TMDL Monitoring for Eutrophication in Famosa Slough

Final Report

In response to
Investigation Order
R9-2006-0076

April 10, 2009

City of San Diego

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Final Report

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

$CBOD_5$	Carbonaceous biochemical oxygen demand
City	City of San Diego
DO	dissolved oxygen
EMC	event mean concentration
FoFS	Friends of Famosa Slough
MDL	minimum detection limit
MES	mass emissions station
Order	Investigation Order R9-2006-0076
QA	quality assurance
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
Regional Board	Regional Water Quality Control Board
SCCWRP	Southern California Coastal Water Research Project
Slough	Famosa Slough
Southland	Southland Surveying, Inc.
SRP	soluble reactive phosphorus
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
UCSB	University of California, Santa Barbara
USGS	United States Geological Survey
WQO	water quality objective

FAMOSA SLOUGH EXECUTIVE SUMMARY

This report provides an overview of the water quality monitoring conducted in Famosa Slough (Slough) to comply with San Diego Regional Water Quality Control Board (Regional Board) Investigation Order R9-2006-0076 (Order) dated July 19, 2006. The Slough was one of the seven lagoons identified in the Order. The Slough was identified as impacted by eutrophication. The results of this water quality investigation complement those currently (2009) being completed by the Southern California Coastal Research Project (SCCWRP) to investigate sediment in the Slough. Both water quality and sediment investigations will then be used to model hydrodynamics within the Slough.

The Slough is a 37-acre wetland with a watershed of approximately 370 acres (0.58 mi^2) located adjacent to the San Diego River in the City of San Diego (City). The two main flow inputs into the Slough are the San Diego River and the surrounding watershed. Inputs into the Slough from storm drains are identified within the Order as potential nutrient sources contributing to eutrophication of the Slough. However, the results of this study indicate that there was no evidence of eutrophication in the water column of the Slough and little indication that San Diego River inputs contributed to eutrophication. There was also no evidence of low dissolved oxygen (DO) levels in the Slough water.

Monitoring of the Slough (October 2007–October 2008) occurred at the main storm drain, the mouth of the Slough, at a midpoint of the Slough, and at 15 transect sites throughout the main body of the Slough and adjacent channel.

A number of key contaminants of concern were monitored during these activities, including assessment of general water quality, nutrients concentrations, and sediments. Assessments were conducted during both dry weather and wet weather.

The results of this monitoring program are presented below in terms of the key management questions posed in the Order.

- **Question 1 – What are the Concentrations of Contaminants at the Base of the Watershed?** Contaminant concentrations were recorded at the base of the watershed during wet weather and dry weather. During wet weather, concentrations of contaminants of concern were below Water Quality Control Plan, (Basin Plan) for the San Diego Region Basin Plan, Multi-Sector General Permit, and Environmental Protection Agency (EPA) water quality objectives (WQOs) for all parameters, with the exception of one total suspended solid (TSS) sample, which was above the Multi-Sector General Permit WQO of 100 mg/L. During the four dry weather monitoring events, contaminant concentrations at the mass emission site (MES) were relatively high. However, flow volumes were very low and therefore the impact of the storm drain on the Slough was minimal.

- **Question 2 – What is the Daily Rainfall?** Rainfall was monitored continuously throughout a 12-month period from October 2007 through October 2008. A total rainfall of 7.02 inches was recorded during this period.

- **Question 3 – What is the Total Annual Flow and Mass Loads of Contaminants from the Watershed into the Slough?** Mass loads and total annual flows were calculated based on pollutant concentration and loads from the MES. The average storm event loads into the Slough from the MES and average dry weather loads were calculated. The highest contributed load was found to be TSS which averaged approximately 400 pounds during a storm event and approximately 18,000 pounds annually from dry weather. Nutrient loads were considerably lower and were not indicative of a significant eutrophication issue in the Slough.

- **Question 4 – What are the Concentrations of Contaminants at the Ocean Inlet Before it Enters Famosa Slough?** The contaminant concentrations were assessed for the Slough Segment Site and the Ocean Inlet Site. This analysis showed that there was no difference between the two sites, with the exception of chlorophyll-a, which was higher in the Slough during the Fall 2008 index period. In assessing all other constituents of concern, the dry weather flow from the San Diego River does not appear to impact the Slough.

