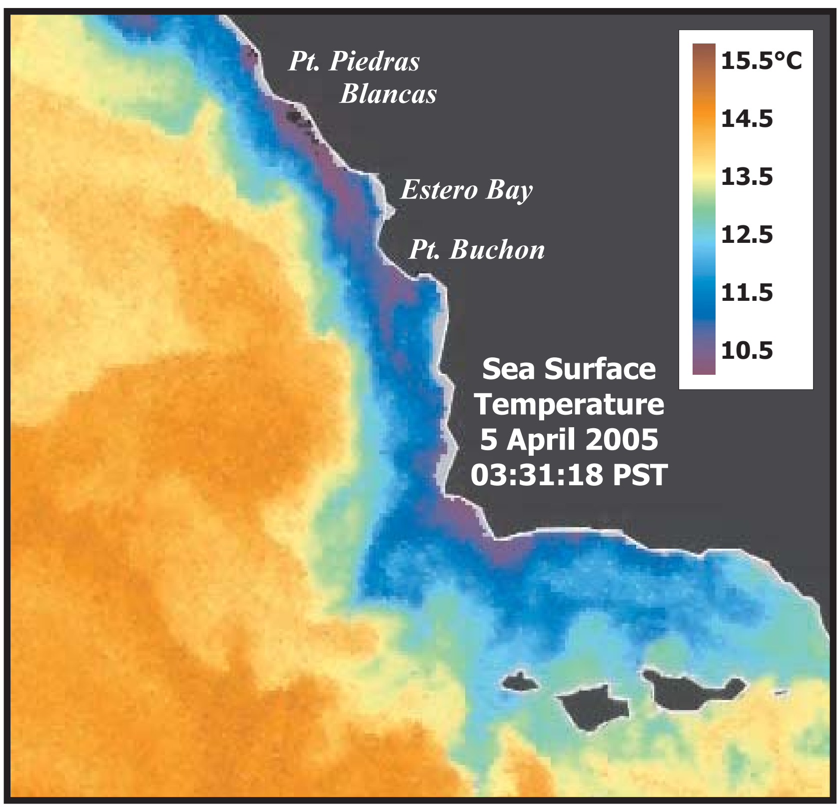
City of Morro Bay and
Cayucos Sanitary District

OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING APRIL 2005 SURVEY



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Report to

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OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING APRIL 2005

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May 2005

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

24 May 2005

Reference: Quarterly Receiving-Water Report – April 2005

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on 5 April 2005. This second-quarter survey assessed the effectiveness of effluent dispersion during early spring 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.

Lateral perturbations in all six of the water properties clearly delineated the effluent signature near the sea surface within and beyond the zone of initial dilution. Dilution levels determined from salinity anomalies within the plume exceeded those anticipated by modeling and outfall design criteria. The anomalies in other water properties were generated by the upward displacement of ambient seawater, rather than the presence of wastewater constituents. All of the measurements were indicative of low contaminant concentrations within the discharged wastewater, and of an outfall operating as designed.

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

Sincerely,

Douglas A. Coats, Ph.D.
Project Manager

Enclosure (Seven Copies)

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

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Mr. Bruce Ambo
City of Morro Bay

Date ____________________________

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INTRODUCTION

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

As part of the new permit provisions, the previous monitoring program was modified to better evaluate short- and long-term effects of the discharge on receiving waters, benthic sediments, and infaunal communities (RWQCB-EPA, 1998b). The program continued to include a requirement for receiving-water-quality monitoring performed on a seasonal basis. Four quarterly surveys were intended to record ambient water properties that approximate winter, spring, summer, and fall conditions. In keeping with seasonal synopses, this quarterly report summarizes the results of water-quality sampling conducted on 5 April 2005. This second-quarter survey was conducted in April to capture ambient oceanographic conditions along the central California coast during the early spring transition to upwelling-dominated oceanographic conditions.

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.

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

The April-2005 field survey was the forty-eighth receiving-water survey conducted by Marine Research Specialists (MRS) since they became responsible for marine monitoring of the MBCSD discharge in July 1993. It was the twenty-sixth receiving-water survey to be conducted under the monitoring provisions of the current permit. Compared to the previous permit, the number of stations increased from 11 to 16, and the stations were relocated closer (≤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 new sampling design also allowed surveying to be conducted more rapidly than before by eliminating the requirement for the time-consuming collection of discrete water samples using Niskin bottles. Continuous deployment of the CTD[1] instrument package between stations now provides a more synoptic

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

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 highly sensitive sensors in the CTD instrument package are capable of detecting minute changes in water properties. These sensors are described in the Methods Section below.

Surveys conducted prior to 1999 rarely detected the effluent plume because sampling stations were too widely separated to resolve the dilute wastewater signature that is highly localized around the outfall diffuser. With the implementation of the new sampling design in 1999, the presence of well-mixed effluent near the diffuser structure was found in all 26 of the subsequent water-quality surveys (MRS, 2000, 2001, 2002, 2003, 2004, 2005), including the one described in this report. Moreover, improved navigation in concert with the denser sampling pattern more precisely delineated the location of the all 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 are better determined by the denser sampling pattern. The amplitudes of discharge-related salinity anomalies reveal the dilution experienced by the effluent plume. These measured dilution levels lend insight into the operational performance of the outfall and diffuser structure. As described in this report, measurements of effluent undergoing turbulent mixing close to the diffuser structure allowed dilution levels to be computed for the April-2005 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 880 m from the shoreline. 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 remaining six diffuser ports remain closed to improve dispersion by increasing the ejection velocity from the remaining ports. For a given flow rate, the diffuser ports were hydraulically designed to create an 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 is approximately 15 m from the centerline of the diffuser structure.

Beyond the ZID, the energetic waves, tides, and coastal currents within Estero Bay further disperse the discharge plume within the open-ocean receiving waters. Areas of special concern, such as sanctuaries and estuaries, are too distant to be affected by the effluent discharge. For example, the southern boundary of the Monterey Bay National Marine Sanctuary is located 38 km to the north, near Cambria Rock. Similarly, although the entrance to the Morro Bay National Estuary lies only 2.8 km to the south of the discharge, direct seawater exchange between the discharge point and the Bay is restricted by the southerly orientation of the mouth of the Bay, and by the presence of Morro Rock. Morro Rock is the largest physiographic feature along the adjacent coastline and extends into Estero Bay approximately 2 km south of the point of discharge (Figure 1). Its presence blocks the direct incursion of unmixed wastewater into the Bay.

Figure 1. Regional Setting of Receiving-Water 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 rapid initial mixing achieved within 15 m of the diffuser structure, impingement of unmixed effluent onto the adjacent coastline 880 m away is highly unlikely. Nevertheless, water samples are regularly collected along the shoreline at the surfzone sampling stations shown in Figure 1.

These surfzone samples are analyzed for total and fecal coliform levels. Results of these analyses are reported in monthly operational summaries and in annual reports. The occasional instances of elevated beach coliform levels result from onshore non-point sources rather than the discharge of disinfected wastewater from the MBCSD outfall (MRS, 2000, 2001, 2002, 2003, 2004, 2005).

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. Stations are situated at three distances relative to the center of the diffuser structure to capture any discharge-related trends in water properties. Six of the stations lie along a north-south axis at the same water depth (15.2 m) as the diffuser centroid. 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 reference stations and are situated 100 meters 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 near and midfield stations could conceivably be influenced by the discharge. Under those circumstances, the midfield station on the opposite side of the diffuser can act as a reference station. Comparisons of water properties at these antipodal stations quantify departures from ambient seawater properties so that compliance with the NPDES discharge permit can be evaluated.

Table 1. Description of Receiving-Water Monitoring Stations

Station	Description	Latitude	Longitude	Closest Approach Distance[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	Onshore ZID	35° 23.199' N	120° 52.489' W	15.0	23
11	Onshore Nearfield	35° 23.199' N	120° 52.464' W	46.7	60
12	Onshore Midfield	35° 23.199' N	120° 52.438' W	85.8	100
13	Southwest Nearfield	35° 23.176' N	120° 52.532' W	59.8	60
14	Northwest Nearfield	35° 23.222' N	120° 52.532' W	40.2	60
15	Northeast Nearfield	35° 23.222' N	120° 52.476' W	59.8	60
16	Southeast Nearfield	35° 23.176' N	120° 52.476' W	40.2	60

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

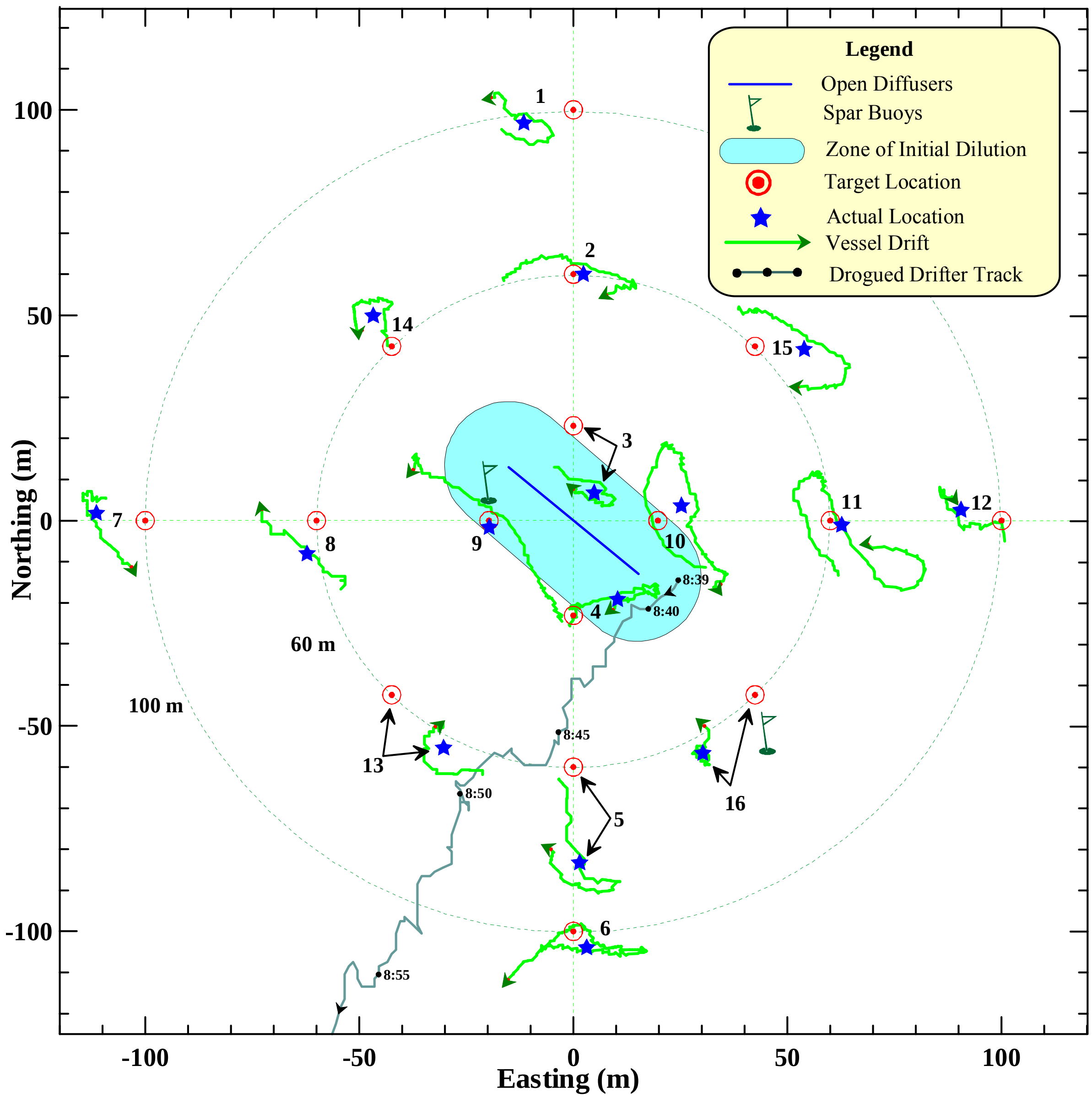

Figure 2. Offshore Water Sampling Locations on 5 April 2005

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

Although the discharge is considered a '*point source*,' it does not occur at a point of infinitesimal size. Instead, the discharge is distributed along a 42-m section of the seafloor. This finite size is an important consideration when assessing wastewater dispersion close to the discharge. Because of the finite length of the discharge, the amount of wastewater dispersion at a given point in the water column is dictated by its distance to the closest diffuser port, rather than its distance to the center of the diffuser structure. Because of the finite size of the source, this '*closest approach*' distance is considerably less than the centerline distance normally cited in modeling studies (Table 1).

Station positioning within the compact sampling pattern became feasible only after the advent of DGPS. The accuracy of traditional navigation systems such as LORAN or standard GPS is typically ±15 m, a span approaching the 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 meters, although it altered most measurements by less than 30 meters. After May 2000, SA was turned off and the accuracy of standard GPS receivers improved substantially, with horizontal position errors of typically less than 10 m.

Nevertheless, extreme atmospheric conditions and physiographic obstructions can cause signals to bounce around, leading to errors in position beyond those that were previously introduced by SA. These other errors are greatly reduced with the Differential GPS (DGPS) system that was first implemented by the U.S. Coast Guard. DGPS incorporates a second signal from a nearby land-based beacon. Because the beacon is fixed at a known location, the position error in the reading from the GPS satellites can be precisely calculated at any given time. This correction is continuously transmitted to the DGPS receiver onboard the survey vessel and results in extremely stable and accurate offshore navigation, typically with position errors of less than 4 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.

In addition, DGPS allows precise determination of sampling locations during individual water-quality surveys. Knowledge of the precise location of the actual sampling sites relative to the diffuser position is crucial for accurate interpretation of the water-property fields. During any given survey, the actual sampling locations do not coincide with the exact target coordinates listed in Table 1. Winds, waves, and currents induce offsets during sampling. Using DGPS, these offsets can be resolved and the vessel location can be precisely tracked during sampling at each station. This is an important consideration because vertical profiling conducted at an individual station can cover a large horizontal distance relative to the ZID. The magnitude of this horizontal drift is apparent in Figure 2 from the length of the green tracklines. These tracklines trace the horizontal location of the CTD instrument package as it was lowered to the seafloor at each station. The drift of the CTD instrument package was particularly severe during the April-2005 survey due to larger-than-normal wind-induced vessel drift. For the first time since MRS began monitoring in July 1993, the vessel had to be dynamically positioned[2] to acquire CTD readings near the target station.

The resulting CTD tracklines shown in Figure 2 reveal a complex horizontal trace of sampling locations surrounding each station. At stations close to the diffuser structure, the horizontal drift in the position of the CTD makes the assessment of compliance with discharge limitations particularly complex. Specifically, downcasts at Stations 4, 9, and 10 traversed the boundary of the ZID. All of the measurements at Station 3 were collected within the ZID. Receiving-water limitations specified in the

[2] Dynamic positioning is a method of maintaining a vessel in a fixed position by using her own propellers and thrusters. This allows operations at sea where mooring or anchoring is not feasible due to deep water, strong winds, or very short-term occupation of stations.

COP only apply to measurements collected beyond the ZID boundary because within the ZID, rapid initial turbulent mixing associated with the effluent discharge is expected to occur.

Compliance assessments notwithstanding, measurements collected close to the diffuser structure within the ZID lend valuable insight into the outfall's effectiveness at dispersing wastewater during this particular survey. Damaged or broken diffuser ports would be reflected by low dilution rates and measurements of concentrated effluent throughout ZID. Without measurements collected within the ZID, the discharge plume would probably 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 by the current NPDES discharge permit.

