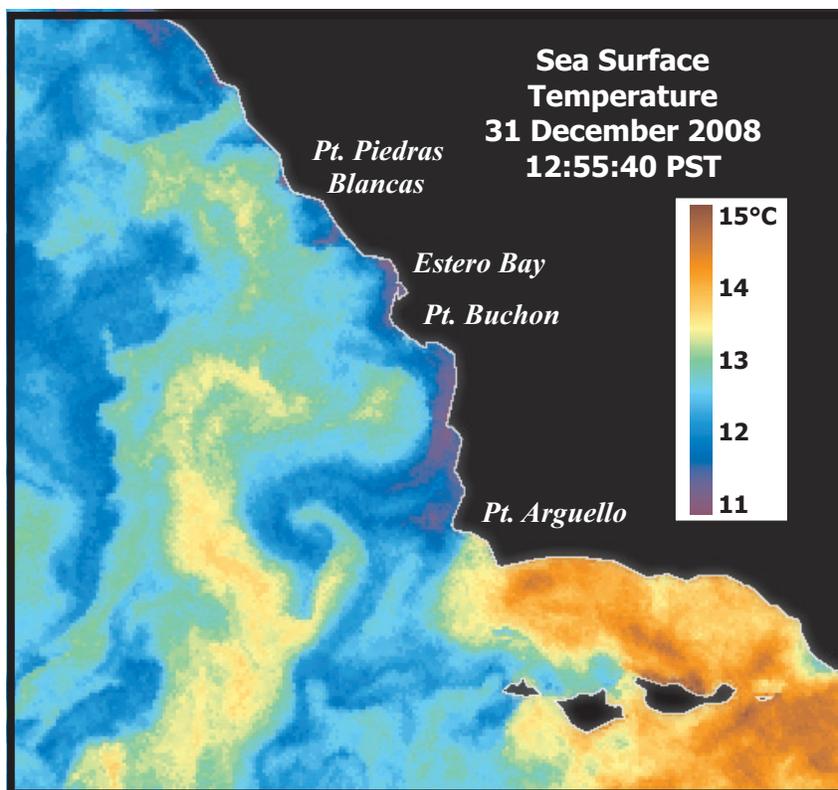


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING JANUARY 2008 SURVEY



Marine Research Specialists

**3140 Telegraph Rd., Suite A
Ventura, California 93003**

Report to

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

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

**OFFSHORE MONITORING
AND
REPORTING PROGRAM**

QUARTERLY REPORT

**WATER-COLUMN SAMPLING
JANUARY 2008**

Prepared by

**Douglas A. Coats
Tyler Eck
Bonnie Luke**

Marine Research Specialists

**3140 Telegraph Rd., Suite A
Ventura, California 93003**

**Telephone: (805) 644-1180
Telefax: (805) 289-3935
E-mail: Doug.Coats@mrsenv.com**

February 2008

marine research specialists

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

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

28 February 2008

Reference: Quarterly Receiving-Water Report – January 2008

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on Wednesday, 2 January 2008. This first-quarter survey assessed the effectiveness of effluent dispersion during winter 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 two of the sixteen sampling stations. However, all of the perturbations were measured within the zone of initial dilution that surrounds the outfall. Minor alteration of seawater properties by the discharge is expected within this zone as the effluent mixes with the receiving waters. Analysis of the perturbations demonstrated that the diffuser structure was achieving dilution levels that significantly 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.

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

Sincerely,

Douglas A. Coats, Ph.D.
Program Manager

Enclosure (Five Report Copies)

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

Mr. Bruce Ambo
City of Morro Bay

Date _____

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INTRODUCTION

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. A National Pollutant Discharge Elimination System (NPDES) permit, modifying secondary treatment requirements, was 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 2 January 2008. Specifically, this first-quarter survey captures ambient oceanographic conditions along the central California coast during the winter season.

The water-quality surveys also provide timely assessments of the performance of the diffuser structure in dispersing wastewater within stratified receiving waters. Any significant, recent damage to the diffuser structure would be revealed by a decline in the level of wastewater dispersion measured in this survey compared to that of prior surveys, and compared to design specifications. As described in this report, no such decline was observed in the January 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 January 2008 field survey was the thirty-seventh 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 collected by the CTD¹ instrument package. Continuous deployment of the CTD between stations now provides a more synoptic snapshot of the water properties immediately surrounding the diffuser structure. Consequently, the extent of the effluent plume and the amplitude of its associated water-property anomalies can be more precisely determined. The sensitive sensors 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 a dilute wastewater signature that is highly localized around the outfall diffuser. With the implementation of the current sampling design in 1999, the presence of well-mixed effluent near the diffuser structure was found in all 37 of the subsequent water-quality surveys (MRS 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007), 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 effluent-related perturbations can be better determined by the denser sampling pattern. The amplitudes of discharge-related salinity anomalies reveal the details of dilution as the effluent plume disperses within receiving waters. Measured dilution factors lend insight into the current operational performance of the outfall and diffuser structure. As described in this report, the presence of dilute effluent undergoing turbulent mixing within the weakly stratified water column north of the diffuser structure was delineated by the data collected during the January 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.

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).

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 discharge (Figure 1). Its presence further restricts the direct exchange of seawater between the discharge point and the Bay.



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

Near the diffuser, prevailing currents generally follow bathymetric contours, which parallel the north-south trend of the adjacent coastline. Because of the rapid initial mixing achieved within 15 m of the diffuser structure, impingement of unmixed effluent onto the adjacent coastline 827 m away is highly unlikely. Nevertheless, water samples are regularly collected along the shoreline at the surfzone sampling stations shown in Figure 1. These surfzone samples are analyzed for total and fecal coliform levels. Results of these analyses are reported in monthly operational summaries and in the 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, 2001, 2002, 2003, 2004, 2005, 2006, 2007).

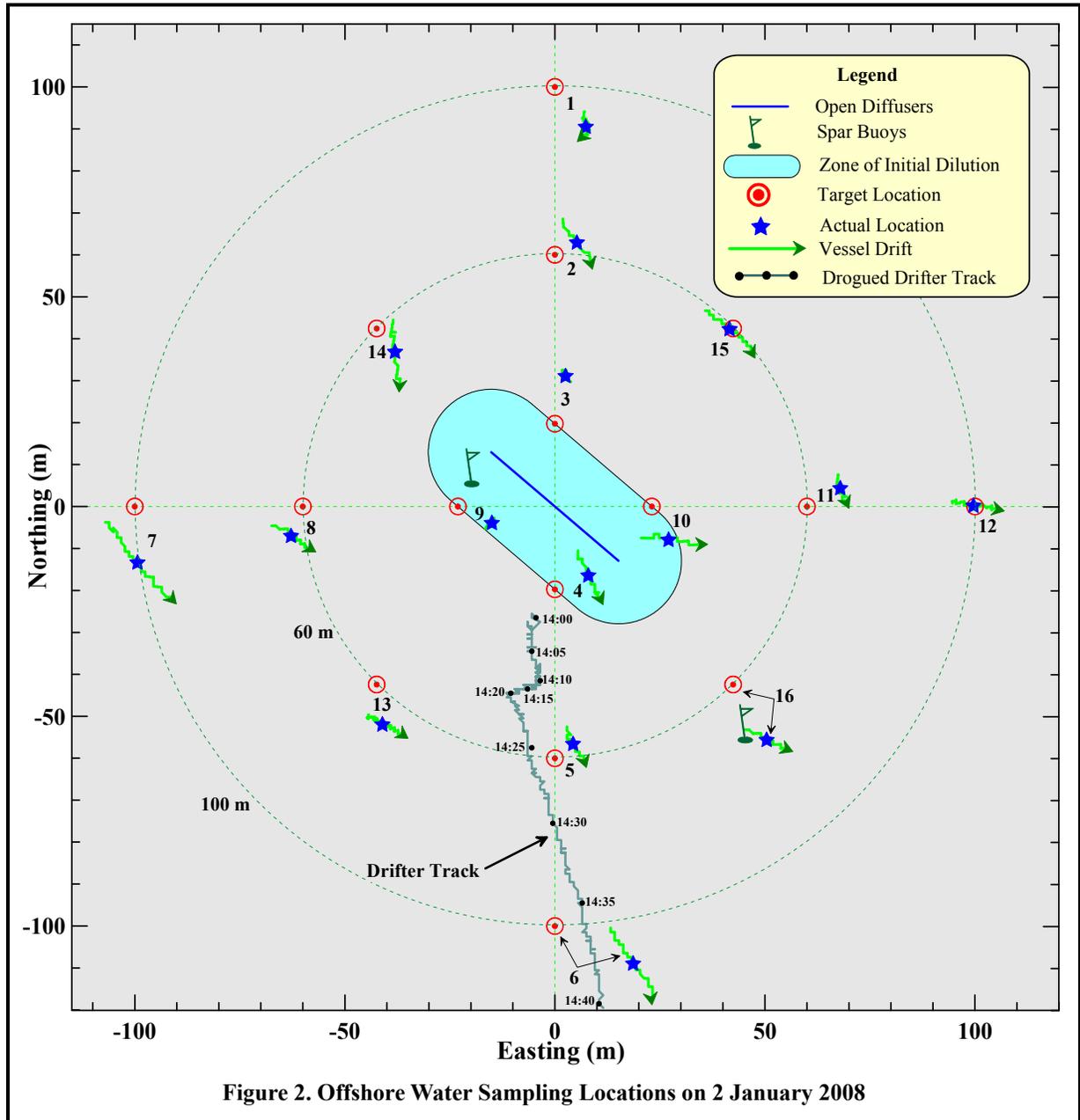
As shown in Figure 2, the water-sampling design consists of 16 fixed offshore stations located within 100 m of the outfall diffuser structure. The target locations of the 16 offshore sampling stations are indicated by the red ⊙ symbols in the Figure. The stations are situated at three distances relative 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.

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

¹Distance to the closest open diffuser port.

²Distance to the center of open diffuser section.



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

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 specified in the discharge permit 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 cause satellite signals to bounce around, leading to errors in position beyond those that were previously introduced by SA. These other errors are greatly reduced with the Differential GPS (DGPS) system that was first implemented by the U.S. Coast Guard 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 an extremely stable and accurate offshore navigational reading, typically with position errors of less than 2 m.

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

Frequent 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 as it approaches the target locations. Using DGPS, these offsets can be resolved and the vessel location can be precisely tracked throughout sampling at each station. This is 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 January 2008 survey is apparent from the length of the green tracklines in Figure 2. These tracklines trace the horizontal location of the CTD instrument package as it is lowered to the seafloor. Their lengths reflect the station-keeping difficulty experienced during the January 2008 survey. During the time it took the CTD to traverse the water column to the seafloor, which averaged 1 min 18 s, the instrument package moved as much as 23.7 m laterally (Station 7). Overall, however, the drift was only 11.0 m when averaged over all the stations. This amount of drift is fairly typical of most surveys.

The CTD trajectories reflect the complex interaction between surface currents, wind forces, and residual momentum as the vessel approached each station. Generally, winds can move the vessel to a greater degree than current flow. However, as summarized in Table B-9, winds were light and variable during the survey. As a result, their influence was minimal compared to the southward drift induced by the prevailing current. As shown by the green tracklines in Figure 2, the drift at many of the stations had a south-eastward component similar to the drifter track. At Stations 10 and 12, however, the due eastward drift of the CTD was induced by residual momentum left after the vessel approached the station from the west. The influence of vessel momentum was determined from the vessel's track before each downcast was conducted. Although these portions of the vessel tracks are not shown in Figure 2, the vessel drift recorded during several of the CTD casts, particularly that at Stations 10 and 12, was consistent with the approach direction.

Although comparable to the survey vessel's 12-m length, drift in the CTD location during the downcasts complicates the assessment of compliance with discharge limitations at stations close to the diffuser structure. Receiving-water limitations specified in the COP only apply to measurements recorded beyond the ZID boundary. Within the ZID, rapid turbulent mixing associated with the momentum of the effluent jet and the rise of the buoyant plume is expected, and the limitations apply to conditions after this initial mixing is complete. Specifically, during the January 2008 survey, the vertical profile at Station 10 traversed the boundary of the ZID (Figure 2). Thus, strictly speaking, only a portion of the data recorded during this cast was subject to the receiving-water limitations specified in the NPDES discharge permit. Additionally, none of the measurements recorded at Stations 4 or 9 were subject to the limitations because the CTD was within the ZID boundary throughout the entire vertical cast at both of those stations.

Compliance assessments notwithstanding, measurements recorded close to the diffuser structure within the ZID lend valuable insight into the outfall's effectiveness at dispersing wastewater during the January 2008 survey. Damaged or broken diffuser ports would be reflected by low dilution rates and measurements of concentrated effluent throughout the ZID. Without measurements recorded within the ZID, the discharge plume might go undetected. This was the case in nearly every water-quality survey conducted prior to 1999, before the denser sampling pattern that is now in use was instituted.

Surveys prior to 1999 also predated the advent of DGPS. Consequently, the 11-m average drift experienced during sampling at individual stations in the January 2008 survey would not have been resolved with the navigation available prior to 1999. In fact, before 1999 sampling was presumed to occur at a single, imprecisely determined, horizontal location near each station. Federal and State reporting of monitoring data still depends on identification of a single position for all of the CTD data collected at a particular station. Thus, for regulatory reporting, and for historical consistency with past surveys, a single sampling location was also reported for each station during the January 2008 survey. These positions were based on the average locations shown for each station by the blue stars in Figure 2. The average positions are also listed in Table 2, along with their distance from the diffuser structure. However, based on the foregoing discussion, an average station position that happens to lie within the ZID does not imply that all of the measurements collected at that particular station were exempt from the receiving-water objectives in the discharge permit.

For example, the hydrocast at Station 10 traversed the ZID boundary during its descent through the water column, as shown by the green arrow in Figure 2. As such, the deepest measurements were subject to receiving-water limitations, even though the average Station-10 location (13 m) was well within the ZID. Moreover, the average 13-m distance listed in Table 2 lends little insight into the true proximity of the measurements relative to the discharge. The CTD began its descent at Station 10 only 7.7 m from the diffuser structure, and crossed the ZID boundary at depth of 10.6 m. The measurements recorded at

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

Station	Time (PST)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ¹ (m)	Bearing ² (°T)
1	2:14:01	2:15:24	35° 23.248' N	120° 52.499' W	80.9	16
2	2:17:36	2:18:41	35° 23.233' N	120° 52.501' W	54.1	22
3	2:20:29	2:21:47	35° 23.216' N	120° 52.502' W	25.4	41
4	2:23:55	2:25:16	35° 23.190' N	120° 52.499' W	7.2³	221
5	2:26:51	2:28:21	35° 23.168' N	120° 52.501' W	44.8	194
6	2:30:00	2:31:36	35° 23.140' N	120° 52.492' W	95.9	178
7	2:39:28	2:41:00	35° 23.192' N	120° 52.570' W	88.2	253
8	2:44:12	2:45:28	35° 23.195' N	120° 52.545' W	51.6	247
9	2:47:23	2:48:46	35° 23.197' N	120° 52.514' W	12.6³	221
10	2:51:29	2:52:38	35° 23.195' N	120° 52.486' W	13.0⁴	67
11	2:54:48	2:55:50	35° 23.201' N	120° 52.459' W	55.6	72
12	2:58:28	2:59:46	35° 23.199' N	120° 52.438' W	85.5	81
13	2:34:21	2:35:52	35° 23.171' N	120° 52.531' W	66.1	221
14	3:13:30	3:14:47	35° 23.219' N	120° 52.529' W	33.2	316
15	3:08:46	3:09:51	35° 23.222' N	120° 52.477' W	59.2	41
16	3:04:31	3:05:25	35° 23.169' N	120° 52.471' W	55.2	140

¹ Distance from the closest open diffuser port to the average station position. Stations with some observations collected within the ZID are shown in bold.

² Direction measured clockwise in degrees from true north from the closest diffuser port to the average sampling location.