- **Question 5 – What are the Concentrations of Contaminants in Famosa Slough? Do They Exceed Water Quality Objectives?** Contaminant concentrations within the main body of the Slough were measured during four index period sampling events which occurred during Winter, Spring, Summer, and Fall 2008. Nutrient concentrations did not exceed WQOs during any of the index period sampling events within the Slough.

- **Question 6 – What are the Dissolved Oxygen Concentrations in Famosa Slough?** DO was recorded within the Slough during each index period and continuously at the Slough Segment Site and the Ocean Inlet Site. The Basin Plan WQO for DO states that DO shall be above 5 mg/L (Regional Board, 1994). DO concentrations were above the Basin Plan WQO throughout the Slough during daylight hours. DO dropped below Basin Plan levels during the night. DO was never below Basin Plan WQOs for prolonged periods of time.

Recommendations based on the results of this study are presented below.

- The total dissolved nitrogen data should not be used for assessment modeling due to observed filter contamination.
- Those samples processed by University of California, Santa Barbara (UCSB), which exceeded holding times, should not be used in the total maximum daily load (TMDL) calculation.
- All other data collected between October 2007 and October 2008 meet the quality control (QC) and quality assurance (QA) requirements set forth in the approved quality assurance project plan (QAPP) and can therefore be used by the Regional Board for calibration and validation of watershed and hydrological models.
- Periodic monitoring of the Slough and coordination with the Friends of Famosa Slough (FoFS) would be beneficial to monitor the long-term condition of the Slough.
- Certified laboratories should be used for any future TMDL monitoring.

1.0 INTRODUCTION

The purpose of this report is to provide an overview of the Slough monitoring conducted during the 2007–2008 wet weather monitoring season and seasonal monitoring periods up to September 2008. The monitoring was conducted in response to Regional Board Order dated July 19, 2006. These data were collected in order to support the development of a TMDL for eutrophication in the Slough. The collection of water quality data is one of several components in the TMDL development. The other components include the collection of sediment quality data (conducted by the SCCWRP), the development of the estuarine model, and the collection of hydraulic information on tidal flows and elevations.

The Slough is a 37-acre wetland located adjacent to the San Diego River in the City (Figure 1-1). The watershed area draining to the Slough is approximately 370 acres (0.58 mi^2) and is comprised of predominantly residential and commercial land uses (Figure 1-2). West Point Loma Boulevard divides the Slough into a northern section and a southern section. The northern section is 12 acres and is comprised of a sinuous channel bordered by apartment complexes on the west and east and is tidally connected to the San Diego River channel by a culvert running under Interstate 8, west of Interstate 5. The southern section is considered the Slough's central basin and is bordered by Famosa Boulevard to the west.

The two main inputs into the Slough are the San Diego River and the surrounding watershed. A portion of the runoff water that flows through the San Diego River channel is forced by tidal action to flow into the Slough. While this flow represents a small fraction relative to seawater from the Pacific Ocean, flows from the San Diego River can enter the Slough during rainstorm events and incoming tides, which have the potential to be a significant input following a rainstorm. Runoff from the surrounding watershed provides a small but continuous flow of urban runoff into the Slough through 19 separate storm drains. Water treatment ponds on the south and southeast sides of the Slough collect dry weather urban runoff, trash, and sediment prior to discharge to the Slough. Collectively, the basins provide passive treatment for approximately 130 acres of the drainage area, approximately one third of the watershed.

All of these hydrodynamic components are critical to the development of a TMDL. This report focuses on the collation of water quality data and complements data collected by other parties for submittal to the Regional Board.

