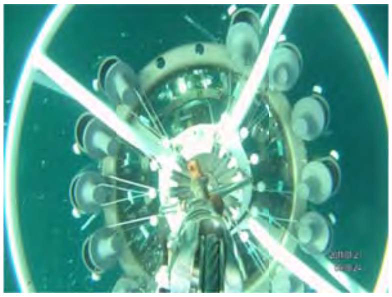
Chapter 3

COASTAL OCEANOGRAPHY AND WATER QUALITY



Chapter 3
COASTAL OCEANOGRAPHY AND WATER QUALITY

INTRODUCTION

The Orange County Sanitation District (District) measures physical, chemical, and biological water quality indicators to determine the location and characteristics of its treated effluent after discharge to the ocean. The goals are to assess discharge-related changes to water quality and compare them to criteria contained in the California Ocean Plan (COP) and the District's NPDES discharge permit to determine compliance (see box) to evaluate potential impacts to the marine environment and public health. This chapter describes results from the July 2009 to June 2010 monitoring year. Chapter 2 (Compliance) has additional compliance evaluation details.

The District's monitoring region is located on the southern portion of the San Pedro Shelf and extends from the shoreline to approximately 12 km offshore and to a water depth of 310 m. The entire sampling area covers approximately 102 km^2 (Figure 3-1). While not part of the Core monitoring program, the District is a member of a regional cooperative sampling effort with the City of Oxnard, City of Los Angeles, and the Los Angeles County Sanitation District, known as the Central Bight Regional Water Quality Monitoring Program (Central Bight). When combined with the Core program, this additional sampling effectively extends the District's monitoring area north to Ventura County and south to Crystal Cove State Beach (Figure 3-2). The Central Bight monitoring provides regional data that improves the evaluation of water quality changes due to natural or other anthropogenic discharges (e.g., stormwater) and provides a regional context for comparisons with the District's monitoring results.

Regional and local changes in ocean conditions strongly influence the District's study area on daily, seasonal, and yearly timescales. Large-scale and long-term climatic events, such as the Pacific Decadal Oscillation (PDO) and El Niño/Southern Oscillation (ENSO) also alter local conditions on decadal and multi-year timescales (OCSD 2004). These events are notable for producing changes in near coastal water surface temperature and rainfall/runoff in the study region (OCSD 2004). One of the primary differences between PDO and ENSO is that PDO events have cycles of 5–20 years, but may persist for up to 70 years, while a typical ENSO event occurs, on average, every 5 years and may last 6–18 months (Chao et al. 2000, Mantua 2000). Upwelling can also strongly influence water quality and productivity in coastal areas by providing a source of additional nutrients to the coastal environment (Fischer et al. 1979, Sverdrup et al. 1963, Valiela 1995). These natural events modify effects seen from human-related sources, such as wastewater discharges, dredged material disposal, atmospheric deposition, and runoff from the adjacent watershed.

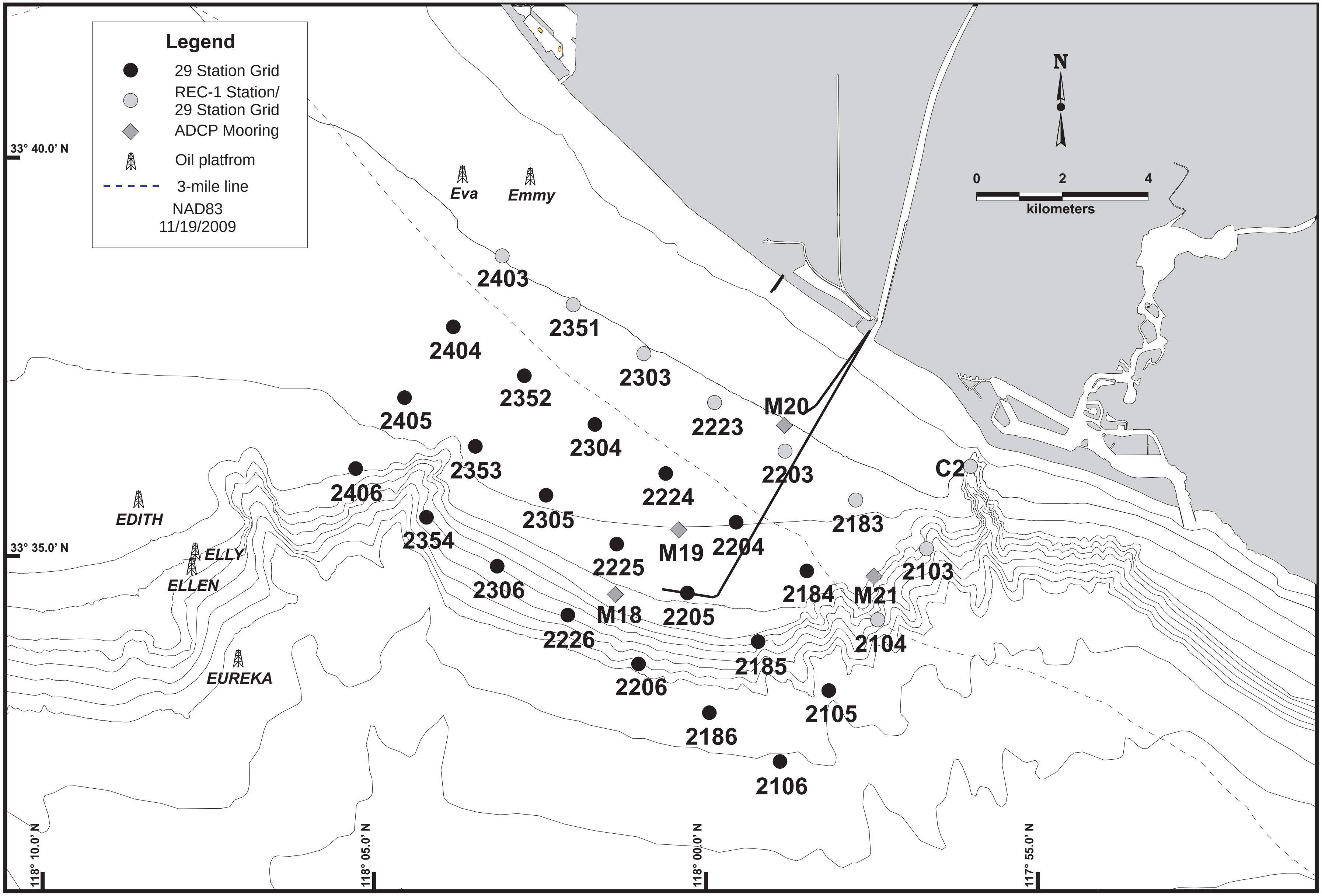


Figure 3-1. **Water quality monitoring and current meter stations for 2009-10.**

Orange County Sanitation District, California.

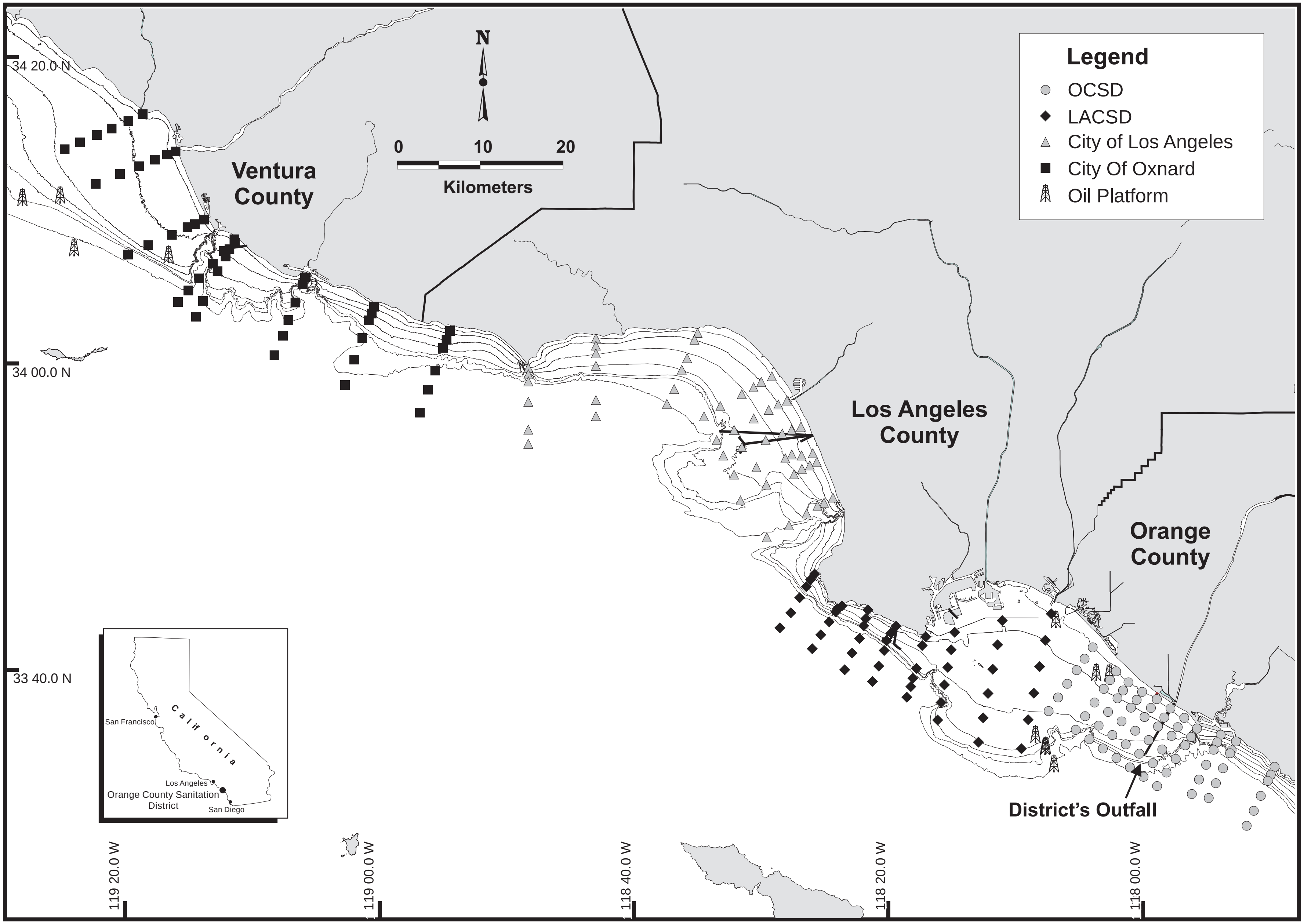


Figure 3-2. **Sampling locations for regional water quality monitoring program.**
Legend denotes agencies responsible for sampling various stations.

Orange County Sanitation District, California.

Compliance Criteria Pertaining to Water Quality Contained in the District's NPDES Ocean Discharge Permit (Order No. R8-2004-0062, Permit No. CAO110604).

Criteria		Description
C.2.a.1	Total coliform (water contact)	Samples of water from each sampling station shall have a density of total coliform organisms less than 1,000 per 100 ml (10 per ml); provided that not more than 20 percent of the samples at any sampling station, in any 30-day period, may exceed 1,000 per 100 ml (10 per ml), and provided further that no single sample when verified by a repeat sample taken within 48 hours shall exceed 10,000 per 100 ml (100 per ml).
C.2.a.2	Fecal coliform (water contact)	The fecal coliform density based on a minimum of not less than five samples for any 30-day period, shall not exceed a geometric mean of 200 per 100 ml nor shall more than 10 percent of the total samples during any 60-day period exceed 400 per 100 ml.
C.2.b	Shellfish harvesting standards	Within the Nearshore Zone, the following bacterial objectives shall be maintained throughout the water column: The median total coliform density shall not exceed 70 per 100 ml, and not more than 10 percent of the samples shall exceed 230 per 100 ml.
C.3.a	Floating particulates, oils and grease	Floating particulates, grease, and oil shall not be visible.
C.3.b	Water clarity and discoloration	The discharge of waste shall not cause aesthetically undesirable discoloration of the ocean surface.
C.3.c	Light transmittance	Natural light shall not be significantly reduced at any point outside the initial dilution zone as a result of the discharge of waste.
C.4.a	Dissolved oxygen	The dissolved oxygen concentration shall not at any time be depressed more than 10 percent from that which occurs naturally, as the result of the discharge of oxygen demanding waste materials.
C.4.b	Acidity (pH)	The pH shall not be changed at any time more than 0.2 units from that which occurs naturally.
C.4.f	Nutrients	Nutrient materials shall not cause objectionable aquatic growths or degrade indigenous biota.

Wastewater discharges from the District's outfall dilute quickly by being "jetted" out through 503 discharge portholes located in the last 1.6 km of the outfall pipe. This initial dilution greatly reduces observable differences between the discharged less saline or "fresh" wastewater and seawater. Predicted changes to receiving water quality from the discharge are proportional to the ratio of wastewater mixed with seawater. The initial dilution ratio used in the permit is 180:1 and represents the lower 10th percentile; the mean is 352:1 (Tetra Tech 2008). Predicted changes in receiving water parameters, based on comparisons with natural conditions using a dilution ratio of 180:1 (OCSD 1991; 2004, SAIC et al. 2001) fall well within typical natural ranges to which local marine organisms are exposed. These changes, therefore, represent insignificant risks to the environment or human health.

Two other factors limit potential discharge effects besides initial dilution. First, after discharge, the wastewater is further diluted by dynamic mixing with the ocean water and transport away from the diffuser by prevailing ocean currents. These currents include both large-scale ocean currents (e.g., Southern California Eddy) as well as smaller-scale local currents (Dailey et al. 1993, Noble and Xu 2004, Noble et al. 2009, OCSD 2010, SCCWRP 1973, SWRCB 1965). Second, natural water layering or stratification restricts upward movement of the wastewater plume toward the surface; stratification off southern California is principally due to temperature (SWRCB 1965). Stratification restricts observable discharge-related changes to below 30–40 m depths during most surveys and limits the plume rise into the upper 10 m of the water column to less than 2 percent of the time (Tetra Tech 2002, 2008). These results were similar to other discharges studied by Petrenko et al. (1998) and Wu et al. (1994). Previous reports provide detailed analysis of currents (OCSD 1994; SAIC 2009), comparisons of water quality data with long-term historical trends (OCSD 1992, 1993, 1996a, b, 2004), and summaries of natural seasonal and human-related factors that affect dilution and movement of the wastewater discharge (OCSD 2004).

METHODS

Field Surveys−Core

Each quarter (summer, fall, winter, and spring) three surveys were completed at 29 stations (Table A-1, Figure 3-1). Two additional days of sampling were done within 30 days at a subset of nine stations for calculating compliance with water contact (Rec-1) bacterial standards (Table A-2). During most surveys, additional bacteriological samples were collected at the outfall Station 2205 and two nearfield stations, 1 and 9 (Table A-1).

A Seabird© electronic sensor package (aka CTD) measured conductivity (used to calculate salinity), temperature, and depth (using pressure). Additional sensors on the package included dissolved oxygen (DO), pH, water clarity, chlorophyll-*a*, colored dissolved organic matter (CDOM), and photosynthetically active radiation (PAR). Data was collected 24 times/second using Seasoft (2010a) data collection software for both the downcast and upcast from the surface to 2 m above the bottom or to a maximum depth of 75 m. Discrete samples were collected at specified depths at a subset of stations, nine for fecal indicator bacteria (FIB) and 20 for ammonium, (Table A-1). Visual observations of water clarity (measured as Secchi-disc depth), water color, and floatable materials were also obtained at each station.

Both PAR and Secchi depth provide measures of natural light penetration through the water column. Use of a Secchi disk dates back to the mid-1800s and still represents a low cost method of studying water clarity. Even though Secchi depth methodology is standardized, data quality issues remain due to the inherent problem of seeing the disk under varying lighting conditions, different readings obtained by different technicians, and the imprecision of measuring depth manually using a marked line. PAR measurements obtained using a CTD offer several advantages over Secchi disks, including the ability to obtain continuous light penetration values throughout the water column as well as standardized measures not subject to human variability (i.e., differences in eyesight).

Field Surveys−Central Bight

As part of the Central Bight program, an expanded grid of water quality stations was sampled each quarter (Figure 3-2, Table A-2). The four agencies used similarly equipped CTDs and comparable field sampling methods. The primary difference between sampling efforts lies in the maximum depth sampled. The District samples to a maximum of 75 meters while some of the other agencies sample to 100 m. No discrete water samples were collected at these additional stations.

Field Surveys−Currents

Teledyne RD Instruments acoustic Doppler current profilers (ADCP) were used to measure ocean currents (Figure 3-1; Table A-3). Set on the ocean bottom, three ADCPs (Stations M20, M19, and M18) were located along a line parallel to the outfall and approximately perpendicular to the local bathymetry at about 20 m, 40 m, and 60 m, respectively. The fourth ADCP (Station M21, 55 m) was located downcoast from the main mooring line and adjacent to the shelf break on the western flank of the Newport Canyon. At each location, measurements of current speed and direction were taken every 6 minutes at 1 m intervals throughout the water column along with bottom water temperatures. Instrument set up is done using WinSC (2003). After deployment recovery, data was exported using WinADCP (2003).