³ All of the CTD cast was within the ZID boundary.

⁴ Portions of the CTD (Conductivity-Temperature-Depth) cast were within the ZID boundary.

greater depth were outside the ZID, and when the CTD reached the seafloor, it was 19.5 m from the diffuser structure. This lateral movement is not reflected in the closest-approach distance of 13 m listed in Table 2 for Station 10, which was based on the average of surface and bottom position fixes measured at the beginning and end of the downcast. The average position, which is shown by the blue star in Figure 2, would suggest that all the data at Station 10 were collected within the ZID, where turbulent initial dilution processes would be expected to be acting.

FLOW FIELD

A satellite-tracked drifter documented the prevailing south southeastward flow during the January 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 14:00 PST and was recovered an hour and twenty minutes later, at 15:20 PST. In contrast to the steady rate of movement seen in most other surveys, drifter transport during the January 2008 survey had three distinct components. During the first ten minutes after deployment, the drifter moved slowly to the south, before the slack low tide resulted in a short ten-minute shift almost directly offshore (Figure 4). For the balance of the survey, however, a moderate current carried the drifter rapidly south southeast, and out of the survey area. During its deployment, the drifter traversed a total of 354 m toward the south southeast (170°T) at an average speed of 7.46 cm/s or 0.15 knots.

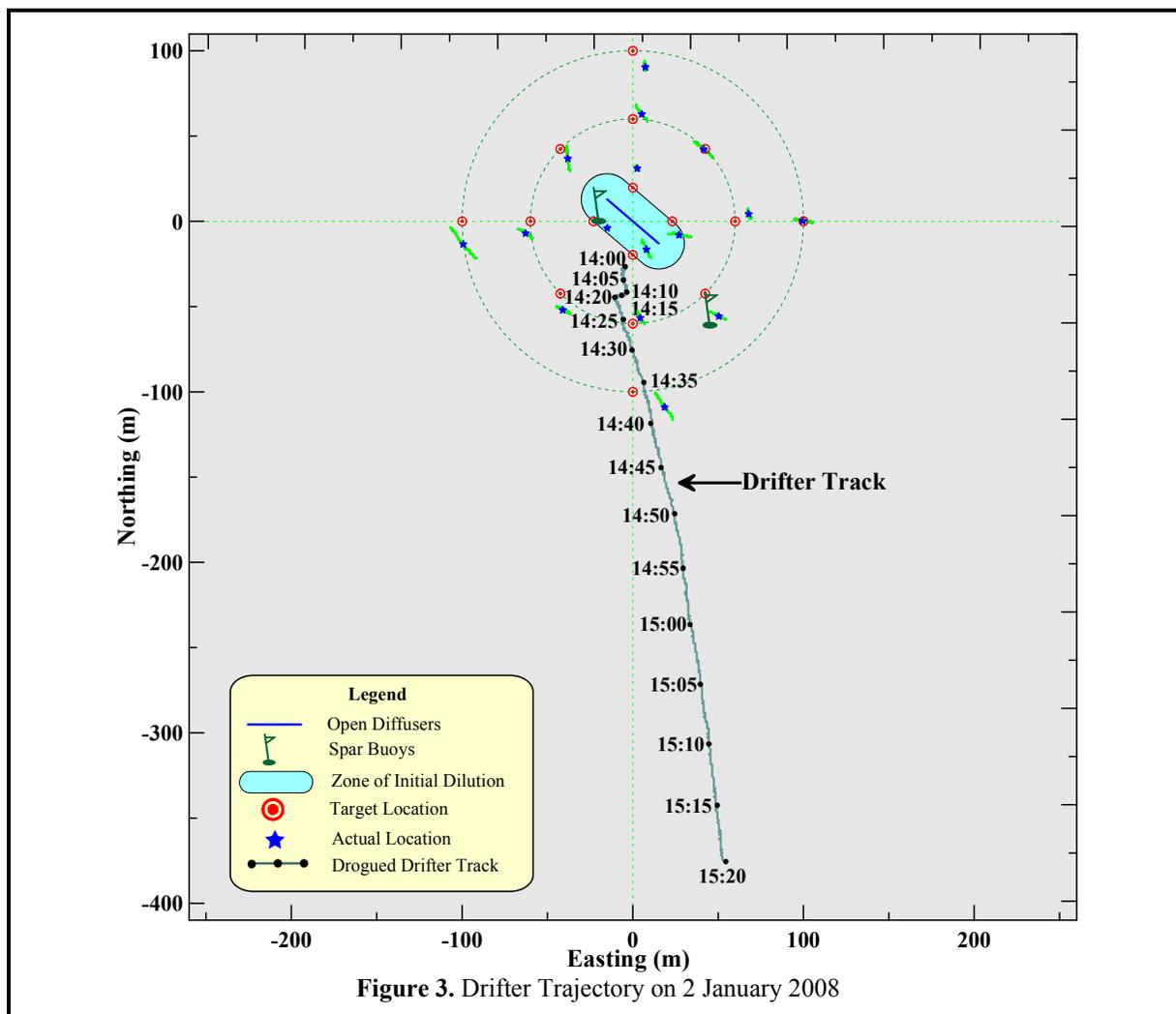


Figure 3. Drifter Trajectory on 2 January 2008

The southward flow component that was measured by the drogued drifter was inconsistent with the incoming flood tide that coincided with the January 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, during the January 2008 survey, the southward prevailing flow shown in Figure 3 was in almost direct opposition to the normal tidal influence.

Although, as stated above, flow can be tidally influenced, within Estero Bay it is more often influenced by external processes, such as wind-generated upwelling or passing offshore eddies. The January 2008 survey was unique in that it was conducted during a comparatively rare shift from upwelling to downwelling conditions (Figure 5). The survey itself occurred at the leading edge of the downwelling event, which was precipitated by a series a severe winter storms that impinged on the central California coast shortly after the survey was completed. Consequently, the distribution of sea surface temperatures shown on the cover of this report is more indicative of weak upwelling conditions that immediately preceded the survey, rather than the downwelling that took hold during and after the survey.

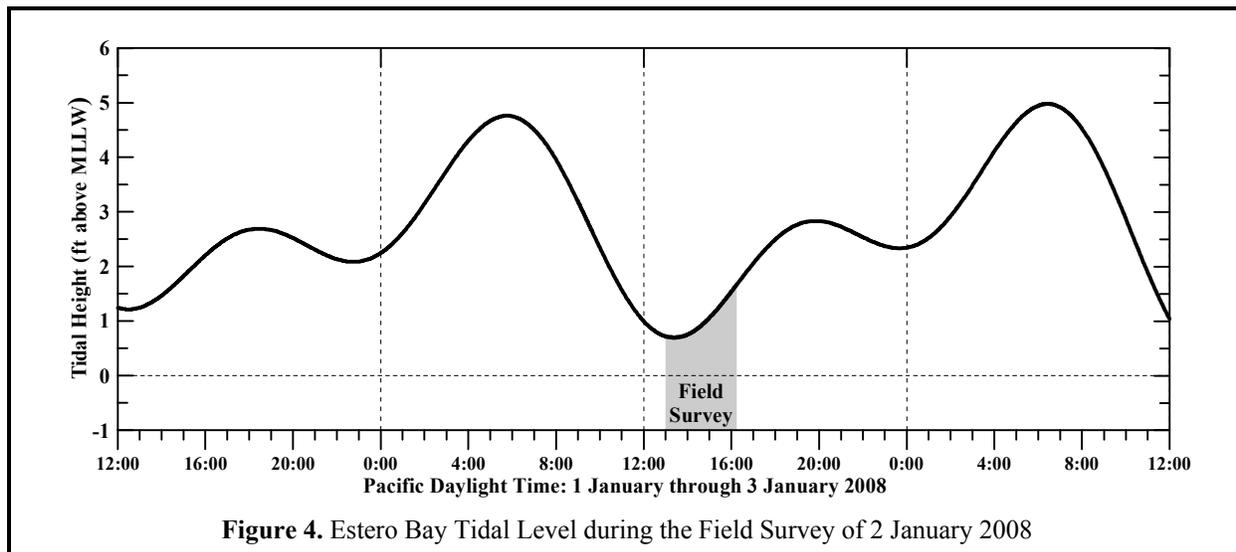
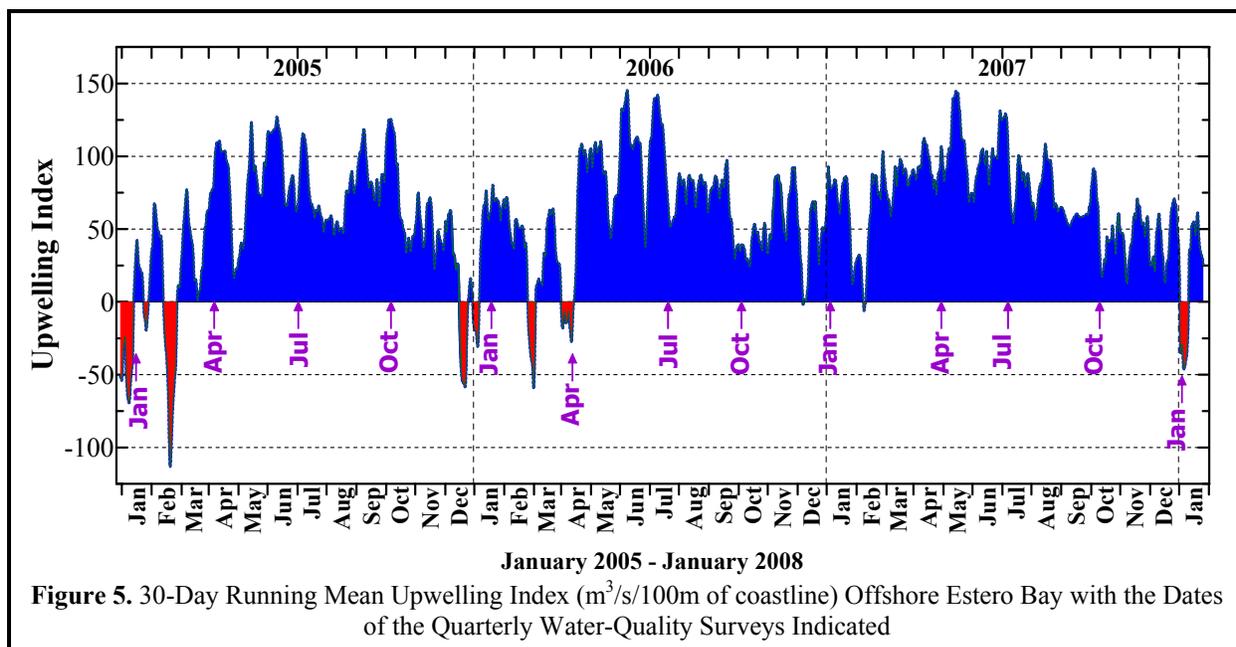


Figure 4. Estero Bay Tidal Level during the Field Survey of 2 January 2008

Upwelling season normally begins sometime during late March and or early April when there is a “spring transition” to more persistent southward-directed winds along the Central California Coast. This transition is marked by the stabilization of a high atmospheric pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive the prevailing northwesterly winds along the Central Coast. These prevailing winds move surface waters southward and offshore. To replace these coastal surface waters, deep, cool, nutrient-rich waters upwell near the coast as delineated on the cover of this report.



January 2005 - January 2008
 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

The satellite image depicts slightly cooler sea-surface temperatures within Estero Bay and along the central California coastline with dark purple and blue shading. The image was generated from data acquired by infrared sensors on one of NOAA's polar orbiting satellites two days prior to the survey, when skies were clear enough for sea-surface temperatures to be recorded throughout the region. Cooler water temperatures near the coast are an indicator of upwelling, so the distribution of seawater temperatures observed during the survey is consistent with conditions on 31 December 2007, which was shortly before the downwelling event began (Figure 5).

Another feature of upwelling conditions is vertical stratification of the water column. At the time of the water-quality survey on 2 January 2008, downwelling processes had begun to erode the existing thermocline, and the water column was only weakly stratified. However, the vertical profiles collected with the CTD exhibit a more complex vertical structure than is normally seen in winter water-quality surveys (Figures A-1 through A-3 in Appendix A). The vertical profiles of dissolved oxygen (DO), shown by the dark blue lines, are particularly unusual in that they exhibit several localized extrema below 5 m that are not reflected in most other seawater properties. The unusual layering probably resulted from the remnants of water masses that were generated by upwelling, and had yet to dissipate during the transition to the weak stratification that is associated with downwelling.

Downwelling usually only occurs when the passage of winter storms shifts the prevailing winds toward the northwest. This causes brief periods of substantial shoreward surface flow, which induces downward transport near the coast (Figure 5). However, coastal downwelling induces a shoreward-directed surface flow toward the north northeast. The slight eastward component to the flow observed during the survey may reflect the influence of downwelling processes that were starting to take hold during the survey, but the more-dominant southward transport that was observed was inconsistent with downwelling-induced surface flow, and was likely related to the upwelling conditions that immediately preceded the survey.

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 2 January 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 additional scientific support and collected 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/coloration 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 recorded during the January 2008 survey were among the deepest ever measured during the MBCSD monitoring program, exceeding 10 m at most

stations, and reaching 12 m at Station 14. Had the Secchi disk attained another 3 m before disappearing at that station, it would have encountered the seafloor. In any regard, the extraordinarily high seawater clarity that was present at the time of the survey reflected a euphotic zone that extended to the seafloor at all of the stations except Station 9, where the presence of the discharge plume perceptibly reduced light penetration, but only because seawater clarity at the time was so exceptionally high. A deeper-than-usual euphotic zone is typical of downwelling conditions when unstratified conditions and decreased primary production, namely, decreased phytoplankton density, increases the transmission of ambient light throughout the water column. The seawater clarity during the January 2008 survey was also unusually high because other confounding factors, such as high onshore runoff, strong winds, and high waves, were absent prior to the survey. These quiescent conditions, along with the onset of downwelling, resulted in an unusually deep euphotic zone.

Because Secchi depths provide less precise measures of light transmittance than the transmissometer mounted on the CTD instrument package, it is reassuring that the CTD measurements and Secchi depth measurements correspond, particularly with respect to the high water clarity overall, and the reduced water clarity at Station 9 (Table B-5). The visibility of the disk, and hence its depth of disappearance, depends on the amount of natural light available at the time of the measurement. Thus, the Secchi depth reading can artificially change by as much as 0.5 m depending on whether the sample is taken on the sunny or shady side of the survey vessel, or when the skies are overcast versus clear. Thus, a record of cloud cover is recorded as part of the auxiliary measurements (Table B-9) in order to mediate any confounding bias in the measurements. Also, to minimize the influence of variations in ambient light, the Secchi depth measurements were collected in a consistent manner with regard to available ambient light throughout the survey. Nevertheless, temporal drift in the measurements can be introduced as the sun rises in the sky, or as cloud cover changes as the survey progresses. Neither of these influences was particularly evident during the January 2008 survey, so the Secchi depth measurements accurately reflected general turbidity levels within the water column. This includes 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 January 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 January 2008 sampling effort. In addition, the January 2008 survey was the twelfth MBCSD survey to record the drifter position 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, for example, it revealed the curious differences in current speed and direction that occurred from 14:00 and 14:20 during the tidal change (Figure 3).

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. During the January 2008, readings from the conductivity and DO sensors were compromised at the last station of the survey (Station 14), when what was probably a salp (Salpidae sp.) was entrained into the ducted portion of the CTD. Salps are barrel-shaped, free-floating tunicates that

move by pumping water through their gelatinous bodies and feed on the phytoplankton filtered from the pumped seawater. Substantial numbers of salp colonies were observed floating in the water column during the January 2008 survey.

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. Because the January 2008 survey was conducted on short notice to avoid an impending period of prolonged severe weather, the CTD did not undergo its normal pre-cruise calibration. As a result, calibration coefficients determined from a post-cruise calibration, and from pre-cruise calibrations conducted for prior surveys, were used to convert sensor output to engineering units.