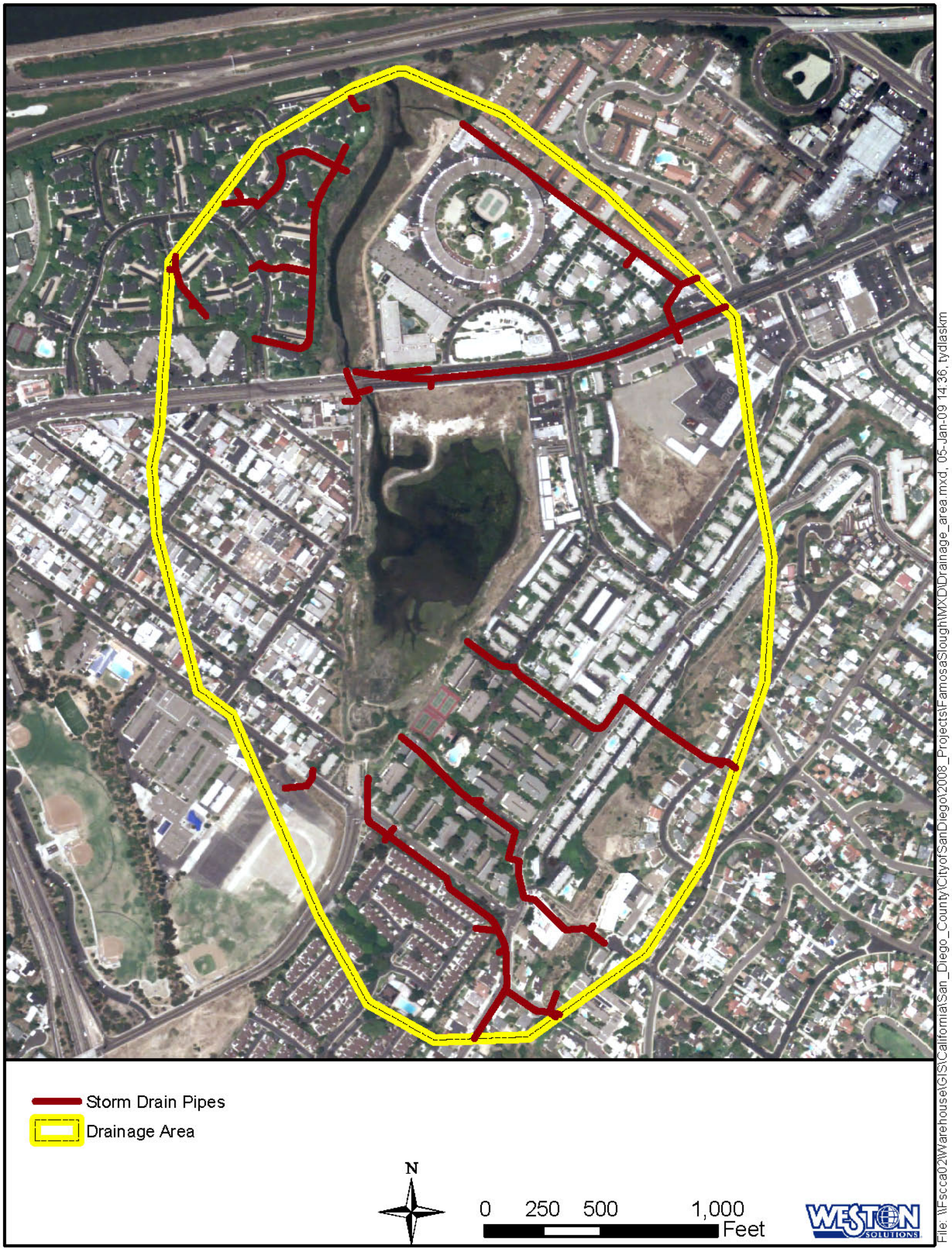

Figure 1-1. Famosa Slough Drainage Area

Figure 1-2. Famosa Slough Land Use

1.1 Investigation Order

The Order, *Owners and Operators of Municipal Separate Storm Sewer Systems, California Department of Transportation, Hale Avenue Resource Recovery Facility, and North County Transit District Responsible for the Discharge of Bacteria, Nutrients, Sediment, and Total Dissolved Solids into Impaired Lagoons, Adjacent Beaches, and Agua Hedionda Creek*, requires monitoring in each of the seven lagoons listed in the Order. The Slough was one of the seven lagoons identified and was listed for eutrophication.