Data Processing and Analysis

Raw CTD data were processed using both CTD manufacturer (Seabird, 2010b) and third party (IGODS, 2010) software. The steps include retaining downcast data and identifying outliers by flagging the data if it exceeded specific criteria limits. Flagged data were removed if it was considered to be due to instrument failures, electrical noise (e.g., large data spikes), or physical interruptions of sensors (e.g., by bubbles) rather than by actual oceanographic events. After outlier removal, averaged 1 m depth values were prepared from downcast scan data; if there were any missing 1 m depths, then the upcast data was used as a replacement. CTD and discrete data were then combined to create a single data file that contained all sampled stations for each survey day. Descriptive statistics were calculated using either Excel (2010) or SYSTAT (2007). ADCP data was processed using in-house MATLAB (2007) routines (m-files). Graphical views were produced using Deltagraph (2009) IGODS (2010), MATLAB (2007), Surfer (2004), or SYSTAT (2007).

Appendix A contains more information on the methods used for collection and analysis of the water quality data. Compliance determinations with water quality criteria are discussed in Chapter 2 (Compliance).

RESULTS AND DISCUSSION

Regional Water Quality Conditions

Several ocean ecosystem indices, such as the PDO, ENSO, and Upwelling Index have been used as indicators of ocean conditions for the California Current system. A persistent change in these indices is reflected in regional ocean conditions. During 2009-10, the cool PDO regime (negative) seen since September 2007 changed to a warmer (positive) phase in August and remained positive for most of the year (Figure 3-3). This change in PDO was mirrored in the development of a moderate to strong El Niño that persisted into May. The upwelling index, representing potential productivity along the coast, was below average for the summer quarter then rebounded and was above normal for most of the remainder of the year, decreasing again to below normal monthly values for May and June 2010

For 2009-10, summer water temperature showed stratification throughout the study area with much warmer surface waters off Palos Verdes and the San Pedro Shelf than off Ventura. (Figure 3-4). During the fall survey, surface waters cooled in the southern portion of the grid, dropping almost 4 °C, but warmed in the north with subsurface temperatures increasing throughout the region. The most isothermal conditions for the year occurred during winter, especially on the San Pedro Shelf and off the Ventura River. During spring, colder water was measured higher up in the water column with evidence of upwelling along the Ventura coast and off the Palos

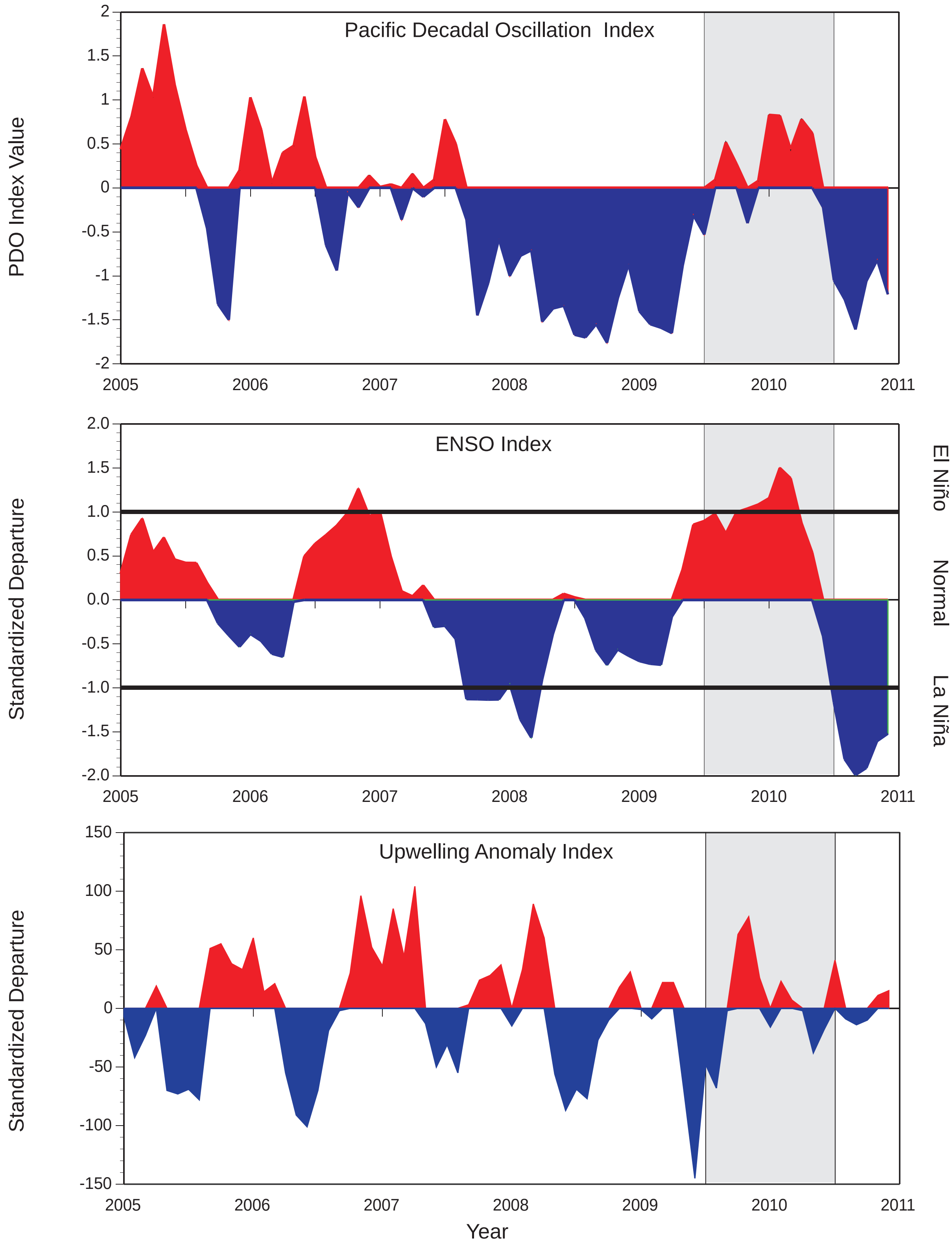


Figure 3-3. **Standardized values for the Pacific Decadal Oscillation (PDO), El Niño Southern Oscillation (ENSO), and Upwelling Anomaly indices, 2005–2010. Current program year denoted in gray.**

PDO: http://jisao.washington.edu/pdo/PDO.latest
ENSO: http://www.cdc.noaa.gov/people/klaus.wolter/MEI/mei.htm
Upwelling: ftp://orpheus.pfeg.noaa.gov/outgoing/upwell/monthly/upanoms.mon

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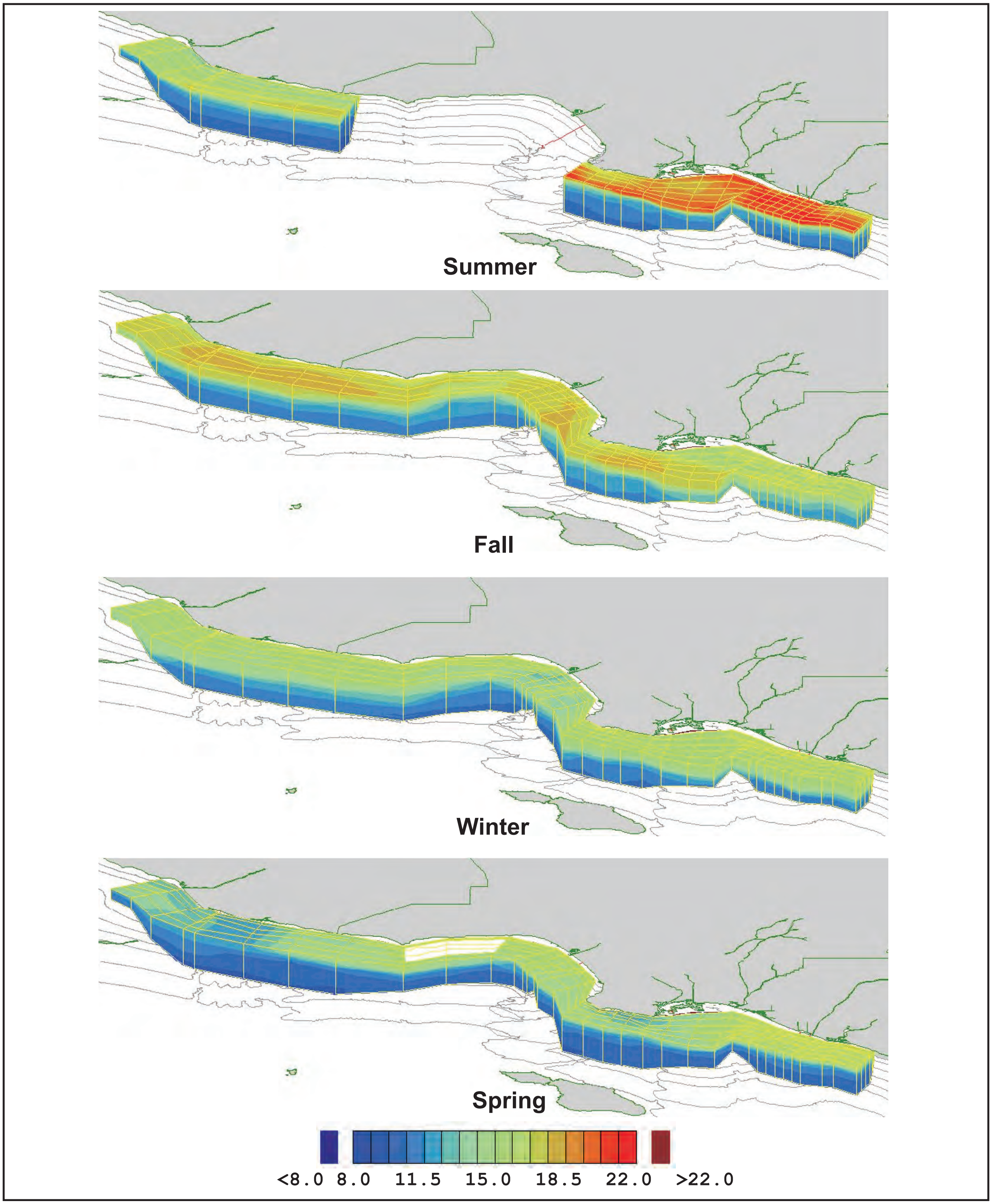

Figure 3-4. **Seasonal patterns of temperature (°C) for summer (August 2009), fall (November 2009), winter (March 2010), and spring (May 2010) for the Central Bight Water Quality grid.**

Orange County Sanitation District, California.

Verdes Peninsula. Summer had the widest range of surface temperature (almost 13 °C) while the winter had the smallest (less than 7 °C; Table 3-1). Summer and spring temperatures were comparable at depths over 75 m, but spring had colder water much higher in the water column. At depths greater than 75 m, variation was small seasonally and regionally with values falling within a range of less than 2 °C.

With the exception of winter, salinity variability was less than 1 psu (Table 3-1). However, there were distinctive patterns seen both seasonally and with depth (Figure 3-5). One region-wide feature found in both the summer and fall, but more pronounced in the fall, was a subsurface lower salinity layer across the Central Bight. This subarctic water is transported into the area by the California Current at water depths consistent with where wastewater plumes stabilize after mixing with receiving waters. Before regional sampling, this layer was often misinterpreted as plume water. Other local features include fresh water inputs from the Los Angeles/Long Beach Harbors throughout the year, but most notably in the fall and winter. The larger areas of lower surface salinity during the winter were due to runoff from almost 9 inches of rain in December 2009 to February 2010 (see Figure 1-4). Higher subsurface salinity values were measured throughout the study area in the summer and winter, but most notably in the spring. Spring also had higher salinities through the water column and at the surface off Ventura that corresponded to colder water temperatures (see Figure 3-4).

Regionally DO values ranged from greater than 13 mg/L at the surface to just over 2 mg/L at depth (Figure 3-6). Surface values for all seasons ranged from around 5 to almost 12 mg/L. At depth, the majority of values for summer and fall were greater than 5 mg/L, while those for winter and spring were less than 5, but greater than 3 mg/L; only during spring were values less than 3 mg/L observed and these were at depths greater than 60 m. Except for spring, DO values were above levels considered stressful (OCSD 1995) or hypoxic (USGS 2009). Regardless of the season, DO showed strong gradients through the water column as well as broad ranges (Table 3-1). In previous years, both the lowest (subsurface) and highest (surface) DO values seen in the spring, typically associated with seasonal upwelling (see Figure 3-4) and higher productivity as evidenced by chlorophyll-*a* (see section below). However, for 2009-10 the highest DO values were seen in the fall and the lowest still in the spring. Summer and fall also showed subsurface DO maximums, associated with chlorophyll-*a*.

Chlorophyll-*a,* used as a surrogate for phytoplankton, varied widely, both seasonally and regionally (Figure 3-7) with the widest range being seen in the spring (Table 3-1). Surface waters off Ventura had elevated chlorophyll-*a* values in the summer and spring. This changed in the fall and winter when the highest surface values were over the San Pedro Shelf. Throughout the year, a subsurface maximum was present on the San Pedro Shelf. Another notable was the localized increase in chlorophyll in the fall off the Los Angeles/Long Beach Harbors and the Santa Ana River, presumably due to runoff from rain the previous fall.

Local Water Quality Conditions

This section focuses on quarterly comparisons for each parameter along with descriptions of significant changes between surveys.

<u>Currents</u>

Current meter data were not continuous for the monitoring year, but there was coverage for all quarters and during each water quality survey (Tables A-2 and A-3).

Table 3-1. Summary of quarterly water quality parameters for the Central Bight Water Quality Group by season during 2009-10.
Orange County Sanitation District, California.

Parameter	Summer			Fall			Winter*			Spring*			Annual*		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Temperature (°C)	13.43	22.56	9.89	13.83	18.30	10.53	12.95	16.67	9.93	11.80	17.44	9.46	13.00	22.56	9.46
Density (kg/m^3)	25.08	26.08	22.93	24.89	25.80	24.03	25.17	26.12	23.42	25.55	26.30	23.91	25.17	26.30	22.93
Salinity (psu)	33.47	33.86	33.11	33.31	33.64	32.75	33.42	33.95	31.91	33.63	34.11	33.22	33.46	34.11	31.91
Dissolved Oxygen (mg/L)	6.51	10.66	3.27	7.25	13.41	4.37	5.99	10.00	3.20	5.35	11.75	2.23	6.28	13.41	2.23
Oxygen Saturation (mg/L)	8.50	9.12	7.11	8.43	9.00	7.69	8.57	9.11	7.95	8.77	9.20	7.83	8.57	9.20	7.11
Oxygen Saturation (%)	77.91	141.56	35.97	86.55	166.08	48.63	70.54	120.01	35.50	61.78	140.89	24.66	74.20	166.08	24.66
pH (pH units)	7.95	8.46	7.54	8.06	8.46	7.74	8.02	8.32	7.71	7.88	8.42	7.42	7.98	8.46	7.42
Light Transmission (%)	85.06	91.28	45.50	86.95	92.56	33.06	87.78	92.07	0.00	83.41	92.13	25.65	85.80	92.56	0.00
Chlorophyll-*a* (µg/L)	2.69	43.72	0.00	2.67	43.80	0.00	3.17	36.71	0.09	6.33	74.04	0.26	3.72	74.04	0.00
CDOM (µg/L)	1.42	3.85	0.00	0.74	5.35	0.00	1.34	6.86	0.00	1.97	5.68	0.30	1.37	6.86	0.00
Ammonia (mg/L)	0.03	0.26	<0.02	0.03	0.28	<0.02	0.03	0.15	<0.02	0.03	0.23	<0.02	0.03	0.28	<0.02
Total coliforms (MPN)**	91	>2000	2	83	2359	2	79	>2000	<10	100	2000	<10	88	2359	2
Fecal coliforms (MPN) **	18	300	2	9	147	2	NS	NS	NS	NS	NS	NS	14	300	2
E. coli (MPN) **	45	1200	<10	43	1400	<10	26	590	<10	37	780	<10	38	1400	<10
Enterococcus (MPN) **	18	560	<2	14	290	<2	16	310	<10	18	320	<10	17	560	<2

* City of San Diego CTD data included, no bacteria or ammonia data
** Bacteria data from City of Oxnard, Hyperion, and OCSD
NS = not sampled

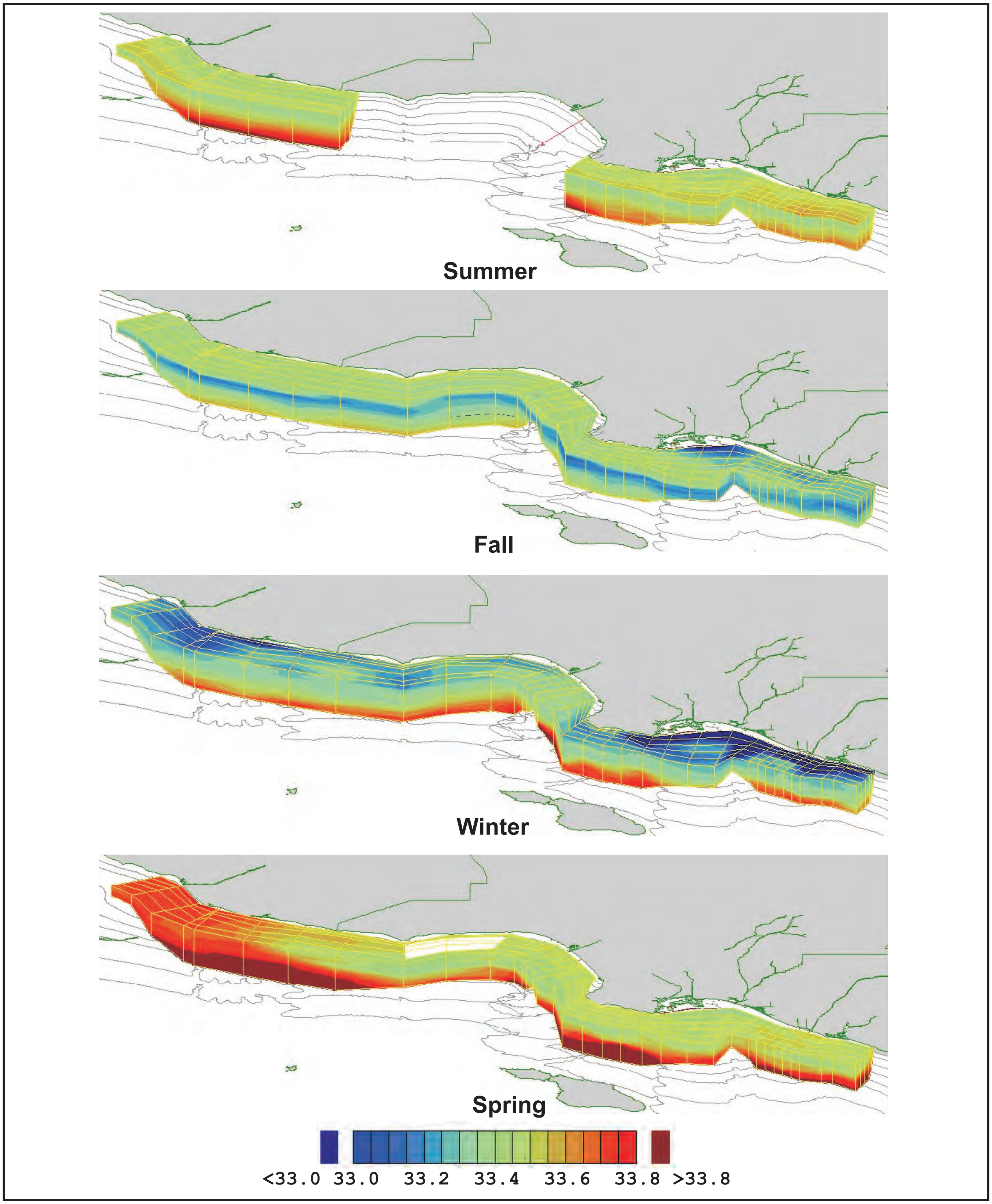

Figure 3-5. **Seasonal patterns of salinity (psu) for summer (August 2009), fall (November 2009), winter (March 2010), and spring (May 2010) for the Central Bight Water Quality grid.**

Orange County Sanitation District, California.