Surveys prior to 1999 also predated the advent of DGPS. Consequently, the 16-m average drift experienced during sampling at each station during April 2005 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. For consistency with past surveys, a single reportable sampling location was also determined for each station during the April-2005 survey. These were based on the average location as shown by the blue stars in Figure 2. Average positions are also listed in Table 2, along with their distance from the diffuser structure. However, based on the foregoing discussion, the distance between the average station position and the ZID does not determine whether all the measurements at that station are subject to the receiving-water objectives in the COP. For example, 19.3-m closest-approach distance specified for Station 10 would suggest that all of the data at Station 10 was collected well outside of the ZID. In reality, as shown by the green tracklines in Figure 2, the near-surface measurements were collected within the ZID where water-quality limitations do not apply.

Table 2. Average Coordinates of Vertical Profiles in April 2005

	Time (PST)				Closest Approach	
Station	**Downcast**	**Upcast**	**Latitude**	**Longitude**	**Range[1](m)**	**Bearing[2](°T)**
1	7:54:37	7:55:53	35° 23.251' N	120° 52.512' W	84.1	2
2	7:51:33	7:52:43	35° 23.232' N	120° 52.502' W	50.4	20
3	7:48:39	7:49:43	35° 23.203' N	120° 52.501' W	**8.4** [3]	41
4	7:44:55	7:46:21	35° 23.189' N	120° 52.497' W	**7.7** [4]	219
5	7:40:10	7:42:08	35° 23.154' N	120° 52.503' W	71.5	191
6	7:33:42	7:36:41	35° 23.143' N	120° 52.502' W	91.6	188
7	8:47:23	8:48:55	35° 23.200' N	120° 52.578' W	96.9	264
8	8:50:50	8:52:19	35° 23.195' N	120° 52.545' W	51.4	246
9	8:54:49	8:56:28	35° 23.198' N	120° 52.517' W	**13.9** [4]	221
10	8:59:21	9:01:22	35° 23.201' N	120° 52.487' W	**19.3** [4]	41
11	9:04:19	9:06:21	35° 23.199' N	120° 52.463' W	49.0	76
12	9:08:59	9:10:11	35° 23.200' N	120° 52.444' W	77.0	78
13	9:18:16	9:20:08	35° 23.169' N	120° 52.524' W	61.6	221
14	8:06:19	8:07:28	35° 23.226' N	120° 52.535' W	48.8	320
15	7:59:26	8:00:26	35° 23.222' N	120° 52.468' W	66.9	41
16	9:13:43	9:15:06	35° 23.168' N	120° 52.484' W	46.0	161

[1] Distance from the closest open diffuser port. Observations collected within the ZID shown in bold
[2] Direction measured clockwise in degrees from true north from the closest diffuser port to the actual sampling location.
[3] All of the CTD (Conductivity-Temperature-Depth) cast was within the ZID boundary.
[4] Portions of the CTD cast were within the ZID boundary.

Conversely, the 13.9-m distance reported for Station 9, does not accurately reflect the fact that sampling at this station traversed most of the ZID, and terminated at the seafloor well beyond the boundary of the ZID.

The vessel drift indicted by the green tracklines in Figure 2 was dictated by the complex interaction of winds and vessel maneuvering that was used to relocate the vessel near the station's target position. As summarized in Table B-7, strong winds out of the east-northeast prevailed throughout the survey, and made vessel positioning a constant struggle. Oceanic currents played a smaller role in determining vessel positioning, although they were directed toward the southwest, in a direction consistent with advection by the prevailing winds. Typically, the drift of the survey vessel is controlled by winds more than currents. The southwestward current velocity is apparent from the track of the drogued drifter that was deployed near the diffuser structure at 08:39. The grey line with black dots shown in Figure 2 traces the path of the satellite-tracked drifter. It is designed to drift with the current, with little influence from the wind. Each dot along the drifter trackline represents a five-minute interval. The drifter was recovered at 09:25 PST at a location 250 m southwest of the diffuser.

The drifter track revealed two distinct periods of flow. Between the time of its deployment at 08:39 and 09:00, the drifter moved continuously toward the south-southwest. In 21 minutes, it covered 167 m and traveled at a relatively high speed of 13.2 cm/s or 0.26 kts. Most of its trackline is shown in Figure 2. After 09:00, when the drifter had moved out of the survey region shown in Figure 2, it began to make a series of large loops, covering an area of approximately 100 m. As a result, the drifter moved at about the same speed, but its net progress between 09:00 and 09:25 was only 138 m, resulting in an average speed of 9.22 cm/s or 0.18 kts. The change in the character of the flow that occurred around 09:00 may have been related to the tidal reversal that occurred during the survey as shown in Figure 3.

Southwestward (offshore) flow measured by the drogued drifter is consistent with the upwelling conditions that are apparent in the satellite image on the cover of this report. The image was recorded on the day of the survey and shows sea-surface temperatures measured by infrared sensors on NOAA's polar orbiting satellite. The image depicts a region of much cooler water located close to the coastline. Most of this surface water had temperatures below 11.5°C, as delineated in dark blue. Some of the coastal water very close to the shoreline had even lower sea surface temperatures, at or below 10.5°C, as delineated in

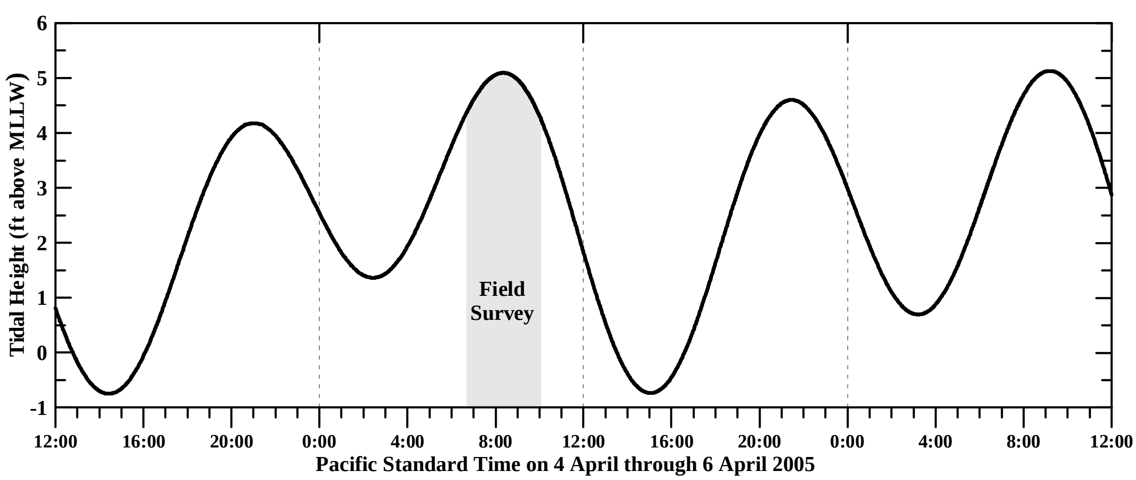

Figure 3. Estero Bay Tidal Level during the Field Survey of 5 April 2005

purple. Estero Bay, where the survey was conducted was one such location. Accordingly, the sea-surface temperatures measured by the CTD during the survey were comparatively cold, at or below 10.52°C as shown in Table B-1 in Appendix B.

The cold surface water that resides near the coastline was generated by wind-driven upwelling. 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. The spring 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. The 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 in the cover image by the purplish-blue water along the coast. The nutrient-rich seawater that is brought to the sea surface by upwelling enables phytoplanktonic blooms that are the foundation of the productive marine fishery found along the California coast. The cross-shore flow associated with persistent upwelling conditions also leads to vertical stratification of the water column. The resulting shallow (~10 m) thermocline is commonly maintained throughout the summer and into the fall. In contrast, winter oceanographic conditions are generally characterized by a vertically uniform water column that has been well mixed by intense winds generated by passing local storm fronts and large waves produced in distant Pacific storms.

METHODS

The 38-ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 5 April 2005. Dr. Douglas Coats of Marine Research Specialists (MRS) was chief scientist. Captain Mark Tognazzini supervised vessel operations, while Mr. Billy Skok acted as marine technician. Secchi depth measurements and standard observations for weather, seas, water clarity/coloration, and the presence of any odors, floating debris, and oil and grease were recorded during the survey. Wind speeds and air temperatures were measured with a Kestrel® 2000 Thermo-Anemometer. These ancillary observations were collected during the rapid water-column profiling that was conducted at each station using a CTD instrument package.

Ancillary Measurements

At all stations, a Secchi disk was lowered through the water column to determine its depth of disappearance (Table B-8). Secchi depths provide a visual measure of near-surface turbidity or water clarity. The depth of disappearance is inversely proportional to the average amount of organic and inorganic suspended material along a line of sight in the upper water column. As such, the Secchi depth measures natural light penetration, which can be limited by increased suspended particulate loads from 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. The comparatively shallow euphotic zone observed during the April-2005 survey, which only reached to a depth of approximately 8 m, is fairly typical of upwelling conditions when increased primary productivity causes a decrease in light transmissivity within the upper water column.

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

During the April-2005 survey, a satellite-tracked drifter was deployed twice near the center of the open section of the diffuser structure. The satellite navigation system failed during the first deployment and no flow information is available for the first half of the survey. 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 time and precise position of the drifter deployment and recovery were recorded. The April-2005 survey was the third MBCSD survey to continuously record the drifter position throughout its deployment. In the past, the average ambient flow velocity during each survey was estimated solely from the drifter's deployment and recovery positions. However, during the April-2005 survey, the added satellite-tracking capability of the drifter revealed complex current reversals that occurred after the drifter moved beyond the 100-m survey area shown in Figure 2. Drifter data collected in prior surveys lack information on such short-term flow fluctuations that often occur within the duration of a survey.

Instrumental Measurements

Vertical water-column profiling was conducted using an electronic instrument package equipped with a number of probes and sensors. A Sea Bird Electronics SBE-19 Seacat CTD package was used to collect profiles of conductivity, salinity, temperature, light transmittance, dissolved oxygen (DO), pH, density, and pressure at each station. A submersible pump on the CTD continuously flushed water through the conductivity cell and oxygen plenum at a constant rate, independent of the CTD's motion through the water column. After the October-2001 survey, the CTD was returned to the factory for full testing, repair, and calibration. Temporal drifts in the oxygen and alkalinity readings during the October-2001 survey indicated that the sensitivity of these probes had degraded because of an accumulation of marine growth. During the factory repair, the pH probe was replaced and the electrolyte in the oxygen sensor was refurbished. The entire CTD system was then recalibrated at the factory. Upon return of the instrument, the transmissivity, dissolved oxygen, and pH sensors were recalibrated at the MRS laboratory. Calibration coefficients determined at the factory and by MRS were nearly identical, and confirmed the accuracy and stability of the refurbished sensors.

The DO and pH sensors were again returned to the factory in May 2003 for testing and recalibration. Because of increasing temporal drift associated with the aging DO probe, it was replaced with a new DO probe. As is the case before all surveys, the CTD system was recalibrated at the MRS laboratory prior to the April-2005 survey. Calibration at upper-bound DO concentrations was established by immersing the CTD in an aerated, temperature-controlled calibration tank. In addition to oxygen readings at full saturation, a zero-oxygen calibration point was determined by filling the oxygen-sensor plenum with an 8% solution of sodium sulfite (Na_2SO_3). Oxygen calibration coefficients were determined by regression analysis of sensor-membrane current and temperature, as recommended by the manufacturer (SBE, 1993). As with prior factory calibrations, pre-cruise calibration coefficients determined by MRS closely corresponded to those determined by the factory.

The prolonged equilibration time of the pH sensor has been an ongoing challenge that has required removal of temporal trends in the pH data collected in most surveys, even those following the pH-sensor replacement. Laboratory tests conducted in conjunction with pre-cruise calibrations have demonstrated that the equilibration time is reduced if the sensor is immersed in water prior to deployment. This was accomplished during the April-2005 survey by attaching a water-filled hose to the sensor during transit to the survey area. Immediately prior to deployment, the hose was removed. Although this procedure did not entirely eliminate the temporal offsets, it markedly reduced their amplitude and the required pH adjustments were small and less than 0.07 pH units.

During the pre-cruise calibration, coefficients for the pH (alkalinity) sensor were determined from a linear regression of output voltage after immersion in three separate buffered solutions of known pH. Buffering solutions with a pH of 4±0.01, 7±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 prior to the survey were used in the algorithms that convert 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 confirmed the continued accuracy and stability of the temperature, pressure, and conductivity sensors, as well as the operational integrity of the oxygen and pH probes.

Six seawater properties were used to assess receiving-water quality in this report. They were derived from the continuously recorded output from the probes and sensors on the CTD. Depth 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 the Table. 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).

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

Table 3. Instrumental Specifications for CTD Profiler

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

[1] Maximum depth limit in meters

Before deployment at the initial station, the CTD was held below the sea surface for a six-minute equilibration period. Subsequently, the CTD was raised to within 1.0 m of the sea surface and profiling commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at multiple stations were collected during each deployment by towing the CTD package below the water surface while transiting between adjacent stations. Upon retrieval of the CTD, the profile data were downloaded to a portable computer.

Temporal Trends in the pH Sensor

The pH sensor exhibited a slight temporal drift during the beginning of the April-2005 survey. Perceptible drift in pH measurements has been consistently observed in prior water-quality surveys as a result of ongoing sensor equilibration during profiling. Prolonged exposure to the atmosphere between surveys results in the largest offsets and can also affect the dynamic range of the measurements. Smaller equilibration offsets have been observed when the CTD is redeployed after being brought onboard to download data. Previous attempts to mitigate sensor drift have included prolonging the soak time of the CTD after deployment below the sea surface prior to profiling. Soak times in excess of 6 minutes at the beginning of a survey were found to reduce but not entirely eliminate sensor drift. During the April-2005 survey, a tube filled with seawater was placed around the pH sensor to limit atmospheric exposure before the CTD was first deployed. This technique was successful at further ameliorating sensor drift.

Temporal drift in the pH sensor was responsible for slight, but perceptibly lower pH measurements at those stations occupied during the first CTD deployment. The pH measurements at these stations were averaged 0.037 pH units lower than the measurements collected during the second deployment. Referring to Table 3 shows that this artificial reduction in measured pH is smaller than the probe's instrumental accuracy (± 0.1 pH). However, it is larger than the instrumental resolution (±0.006 pH). As a result, slight but statistically significant artificial differences are apparent in the measurements reported at Stations 4 and 6 in Table B-7. Statistically significant anomalies are indicated by values listed in bold typeface and enclosed in a box. Stations 4 and 6 were among the first stations occupied during the survey and required the largest adjustment for sensor drift. Temporal detrending removed these instrumental anomalies, as shown in Table B-6. Note that Table B-6 also reveals slight but significant pH anomalies at Station 9 that were not apparent in Table B-7. Thus, only by removing the slight temporal drift in the pH data did the discharge-induced pH anomaly become apparent at Station 9. This was largely because the overall range in pH was small during the April-2005 survey, causing even slight temporal drift in the pH sensor to become relatively important.

RESULTS

The water-quality survey for the second quarter of 2005 began on Monday, 5 April 2005, at 07:12 PST with the initial deployment of the drogued drifter. Subsequently, all water-column measurements were collected as required by the NPDES monitoring program (Table 2 and B-8). Sunrise was at 06:44 PST and skies were clear throughout the survey which ended at 10:15 PST. Although wind direction was relatively consistent throughout the survey, one-minute average speeds were variable and ranged between 7.2 kt and 17.4 kt, with a maximum instantaneous speed approaching 20 kts. Winds were directed offshore, while the 4-ft swell arrived from the opposite direction. Atmospheric visibility was greater than 2 nM along the ocean surface owing to the absence of fog and haze at that time. As such, Morro Rock and the shoreline remained visible throughout the survey. At an average near at 14.5°C, air temperature was warm and relatively constant throughout the survey. Surface seawater temperature (10.5°C) in the survey area was notably cooler than the average air temperature, and was consistent with coastal sea-surface temperatures within Estero Bay recorded by the satellite image shown on the cover of this report. The discharge plume was not visibly apparent at the sea surface at any time during the survey. Throughout the survey, there was no visual evidence of floating particulates, oil and grease, or seawater discoloration associated with the discharge.