The six seawater properties that were 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 (Siemens/m) measurements. Density was derived from 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). Because salinity and density is computed from conductivity, whose measurement was compromised at Station 14, neither parameter was reported for that station (Tables B-2 and B-3). Similarly, readings from the DO sensor were also compromised at that station, and were not reported (Table B-4 and B-8).

Table 3. Instrumental Specifications for CTD Instrumentation Package

Component	Depth¹	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	°C	-5 to 35	± 0.01	± 0.001
Transmissivity	2000	%	0 to 100	± 0.1	± 0.025
Dissolved Oxygen	200	mg/L	0 to 21.5	± 0.14	± 0.014
Acidity/Alkalinity	200	pH	0 to 14	± 0.1	± 0.006

¹ Maximum depth limit in meters

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 post-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). Revised calibration coefficients determined after the survey were used in the algorithms that converted sensor voltage to engineering units when the field data were processed. Comparison with the factory calibration of the entire CTD package that was conducted in December 2001, and the more recent June 2006 replacement and calibration of the DO probe, confirmed the continued accuracy and stability of the temperature, pressure, and conductivity sensors, as well as the operational integrity of the oxygen and pH probes.

Before deployment at the initial station, the CTD was held below the sea surface for a six-minute equilibration period. Subsequently, the CTD was raised to within 1.0 m of the sea surface and profiling commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at 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 temporal drift during the January 2008 survey. Perceptible drift in pH measurements has been consistently observed in prior water-quality surveys as the result of ongoing sensor equilibration during profiling. The very small 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 January 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, 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 January 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. Soak times of six minutes at the beginning of a survey were found to reduce, but not entirely eliminate sensor drift. During the January survey, a tube filled with seawater was placed around the pH sensor while in transit to the survey site to limit atmospheric exposure of the probe immediately 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 1, where the respective DO and pH offsets were -0.76 mg/L and -0.149 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 seafloor, 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 the artificial DO and pH trends was important because the drifts were large compared to reported accuracy and precision of the probes. As a result, they could potentially mask smaller-amplitude, discharge-related anomalies. The artificial pH reduction (-0.149 pH) at the beginning of the deployment was significantly larger than the instrumental resolution (± 0.006 pH) reported by the probe manufacturer (Table 3), as was the artificial DO reduction (-0.76 mg/L) when compared to that sensor's reported accuracy (± 0.14 mg/L). Before correction, equilibration-related offsets induced artificial lateral gradients in the data that produced erroneous statistically significant anomalies (Tables B-7 and B-8). As expected from the temporal trends, the largest of these erroneous anomalies appeared at stations sampled at the beginning and end of the survey. Statistically significant negative DO anomalies were determined for measurements recorded near the seafloor at Stations 1, 2, and 4, while large positive anomalies were identified at depth at Stations 10, 12, and 15 (Table B-8). All of the pH measurements were found to be significantly higher at Station 14, the last station sampled during the survey; and a number of the mid-depth samples were also found to have comparatively large pH values at Station 15, the second-to-the-last station sampled (Table B-7). In the case of the pH measurements, the artificial temporal trend also completely missed the significance of the discharge-related anomalies that were present at Station 9 (*cf.* Tables B-6 and B-7).

RESULTS

The first-quarter water-quality survey began on Wednesday, 2 January 2008, at 14:00 PST with the deployment of the drogued drifter. Subsequently, water-column measurements were collected as required by the NPDES monitoring program (Tables 2 and B-9). Skies were mostly clear throughout the survey, which ended at 15:20 PST with the retrieval of the drogued drifter. Some high clouds began moving into the area toward the latter half of the survey but did not obscure direct sunlight. Sunset was at 17:01 PST, well after sampling was complete. Atmospheric visibility was clear along the ocean surface owing to the absence of low-lying fog. As a result, Morro Rock and the shoreline remained visible throughout the survey.

Average wind speeds, calculated over one-minute intervals, varied throughout the survey, ranging from 0.5 kt to 1.9 kt (Table B-9). Corresponding, peak wind speeds ranged from 1.1 kt to 2.7 kt. In accordance with these very light winds, seas were calm with a significant wave height of less than one meter, mostly due to a gentle swell out of the north northwest. Air temperatures were slightly warmer than sea surface temperatures and ranged between 12.8°C and 17.2°C.

The discharge plume was identified in the water column at Station 9 as a diffuse light-green discoloration of the Secchi disk as it reached mid-depths in the water column, and just before it disappeared at a depth of 7.5 m (Table B-9). This station was located entirely within the ZID, and was undoubtedly influenced by an increase in turbidity due to the presence of the discharge plume within receiving waters that otherwise had extraordinarily high ambient visibility. Accordingly, the reduced Secchi depth measurement at Station 9 stood out against the backdrop of average Secchi depths that measured 3.5 m deeper at most other stations. Although the plume was not visible beneath the sea surface at Station 4, the 2-m shallower depth measured at that station probably also reflected the influence of the discharge. However, as described below, the reduced visibility at Station 4 was generated by the upward transport of naturally turbid bottom water, rather than the presence of wastewater particulates. Despite the visible signature of the discharge deep within the water column at two stations close to the discharge, there was no visual evidence of either floating particulates, or oil and grease, at any time during the survey.

Beneficial Use

During the January 2008 survey, observations of beneficial use demonstrated that the coastal waters within Estero Bay continued to be utilized by wildlife and for recreation. Smaller numbers than usual of California brown pelicans (*Pelecanus occidentalis californicus*), Surf Scoters (*Melanitta perspicillata*), Heermann's gulls (*Larus heermanni*), and western gulls (*Larus occidentalis*) were observed during transit to and from the survey area, and during the course of the survey. Similarly unusual was the dearth of cormorants (*Phalacrocorax*) that were observed; however, this likely has to do with the later hour during which the survey was conducted. Normally, the survey is performed near dawn, when many birds are seen in flight, transiting to and from feeding sites up and down the coast. In contrast, the January 2008 survey took place in the early afternoon, and combined with the short duration of the survey, substantially fewer birds were noted than in other surveys. In addition to avian fauna, three southern sea otters (*Enhydra lutris*) were observed during transit to the survey site. Pieces of detached bull kelp (*Nereocystis luetkeana*) were also noted drifting in the survey area and during transit to the survey area.

As mentioned previously, salps (Salpidae) were abundant throughout the area during the survey, to the point that CTD measurements at one or more of the stations may have been adversely affected by their presence. Salps are rarely observed in the survey area, although they are widespread throughout the world's oceans. They are most often found in warmer equatorial waters where they feed on phytoplankton. Recent studies have found that salps may help to counteract global warming by carrying carbon dioxide from the ocean surface to the deep sea, preventing it from re-entering the atmosphere.

In contrast to the decreased number of wildlife noted due to the later hour at which the survey took place, beach and water use by humans was substantially greater than in the early morning. Approximately thirty people were seen utilizing Atascadero Beach during the survey. Additionally, one surfer was observed in the water close to Morro Rock, and two surfers were seen on the south side of the harbor entrance.

Ambient Seawater Properties

The January 2008 survey occurred during a period of transition between upwelling and downwelling conditions. Data collected during the January 2008 survey generally reflect weakly stratified conditions that are indicative of mild downwelling conditions. In contrast, strong downwelling normally results in a well-mixed water column where vertical variation in seawater properties is nearly imperceptible. This was not the case during the January 2008 survey because weak, but perceptible vertical gradients were apparent in the vertical profiles (Figures A-1 through A-3). However, the vertical ranges in seawater properties were much smaller than those found during even mild upwelling conditions. For example, the vertical temperature range during the January 2008 survey was less than 1°C, while vertical temperature differences at least twice as large are found when upwelling conditions prevail. Moreover, upwelling-induced vertical gradients tend to be compressed within a narrow depth range. The resulting thermoclines, haloclines, and pycnoclines, where temperature, salinity, and density change rapidly, serve to separate two distinct watermasses. The resulting interface restricts vertical transport, and if strong enough, can trap the effluent plume beneath the sea surface and limit its initial dilution.

Although many of the vertical profiles measured in the January 2008 survey also exhibit a small but distinct thermocline (red line), halocline (green line), and pycnocline (black line) very close to the sea surface, much of the vertical change in properties was uniformly distributed throughout the water column. This suggests that downwelling processes had begun to erode the sharp upwelling-induced gradient that probably existed at mid-depth during the strong upwelling conditions that prevailed at the end of December 2007. The profiles at Station 4 (middle right frame of Figure A-1) and Station 9 (middle left frame of Figure A-1) did not exhibit a vertically distributed gradient similar to the other stations. This is because upward transport and mixing generated by the rising effluent plume resulted in relatively uniform

mid-depth water properties at those stations. This upward movement also compressed the gradients near the sea surface, which is particularly evident in the more-sharply defined shallow thermocline (red line). The fact that those stations still have a thermocline indicates that the discharge plume did not quite reach the sea surface, at least not at those particular locations.

The vertical profiles of physical properties at Station 5 (lower left frame of Figure A-1) also departed markedly from those at most other stations. In particular, the salinity (green line) and density (black line) profiles exhibit two very large, localized, negative excursions within 5 m of the sea surface. However, in contrast to fluctuations seen in other vertical profiles, these excursions were caused by instrumental artifacts unrelated to natural physical oceanographic processes or effluent discharge. These spikes occurred in conjunction with localized sharp vertical changes in temperature, and milder versions can also be seen near 6 m at Station 12 (bottom right frame of Figure A-2) and near 13 m at Station 15 (lower left frame of Figure A-3). Salinity spikes are instrumental artifacts arising from the mismatch between conductivity and temperature measurements collected near sharp, localized thermoclines. The spikes are evident as erroneous zigzag patterns, or localized salinity decreases that appear in conjunction with sharp changes in temperature. Some of the larger salinity spikes also manifest themselves in the vertical density profiles (black lines) because density is computed from salinity. Unless properly identified, salinity spikes can be misinterpreted as a signature of the low-salinity effluent plume.

A discharge-related alteration of the thermal structure near the sea surface at Station 5 may have contributed to the markedly higher amplitudes of salinity spiking there. As with Stations 4 and 9, upward movement of the discharge plume can alter the shallow thermal structure. Station 5 lies south of the diffuser structure, and in the path the southward-directed plume transport (Figure 3), so it is possible that the discharge influenced shallow water properties there. However, the influence of the discharge at Station 5 would have had to create a complex vertical structure with interleaved layers of dilute effluent and ambient seawater to create the series of thermal inversions that caused the salinity spikes at depths of 2 m, 4 m, and 8 m. It is equally plausible that a salp became temporarily attached to the temperature probe and interfered with shallow measurements during profiling at Station 5. Regardless of their cause, such thermal and density inversions are not normally observed under ambient oceanic conditions because overturn occurs rapidly. The spike at 4 m was so large that it resulted in the only statistically significant salinity anomaly measured during the survey (highlighted in Table B-2). However, it would be incorrect to assume that the presence of effluent itself contributed tangibly to the salinity reduction within the spike. This is because there was no perceptible salinity anomaly present at Station 4, which lies much closer to the diffuser structure and along the same plume trajectory.

As with the erroneous spiking at Station 5, the erratic measurements in salinity, density, and DO at Station 14 were an artifact of sampling. However, in the case of the Station-14 measurements, the readings were so anomalous that they did not warrant reporting, and their vertical profiles are not shown in the upper right frame of Figure A-3. Historically, measurements this erratic have only been observed when a piece of detached kelp or other debris temporarily became entangled on the CTD. They were clearly not caused by the discharge because Station 14 lies north of the diffuser structure, in a direction opposite of the plume transport (Figure 2). In contrast to previous instances when attached debris affected CTD readings, particularly transmissivity readings, the anomalous readings at Station 14 were recorded only in salinity, density, and DO fields. Meanwhile, the temperature, pH, and transmissivity readings appeared normal. The affected seawater properties were all measured by sensors contained within the ducted portion of the CTD, through which seawater is pumped. Thus, it is likely that a gelatinous portion of one of the numerous salps observed throughout the survey encountered the intake and was circulated through the duct, resulting in the erroneous readings recorded from those three sensors alone.

The vertical profiles of the three other seawater properties, namely DO (dark blue lines), transmissivity (light blue lines), and pH (olive lines), departed from the vertical distribution in the three physical

properties that were described above. In particular, they did not exhibit a uniform gradient throughout the water column or a sharp increase in the gradient above 2 m. Normally, when upwelling processes dominate, vertical profiles in all six seawater properties reflect the same heavily stratified shape, or a mirror image of that shape. In the January 2008 survey, however, the shallow 2-m surface layer was absent from the DO, pH, and transmissivity profiles. However, in contrast to the relatively uniform vertical gradient throughout the rest of the water column, DO and pH exhibited a distinct excursion at depth, while the transmissivity profile showed little vertical change whatsoever.

Although the oceanographic processes responsible for altering some properties and not others is difficult to decipher, it is likely that the deep, lateral intrusion of the oxygenated, high-pH watermass observed during the survey resulted from downwelling. Saturated DO concentrations within this watermass indicate recent contact with the sea surface, where atmospheric exchange brought DO concentrations into equilibrium. Atmospheric cooling or downwelling then transported the watermass to depth, where the ambient surrounding seawater was naturally lower in DO and pH due to biotic respiration and decomposition. These natural processes slowly deplete oxygen and produce carbonic acid (dissolved carbon dioxide CO₂), which is reflected in reduced pH (more acidic).

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, all of the cross-sections shown in Figures A-6 and A-7 reflect the influence of the discharge at Station 9. The large-amplitude, discharge-related reduction in salinity is especially apparent near 5 m in the top frame of Figure A-6. In contrast, it is difficult to assess the significance of the same salinity reduction by comparing the Station-9 vertical profile, shown in the middle-left frame of Figure A-2, with the salinity profiles at the other stations, particularly in the presence of salinity spiking, such as at Station 5 in the lower left frame of Figure A-1.

The vertical cross-sections also lend insight into the mechanism that caused the discharge-related anomaly in each seawater property. The character of the salinity and transmissivity anomalies near 5 m at Station 9, which are apparent in the top frames of Figures A-6 and A-7, are distinctly different from the anomalies in the other seawater properties that are spatially coincident. In particular, the localized reductions in salinity and transmissivity were disconnected from the ambient seawater properties at depth. They could only have been induced by the presence of dilute wastewater constituents. In contrast, the other seawater anomalies arise because of an upward excursion in the contour lines at Station 9. They have the same characteristics as ambient seawater at depth and were generated by the upward displacement of ambient seawater near the seafloor. During even mildly stratified conditions, ambient seawater properties near the seafloor differ from the properties in the upper water column. Thus, discharge-related anomalies can be generated when deep ambient seawater is entrained in the discharge plume, and is displaced upward into the water column where the surrounding seawater characteristics provide a contrast.

Both entrainment-generated and wastewater-induced anomalies become apparent when seawater properties measured at the same depth level are 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. 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.

Statistically significant departures from mean conditions were found to occur in four of the six seawater properties in the January 2008 data. These anomalies are highlighted in Table B-2, which isolates a single salinity anomaly at Station 4, and in Tables B-4, B-5, and B-6, which identify a broad depth range at Station 9 where DO, transmissivity, and pH, depart significantly from mean conditions at the same depth levels. However, only one of the four sets of significant anomalies was unequivocally related to the presence of effluent constituents. The reduced transmissivity (water clarity) at Station 9 was undoubtedly caused by the presence of particulate loads within the effluent plume, because the anomalous transmissivity levels were perceptibly lower than measurements recorded at any other location. Consequently, they could not have arisen from the movement of ambient seawater at depth.