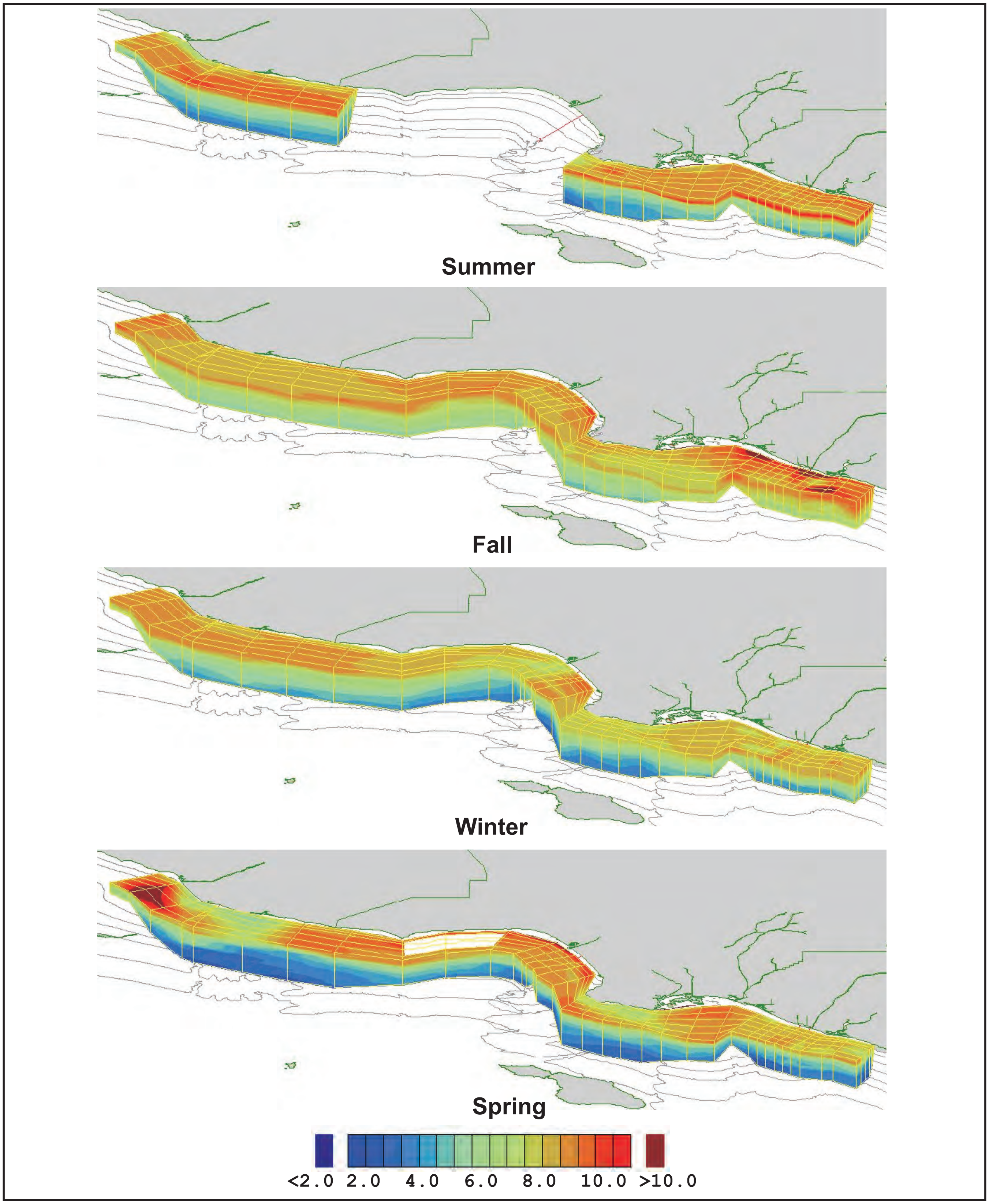

Figure 3-6. **Seasonal patterns of dissolved oxygen (mg/L) for summer (August 2009), fall (November 2009), winter (March 2010), and spring (May 2010) for the Central Bight Water Quality grid.**

Orange County Sanitation District, California.

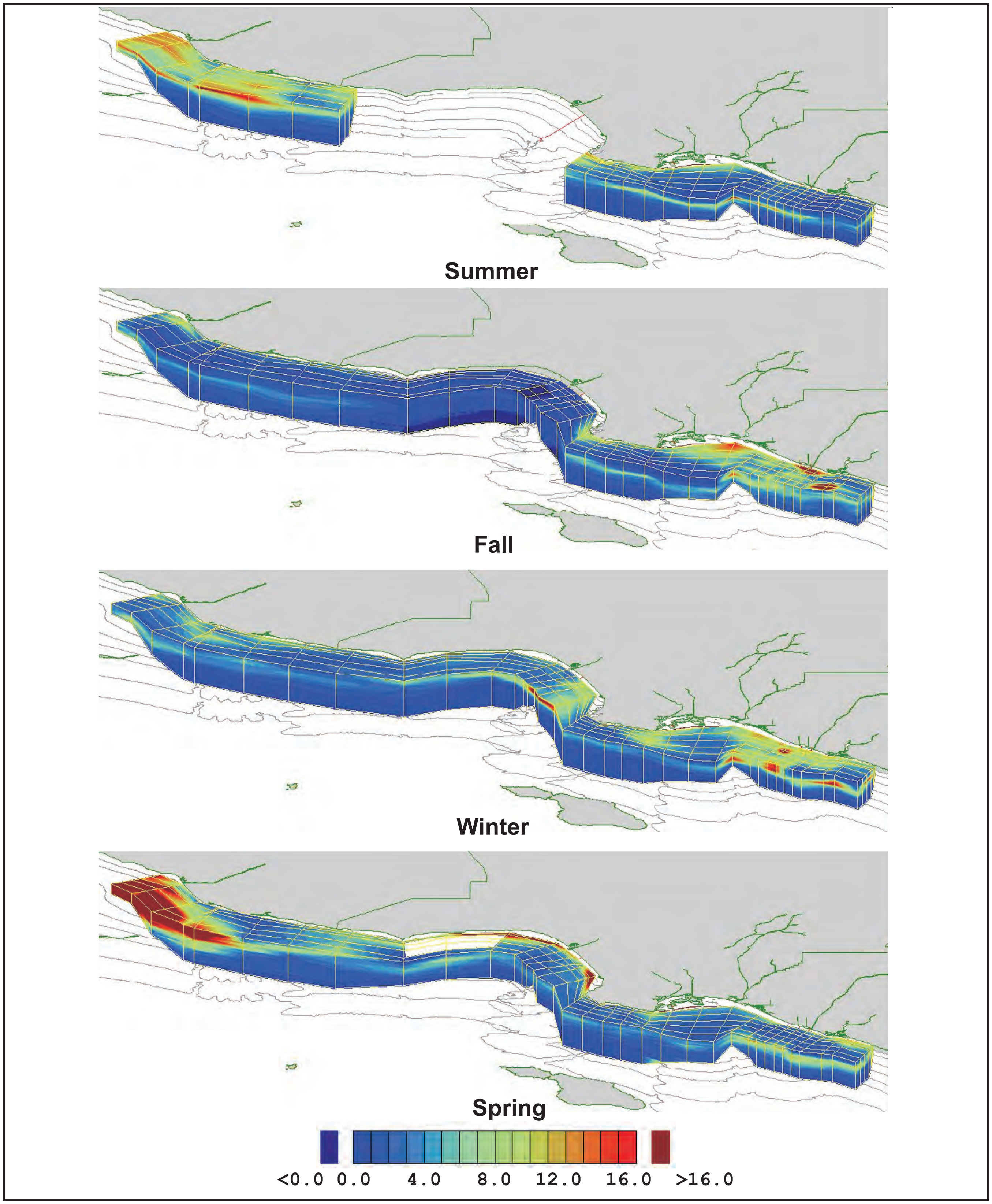

Figure 3-7. **Seasonal patterns of chlorophyll-*a* (µg/L) for summer (August 2009), fall (November 2009), winter (March 2010), and spring (May 2010) for the Central Bight Water Quality grid.**

Orange County Sanitation District, California.

The vast majority (88–100%) of current speeds for 2009-10 were less than 20 cm/s (or 0.45 mph) with flows directed alongshore throughout the year (Figures 3-8 and 3-9, B-1 to B-6). This is consistent with previous current meter results (OCSD 2004, SAIC 2009). Stratified currents were seen at all stations except for the 20 m Station M20. With the exception of Station M19, surface currents flowed predominantly downcoast, while currents near the bottom were directed upcoast or offshore for most of the year; Station M19 currents were mostly upcoast throughout the water column. Unlike previous findings (e.g., SAIC 2009) where the likelihood of up- or downcoast transport at plume depth (waters below 30 m) was equal, 2009-10 currents were consistently upcoast.

<u>Temperature and Density</u>

Water temperature is dependent on both depth and season (Table 3-2). The upper 30 m, had the highest maximum temperatures and the biggest annual range. Seasonally, with the exception of the winter quarter, these upper water depth temperatures were twice as variable as values below 30 m. Winter was the least variable at most depths indicating less stratification. Overall, summer had the biggest temperature range and the highest variability. Unlike the previous year when subsurface (>20 m) average temperatures were warmest in the fall, the warmest average temperatures this year occurred below 15 m. Spring had the coldest water temperatures for all depths with 10 °C water reaching to the surface.

Figures 3-10 and 3-11 depict water temperature and the thermocline with depth, respectively, across the survey region for each survey. Very warm surface water (red) and a very thick thermocline were present in the summer. As the year progressed, surface waters cooled and the thermocline dissipated above 40 m in the winter season. In spring, cold subsurface water (the result of seasonal upwelling) rose high in the water column resulting in the reformation of a strong, though shallow, thermocline. Some differences were apparent between the survey dates each quarter, but the general patterns noted above were evident during each cruise. For example, summer surface waters cooled from the first to third survey day, though the thermocline pattern remained consistent. A notable change in the spring occurred between the first two surveys with the intrusion of cold water up into the water column and the formation of a strong thermocline; this pattern changed the following week with a relaxation of upwelling and a weakening of the thermocline.

Density was highly correlated (r=-0.979) with temperature and showed comparable seasonal and depth related patterns. The least and most dense water associated with the warmer summer surface and colder spring bottom water temperatures, respectively (Table 3-2; Figure B-7). The variability in seawater density in summer was twice that of the other seasons and was greatest in the upper 30 m. The least variability occurred in the spring at depths greater than 45 m. Overall, for both temperature and density, the ranges, mean values, spatial and temporal patterns for 2009-10 were typical of long-term observations (OCSD 1996b; 2004; SAIC 2009) and with regional observations (Table 3-1).

Plume Related Changes

The primary temperature affect from the discharge is the entrainment of colder, deeper water as the buoyant plume rises in the water column (Figure 3-10, November 2, 2009 and February 17, 2010).

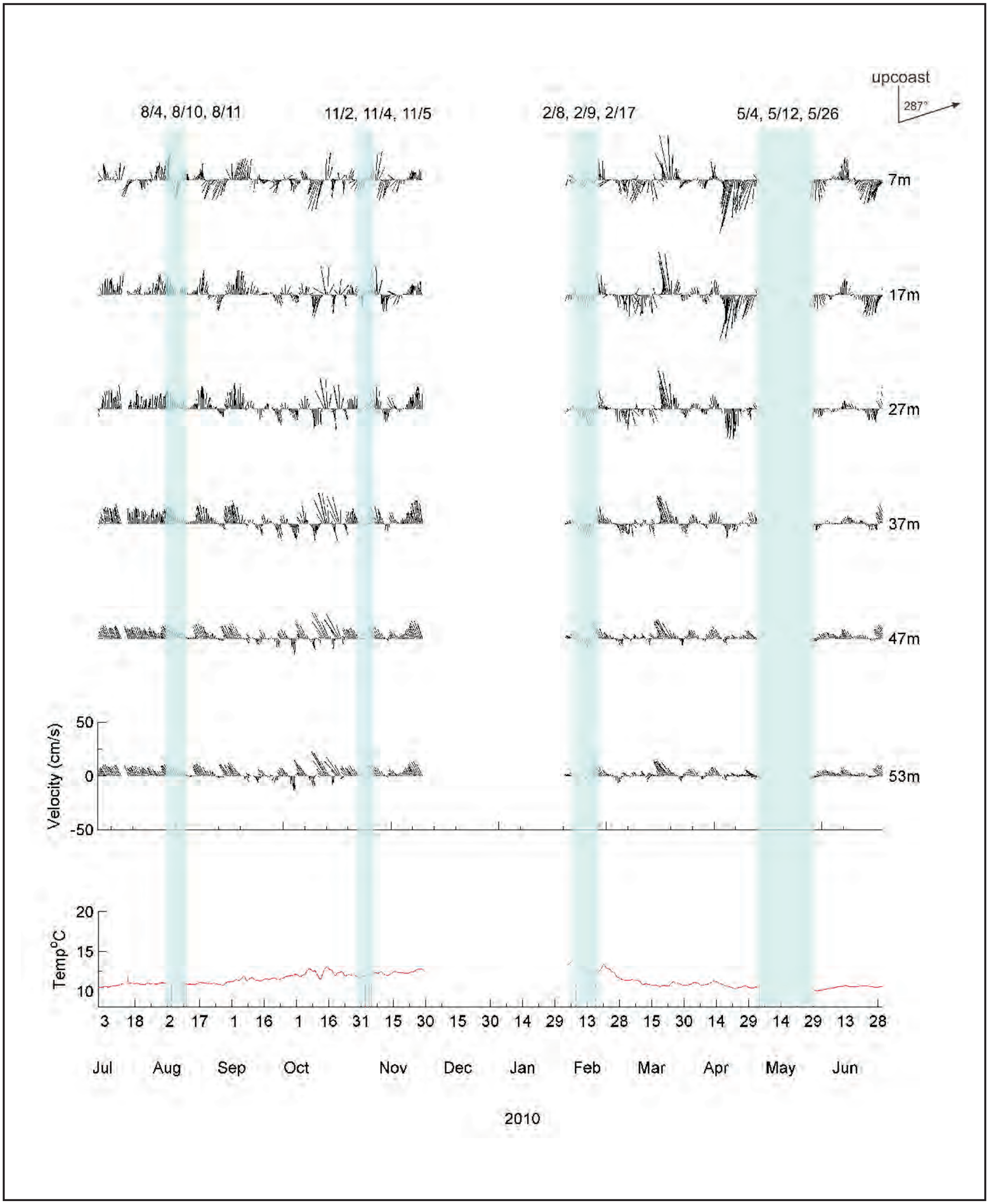

Figure 3-8. **Bottom temperature (°C) and current speed (cm/s) and direction by depth for mooring M21, July 2009–June 2010. Blue lines denote water quality sampling events.**

Orange County Sanitation District, California.

