station 8. Moreover, the transmissivity anomaly was situated at 15 m, which is below the 14-m euphotic zone that was present at that station, so even if it were related to the discharge, it would not have caused a significant "*…reduction in the transmittance of natural light….*"

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*." However, effluent samples routinely collected prior to discharge demonstrate that the treatment process is highly effective at removing oxygen-demanding material from the wastestream. As a result, reductions in DO caused by the presence of wastewater constituents have never been observed within the receiving waters as part of this monitoring program. Additionally, the DO limitation does not apply to reductions in DO caused by the movement of ambient waters, regardless of whether they were induced by the physics of the discharge. As described previously, the discharge-related DO reductions were all generated by the entrainment and upward displacement of ambient bottom water that was naturally depleted in oxygen. Although, the observed DO anomalies would not be subject to COP limitations for that reason alone, all of the DO measurements collected during the October 2008 survey also complied with the numerical limits on DO concentrations. Specifically, none of the DO concentrations measured during the October 2008 survey fell below the 5-mg/L minimum specified in the Basin Plan and the NPDES discharge permit. In fact, none of the 481 measurements collected fell below 6.22 mg/L. Similarly, none of the DO measurements can be considered "*…to be depressed more than 10 percent from that which occurs naturally*" because DO concentrations in ambient seawater at depth was at, or below, the concentrations observed in the discharge-related perturbation.

pH

None of the pH measurements in the October 2008 survey were found to be statistically significant. Additionally, the pH anomaly associated with Perturbation P1 was generated by the upward displacement of ambient bottom water, which is naturally low in pH, rather than the presence of wastewater constituents. As such, the numerical limits do not apply to the anomalous pH measurement. However, regardless of origin, the pH data still complied with the numerical limits specified in the discharge permit. Specifically, since the pH ranged between 7.94 and 8.03, none of the observations exceeded the lower (7.0 pH) and upper (8.3 pH) bounds on discharge-induced pH changes. Also, because the entire range in pH measurements was only 0.09 pH units, none of the measurements would be considered changed by "*…more than 0.2 pH units from that which occurs naturally*."

Temperature and Salinity

The total range in temperature of 2.1ºC across all observations was entirely due to naturally occurring vertical stratification. Even if changes this large were generated by the discharge, they would be considered too small '*…to adversely affect beneficial uses….*' The observed temperature range was less than the large-scale spatial variability in sea-surface temperature shown in the satellite image on the cover of this report. The statistically insignificant, discharge-induced decreases in temperature within Perturbation P1 resulted from the upward displacement of naturally occurring, cooler bottom water, and could not have been generated by the presence of warmer wastewater constituents. Additionally, although salinity anomalies provide the best tracers of discharged effluent, the actual maximum amplitude (≈0.1‰) of the largest salinity anomaly observed during the October 2008 survey was small compared to the seasonal and spatial differences in salinity that occur along the south-central California coast. For example, seasonal differences in average salinity at this location are seven times higher (0.64‰) than the spike-inflated salinity anomaly reported at Station 9 during the October 2008 survey. In any regard, the observed ranges in both the reported temperature (2.1ºC) and salinity (0.21‰) across all data collected during the October 2008 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 2008 survey complied with the receiving-water limitations specified in the NPDES discharge permit. The discharge-related anomalies in transmissivity, DO, and pH that were found within the water column at Stations 4, 9, and 13 were not statistically significant, and were caused by the upward displacement of ambient seawater. Nevertheless, they still met the numerical limits specified in the discharge permit even though those limits only apply to statistically significant changes caused by the presence of wastewater particulates.

In addition, salinity measurements collected just outside the ZID boundary demonstrated that discharged wastewater had achieved dilutions of more than 597-fold and was continuing to undergoing rapid mixing within the rising plume. This dilution level far exceeds the 133:1 dilution predicted by modeling for the entire dilution process. This confirmed that the diffuser structure and the outfall were operating better than would be expected from the modeling.