Beneficial Use

During the April-2005 survey, observations of beneficial use demonstrated that the coastal waters in the outfall vicinity continued to be utilized by wildlife and for recreation. In addition to a number of unidentified seabirds observed flying through the survey area, western gulls (*Larus occidentalis*) were prevalent throughout the area. Several vessels were also observed near the survey area during the course of the monitoring. An Associated Divers barge was located near the entrance to Morro Bay. A number of private recreational fishing boats were observed offshore of the survey area as they fished for Chinook salmon (*Oncorhynchus tshawytscha*). The opening of the recreational salmon season that began two days prior to the survey on 2 April 2005. No other evidence of beneficial use of receiving waters was noted during the survey.

Ambient Seawater Properties

Data collected during the April-2005 survey reflect the classical, stratified conditions that are indicative of upwelling. Upwelling results in an influx of dense, cold, saline water at depth and often leads to a sharp thermocline, halocline, and pycnocline where temperature, salinity, and density change rapidly over short vertical distances. Under stratified conditions, isotherms crowd together to form a thermocline that restricts the vertical transport of the effluent plume and reduces its dispersion.

Sharp upwelling-induced vertical gradients are plainly evident above the seafloor in the vertical profiles of Figures A-1 through A-3. During the first part of the survey, when data at Stations 1 through 6 were collected, the high vertical gradients were located below a 7-m thick surface mixed layer as shown in Figure A-1. Later in the survey, when data at Stations 7 through 12 were collected (Figure A-2), the mixed layer was thicker and the vertical gradients were largely restricted to depths exceeding 11 m.

In particular, a thermocline, where temperature increases rapidly above the seafloor, is evident in the vertical profiles shown in Figures A-1 through A-3 (red lines). It is less distinct at Station 4 (middle right frame of Figure A-1), Station 9 (middle left frame of Figure A-2), and Station 13 (upper left frame of Figure A-3). The irregular vertical profiles at these three stations were caused by the vertical mixing induced by the buoyant effluent plume as it rose through the stratified water column and reached the surface. Discharge-induced perturbations in seawater properties are discussed in the next section.

In general, however, most ambient seawater properties exhibit vertical stratification similar to the thermal structure. For example, the shallow thermocline coincides with a pycnocline (rapid vertical change in density – shown in black) and a halocline (vertical gradient in salinity – shown in green). Upwelling-induced vertical stratification is also evident in the dissolved oxygen (dark blue) and alkalinity (pH – gold) fields.

In contrast to the other water properties, transmissivity also shows a marked reduction immediately above the seafloor. The distinctive decrease in transmissivity within a thin layer immediately above the seafloor indicates the presence of a bottom nepheloid layer (BNL), which is a widespread phenomenon on continental shelves (Kuehl *et al.*, 1996). The increased turbidity within the BNL is caused by the presence of naturally occurring particulates formed from light-weight flocs of detritus. This detritus is easily suspended by oscillatory bottom currents generated by passing surface gravity waves.

Immediately above the BNL, the presence of cool saline seawater results from large-scale upwelling processes in the region. This dense seawater is transported onshore at depth to replace nearshore surface waters that are driven offshore by prevailing winds. Large-scale features of the upwelling process within Estero Bay were documented during regional surveys conducted by MRS (2002 and Morro Group, Inc., 2000). For example, the low dissolved oxygen found in the seafloor water mass is a clear indicator of its deep offshore origin. Deep offshore waters are undersaturated in oxygen because they have not had direct contact with the atmosphere for long periods of time, and biotic respiration and decomposition have slowly depleted dissolved-oxygen levels. Similarly, elevated salinity is indicative of waters that originate in the Southern California Bight and are carried northward by the Davidson undercurrent. They differ from the relatively fresh surface water associated with the southward-flowing California Current.

In contrast to deep seawater properties, the near-surface seawater properties reflect the increased primary productivity associated with upwelling conditions. Nutrient-rich seawater brought to the sea surface by upwelling enables phytoplanktonic blooms (primary productivity) that are normally limited by the lack of nutrients. Localized increases in phytoplankton density occur when nutrients suddenly move into the euphotic zone as a result of upwelling. The resulting large increase in phytoplankton biomass forms the foundation of the productive marine fishery found along the central California coast. The reduced water clarity (light-blue lines) below the sea surface results from increased planktonic biomass within the euphotic zone. The enhanced primary productivity near the sea surface also produces oxygen and consumes carbon dioxide (CO_2). This removal of carbonic acid (dissolved CO_2) accounts for the higher alkalinity (pH) found at the sea surface (gold line). As the ratio of respiration to photosynthesis increases with depth, there is an increase in dissolved CO_2 (carbonic acid) and a concomitant decline in pH (more acidic). Accordingly, respiration consumes oxygen, which accounts for the decline in DO with increasing depth seen in Figures A-1 through A-3.

Lateral Variability

The influence of the effluent discharge can be best identified from localized anomalies in seawater properties, particularly salinity. During the April-2005 survey, very slight discharge-related perturbations were observed near the sea surface at Stations 4, 9, and 13. As shown in Figure 2, all of these stations are located southwest of the diffuser structure, in a direction consistent with the path of the drogued drifter and, ostensibly, in the path of plume transport. Two of the discharge-related perturbations are evident within the surface mixed layer at Stations 4 and 9 in the vertical sections shown in Figures A-4 through A-7. Station 13 was not located along the transects shown in the vertical sections.

Discharge-related anomalies are especially apparent when seawater properties from the same depth level are compared at adjacent stations. The vertical sections show that for all of the seawater properties except salinity and density, shallow anomalies have the same characteristics as ambient waters at depth. They are only apparent because these deep water properties have been displaced upward into the mixed layer, where the surrounding seawater characteristics differ. Because of this, the analysis of lateral variability in seawater properties forms the basis for assessments of water-quality impacts.

In particular, the significance of each potential discharge-related anomaly can be evaluated statistically by comparing its amplitude to the natural background variability. To that end, each observation at a particular station was compared with the observations from other stations at the same depth level. Measurements collected 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 collected at the same height above the sloping seafloor. This is done because deep seawater properties tend to parallel the sloping seafloor rather than the horizontal sea surface.

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

In the April-2005 dataset, a number of observations that were found to be statistically significant were unrelated to the effluent discharge. For example, the apparently significant anomalies in temperature, density, and DO that are highlighted in Tables B-1, B-3, and B-4, were artifacts of the slightly deeper mixed layer that was present at Station 7 (*cf.* upper left frame of Figure A-2). This station lies farthest offshore. Its slightly deeper mixed layer meant that water properties at depths between 13.5 m and 14.5 m, which were within the mixed layer at Station 7, were being contrasted with much-different water properties within the deep thermocline at adjacent stations. It is also clear that these anomalies were unrelated to the discharge because of their location relative to the discharge (*cf.* Figure 2). First, Station 8, where anomalies were not apparent, lies between the diffuser structure and the outermost Station 7. Second, the prevailing flow was toward the south southwest and not toward Station 7. Instead, the deep lateral anomalies at Station 7 appeared because of slight differences in the depth of the interface between the mixed layer and deep thermocline.

A similar phenomenon caused the significant transmissivity anomalies found near the seafloor at several stations (Table B-5). Again, lateral variability was artificially introduced by differences in the thickness of the BNL and by how close the CTD samples were taken to the seafloor; namely, by how far into the BNL the measurements were collected. The 1-m thick BNL had remarkably high turbidity compared to waters immediately above the BNL. Consequently, the vertical sampling interval of 0.5 m spanned a significant portion of this thin layer, which lies immediately above the seafloor. Also, the BNL interface was sharp, so slight variations in the thickness of the boundary layer between stations would easily appear as marked lateral variations in transmissivity. Although it is not immediately apparent from the listings in Table B-5, the Station-7 anomalies represent significant increases in transmissivity near the seafloor. Clearly, these instances of comparatively low turbidity were unrelated to the discharge of wastewater particulates. Instead, they were artifacts of random variation in sampling of the BNL, as were the "*significant*" reductions that were found near the seafloor at Stations 1, 2, and 12.

In contrast, the statistically significant reductions in pH at Station 6, which are highlighted in Table B-7, were not related to a natural phenomenon, or to the discharge. Instead, they were artifacts of the temporal drift in the pH probe that was described previously, in the section entitled *Temporal Trends in the pH Sensor*. Station 6 was the first station occupied during the April-2005 survey, and, as a result, the pH measurements at this location required the greatest adjustment (0.065) to account for ongoing equilibration. The anomalous measurements at Station 6 (Table B-7) are eliminated (Table B-6) after removal of the slight temporal trend in pH.

Even without instrumental discrepancies, the presence of statistically significant anomalies that are unrelated to the discharge is expected. From the definition of a 95% confidence level, one '*significant*' departure out of every 20 measurements should occur by chance alone. With more than 500 measurements examined for each of the six parameters, it is not surprising that a few departed from the mean by an amount more than the 95% confidence interval. Moreover, when multiple hypotheses are being tested (*i.e.*, one for each observation), the error rate for each individual test should be adjusted to achieve the overall experimentwise error rate of 5% (95% confidence). By definition, this error rate is the probability that one or more of the hypothesis tests would incorrectly find a significant difference when none exists. Thus, without correcting for repeated hypothesis testing, the individual tests are conservative and "significant" departures will be found more often than if a single test were being performed at the 95% confidence level.

Discharge-Related Perturbations

During the April-2005 survey, there were three perturbations in seawater properties that were unequivocally related to the discharge (Perturbations P1, P2, and P3 in Table 4). A discharge-related perturbation is a group of anomalies in one or more seawater properties that are contiguous in depth at a particular station. In addition to their spatial co-occurrence, the sign, or direction of the anomalies, lends insight into their origins. For example, the negative salinity anomaly at 1.5 m at Station 9 definitively indicates the presence of dilute wastewater constituents. This anomaly is delineated in red in the top frame of Figure A-4. Its vertical isolation is a signature unique to salinity and density anomalies. None of the ambient water properties have salinities or densities as low as those of Perturbation P2. Consequently, these anomalies could not have been created by the upward displacement of ambient water properties

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

Perturbation[b]	Station	Depth Range	Depth of Extremum	Property	Magnitude	Process
P1 Dilution=762:1	4	0 to 5 m	3.5 m	Salinity	–0.044 ‰	Effluent
		0 to 8 m	2.0 m	Temperature	–0.13 ºC	Entrainment
		0 to 5 m	3.5 m	Density	–0.015 σ_t	Effluent
		0 to 8 m	1.0 m	Transmissivity	+5.0 %	Entrainment
		0 to 8 m	2.0 m	Dissolved Oxygen	–0.66 mg/L	Entrainment
		0 to 8 m	0.5 m	pH	–0.019 pH	Entrainment
P2 Dilution=413:1	9	**0 to 2.5 m**	**1.5 m**	**Salinity**	**–0.081 ‰**	**Effluent**
		0 to 7 m	1.0 m	Temperature	–0.10 ºC	Entrainment
		0 to 10 m	1.5 m	Density	–0.049 σ_t	Effluent
		0 to 5 m	1.0 m	Transmissivity	+2.1 %	Entrainment
		0 to 8 m	1.0 m	Dissolved Oxygen	–0.60 mg/L	Entrainment
		0 to 9 m	**1.0 m**	**pH**	**–0.031 pH**	**Entrainment**
P3 Dilution=465:1	13	**0 to 3 m**	**2.5 m**	**Salinity**	**–0.041 ‰**	**Effluent**
		0 to 3 m	2.5 m	Temperature	–0.06 ºC	Entrainment
		0 to 3 m	2.5 m	Density	–0.046 σ_t	Effluent
		0 to 3.5 m	1.0 m	Transmissivity	+2.2 %	Entrainment
		0 to 3.5 m	2.5 m	Dissolved Oxygen	–0.41 mg/L	Entrainment
		0 to 5.0 m	3.5 m	pH	–0.017 pH	Entrainment

[a] Anomalies shown in bold type were statistically significant
[b] Perturbations consist of a group of spatially consistent anomalies in different seawater properties

alone. Instead, the salinity and density anomalies could only have been induced by the presence of dilute wastewater, which has effectively no salinity and is much less dense than ambient waters upon discharge. The same can be said of the salinity and density anomalies associated with Perturbations P1 and P3 at Stations 4 and 13. As with Perturbation P2, vertically isolated salinity and density anomalies associated with Perturbation P1 are apparent in the vertical sections shown in the top and bottom frame of Figure A-4.

In contrast, discharge-related anomalies in other water properties reflect ambient conditions within the thermocline at depth. This strongly suggests that these anomalies were generated by the upward displacement of ambient bottom water, rather than the presence of effluent constituents. Namely, these entrainment-generated anomalies were produced when ambient seawater at depth was entrained in the rising effluent plume. After being displaced upward, the differing bottom-water properties are juxtaposed with shallow-water properties, and the contrast becomes apparent as an anomaly. During the April-2005 survey, the presence of a deep watermass caused seawater within the deep thermocline to be naturally low in temperature, pH, and DO, and high in transmissivity. The vertical sections shown in Figures A-4 through A-7 show that all of these unique ambient seawater properties at depth can be traced to the anomalies observed in the upper water column at Stations 4 and 9.

Entrainment-generated anomalies only become apparent when ambient seawater properties at depth are distinctly different from shallow water properties. Without this naturally occurring stratification, entrainment of deep ambient seawater within the rising effluent plume would not produce obvious differences between the entrained water and shallow water properties. Thus, the entrained deep seawater acts as a tracer of the effluent plume after discharge. These same entrainment-generated anomalies could just as easily have been produced by the discharge of warm seawater, containing no suspended solids or other contaminants whatsoever.

Not only is there a direct connection between the shallow entrainment-generated anomalies and deeper ambient seawater properties, but the character of the anomalies demonstrates why they could not have been induced by the presence of wastewater constituents alone. Wastewater is generally warmer and carries higher suspended particulate loads than receiving ocean waters. It also tends to have a higher pH and DO than seawater at depth. If wastewater properties were materially contributing to the perturbations, then positive thermal, pH, and DO anomalies would be generated along with a negative transmissivity anomaly. Instead, the opposite was the case for all three of the discharge-related perturbations listed in Table 4. Thermal, pH, and DO anomalies were all negative, indicating that the perturbation was cooler, more acid, and less oxygenated than surrounding shallow seawater. These are characteristics comparable to deep ambient seawater, not wastewater. Although localized reductions in DO can be caused by the discharge of large amounts of oxygen-demanding material in wastewater, this is not the case with the MBCSD discharge. Most of the oxygen-demanding material is removed in the treatment process, and the MBCSD effluent has low biochemical oxygen demand (MRS, 2005). Instead, because of its recent contact with the atmosphere, MBCSD wastewater generally has higher DO than ambient seawater at depth, which has depleted oxygen levels due to respiration and decay over a long period since its equilibration with the atmosphere.

The positive transmissivity anomaly is even more diagnostic. The top frames of Figures A-5 and A-7 show that low-turbidity seawater at mid-depth, shown in light blue, was moved upward into the water column by the buoyant effluent plume. As a result of this low-turbidity seawater near the sea surface, the transmission of natural light is increased. The increased light transmission at Station 13 was captured by the 4.5-m Secchi depth, which was the deepest recorded during the April-2005 survey (Table B-8). Increased water clarity is opposite of the negative impact on ambient light transmission that is normally thought to be produced by the discharge of wastewater particulates. It emphasizes why many of the receiving-water limitations specified in the COP explicitly state that limitations only apply to impacts caused by the presence of wastewater constituents, and, by implication, not to changes generated by the entrainment of ambient seawater. This is also implied by the 95% significance tests, which restrict attention to discharge-induced changes beyond the range of natural variation in ambient seawater properties. Otherwise, credit would have to be given for the beneficial impact of the discharge whenever the buoyant plume happens to mix with less-turbid seawater, as in the case of the April-2005 survey. In any regard, entrainment-generated impacts, beneficial or otherwise, are largely dictated by the existing ambient seawater stratification rather than the quality of discharged wastewater. None of these anomalies would have been apparent during the unstratified conditions found in winter. Besides, naturally occurring vertical differences in seawater properties are eventually mixed throughout the water column by nearshore processes; plume entrainment simply serves to accelerate this process within a localized area.