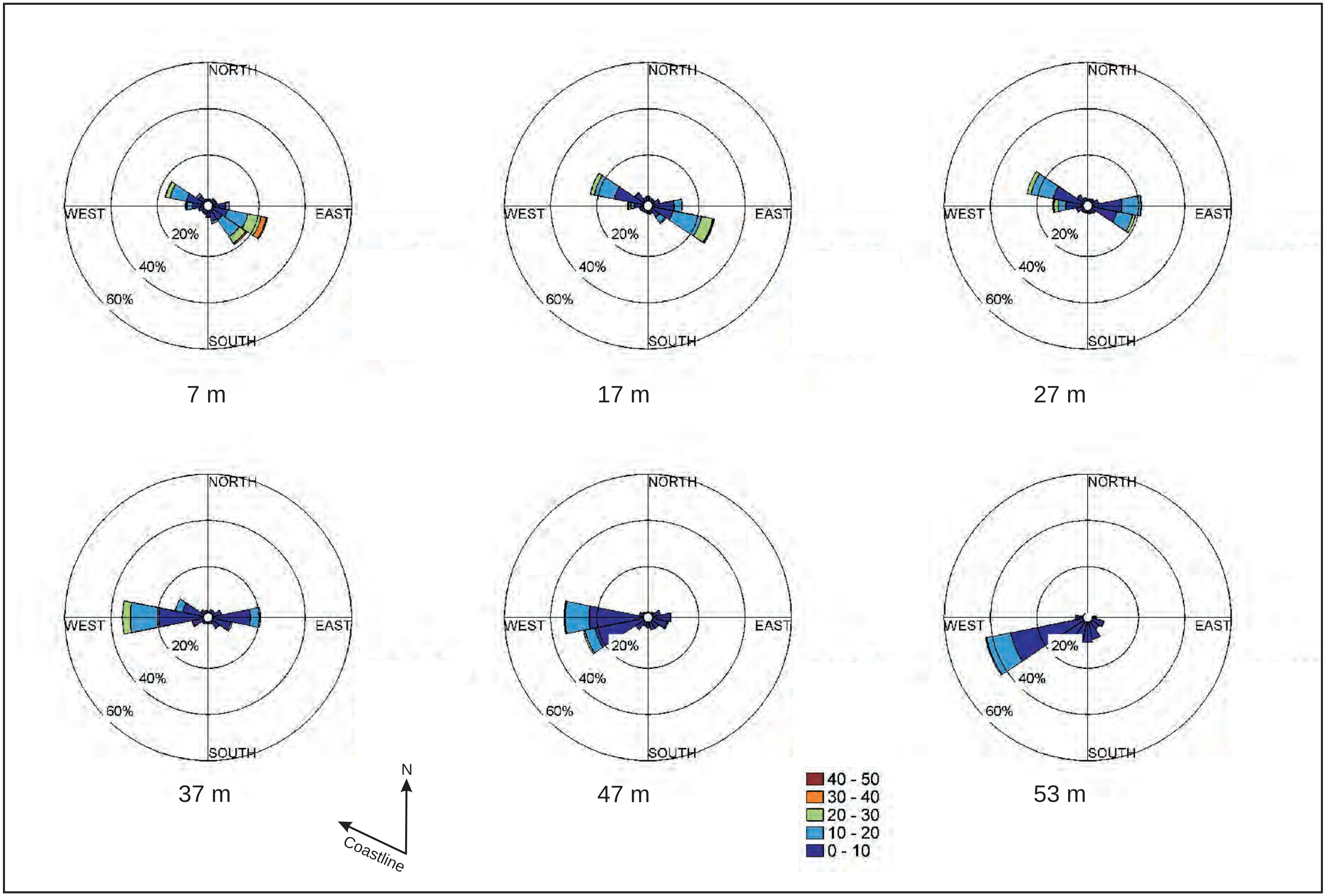

Figure 3-9. Average current speed (cm/s) and direction by depth for mooring M21, July 2009–June 2010.

Table 3-2. Summary of quarterly water quality parameters by depth strata and season during 2009-10.

Orange County Sanitation District, California.

Depth (m)	Summer 2009				Fall 2009				Winter 2010				Spring 2010				Annual			
	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev
Temperature (°C)																				
1-15	17.79	22.55	11.88	2.52	15.92	19.94	12.85	1.58	15.18	16.78	13.29	0.32	14.56	17.44	10.90	1.15	15.81	22.55	10.90	2.01
16-30	13.39	20.60	11.06	1.48	14.61	19.14	12.43	1.20	14.73	15.41	11.75	0.56	12.36	15.77	10.44	1.14	13.70	20.60	10.44	1.52
31-45	11.75	14.64	10.37	0.63	13.19	15.61	11.95	0.70	14.07	15.13	11.33	0.94	11.15	14.46	10.27	0.71	12.46	15.61	10.27	1.38
46-60	11.08	12.57	10.15	0.40	12.40	14.22	11.47	0.36	13.00	15.06	10.96	1.27	10.63	12.49	10.07	0.36	11.71	15.06	10.07	1.19
61-75	10.68	11.52	10.14	0.27	11.89	12.85	11.33	0.23	11.65	14.77	10.44	0.76	10.34	11.09	9.96	0.17	11.08	14.77	9.96	0.78
All	13.89	22.55	10.14	3.25	14.19	19.94	11.33	1.86	14.19	16.78	10.44	1.35	12.37	17.44	9.96	1.88	13.60	22.55	9.96	2.33
Density (kg/m^3)																				
1-15	24.12	25.41	22.96	0.58	24.47	25.05	23.57	0.31	24.48	25.16	23.38	0.21	24.89	25.99	23.77	0.26	24.51	25.99	22.96	0.46
16-30	25.07	25.65	23.47	0.33	24.72	25.15	23.83	0.23	24.71	25.41	24.27	0.16	25.35	25.93	24.58	0.26	24.98	25.93	23.47	0.37
31-45	25.42	25.94	24.73	0.18	24.99	25.29	24.50	0.13	24.90	25.58	24.60	0.21	25.64	26.05	24.86	0.20	25.26	26.05	24.50	0.36
46-60	25.61	26.03	25.12	0.16	25.16	25.45	24.81	0.09	25.16	25.72	24.69	0.30	25.85	26.09	25.26	0.14	25.47	26.09	24.69	0.36
61-75	25.74	26.02	25.36	0.14	25.31	25.53	25.09	0.07	25.51	25.96	24.79	0.24	26.00	26.15	25.65	0.08	25.67	26.15	24.79	0.30
All	24.98	26.03	22.96	0.73	24.81	25.53	23.57	0.37	24.82	25.96	23.38	0.39	25.40	26.15	23.77	0.46	25.02	26.15	22.96	0.56
Salinity (psu)																				
1-15	33.47	33.64	33.36	0.05	33.33	33.59	33.03	0.09	33.11	33.52	31.82	0.24	33.48	33.70	33.09	0.05	33.35	33.70	31.82	0.19
16-30	33.41	33.57	33.25	0.05	33.28	33.51	33.09	0.06	33.29	33.48	32.83	0.08	33.50	33.78	33.33	0.07	33.37	33.78	32.83	0.11
31-45	33.44	33.78	33.12	0.09	33.23	33.39	33.05	0.04	33.35	33.54	33.05	0.06	33.58	33.90	33.38	0.10	33.41	33.90	33.05	0.15
46-60	33.52	33.85	33.15	0.12	33.26	33.40	33.08	0.04	33.42	33.67	33.16	0.09	33.72	33.95	33.41	0.11	33.49	33.95	33.08	0.20
61-75	33.60	33.84	33.30	0.11	33.33	33.49	33.23	0.05	33.52	33.83	33.34	0.13	33.85	34.01	33.56	0.08	33.59	34.01	33.23	0.22
All	33.47	33.85	33.12	0.10	33.29	33.59	33.03	0.07	33.29	33.83	31.82	0.21	33.58	34.01	33.09	0.15	33.41	34.01	31.82	0.19
Dissolved Oxygen (mg/L)																				
1-15	8.66	10.66	6.00	0.67	8.15	13.41	6.46	0.69	7.86	9.83	6.13	0.50	7.76	10.32	4.19	0.85	8.09	13.41	4.19	0.78
16-30	7.53	10.09	5.06	1.17	7.85	9.06	6.61	0.50	7.30	9.97	5.22	0.61	6.03	9.13	3.24	1.15	7.13	10.09	3.24	1.17
31-45	5.81	9.02	3.91	0.93	7.33	8.90	6.30	0.60	6.69	8.33	4.59	0.71	4.63	7.57	3.01	0.91	6.04	9.02	3.01	1.31
46-60	5.11	7.72	3.33	0.78	6.79	8.80	5.82	0.44	5.96	7.57	4.29	0.90	3.80	6.02	2.76	0.63	5.33	8.80	2.76	1.34
61-75	4.70	6.79	3.51	0.73	6.29	7.38	5.39	0.35	5.10	6.96	3.64	0.77	3.34	4.80	2.45	0.40	4.75	7.38	2.45	1.23
All	6.95	10.66	3.33	1.74	7.55	13.41	5.39	0.84	6.95	9.97	3.64	1.11	5.71	10.32	2.45	1.86	6.74	13.41	2.45	1.63

Table 3-2 continues.

Table 3-2 continued.

Depth (m)	Summer				Fall				Winter				Spring				Annual			
	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev
pH (pH units)																				
1-15	8.17	8.46	7.96	0.09	8.19	8.49	8.05	0.06	8.13	8.25	7.97	0.05	7.99	8.18	7.69	0.08	8.11	8.49	7.69	0.11
16-30	8.10	8.36	7.78	0.12	8.14	8.30	7.96	0.06	8.08	8.23	7.83	0.06	7.83	8.09	7.49	0.12	8.03	8.36	7.49	0.16
31-45	7.96	8.29	7.69	0.12	8.07	8.35	7.92	0.07	8.02	8.18	7.77	0.08	7.69	8.03	7.48	0.11	7.92	8.35	7.48	0.18
46-60	7.89	8.25	7.61	0.12	8.01	8.27	7.86	0.06	7.94	8.13	7.72	0.10	7.61	7.91	7.43	0.08	7.85	8.27	7.43	0.19
61-75	7.84	8.14	7.54	0.14	7.96	8.22	7.82	0.06	7.84	8.08	7.63	0.09	7.56	7.75	7.42	0.06	7.78	8.22	7.42	0.18
All	8.04	8.46	7.54	0.17	8.11	8.49	7.82	0.10	8.04	8.25	7.63	0.12	7.79	8.18	7.42	0.18	7.99	8.49	7.42	0.19
Light Transmission (%)																				
1-15	82.17	89.91	57.93	4.45	84.55	90.72	47.46	4.30	78.75	89.21	14.46	9.44	80.12	88.56	29.35	6.09	81.36	90.72	14.46	6.72
16-30	83.92	90.59	56.67	3.45	86.06	90.09	58.41	2.81	81.85	90.77	20.47	8.52	82.47	88.57	56.36	4.46	83.55	90.77	20.47	5.45
31-45	86.22	91.07	70.78	2.78	86.83	90.55	57.05	3.38	84.38	91.50	26.63	7.79	85.04	89.13	65.55	3.49	85.60	91.50	26.63	4.81
46-60	86.62	91.42	62.93	4.38	87.66	91.33	61.22	3.57	86.21	91.86	29.28	7.97	85.72	89.28	52.79	3.90	86.51	91.86	29.28	5.23
61-75	88.02	91.54	82.18	1.88	89.03	91.48	83.22	1.63	88.89	92.07	79.94	2.06	87.13	89.74	77.48	2.15	88.19	92.07	77.48	2.10
All	84.57	91.54	56.67	4.25	86.24	91.48	47.46	3.76	82.67	92.07	14.46	8.87	83.16	89.74	29.35	5.28	84.12	92.07	14.46	5.99
Chlorophyll-*a* (µg/L)																				
1-15	3.82	30.35	0.43	3.66	2.39	43.80	0.00	3.64	4.82	24.82	0.51	3.12	6.72	52.88	0.79	6.53	4.62	52.88	0.00	4.86
16-30	6.52	41.87	1.27	3.59	2.03	19.56	0.00	1.98	4.88	19.51	0.78	3.45	8.53	64.64	0.77	7.40	5.79	64.64	0.00	5.35
31-45	2.81	10.69	0.70	1.22	2.10	9.15	0.00	1.55	2.55	16.20	0.66	1.78	4.18	32.59	0.52	3.59	3.01	32.59	0.00	2.47
46-60	1.20	3.68	0.28	0.48	1.50	6.30	0.00	0.87	1.18	8.01	0.19	0.74	1.82	16.61	0.30	1.59	1.45	16.61	0.00	1.09
61-75	0.59	1.57	0.27	0.25	1.00	2.34	0.00	0.47	0.57	2.33	0.13	0.30	0.73	3.24	0.26	0.36	0.71	3.24	0.00	0.39
All	3.64	41.87	0.27	3.46	1.98	43.80	0.00	2.46	3.47	24.82	0.13	3.10	5.37	64.64	0.26	6.12	3.77	64.64	0.00	4.38
Normalized Irradiance (µE/(cm^2 ·sec))																				
1-15	22.36	100	0.60	20.76	19.05	100	0.34	21.33	18.34	100	0.00	21.46	23.53	100	0.30	21.85	20.96	100	0.00	21.48
16-30	3.83	78.85	0.07	5.75	4.75	100	0.08	10.07	1.67	46.62	0.00	2.52	3.61	84.90	0.03	5.31	3.49	100	0.00	6.57
31-45	0.70	12.75	0.04	0.86	1.00	24.02	0.00	2.08	0.26	3.51	0.00	0.32	0.77	16.10	0.02	1.28	0.69	24.02	0.00	1.33
46-60	0.24	0.90	0.00	0.16	0.28	4.88	0.00	0.45	0.09	0.74	0.00	0.10	0.26	4.00	0.00	0.40	0.22	4.88	0.00	0.33
61-75	0.16	0.60	0.00	0.12	0.18	1.86	0.00	0.23	0.05	0.60	0.00	0.08	0.14	1.60	0.00	0.19	0.13	1.86	0.00	0.18
All	8.28	100	0.00	15.49	7.58	100	0.00	15.43	6.34	100	0.00	14.71	8.53	100	0.00	16.24	7.74	100	0.00	15.54

Table 3-2 continues.

Table 3-2 continued.

Depth (m)	Summer				Fall				Winter				Spring				Annual			
	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev
Ammonium (mg/L)																				
1-15	<0.02	0.20	<0.02	0.01	<0.02	0.15	<0.02	0.01	<0.02	0.11	<0.02	0.01	<0.02	0.100	<0.02	0.01	<0.02	0.200	<0.02	0.01
16-30	0.02	0.26	0.02	0.03	0.03	0.29	0.02	0.05	0.03	0.26	0.02	0.04	0.02	0.09	0.02	0.02	0.03	0.29	0.02	0.04
31-45	0.03	0.20	0.02	0.04	0.05	0.46	0.02	0.08	0.03	0.31	0.02	0.05	0.03	0.11	0.02	0.03	0.04	0.46	0.02	0.05
46-60	0.03	0.17	0.02	0.03	0.04	0.25	0.02	0.06	0.02	0.07	0.02	0.01	0.02	0.07	0.02	0.01	0.03	0.25	0.02	0.03
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	0.02	0.26	0.02	0.02	0.02	0.46	0.02	0.04	0.02	0.31	0.02	0.02	0.02	0.11	0.02	0.01	0.02	0.46	0.02	0.03
Total Coliform Bacteria (MPN/100 mL)																				
1-15	<10	41.00	<10	1.17	<10	1019	<10	2.11	32.55	4611	<10	4.80	<10	41	<10	1.23	11.95	4611	<10	2.94
16-30	10.22	1785	<10	2.77	16.88	2359	<10	5.01	45.69	8164	<10	4.67	16.31	2098	<10	5.37	19.09	8164	<10	4.84
31-45	17.95	2098	<10	5.60	35.28	6488	<10	9.85	74.70	14136	<10	8.20	29.18	5172	<10	7.34	35.04	14136	<10	8.11
46-60	14.28	1067	<10	4.51	38.77	7701	<10	8.63	91.18	10462	<10	10.22	23.18	12997	<10	8.25	33.85	12997	<10	8.51
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	9.74	2098	<10	2.63	14.44	7701	<10	4.44	42.80	14136	<10	5.82	11.84	12997	<10	3.70	16.64	14136	<10	4.63
Fecal Coliform Bacteria (MPN/100 mL)																				
1-15	<10	11	<10	1.03	<10	149	<10	1.43	<10	331	<10	1.68	<10	22	<10	1.09	<10	331	<10	1.39
16-30	<10	223	<10	1.70	11.65	355	<10	2.66	11.38	1467	<10	2.34	10.63	221	<10	2.42	10.44	1467	<10	2.30
31-45	11.16	385	<10	2.57	16.20	630	<10	3.72	17.25	889	<10	3.92	12.78	317	<10	2.95	14.21	889	<10	3.33
46-60	<10	83	<10	1.86	15.84	801	<10	3.46	20.77	1449	<10	5.05	11.94	582	<10	3.56	14.07	1449	<10	3.55
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	<10	385	<10	1.64	10.20	801	<10	2.31	10.98	1467	<10	2.54	9.02	582	<10	1.99	<10	1467	<10	2.15
Enterococcus Bacteria (MPN/100 mL)																				
1-15	<10	20	<10	1.20	<10	30	<10	1.17	<10	262	<10	1.88	<10	63	<10	1.24	<10	262	<10	1.45
16-30	<10	122	<10	1.49	<10	122	<10	1.67	10.61	199	<10	1.92	9.90	97	<10	1.89	<10	199	<10	1.76
31-45	10.37	535	<10	2.47	12.81	158	<10	2.54	14.49	285	<10	2.80	12.01	122	<10	2.40	12.38	535	<10	2.57
46-60	11.80	1423	<10	3.46	13.05	122	<10	2.60	17.10	428	<10	3.17	11.26	282	<10	2.59	13.25	1423	<10	2.96
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	<10	1423	<10	1.73	<10	158	<10	1.73	11.07	428	<10	2.19	<10	282	<10	1.74	<10	1423	<10	1.87