The Order requires the responsible dischargers to the Slough to conduct specific water quality monitoring at the base of the watershed and within the Slough. Water quality monitoring data reports were required to be submitted to the Regional Board for the purposes of parameterizing, calibrating, and validating the watershed and lagoon models in development. The models will be used to estimate existing loading, to develop TMDLs, and to identify sources of pollutants. The responsible dischargers to the Slough are the City and California Department of Transportation (Caltrans).

Several addendums to the original Order, outlined below, subsequently followed during the development and execution of this project, and relevant items to the Slough are described below. Copies of the Order and each addendum are provided in Appendix A.

- **Addendum 1 (November 1, 2006)** – Addendum 1 allowed for postponing the workplan due dates by one month so long as field activities were initiated by October 1, 2007.
- **Addendum 2 (June 21, 2007)** – The workplan written by the SCCWRP, *San Diego Coastal Lagoons TMDL Monitoring Workplan*, was received by the Regional Board on June 18, 2007. This workplan superseded the study questions in *Directive A1.a* through *A1.h3* of the Order. The monitoring requirements of the Order in *Directive A2* through *A8* were superseded by the Monitoring Program Workplan. Finally, quarterly data submittal requirements were refined and specified.
- **Addendum 3 (October 5, 2007)** – Addendum 3 specified requirements to conduct ocean inlet land elevation surveys on a periodic basis.

This report was written in response to the Order and supplements the complete data set compiled under the monitoring program due for submittal to the Regional Board in June 2010. This report also presents evaluated data for the purposes of identifying short-term potential management actions that may be taken prior to the outcome of the modeling efforts and technical reports provided by the Regional Board.

1.2 Water Quality or Regulatory Criteria for Famosa Slough

Water chemistry results were compared to the Basin Plan (SDRWQCB, 1994) for the San Diego Region, Title 40 of the Code of Federal Regulations (Part 131; Water Quality Standards) (USEPA, 2000a), and the National Pollutant Discharge Elimination System (NPDES) Stormwater Multi-Sector General Permit (USEPA, 2000b).

The Basin Plan for the San Diego Region lists the beneficial uses for the Slough as follows:

- **REC1** (recreational activities involving body contact with water).
- **REC2** (recreational activities involving proximity to water).
- **COMM** (commercial and sports fishing).
- **EST** (estuarine habitat).
- **WILD** (wildlife habitat).
- **RARE** (rare, threatened, or endangered species).
- **MAR** (marine habitat).
- **MIGR** (migration of aquatic organisms).
- **SPWN** (aquatic spawning habitat).
- **SHELL** (shellfish harvesting).

Table 1-1 presents the full list of constituents monitored during this project and the applicable water quality criteria.

Table 1-1. Full List of Constituents and Water Quality Criteria

Analyte	Criteria	Source
Temperature	–	–
Conductivity	–	–
Turbidity	<20 NTU	Basin Plan (SDRWQCB, 1994)
pH	6.5–9.0	Basin Plan (SDRWQCB, 1994)
Total suspended solids (TSS)	<100 mg/L	Multi-Sector General Permit (USEPA, 2000b)
DO	>5.0 mg/L	Basin Plan (SDRWQCB, 1994)
Total nitrogen (TN)	–	–
Total phosphorus (TP)	<2 mg/L	Multi-Sector General Permit (USEPA, 2000b)
Total dissolved nitrogen (TDN)	–	–
Total dissolved phosphorus (TDP)	<2 mg/L	Multi-Sector General Permit (USEPA, 2000b)
Nitrate	<10 mg/L	Basin Plan (SDRWQCB, 1994)
Nitrite	<1 mg/L	Basin Plan (SDRWQCB, 1994)
Ammonia as N	Varied	Basin Plan (SDRWQCB, 1994), USEPA (1989)
Soluble reactive phosphorus (SRP)	–	–
Chlorophyll-a	–	–
Carbonaceous biological oxygen demand ($CBOD_5$)	–	–
%Fines or % sand/silt/clay	–	–
% Organic carbon (OC)	–	–
% TN	–	–
% TP	–	–

– A WQO has not been developed.