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APPENDIX A

Water Quality Profiles and Cross Sections

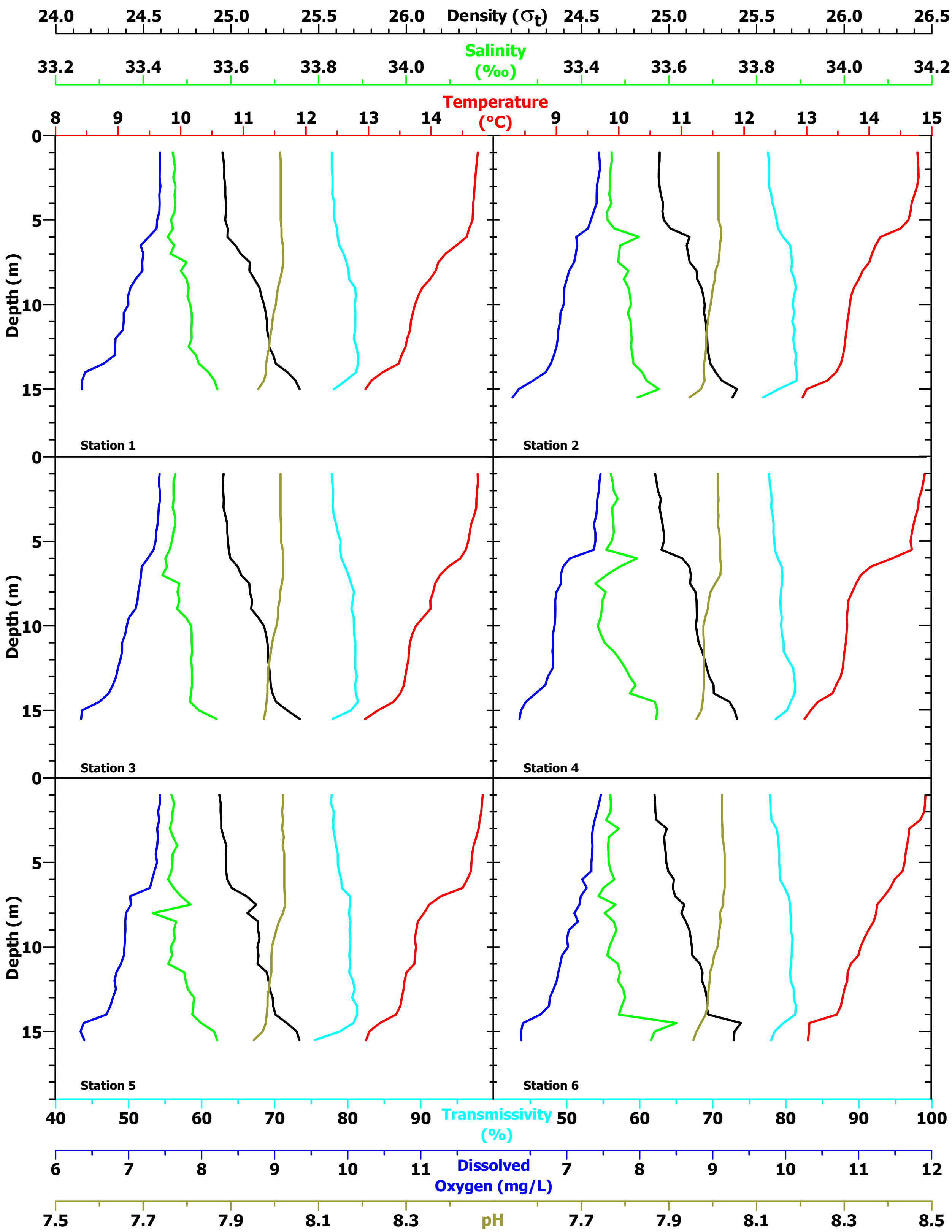

Figure A-1. Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 7 October 2008

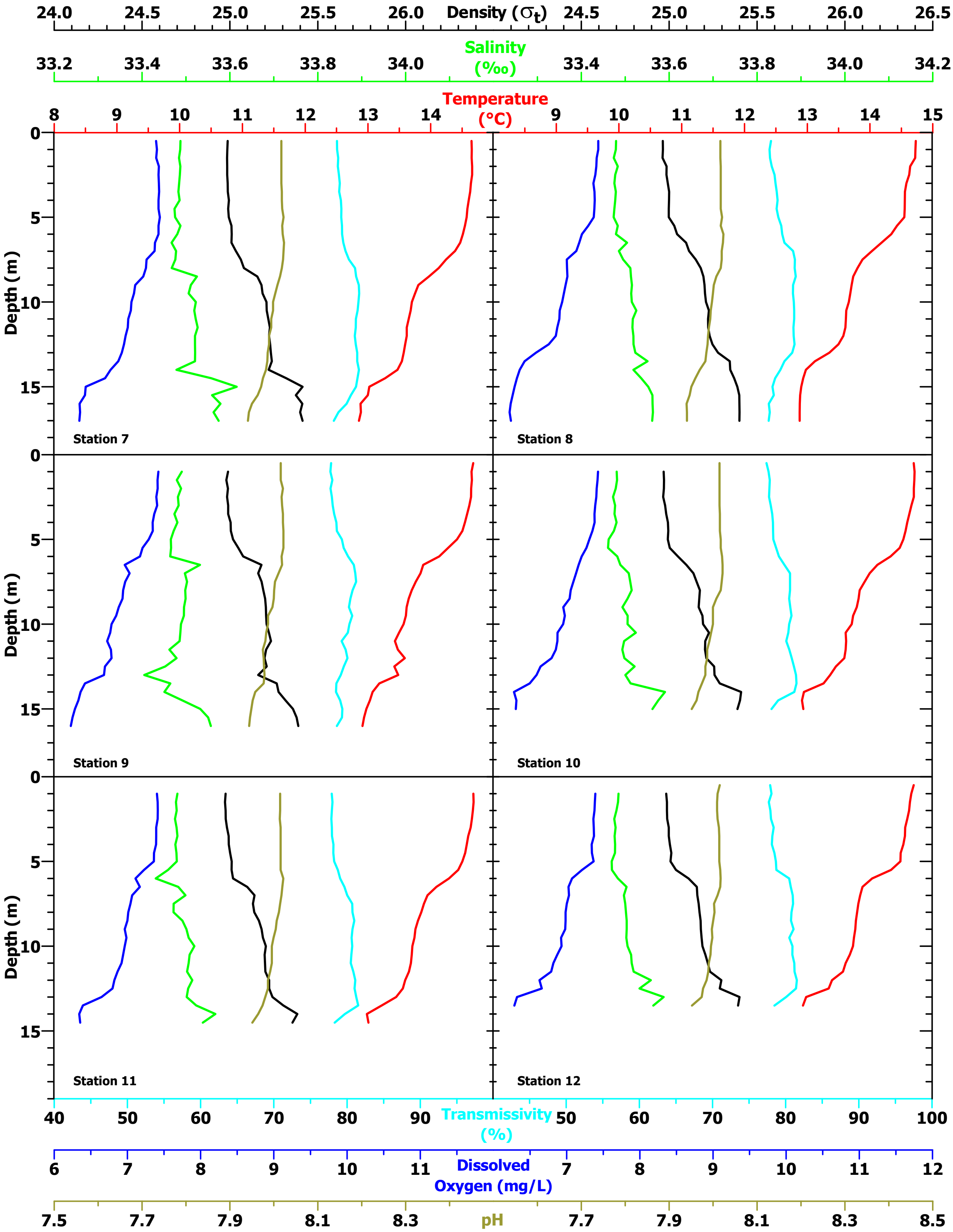

Figure A-2. Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 7 October 2008

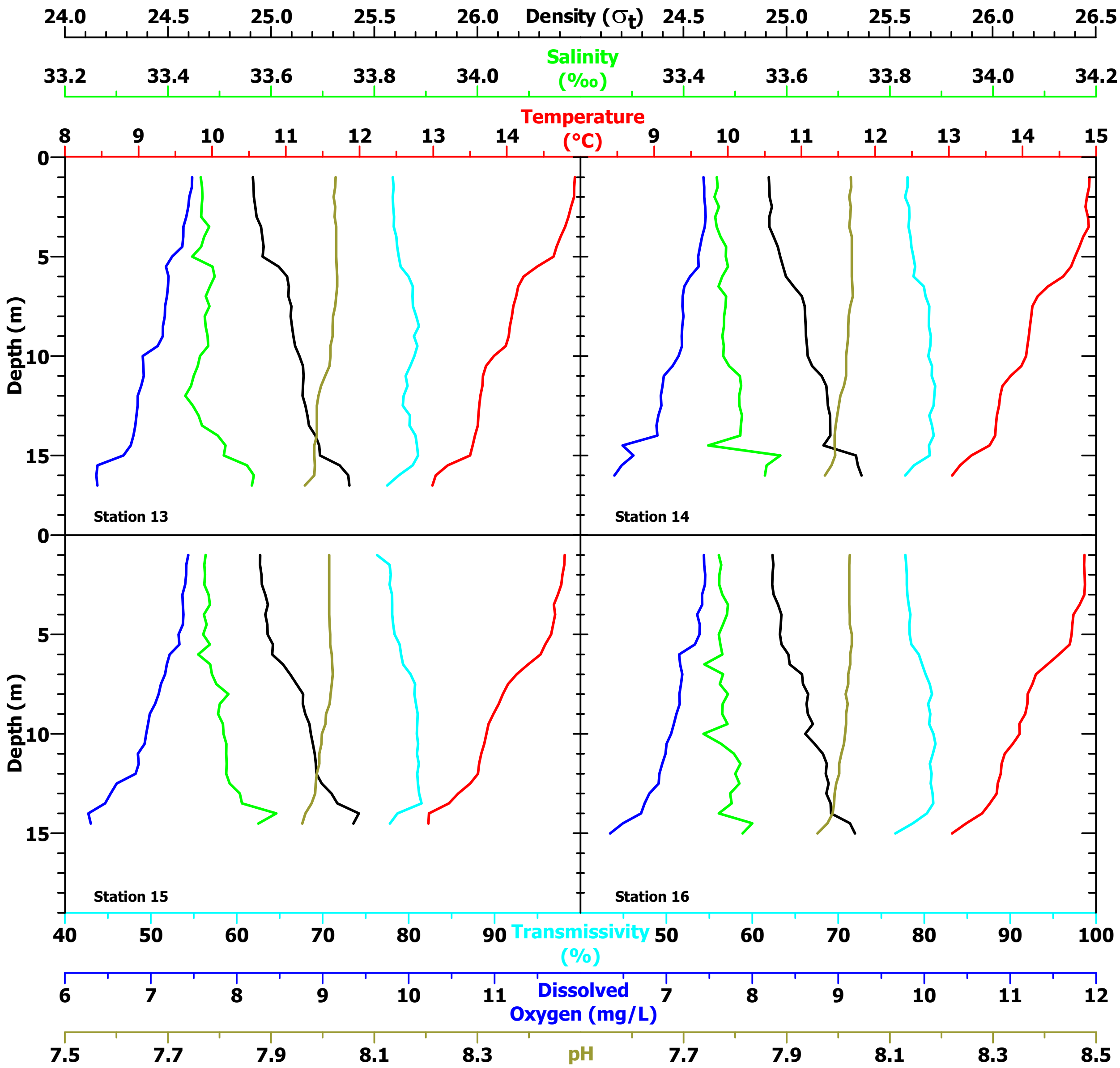

Figure A-3. Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 7 October 2008

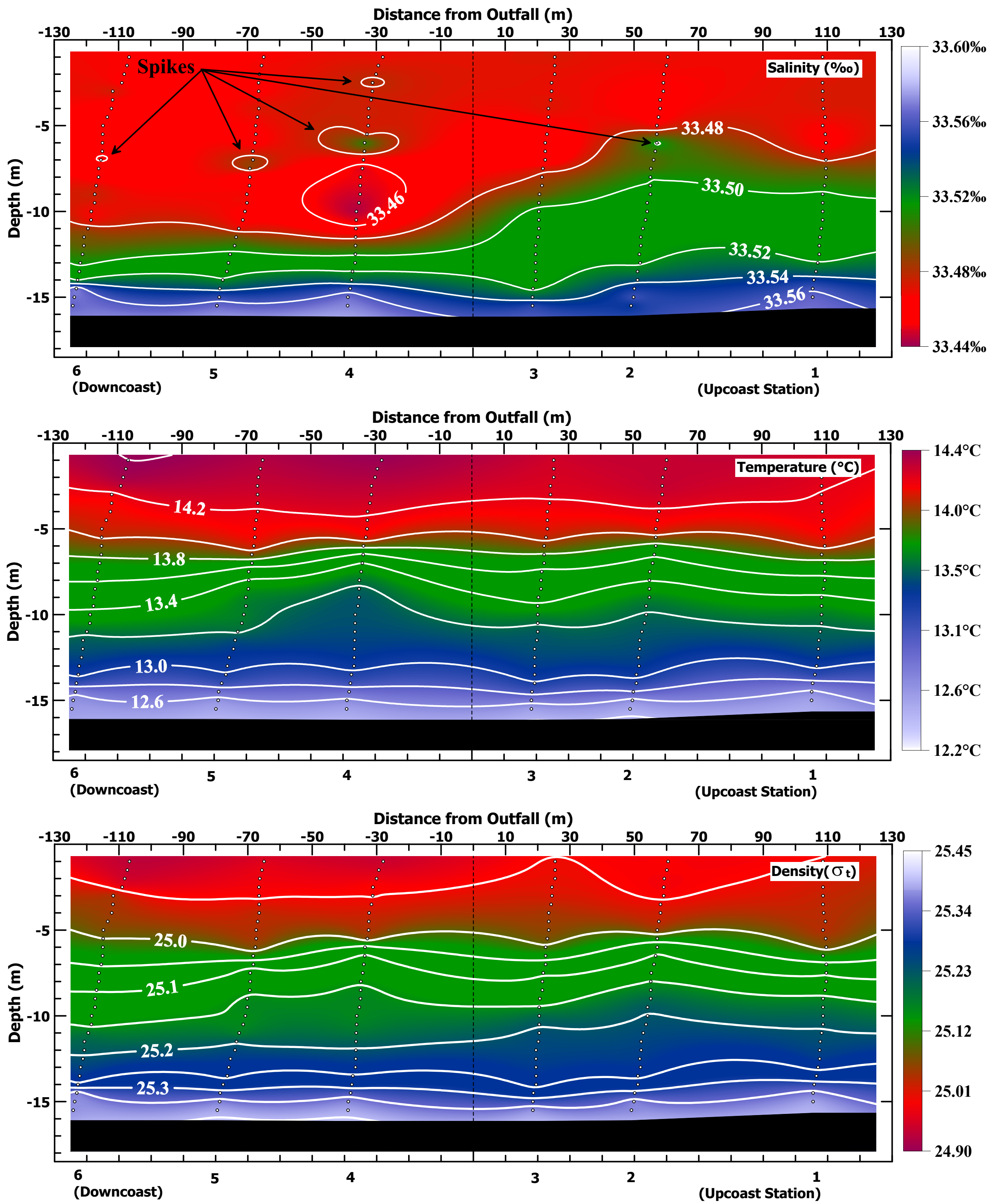

Figure A-4. Along-Shore Transects of Salinity, Temperature, and Density on 7 October 2008