NS = No sample

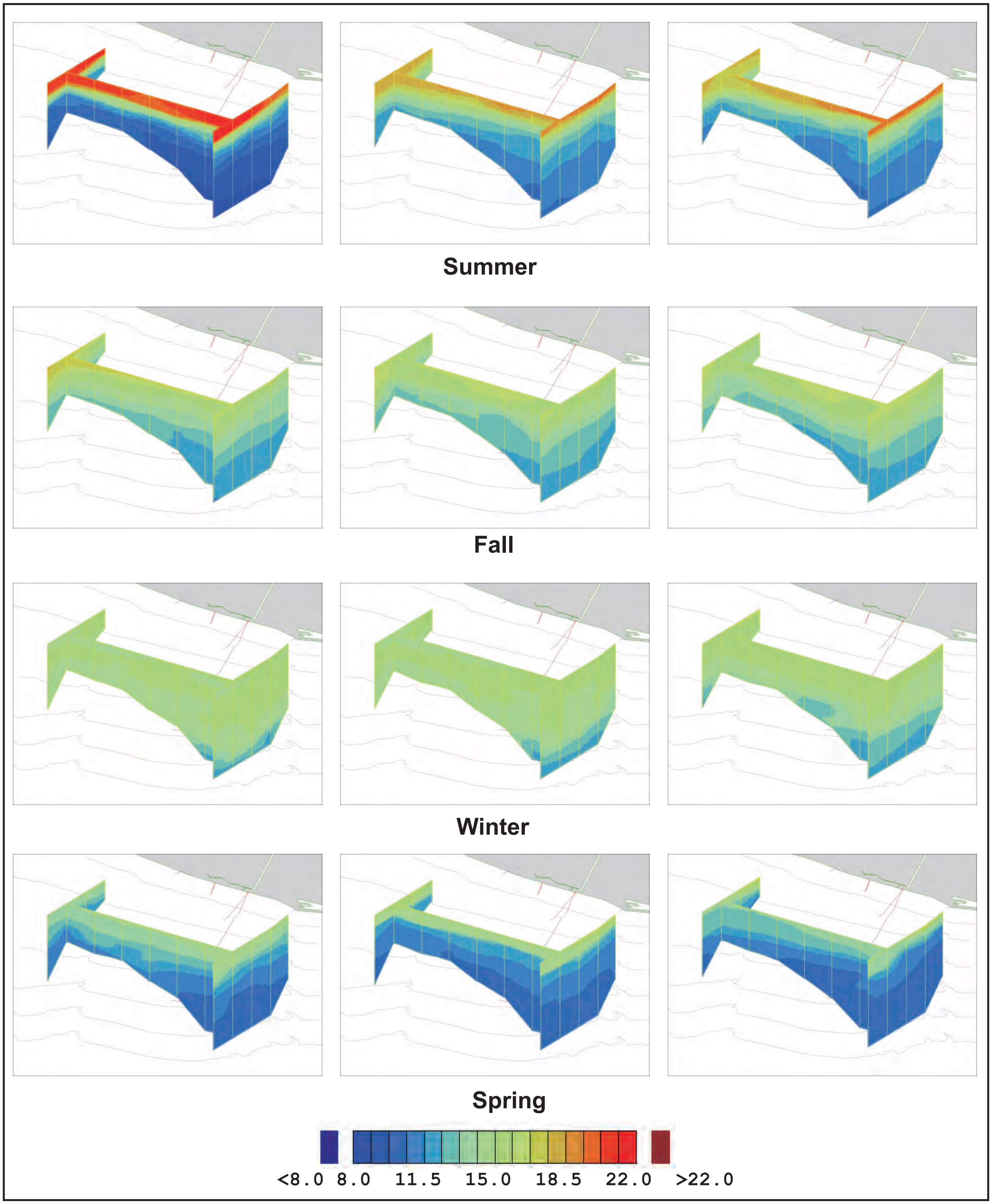

Figure 3-10. **Seasonal patterns of temperature (°C) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

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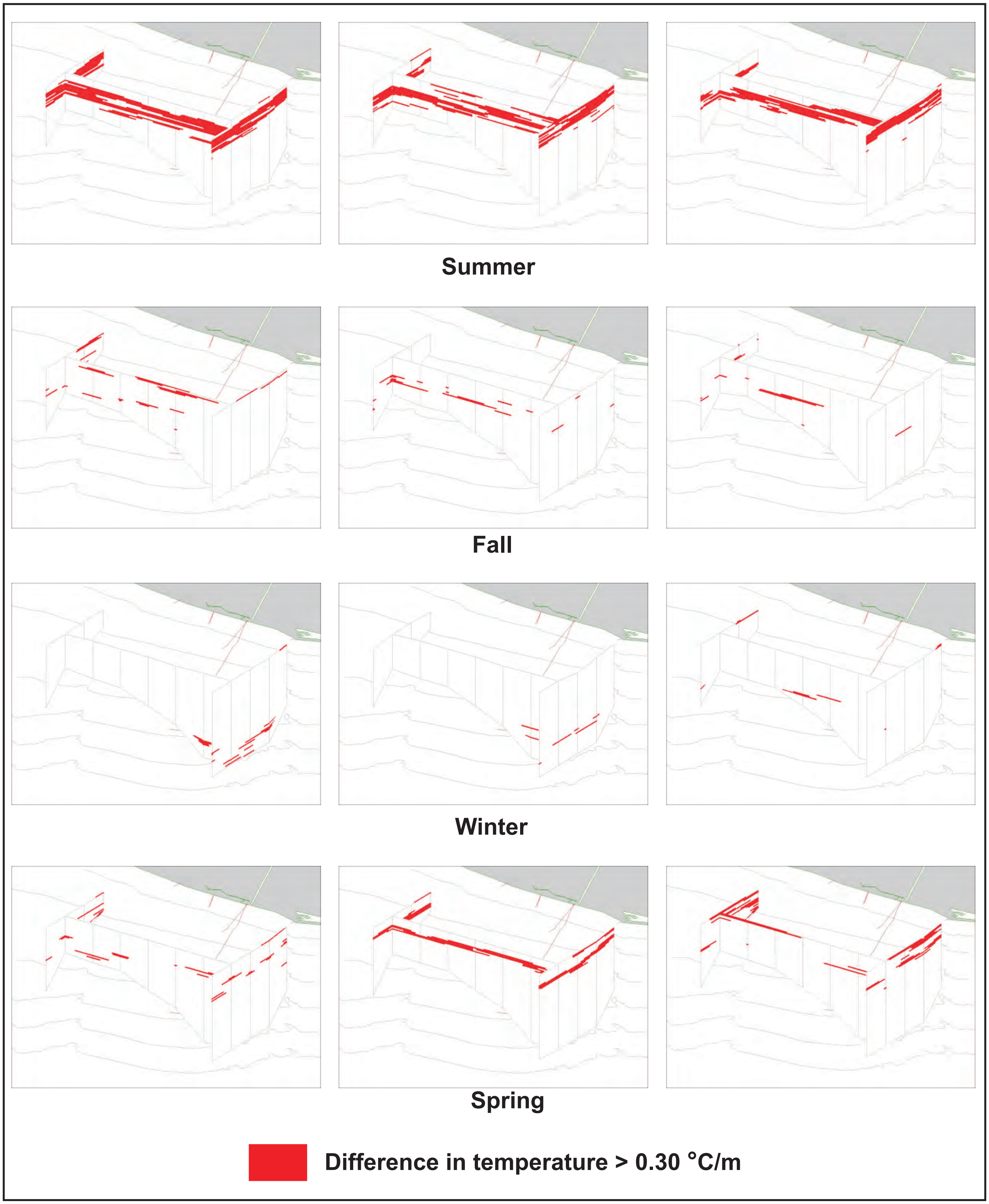

Figure 3-11. **Seasonal patterns of thermocline depth for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010). The thermocline is defined as change in temperature >0.30 °C/m.**

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Figure 3-12 illustrates the relationship between the plume (lower salinity) and entrainment of colder water off the slope onto the shelf. These discharge-related temperature decreases were typically less than 1.0 ºC and occurred near the diffuser and below the pycnocline or to mid-depth during weakly stratified conditions. Plume entrainment was less apparent during periods when deeper colder water intruded onto the shelf by upcoast currents or seasonal upwelling (e.g., Figure 3-10, May 12, 2010).

Salinity

For 2009-10 salinity values had a very narrow range (<1 psu) and small variability both seasonally and with depth (Table 3-2). Average salinity generally increased with depth except in the summer and fall when average salinity values were slightly lower at mid-depths. The increase in salinity with depth and the low variability is consistent with previous southern California studies (SWRCB, 1965). The one exception was in the winter when storm runoff significantly lowered surface salinities and more than doubled the range seen at any other depth throughout the entire year. Fall had the lowest average salinity overall, the lowest value at depths below 15 m, and the lowest variability. The low surface salinities in the winter and spring were most likely due to stormwater runoff. Spring also had the highest average and maximum values overall and for each depth category.

Figure 3-13 illustrates changes in salinity for each survey and season. Generally, little change was noted within between surveys, but significant seasonal patterns were observed. The lower subsurface salinity in summer was primarily due to the intrusion of subarctic water from the southeast, with some contribution by the discharged wastewater (e.g., August 10th). This subarctic water mass was observed throughout the region as shown in the Central Bight data (see Figure 3-5). In the fall and winter, salinity values were fairly uniform, though colder, more saline water was still present in the Newport Canyon and at depth to the southeast. The discharge was also evident during these two seasons. The effects of stormwater runoff in the surface waters were most notable in the winter. In spring, surface salinity values were still depressed, while upwelling caused higher salinity water to come onto the shelf (red and orange colors southeast of the outfall). As was the case for temperature, the general patterns and ranges for salinity were consistent with long-term monitoring (e.g., summarized in OCSD 1996b, 2004) and CBWQ (Table 3-1) results.

Plume Related Changes

Since the discharge plume is essentially freshwater being discharged into saline waters, a primary plume signature is the difference in salinity after initial dilution. With the exception of spring, minor discharge-related decreases in salinity of about 0.2 psu were apparent each quarter below the pycnocline or at mid-depth. Subsequent transport of the lower salinity plume water was consistent with measured currents (see Figure 3-8). For example, upcoast currents were very weak at the start of the November survey and then strengthened moving the plume upcoast.

Dissolved Oxygen, and pH

Changes in water temperature, salinity, and depth, along with the presence of oxygen producing phytoplankton all affect oxygen values. The water column was well oxygenated for most of the year. Over 90% of the DO values were typically above 4 mg/L and no value fell below 2 mg/L (hypoxic). Average DO values decreased with depth for all seasons (Table 3-2, Figure 3-14). Spring had the lowest average and minimum DO values overall and for each depth bin. The highest DO value recorded for the year was in the fall at the surface (1 m) and was associated with

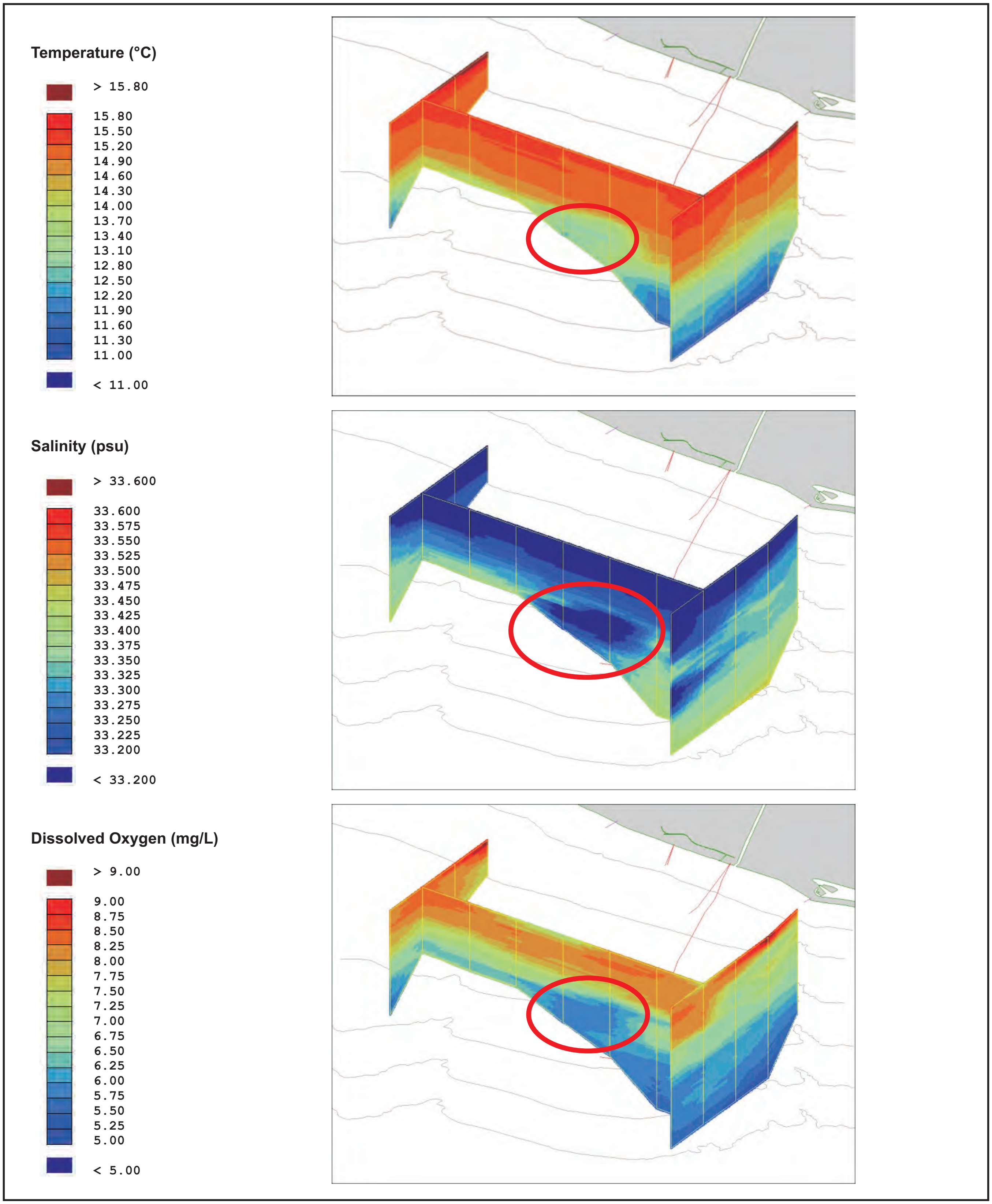

Figure 3-12. **Examples of plume-related changes (circled in red) in temperature (°C), salinity (psu), and dissolved oxygen (mg/L) near the outfall on February 17, 2010.**

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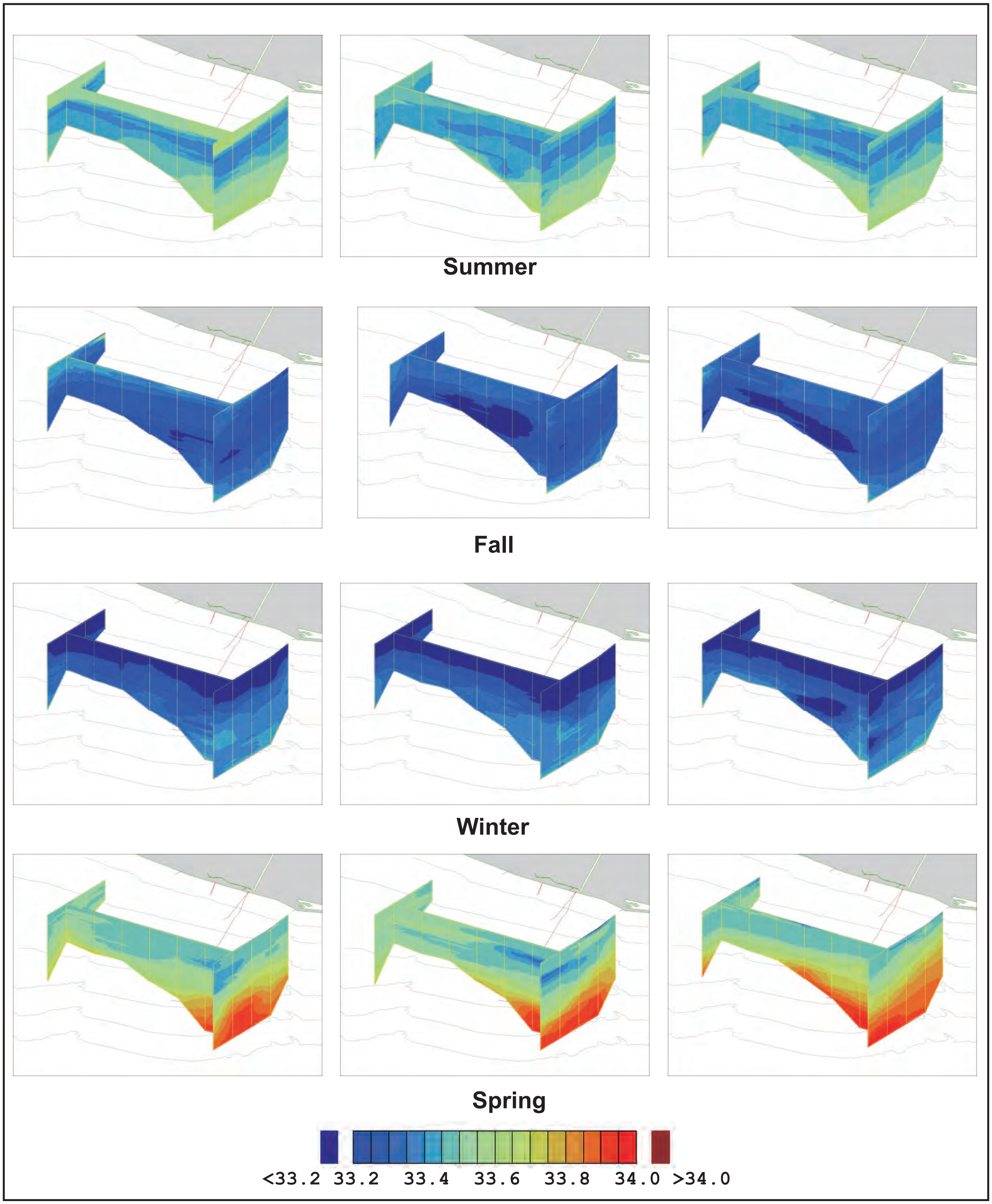