In contrast, the anomalous DO and pH measurements at Station 9 could have arisen from the upward displacement of ambient seawater at depth. Although not readily apparent in the vertical profiles, the downwelling-induced layering in the transmissivity, DO, and pH fields above seafloor become evident in the cross-sections shown in Figure A-5. Because of the sharply defined vertical contrast in these layers, upward transport of seafloor properties by the rising effluent plume produces a perceptible lateral difference at mid-depth. Finally, as described previously, the only statistically significant salinity anomaly recorded at Station 5 was the result of an artifactual salinity spike.

Even in the absence of salinity spiking, sensor drift, and salp entrainment, 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 476 measurements examined for each of the temperature, pH, and transmissivity parameters; and 443 measurements examined for the remaining three parameters (excluding Station 14 data), 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.

Discharge-Related Perturbations

Despite the confounding influence of salinity spiking, sensor blockage, and sensor drift during the January 2008 survey, two distinct perturbations in seawater properties were unequivocally related to the discharge (Perturbations P1 and P2 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. In addition, the

Table 4. Discharge-Related Water-Property Anomalies^a

Perturbation ^b	Station	Depth Range	Depth of Extremum	Property	Magnitude	Mechanism
P1	4	1.0 to 8.0 m	3.0 m	Temperature	-0.47 °C	Entrainment
Dilution		2.5 to 5.5 m	3.5 m	Transmissivity	-3.69 %	Entrainment
Indeterminate ^c		4.0 to 7.5 m	5.0 m	pH	-0.27	Entrainment
P2	9	4.0 to 8.5 m	5.0 m	Salinity	-0.096 ‰	Effluent
		1.5 to 11.0 m	4.0 m	Temperature	-0.41 °C	Entrainment
		2.0 to 11.5 m	5.0 m	Transmissivity	-9.14 %	Effluent
		6.0 to 13.5 m	13.0 m	pH	-0.054	Entrainment
		9.0 to 13.5 m	12.5 m	DO	-1.16 mg/L	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 Dilution could not be computed due to the absence of a perceptible salinity anomaly, but probably exceeded 700:1

vertical distribution of seawater properties within and below the perturbation lends insight into which of two possible discharge processes was responsible for generating a particular anomaly.

As described previously, discharge-related anomalies are either induced by the presence of dilute wastewater constituents, or are generated by the upward displacement of ambient seawater that is entrained in the rising effluent plume. Wastewater-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 the salinity field. Under the right circumstances, however, wastewater-induced anomalies can also be apparent in density and transmissivity. Such was the case in the January 2008 survey when the extraordinarily high ambient seawater visibility allowed observation of the slightly reduced water clarity caused by the presence of wastewater particulates (Perturbation P2 in Table 4).

Similarly, entrainment-generated anomalies are only apparent when the water column is sufficiently stratified that the juxtaposition of deep seawater properties carried upward in the rising effluent plume provides a contrast against shallow seawater properties. Upward transport of ambient seawater was responsible for generating temperature, pH, and DO anomalies within Perturbations P1 and P2. However, the amplitudes of these entrainment-generated anomalies were quite small compared to those measured in past quarterly surveys when intense upwelling conditions strongly stratified the water column and provided a larger vertical contrast in seawater properties.

The mechanism that produced a discharge-related anomaly is an important consideration when assessing the discharge's compliance with the receiving-water objectives of the COP, and the requirements of the NPDES permit. As indicated in Table 4, only two of the eight anomalies recorded the presence of dilute wastewater. The anomalies detected in other water properties were generated by entrainment of ambient seawater within the rising effluent plume. Because these anomalies reflect properties of ambient seawater that has been displaced upward, they are not subject to water-quality restrictions that were developed to limit impacts from the presence of wastewater contaminants.

Perturbation P1 was unusual because all of the anomalies associated with it were generated by entrainment processes, while a clear salinity anomaly was conspicuously absent. Salinity anomalies are almost always associated with discharge-induced perturbations in seawater properties because they are the strongest tracer of the presence of wastewater constituents. The absence of a salinity anomaly within

Perturbation P1 indicates that the plume was so dilute by that point that even its salinity signature had dissipated. Based on analyses of data collected in the 36 surveys conducted over the past nine years, discharge-induced salinity anomalies with amplitudes smaller than -0.050‰ usually become indistinguishable from background variation (MRS 2008). This occurs when dilution exceeds 700-fold. Thus, the entrainment-generated anomalies within Perturbation P1 were probably a relatively persistent, remnant signature left after the rise of the plume within the water column. The distinctive upward-bow in water-quality contours that is apparent in the middle and bottom frames of Figure A-4, and in the top frame of Figure A-5, is diagnostic of entrained seawater that has moved into the upper water column, where it contrasts with the surrounding seawater.

The transmissivity anomaly associated with Perturbation P2 was unusual because it was generated by the presence of effluent particulates. Over two decades of monitoring has shown that discharge-related anomalies in seawater properties, other than salinity and density, are almost always caused by entrainment. However, because of the unusually high seawater clarity during the survey, the sensitive transmissometer on the CTD captured the plume's particulate signature before it had much of a chance to dissipate within the less turbid receiving seawater. The resulting transmissivity of 73.09%, although well within the range of ambient seawater during most surveys, was 9.14% lower than the average ambient transmissivity measured at the same depth at other stations during the January 2008 survey (Table B-5).

Given its location along the plume's transport path to the south of the diffuser structure, and the fact that ambient transmissivity levels below 78.3% were not recorded elsewhere, the Station-9 transmissivity anomaly was clearly associated with the effluent discharge. Additionally, its depth range and location coincided with anomalies in four of the five remaining seawater properties. The presence of a salinity anomaly at the same location, albeit small, is particularly diagnostic of the presence of dilute wastewater. However, the absence of a distinct density anomaly suggests that most of the plume's buoyancy had dissipated within this perturbation. Accordingly, the vertical extent of the anomalies at Station 9 suggests that the perturbation did not quite reach the sea surface, although it came within 1.5 m of it (Table 4, Figures A-6 and A-7).

Initial Dilution Computations

The amplitude of the negative salinity anomalies at Station 9 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 the 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.

However, as described below, computations of dilution based on the salinity anomaly measured at a depth of 5 m within Perturbation P2 demonstrates that the effluent plume actually achieved a far higher dilution ($\geq 348:1$) than the total dilution (133:1) predicted by conservative modeling. Thus, rapid mixing associated with the momentum of the discharge jet and the buoyant plume's subsequent rise through the water column was capable of achieving higher dilutions than that predicted by modeling. This demonstrates that, during the January 2008 survey, the diffuser structure was operating more efficiently than predicted by the modeling.

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.

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

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

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:

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

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

The magnitude of the observed salinity anomaly at Station 9 (-0.096‰) was used in Equation 2 to compute the dilution level achieved within Perturbation P2. The computed dilution, listed in the left column of Table 4, demonstrates that the modeled dilution factor (133:1) was significantly more conservative than that actually achieved by the discharge ($\geq 348:1$) at a location within the ZID and only 12.6 m from the diffuser structure. The measured dilution ratio (348:1) was two-and-a-half times higher than the dilution predicted by conservative modeling. This dilution computation demonstrates that, during the January 2008 survey, the outfall was performing far better than designed, and was rapidly diluting effluent more than 348-fold within the ZID boundary. Consequently, COP receiving-water objectives were being easily met by the chemical concentration limits promulgated by the NPDES discharge permit issued to the MBCSD.

DISCUSSION

Sampling during the January 2008 survey demonstrated that the wastewater discharge was in compliance with the receiving-water limitations specified in the NPDES permit, and with the water-quality objectives of the COP (SWRCB 1997) and the Central Coast Basin Plan (RWQCB 1994). Specifically, there were no

particulates of sewage origin seen floating on the ocean surface at any of the stations sampled during the January 2008 water-quality survey, and the discharge complied with all quantitative limits on seawater properties.

Although discharge-related changes in five of the six water properties were observed during the January 2008 survey, the changes were not statistically significant, were measured within the boundary of the ZID, or resulted from the displacement of ambient seawater rather than the presence of effluent constituents. Receiving-water limitations only apply to statistically significant changes caused by the presence of effluent constituents beyond the ZID boundary. The measurements collected during the January 2008 survey demonstrated that the receiving-water limitations were being met within 7.2 m of the discharge (Perturbation P1). Beyond the ZID, the effluent had experienced such a high level of dilution that no perceptible changes in seawater properties were caused by the presence of effluent constituents. Moreover, the discharge-related anomalies in temperature, DO, and pH recorded during the survey 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.

Outfall Performance

The salinity anomaly measured at Station 9, located within 12.6 m of the diffuser, demonstrated that the receiving-water objectives of the COP were being met well within the ZID. This and other high-precision observations demonstrated that the diffuser structure was operating better than predicted by modeling, and that discharged wastewater was achieving dilutions well in excess of the minimum critical dilution of 133:1. The amplitude of the only discharge-related salinity anomaly indicates that wastewater had been diluted more than 348-fold at Station 9. Similarly, the lack of a salinity anomaly within Perturbation P1 at Station 4 indicates that the wastewater constituents had been diluted beyond recognition by the time the plume had reached the boundary of the ZID. Thus, the high dilution ratio that was determined from actual measurements Station 9 demonstrates that the outfall was performing better than expected. At that point, the limits on wastewater contaminant concentrations specified in the MBCSD NPDES discharge permit could have been two-and-a-half times higher, and the receiving-water objectives of the California Ocean Plan (COP) would still have been met.

NPDES Permit Limits

The seawater properties measured during the January 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 significant reductions in instrumentally recorded light transmittance at one of the sixteen monitoring stations during the January 2008 survey (highlighted by bold typeface in Table B-5). The significant reduction in transmissivity extended over most of the water column, from 2.0 m to 11.5 m, at Station 9. Although not statistically significant, instrumentally recorded transmissivity was perceptibly lower at Station 4 as well. Increased suspended material was also visually apparent within the water column south of the diffuser structure during part of the survey. The accompanying reduction in the penetration of ambient light was quantified by a marked reduction in the Secchi depths measured at Stations 4 and 9. Compared to the 11-m average depth measured at all the other stations, these stations had Secchi depths of 9 m and 7.5 m, respectively (Table B-9). However, both of these stations were located within the ZID where the COP limitation does not apply. In addition, not only was the discharge-related transmissivity anomaly at Station 4 not statistically significant, but the upward movement of naturally turbid ambient seawater may have contributed to the anomaly. Thus, it may not have been generated solely “...as the result of the discharge of waste” (SWRCB 1997).

Dissolved Oxygen

Although it is not explicitly stated in the NPDES discharge permit, the COP specifies that the DO limitation only applies to reductions that occur “...as a result of the discharge of oxygen demanding waste materials.” 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 effluent constituents have never been observed within the receiving waters. Additionally, the DO limitation does not apply to reductions in DO caused by the movement of ambient waters, regardless of whether or not they were induced by the physics of the discharge. During the January 2008 survey, the statistically significant DO anomaly at Station 9 (Table B-4) was, at least in part, the result of the upward movement of ambient seawater entrained in the effluent plume as it rose through the water column. However, seawater at depth is naturally depleted in DO. Therefore, the DO anomaly would not be subject to COP limitations for that reason, as well as because it was located within the ZID. Regardless, all of the DO measurements collected during the January 2008 survey complied with the numerical limits on DO concentrations. All of the DO measurements remained between 7.1 and 8.8 and, thus, were well above the 5-mg/L minimum specified in the Basin Plan and the NPDES discharge permit.

pH

The only statistically significant lateral anomaly in pH (Table B-6) was measured at mid-depth at Station 9. As with the DO anomaly, this pH anomaly was probably generated by the upward displacement of ambient bottom water, which is naturally low in pH. Moreover, the maximum amplitude of this anomaly (-0.054) was so small that it easily complied with the numerical limit that restricts changes to less than 0.2 pH units. In fact, the range in pH among all of the measurements was only 0.102, so none of the

measurements would be considered changed by ‘...more than 0.2 pH units from that which occurs naturally.’ The range across the entire pH field remained between 7.56 and 7.66, and thus, all of the measurements also complied with the lower (7.0 pH) and upper (8.3 pH) bounds on discharge-induced pH changes.

Temperature and Salinity

The total range in temperature of 0.93°C across all observations was largely 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 much less than the large-scale spatial variability in sea-surface temperature shown in the satellite image on the cover of this report. The small, discharge-induced decreases in temperature (-0.47°C and -0.41 °C) that are visually apparent in the vertical sections at Stations 4 and 9 must have resulted from the upward displacement of naturally occurring, cooler bottom water, rather than as a result of the presence of warmer wastewater constituents. In any regard, the slightly depressed mid-depth temperature was comparable to average temperatures measured near the seafloor throughout the January 2008 survey. Accordingly, the Station 4 and 9 thermal anomalies were not found to be statistically significant.

Additionally, although salinity anomalies provide the best tracers of discharged effluent, the actual maximum amplitude (-0.096‰) of the sole salinity anomaly observed during the January 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 six times higher (0.64‰) than the salinity anomaly recorded at Station 9 during the January 2008 survey. In any regard, the observed ranges in both the reported temperature (0.93°C) and salinity (-0.297‰) across all data collected during the January 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 January 2008 survey complied with the receiving-water limitations specified in the NPDES discharge permit. The discharge-related anomalies that were found at Stations 4 and 9 were caused by the presence of effluent that had completed the initial dilution process after the buoyant plume had reached equilibrium upon completing its rise through the water column. Other than the salinity and transmissivity anomalies at Station 9, all discharge-related anomalies were generated by upward displacement of ambient seawater rather than the presence of dilute effluent. At Station 9, effluent had been diluted at least 348-fold, and any perceptible trace of anomalous wastewater characteristics, other than low salinity and transmissivity, had long since dissipated. Farther away from the diffuser structure, at Station 4, the effluent plume achieved even higher dilutions. These measurements confirm that the diffuser structure and the outfall were operating better than predicted by modeling.