The Famosa Slough QAPP listed the WQO for ammonia as 0.025 mg/L as unionized ammonia. The ammonia WQO was based on the San Diego Region Basin Plan, and the excerpt is provided below:

> ***AMMONIA, UN-IONIZED***
> *Ammonia is a pungent, colorless, gaseous alkaline compound of nitrogen and hydrogen that is highly soluble in water. Un-ionized ammonia (NH_3) is toxic to fish and other aquatic organisms. In water, NH_3 exists in equilibrium with ammonium (NH_4^+) and hydroxide (OH^-) ions. The proportions of each change as the temperature, pH, and salinity of the water change.*

Water Quality Objective for Un-ionized Ammonia:
The discharge of wastes shall not cause concentrations of un-ionized ammonia (NH_3) to exceed 0.025 mg/L (as N) in inland surface waters, enclosed bays and estuaries and coastal lagoons.

The Famosa QAPP was written in September 2007. During a review of the applicable benchmarks and WQOs for the San Diego Regional Monitoring Program, the ammonia standard listed in the Basin Plan was determined to be outdated with no reference for the basis of the standard. Conversation Regional Board[1] indicated the plan was based on *Ambient Water Quality Criteria for Ammonia – 1984* (USEPA, 1984).

Because the EPA has updated this document several times, the most recent standards and updates were used. The most recent version is *Ambient Water Quality Criteria for Ammonia (Saltwater)-1989* (USEPA 1989b).

An excerpt from the introduction of this document is provided below:

Section 304(a)(1) of the Clean Water Act of 1977 (P.L. 95-217 requires the Administrator of the Environmental Protection Agency to publish water quality criteria that accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare which might be expected from the presence of pollutants in any body of water, including ground water. This document is a revision of proposed criteria based upon a consideration of comments received from other Federal agencies, State agencies, special interest groups, and individual scientists. Criteria contained in this document replace any previously published EPA aquatic life criteria for the same pollutants.

[1] Pardy, Pers Comm 2008

1.3 Project Basis and Section 303(d) Listing

Under the 2006 Clean Water Act Section 303(d) list of water quality limited segments requiring TMDLs, the Slough and channel are listed as eutrophic, with potential sources identified as non-point discharges (SDRWQCB, 2006). This 37-acre Slough and channel are scheduled for TMDL implementation in 2019. Dischargers to the Slough have been identified as the City and Caltrans.

1.4 Modeling Development and Outcomes

The Regional Board determined the need to develop a watershed model and estuary model to understand the fate and transport of nutrients from the watershed to the Slough and the interaction of the transport into and out of the Slough via the San Diego River channel, as illustrated on Figure 1-3 and Figure 1-4. Tetra Tech, under contract with the Regional Board, is responsible for the development of each model. The model selected for the watersheds was the Hydrologic Simulation Program Fortran (HSPF). The model selected for the estuary was the Environmental Fluid Dynamics Code (EFDC). EFDC can simulate water and water quality constituent transport in geometrically and dynamically complex waterbodies, such as vertically mixed shallow estuaries, lakes, and coastal areas. The model results will be presented by the Regional Board following the completion of the Lagoon TMDL Monitoring Program.