Figure 3-13. **Seasonal patterns of salinity (psu) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

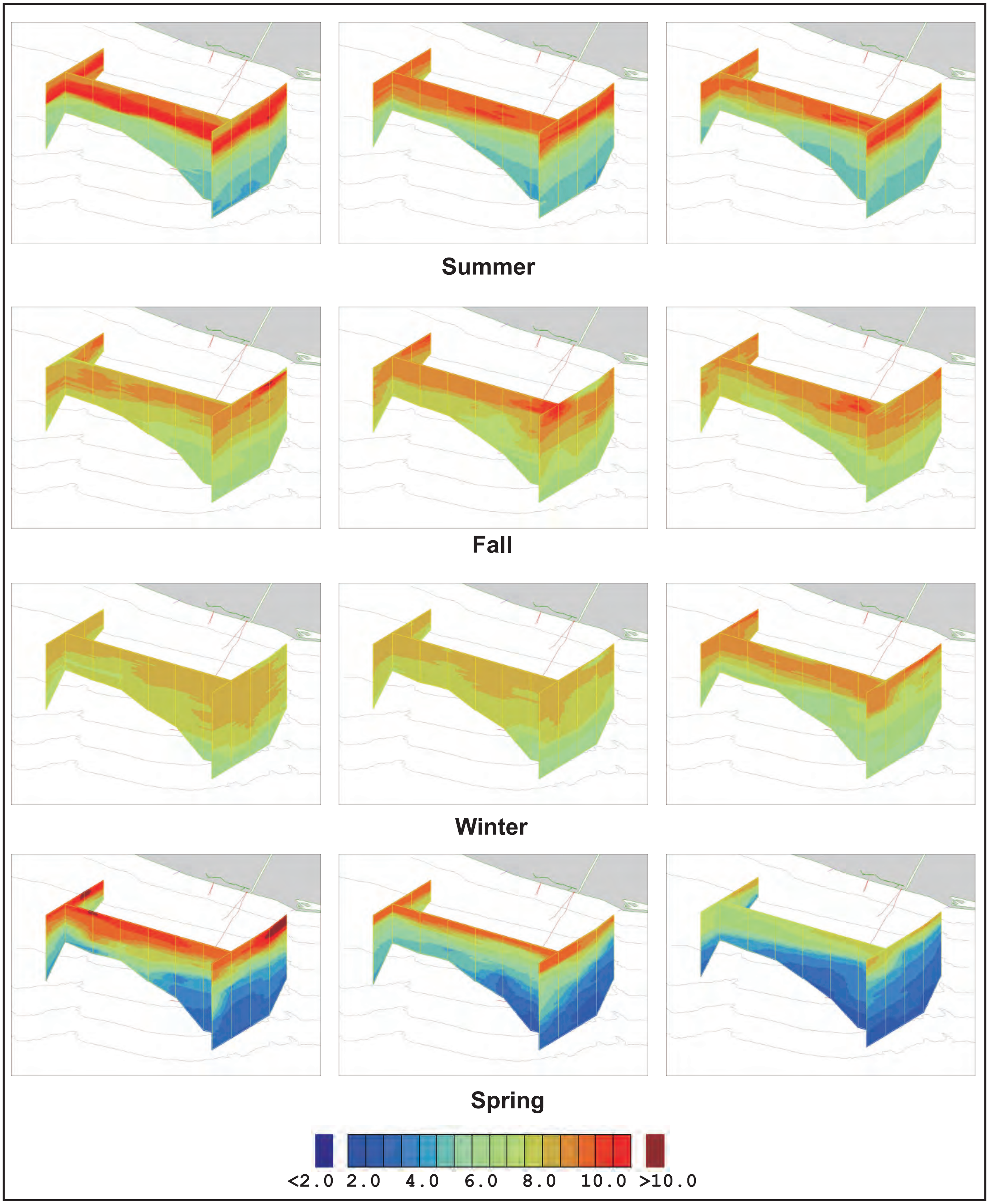

Figure 3-14. **Seasonal patterns of dissolved oxygen (mg/L) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

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elevated chlorophyll-*a*. While not as evident as previous monitoring years (e.g., 2008-09), there was a subsurface DO maximum in the summer associated with the presence of phytoplankton (as measured by chlorophyll-*a* fluorescence); what was different this year was the elevated DO levels in the upper 15 m as compared to the prior year. The 2009-10 DO patterns and values were consistent with regional values and within the range of long-term monitoring results (summarized in OCSD 1996b, 2004).

Dissolved oxygen and pH were well correlated (r=0.875) so the spatial and seasonal pH patterns nearly mirrored DO (Table 3-2, Figure 3-15). Values decreased from the surface to the bottom. Fall had the highest average pH and spring the lowest. Overall, less than 0.5% of the pH values were below 7.5, a level at which slight reductions in hatching and juvenile survival of copepods and euphausids have been measured (Peterson, et al. 2010). These general patterns for pH were consistent with 2009-10 regional data as well as with past monitoring years (e.g., OCSD 1996a, b, 2004–2010).

Plume Related Changes

None of the major DO and pH spatial patterns were plume related. However, minor, localized decreases in DO and pH (e.g., less than 0.5–1.0 mg/L and 0.1–0.2 units, respectively) occurred below the pycnocline or at mid-depth during summer and fall. These patterns were primarily due to secondary entrainment of deeper water caused by the rising plume (Figure 3-12). Since the plume water is “fresher” than the receiving water, it is more buoyant and rises in the water column. When it rises, it can entrain deeper oceanic waters that have lower DO. Overall compliance with criterion C.4.a (10% depression from background) was high (over 95%, Chapter 2) while the pH criterion (C.4.b) was fully met this year.

<u>Water Clarity</u>

Percent Transmissivity

During 2009-10, water clarity showed considerable variability with depth and season (Table 3-2) with the highest maximum and depth-averaged transmissivity (clearest water) occurring in the fall. The lowest values occurred in winter extending from the surface down to 60 m. This is most likely due to the significant rainfall (~9 in) that occurred in the three months prior to the survey. Additionally, phytoplankton, plume entrainment, upwelling, and resuspension of sediments in the Newport Canyon contributed to this variability. These effects were apparent in the patterns of decreased transmissivity throughout the year (Figure 3-16). Generally, transmissivity data was comparable to regional values with two exceptions for 2009-10. Those were a lower average transmissivity in the Districts study area during the winter and higher minimum values in all seasons as compared to the CBWQ (Table 3-1).

Secchi and Water Color

Spatial and temporal patterns in Secchi depth and water color data were generally consistent with the transmissivity results. The lowest water clarity (shallowest Secchi depth and highest Forel/Ule values) occurred at the nearshore stations and in the Newport Canyon (Station C2) with progressively clearer water with increasing distance offshore during most surveys (Figures 3-17 and 3-18). The clearest water was in the fall and the most turbid in the winter and spring.

Photosynthetically Active Radiation (PAR)

Bivariate plots of quarterly averaged PAR data showed expected patterns of rapid reduction of light within the upper 10 m of the water column (Figure 3-19). For 2009-10, the range of depths for the 10% light level was between 8–16 m, except for the fall quarter where it exceeded 20 m. The

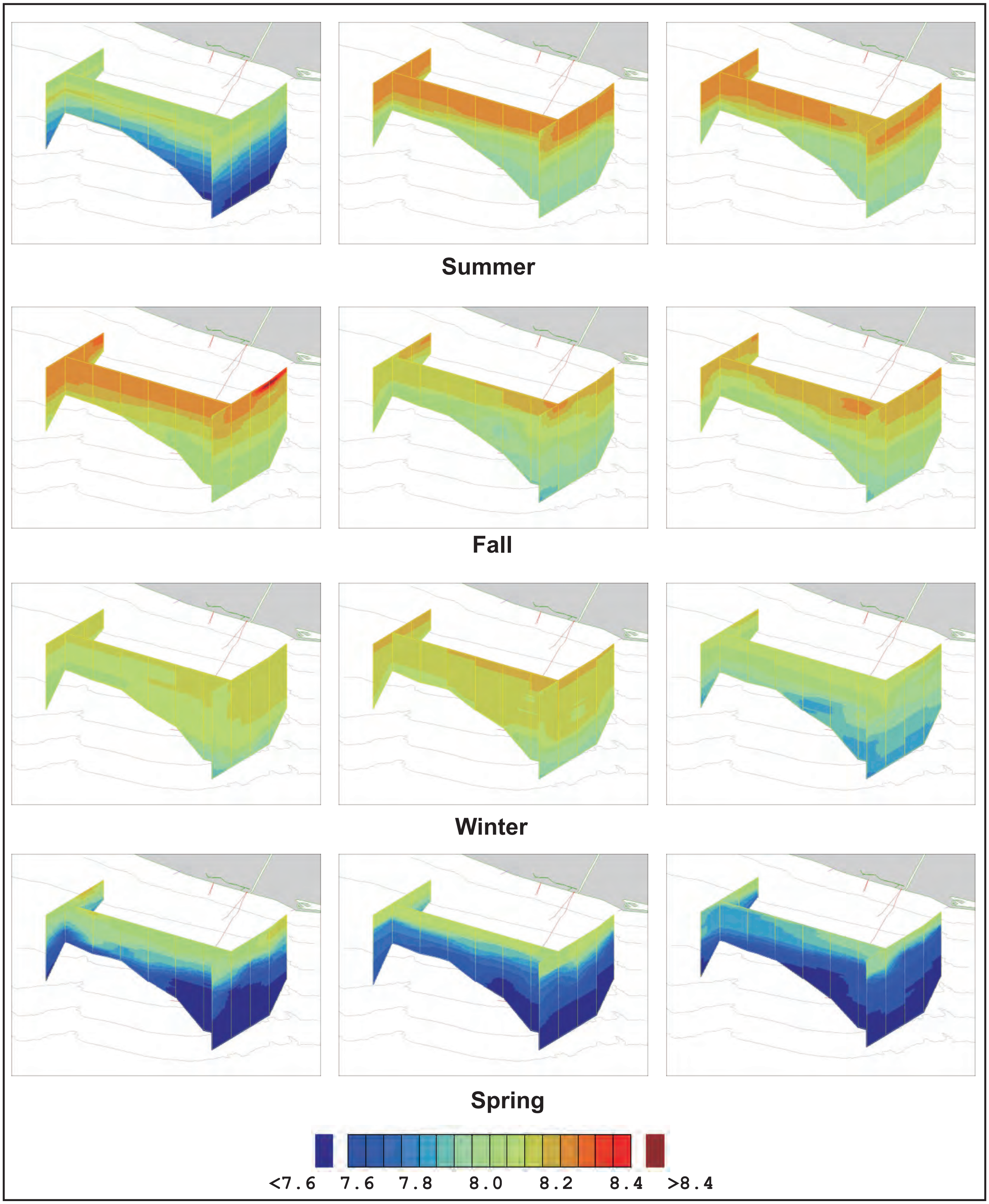

Figure 3-15. **Seasonal patterns of pH for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

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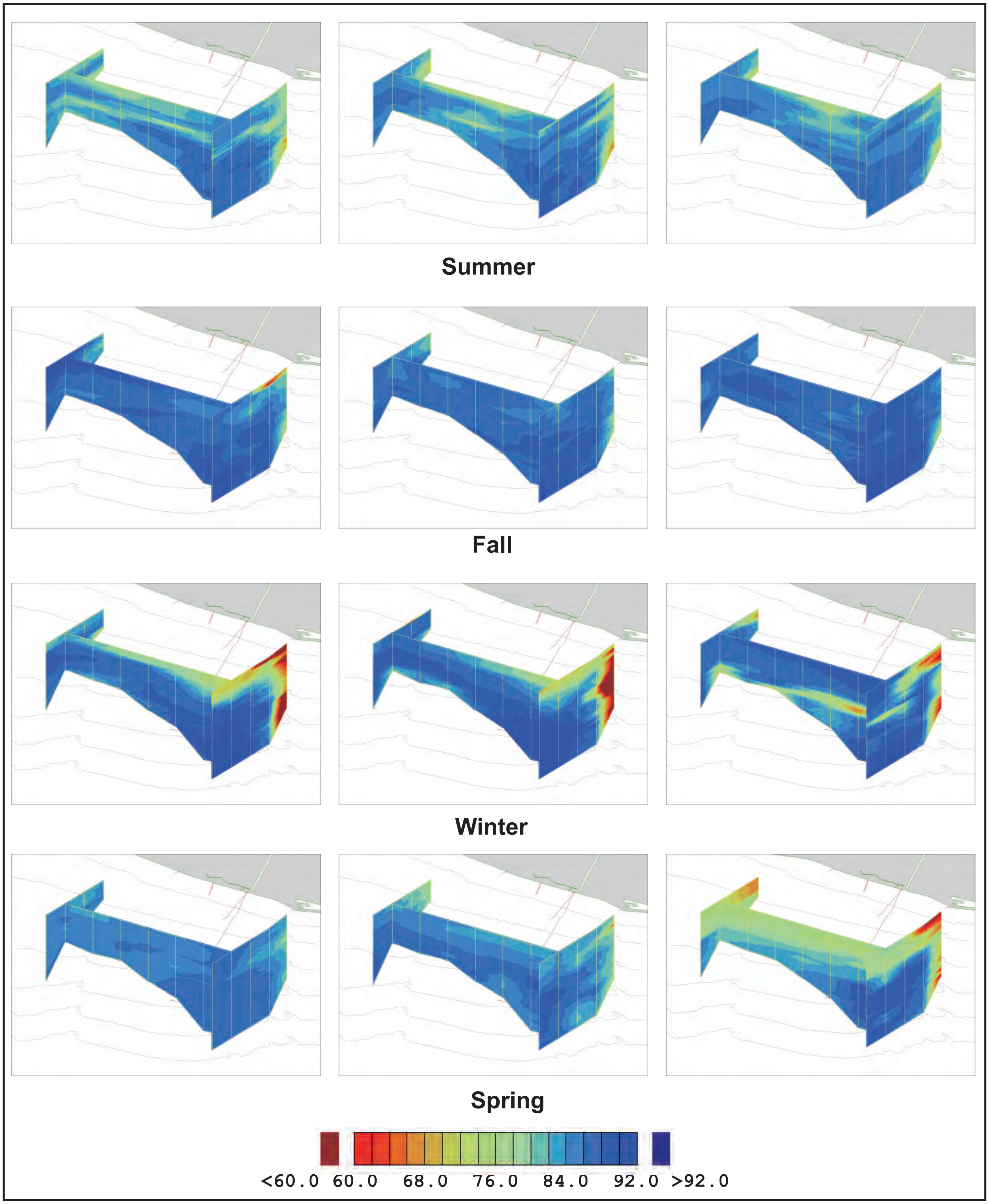

Figure 3-16. **Seasonal patterns of light transmission (%) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

Orange County Sanitation District, California.