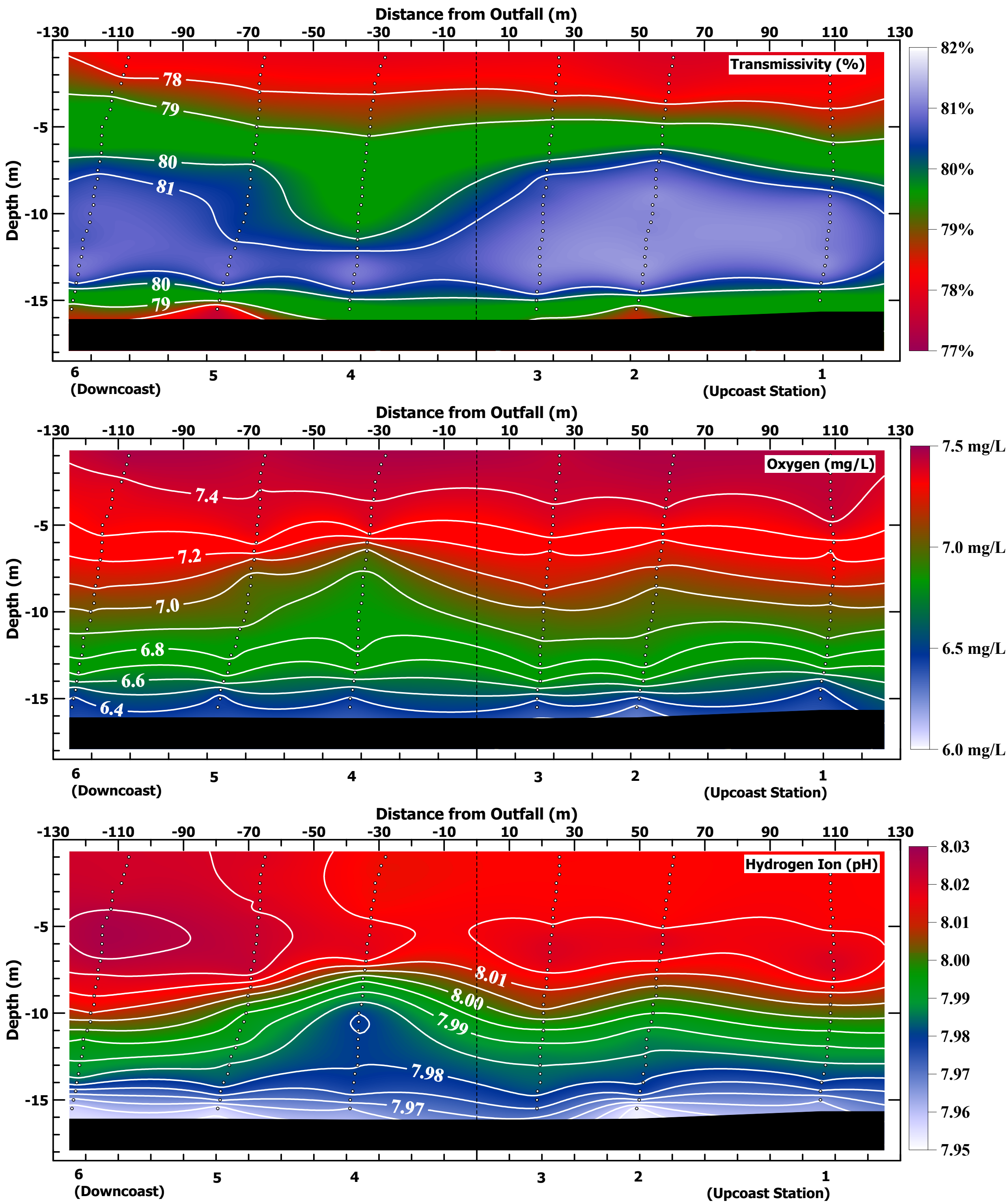

Figure A-5. Along-Shore Transects of Transmissivity, Oxygen, and pH on 7 October 2008

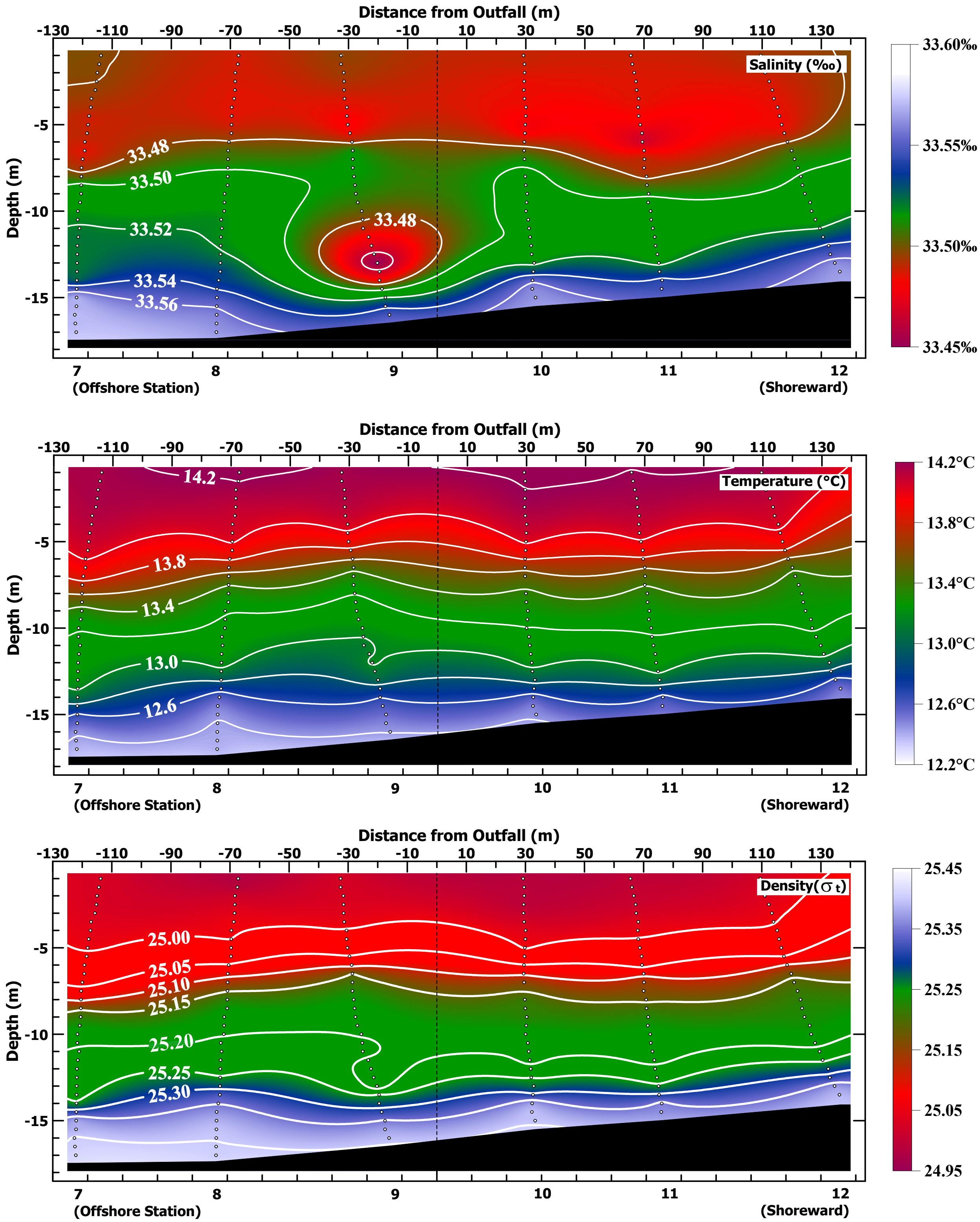

Figure A-6. Cross-Shore Transects of Salinity, Temperature, and Density on 7 October 2008