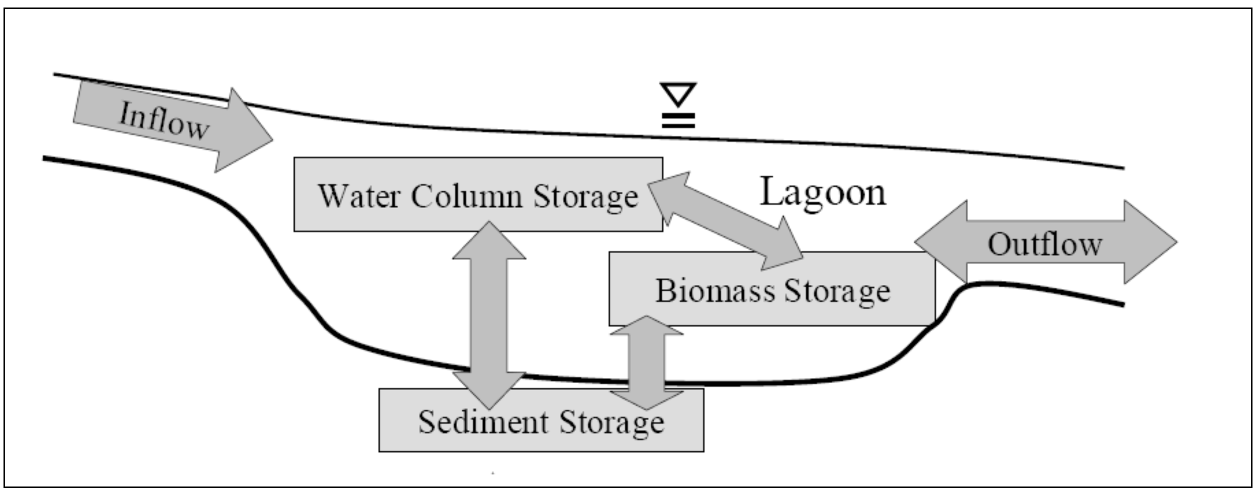

Figure 1-3. Conceptual Model for Nutrient/Eutrophication within Famosa Slough (SCCWRP, 2007)

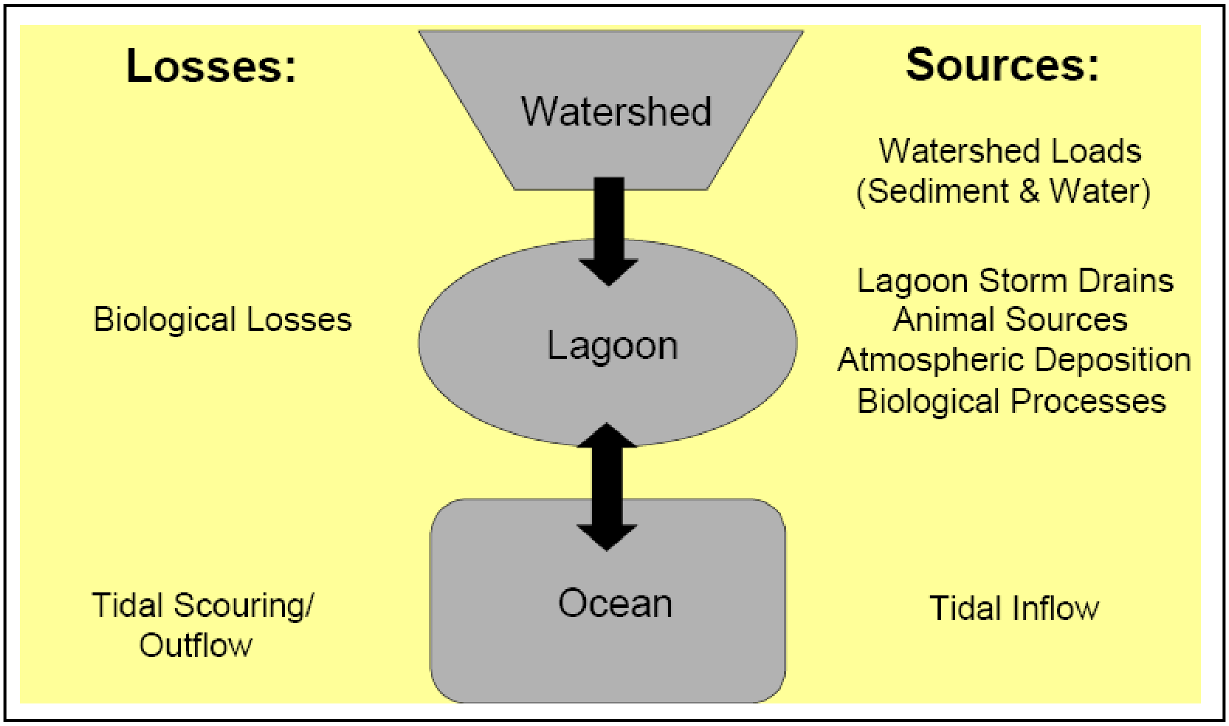

Figure 1-4. Basic Conceptual Model Outlining Sources and Losses of Constituents within the Watershed, Lagoon, and Ocean (SCCRWP, 2007)

1.5 Key Management Questions to be Answered

The key program questions developed by the Regional Board and stakeholders, the elements to answer those questions, and expected project outcomes are presented in Table 1-2. Key questions in yellow boxes indicate questions that are addressed by this report; questions that are not in bold will be addressed by the Regional Board.