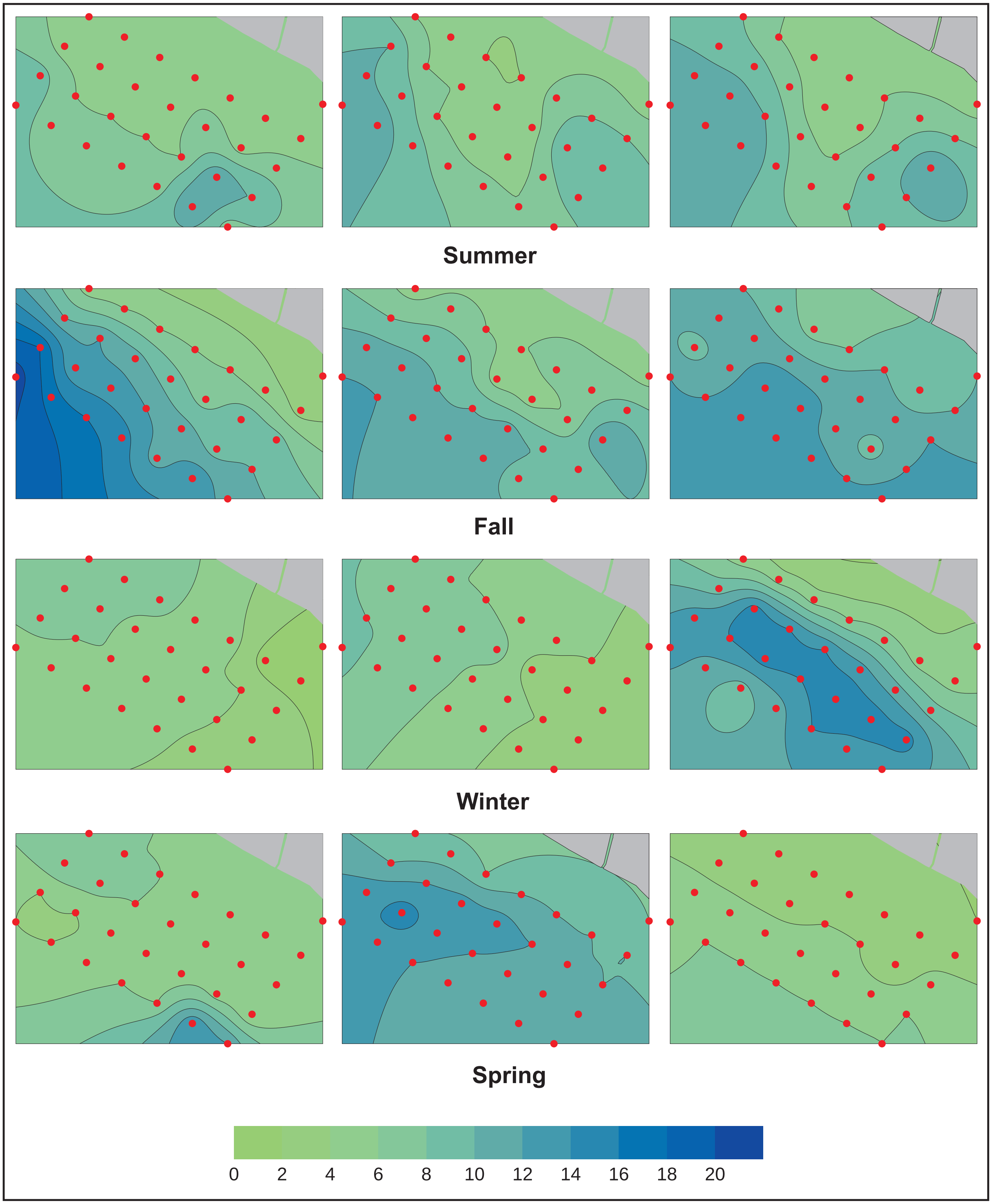

Figure 3-17. **Seasonal patterns of secchi depth (m) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010). Higher secchi values indicate clearer water.**

Orange County Sanitation District, California.

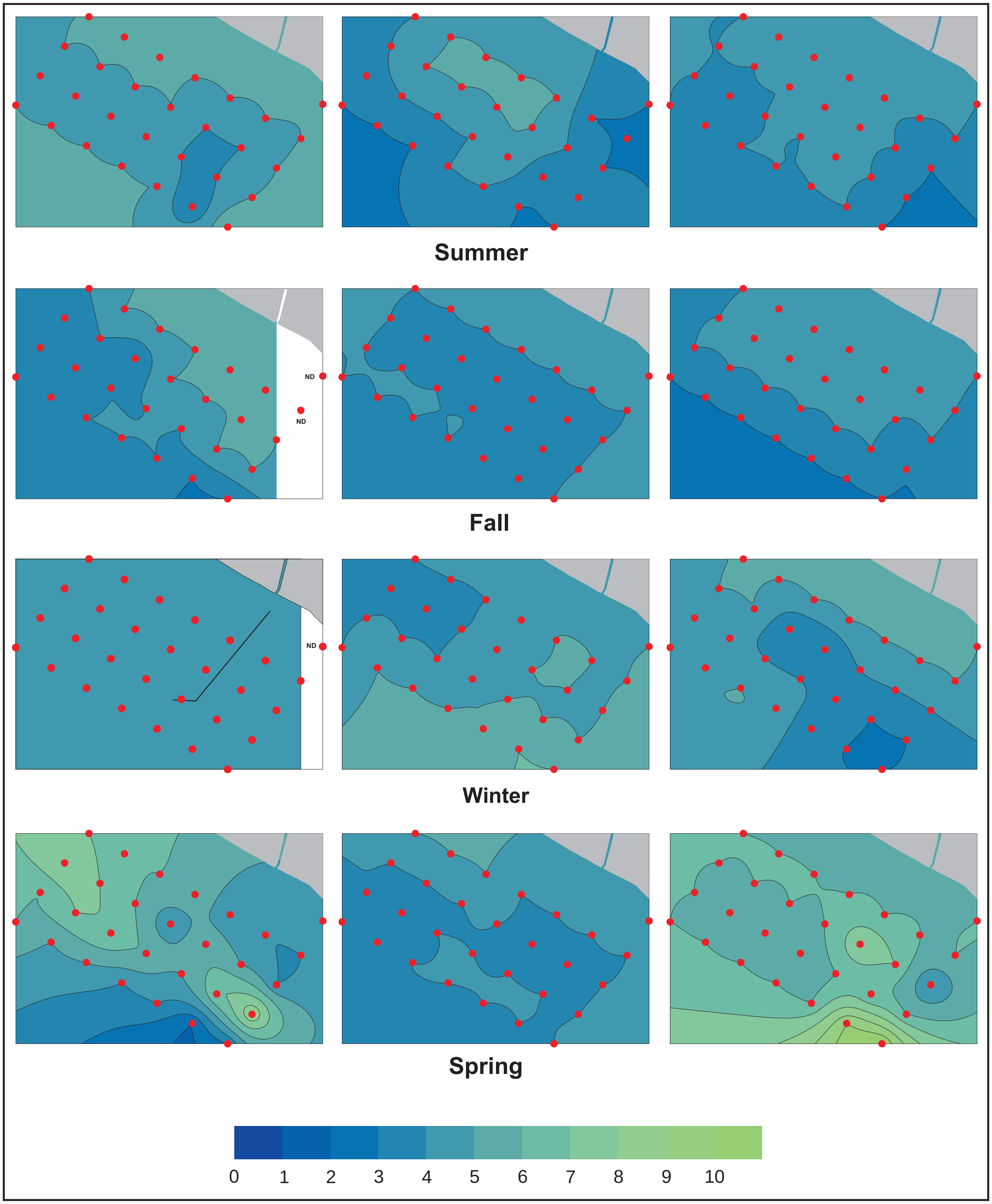

Figure 3-18. **Seasonal patterns of water color (Forel/Ule) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010). Lower water color values indicate clearer water.**

Orange County Sanitation District, California.

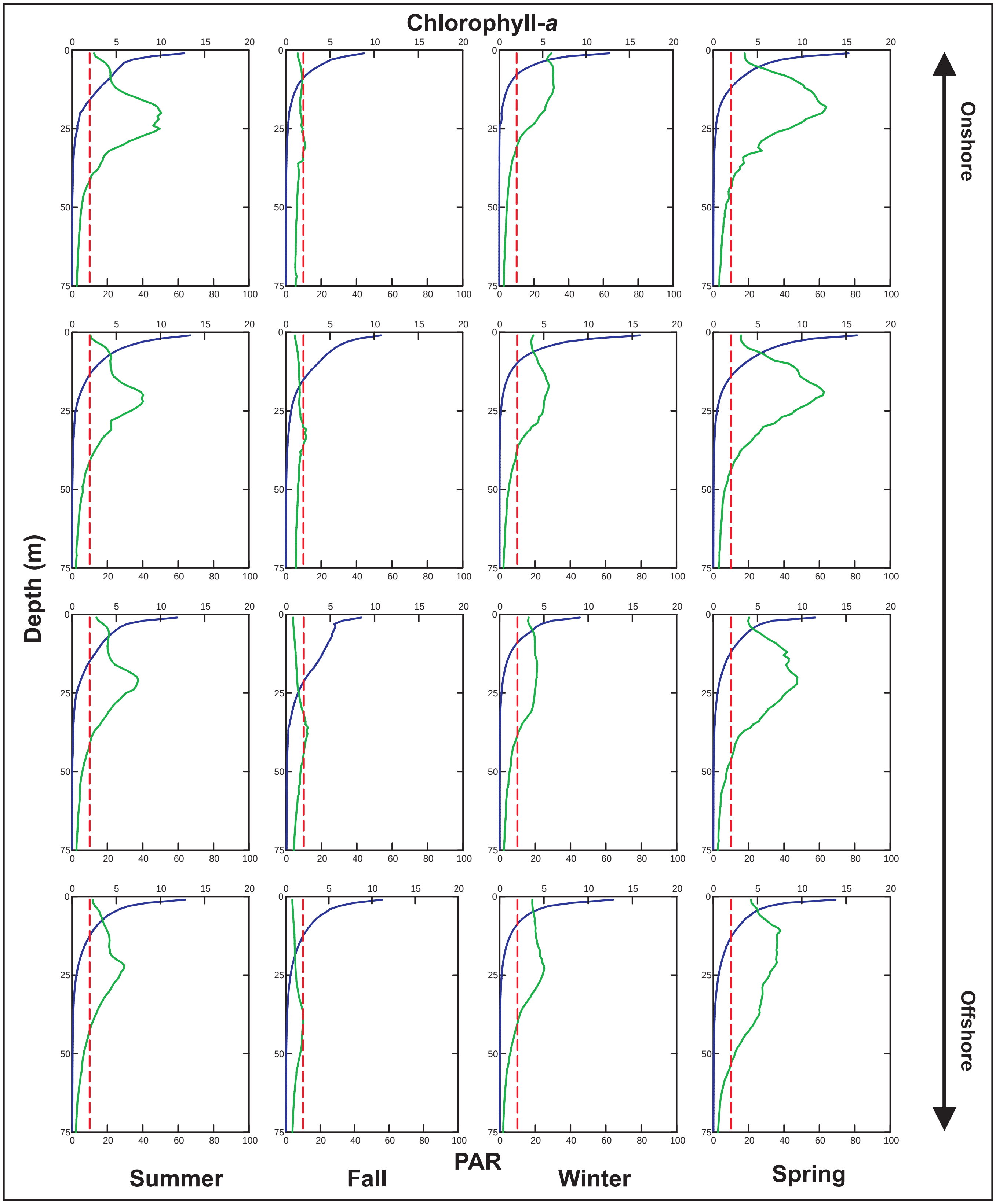

Figure 3-19. **Quarterly average chlorophyll-*a* fluorescence (μg/L; green line) and photosynthetically active radiation (PAR; μE/(cm^2·sec); blue line) with depth for summer (August 2009), fall (November 2009), winter (February 2010), and spring (May 2010). Red dashed line represents the 10% light penetration level.**

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shallowest depth and narrowest range (8-9 m) for the 10% light level was in winter. Fall, also had the widest range at 9–22 m.

An analysis of 2009-10 Secchi depth and PAR data showed that both the 10% and 1% PAR light levels positively correlated to Secchi depth (0.39 and 0.72, respectively). Spatial patterns also showed a closer affinity between 1% light levels and Secchi depth than to the 10% light levels (Figure 3-20). Intuitively, this makes sense since both the 1% PAR and Secchi depth measure a more comparable light extinction endpoint.

Chlorophyll-a

Measurements of chlorophyll-*a* fluorescence, taken as a surrogate to collecting discrete samples for phytoplankton, are an indicator of phytoplankton abundance and biomass in coastal waters. While chlorophyll-*a* does not distinguish between the source of chlorophyll (terrestrial versus marine) or plankton species, high concentrations indicate high phytoplankton biomass and reflect a potential response to nutrient loads. For 2009-10, spring had the highest depth-averaged mean values, while fall had the lowest. Elevated chlorophyll-*a* was measured subsurface (16–30 m) in the summer and from the surface down to 45 m in the winter and spring (Table 3-2). Subsurface maxima were evident throughout the year, but this pattern muted in the fall (Figures 3-19 and 3-21).

For most quarters, the chlorophyll-*a* peak was below the 10% light level and showed no relationship with PAR (Figure 3-19). The 10% light level generally corresponds to minimum levels needed by phytoplankton for photosynthesis. Subsurface layering patterns also correspond to typical sinking depths for phytoplankton (Hardy 1993).

Plume Related Changes

Chlorophyll-*a*, Secchi depth, water color, and PAR showed no patterns relative to the outfall, therefore criteria C.3.b was met. Transmissivity showed a slight reduction in light transmittance (<10%) below the pycnocline or at mid-depth (Figure 3-16). These reductions were typically below the 10% light level as defined by PAR (Figure 3-19), so the overall effect on the "natural" light criterion (C.3.c) was minimal and not ecologically significant (see Chapter 2).

<u>Nutrients, Bacteria, and Floatables</u>

Ammonium

Ammonium concentrations in 87% (n=2212) of the samples collected in 2009-10 were below the detection level (0.2 mg/L). Out of the 13% of samples with detectable ammonium, 64% (n=185) occurred below 20 m. Highest values throughout the year were measured below 15 m (Table 3-2) The maximum ammonium value (0.46 mg/L) was comparable to the previous year (0.41 mg/L), but nearly twice the maximum from the last 2 years prior (0.22 mg/L and 0.26 mg/L, respectively). Each survey showed elevated ammonium concentrations due to the discharge; however, these values remained well below the ocean surface (Figure 3-22). Overall, the spatial patterns and concentration ranges were similar to prior year's results (OCSD 2004–2010). Local ammonium values were significantly higher in the fall and winter, but lower in the spring as compared to regional values (Table 3-1). However the limited extent and lack of correspondence with chlorophyll-*a* and low probability of toxicity indicted that compliance with the nutrient criterion (C.4.f) was met.

Bacteria

Since disinfection began in August 2002, measures of FIBs [total coliform, *Escherichia coli* (*E. coli*), and enterococcus] have been greatly reduced. For 2009-10,

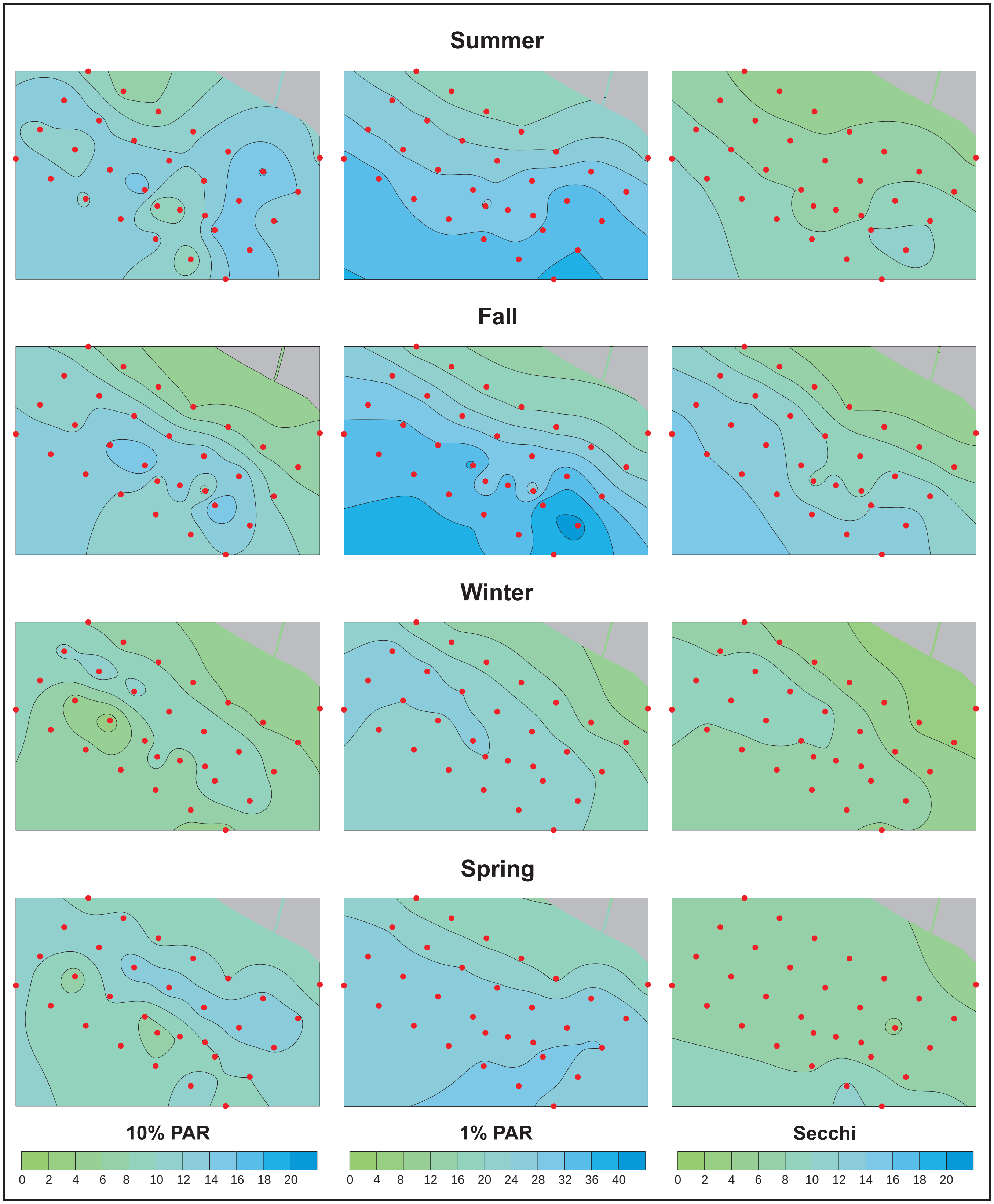

Figure 3-20. **Comparisons of quarterly average depths (m) for 10% PAR, 1% PAR, and Secchi for summer (August 2009), fall (November 2009), winter (February 2010), and spring (May 2010).**