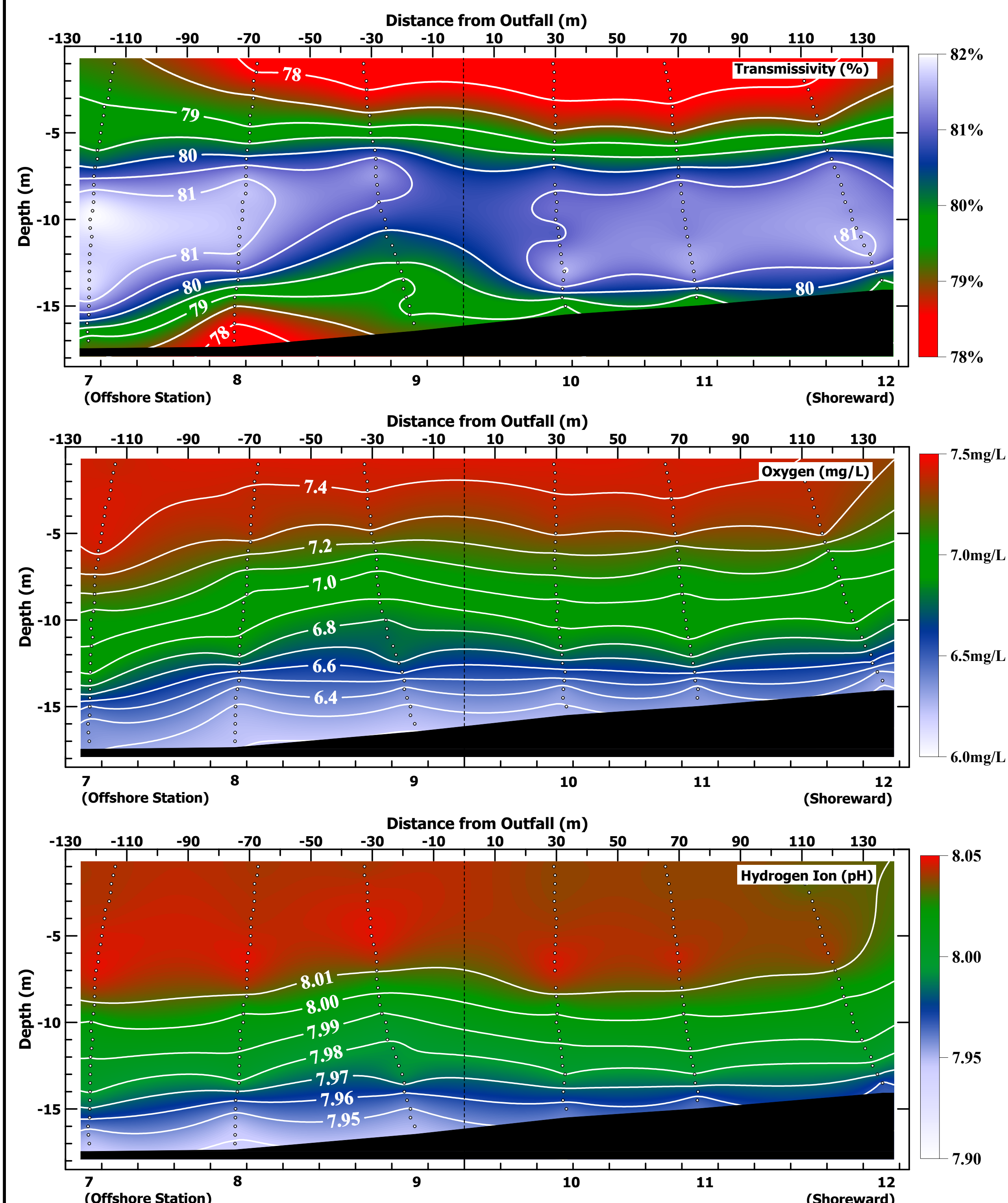

Figure A-7. Cross-Shore Transects of Transmissivity, Dissolved Oxygen, and pH on 7 October 2008

APPENDIX B

Tables of Profile Data and Standard Observations

Table B-1. Seawater Temperature on 7 October 2008

	Temperature (°C)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5							14.15	14.23	14.18	14.20		14.20				
1.0	14.25	14.27	14.24	14.39	14.32	14.40	14.15	14.22	14.15	14.21	14.18	14.16	14.42	14.41	14.29	14.34
1.5	14.23	14.28	14.25	14.37	14.31	14.39	14.15	14.22	14.16	14.21	14.18	14.14	14.41	14.40	14.28	14.34
2.0	14.22	14.29	14.24	14.34	14.30	14.38	14.16	14.14	14.15	14.20	14.17	14.12	14.41	14.37	14.25	14.34
2.5	14.21	14.29	14.22	14.29	14.28	14.31	14.16	14.12	14.14	14.20	14.16	14.09	14.37	14.36	14.24	14.35
3.0	14.19	14.27	14.22	14.28	14.26	14.14	14.14	14.08	14.12	14.16	14.14	14.06	14.34	14.39	14.19	14.34
3.5	14.19	14.22	14.19	14.24	14.22	14.13	14.13	14.06	14.08	14.13	14.10	14.06	14.29	14.40	14.14	14.28
4.0	14.17	14.18	14.14	14.21	14.18	14.10	14.11	14.05	14.05	14.09	14.08	14.03	14.23	14.33	14.15	14.19
4.5	14.17	14.16	14.12	14.18	14.16	14.08	14.08	14.05	14.01	14.07	14.05	13.99	14.18	14.27	14.13	14.18
5.0	14.16	14.13	14.09	14.16	14.15	14.07	14.07	14.05	13.92	14.03	14.01	13.98	14.13	14.21	14.10	14.17
5.5	14.11	14.00	14.06	14.18	14.14	14.03	14.05	13.93	13.78	13.97	13.94	13.84	13.91	14.16	14.02	14.14
6.0	14.07	13.68	13.97	13.87	14.08	13.91	14.01	13.84	13.63	13.83	13.79	13.54	13.73	14.05	13.96	14.00
6.5	13.90	13.60	13.78	13.52	14.01	13.84	13.97	13.68	13.38	13.62	13.59	13.38	13.65	13.84	13.79	13.84
7.0	13.73	13.55	13.64	13.36	13.66	13.74	13.89	13.53	13.34	13.49	13.45	13.34	13.63	13.71	13.63	13.68
7.5	13.62	13.50	13.57	13.29	13.47	13.63	13.74	13.38	13.26	13.42	13.39	13.32	13.59	13.63	13.51	13.63
8.0	13.57	13.40	13.53	13.23	13.39	13.61	13.63	13.30	13.20	13.34	13.35	13.29	13.57	13.62	13.44	13.57
8.5	13.48	13.34	13.49	13.17	13.29	13.57	13.47	13.23	13.15	13.32	13.30	13.28	13.54	13.60	13.39	13.57
9.0	13.36	13.26	13.49	13.16	13.26	13.49	13.30	13.21	13.12	13.29	13.26	13.27	13.53	13.59	13.32	13.54
9.5	13.30	13.21	13.37	13.14	13.24	13.42	13.25	13.19	13.11	13.23	13.24	13.24	13.49	13.57	13.25	13.46
10.0	13.24	13.19	13.26	13.15	13.26	13.36	13.20	13.16	13.07	13.21	13.21	13.23	13.32	13.55	13.22	13.46
10.5	13.21	13.17	13.20	13.14	13.24	13.33	13.18	13.12	13.00	13.11	13.20	13.18	13.22	13.49	13.19	13.37
11.0	13.18	13.15	13.16	13.13	13.23	13.21	13.15	13.12	12.93	13.12	13.18	13.11	13.18	13.34	13.15	13.26
11.5	13.17	13.14	13.14	13.11	13.11	13.16	13.12	13.11	12.98	13.11	13.15	13.07	13.17	13.23	13.12	13.22
12.0	13.12	13.12	13.14	13.09	13.08	13.15	13.12	13.07	13.09	13.09	13.09	12.89	13.14	13.20	13.11	13.21
12.5	13.09	13.10	13.11	13.08	13.06	13.10	13.09	13.00	12.92	12.96	13.06	12.84	13.13	13.18	13.00	13.16
13.0	13.03	13.08	13.09	13.04	13.03	13.08	13.07	12.85	12.98	12.86	12.95	12.48	13.11	13.15	12.84	13.15
13.5	12.98	13.05	13.07	12.97	13.01	13.05	13.04	12.62	12.68	12.76	12.72	12.43	13.10	13.14	12.71	13.06
14.0	12.73	12.97	13.01	12.91	12.94	12.98	12.97	12.48	12.57	12.45	12.48		13.07	13.13	12.44	12.95
14.5	12.55	12.83	12.90	12.68	12.68	12.54	12.77	12.43	12.53	12.42	12.51		13.04	13.05	12.44	12.74
15.0	12.45	12.50	12.65	12.56	12.51	12.54	12.52	12.41	12.47	12.44			13.00	12.81		12.54
15.5		12.43	12.45	12.47	12.46	12.52	12.50	12.39	12.44				12.70	12.65		
16.0							12.38	12.38	12.41				12.53	12.55		
16.5							12.39	12.38					12.49			
17.0							12.36	12.38								