Initial Dilution Computations

The amplitude of negative salinity anomalies at Stations 4, 9 and 13 lends insight into effectiveness of the outfall at dispersing effluent and, ultimately, compliance with the receiving-water objectives of the COP and NPDES discharge permit. The critical initial dilution applicable to the MBCSD outfall was conservatively estimated to be 133:1 (Tetra Tech, 1992). This estimate was based on worst-case modeling results using highly stratified conditions. These dispersion models found that 133 parts of ambient water would have mixed with each part of wastewater after initial mixing was complete. This dilution ratio was predicted to occur after the plume rose 9 m from the seafloor, whereupon it became trapped below a thermocline and spread laterally with no further substantive dilution. A 9-m rise translates into a trapping depth 6.4 m below the sea surface. This trapping depth lies below the depth of the salinity anomalies observed in the April-2005 survey (Table 4), so slightly higher dilution levels than those predicted by modeling would be expected. However, as described below, the smallest dilution ratio of 413:1, which was computed from the largest salinity anomaly, was far larger than the critical dilution ratio predicted by modeling. This demonstrates that the diffuser structure was operating more efficiently than predicted by 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 modeling. Use of a higher critical dilution ratio would relax the stringent end-of-pipe effluent limitations that were thought to be necessary in order to meet Ocean-Plan standards.

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

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

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

The actual dilution achieved by the outfall at any given time can also be computed from Equation 1 using measured seawater anomalies. This measured dilution can then be compared with the critical dilution factor determined from modeling. Salinity is an especially useful tracer because it directly reflects the magnitude of ongoing dilution. Specifically, the salinity concentration in effluent is negligible so C_e is eliminated in Equation 1 and the dilution ratio (D) can be computed from the salinity anomaly ($A = C_o - C_s$) as:

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

where: D = the dilution ratio of the volume of seawater mixed with effluent,
C_o = the salinity of the effluent-seawater mixture after dilution by D,
C_s = the background seawater salinity (approximately 33.6‰), and
$A = C_o - C_s$ = the salinity anomaly.

Computed dilutions during the stratified conditions of the April-2005 survey demonstrate that the modeled dilution factors are far more conservative than those actually achieved by the diffuser structure. Specifically, the largest salinity anomaly (–0.081‰) yields a dilution ratio of 413:1 in Equation 2. It indicates a dilution ratio that was three-times higher than the 133:1 critical dilution used to establish limitations on contaminant concentrations in wastewater. The dilution computation demonstrates that, during the April-2005 survey, the outfall was performing better than designed, and was rapidly diluting effluent more than 400-fold. Consequently, COP receiving-water objectives would be easily met by the chemical concentration limits promulgated by the NPDES discharge permit issued to the MBCSD.

DISCUSSION

Sampling during the April-2005 survey indicated that the wastewater discharge was in compliance with the receiving-water limitations specified in the NPDES permit, and with the water-quality objectives of the COP (SWRCB, 1997) and the Central Coast Basin Plan (RWQCB, 1994). Specifically, there were no particulates of sewage origin seen floating on the ocean surface at any of the stations sampled during the April-2005 water-quality survey. Although statistically significant reductions in salinity and pH were generated by the discharge plume, they were small compared to the receiving-water limits specified in the NPDES discharge permit. Discharge-related reductions in DO, pH, and temperature were also apparent near the sea surface southwest of the ZID. However, these localized reductions resulted from entrainment of deep ambient seawater and not the presence of wastewater itself. Wastewater constituents were too dilute to measurably contribute to anomalies in these other seawater properties. The DO measured near the sea surface at Stations 4, 9, and 13 was comparable to the DO of ambient seawater at depth, so the surface DO anomaly could not be ascribed to the presence of oxygen-demanding material within the effluent after being diluted 400-fold. Similarly, the reduced pH measured near the sea surface was produced by the upward movement of ambient seawater, which is naturally low in pH at depth. Finally, salinity and temperature remained close to natural levels at all stations within and beyond the ZID. This includes the discharge-related anomalies identified at Stations 4, 9, and 13. The ranges in measured temperatures (0.3ºC) and salinities (0.17‰) across all data collected in April 2005 were too small to be considered harmful to marine biota or deleterious to beneficial uses.

Outfall Performance

Small but statistically significant anomalies in salinity indicated the presence of dilute wastewater near the sea surface at Stations 4 and 9, near the boundary of the ZID, and at Station 13, approximately 47 m to the southwest of the ZID. These sensitive instrumental observations demonstrated that the diffuser structure was operating better than predicted by modeling, and that the discharged wastewater experienced high levels of dilution within and beyond the ZID. A dilution of 413:1 was determined from the salinity anomaly located at Station 9. This is more than three times the minimum critical dilution of 133:1 specified in the NPDES permit. With the higher dilution ratio that was determined from actual measurements during the April-2005 survey, contaminant concentrations within the wastewater could have been more than three-times the limits specified in the NPDES discharge permit, and the receiving-water objectives of the California Ocean Plan (COP) would still have been achieved.

NPDES Permit Limits

The seawater properties measured during the April-2005 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:

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-6, the statistical significance of departures from mean conditions at a given depth level were determined with an analysis of variance that compares a single observation with the mean of a larger set of samples (see Page 228 in Sokal and Rohlf, 1997; Ury, 1976). Although 15 independent hypothesis tests were performed at each depth level, no Bonferroni adjustment to the error rate was included, so the tests are conservative. Specifically, Bonferroni adjustment indicates that the actual confidence level for the overall null hypothesis test for differences in properties is higher, around 99.7%, rather than the 95% level that applies to a single test. The standard deviation that was applied in the tests was determined from the entire data set to reflect the full range in ambient properties, including vertical variations.

Light Transmittance

Based on the statistical analysis, no significant reductions in instrumentally recorded light transmittance were found in the euphotic zone within or beyond the ZID (Table B-5). Although not statistically significant, discharge-related changes in transmissivity were visually perceptible at Stations 4 and 9 as shown in the top frames of Figures A-5 and A-7. However, these anomalies reflect an increased transmissivity of up to 5% rather than a "…*reduction in the transmittance of natural light….*" The observed increase in transmissivity is opposite of the degradation in water quality that would be expected in effluent discharges with heavy particulate loads. As described previously, the anomalies were caused by the upward displacement of clear seawater at mid-depth into the relatively turbid near-surface waters. Increased transmissivity near the sea surface beneficially impacts the euphotic zone by increasing the penetration of ambient light and enhancing primary production.

Statistically significant anomalies in light transmission were observed near the seafloor at Stations 1, 2, 7, and 12 (Table B-5). Although statistically significant, the deep transmissivity reductions were unrelated to effluent discharge because they did not coincide with anomalies in other water properties and were not located in the path of the discharge plume. Instead, these deep transmissivity anomalies were generated by natural fluctuations in the thickness of the turbid boundary layer that was present at all stations near the seafloor. Even if the seafloor transmissivity reductions were discharge-related, they would not represent a violation of the Ocean-Plan objectives. Because they were located on the seafloor, they could not have caused a "…*reduction in the transmittance of natural light….*" Based on the measured Secchi depths of 4.0 m (Table B-8), the bottom of the euphotic zone was approximately 8.0 m, indicating that very little natural light was reaching the seafloor where the statistically significant anomalies in transmissivity were observed.

Dissolved Oxygen

Although it is not stated in the NPDES discharge permit, the COP specifies that the DO limitation only applies to reductions that occur "…*as a result of the discharge of oxygen demanding waste materials*." Clearly, then, the DO limitation does not apply to reductions in DO caused by the movement of ambient waters, regardless of whether they were induced by the physics of the discharge. Thus, the slightly reduced DO concentrations observed near the sea surface at Stations 4, 9, and 13, which were generated by entrainment of ambient seawater, are not subject to the limitations. Even so, the amplitudes of the DO anomalies were so small (-0.66 mg/L) that they did not constitute statistically significant deviations from the norm. Moreover, they complied with the numerical limits specified in the permit. Specifically, none of the anomalous DO concentrations fell below the 5-mg/L minimum specified in the Basin Plan and the NPDES discharge permit. Of the 513 measurements collected during the April-2005 survey, only 6 fell between 4.94 mg/L and 5 mg/L. All six were measured near the seafloor within a benthic water mass that was naturally depleted in oxygen due to its deep offshore origin. Because these lowest oxygen concentrations arose from natural processes, the amplitude of all of the other DO measurements, including the discharge-related anomalies at Stations 4, 9, and 13, cannot be considered *"…to be depressed more than 10 percent from that which occurs naturally*."

pH

The only statistically significant lateral anomaly in pH (Table B-6) was measured near the sea surface at Station 9. As with the other water properties, this pH anomaly was generated by the upward displacement of ambient bottom water, which is naturally low in pH. Moreover, the maximum amplitude of this anomaly (-0.037) 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 0.043, so none of the measurements can be considered changed by '…*more than 0.2 pH units from that which occurs naturally*.' The range across the entire pH field remained between 7.271 and 7.314, 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 0.31ºC 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*….' This is because the 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 (-0.13ºC) that are visually apparent in the vertical section at Station 4 (middle frame of Figure A-4) clearly resulted from the upward displacement of naturally occurring, cooler bottom water rather than the presence of warmer wastewater constituents.

Although salinity anomalies provide the best tracer of discharged effluent, their actual amplitude (≤0.081‰) was small compared to ambient salinity variability observed during the April-2005 survey. The total range in measured salinities was 0.17‰. This salinity range is less than the 0.25‰ average seasonal difference in mean surface salinity, and is well within the spatial differences in salinity that occur along the south-central California coast. Thus, the observed range in both the measured temperature (0.31ºC) and salinity (0.17‰) across all data collected during the April-2005 survey was too small to be considered harmful to marine biota or deleterious to beneficial uses.

Conclusions

The measurements collected at all stations during the April-2005 survey complied with receiving-water limitations specified in the NPDES discharge permit. The discharge-related anomalies found in the upper water column near the boundary of the ZID, and farther to the southwest, were largely caused by the upward displacement of ambient seawater, and not the presence of wastewater constituents. Computations of effluent mixing demonstrated that discharged wastewater was undergoing rapid dilution close to the diffuser structure, and that the outfall was operating as designed.