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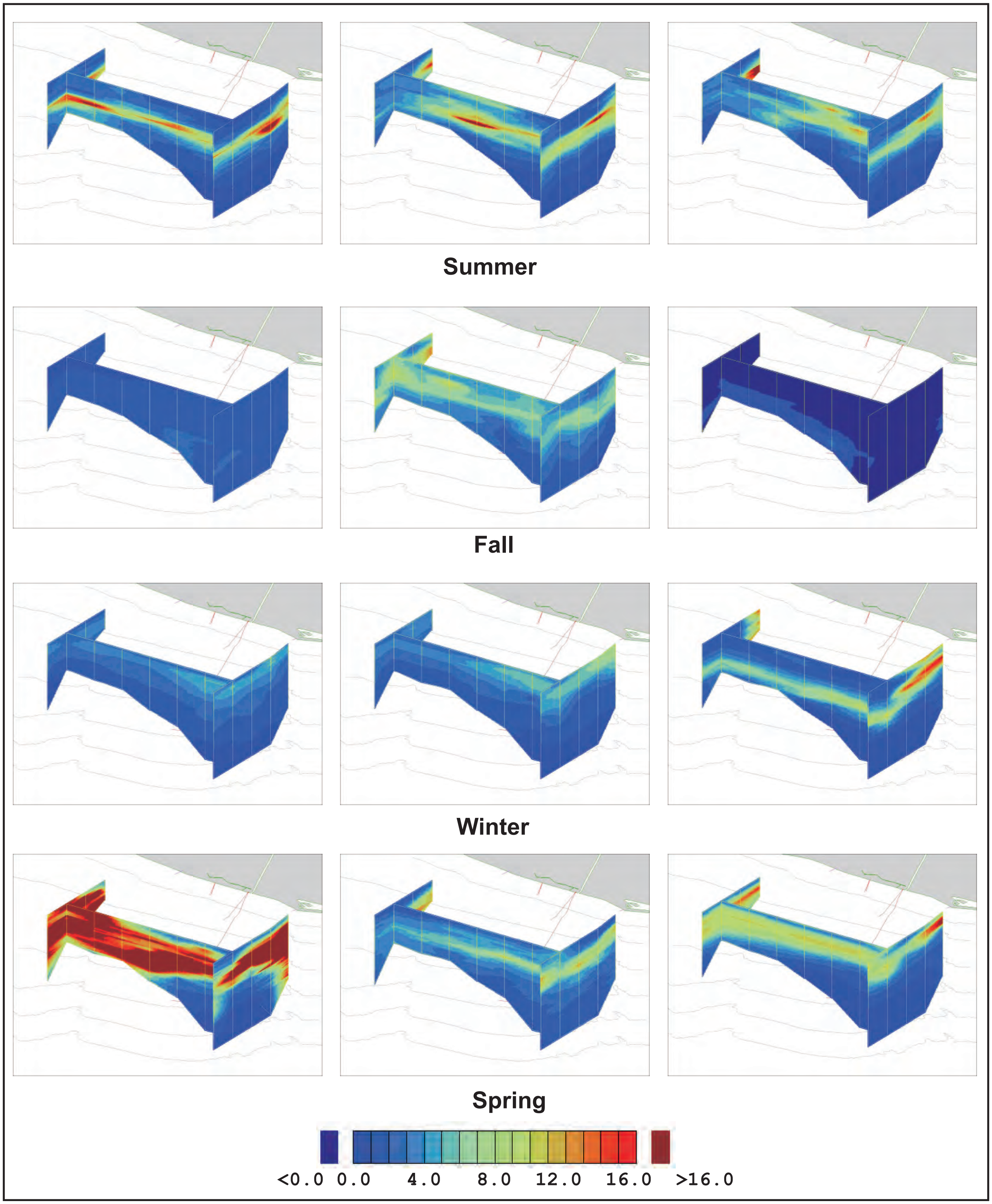

Figure 3-21. **Seasonal patterns of chlorophyll-*a* (μg/L) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

Orange County Sanitation District, California.

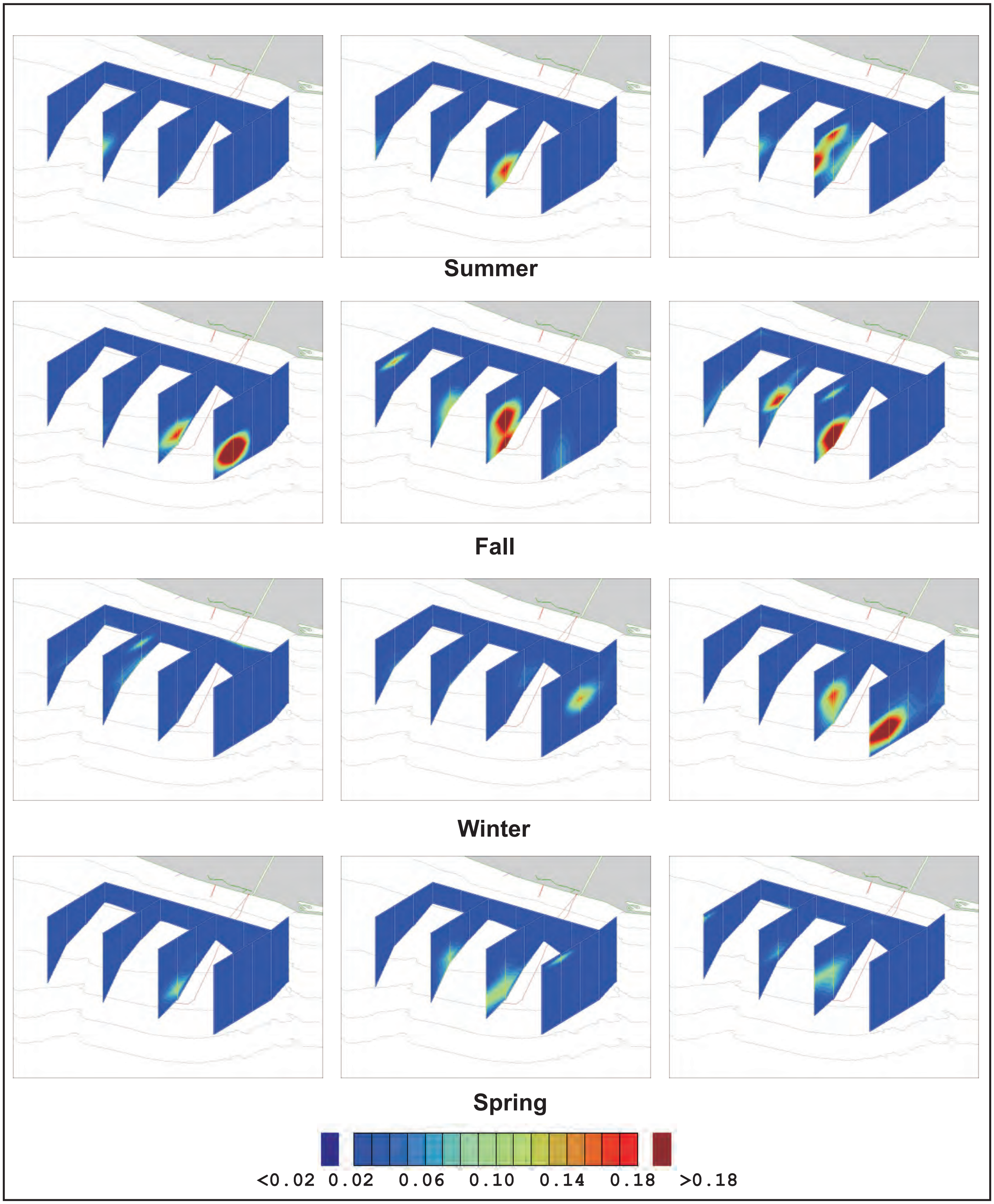

Figure 3-22. **Seasonal patterns of ammonia (mg/L) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

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three additional outfall and near–outfall stations were sampled for bacteria in order to better define the outfall gradient. All three FIBs were correlated (r values ranged from 0.787 to 0.831) so total coliform bacteria, which had the highest counts, was used as a "worse-case" analysis of the impact of bacteria to the receiving water. Elevated total coliform bacteria typically occurred below 15 m, with the exception of the winter season when total coliform were elevated in the upper 15 m of water. This is most likely due to storm related runoff, since fecal coliform and enterococcus bacteria did not show this winter surface expression (Table 3-2). Spatially, FIBs occurred primarily near the outfall with no evidence of impact at the Rec-1 stations along the 20 m isobaths (Figures 3-23, B-8, B-9, and B-10). Most total coliform samples (64%) were below the detection limit of 10 MPN/100 mL with just over 3% greater than 1,000/100 mL, and <1% greater than 10,000/100 mL. All offshore criteria for bacteria (C.2.a.1 and C.2.a.2) were met.

Floatables

Grease and floatables were used, respectively, to evaluate potential effects from the wastewater discharge to beaches and offshore surface waters. No beach station had any observable grease during 2009-10 (Table B-10). In addition, there were also no offshore observations of floatable material that affected water clarity or showed any patterns related to the discharge (Tables B-11 and B-12). These results demonstrated compliance with criterion C.3.a and were consistent with finding from previous years (OCSD 2004–2010).

CONCLUSIONS

Results from the District's 2009-10 water quality monitoring program detected only minor changes in measured water quality parameters related to the discharge of wastewater to the coastal ocean, which is consistent with previously reported results (OCSD 1986–2010). Plume-related changes in temperature, salinity, DO, pH, and transmissivity were measurable beyond the initial mixing zone during some surveys, but usually extended only into the nearfield stations, typically <2 km away from the outfall. None of these changes were determined to be environmentally significant since they fell within natural ranges to which marine organisms are exposed (Allen et al. 2005; Chavez et al. 2002; Hsieh et al. 2005; Jarvis et al. 2004; OCSD 1996 and 2004; Wilber and Clarke 2001).

Prevailing ocean currents and stratification are two of the primary factors in determining the location of the discharged wastewater plume. Current flows for 2009-10 were oriented along the coast (parallel to the depth contours) and had weak, short-lived shoreward flows. Currents were more uniform than the previous year, but transport directions were consistent with long-term patterns (Nobel et al. 2009, SAIC 2009).

The use of CDOM data as a plume tracer was not available for most of the year, so salinity was used to identify the discharge plume. While salinity was reduced near the outfall during all surveys, the ability to see any potential salinity discharge effects away from the outfall was affected by the presence of naturally occurring lower salinity water mass.

Oxygen and pH measurements showed expected natural patterns of decreasing values with depth and no outfall signal. Exceptions included some minor affects due to the secondary entrainment of deeper lower oxygen water caused by the rising effluent plume. These results were consistent with predicted changes in DO and pH levels using a dilution value of 180:1 (less than 0.03 mg/l and 0.003 units,

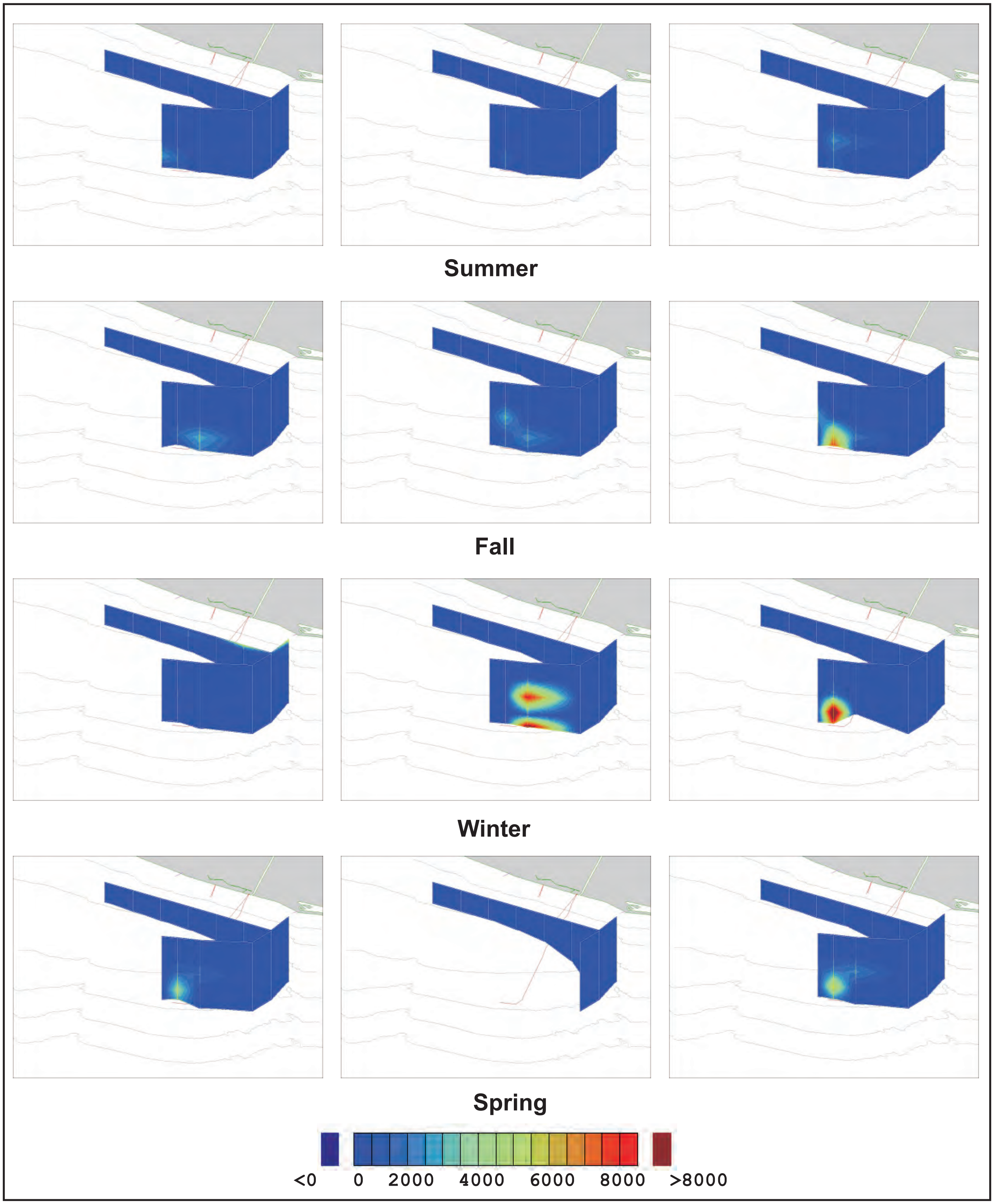

Figure 3-23. **Seasonal patterns of total coliforms (MPN/100mL) for summer (August 4, 10, 11, 2009), fall (November 2, 4, 5, 2009), winter (February 8, 9, 17, 2010), and spring (May 4, 12, 26, 2010).**

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respectively; OCSD 2002). Mean surface DO values were above 8 mg/L with peak values as high as 13 mg/L. Although subsurface DO dipped to as low as 2.4 mg/L, average DO levels at depth exceeded 3 mg/L, and these lower values were attributed to naturally occurring upwelling.

The District obtains two measures of water clarity. One is light transmission, which measures the amount of artificial light available at a particular depth (e.g., 5 m) as measured by a light transmissometer throughout the water column. The other is the amount of natural light (light penetration) that enters the water and reaches various depths. Light penetration represents the cumulative impacts of particles throughout the water column and is measured using Secchi disk depth and PAR measurements.

Light transmissivity was more variable, than other measured parameters (e.g., salinity), as it is affected by particles from multiple sources, such as the disturbance of near-bottom sediments due to waves and currents (resuspension), phytoplankton blooms, rainfall runoff, and the discharge plume. During 2009-10, strong decreases in light transmittance (upwards to 30%) were associated with the Newport Canyon while much smaller changes (less than 10%) associated with the discharge plume. In all surveys, chlorophyll-*a* and, putatively, the resuspension of bottom sediments within the Newport Canyon had the greatest impacts on water clarity.

Both Secchi depth and the 1% PAR value showed similar spatial patterns of reduced water clarity nearshore compared to offshore waters. However, the 10% PAR showed a better relationship with the subsurface chlorophyll-*a* maxima in the previous year than during the current one, when subsurface peak was located below the 10% light level.

Direct measures of the wastewater plume were nutrients (ammonium) and bacteria. Maximum ammonium concentrations were, respectively, 10 and 15 times less than the COP receiving water objectives for chronic (4 mg/L) and acute (6 mg/L) toxicity to marine organisms (OCSD 2004). Average values at all depths and for all seasons were several hundred times lower than these objectives. Only 13% of the ammonium samples collected were above the detection limit of 0.02 mg/L and the vast majority of these (64%) were found below 20 m. This subsurface distribution was limited primarily to within 2 km of the outfall. The low levels and limited distribution of ammonium along with the lack of association with chlorophyll-*a* suggest that the concentrations seen were not environmentally significant.

Prior to disinfection, FIB levels were the primary plume tracer of the discharged wastewater plume. Since disinfection began in August 2002, offshore bacterial concentrations have remained low and predominately below measurement detection (10 MPN/100 mL). This was the case for 2009-10 where only 3% of the total coliform measurements were greater than 1000/100 mL while 64% were below 10 MPN/100 mL. Enterococcus and *E. coli* showed similar patterns, but at proportionally much lower counts (e.g., 1 to 2 orders of magnitude).

Outfall effects to the receiving water continue to be relatively small and within the ranges of natural variability for the study area. Plume effects occurred primarily at depth, even in the winter when temperature differences between the surface and subsurface were reduced. In summary, the results support the conclusion that the discharge is not greatly affecting the receiving water environment and that beneficial uses were maintained.

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