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APPENDIX A

Water Quality Profiles and Cross Sections

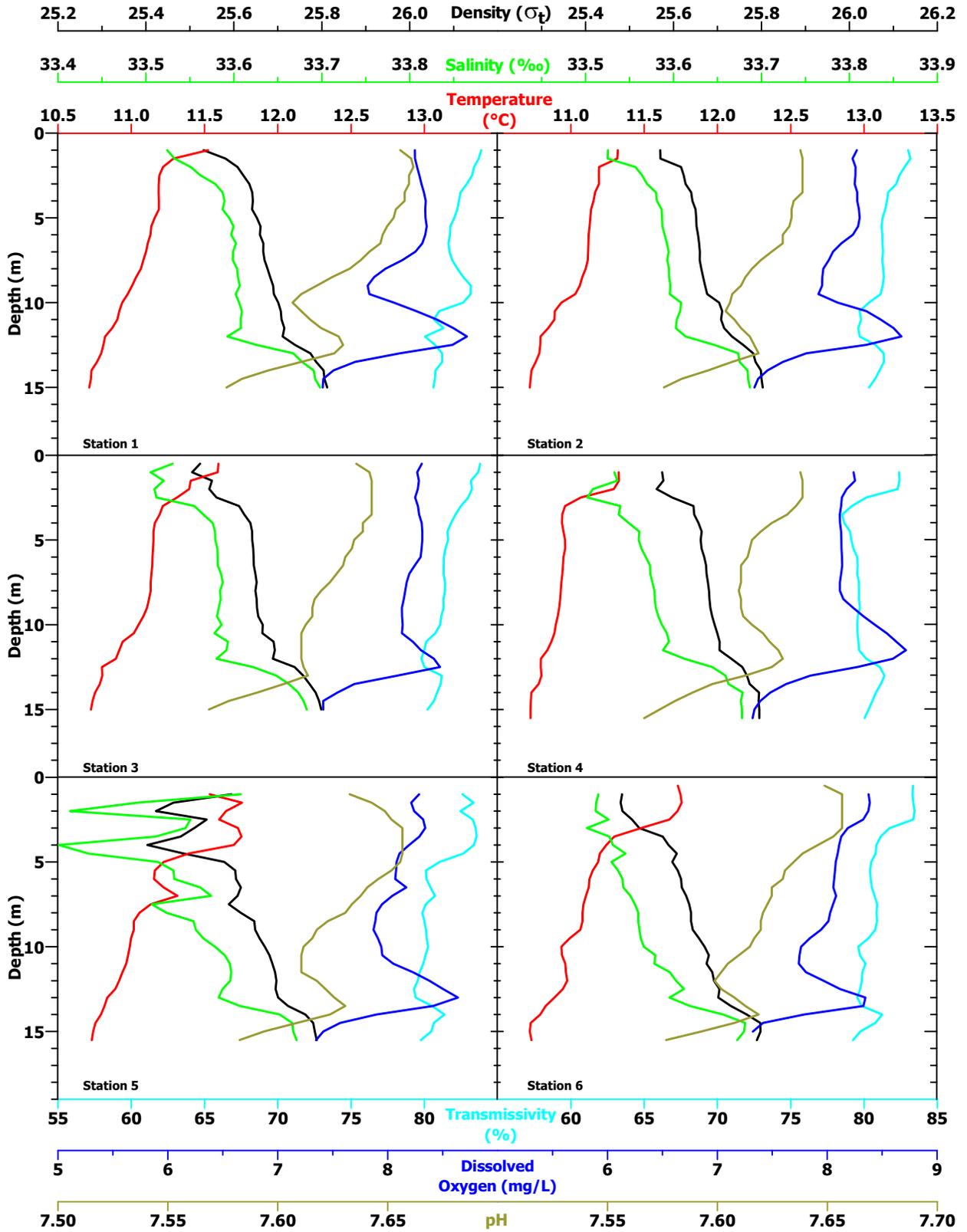


Figure A-1. Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 2 January 2008

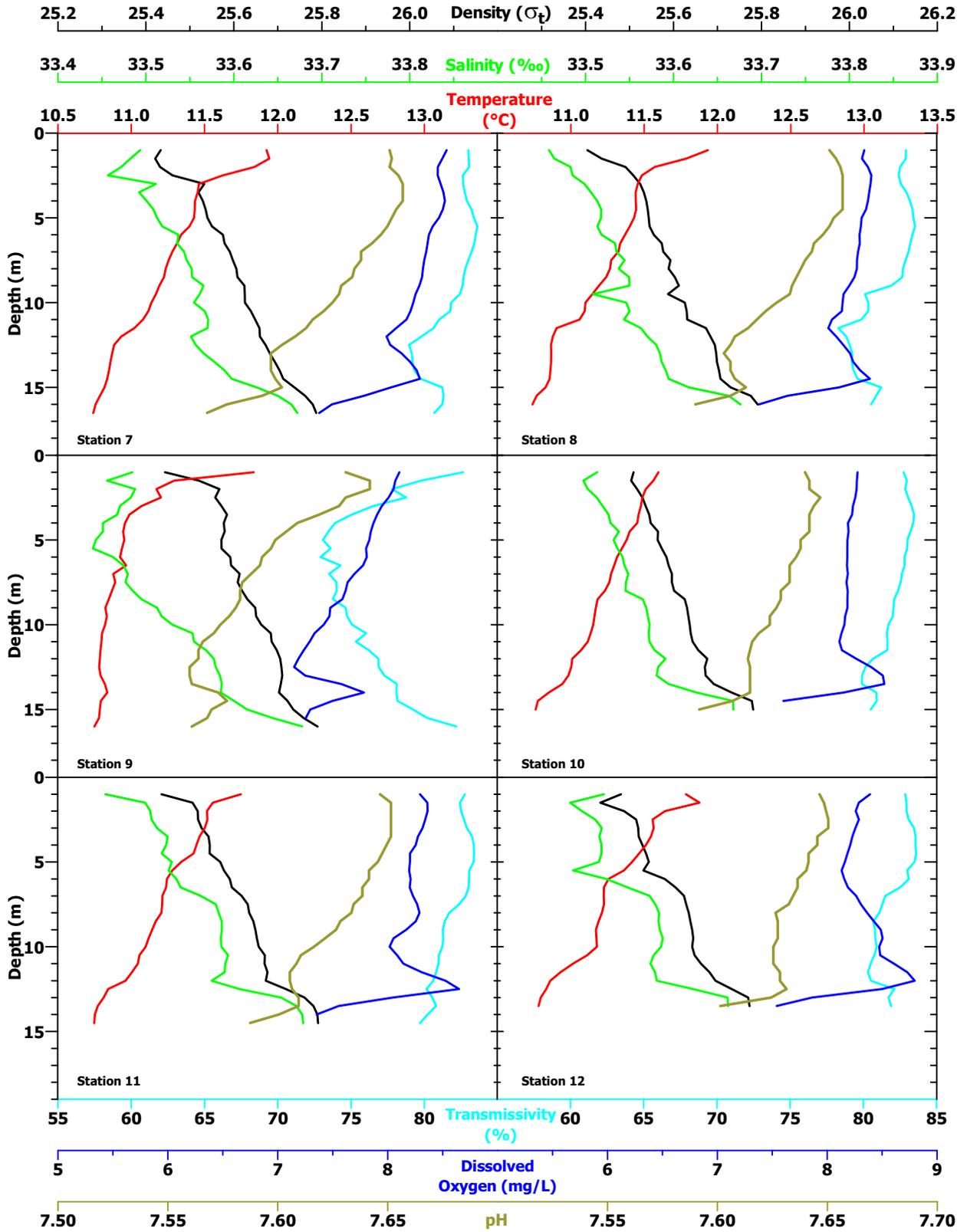


Figure A-2. Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 2 January 2008

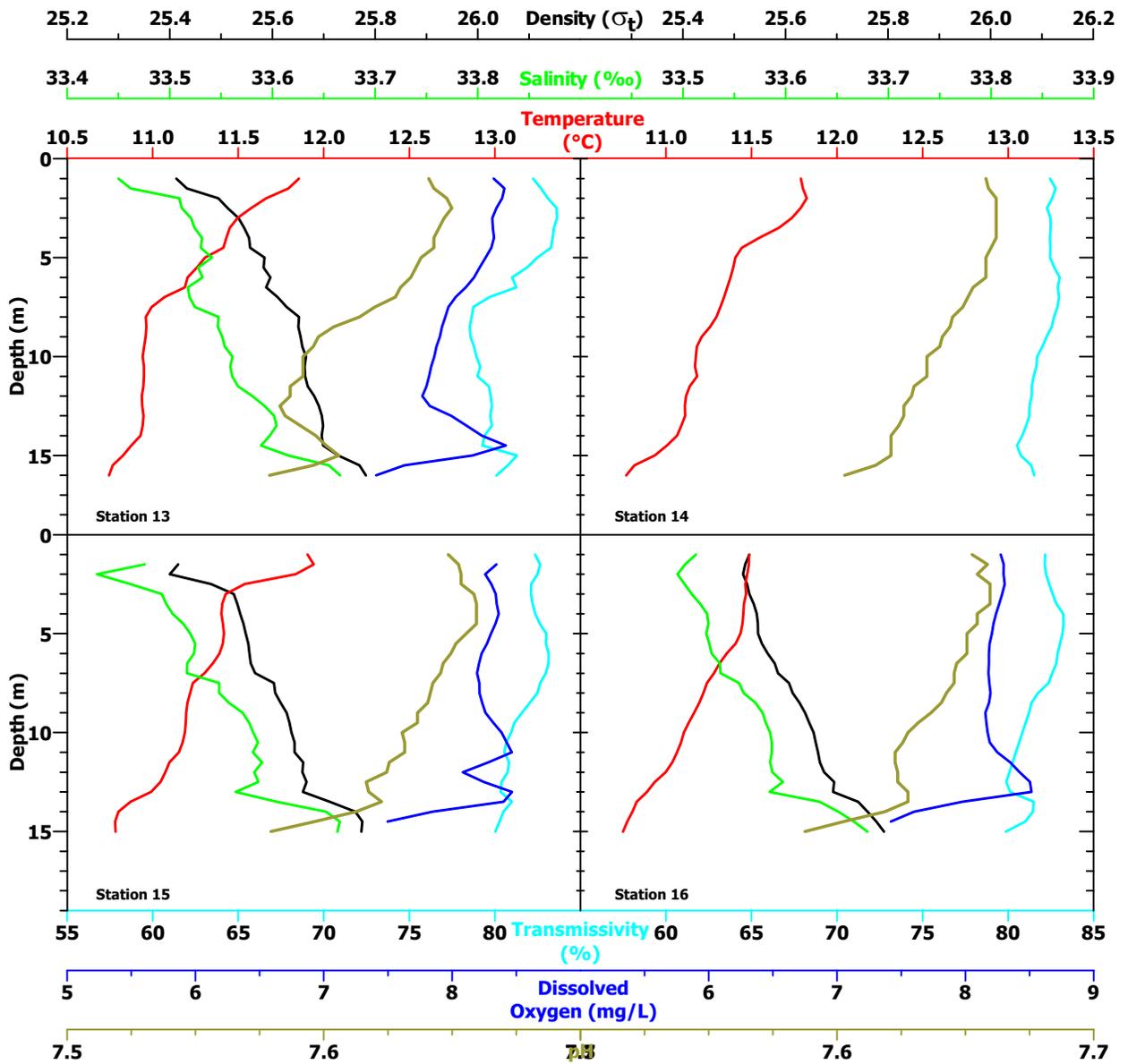


Figure A-3. Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 2 January 2008

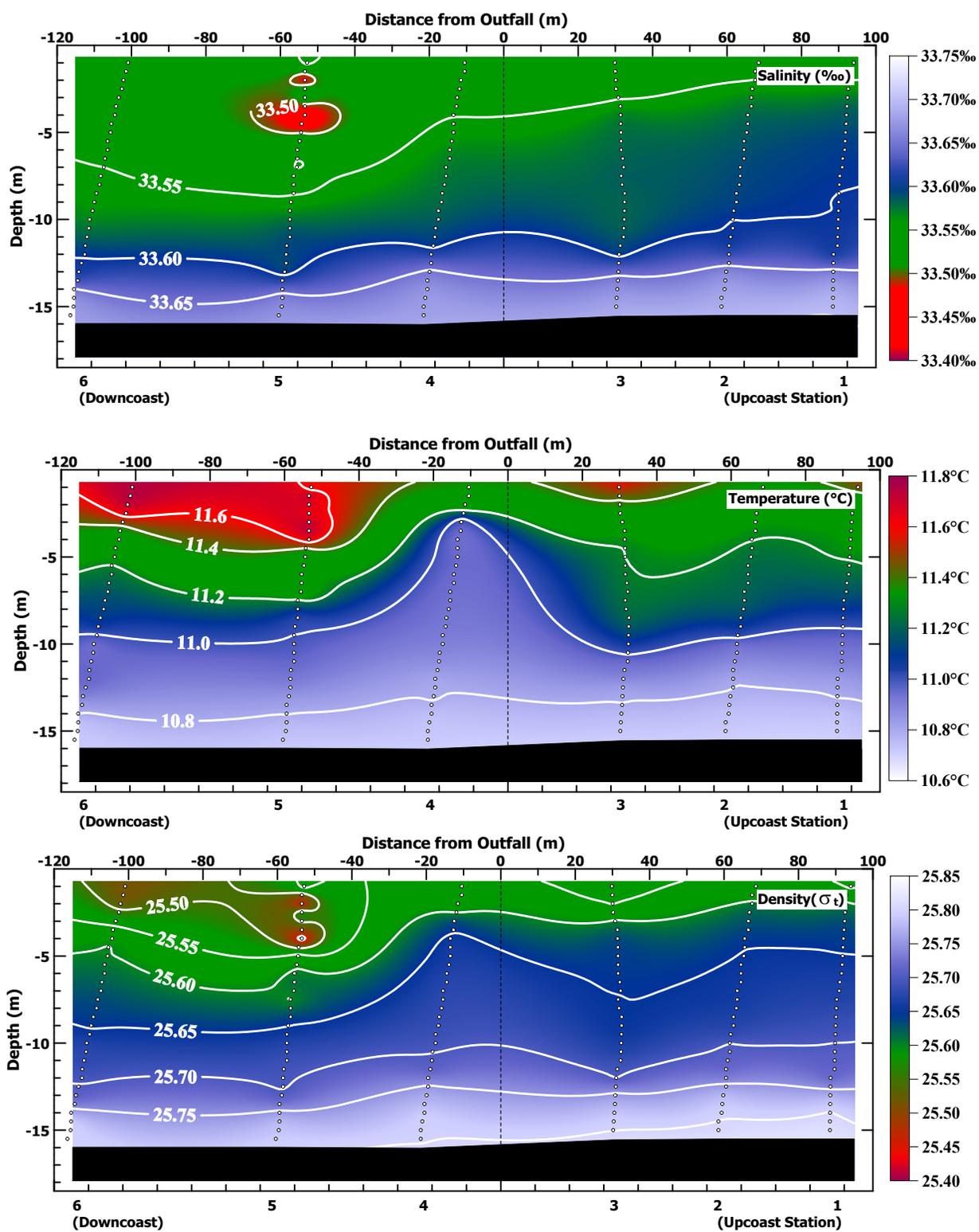


Figure A-4. Along-Shore Transects of Salinity, Temperature, and Density on 2 January 2008

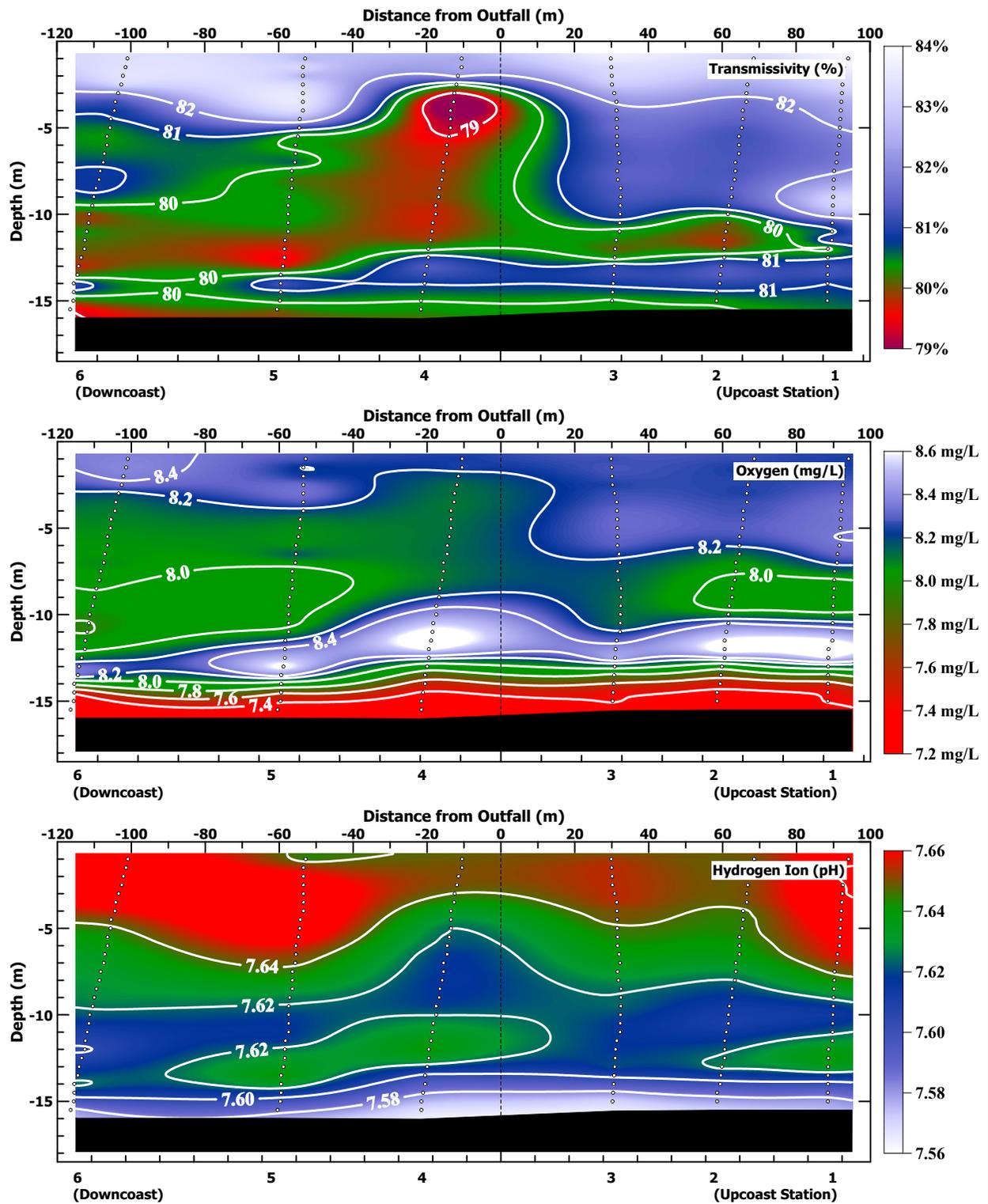


Figure A-5. Along-Shore Transects of Transmissivity, Dissolved Oxygen, and pH on 2 January 2008