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APPENDIX A

Water Quality Profiles and Vertical Sections

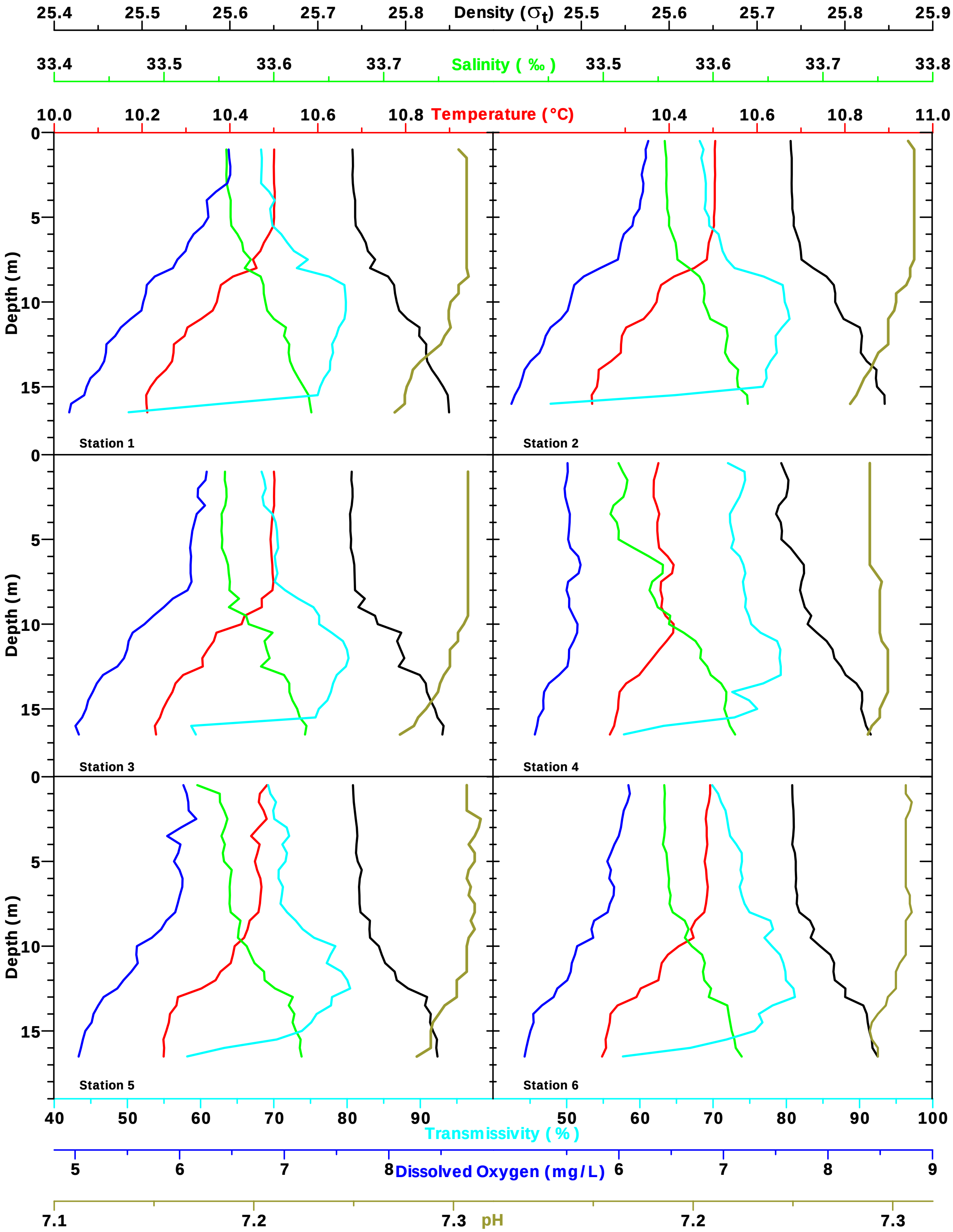

Figure A-1. Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 5 April 2005

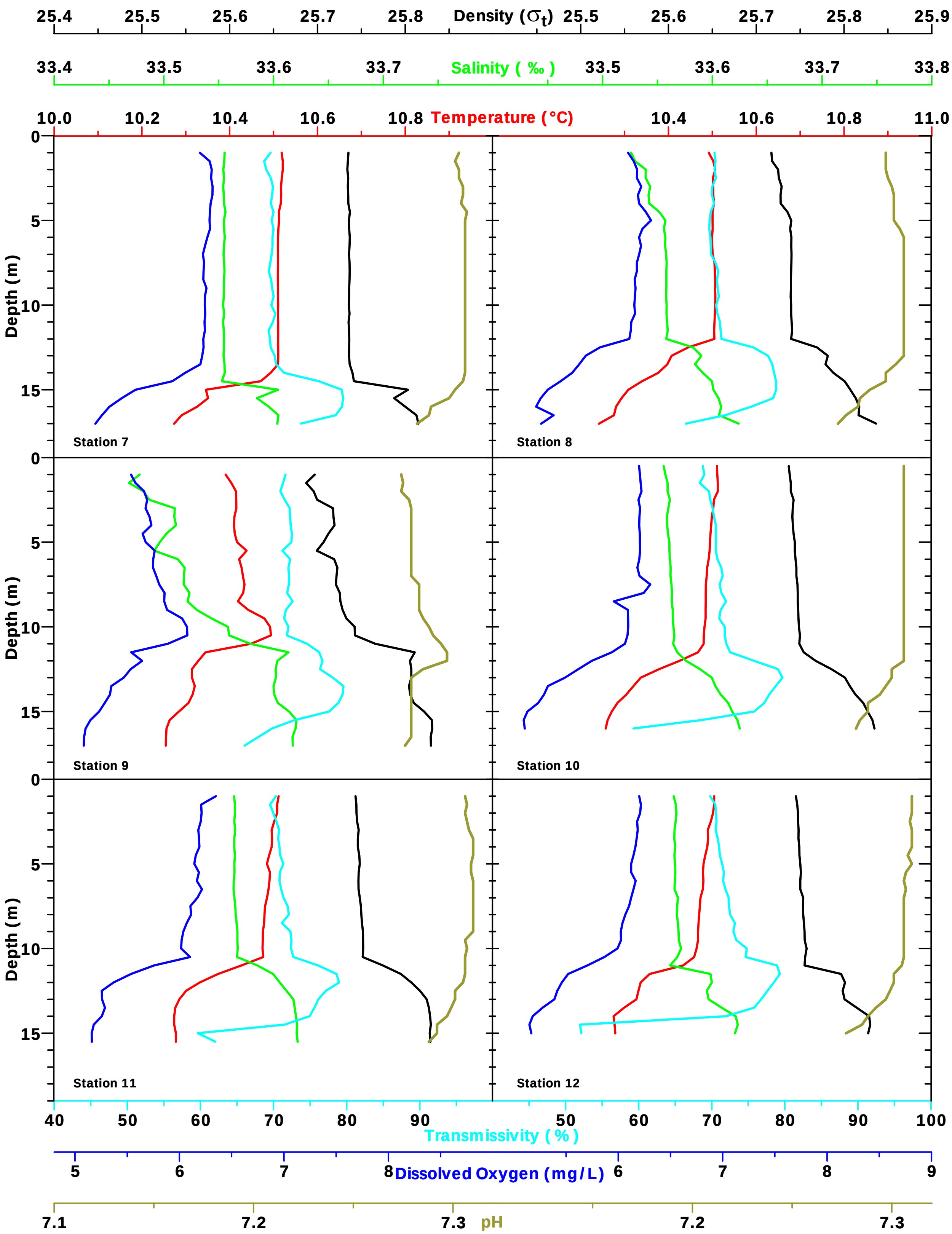

Figure A-2. Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 5 April 2005

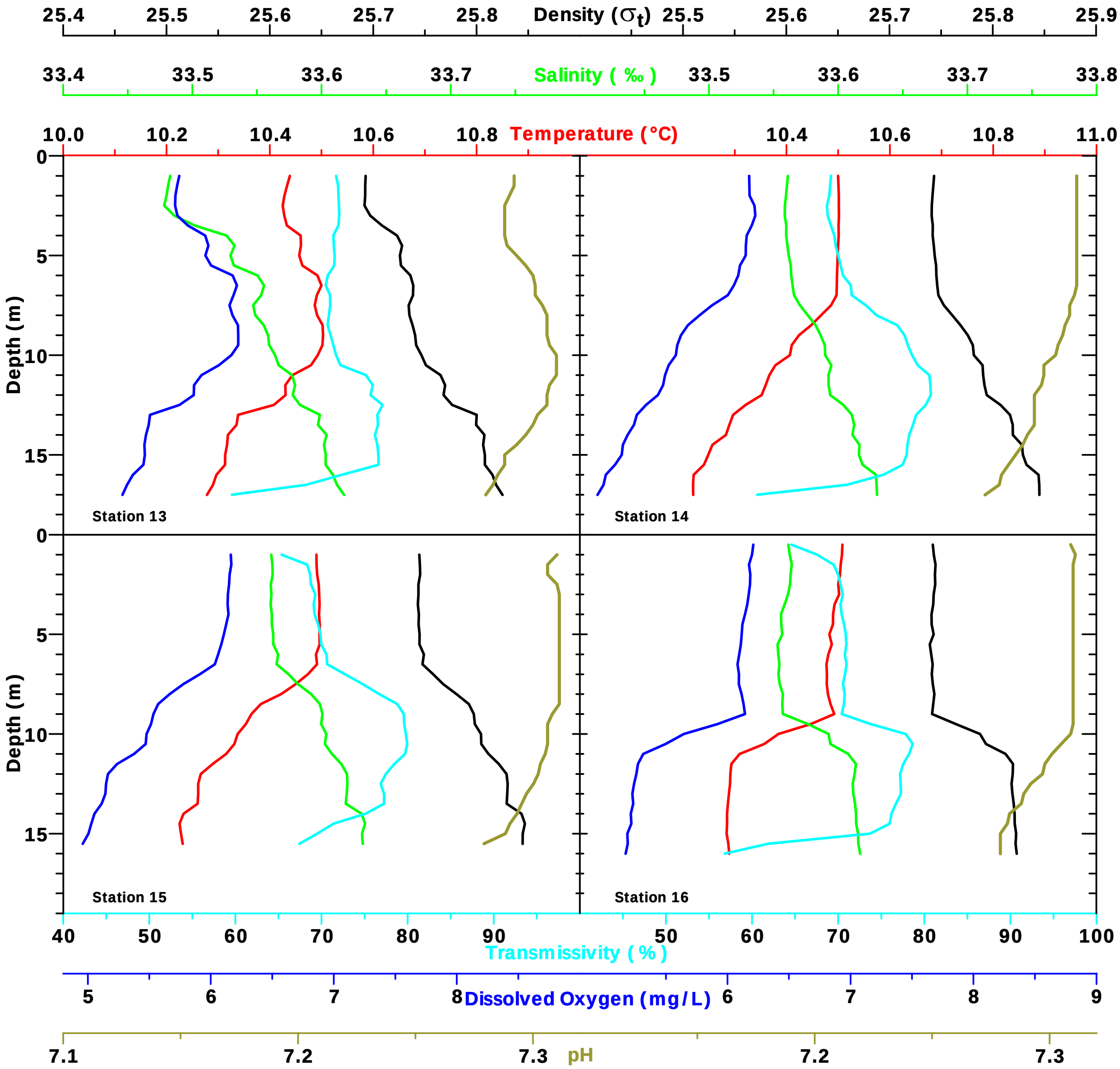

Figure A-3. Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 5 April 2005

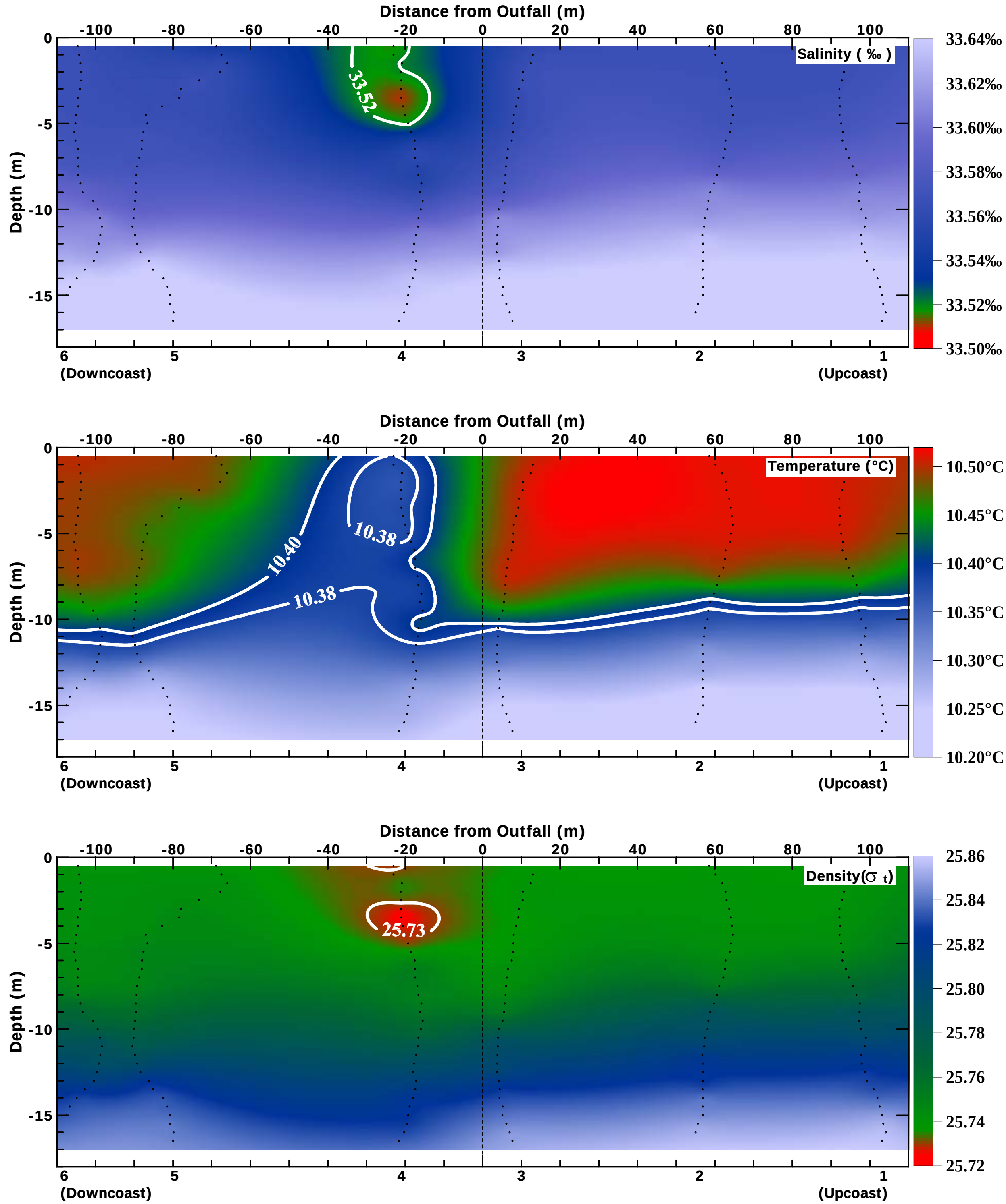

Figure A-4. Along-Shore Transects of Salinity, Temperature, and Density on 5 April 2005

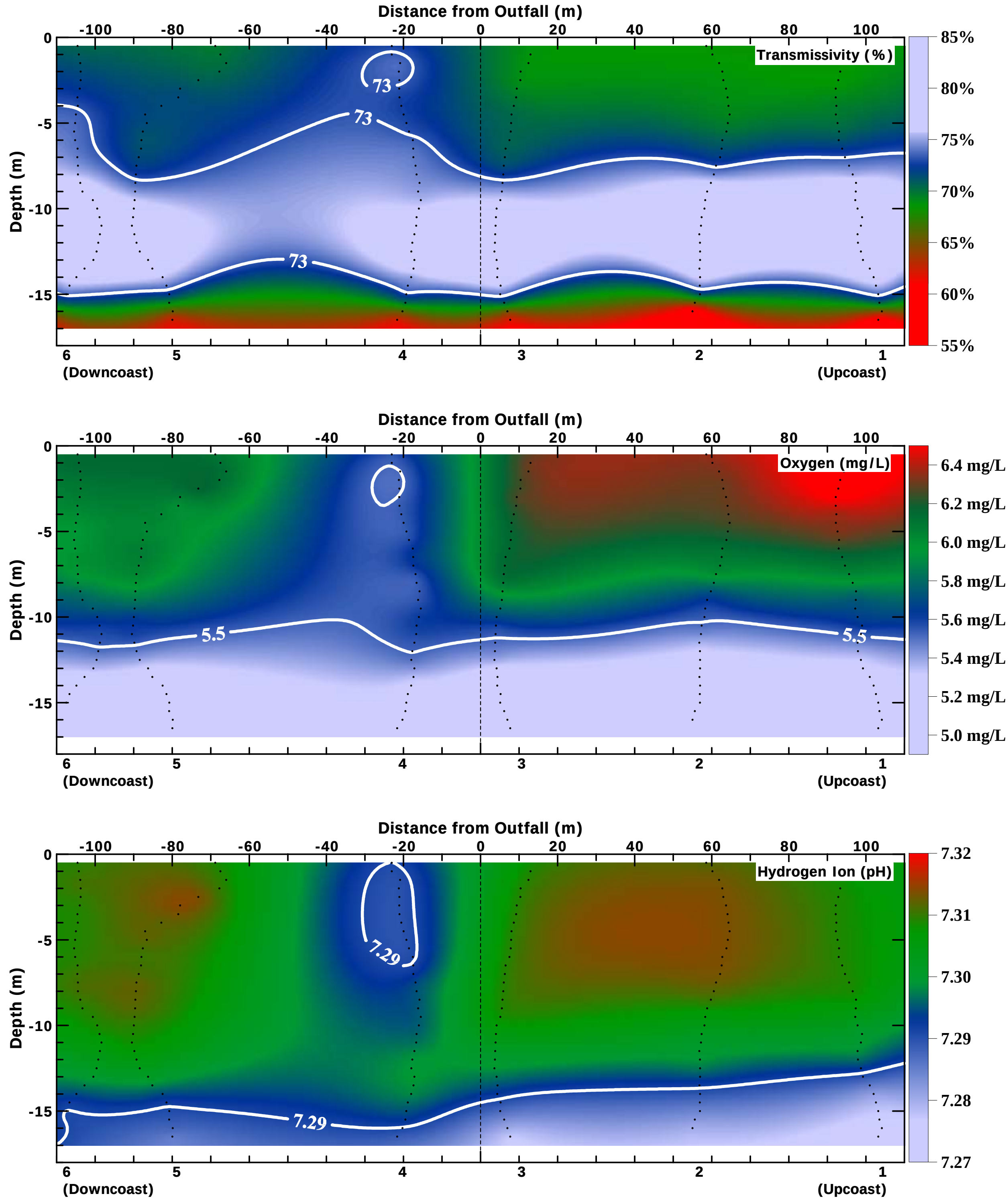

Figure A-5. Along-Shore Transects of Transmissivity, Oxygen, and pH on 5 April 2005

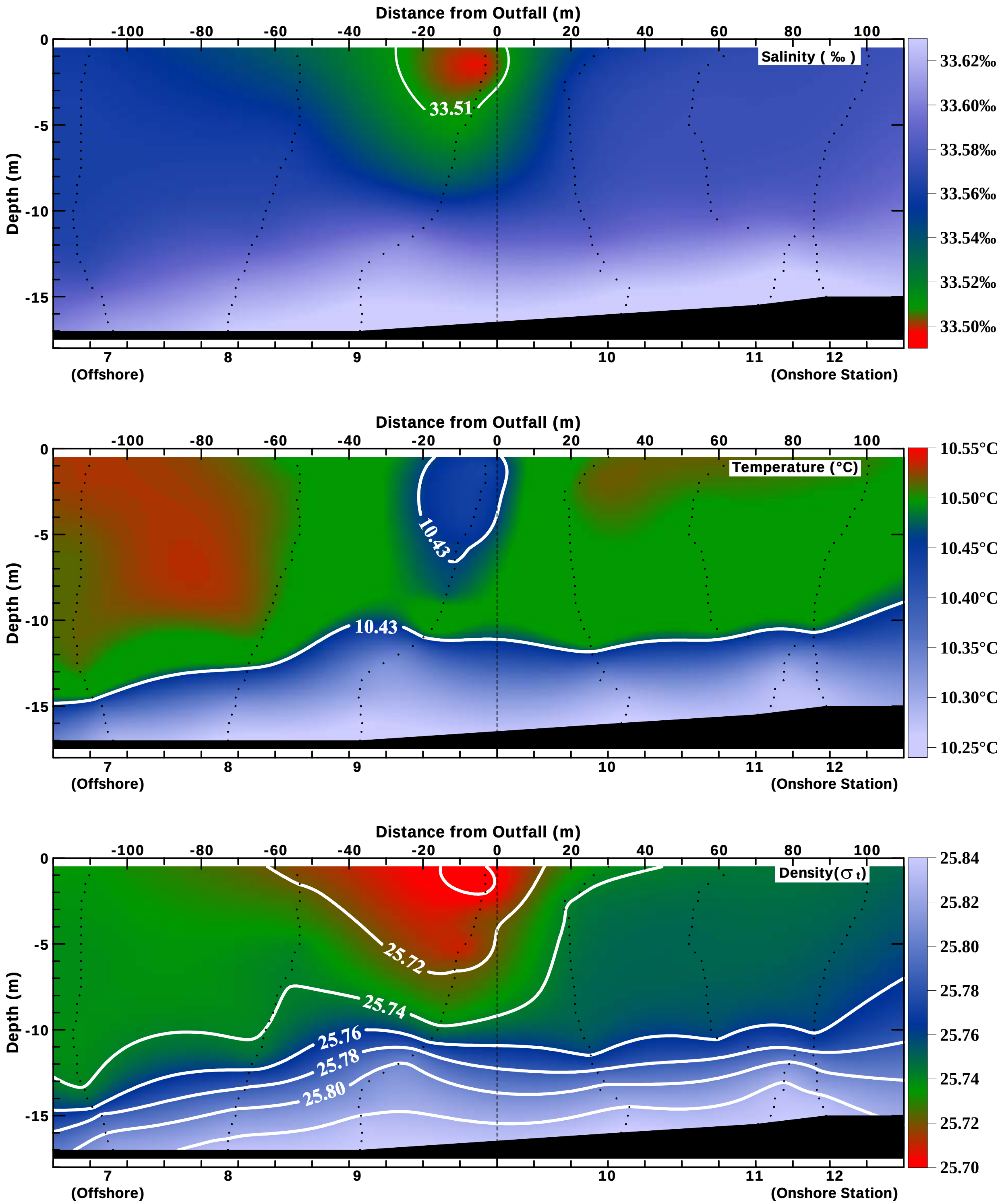

Figure A-6. Cross-Shore Transects of Salinity, Temperature, and Density on 5 April 2005