Table 1-2. Key Management Questions to be Answered by the TMDL Monitoring of Famosa Slough

Type	Regional Water Quality Control Board Key Questions to Be Answered	Project Element(s) that Will Address these Questions	Project Outcomes
Questions that characterize sources of targeted contaminants to the Slough	▪ What are the relative contributions for contaminants from each land use type? ▪ **What are the concentrations of contaminants at the base of the watershed?** ▪ **What is the daily rainfall?** ▪ **What is the total annual flow and mass loads of contaminants from the watershed into the lagoon?** ▪ **What is the concentration of contaminants at the ocean inlet before it enters Famosa Slough?** ▪ What is the net annual flux of contaminants from Famosa Slough to the coastal ocean?	▪ Sample collection at tributaries. ▪ Measurements of daily rainfall. ▪ Continuous flow data collection. ▪ Measurement of water quality at Ocean Inlet Site. ▪ Modeling of collected data to determine net flux.	▪ Data from watershed and tributaries that accurately reflect current water quality and loads entering the Slough.
Questions that characterize hydrodynamics and water quality within the Slough	▪ **What are the concentrations of contaminants in Famosa Slough? Do they exceed WQOs?** ▪ **What are the DO concentrations in Famosa Slough?** ▪ What physical factors control contaminant and sediment transport? ▪ What are the sediment flux rates for nutrients in Famosa Slough? ▪ What are the standing crop totals and primary productivity rates for plants/macroalgae biomass in Famosa Slough?	▪ Index period sampling and wet weather monitoring. ▪ Continuous measurements of DO. ▪ Sediment flux will be answered through special studies.	▪ Data from Slough Segment and Ocean Inlet sites which accurately reflect current water quality and loads within Famosa Slough and loads transported in and out.
Questions that relate to the implementation of models to set load allocations	▪ What is the total annual load reduction of nutrients needed to meet the WQO? ▪ What annual total load reduction of sediment would be needed to meet water quality, physical, and biological habitat objectives?	▪ Modeling of data to attain a defensible TMDL.	▪ A defensible TMDL.

The study questions presented in Table 1-2 were designed to be answered through the modeling efforts proposed by the Regional Board. Therefore, the majority of the study questions presented in Table 1-2, above, can not be answered without the results of the modeling efforts scheduled to be undertaken by Tetra Tech on behalf of the Regional Board.

1.6 Famosa Slough History

The Slough was originally part of a Mission Bay wetland in False Bay. In the 1930s, drilling began on the south side of the Slough as part of an oil exploration project. Isolation of the Slough gradually occurred over the following decades with the construction of transport corridors, landfills, and channelization of the San Diego River. Further development and infilling decreased significantly in the 1970s (FoFS, 2007).

The Slough was once connected to the San Diego River, but was separated from it with the construction of Interstate 8. Currently, the only connection to the river for tidal interchange is through a culvert with the flap gates, under the northern edge of the freeway. Flows to and from the ocean inlet are partially constricted by three 5-ft diameter flap gates (Figure 1-5). The culvert consists of three circular 5-ft diameter concrete pipes running a distance of 324 ft perpendicular to Interstate 8 connecting the San Diego River to the Slough channel (State Coastal Conservancy, 1987). Flap gates were first constructed at the northern edge of the freeway in the 1950s such that water could flow out of, but not into, the Slough. These flap gates were replaced between 1991 and 1995. The new gates are raised above the pipes so that the pipes remain completely open. Flaps can be lowered to cover the ends of the pipes in emergency situations[2].

Figure 1-5. Flap Gates on the San Diego River Side of the Famosa Slough Ocean Entry Point

[2] Peugh, Pers Comm, 2009.