Table B-2. Salinity[1] on 7 October 2008

	Salinity (‰)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5							33.488	33.479								
1.0	33.467	33.469	33.474	33.467	33.465	33.466	33.487	33.479	33.491	33.481	33.481	33.485	33.464	33.464	33.473	33.468
1.5	33.471	33.470	33.469	33.472	33.471	33.468	33.484	33.474	33.479	33.481	33.477	33.484	33.466	33.466	33.471	33.473
2.0	33.473	33.467	33.469	33.474	33.467	33.467	33.487	33.483	33.489	33.478	33.479	33.480	33.467	33.460	33.472	33.469
2.5	33.469	33.466	33.470	33.483	33.466	33.457	33.486	33.477	33.482	33.472	33.475	33.475	33.465	33.469	33.471	33.469
3.0	33.474	33.466	33.467	33.471	33.461	33.486	33.485	33.475	33.483	33.477	33.479	33.478	33.464	33.461	33.479	33.475
3.5	33.472	33.464	33.472	33.471	33.468	33.463	33.483	33.479	33.474	33.476	33.481	33.476	33.480	33.464	33.481	33.486
4.0	33.473	33.469	33.473	33.473	33.478	33.461	33.486	33.477	33.481	33.480	33.476	33.477	33.470	33.472	33.470	33.484
4.5	33.472	33.459	33.469	33.474	33.467	33.462	33.474	33.475	33.472	33.474	33.478	33.477	33.464	33.482	33.475	33.476
5.0	33.463	33.460	33.465	33.469	33.467	33.463	33.475	33.474	33.466	33.462	33.479	33.469	33.447	33.482	33.468	33.468
5.5	33.468	33.475	33.461	33.457	33.465	33.467	33.488	33.483	33.466	33.461	33.459	33.470	33.486	33.486	33.481	33.471
6.0	33.456	33.531	33.451	33.527	33.457	33.475	33.480	33.479	33.464	33.482	33.431	33.483	33.491	33.475	33.459	33.475
6.5	33.471	33.489	33.454	33.488	33.470	33.451	33.467	33.504	33.532	33.489	33.483	33.503	33.481	33.468	33.482	33.440
7.0	33.463	33.486	33.444	33.457	33.486	33.439	33.478	33.486	33.498	33.508	33.499	33.497	33.473	33.482	33.485	33.477
7.5	33.499	33.485	33.482	33.432	33.508	33.478	33.476	33.495	33.503	33.511	33.472	33.500	33.481	33.481	33.494	33.470
8.0	33.486	33.508	33.478	33.455	**33.422**	33.453	33.468	33.512	33.498	33.515	33.472	33.502	33.471	33.479	33.517	33.486
8.5	33.499	33.497	33.483	33.448	33.475	33.474	33.525	33.513	33.499	33.505	33.492	33.503	33.473	33.478	33.501	33.476
9.0	33.504	33.508	33.477	33.447	33.470	33.480	33.511	33.515	33.496	33.494	33.501	33.503	33.477	33.475	33.497	33.475
9.5	33.501	33.511	33.497	33.444	33.472	33.472	33.506	33.513	33.495	33.506	33.506	33.503	33.478	33.478	33.507	33.485
10.0	33.507	33.513	33.510	33.438	33.463	33.464	33.523	33.515	33.489	33.505	33.519	33.505	33.462	33.477	33.508	33.439
10.5	33.510	33.506	33.511	33.445	33.466	33.459	33.519	33.525	33.487	33.524	33.508	33.513	33.458	33.488	33.513	33.473
11.0	33.511	33.513	33.511	33.453	33.457	33.484	33.522	33.517	33.486	33.498	33.506	33.515	33.450	33.509	33.513	33.498
11.5	33.510	33.513	33.512	33.474	33.494	33.488	33.527	33.516	33.462	33.493	33.503	33.519	33.445	33.511	33.514	33.510
12.0	33.511	33.515	33.509	33.488	33.497	33.484	33.521	33.519	33.479	33.498	33.515	33.558	**33.434**	33.508	33.513	33.500
12.5	33.504	33.514	33.511	33.500	33.502	33.496	33.521	33.519	33.453	33.521	33.505	33.533	33.448	33.508	33.520	33.508
13.0	33.521	33.516	33.512	33.510	33.516	33.500	33.521	33.523	**33.405**	33.500	33.502	33.588	33.459	33.513	33.539	33.490
13.5	33.527	33.519	33.512	33.523	33.514	33.492	33.521	33.551	33.465	33.512	33.523	33.564	33.466	33.511	33.543	33.493
14.0	33.549	33.539	33.509	33.511	33.512	33.486	33.478	33.519	**33.451**	33.591	33.567		33.497	33.510	33.610	**33.468**
14.5	33.563	33.549	33.507	33.568	33.532	***33.618***	33.558	33.536	33.492	33.575	33.538		33.512	**33.448**	33.576	33.533
15.0	33.569	33.577	33.527	33.574	33.562	33.568	***33.615***	33.553	33.532	33.562			33.508	33.588		33.515
15.5		33.529	33.567	33.571	33.569	33.559	33.560	33.562	33.551				33.553	33.558		
16.0							33.578	33.562	33.557				33.567	33.558		
16.5							33.563	33.563					33.562			
17.0							33.574	33.561								

[1] Values enclosed in boxes differed significantly from the mean of other salinity measurements at the same distance above the seafloor.
The thinner boxes encompass values that were significantly higher than the mean of other measurements at the same distance above the seafloor.

Table B-3. Seawater Density on 7 October 2008

Depth (m)	Density (sigma-t)															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5							24.987	24.964								
1.0	24.951	24.948	24.957	24.921	24.933	24.918	24.986	24.965	24.990	24.969	24.975	24.983	24.911	24.915	24.947	24.932
1.5	24.957	24.946	24.952	24.930	24.941	24.921	24.984	24.962	24.979	24.971	24.972	24.987	24.915	24.917	24.947	24.937
2.0	24.962	24.943	24.955	24.937	24.940	24.923	24.985	24.985	24.989	24.970	24.976	24.987	24.916	24.919	24.953	24.932
2.5	24.961	24.941	24.958	24.954	24.944	24.929	24.984	24.985	24.984	24.965	24.976	24.989	24.923	24.929	24.955	24.931
3.0	24.967	24.946	24.956	24.947	24.944	24.988	24.987	24.992	24.991	24.977	24.983	24.998	24.930	24.917	24.972	24.938
3.5	24.967	24.954	24.968	24.955	24.957	24.973	24.988	25.000	24.991	24.983	24.993	24.998	24.952	24.917	24.985	24.959
4.0	24.971	24.967	24.979	24.964	24.973	24.977	24.995	24.999	25.004	24.993	24.994	25.004	24.957	24.938	24.973	24.975
4.5	24.971	24.963	24.979	24.971	24.970	24.982	24.990	24.998	25.005	24.994	25.001	25.013	24.964	24.958	24.982	24.973
5.0	24.966	24.970	24.982	24.971	24.972	24.986	24.994	24.998	25.018	24.992	25.011	25.007	24.959	24.970	24.983	24.969
5.5	24.981	25.009	24.986	24.957	24.973	24.996	25.009	25.029	25.048	25.003	25.010	25.039	25.036	24.984	25.009	24.976
6.0	24.980	25.118	24.997	25.076	24.978	25.028	25.010	25.045	25.076	25.050	25.018	25.111	25.077	24.998	25.005	25.010
6.5	25.026	25.102	25.039	25.116	25.003	25.023	25.009	25.097	25.180	25.098	25.099	25.157	25.085	25.035	25.057	25.015
7.0	25.055	25.111	25.058	25.125	25.088	25.035	25.034	25.113	25.161	25.138	25.140	25.160	25.084	25.075	25.092	25.075
7.5	25.107	25.118	25.104	25.120	25.143	25.088	25.062	25.152	25.181	25.156	25.131	25.168	25.098	25.089	25.123	25.081
8.0	25.105	25.158	25.107	25.151	25.093	25.072	25.080	25.180	25.190	25.175	25.139	25.173	25.095	25.090	25.155	25.106
8.5	25.133	25.161	25.120	25.158	25.155	25.096	25.156	25.194	25.201	25.172	25.166	25.179	25.101	25.094	25.154	25.098
9.0	25.162	25.186	25.115	25.159	25.155	25.117	25.179	25.202	25.204	25.168	25.181	25.180	25.108	25.094	25.166	25.104
9.5	25.173	25.198	25.154	25.160	25.162	25.125	25.186	25.204	25.206	25.189	25.188	25.184	25.117	25.100	25.186	25.128
10.0	25.188	25.203	25.187	25.154	25.151	25.131	25.208	25.210	25.209	25.193	25.205	25.190	25.137	25.103	25.193	25.091
10.5	25.198	25.202	25.200	25.161	25.156	25.134	25.210	25.226	25.222	25.227	25.198	25.206	25.155	25.125	25.203	25.137
11.0	25.204	25.210	25.207	25.170	25.152	25.177	25.219	25.221	25.234	25.205	25.199	25.220	25.157	25.171	25.211	25.177
11.5	25.205	25.214	25.212	25.190	25.205	25.191	25.228	25.222	25.206	25.203	25.202	25.232	25.155	25.194	25.217	25.196
12.0	25.215	25.219	25.211	25.204	25.214	25.189	25.223	25.231	25.197	25.211	25.224	25.297	25.152	25.198	25.220	25.190
12.5	25.216	25.221	25.218	25.216	25.221	25.207	25.228	25.246	25.210	25.256	25.224	25.288	25.166	25.201	25.246	25.205
13.0	25.241	25.227	25.223	25.230	25.237	25.216	25.233	25.278	25.161	25.258	25.242	25.400	25.177	25.211	25.293	25.194
13.5	25.256	25.237	25.226	25.255	25.240	25.216	25.239	25.344	25.266	25.288	25.304	25.392	25.184	25.212	25.321	25.215
14.0	25.322	25.267	25.237	25.257	25.253	25.224	25.220	25.348	25.277	25.409	25.384		25.215	25.213	25.425	25.216
14.5	25.368	25.302	25.256	25.346	25.318	25.412	25.320	25.370	25.316	25.403	25.357		25.233	25.180	25.400	25.308
15.0	25.391	25.388	25.320	25.374	25.374	25.374	25.414	25.388	25.359	25.389			25.237	25.337		25.332
15.5		25.364	25.391	25.390	25.390	25.370	25.375	25.399	25.380				25.332	25.346		
16.0							25.412	25.400	25.390				25.374	25.364		
16.5							25.400	25.401					25.379			
17.0							25.414	25.399								