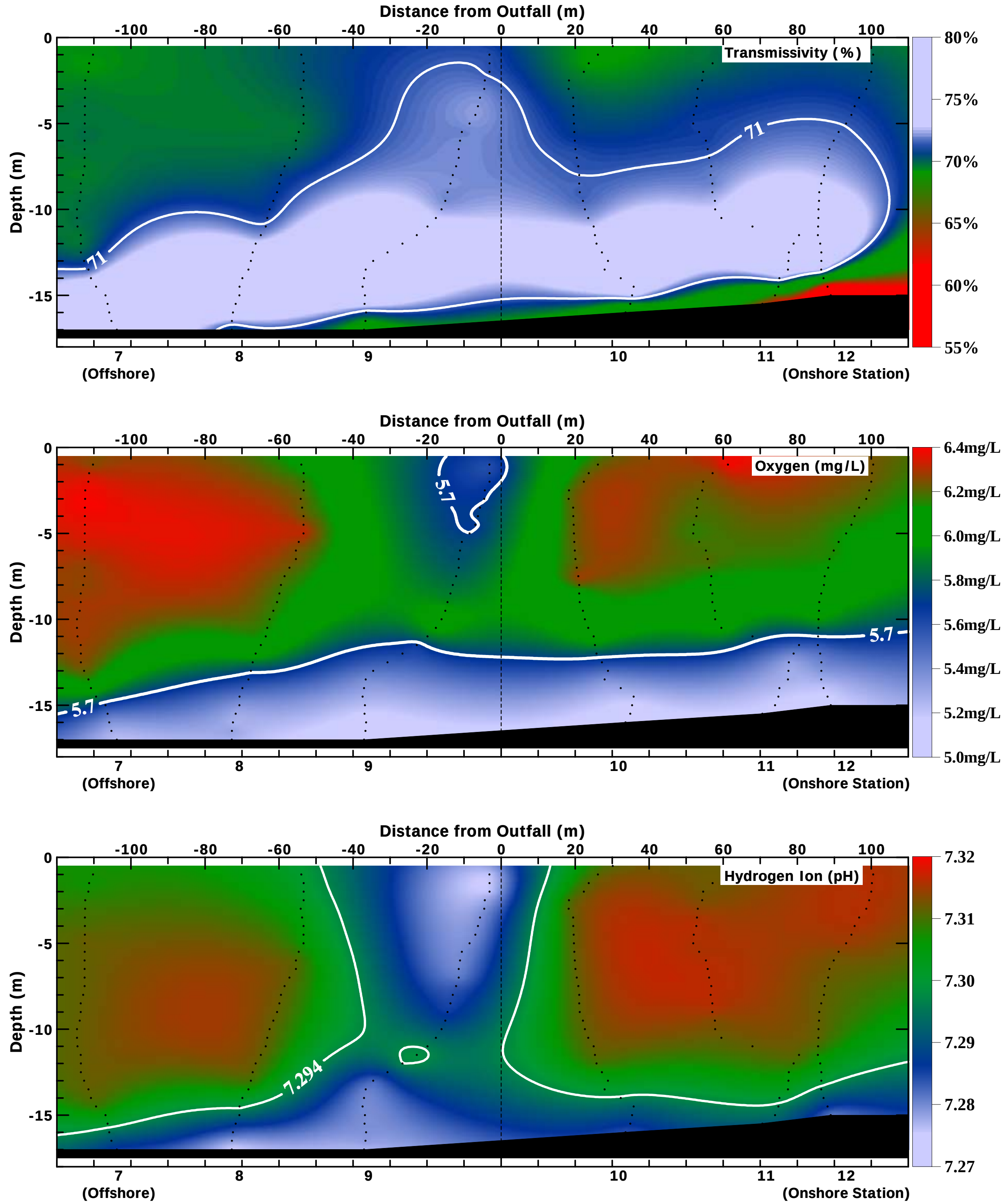

Figure A-7. Cross-Shore Transects of Transmissivity, Oxygen, and pH on 5 April 2005

APPENDIX B

Tables of Profile Data and Standard Observations

Table B-1. Seawater Temperature[1] on 5 April 2005

	Temperature (°C)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5		10.51		10.38	10.48	10.49				10.51						10.51
1.0	10.50	10.50	10.50	10.37	10.47	10.49	10.52	10.49	10.39	10.51	10.51	10.50	10.44	10.50	10.49	10.51
1.5	10.50	10.50	10.50	10.37	10.47	10.49	10.52	10.50	10.40	10.51	10.51	10.50	10.43	10.50	10.49	10.50
2.0	10.50	10.50	10.50	10.36	10.48	10.49	10.52	10.51	10.41	10.51	10.51	10.50	10.43	10.50	10.49	10.50
2.5	10.50	10.50	10.50	10.36	10.48	10.48	10.52	10.50	10.41	10.50	10.50	10.50	10.42	10.50	10.49	10.50
3.0	10.50	10.50	10.50	10.37	10.47	10.49	10.52	10.50	10.42	10.50	10.50	10.49	10.43	10.50	10.50	10.50
3.5	10.50	10.50	10.50	10.38	10.45	10.49	10.52	10.50	10.41	10.50	10.50	10.49	10.43	10.50	10.50	10.49
4.0	10.50	10.50	10.50	10.37	10.47	10.49	10.52	10.50	10.41	10.50	10.50	10.49	10.46	10.50	10.50	10.49
4.5	10.50	10.50	10.49	10.37	10.46	10.48	10.51	10.50	10.41	10.50	10.49	10.48	10.46	10.50	10.50	10.49
5.0	10.50	10.50	10.49	10.37	10.46	10.48	10.51	10.50	10.42	10.49	10.48	10.48	10.46	10.50	10.50	10.48
5.5	10.50	10.50	10.49	10.38	10.46	10.48	10.51	10.50	10.44	10.49	10.49	10.48	10.46	10.50	10.50	10.49
6.0	10.49	10.50	10.49	10.40	10.47	10.49	10.51	10.50	10.42	10.49	10.49	10.48	10.49	10.50	10.49	10.48
6.5	10.48	10.49	10.50	10.41	10.47	10.49	10.51	10.50	10.43	10.49	10.49	10.48	10.50	10.50	10.49	10.48
7.0	10.47	10.49	10.50	10.41	10.47	10.49	10.51	10.50	10.43	10.49	10.49	10.47	10.49	10.50	10.47	10.48
7.5	10.45	10.49	10.50	10.38	10.47	10.48	10.51	10.50	10.43	10.49	10.48	10.47	10.49	10.49	10.45	10.48
8.0	10.46	10.46	10.50	10.38	10.47	10.48	10.51	10.51	10.43	10.48	10.48	10.47	10.49	10.47	10.42	10.48
8.5	10.41	10.41	10.47	10.38	10.44	10.46	10.51	10.51	10.42	10.48	10.48	10.47	10.50	10.45	10.38	10.49
9.0	10.38	10.38	10.47	10.38	10.44	10.45	10.51	10.51	10.44	10.48	10.48	10.47	10.50	10.42	10.36	10.49
9.5	10.37	10.37	10.43	10.39	10.43	10.46	10.51	10.51	10.48	10.48	10.48	10.47	10.50	10.41	10.35	10.45
10.0	10.37	10.37	10.43	10.41	10.41	10.42	10.51	10.51	10.49	10.48	10.47	10.46	10.49	10.41	10.34	10.38
10.5	10.36	10.36	10.37	10.41	10.41	10.40	10.51	10.51	10.49	10.48	10.48	10.46	10.48	10.38	10.33	10.36
11.0	10.33	10.34	10.36	10.39	10.40	10.38	10.51	10.51	10.45	10.48	10.43	10.43	10.44	10.37	10.32	10.31
11.5	10.30	10.30	10.35	10.38	10.38	10.38	10.51	10.50	10.34	10.47	10.37	10.36	10.43	10.36	10.29	10.29
12.0	10.30	10.29	10.34	10.36	10.37	10.38	10.51	10.50	10.33	10.43	10.33	10.34	10.43	10.35	10.27	10.29
12.5	10.27	10.29	10.34	10.35	10.33	10.33	10.51	10.45	10.31	10.38	10.30	10.33	10.41	10.32	10.26	10.29
13.0	10.27	10.29	10.29	10.33	10.28	10.33	10.51	10.41	10.31	10.34	10.29	10.33	10.34	10.30	10.26	10.29
13.5	10.27	10.27	10.28	10.30	10.28	10.28	**10.51**	10.40	10.32	10.32	10.28	10.30	10.34	10.29	10.26	10.29
14.0	10.25	10.24	10.27	10.29	10.26	10.27	**10.49**	10.38	10.32	10.30	10.27	10.28	10.32	10.28	10.23	10.28
14.5	10.23	10.24	10.26	10.28	10.26	10.26	10.47	10.34	10.31	10.28	10.27	10.28	10.32	10.26	10.23	10.28
15.0	10.22	10.24	10.25	10.28	10.26	10.26	10.35	10.31	10.28	10.27	10.28	10.28	10.31	10.25	10.23	10.28
15.5	10.21	10.22	10.24	10.28	10.25	10.26	10.35	10.29	10.26	10.26	10.28		10.31	10.24	10.23	10.29
16.0	10.21	10.22	10.23	10.27	10.25	10.26	10.33	10.28	10.26	10.26			10.30	10.22		10.29
16.5	10.21		10.23	10.26	10.25	10.25	10.29	10.28	10.25				10.29	10.22		
17.0							10.27	10.24	10.25				10.28	10.22		

[1] Values enclosed in boxes were significantly higher than the mean of other temperature measurements at the same distance above the seafloor.

Table B-2. Salinity[1] on 5 April 2005

Depth (m)	Salinity (‰)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5		33.556		33.514	33.530	33.556				33.556						33.561
1.0	33.557	33.557	33.556	33.518	33.551	33.556	33.555	33.526	**33.478**	33.557	33.564	33.565	33.483	33.561	33.561	33.563
1.5	33.557	33.557	33.555	33.522	33.551	33.556	33.555	33.530	**33.468**	33.559	33.565	33.567	**33.481**	33.560	33.562	33.564
2.0	33.557	33.557	33.557	33.521	33.555	33.556	33.554	33.539	**33.482**	33.559	33.565	33.567	**33.480**	33.560	33.562	33.563
2.5	33.557	33.558	33.557	33.518	33.558	33.556	33.555	33.539	**33.487**	33.561	33.564	33.567	**33.478**	33.559	33.561	33.563
3.0	33.557	33.557	33.556	33.509	33.555	33.556	33.554	33.543	33.510	33.560	33.565	33.566	**33.486**	33.559	33.561	33.561
3.5	33.559	33.558	33.553	33.507	33.552	33.556	33.555	33.542	33.510	33.559	33.564	33.565	33.502	33.560	33.561	33.559
4.0	33.561	33.558	33.553	33.512	33.555	33.554	33.555	33.543	33.511	33.559	33.564	33.566	33.526	33.560	33.562	33.556
4.5	33.561	33.558	33.552	33.514	33.554	33.558	33.556	33.552	33.502	33.560	33.565	33.565	33.533	33.561	33.562	33.556
5.0	33.561	33.560	33.553	33.514	33.555	33.558	33.555	33.557	33.496	33.561	33.564	33.566	33.530	33.562	33.563	33.557
5.5	33.561	33.560	33.553	33.528	33.562	33.559	33.555	33.556	**33.491**	33.561	33.565	33.566	33.532	33.563	33.563	33.553
6.0	33.567	33.563	33.556	33.542	33.561	33.560	33.556	33.557	33.513	33.561	33.564	33.566	33.550	33.564	33.566	33.554
6.5	33.571	33.566	33.558	33.554	33.560	33.560	33.555	33.557	33.519	33.562	33.564	33.566	33.556	33.565	33.565	33.555
7.0	33.572	33.567	33.559	33.554	33.560	33.561	33.555	33.558	33.518	33.562	33.564	33.569	33.553	33.566	33.574	33.554
7.5	33.579	33.568	33.560	33.545	33.560	33.560	33.555	33.558	33.518	33.563	33.565	33.568	33.547	33.570	33.582	33.555
8.0	33.574	33.578	33.560	33.542	33.561	33.563	33.555	33.558	33.523	33.563	33.566	33.568	33.549	33.577	33.592	33.557
8.5	33.588	33.588	33.568	33.547	33.570	33.574	33.555	33.558	33.522	33.563	33.566	33.569	33.555	33.583	33.599	33.557
9.0	33.591	33.592	33.559	33.550	33.568	33.578	33.555	33.558	33.530	33.564	33.567	33.569	33.559	33.586	33.601	33.557
9.5	33.591	33.592	33.575	33.561	33.567	33.574	33.555	33.558	33.544	33.564	33.567	33.569	33.560	33.590	33.600	33.577
10.0	33.592	33.591	33.577	33.560	33.575	33.581	33.554	33.558	33.559	33.565	33.567	33.572	33.564	33.590	33.604	33.593
10.5	33.594	33.595	33.599	33.573	33.579	33.590	33.555	33.558	33.560	33.565	33.567	33.568	33.567	33.595	33.603	33.594
11.0	33.600	33.597	33.592	33.584	33.583	33.593	33.554	33.559	33.579	33.564	33.585	33.562	33.577	33.593	33.608	33.608
11.5	33.611	33.612	33.594	33.589	33.591	33.591	33.555	33.559	33.614	33.568	33.600	33.598	33.580	33.593	33.615	33.614
12.0	33.609	33.613	33.596	33.588	33.592	33.592	33.555	33.558	33.603	33.576	33.606	33.600	33.578	33.594	33.620	33.613
12.5	33.614	33.612	33.588	33.595	33.601	33.598	33.555	33.582	33.602	33.589	33.612	33.595	33.583	33.604	33.620	33.611
13.0	33.614	33.611	33.609	33.598	33.617	33.596	33.555	33.590	33.602	33.600	33.618	33.597	33.599	33.611	33.620	33.612
13.5	33.615	33.615	33.614	33.607	33.614	33.613	33.555	33.584	33.600	33.603	33.619	33.608	33.597	33.612	33.619	33.613
14.0	33.618	33.623	33.614	33.612	33.619	33.614	33.556	33.591	33.601	33.608	33.620	33.621	33.604	33.611	33.631	33.614
14.5	33.622	33.622	33.617	33.612	33.617	33.616	33.553	33.600	33.604	33.615	33.622	33.623	33.602	33.616	33.634	33.614
15.0	33.627	33.623	33.621	33.610	33.620	33.617	33.604	33.601	33.614	33.618	33.621	33.621	33.603	33.616	33.631	33.615
15.5	33.632	33.631	33.624	33.613	33.625	33.619	33.585	33.606	33.621	33.623	33.622		33.603	33.619	33.632	33.616
16.0	33.633	33.632	33.630	33.615	33.624	33.621	33.596	33.608	33.620	33.625			33.609	33.629		33.617
16.5	33.634		33.629	33.620	33.625	33.626	33.605	33.606	33.617				33.612	33.630		
17.0							33.603	33.624	33.618				33.618	33.630		

[1] Values enclosed in boxes were significantly lower than the mean of other salinity measurements at the same depth.