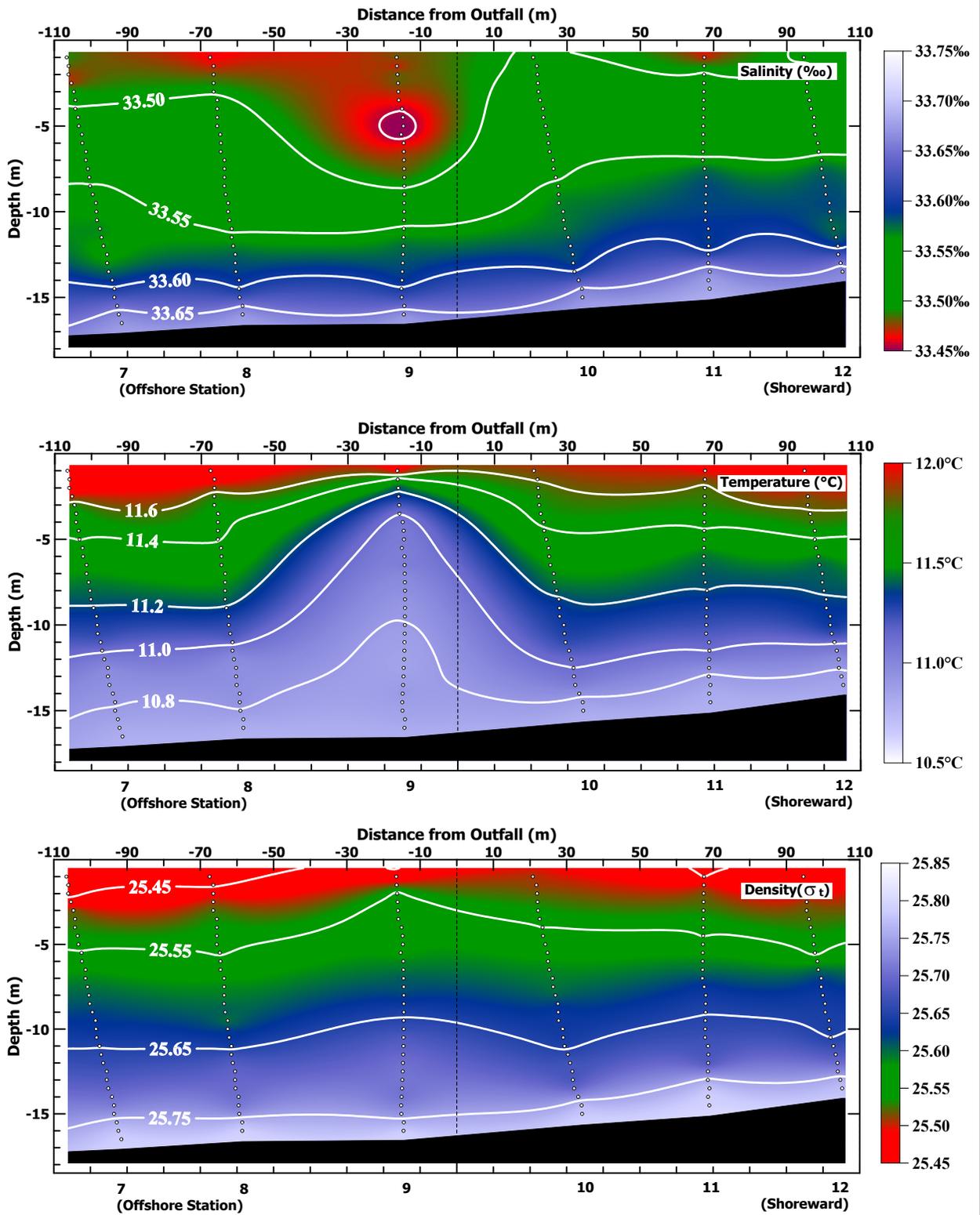


Figure A-6. Cross-Shore Transects of Salinity, Temperature, and Density on 2 January 2008

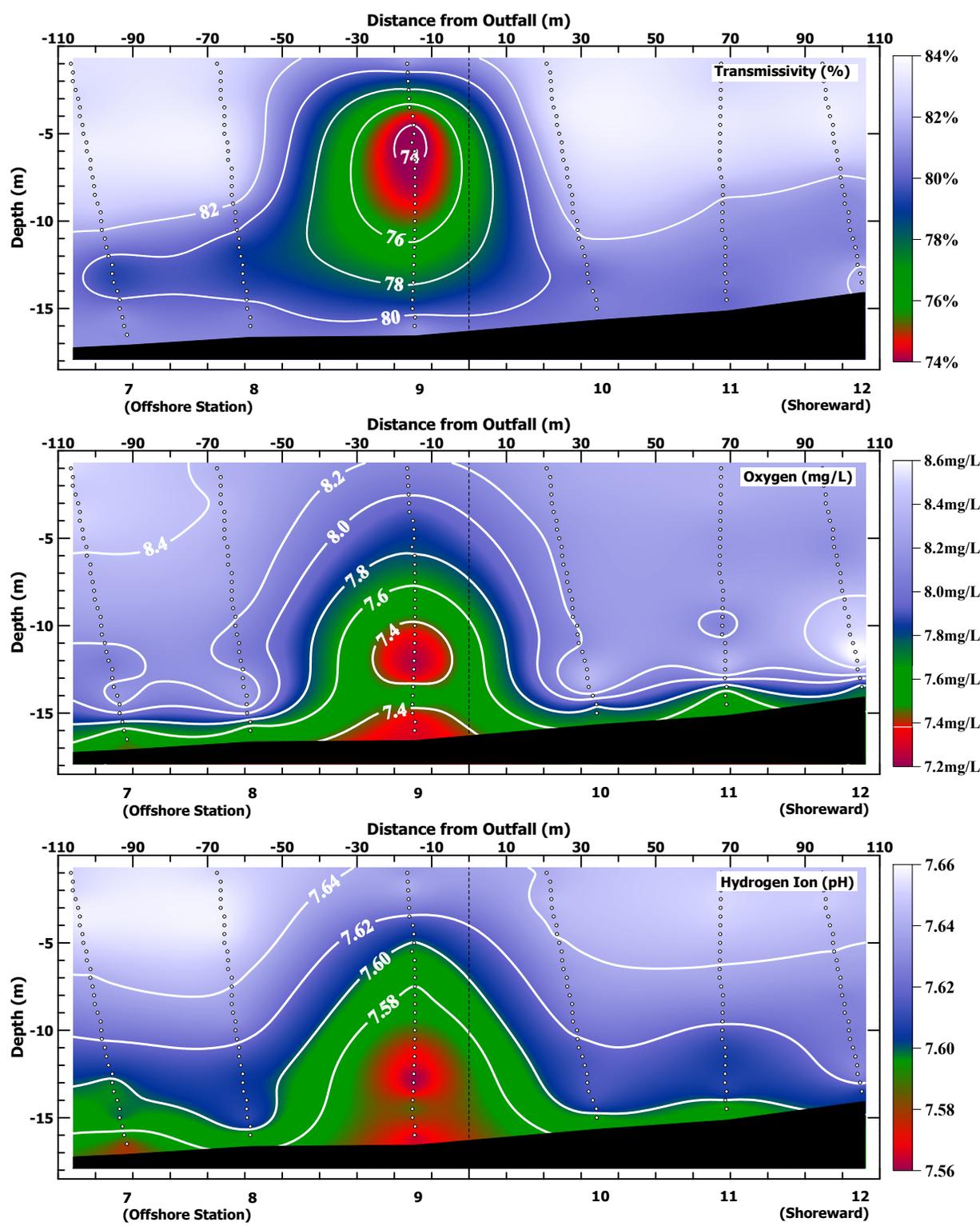


Figure A-7. Cross-Shore Transects of Transmissivity, Dissolved Oxygen, and pH on 2 January 2008

APPENDIX B

Tables of Profile Data and Standard Observations

Table B-2. Salinity¹ on 2 January 2008

Depth (m)	Salinity (‰)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14 ²	15	16
0.5			33.531													
1.0	33.524	33.525	33.505	33.533	33.608	33.515	33.493	33.459	33.485	33.513	33.454	33.521	33.450			33.513
1.5	33.533	33.525	33.520	33.536	33.490	33.512	33.482	33.465	33.456	33.498	33.499	33.483	33.462		33.475	33.502
2.0	33.551	33.557	33.510	33.508	33.414	33.511	33.472	33.483	33.488	33.503	33.505	33.496	33.509		33.429	33.494
2.5	33.562	33.564	33.512	33.502	33.551	33.526	33.457	33.485	33.483	33.513	33.506	33.511	33.512		33.462	33.502
3.0	33.579	33.570	33.555	33.540	33.545	33.502	33.511	33.499	33.471	33.519	33.512	33.518	33.521		33.492	33.508
3.5	33.587	33.580	33.565	33.538	33.511	33.527	33.492	33.506	33.468	33.526	33.525	33.516	33.524		33.497	33.517
4.0	33.589	33.581	33.576	33.549	33.401	33.531	33.501	33.513	33.451	33.528	33.523	33.518	33.531		33.503	33.524
4.5	33.587	33.587	33.579	33.561	33.435	33.546	33.509	33.518	33.451	33.538	33.518	33.518	33.530		33.513	33.525
5.0	33.595	33.587	33.579	33.560	33.514	33.529	33.513	33.518	33.443	33.532	33.530	33.515	33.541		33.520	33.523
5.5	33.600	33.587	33.581	33.563	33.531	33.537	33.519	33.513	33.440	33.536	33.526	33.486	33.528		33.525	33.525
6.0	33.597	33.590	33.582	33.568	33.532	33.542	33.537	33.518	33.463	33.542	33.535	33.524	33.532		33.524	33.528
6.5	33.603	33.592	33.582	33.573	33.562	33.543	33.536	33.534	33.475	33.544	33.539	33.548	33.518		33.517	33.536
7.0	33.599	33.594	33.585	33.574	33.574	33.551	33.543	33.535	33.480	33.549	33.562	33.573	33.519		33.517	33.537
7.5	33.599	33.593	33.587	33.576	33.507	33.556	33.546	33.544	33.477	33.546	33.580	33.579	33.524		33.548	33.555
8.0	33.604	33.595	33.584	33.578	33.523	33.560	33.552	33.538	33.485	33.545	33.583	33.584	33.547		33.548	33.559
8.5	33.605	33.595	33.585	33.579	33.554	33.560	33.553	33.549	33.495	33.565	33.586	33.583	33.547		33.558	33.570
9.0	33.607	33.597	33.583	33.580	33.557	33.561	33.566	33.550	33.513	33.569	33.587	33.584	33.551		33.571	33.577
9.5	33.602	33.596	33.581	33.583	33.565	33.563	33.561	33.508	33.518	33.571	33.585	33.588	33.554		33.577	33.580
10.0	33.606	33.609	33.586	33.587	33.579	33.566	33.555	33.546	33.530	33.573	33.586	33.586	33.561		33.581	33.585
10.5	33.609	33.608	33.578	33.592	33.590	33.580	33.567	33.550	33.553	33.572	33.594	33.578	33.559		33.586	33.586
11.0	33.608	33.604	33.593	33.595	33.596	33.578	33.571	33.544	33.555	33.573	33.590	33.574	33.561		33.581	33.587
11.5	33.608	33.603	33.592	33.588	33.597	33.596	33.570	33.563	33.568	33.579	33.590	33.579	33.567		33.590	33.585
12.0	33.593	33.614	33.580	33.612	33.596	33.603	33.551	33.570	33.577	33.591	33.575	33.581	33.580		33.582	33.587
12.5	33.626	33.646	33.622	33.644	33.587	33.612	33.557	33.580	33.579	33.582	33.606	33.622	33.592		33.586	33.597
13.0	33.668	33.674	33.648	33.659	33.583	33.595	33.566	33.585	33.584	33.581	33.654	33.662	33.602		33.564	33.584
13.5	33.678	33.675	33.663	33.663	33.607	33.619	33.578	33.587	33.586	33.595	33.671	33.662	33.604		33.604	33.633
14.0	33.691	33.684	33.673	33.679	33.652	33.656	33.590	33.591	33.585	33.626	33.678		33.597		33.652	33.651
14.5	33.692	33.685	33.679	33.677	33.666	33.681	33.598	33.594	33.600	33.668	33.679		33.589		33.666	33.666
15.0	33.698	33.687	33.683	33.678	33.668	33.680	33.626	33.617	33.615	33.668			33.616		33.663	33.679
15.5				33.678	33.671	33.673	33.650	33.663	33.644				33.655			
16.0								33.665	33.676	33.678			33.666			
16.5								33.672								

¹ The value enclosed in the box was significantly lower than the mean of other salinity measurements at the same depth below the sea surface.