Table B-4. Detrended[1] Dissolved Oxygen on 7 October 2008

Depth (m)	Dissolved Oxygen (mg/L)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5							7.39	7.43								
1.0	7.43	7.44	7.43	7.46	7.43	7.47	7.40	7.43	7.42	7.43	7.40	7.39	7.48	7.43	7.44	7.44
1.5	7.43	7.45	7.42	7.45	7.43	7.44	7.39	7.41	7.41	7.42	7.41	7.39	7.48	7.44	7.41	7.44
2.0	7.43	7.46	7.43	7.44	7.40	7.42	7.43	7.41	7.41	7.41	7.42	7.38	7.45	7.44	7.41	7.45
2.5	7.43	7.44	7.43	7.42	7.42	7.38	7.43	7.39	7.40	7.41	7.41	7.37	7.44	7.45	7.40	7.45
3.0	7.44	7.41	7.41	7.42	7.39	7.36	7.43	7.37	7.41	7.39	7.39	7.37	7.41	7.46	7.37	7.41
3.5	7.42	7.41	7.41	7.41	7.40	7.35	7.43	7.38	7.37	7.38	7.39	7.37	7.38	7.45	7.37	7.42
4.0	7.43	7.41	7.40	7.37	7.39	7.36	7.43	7.38	7.35	7.38	7.39	7.34	7.38	7.41	7.38	7.36
4.5	7.42	7.37	7.38	7.39	7.37	7.35	7.43	7.38	7.35	7.35	7.36	7.35	7.36	7.39	7.37	7.39
5.0	7.39	7.33	7.37	7.39	7.39	7.34	7.44	7.37	7.29	7.31	7.36	7.37	7.25	7.37	7.32	7.38
5.5	7.38	7.29	7.34	7.37	7.36	7.34	7.43	7.30	7.21	7.27	7.23	7.21	7.18	7.37	7.33	7.33
6.0	7.28	7.13	7.26	7.05	7.32	7.22	7.43	7.21	7.17	7.21	7.11	7.07	7.21	7.27	7.22	7.15
6.5	7.17	7.14	7.18	6.95	7.29	7.27	7.38	7.17	6.96	7.16	7.17	7.03	7.20	7.21	7.19	7.16
7.0	7.20	7.13	7.17	6.92	7.02	7.19	7.37	7.13	7.03	7.13	7.07	7.03	7.19	7.19	7.17	7.18
7.5	7.19	7.10	7.16	6.92	7.03	7.18	7.26	7.00	6.97	7.09	7.04	7.00	7.17	7.19	7.12	7.17
8.0	7.19	7.04	7.13	6.86	6.96	7.11	7.25	7.01	6.94	7.06	7.01	6.99	7.16	7.20	7.09	7.15
8.5	7.10	7.00	7.12	6.84	6.96	7.16	7.22	7.01	6.93	7.04	7.00	6.99	7.14	7.18	7.05	7.15
9.0	7.03	6.97	7.10	6.85	6.96	7.03	7.11	6.99	6.88	6.96	6.96	6.98	7.14	7.18	6.99	7.12
9.5	6.99	6.96	7.01	6.84	6.95	7.00	7.09	6.96	6.85	6.98	6.99	6.92	7.08	7.18	6.97	7.09
10.0	7.00	6.96	6.98	6.84	6.94	7.02	7.06	6.94	6.78	6.95	6.96	6.93	6.90	7.14	6.95	7.05
10.5	6.93	6.92	6.95	6.81	6.94	6.94	7.05	6.91	6.77	6.88	6.94	6.87	6.91	7.07	6.93	7.00
11.0	6.93	6.91	6.91	6.81	6.90	6.91	7.01	6.90	6.72	6.87	6.92	6.82	6.92	6.97	6.85	6.99
11.5	6.92	6.89	6.91	6.81	6.83	6.89	7.00	6.87	6.77	6.85	6.87	6.79	6.89	6.95	6.86	6.95
12.0	6.82	6.88	6.89	6.81	6.81	6.86	6.98	6.85	6.78	6.79	6.82	6.63	6.85	6.93	6.82	6.92
12.5	6.82	6.86	6.85	6.81	6.83	6.82	6.95	6.76	6.69	6.64	6.80	6.66	6.85	6.94	6.60	6.91
13.0	6.81	6.83	6.83	6.74	6.78	6.77	6.92	6.58	6.68	6.59	6.65	6.32	6.83	6.91	6.53	6.80
13.5	6.66	6.78	6.79	6.71	6.75	6.76	6.88	6.43	6.42	6.50	6.39	6.29	6.82	6.88	6.47	6.75
14.0	6.41	6.71	6.73	6.58	6.70	6.64	6.77	6.36	6.36	6.28	6.34		6.80	6.89	6.27	6.70
14.5	6.36	6.54	6.60	6.44	6.39	6.40	6.70	6.32	6.33	6.31	6.36		6.77	6.49	6.30	6.49
15.0	6.36	6.35	6.36	6.37	6.34	6.37	6.43	6.29	6.28	6.31			6.68	6.62		6.35
15.5		6.26	6.35	6.35	6.39	6.38	6.42	6.26	6.25				6.38	6.48		
16.0							6.35	6.24	6.23				6.37	6.39		
16.5							6.35	6.22					6.38			
17.0							6.34	6.24								

[1] Measured DO concentrations were corrected for temporal drift to account for ongoing equilibration of the sensor.

Table B-5. Light Transmittance[1] across a 0.25-m path on 7 October 2008

	Light Transmittance (%)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5							78.63	77.99	77.83	77.38		77.87				
1.0	77.85	77.55	77.83	77.68	77.81	77.85	78.65	77.79	77.73	77.64	77.92	78.06	78.15	78.06	76.33	77.82
1.5	77.83	77.71	77.89	77.79	77.71	77.88	78.80	77.85	78.00	77.82	78.01	77.70	78.25	78.06	77.78	77.90
2.0	77.85	77.66	77.98	77.92	78.09	77.93	78.75	78.09	77.74	77.77	77.92	77.92	78.14	77.76	77.92	77.97
2.5	77.93	77.67	77.96	78.06	78.05	78.05	78.88	78.47	77.94	77.73	77.87	77.99	78.20	78.23	77.79	77.97
3.0	77.92	77.70	77.94	78.02	78.02	78.73	79.00	78.62	78.04	77.96	77.93	78.35	78.30	78.26	78.07	78.03
3.5	77.89	78.00	78.10	78.20	78.23	78.94	78.94	78.78	78.25	78.15	77.95	78.18	78.27	78.17	78.08	78.19
4.0	78.20	78.17	78.43	78.32	78.38	79.02	79.17	78.89	78.55	78.24	78.16	78.11	78.57	78.41	78.09	78.38
4.5	78.14	78.53	78.66	78.32	78.64	79.11	79.23	78.76	78.60	78.27	78.14	78.45	78.67	78.52	78.22	78.27
5.0	78.18	78.74	79.03	78.46	78.65	79.08	79.20	78.99	79.29	78.32	78.25	78.65	78.85	78.73	78.38	78.30
5.5	78.55	78.95	78.97	78.51	78.79	79.18	79.30	79.39	79.55	78.69	78.75	78.73	79.06	78.94	78.95	78.50
6.0	78.62	79.61	79.13	78.90	79.10	79.21	79.33	79.54	80.16	79.07	79.07	80.47	79.99	78.75	79.13	79.36
6.5	78.84	80.61	79.66	79.45	79.20	79.85	79.48	79.84	80.92	79.83	79.64	80.70	80.50	79.94	79.35	79.74
7.0	79.45	80.75	80.10	79.55	80.31	80.37	79.78	81.02	81.13	80.60	80.02	80.96	80.45	80.16	80.22	80.16
7.5	79.85	80.84	80.46	79.49	80.35	80.59	80.27	81.25	81.25	80.60	80.70	81.02	80.51	80.59	80.76	80.62
8.0	80.13	80.75	80.87	79.33	80.16	80.65	81.08	81.22	80.76	80.59	80.75	80.78	80.89	80.56	80.66	80.91
8.5	80.19	81.18	80.68	79.26	80.39	80.75	81.25	81.36	80.46	80.47	80.99	80.73	81.20	80.52	80.85	80.44
9.0	81.02	81.36	80.51	79.28	80.27	80.68	81.61	81.02	80.27	80.64	80.75	81.08	80.63	80.77	81.05	80.70
9.5	81.12	81.13	80.83	79.44	80.39	80.92	81.67	80.99	80.72	80.79	80.63	80.49	81.03	80.72	81.00	80.57
10.0	80.97	80.95	80.84	79.37	80.32	80.83	81.58	81.12	80.32	80.47	80.72	80.94	80.67	80.48	80.95	81.06
10.5	81.05	81.17	80.89	79.46	80.22	80.81	81.46	81.16	80.12	80.35	80.60	80.91	80.18	80.90	81.11	81.31
11.0	81.03	80.88	81.06	79.71	80.36	80.71	81.20	81.15	79.26	80.07	80.51	81.18	79.65	80.88	80.97	81.01
11.5	81.01	81.24	81.07	79.71	80.20	80.60	81.19	81.05	79.81	80.50	80.86	81.21	79.87	81.27	81.18	80.64
12.0	80.85	81.03	81.02	80.32	80.73	80.66	81.07	81.09	80.07	80.83	81.12	81.52	79.42	81.18	81.01	80.85
12.5	81.19	81.15	81.02	81.01	80.97	81.08	81.19	81.21	79.57	81.14	81.03	81.42	79.33	81.10	81.09	80.74
13.0	81.43	81.39	81.27	81.14	80.60	81.09	81.39	80.90	79.14	81.41	81.26	80.05	80.15	80.58	81.23	80.97
13.5	81.40	81.28	81.01	81.27	81.30	81.38	81.40	79.83	78.54	81.48	81.53	78.47	80.11	80.91	81.51	81.04
14.0	81.16	81.50	81.14	81.22	81.28	81.26	81.62	79.27	78.50	81.17	79.71		80.80	81.12	78.72	80.30
14.5	79.72	81.49	81.42	80.67	80.79	79.66	81.42	78.54	79.07	78.96	78.32		80.96	80.54	77.85	78.69
15.0	78.14	79.05	80.44	80.15	78.90	78.48	81.22	**78.20**	79.37	78.08			81.11	80.63		76.64
15.5		76.91	77.96	78.65	75.52	77.98	80.52	**78.38**	79.31				80.46	78.80		
16.0							79.95	**77.68**	78.62				78.85	77.80		
16.5							78.84	77.84					77.54			
17.0							78.22	77.67								

[1] The values enclosed in the box were significantly lower than the mean of other transmissivity measurements at the same distance above the seafloor.