Table B-3. Seawater Density[1] on 5 April 2005

	Density (sigma-t)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5		25.738		25.728	25.740	25.740				25.737						25.742
1.0	25.740	25.739	25.739	25.732	25.741	25.740	25.735	25.717	25.697	25.738	25.743	25.745	25.693	25.743	25.745	25.743
1.5	25.740	25.740	25.738	25.736	25.741	25.741	25.735	25.718	25.687	25.739	25.744	25.747	25.692	25.742	25.745	25.745
2.0	25.740	25.740	25.740	25.735	25.742	25.741	25.734	25.725	25.696	25.739	25.745	25.748	25.692	25.742	25.745	25.744
2.5	25.740	25.740	25.740	25.733	25.743	25.742	25.735	25.726	25.700	25.743	25.745	25.748	25.692	25.741	25.744	25.744
3.0	25.740	25.739	25.739	25.725	25.745	25.742	25.735	25.729	25.718	25.742	25.747	25.748	25.697	25.741	25.744	25.743
3.5	25.741	25.740	25.737	25.722	25.745	25.741	25.735	25.728	25.718	25.741	25.746	25.748	25.709	25.742	25.743	25.742
4.0	25.743	25.740	25.737	25.727	25.744	25.740	25.735	25.728	25.720	25.742	25.746	25.749	25.723	25.742	25.744	25.741
4.5	25.743	25.740	25.737	25.728	25.744	25.743	25.737	25.736	25.712	25.743	25.748	25.749	25.728	25.743	25.744	25.741
5.0	25.743	25.742	25.738	25.728	25.746	25.744	25.736	25.740	25.707	25.744	25.748	25.750	25.726	25.744	25.745	25.743
5.5	25.743	25.742	25.738	25.738	25.750	25.744	25.736	25.739	25.699	25.744	25.747	25.751	25.727	25.745	25.745	25.739
6.0	25.750	25.745	25.740	25.746	25.748	25.745	25.737	25.740	25.719	25.745	25.747	25.750	25.736	25.746	25.749	25.740
6.5	25.755	25.748	25.742	25.753	25.747	25.744	25.737	25.740	25.723	25.746	25.747	25.750	25.739	25.746	25.748	25.742
7.0	25.757	25.750	25.742	25.754	25.747	25.746	25.736	25.740	25.722	25.746	25.748	25.754	25.739	25.747	25.758	25.741
7.5	25.765	25.751	25.742	25.751	25.748	25.745	25.737	25.740	25.721	25.747	25.750	25.753	25.734	25.753	25.768	25.742
8.0	25.760	25.764	25.742	25.749	25.749	25.748	25.737	25.740	25.726	25.747	25.750	25.754	25.735	25.761	25.781	25.743
8.5	25.780	25.779	25.754	25.752	25.759	25.760	25.737	25.740	25.726	25.747	25.751	25.754	25.738	25.769	25.793	25.742
9.0	25.787	25.787	25.746	25.754	25.759	25.765	25.736	25.740	25.729	25.748	25.752	25.755	25.741	25.776	25.797	25.741
9.5	25.788	25.789	25.765	25.762	25.760	25.761	25.736	25.739	25.733	25.748	25.752	25.755	25.742	25.781	25.798	25.764
10.0	25.790	25.789	25.768	25.758	25.770	25.772	25.736	25.740	25.742	25.749	25.752	25.757	25.747	25.782	25.804	25.788
10.5	25.793	25.794	25.795	25.768	25.773	25.783	25.737	25.740	25.743	25.750	25.752	25.756	25.751	25.790	25.805	25.793
11.0	25.802	25.799	25.790	25.779	25.777	25.788	25.736	25.740	25.766	25.749	25.775	25.755	25.765	25.791	25.812	25.812
11.5	25.816	25.817	25.794	25.786	25.788	25.787	25.736	25.741	25.811	25.754	25.80	25.797	25.770	25.792	25.822	25.820
12.0	25.816	25.820	25.799	25.788	25.790	25.789	25.736	25.740	25.806	25.768	25.807	25.801	25.768	25.794	25.829	25.819
12.5	25.824	25.819	25.792	25.796	25.803	25.801	25.736	25.769	25.807	25.786	25.817	25.799	25.776	25.808	25.830	25.818
13.0	25.823	25.818	25.816	25.801	25.825	25.800	25.736	25.782	25.807	25.801	25.825	25.801	25.800	25.817	25.830	25.819
13.5	25.825	25.825	25.823	25.813	25.822	25.821	25.737	25.779	25.804	25.807	25.827	25.815	25.800	25.819	25.829	25.820
14.0	25.830	25.836	25.824	25.820	25.829	25.825	25.740	25.788	25.806	25.813	25.828	25.829	25.808	25.819	25.844	25.821
14.5	25.837	25.835	25.828	25.820	25.828	25.826	**25.742**	25.801	25.810	25.822	25.829	25.830	25.806	25.828	25.847	25.821
15.0	25.843	25.837	25.833	25.819	25.831	25.828	25.803	25.807	25.822	25.827	25.828	25.828	25.808	25.829	25.845	25.823
15.5	25.848	25.845	25.836	25.822	25.836	25.831	25.787	25.813	25.830	25.832	25.829		25.808	25.833	25.845	25.822
16.0	25.849	25.845	25.843	25.824	25.835	25.831	25.800	25.817	25.831	25.835			25.815	25.844		25.823
16.5	25.850		25.842	25.829	25.836	25.837	25.813	25.817	25.829				25.819	25.845		
17.0							25.815	25.837	25.829				25.825	25.845		

[1] Values enclosed in boxes were significantly lower than the mean of other density measurements at the same distance above the seafloor.

Table B-4. Dissolved Oxygen[1] on 5 April 2005

	Dissolved Oxygen (mg/L)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5		6.28		5.51	6.04	6.09				6.20						6.21
1.0	6.47	6.26	6.26	5.51	6.07	6.10	6.20	6.09	5.54	6.21	6.35	6.20	5.74	6.18	6.16	6.20
1.5	6.47	6.26	6.25	5.50	6.08	6.08	6.29	6.15	5.58	6.21	6.21	6.22	5.73	6.18	6.17	6.17
2.0	6.48	6.23	6.18	5.48	6.09	6.05	6.31	6.18	5.66	6.22	6.21	6.21	5.71	6.18	6.15	6.19
2.5	6.48	6.22	6.17	5.49	6.16	6.03	6.30	6.18	5.69	6.19	6.20	6.18	5.71	6.22	6.15	6.18
3.0	6.46	6.23	6.24	5.51	6.01	6.02	6.32	6.22	5.67	6.21	6.18	6.19	5.73	6.23	6.14	6.17
3.5	6.35	6.23	6.16	5.53	5.88	6.00	6.32	6.19	5.71	6.20	6.19	6.18	5.81	6.20	6.14	6.16
4.0	6.26	6.21	6.14	5.53	6.01	5.96	6.30	6.20	5.73	6.20	6.19	6.16	5.95	6.16	6.14	6.14
4.5	6.27	6.20	6.12	5.52	5.99	5.92	6.29	6.26	5.65	6.21	6.16	6.15	5.98	6.15	6.13	6.12
5.0	6.27	6.14	6.11	5.51	5.95	5.89	6.29	6.31	5.68	6.21	6.14	6.12	5.96	6.15	6.11	6.12
5.5	6.23	6.13	6.10	5.54	6.00	5.92	6.29	6.23	5.76	6.21	6.19	6.12	6.00	6.10	6.08	6.11
6.0	6.13	6.05	6.11	5.61	6.03	5.91	6.27	6.20	5.75	6.20	6.17	6.17	6.18	6.09	6.06	6.10
6.5	6.08	6.02	6.10	5.63	6.02	5.95	6.24	6.22	5.75	6.18	6.21	6.15	6.21	6.05	6.03	6.08
7.0	6.06	6.01	6.11	5.61	6.00	5.95	6.22	6.20	5.78	6.20	6.17	6.12	6.18	6.00	5.91	6.09
7.5	5.98	5.99	6.11	5.51	5.98	5.91	6.23	6.18	5.81	6.31	6.10	6.10	6.15	5.87	5.78	6.09
8.0	5.94	5.82	6.07	5.50	5.96	5.89	6.23	6.18	5.86	6.24	6.11	6.07	6.18	5.77	5.67	6.11
8.5	5.76	5.66	5.93	5.52	5.87	5.76	6.23	6.16	5.85	5.96	6.07	6.04	6.22	5.68	5.57	6.13
9.0	5.69	5.57	5.85	5.52	5.82	5.74	6.26	6.17	5.88	6.09	6.04	6.02	6.22	5.62	5.53	6.14
9.5	5.68	5.55	5.75	5.56	5.73	5.76	6.24	6.16	6.02	6.09	6.02	6.03	6.22	5.59	5.51	5.92
10.0	5.65	5.53	5.66	5.60	5.59	5.60	6.24	6.15	6.07	6.10	6.02	5.99	6.17	5.58	5.48	5.65
10.5	5.63	5.51	5.55	5.60	5.58	5.58	6.25	6.16	6.07	6.09	6.10	5.87	6.07	5.52	5.47	5.50
11.0	5.53	5.45	5.51	5.57	5.60	5.55	6.24	6.13	5.89	6.06	5.76	5.71	5.92	5.49	5.38	5.31
11.5	5.44	5.35	5.50	5.52	5.54	5.54	6.24	6.12	5.54	5.94	5.54	5.52	5.86	5.48	5.24	5.27
12.0	5.38	5.30	5.47	5.52	5.46	5.51	6.23	6.11	5.64	5.75	5.37	5.46	5.86	5.43	5.16	5.26
12.5	5.30	5.28	5.40	5.51	5.40	5.41	6.23	5.82	5.53	5.62	5.26	5.42	5.74	5.34	5.15	5.24
13.0	5.29	5.24	5.27	5.43	5.27	5.38	6.22	5.69	5.47	5.49	5.26	5.39	5.51	5.26	5.14	5.23
13.5	5.28	5.15	5.21	5.33	5.22	5.26	**6.20**	5.63	5.35	5.33	5.29	5.27	5.50	5.24	5.11	5.23
14.0	5.23	5.10	5.17	5.28	5.18	5.18	6.05	5.56	5.33	5.29	5.26	5.18	5.47	5.19	5.05	5.21
14.5	5.15	5.08	5.13	5.28	5.16	5.18	5.93	5.45	5.28	5.23	5.18	5.15	5.46	5.15	5.03	5.22
15.0	5.11	5.05	5.11	5.28	5.10	5.15	5.58	5.32	5.23	5.13	5.16	5.17	5.46	5.14	5.01	5.19
15.5	5.09	5.00	5.07	5.23	5.07	5.13	5.45	5.26	5.15	5.09	5.16		5.45	5.09	4.96	5.19
16.0	4.96	4.97	5.00	5.22	5.06	5.11	5.33	5.21	5.10	5.10			5.37	5.01		5.17
16.5	4.94		5.04	5.20	5.03	5.10	5.26	5.38	5.09				5.32	4.99		
17.0							5.20	5.26	5.08				5.28	4.94		

[1] Values enclosed in boxes were significantly higher than the mean of other dissolved oxygen measurements at the same distance above the seafloor.

Table B-5. Light Transmittance[1] across a 0.25-m path on 5 April 2005

	Light Transmittance (%)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5		68.17		72.03	69.24	69.88				68.77						64.54
1.0	68.26	68.70	68.34	74.28	69.53	70.69	69.58	70.37	71.65	69.00	70.33	69.77	71.69	69.14	65.36	67.56
1.5	68.36	68.39	68.69	74.37	70.29	71.08	68.72	70.51	71.30	68.36	69.53	70.49	71.94	69.06	68.32	69.45
2.0	68.36	68.64	68.88	74.05	69.92	71.68	69.00	70.38	70.93	69.62	69.98	70.55	71.97	68.97	68.67	69.99
2.5	68.28	68.87	68.46	73.61	70.07	71.92	69.63	70.54	71.53	69.78	70.39	70.65	72.04	68.68	68.77	70.28
3.0	68.28	69.02	68.66	72.95	71.77	72.09	69.92	70.07	72.21	70.14	70.77	70.53	72.05	68.79	69.26	70.52
3.5	69.36	68.98	69.81	72.28	72.09	72.32	69.82	70.02	72.27	70.32	70.62	70.83	71.95	69.15	69.10	70.27
4.0	70.10	68.99	70.25	72.32	71.17	73.17	69.62	70.33	72.35	70.56	70.82	71.02	71.36	69.56	69.19	70.40
4.5	69.50	68.85	70.42	72.56	71.79	73.92	70.00	69.86	72.52	70.55	70.91	71.12	71.42	69.71	69.61	70.69
5.0	69.65	69.44	70.49	72.85	71.58	73.95	69.74	69.71	72.46	70.56	71.35	71.44	71.54	70.01	69.87	70.87
5.5	69.82	69.48	70.58	72.47	70.67	73.76	69.99	69.64	71.21	70.55	70.87	71.65	71.47	70.29	69.94	70.95
6.0	71.00	70.74	70.13	73.65	70.64	74.03	69.87	69.84	72.30	70.76	70.81	71.56	70.74	70.55	70.56	70.77
6.5	71.84	71.04	70.27	74.15	71.24	73.62	69.88	69.84	72.03	71.32	71.06	71.87	70.50	71.47	70.65	70.96
7.0	72.76	71.29	70.49	74.41	71.09	73.91	69.75	69.89	72.14	71.50	71.38	72.31	71.00	71.57	72.71	70.78
7.5	74.65	71.87	70.13	74.07	70.92	74.29	69.57	70.52	72.10	71.07	71.94	72.35	71.01	73.22	74.78	70.55
8.0	73.15	72.94	71.55	74.23	71.80	74.97	69.37	70.88	71.87	71.33	72.09	72.51	70.86	74.44	76.71	70.75
8.5	77.51	76.89	73.32	74.48	72.99	77.82	69.67	70.74	72.60	71.96	71.16	73.15	70.71	76.84	78.79	70.66
9.0	79.66	79.52	75.41	74.36	73.96	78.19	69.81	70.80	71.68	71.22	72.32	72.94	71.06	77.71	79.55	70.42
9.5	79.76	79.67	76.19	74.87	75.50	77.00	70.01	70.97	71.45	71.03	72.45	73.35	71.36	78.08	79.60	73.78
10.0	79.84	79.78	76.19	75.20	78.41	78.04	69.69	70.58	72.04	71.78	72.39	74.79	71.70	78.58	79.79	77.83
10.5	79.83	80.23	77.89	76.48	77.75	79.15	70.25	70.76	71.83	71.77	72.71	74.63	72.22	79.23	79.95	78.64
11.0	79.64	80.44	79.45	78.75	77.23	79.58	69.92	71.13	74.58	72.00	76.10	78.94	75.15	80.58	79.71	78.22
11.5	78.88	79.41	80.00	79.20	79.24	79.86	69.32	71.20	76.24	72.52	78.61	79.32	75.95	80.70	78.46	77.55
12.0	78.53	78.54	80.21	79.07	80.06	79.94	69.51	71.33	76.69	75.79	78.98	78.50	75.70	80.74	77.47	77.19
12.5	77.97	78.58	79.85	79.25	80.43	80.97	69.61	75.68	76.38	79.05	77.17	77.64	77.09	80.16	76.87	77.25
13.0	78.08	78.71	78.59	79.24	77.95	81.17	70.18	77.69	78.08	79.67	76.14	76.74	76.49	79.05	77.25	77.28
13.5	77.70	77.85	78.08	76.85	77.80	78.12	70.36	78.27	79.58	78.75	75.58	75.78	76.55	78.68	77.27	76.72
14.0	77.66	77.21	77.78	72.61	75.86	76.25	71.45	78.54	79.44	77.85	74.92	71.94	76.21	78.26	75.11	76.20
14.5	76.87	77.30	77.30	74.92	75.11	76.74	76.19	78.80	78.87	77.18	71.50	**51.98**	76.49	78.03	71.40	75.99
15.0	76.32	76.79	76.14	76.04	73.83	75.67	79.32	78.80	77.58	75.81	59.65	52.15	76.60	77.94	69.50	73.69
15.5	75.99	64.76	75.69	72.90	70.38	71.85	79.51	78.41	72.92	68.60	62.04		76.62	77.49	67.46	61.89
16.0	62.81	**47.81**	58.71	63.24	63.26	66.87	79.37	75.42	69.79	59.32			72.35	75.23		56.83
16.5	**50.19**		59.33	57.83	58.20	57.70	**78.48**	71.83	67.93				68.19	71.00		
17.0							**73.77**	66.45	66.05				59.61	60.60		

[1] Values enclosed in boxes were significantly different from the mean of other transmissivity measurements at the same distance above the seafloor.