² Salinity, density, and dissolved oxygen measurements were compromised at Station 14 by the probable intake of a salp into the ducted portion of the CTD

Table B-3. Seawater Density on 2 January 2008

Depth (m)	Density (sigma-t)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14 ¹	15	16
0.5			25.523													
1.0	25.531	25.570	25.505	25.574	25.595	25.483	25.434	25.404	25.443	25.509	25.436	25.481	25.413			25.529
1.5	25.581	25.570	25.550	25.577	25.463	25.480	25.421	25.436	25.521	25.504	25.506	25.434	25.433		25.416	25.522
2.0	25.608	25.617	25.544	25.561	25.423	25.484	25.432	25.491	25.567	25.517	25.518	25.488	25.494		25.400	25.518
2.5	25.622	25.623	25.561	25.597	25.538	25.506	25.461	25.509	25.558	25.529	25.518	25.515	25.512		25.480	25.525
3.0	25.635	25.628	25.612	25.646	25.510	25.522	25.533	25.524	25.572	25.536	25.527	25.520	25.534		25.525	25.530
3.5	25.642	25.640	25.624	25.647	25.479	25.575	25.520	25.533	25.584	25.544	25.543	25.521	25.545		25.532	25.538
4.0	25.643	25.643	25.638	25.657	25.403	25.588	25.530	25.538	25.577	25.548	25.545	25.529	25.554		25.537	25.544
4.5	25.642	25.650	25.642	25.664	25.486	25.608	25.536	25.541	25.579	25.565	25.545	25.538	25.557		25.544	25.546
5.0	25.653	25.652	25.642	25.662	25.578	25.597	25.540	25.543	25.572	25.564	25.569	25.544	25.585		25.548	25.547
5.5	25.661	25.653	25.644	25.664	25.603	25.610	25.550	25.545	25.572	25.573	25.577	25.531	25.583		25.553	25.554
6.0	25.660	25.656	25.645	25.670	25.605	25.617	25.575	25.555	25.592	25.584	25.591	25.580	25.596		25.555	25.565
6.5	25.667	25.658	25.645	25.674	25.616	25.619	25.579	25.573	25.594	25.589	25.596	25.604	25.588		25.557	25.579
7.0	25.667	25.660	25.649	25.675	25.609	25.629	25.591	25.577	25.613	25.596	25.618	25.624	25.610		25.566	25.585
7.5	25.670	25.659	25.652	25.678	25.589	25.636	25.598	25.593	25.609	25.596	25.632	25.629	25.628		25.603	25.607
8.0	25.677	25.663	25.649	25.681	25.616	25.640	25.606	25.589	25.619	25.601	25.635	25.635	25.652		25.606	25.614
8.5	25.683	25.667	25.652	25.682	25.647	25.640	25.608	25.603	25.631	25.625	25.645	25.638	25.651		25.616	25.628
9.0	25.690	25.672	25.653	25.684	25.649	25.644	25.624	25.612	25.649	25.631	25.649	25.643	25.655		25.628	25.638
9.5	25.691	25.677	25.656	25.688	25.659	25.658	25.625	25.588	25.651	25.634	25.653	25.645	25.658		25.633	25.646
10.0	25.701	25.704	25.666	25.693	25.671	25.671	25.625	25.626	25.663	25.637	25.657	25.642	25.666		25.637	25.655
10.5	25.707	25.711	25.665	25.699	25.681	25.680	25.639	25.630	25.684	25.639	25.670	25.648	25.663		25.643	25.659
11.0	25.708	25.708	25.691	25.705	25.688	25.675	25.648	25.631	25.686	25.644	25.670	25.662	25.664		25.643	25.663
11.5	25.715	25.715	25.693	25.705	25.694	25.688	25.658	25.674	25.698	25.656	25.677	25.682	25.669		25.660	25.667
12.0	25.711	25.733	25.689	25.731	25.697	25.692	25.659	25.684	25.706	25.677	25.673	25.696	25.681		25.658	25.676
12.5	25.739	25.759	25.738	25.756	25.695	25.704	25.672	25.694	25.708	25.671	25.718	25.733	25.690		25.667	25.695
13.0	25.774	25.781	25.758	25.767	25.701	25.702	25.682	25.697	25.710	25.673	25.761	25.770	25.696		25.659	25.693
13.5	25.787	25.787	25.772	25.773	25.723	25.731	25.693	25.699	25.707	25.692	25.781	25.773	25.699		25.712	25.742
14.0	25.804	25.799	25.786	25.795	25.763	25.767	25.704	25.704	25.703	25.733	25.790		25.696		25.761	25.760
14.5	25.806	25.800	25.794	25.793	25.780	25.797	25.713	25.707	25.722	25.778	25.792		25.699		25.775	25.777
15.0	25.812	25.803	25.799	25.795	25.784	25.798	25.738	25.730	25.735	25.781			25.728		25.773	25.792
15.5				25.795	25.789	25.790	25.762	25.776	25.759				25.769			
16.0							25.779	25.791	25.790				25.782			
16.5							25.788									

¹ Salinity, density, and dissolved oxygen measurements were compromised at Station 14 by the probable intake of a salp into the ducted portion of the CTD

Table B-4. Detrended¹ Dissolved Oxygen² on 2 January 2008

Depth (m)	Dissolved Oxygen (mg/L)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14 ³	15	16
0.5			8.31													
1.0	8.25	8.27	8.27	8.24	8.29	8.38	8.54	8.34	8.11	8.28	8.29	8.39	8.32			8.27
1.5	8.25	8.23	8.28	8.25	8.21	8.39	8.50	8.32	8.07	8.27	8.36	8.29	8.41		8.35	8.30
2.0	8.27	8.26	8.27	8.18	8.24	8.37	8.46	8.37	8.05	8.27	8.36	8.26	8.39		8.26	8.30
2.5	8.29	8.26	8.25	8.13	8.32	8.33	8.45	8.40	8.01	8.26	8.34	8.29	8.35		8.31	8.31
3.0	8.31	8.25	8.28	8.13	8.34	8.19	8.48	8.39	7.95	8.23	8.32	8.26	8.31		8.34	8.29
3.5	8.33	8.27	8.28	8.11	8.29	8.13	8.51	8.38	7.90	8.23	8.27	8.23	8.32		8.35	8.26
4.0	8.35	8.27	8.31	8.12	8.19	8.11	8.52	8.37	7.87	8.19	8.26	8.21	8.33		8.36	8.24
4.5	8.34	8.29	8.32	8.13	8.11	8.10	8.50	8.35	7.85	8.19	8.20	8.19	8.31		8.34	8.22
5.0	8.34	8.30	8.31	8.13	8.08	8.08	8.47	8.31	7.83	8.18	8.20	8.16	8.26		8.30	8.21
5.5	8.36	8.28	8.31	8.13	8.08	8.07	8.41	8.31	7.80	8.18	8.19	8.13	8.21		8.27	8.19
6.0	8.34	8.23	8.30	8.13	8.07	8.06	8.38	8.29	7.81	8.18	8.21	8.16	8.17		8.23	8.18
6.5	8.32	8.13	8.25	8.14	8.17	8.06	8.36	8.30	7.78	8.18	8.20	8.19	8.11		8.21	8.18
7.0	8.25	8.05	8.20	8.13	8.04	8.08	8.35	8.28	7.70	8.19	8.23	8.26	8.03		8.19	8.18
7.5	8.13	8.01	8.17	8.12	7.95	8.05	8.33	8.27	7.64	8.18	8.27	8.31	7.97		8.21	8.19
8.0	7.98	7.97	8.16	8.12	7.90	8.03	8.32	8.27	7.62	8.19	8.29	8.36	7.95		8.21	8.19
8.5	7.88	7.96	8.15	8.15	7.89	8.01	8.31	8.25	7.59	8.19	8.26	8.42	7.92		8.24	8.18
9.0	7.82	7.95	8.13	8.24	7.87	7.94	8.29	8.20	7.48	8.19	8.17	8.49	7.90		8.26	8.15
9.5	7.83	7.92	8.13	8.33	7.91	7.84	8.25	8.15	7.47	8.16	8.05	8.51	7.88		8.32	8.16
10.0	8.06	8.10	8.14	8.43	7.94	7.76	8.23	8.14	7.42	8.16	8.02	8.47	7.86		8.38	8.17
10.5	8.26	8.36	8.13	8.54	7.95	7.75	8.21	8.13	7.33	8.13	8.09	8.48	7.84		8.42	8.19
11.0	8.45	8.49	8.23	8.63	8.05	7.74	8.17	8.04	7.29	8.11	8.14	8.61	7.82		8.47	8.25
11.5	8.60	8.61	8.30	8.72	8.23	7.81	8.08	8.01	7.24	8.13	8.31	8.73	7.80		8.28	8.35
12.0	8.72	8.68	8.42	8.60	8.38	7.97	7.99	8.08	7.19	8.27	8.53	8.80	7.77		8.08	8.42
12.5	8.59	8.35	8.48	8.27	8.50	8.12	8.02	8.15	7.15	8.40	8.65	8.50	7.83		8.25	8.50
13.0	8.11	7.81	8.09	7.85	8.64	8.35	8.13	8.21	7.25	8.51	8.05	7.86	7.99		8.47	8.51
13.5	7.70	7.60	7.70	7.63	8.41	8.33	8.20	8.24	7.58	8.52	7.55	7.54	8.11		8.40	7.98
14.0	7.51	7.46	7.54	7.48	7.90	7.79	8.26	8.30	7.78	8.15	7.35		8.23		7.85	7.60
14.5	7.41	7.37	7.41	7.39	7.57	7.42	8.29	8.39	7.50	7.60			8.42		7.50	7.42
15.0	7.41	7.34	7.41	7.34	7.41	7.33	8.03	8.11	7.29				8.16			
15.5				7.32	7.35			7.78	7.64	7.26				7.63		
16.0								7.49	7.38					7.41		
16.5								7.38								

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

² The DO values enclosed in the box were significantly lower than the mean of other DO measurements at the same distance above the seafloor.

³ Salinity, density, and dissolved oxygen measurements were compromised at Station 14 by the probable intake of a salp into the ducted portion of the CTD

Table B-5. Light Transmittance¹ across a 0.25-m path on 2 January 2008

Depth (m)	Light Transmittance (%)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5			83.81			83.34										
1.0	83.88	83.01	83.67	82.39	82.59	83.31	83.00	82.91	82.64	82.75	82.76	82.87	82.23	82.45	82.35	82.16
1.5	83.71	83.17	83.18	82.42	83.36	83.36	83.03	82.90	79.77	82.97	82.44	82.94	82.70	82.77	82.64	82.14
2.0	83.39	82.77	83.24	82.29	82.46	83.45	83.05	82.51	77.79	82.86	82.51	82.95	83.09	82.57	82.49	82.21
2.5	83.25	82.41	82.99	80.15	83.30	83.36	82.63	82.41	78.76	83.06	82.70	83.09	83.61	82.28	82.12	82.40
3.0	82.90	82.20	82.49	79.17	83.50	81.74	82.64	82.56	76.51	83.30	82.90	83.46	83.63	82.47	82.11	82.60
3.5	82.47	81.64	82.12	78.50	83.56	81.14	82.76	82.95	75.05	83.46	83.26	83.57	83.45	82.48	82.21	82.82
4.0	82.36	81.57	81.83	78.65	83.38	80.84	82.90	83.18	73.90	83.40	83.37	83.56	83.37	82.44	82.36	83.21
4.5	82.24	81.44	81.58	79.04	82.67	80.79	83.22	83.36	73.46	83.22	83.39	83.61	83.27	82.46	82.62	83.24
5.0	82.04	81.27	81.63	79.14	81.04	80.49	83.38	83.42	73.09	83.01	83.36	83.49	82.48	82.45	83.01	83.17
5.5	81.78	81.19	81.44	79.28	80.10	80.41	83.62	83.53	73.60	82.98	83.07	82.99	81.87	82.70	82.98	83.04
6.0	81.74	81.25	81.33	79.53	80.15	80.46	83.50	83.35	72.92	82.81	83.04	83.11	81.01	83.01	83.14	82.89
6.5	81.64	81.26	81.32	79.57	80.43	80.53	83.41	83.21	74.29	82.82	83.02	82.51	81.25	82.90	83.13	82.81
7.0	81.71	81.30	81.31	79.54	80.73	80.73	83.23	83.09	73.50	82.63	82.83	81.51	79.70	82.97	82.97	82.57
7.5	81.90	81.25	81.41	79.65	80.10	80.89	83.00	82.87	74.00	82.54	82.38	81.30	78.75	82.88	82.65	82.36
8.0	82.25	81.31	81.40	79.66	79.86	80.85	82.79	82.69	74.02	82.37	81.70	81.08	78.64	82.68	82.48	81.75
8.5	82.67	81.35	81.30	79.65	80.01	80.88	82.68	82.66	73.75	82.11	81.39	80.68	78.53	82.54	82.04	81.36
9.0	83.17	81.27	81.31	79.72	80.11	80.77	82.61	81.91	74.63	82.06	81.27	80.80	78.57	82.25	81.58	81.23
9.5	83.15	81.13	81.16	79.58	80.16	80.30	82.43	80.11	74.73	82.02	81.29	80.82	78.79	82.00	81.14	81.02
10.0	82.65	80.33	81.08	79.55	80.26	79.60	81.83	80.34	75.06	81.71	81.23	80.91	78.92	81.70	80.95	80.83
10.5	81.01	79.69	80.74	79.55	80.08	79.72	81.77	80.34	76.03	81.60	80.99	80.75	79.14	81.65	80.67	80.64
11.0	80.65	79.80	80.13	79.62	79.93	80.11	81.01	79.87	75.33	81.65	80.97	80.50	78.99	81.50	80.56	80.45
11.5	81.30	79.60	80.00	79.66	79.68	79.88	80.63	78.29	76.20	81.63	80.81	80.31	79.66	81.38	80.83	80.26
12.0	80.04	79.70	79.79	80.15	79.54	79.85	79.80	78.84	76.86	80.67	80.60	80.52	79.76	81.37	80.74	80.07
12.5	80.73	80.79	80.00	81.08	79.30	79.73	78.96	79.06	76.88	80.14	80.15	82.11	79.82	81.25	80.39	79.89
13.0	81.21	81.34	81.18	81.39	79.40	79.53	79.14	79.24	77.29	79.92	80.54	81.72	79.73	81.24	80.34	80.12
13.5	81.22	81.36	81.11	81.15	80.52	79.85	79.19	79.21	78.12	79.91	80.80	81.90	79.82	81.06	80.99	81.49
14.0	80.76	81.06	80.87	80.81	81.38	81.24	79.32	79.33	78.09	80.89	80.23		79.39	80.82	80.50	81.45
14.5	80.73	80.77	80.65	80.57	80.65	80.77	79.76	79.61	78.18	80.92	79.70		79.27	80.51	80.27	81.00
15.0	80.61	80.34	80.22	80.32	80.49	79.75	81.23	81.22	79.23	80.51			81.29	80.74	80.02	79.87
15.5				80.03	79.78	79.25	81.31	80.88	80.20				80.76	81.35		
16.0							81.23	80.53	82.17				80.10	81.52		
16.5							80.69									

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

Table B-6. Detrended¹ pH² on 2 January 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			7.636			7.649										
1.0	7.656	7.638	7.642	7.638	7.633	7.657	7.651	7.651	7.631	7.640	7.647	7.646	7.641	7.658	7.649	7.653
1.5	7.661	7.639	7.643	7.639	7.643	7.657	7.652	7.654	7.642	7.642	7.652	7.648	7.643	7.659	7.653	7.659
2.0	7.662	7.639	7.643	7.639	7.649	7.657	7.651	7.656	7.642	7.642	7.652	7.649	7.648	7.662	7.654	7.655
2.5	7.660	7.639	7.643	7.639	7.652	7.657	7.655	7.657	7.631	7.647	7.652	7.650	7.650	7.662	7.654	7.660
3.0	7.660	7.639	7.643	7.636	7.657	7.657	7.657	7.657	7.628	7.644	7.652	7.650	7.647	7.662	7.659	7.660
3.5	7.658	7.639	7.643	7.632	7.657	7.653	7.657	7.657	7.619	7.642	7.652	7.645	7.645	7.662	7.660	7.660
4.0	7.658	7.635	7.639	7.625	7.657	7.646	7.657	7.657	7.609	7.642	7.650	7.645	7.643	7.662	7.660	7.655
4.5	7.654	7.634	7.639	7.620	7.657	7.639	7.654	7.657	7.604	7.642	7.648	7.641	7.643	7.660	7.660	7.655
5.0	7.653	7.634	7.635	7.616	7.656	7.635	7.652	7.653	7.599	7.638	7.646	7.641	7.638	7.658	7.655	7.651
5.5	7.650	7.633	7.634	7.615	7.652	7.631	7.650	7.651	7.597	7.638	7.642	7.640	7.636	7.658	7.652	7.651
6.0	7.648	7.630	7.631	7.614	7.646	7.630	7.647	7.648	7.593	7.636	7.642	7.636	7.634	7.658	7.650	7.651
6.5	7.647	7.630	7.630	7.611	7.641	7.625	7.643	7.644	7.592	7.633	7.639	7.636	7.630	7.653	7.647	7.647
7.0	7.642	7.625	7.627	7.611	7.638	7.625	7.638	7.643	7.588	7.633	7.639	7.634	7.628	7.651	7.646	7.646
7.5	7.638	7.620	7.624	7.611	7.634	7.623	7.638	7.640	7.584	7.633	7.635	7.632	7.620	7.649	7.643	7.646
8.0	7.633	7.616	7.620	7.610	7.631	7.621	7.635	7.638	7.583	7.629	7.634	7.626	7.614	7.645	7.642	7.643
8.5	7.625	7.613	7.617	7.611	7.623	7.620	7.634	7.636	7.583	7.629	7.629	7.627	7.604	7.644	7.641	7.641
9.0	7.618	7.611	7.616	7.611	7.618	7.620	7.629	7.634	7.581	7.627	7.627	7.627	7.598	7.641	7.637	7.637
9.5	7.611	7.607	7.616	7.612	7.616	7.617	7.628	7.633	7.578	7.624	7.622	7.627	7.596	7.640	7.637	7.632
10.0	7.607	7.606	7.613	7.616	7.612	7.615	7.625	7.627	7.574	7.624	7.617	7.625	7.592	7.635	7.631	7.628
10.5	7.611	7.604	7.611	7.621	7.611	7.610	7.621	7.622	7.571	7.619	7.611	7.625	7.592	7.635	7.632	7.626
11.0	7.615	7.608	7.611	7.624	7.611	7.605	7.616	7.618	7.566	7.616	7.609	7.625	7.592	7.635	7.632	7.623
11.5	7.620	7.611	7.611	7.628	7.611	7.602	7.613	7.614	7.564	7.615	7.606	7.628	7.587	7.630	7.626	7.623
12.0	7.628	7.615	7.611	7.630	7.618	7.599	7.608	7.608	7.564	7.614	7.606	7.628	7.587	7.629	7.625	7.624
12.5	7.630	7.617	7.612	7.625	7.622	7.602	7.602	7.606	7.560	7.615	7.607	7.631	7.583	7.626	7.617	7.624
13.0	7.626	7.619	7.614	7.613	7.626	7.608	7.597	7.603	7.560	7.615	7.610	7.624	7.585	7.626	7.618	7.628
13.5	7.611	7.607	7.603	7.598	7.631	7.613	7.597	7.606	7.561	7.615	7.610	7.601	7.591	7.624	7.623	7.628
14.0	7.596	7.596	7.591	7.589	7.624	7.619	7.597	7.606	7.573	7.615	7.601		7.597	7.621	7.613	7.619
14.5	7.584	7.584	7.578	7.581	7.609	7.608	7.599	7.608	7.577	7.607	7.588		7.601	7.621	7.597	7.603
15.0	7.577	7.576	7.569	7.574	7.594	7.593	7.602	7.613	7.570	7.592			7.606	7.621	7.580	7.588
15.5				7.567	7.583	7.577	7.593	7.606	7.568				7.596	7.615		
16.0							7.577	7.590	7.561				7.579	7.603		
16.5							7.568									