Table B-6. Detrended[1] pH on 7 October 2008

	Hydrogen Ion Concentration (pH)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5							8.017	8.017	8.016	8.015		8.015				
1.0	8.013	8.013	8.013	8.012	8.019	8.021	8.017	8.017	8.016	8.015	8.015	8.010	8.025	8.024	8.013	8.022
1.5	8.014	8.013	8.013	8.012	8.019	8.021	8.017	8.017	8.016	8.015	8.015	8.009	8.024	8.025	8.013	8.021
2.0	8.014	8.013	8.013	8.012	8.017	8.021	8.017	8.018	8.021	8.015	8.015	8.009	8.021	8.021	8.013	8.021
2.5	8.014	8.013	8.013	8.013	8.019	8.021	8.017	8.018	8.018	8.015	8.014	8.010	8.024	8.024	8.013	8.021
3.0	8.014	8.013	8.013	8.012	8.017	8.022	8.017	8.018	8.019	8.015	8.016	8.013	8.023	8.023	8.013	8.021
3.5	8.014	8.013	8.013	8.013	8.021	8.022	8.018	8.018	8.021	8.016	8.016	8.014	8.026	8.021	8.013	8.021
4.0	8.014	8.013	8.014	8.012	8.018	8.025	8.018	8.018	8.021	8.016	8.016	8.014	8.026	8.026	8.013	8.022
4.5	8.014	8.013	8.014	8.015	8.022	8.027	8.019	8.018	8.022	8.016	8.016	8.014	8.026	8.026	8.014	8.022
5.0	8.014	8.013	8.014	8.016	8.022	8.027	8.022	8.021	8.022	8.018	8.016	8.014	8.026	8.026	8.015	8.026
5.5	8.016	8.019	8.018	8.017	8.022	8.027	8.019	8.018	8.022	8.018	8.016	8.016	8.027	8.026	8.015	8.026
6.0	8.016	8.019	8.019	8.017	8.022	8.027	8.020	8.024	8.018	8.021	8.022	8.017	8.028	8.026	8.018	8.023
6.5	8.019	8.016	8.019	8.019	8.022	8.027	8.023	8.023	8.019	8.022	8.020	8.016	8.028	8.027	8.019	8.023
7.0	8.020	8.015	8.019	8.017	8.023	8.024	8.022	8.020	8.011	8.022	8.018	8.010	8.026	8.028	8.020	8.019
7.5	8.020	8.013	8.016	8.006	8.024	8.024	8.021	8.020	8.003	8.020	8.015	8.002	8.024	8.023	8.018	8.019
8.0	8.017	8.006	8.012	7.995	8.019	8.016	8.018	8.018	8.001	8.018	8.012	8.003	8.020	8.020	8.016	8.014
8.5	8.013	8.005	8.011	7.991	8.010	8.018	8.014	8.008	8.000	8.008	8.007	8.000	8.019	8.019	8.014	8.018
9.0	8.008	8.000	8.007	7.989	8.004	8.015	8.008	8.002	7.997	8.000	8.005	7.997	8.019	8.019	8.007	8.015
9.5	8.005	7.998	8.007	7.983	7.999	8.013	8.003	8.000	7.987	8.000	8.000	7.998	8.015	8.017	8.006	8.015
10.0	8.003	7.995	8.004	7.979	7.994	8.011	7.998	7.998	7.987	8.000	7.996	7.995	8.015	8.015	7.999	8.013
10.5	7.998	7.991	7.998	7.979	7.993	8.003	7.998	7.995	7.983	7.996	7.996	7.994	8.013	8.015	7.998	8.011
11.0	7.995	7.989	7.994	7.980	7.993	8.000	7.994	7.994	7.981	7.992	7.996	7.990	8.005	8.015	7.994	8.006
11.5	7.993	7.986	7.991	7.980	7.993	7.994	7.994	7.991	7.975	7.987	7.992	7.989	7.997	8.011	7.994	8.002
12.0	7.989	7.985	7.988	7.980	7.989	7.993	7.989	7.989	7.977	7.987	7.987	7.985	7.992	8.004	7.989	8.002
12.5	7.988	7.985	7.985	7.980	7.987	7.991	7.989	7.988	7.978	7.983	7.987	7.977	7.989	8.001	7.987	7.996
13.0	7.984	7.983	7.985	7.980	7.984	7.989	7.986	7.985	7.979	7.983	7.981	7.974	7.989	7.998	7.986	7.993
13.5	7.981	7.980	7.983	7.980	7.984	7.988	7.985	7.983	7.977	7.975	7.975	7.952	7.989	7.995	7.979	7.992
14.0	7.981	7.980	7.983	7.979	7.982	7.984	7.982	7.970	7.958	7.967	7.965		7.989	7.993	7.967	7.989
14.5	7.976	7.981	7.981	7.977	7.980	7.973	7.975	7.960	7.952	7.963	7.952		7.984	7.993	7.961	7.979
15.0	7.963	7.973	7.979	7.974	7.973	7.963	7.971	7.951	7.949	7.952			7.984	7.994		7.960
15.5		7.947	7.975	7.963	7.953	7.956	7.963	7.947	7.946				7.985	7.987		
16.0							7.950	7.940	7.944				7.984	7.974		
16.5							7.943	7.941					7.966			
17.0							7.941	7.941								

[1] Measured pH levels were corrected for temporal drift to account for ongoing equilibration of the pH sensor.

Table B-7. Uncorrected pH[1] on 7 October 2008

Depth (m)	Hydrogen Ion Concentration (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5							8.003	8.003	8.003	8.003		8.005				
1.0	8.007	8.008	8.012	8.012	8.019	8.021	8.003	8.003	8.003	8.003	8.003	8.000	8.025	8.024	8.003	8.022
1.5	8.008	8.008	8.012	8.012	8.019	8.021	8.003	8.003	8.003	8.003	8.003	7.999	8.024	8.025	8.003	8.021
2.0	8.008	8.008	8.012	8.012	8.017	8.021	8.003	8.004	8.008	8.003	8.003	7.999	8.021	8.021	8.003	8.021
2.5	8.008	8.008	8.012	8.013	8.019	8.021	8.003	8.004	8.005	8.003	8.002	8.000	8.024	8.024	8.003	8.021
3.0	8.008	8.008	8.012	8.012	8.017	8.022	8.003	8.004	8.006	8.003	8.004	8.003	8.023	8.023	8.003	8.021
3.5	8.008	8.008	8.012	8.013	8.021	8.022	8.004	8.004	8.008	8.004	8.004	8.004	8.026	8.021	8.003	8.021
4.0	8.008	8.008	8.013	8.012	8.018	8.025	8.004	8.004	8.008	8.004	8.004	8.004	8.026	8.026	8.003	8.022
4.5	8.008	8.008	8.013	8.015	8.022	8.027	8.005	8.004	8.009	8.004	8.004	8.004	8.026	8.026	8.004	8.022
5.0	8.008	8.008	8.013	8.016	8.022	8.027	8.008	8.007	8.009	8.006	8.004	8.004	8.026	8.026	8.005	8.026
5.5	8.010	8.014	8.017	8.017	8.022	8.027	8.005	8.004	8.009	8.006	8.004	8.006	8.027	8.026	8.005	8.026
6.0	8.010	8.014	8.018	8.017	8.022	8.027	8.006	8.010	8.005	8.009	8.010	8.007	8.028	8.026	8.008	8.023
6.5	8.013	8.011	8.018	8.019	8.022	8.027	8.009	8.009	8.006	8.010	8.008	8.006	8.028	8.027	8.009	8.023
7.0	8.014	8.010	8.018	8.017	8.023	8.024	8.008	8.006	7.998	8.010	8.006	8.000	8.026	8.028	8.010	8.019
7.5	8.014	8.008	8.015	8.006	8.024	8.024	8.007	8.006	7.990	8.008	8.003	7.992	8.024	8.023	8.008	8.019
8.0	8.011	8.001	8.011	7.995	8.019	8.016	8.004	8.004	7.988	8.006	8.000	7.993	8.020	8.020	8.006	8.014
8.5	8.007	8.000	8.010	7.991	8.010	8.018	8.000	7.994	7.987	7.996	7.995	7.990	8.019	8.019	8.004	8.018
9.0	8.002	7.995	8.006	7.989	8.004	8.015	7.994	7.988	7.984	7.988	7.993	7.987	8.019	8.019	7.997	8.015
9.5	7.999	7.993	8.006	7.983	7.999	8.013	7.989	7.986	7.974	7.988	7.988	7.988	8.015	8.017	7.996	8.015
10.0	7.997	7.990	8.003	7.979	7.994	8.011	7.984	7.984	7.974	7.988	7.984	7.985	8.015	8.015	7.989	8.013
10.5	7.992	7.986	7.997	7.979	7.993	8.003	7.984	7.981	7.970	7.984	7.984	7.984	8.013	8.015	7.988	8.011
11.0	7.989	7.984	7.993	7.980	7.993	8.000	7.980	7.980	7.968	7.980	7.984	7.980	8.005	8.015	7.984	8.006
11.5	7.987	7.981	7.990	7.980	7.993	7.994	7.980	7.977	7.962	7.975	7.980	7.979	7.997	8.011	7.984	8.002
12.0	7.983	7.980	7.987	7.980	7.989	7.993	7.975	7.975	7.964	7.975	7.975	7.975	7.992	8.004	7.979	8.002
12.5	7.982	7.980	7.984	7.980	7.987	7.991	7.975	7.974	7.965	7.971	7.975	7.967	7.989	8.001	7.977	7.996
13.0	7.978	7.978	7.984	7.980	7.984	7.989	7.972	7.971	7.966	7.971	7.969	7.964	7.989	7.998	7.976	7.993
13.5	7.975	7.975	7.982	7.980	7.984	7.988	7.971	7.969	7.964	7.963	7.963	7.942	7.989	7.995	7.969	7.992
14.0	7.975	7.975	7.982	7.979	7.982	7.984	7.968	7.956	7.945	7.955	7.953		7.989	7.993	7.957	7.989
14.5	7.970	7.976	7.980	7.977	7.980	7.973	7.961	7.946	7.939	7.951	7.940		7.984	7.993	7.951	7.979
15.0	7.957	7.968	7.978	7.974	7.973	7.963	7.957	7.937	7.936	7.940			7.984	7.994		7.960
15.5		7.942	7.974	7.963	7.953	7.956	7.949	7.933	7.933				7.985	7.987		
16.0							7.936	**7.926**	7.931				7.984	7.974		
16.5							7.929	7.927					7.966			
17.0							7.927	7.927								