Table B-6. Detrended[1] pH[2] on 5 April 2005

	Alkalinity (pH)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5		7.308		7.289	7.307	7.307				7.306						7.309
1.0	7.303	7.311	7.307	7.289	7.307	7.307	7.303	7.297	**7.274**	7.306	7.306	7.310	7.292	7.312	7.310	7.311
1.5	7.307	7.311	7.307	7.289	7.307	7.310	7.301	7.297	**7.275**	7.306	7.307	7.310	7.292	7.312	7.306	7.310
2.0	7.307	7.311	7.307	7.289	7.307	7.309	7.303	7.297	**7.274**	7.306	7.306	7.310	7.290	7.312	7.306	7.310
2.5	7.307	7.311	7.307	7.289	7.314	7.307	7.303	7.298	**7.278**	7.306	7.307	7.309	7.288	7.312	7.310	7.310
3.0	7.307	7.311	7.307	7.289	7.313	7.307	7.305	7.300	**7.279**	7.306	7.308	7.310	7.288	7.312	7.311	7.310
3.5	7.307	7.311	7.307	7.289	7.311	7.307	7.305	7.301	**7.279**	7.306	7.310	7.310	7.288	7.312	7.311	7.310
4.0	7.307	7.311	7.307	7.289	7.308	7.307	7.304	7.301	**7.279**	7.306	7.310	7.310	7.288	7.312	7.311	7.310
4.5	7.307	7.311	7.307	7.289	7.311	7.307	7.307	7.301	**7.279**	7.306	7.310	7.308	7.289	7.312	7.311	7.310
5.0	7.307	7.311	7.307	7.289	7.311	7.307	7.306	7.301	**7.279**	7.306	7.309	7.310	7.293	7.312	7.311	7.310
5.5	7.307	7.311	7.307	7.289	7.308	7.307	7.306	7.304	**7.279**	7.306	7.309	7.307	7.297	7.312	7.311	7.310
6.0	7.307	7.311	7.307	7.289	7.307	7.307	7.306	7.306	**7.279**	7.306	7.310	7.306	7.300	7.312	7.311	7.310
6.5	7.307	7.311	7.307	7.289	7.309	7.307	7.306	7.306	**7.279**	7.306	7.310	7.307	7.301	7.312	7.311	7.310
7.0	7.307	7.311	7.307	7.292	7.308	7.309	7.306	7.306	**7.279**	7.306	7.310	7.306	7.301	7.311	7.311	7.310
7.5	7.307	7.311	7.307	7.295	7.311	7.309	7.306	7.306	**7.283**	7.306	7.310	7.306	7.304	7.309	7.311	7.310
8.0	7.307	7.309	7.307	7.294	7.311	7.310	7.306	7.306	**7.283**	7.306	7.310	7.306	7.306	7.309	7.311	7.310
8.5	7.308	7.309	7.307	7.294	7.309	7.307	7.306	7.306	**7.283**	7.306	7.310	7.306	7.306	7.307	7.311	7.310
9.0	7.303	7.307	7.307	7.294	7.311	7.307	7.306	7.306	**7.283**	7.306	7.310	7.306	7.306	7.306	7.308	7.310
9.5	7.303	7.302	7.307	7.294	7.31	7.307	7.306	7.306	7.285	7.306	7.306	7.306	7.307	7.304	7.306	7.310
10.0	7.299	7.302	7.305	7.294	7.307	7.307	7.306	7.306	7.288	7.306	7.307	7.306	7.310	7.303	7.306	7.309
10.5	7.298	7.301	7.302	7.294	7.307	7.307	7.306	7.306	7.290	7.306	7.306	7.306	7.310	7.298	7.306	7.305
11.0	7.298	7.298	7.302	7.295	7.307	7.304	7.306	7.306	7.294	7.306	7.306	7.305	7.310	7.298	7.305	7.301
11.5	7.299	7.298	7.298	7.298	7.307	7.302	7.306	7.306	7.297	7.306	7.306	7.301	7.307	7.297	7.303	7.298
12.0	7.296	7.298	7.298	7.298	7.302	7.302	7.306	7.306	7.297	7.306	7.305	7.301	7.306	7.294	7.302	7.297
12.5	7.294	7.298	7.298	7.298	7.302	7.302	7.306	7.306	7.285	7.300	7.301	7.299	7.306	7.294	7.300	7.292
13.0	7.289	7.293	7.295	7.298	7.302	7.298	7.306	7.306	**7.279**	7.300	7.301	7.297	7.302	7.294	7.297	7.289
13.5	7.284	7.291	7.293	7.298	7.296	7.297	7.306	7.302	7.279	7.297	7.299	7.292	7.300	7.294	7.295	7.288
14.0	7.280	7.289	7.292	7.298	7.293	7.293	7.306	7.297	7.279	7.294	7.297	7.288	7.297	7.291	7.293	7.283
14.5	7.279	7.286	7.289	7.296	7.290	7.290	7.305	7.297	7.279	7.288	7.292	7.285	7.293	7.289	7.290	7.282
15.0	7.277	7.284	7.286	7.294	7.289	7.289	7.301	7.289	7.279	7.288	7.292	7.277	7.288	7.286	7.288	7.279
15.5	7.276	7.282	7.282	7.294	7.289	7.290	7.298	7.284	7.279	7.284	7.288		7.288	7.283	7.279	7.279
16.0	7.276	7.279	7.280	7.290	7.289	7.293	7.289	7.283	7.279	7.282			7.285	7.280		7.279
16.5	7.271		7.273	7.288	7.282	7.293	7.288	7.277	7.279				7.283	7.279		
17.0							7.282	7.273	7.276				7.280	7.273		

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

[2] Values enclosed in boxes were significantly lower than the mean of other pH measurements at the same depth.

Table B-7. Uncorrected pH[1] on 5 April 2005

	Alkalinity (pH)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5		7.275		7.242	7.256	7.242				7.306						7.309
1.0	7.274	7.278	7.274	7.242	7.256	7.242	7.303	7.297	7.274	7.306	7.306	7.310	7.292	7.297	7.287	7.311
1.5	7.278	7.278	7.274	7.242	7.256	7.245	7.301	7.297	7.275	7.306	7.307	7.310	7.292	7.297	7.283	7.310
2.0	7.278	7.278	7.274	7.242	7.256	7.244	7.303	7.297	7.274	7.306	7.306	7.310	7.290	7.297	7.283	7.310
2.5	7.278	7.278	7.274	**7.242**	7.263	**7.242**	7.303	7.298	7.278	7.306	7.307	7.309	7.288	7.297	7.287	7.310
3.0	7.278	7.278	7.274	**7.242**	7.262	**7.242**	7.305	7.300	7.279	7.306	7.308	7.310	7.288	7.297	7.288	7.310
3.5	7.278	7.278	7.274	**7.242**	7.260	**7.242**	7.305	7.301	7.279	7.306	7.310	7.310	7.288	7.297	7.288	7.310
4.0	7.278	7.278	7.274	**7.242**	7.257	**7.242**	7.304	7.301	7.279	7.306	7.310	7.310	7.288	7.297	7.288	7.310
4.5	7.278	7.278	7.274	**7.242**	7.260	**7.242**	7.307	7.301	7.279	7.306	7.310	7.308	7.289	7.297	7.288	7.310
5.0	7.278	7.278	7.274	**7.242**	7.260	**7.242**	7.306	7.301	7.279	7.306	7.309	7.310	7.293	7.297	7.288	7.310
5.5	7.278	7.278	7.274	**7.242**	7.257	**7.242**	7.306	7.304	7.279	7.306	7.309	7.307	7.297	7.297	7.288	7.310
6.0	7.278	7.278	7.274	**7.242**	7.256	**7.242**	7.306	7.306	7.279	7.306	7.310	7.306	7.300	7.297	7.288	7.310
6.5	7.278	7.278	7.274	**7.242**	7.258	**7.242**	7.306	7.306	7.279	7.306	7.310	7.307	7.301	7.297	7.288	7.310
7.0	7.278	7.278	7.274	7.245	7.257	**7.244**	7.306	7.306	7.279	7.306	7.310	7.306	7.301	7.296	7.288	7.310
7.5	7.278	7.278	7.274	7.248	7.260	**7.244**	7.306	7.306	7.283	7.306	7.310	7.306	7.304	7.294	7.288	7.310
8.0	7.278	7.276	7.274	7.247	7.260	**7.245**	7.306	7.306	7.283	7.306	7.310	7.306	7.306	7.294	7.288	7.310
8.5	7.279	7.276	7.274	7.247	7.258	**7.242**	7.306	7.306	7.283	7.306	7.310	7.306	7.306	7.292	7.288	7.310
9.0	7.274	7.274	7.274	7.247	7.260	**7.242**	7.306	7.306	7.283	7.306	7.310	7.306	7.306	7.291	7.285	7.310
9.5	7.274	7.269	7.274	7.247	7.26	**7.242**	7.306	7.306	7.285	7.306	7.306	7.306	7.307	7.289	7.283	7.310
10.0	7.270	7.269	7.272	7.247	7.256	**7.242**	7.306	7.306	7.288	7.306	7.307	7.306	7.310	7.288	7.283	7.309
10.5	7.269	7.268	7.269	7.247	7.256	**7.242**	7.306	7.306	7.290	7.306	7.306	7.306	7.310	7.283	7.283	7.305
11.0	7.269	7.265	7.269	7.248	7.256	**7.239**	7.306	7.306	7.294	7.306	7.306	7.305	7.310	7.283	7.282	7.301
11.5	7.270	7.265	7.265	7.251	7.256	**7.237**	7.306	7.306	7.297	7.306	7.306	7.301	7.307	7.282	7.280	7.298
12.0	7.267	7.265	7.265	7.251	7.251	**7.237**	7.306	7.306	7.297	7.306	7.305	7.301	7.306	7.279	7.279	7.297
12.5	7.265	7.265	7.265	7.251	7.251	**7.237**	7.306	7.306	7.285	7.300	7.301	7.299	7.306	7.279	7.277	7.292
13.0	7.260	7.260	7.262	7.251	7.251	**7.233**	7.306	7.306	7.279	7.300	7.301	7.297	7.302	7.279	7.274	7.289
13.5	7.255	7.258	7.260	7.251	7.245	**7.232**	7.306	7.302	7.279	7.297	7.299	7.292	7.300	7.279	7.272	7.288
14.0	7.251	7.256	7.259	7.251	7.242	**7.228**	7.306	7.297	7.279	7.294	7.297	7.288	7.297	7.276	7.270	7.283
14.5	7.250	7.253	7.256	7.249	7.239	**7.225**	7.305	7.297	7.279	7.288	7.292	7.285	7.293	7.274	7.267	7.282
15.0	7.248	7.251	7.253	7.247	7.238	**7.224**	7.301	7.289	7.279	7.288	7.292	7.277	7.288	7.271	7.265	7.279
15.5	7.247	7.249	7.249	7.247	7.238	7.225	7.298	7.284	7.279	7.284	7.288		7.288	7.268	7.256	7.279
16.0	7.247	7.246	7.247	7.243	7.238	7.228	7.289	7.283	7.279	7.282			7.285	7.265		7.279
16.5	7.242		7.240	7.241	7.231	7.228	7.288	7.277	7.279				7.283	7.264		
17.0							7.282	7.273	7.276				7.280	7.258		

[1] Values enclosed in boxes were significantly lower than the mean of other measurements at the same depth.

Table B-8. Ancillary Observations on 5 April 2005 during the Receiving-Water Survey

Station	Location		Diffuser Distance	Time	Air Temperature	Cloud Cover	Wind Avg	Wind Max	Wind Dir (from)	Swell Ht/Dir	Secchi Depth
	Latitude	Longitude	(m)	(PST)	(°C)	(%)	(kt)	(kt)	(°T)	(ft/°T)	(m)
1	35°23.2583' N	120°52.5116' W	110.3	07:55:44	14.0	0	13.0	15.1	73	4 W	3.5
2	35°23.2291' N	120°52.5091' W	56.1	07:53:10	13.8	0	17.4	19.3	73	4 W	3.5
3	35°23.2058' N	120°52.5090' W	14.6	07:50:06	14.1	0	15.5	17.1	73	4 W	3.5
4	35°23.1841' N	120°52.5056' W	27.5	07:46:50	14.8	0	13.3	18.9	73	4 W	3.8
5	35°23.1521' N	120°52.4979' W	87.3	07:41:19	15.0	0	12.4	17.6	73	4 W	4.0
6	35°23.1409' N	120°52.5061' W	107.5	07:35:39	14.8	0	11.5	15.0	53	4 W	4.0
7	35°23.2043' N	120°52.5738' W	105.8	08:47:44	14.8	0	10.8	11.7	43	4 W	4.0
8	35°23.2005' N	120°52.5448' W	61.5	08:51:49	14.8	0	12.7	13.8	43	4 W	4.0
9	35°23.1903' N	120°52.5206' W	29.5	08:57:14	15.0	0	11.8	14.1	73	4 W	4.0
10	35°23.2033' N	120°52.4893' W	24.1	09:00:27	14.6	0	13.2	15.1	73	4 W	4.2
11	35°23.1997' N	120°52.4656' W	58.6	09:05:22	15.1	0	15.7	17.9	73	4 W	4.0
12	35°23.2003' N	120°52.4411' W	95.6	09:10:07	15.2	0	12.8	15.9	73	4 W	4.0
13	35°23.1748' N	120°52.5296' W	59.0	09:19:21	14.5	0	7.2	8.4	73	4 W	4.5
14	35°23.2192' N	120°52.5331' W	57.6	08:07:43	14.3	0	11.6	13.2	73	4 W	3.5
15	35°23.2192' N	120°52.4690' W	65.1	08:00:22	13.7	0	8.8	13.6	63	4 W	3.5
16	35°23.1675' N	120°52.4803' W	68.6	09:14:41	15.2	0	9.0	11.4	73	4 W	4.0

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

Tidal Conditions (Pacific Standard Time)
Low Tide: 02:26 1.36 ft
High Tide: 08:21 5.10 ft
Low Tide: 15:02 -0.74 ft
High Tide: 21:27 4.60 ft