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

² The values enclosed in the box were significantly lower than the mean of other pH measurements at the same depth or at the same distance above the seafloor.

Table B-7. Uncorrected pH¹ on 2 January 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			7.487			7.500										
1.0	7.507	7.489	7.493	7.489	7.484	7.508	7.521	7.521	7.501	7.534	7.559	7.579	7.511	7.658	7.638	7.618
1.5	7.512	7.490	7.494	7.490	7.494	7.508	7.522	7.524	7.512	7.536	7.564	7.581	7.513	7.659	7.642	7.624
2.0	7.513	7.490	7.494	7.490	7.500	7.508	7.521	7.526	7.512	7.536	7.564	7.582	7.518	7.662	7.643	7.620
2.5	7.511	7.490	7.494	7.490	7.503	7.508	7.525	7.527	7.501	7.541	7.564	7.583	7.520	7.662	7.643	7.625
3.0	7.511	7.490	7.494	7.487	7.508	7.508	7.527	7.527	7.498	7.538	7.564	7.583	7.517	7.662	7.648	7.625
3.5	7.509	7.490	7.494	7.483	7.508	7.504	7.527	7.527	7.489	7.536	7.564	7.578	7.515	7.662	7.649	7.625
4.0	7.509	7.486	7.490	7.476	7.508	7.497	7.527	7.527	7.479	7.536	7.562	7.578	7.513	7.662	7.649	7.620
4.5	7.505	7.485	7.490	7.471	7.508	7.490	7.524	7.527	7.474	7.536	7.560	7.574	7.513	7.660	7.649	7.620
5.0	7.504	7.485	7.486	7.467	7.507	7.486	7.522	7.523	7.469	7.532	7.558	7.574	7.508	7.658	7.645	7.616
5.5	7.501	7.484	7.485	7.466	7.503	7.482	7.520	7.521	7.467	7.532	7.554	7.573	7.506	7.658	7.641	7.616
6.0	7.499	7.481	7.482	7.465	7.497	7.481	7.517	7.518	7.463	7.530	7.554	7.569	7.504	7.658	7.639	7.616
6.5	7.498	7.481	7.481	7.462	7.492	7.476	7.513	7.514	7.462	7.527	7.551	7.569	7.500	7.653	7.636	7.612
7.0	7.493	7.476	7.478	7.462	7.489	7.476	7.508	7.513	7.458	7.527	7.551	7.567	7.498	7.651	7.635	7.611
7.5	7.489	7.471	7.475	7.462	7.485	7.474	7.508	7.510	7.454	7.527	7.547	7.565	7.490	7.649	7.632	7.611
8.0	7.484	7.467	7.471	7.461	7.482	7.472	7.505	7.508	7.453	7.523	7.546	7.559	7.484	7.645	7.631	7.608
8.5	7.476	7.464	7.468	7.462	7.474	7.471	7.504	7.506	7.453	7.523	7.541	7.560	7.474	7.644	7.630	7.606
9.0	7.469	7.462	7.467	7.462	7.469	7.471	7.499	7.504	7.451	7.521	7.539	7.560	7.468	7.641	7.626	7.602
9.5	7.462	7.458	7.467	7.463	7.467	7.468	7.498	7.503	7.448	7.518	7.534	7.560	7.466	7.640	7.626	7.597
10.0	7.458	7.457	7.464	7.467	7.463	7.466	7.495	7.497	7.444	7.518	7.529	7.558	7.462	7.635	7.620	7.593
10.5	7.462	7.455	7.462	7.472	7.462	7.461	7.491	7.492	7.441	7.513	7.523	7.558	7.462	7.635	7.621	7.591
11.0	7.466	7.459	7.462	7.475	7.462	7.456	7.486	7.488	7.436	7.510	7.521	7.558	7.462	7.635	7.621	7.588
11.5	7.471	7.462	7.462	7.479	7.462	7.453	7.483	7.484	7.434	7.509	7.518	7.561	7.457	7.630	7.615	7.588
12.0	7.479	7.466	7.462	7.481	7.469	7.450	7.478	7.478	7.434	7.508	7.518	7.561	7.457	7.629	7.614	7.589
12.5	7.481	7.468	7.463	7.476	7.473	7.453	7.472	7.476	7.430	7.509	7.519	7.564	7.453	7.626	7.606	7.589
13.0	7.477	7.470	7.465	7.464	7.477	7.459	7.467	7.473	7.430	7.509	7.522	7.557	7.455	7.626	7.607	7.593
13.5	7.462	7.458	7.454	7.449	7.482	7.464	7.467	7.476	7.431	7.509	7.522	7.534	7.461	7.624	7.612	7.593
14.0	7.447	7.447	7.442	7.440	7.475	7.470	7.467	7.476	7.443	7.509	7.513		7.467	7.621	7.602	7.584
14.5	7.435	7.435	7.429	7.432	7.460	7.459	7.469	7.478	7.447	7.501	7.500		7.471	7.621	7.586	7.568
15.0	7.428	7.427	7.420	7.425	7.445	7.444	7.472	7.483	7.440	7.486			7.476	7.621	7.569	7.553
15.5				7.418	7.434	7.428	7.463	7.476	7.438				7.466	7.615		
16.0							7.447	7.460	7.431				7.449	7.603		
16.5							7.438									

¹ The values enclosed in the box were significantly higher than the mean of other pH measurements at the same depth or at the same distance above the seafloor.

Table B-8. Uncorrected Dissolved Oxygen¹ on 2 January 2008

Depth (m)	Dissolved Oxygen (mg/L)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14 ²	15	16
0.5			7.76													
1.0	7.49	7.67	7.72	7.75	7.84	7.99	8.29	8.17	7.98	8.22	8.26	8.38	8.00			8.27
1.5	7.49	7.63	7.74	7.76	7.77	8.00	8.25	8.14	7.95	8.21	8.32	8.28	8.08		8.35	8.30
2.0	7.51	7.66	7.72	7.68	7.80	7.99	8.21	8.20	7.93	8.21	8.32	8.25	8.07		8.26	8.30
2.5	7.53	7.66	7.70	7.64	7.88	7.94	8.21	8.23	7.89	8.20	8.30	8.28	8.02		8.31	8.31
3.0	7.55	7.65	7.73	7.63	7.90	7.80	8.24	8.22	7.82	8.18	8.28	8.25	7.99		8.34	8.29
3.5	7.57	7.68	7.74	7.62	7.85	7.74	8.26	8.21	7.78	8.17	8.24	8.22	7.99		8.35	8.26
4.0	7.58	7.68	7.76	7.62	7.75	7.72	8.28	8.20	7.75	8.13	8.22	8.20	8.00		8.36	8.24
4.5	7.58	7.69	7.77	7.63	7.66	7.71	8.26	8.18	7.72	8.14	8.17	8.18	7.98		8.34	8.22
5.0	7.58	7.70	7.77	7.64	7.64	7.69	8.22	8.14	7.71	8.13	8.16	8.15	7.94		8.30	8.21
5.5	7.59	7.68	7.76	7.64	7.63	7.68	8.17	8.13	7.68	8.13	8.16	8.12	7.89		8.27	8.19
6.0	7.58	7.64	7.75	7.64	7.63	7.68	8.13	8.12	7.69	8.13	8.17	8.15	7.85		8.23	8.18
6.5	7.55	7.53	7.70	7.64	7.73	7.67	8.12	8.12	7.65	8.12	8.16	8.18	7.78		8.21	8.18
7.0	7.49	7.46	7.65	7.63	7.60	7.69	8.11	8.11	7.58	8.13	8.19	8.25	7.70		8.19	8.18
7.5	7.37	7.42	7.62	7.62	7.51	7.66	8.09	8.10	7.51	8.12	8.23	8.30	7.65		8.21	8.19
8.0	7.22	7.37	7.61	7.62	7.46	7.64	8.08	8.10	7.49	8.13	8.25	8.35	7.62		8.21	8.19
8.5	7.12	7.36	7.60	7.65	7.44	7.62	8.07	8.07	7.47	8.13	8.22	8.42	7.60		8.24	8.18
9.0	7.06	7.36	7.58	7.74	7.43	7.56	8.04	8.03	7.36	8.13	8.13	8.48	7.58		8.26	8.15
9.5	7.07	7.32	7.58	7.84	7.47	7.45	8.01	7.98	7.35	8.11	8.01	8.50	7.55		8.32	8.16
10.0	7.30	7.50	7.59	7.94	7.50	7.37	7.99	7.97	7.30	8.10	7.98	8.46	7.54		8.38	8.17
10.5	7.50	7.76	7.58	8.05	7.51	7.36	7.96	7.96	7.21	8.07	8.05	8.47	7.51		8.42	8.19
11.0	7.69	7.89	7.68	8.14	7.61	7.35	7.93	7.87	7.17	8.05	8.10	8.60	7.50		8.47	8.25
11.5	7.84	8.01	7.75	8.22	7.79	7.42	7.83	7.84	7.12	8.08	8.27	8.72	7.48		8.28	8.35
12.0	7.96	8.08	7.87	8.10	7.94	7.58	7.75	7.91	7.07	8.21	8.49	8.79	7.45		8.08	8.42
12.5	7.83	7.76	7.93	7.78	8.06	7.73	7.78	7.97	7.03	8.34	8.61	8.49	7.50		8.25	8.50
13.0	7.35	7.21	7.54	7.35	8.20	7.96	7.88	8.03	7.13	8.45	8.01	7.85	7.67		8.47	8.51
13.5	6.94	7.00	7.15	7.13	7.97	7.94	7.96	8.06	7.46	8.46	7.52	7.53	7.79		8.40	7.98
14.0	6.75	6.86	6.99	6.99	7.45	7.40	8.02	8.13	7.66	8.09	7.32		7.91		7.85	7.60
14.5	6.65	6.77	6.86	6.90	7.12	7.03	8.05	8.22	7.38	7.54			8.10		7.50	7.42
15.0	6.65	6.74	6.86	6.84	6.97	6.94	7.79	7.94	7.17				7.83			
15.5				6.83	6.91			7.54	7.46	7.13				7.30		
16.0								7.25	7.21					7.09		
16.5								7.13								

¹ Values enclosed in boxes and shown in bold were significantly lower than the mean of other dissolved oxygen measurements at the same depth level.

The thinner boxes encompass italicized values that were significantly higher than the mean of other measurements at the same distance above the seafloor.

² Salinity, density, and dissolved oxygen measurements were compromised at Station 14 by the probable intake of a salp into the ducted portion of the CTD

Table B-9. Auxiliary Observations on 2 January 2008 during the Quarterly Water-Quality Survey

Station	Location		Diffuser Distance (m)	Time (PST)	Air Temperature (°C)	Cloud Cover (%)	Wind Avg (kt)	Wind Max (kt)	Wind Dir (from) (°T)	Swell Ht/Dir (ft/°T)	Secchi Depth (m)
	Latitude	Longitude									
1	35° 23.248' N	120° 52.499' W	80.9	14:14:01	17.2	0	0.9	2.1	NW	<1 NNW	11.0
2	35° 23.233' N	120° 52.501' W	54.1	14:17:36	13.6	0	1.4	1.9	NW	<1 NNW	11.0
3	35° 23.216' N	120° 52.502' W	25.4	14:20:29	13.5	0	1.9	2.1	NW	<1 NNW	11.5
4	35° 23.190' N	120° 52.499' W	7.2	14:23:55	13.2	0	1.3	1.9	NW	<1 NNW	9.0
5	35° 23.168' N	120° 52.501' W	44.8	14:26:51	14.4	0	0.8	1.1	NW	<1 NNW	10.5
6	35° 23.140' N	120° 52.492' W	95.9	14:30:00	14.3	5	1.0	1.3	NW	<1 NNW	11.0
7	35° 23.192' N	120° 52.570' W	88.2	14:39:28	14.2	10	1.3	1.8	NW	<1 NNW	11.5
8	35° 23.195' N	120° 52.545' W	51.6	14:44:12	13.6	10	1.5	1.8	NW	<1 NNW	10.5
9	35° 23.197' N	120° 52.514' W	12.6	14:47:23	14.1	10	0.9	2.0	NW	<1 NNW	7.5
10	35° 23.195' N	120° 52.486' W	13.0	14:51:29	13.3	10	1.5	2.7	NW	<1 NNW	11.0
11	35° 23.201' N	120° 52.459' W	55.6	14:54:48	12.8	15	1.6	2.5	NW	<1 NNW	10.5
12	35° 23.199' N	120° 52.438' W	85.5	14:58:28	14.2	15	0.7	1.2	NW	<1 NNW	10.5
13	35° 23.171' N	120° 52.531' W	66.1	14:34:21	13.7	10	1.3	1.8	NW	<1 NNW	10.0
14	35° 23.219' N	120° 52.529' W	33.2	15:13:30	13.3	15	1.4	1.9	NW	<1 NNW	12.0
15	35° 23.222' N	120° 52.477' W	59.2	15:08:46	15.0	15	0.7	1.4	NW	<1 NNW	11.5
16	35° 23.169' N	120° 52.471' W	55.2	15:04:31	16.3	15	0.5	1.1	NW	<1 NNW	11.5

Due to the extraordinarily high seawater clarity at the time of the survey, the signature of the effluent plume, apparent as a slightly lighter color, was visible deep beneath the sea surface to the south of the diffuser structure. Neither odors nor debris of sewage origin were observed at any time during the survey.

Tidal Conditions (Pacific Standard Time)

High Tide: 05:45 4.8 ft
 Low Tide: 13:22 0.7 ft
 High Tide: 19:50 2.8 ft
 Low Tide: 23:40 2.3 ft