[1] The value enclosed in the box was significantly lower than the mean of other pH measurements at the same distance above the seafloor.

Table B-8. Uncorrected Dissolved Oxygen on 7 October 2008

	Dissolved Oxygen (mg/L)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5							7.27	7.37								
1.0	7.43	7.44	7.43	7.46	7.43	7.47	7.28	7.36	7.37	7.39	7.39	7.39	7.48	7.43	7.44	7.44
1.5	7.43	7.45	7.42	7.45	7.43	7.44	7.27	7.34	7.36	7.39	7.40	7.39	7.48	7.44	7.41	7.44
2.0	7.43	7.46	7.43	7.44	7.40	7.42	7.31	7.34	7.36	7.38	7.40	7.38	7.45	7.44	7.41	7.45
2.5	7.43	7.44	7.43	7.42	7.42	7.38	7.31	7.32	7.34	7.37	7.40	7.37	7.44	7.45	7.40	7.45
3.0	7.44	7.41	7.41	7.42	7.39	7.36	7.31	7.30	7.36	7.36	7.38	7.37	7.41	7.46	7.37	7.41
3.5	7.42	7.41	7.41	7.41	7.40	7.35	7.31	7.31	7.32	7.35	7.37	7.37	7.38	7.45	7.37	7.42
4.0	7.43	7.41	7.40	7.37	7.39	7.36	7.31	7.32	7.29	7.35	7.37	7.34	7.38	7.41	7.38	7.36
4.5	7.42	7.37	7.38	7.39	7.37	7.35	7.31	7.31	7.30	7.32	7.35	7.35	7.36	7.39	7.37	7.39
5.0	7.39	7.33	7.37	7.39	7.39	7.34	7.32	7.30	7.24	7.28	7.34	7.37	7.25	7.37	7.32	7.38
5.5	7.38	7.29	7.34	7.37	7.36	7.34	7.31	7.23	7.15	7.24	7.21	7.21	7.18	7.37	7.33	7.33
6.0	7.28	7.13	7.26	7.05	7.32	7.22	7.31	7.14	7.12	7.17	7.09	7.07	7.21	7.27	7.22	7.15
6.5	7.17	7.14	7.18	6.95	7.29	7.27	7.26	7.10	6.91	7.13	7.15	7.03	7.20	7.21	7.19	7.16
7.0	7.20	7.13	7.17	6.92	7.02	7.19	7.25	7.06	6.98	7.09	7.05	7.03	7.19	7.19	7.17	7.18
7.5	7.19	7.10	7.16	6.92	7.03	7.18	7.14	6.93	6.92	7.06	7.02	7.00	7.17	7.19	7.12	7.17
8.0	7.19	7.04	7.13	6.86	6.96	7.11	7.13	6.94	6.89	7.02	6.99	6.99	7.16	7.20	7.09	7.15
8.5	7.10	7.00	7.12	6.84	6.96	7.16	7.10	6.94	6.88	7.01	6.98	6.99	7.14	7.18	7.05	7.15
9.0	7.03	6.97	7.10	6.85	6.96	7.03	6.99	6.92	6.83	6.92	6.95	6.98	7.14	7.18	6.99	7.12
9.5	6.99	6.96	7.01	6.84	6.95	7.00	6.97	6.89	6.80	6.94	6.97	6.92	7.08	7.18	6.97	7.09
10.0	7.00	6.96	6.98	6.84	6.94	7.02	6.94	6.87	6.73	6.92	6.95	6.93	6.90	7.14	6.95	7.05
10.5	6.93	6.92	6.95	6.81	6.94	6.94	6.93	6.84	6.71	6.84	6.92	6.87	6.91	7.07	6.93	7.00
11.0	6.93	6.91	6.91	6.81	6.90	6.91	6.89	6.83	6.67	6.84	6.90	6.82	6.92	6.97	6.85	6.99
11.5	6.92	6.89	6.91	6.81	6.83	6.89	6.88	6.80	6.72	6.82	6.85	6.79	6.89	6.95	6.86	6.95
12.0	6.82	6.88	6.89	6.81	6.81	6.86	6.86	6.78	6.73	6.76	6.80	6.63	6.85	6.93	6.82	6.92
12.5	6.82	6.86	6.85	6.81	6.83	6.82	6.83	6.69	6.64	6.61	6.78	6.66	6.85	6.94	6.60	6.91
13.0	6.81	6.83	6.83	6.74	6.78	6.77	6.80	6.51	6.63	6.55	6.63	6.32	6.83	6.91	6.53	6.80
13.5	6.66	6.78	6.79	6.71	6.75	6.76	6.76	6.36	6.37	6.46	6.37	6.29	6.82	6.88	6.47	6.75
14.0	6.41	6.71	6.73	6.58	6.70	6.64	6.65	6.29	6.31	6.25	6.32		6.80	6.89	6.27	6.70
14.5	6.36	6.54	6.60	6.44	6.39	6.40	6.58	6.25	6.28	6.28	6.34		6.77	6.49	6.30	6.49
15.0	6.36	6.35	6.36	6.37	6.34	6.37	6.31	6.22	6.23	6.27			6.68	6.62		6.35
15.5		6.26	6.35	6.35	6.39	6.38	6.30	6.19	6.20				6.38	6.48		
16.0							6.23	6.17	6.18				6.37	6.39		
16.5							6.23	6.15					6.38			
17.0							6.22	6.17								

Table B-9. Auxiliary Observations on 7 October 2008 during the Quarterly Water-Quality Survey

Station	Location Latitude	Location Longitude	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)
1	35°23.2519' N	120°52.4867' W	99.7	13:28:39	23.5	0	10.0	11.1	NE	4-6 WNW	7.5
2	35°23.2243' N	120°52.4814' W	48.5	13:34:02	20.0	0	6.7	10.5	NE	4-6 WNW	7.5
3	35°23.2050' N	120°52.4932' W	22.6	13:38:12	24.1	0	4.2	10.7	NE	4-6 WNW	7.0
4	35°23.1800' N	120°52.4839' W	21.3	13:43:56	19.3	0	10.5	14.0	N	4-6 WNW	7.0
5	35°23.1572' N	120°52.4786' W	58.1	13:48:27	17.6	0	13.9	17.2	N	4-6 WNW	6.5
6	35°23.1344' N	120°52.4785' W	103.2	13:52:55	17.2	0	13.1	17.1	NW	4-6 WNW	7.0
7	35°23.1784' N	120°52.5824' W	108.4	12:55:12	27.0	0	10.2	10.6	S	4-6 WNW	7.0
8	35°23.1817' N	120°52.5512' W	61.5	13:01:11	26.3	0	8.8	13.2	S	4-6 WNW	7.0
9	35°23.1848' N	120°52.5102' W	28.1	13:05:21	26.0	0	4.1	8.2	S	4-6 WNW	7.5
10	35°23.1956' N	120°52.4829' W	21.7	13:09:23	24.6	0	3.2	7.5	SE	4-6 WNW	6.5
11	35°23.1983' N	120°52.4511' W	59.7	13:13:24	24.0	0	8.6	13.0	E	4-6 WNW	7.5
12	35°23.1939' N	120°52.4142' W	107.5	13:17:54	24.8	0	10.6	13.7	E	4-6 WNW	7.0
13	35°23.1692' N	120°52.5152' W	50.5	14:01:49	17.3	0	10.9	12.9	NW	4-6 WNW	7.5
14	35°23.2187' N	120°52.5034' W	24.5	14:06:56	16.9	0	13.7	16.2	NW	4-6 WNW	6.5
15	35°23.2195' N	120°52.4578' W	62.9	13:23:36	22.1	0	10.0	14.1	E	4-6 WNW	6.5
16	35°23.1675' N	120°52.4525' W	66.5	13:57:23	17.3	0	12.2	15.4	NW	4-6 WNW	7.0

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

Tidal Conditions (Pacific Daylight Time)
High Tide: 08:31 3.5 ft
Low Tide: 11:19 3.4 ft
High Tide: 16:50 4.1 ft