According to the Order (Appendix A), "when the gates are open, water can enter the Slough during high tides or storm events. However, the gates are usually closed during storm events to prevent water from entering the Slough from the river channel" (SDRWQCB, 2006). Visual observations and discussions with City officials confirmed that the flap gates were not closed during the 2007–2008 monitoring period. This is an important consideration when assessing tidal flows into and out of the Slough.

The 12-acre channel portion and the 25-acre southern portion of the Slough are owned and maintained by the City. The southern portion was acquired by the City in September 1990. The Slough is managed as a wetland preserve by the City Park and Recreation Department with the help of the FoFS. An Enhancement Plan was developed with the support of the California Coastal Conservancy and published in 1993 (Pacific Southwest Biological Services, 1993). Outcomes of this Enhancement Plan included the development of treatment ponds and wetlands and the enhancement of tidal flows (FoFS, 2007).

In November 2006, a culvert extension was completed under West Point Loma Boulevard. This extension opened a second 24-inch concrete pipe between the channel and the Slough to increase flow and tidal interchange.

1.7 Historical Data

The FoFS is a 501(c)(3) nonprofit organization that has monitored water quality within the Slough since 2002 at five sites (Figure 1-6). FoFS measures the following parameters twice monthly:

- Temperature
- DO
- pH
- Salinity
- Turbidity
- Nitrate
- Nitrite
- Orthophosphate

Figure 1-6. Friends of Famosa Slough Water Quality Monitoring Site Locations

In addition to the parameters bulleted above, chlorine and bacteria have also been measured (FoFS, 2007).

The data presented in Table 1-3 and Table 1-4 were accessed from the FoFS website (FoFS, 2007).

Table 1-3. Friends of Famosa Slough Water Quality Parameters in Famosa Slough (2002–2008)

	Temperature (°C)		DO (mg/L)		pH		Salinity (ppt)		Turbidity	
Site	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	7.6	24.2	0.5	8.9	6.91	8.38	0	2.5	5	95
2	7.3	22.1	0.7	9.0	6.91	8.37	0	13.4	3	250
3	7.3	24.9	0.6	6.5	7.62	8.96	3.1	34.8	0	76
4	5.3	24.4	0.5	8.5	7.38	9.27	0.5	35.4	0	82
5	10.4	26.8	0.2	9.6	7.18	9.04	2.4	35.2	0	55

Table 1-4. Friends of Famosa Slough Nutrient Concentrations in Famosa Slough (2002–2008)

		Site 1	Site 2	Site 3	Site 4	Site 5
Nitrates (mg/L)	Mean	1.82	0.57	0.88	0.96	1.17
	StdD	1.8	1.38	0.84	1.35	1.4
	Min	0	0	0	0	0
	Max	6.8	7.1	2.9	5.7	5.9
Nitrite (mg/L)	Mean	0.015	0.003	0.003	0.003	0.002
	StdD	0.043	0.009	0.003	0.004	0.001
	Min	0	0	0	0	0
	Max	0.357	0.078	0.011	0.028	0.023
Ortho-phosphate (mg/L)	Mean	1.33	0.84	0.31	0.23	0.25
	StdD	0.88	0.51	0.42	0.23	0.17
	Min	0	0	0	0	0.1
	Max	4.8	3.1	2.6	1.1	0.7

2.0 METHODS AND INSTRUMENTATION

All materials and methods used in this study are presented in the Famosa Slough QAPP. On March 26, 2008, an addendum to the Famosa Slough QAPP was submitted to the Regional Board. Both the QAPP and addendum are provided in Appendix B.

The focus of the monitoring program was to address data needs with regard to current watershed loading and water quality models. Water quality parameters within the Slough were measured over the course of ten months to provide calibration and validation data for the models to be used in the development of TMDLs for the Slough. Several types of monitoring and sampling techniques were used to assess and characterize the Slough:

- Continuous monitoring of hydrodynamic and water quality parameters.
- Storm event monitoring.
- Post-storm sediment sampling.
- Index period sampling.
- Topographic survey of the ocean inlet.

This section also presents the specific methodologies used in sample analysis.

2.1 Continuous Water Quality Monitoring

Continuous water quality monitoring was conducted at three locations in the Slough:

- MES.
- Slough Segment Site.
- Ocean Inlet Site (though this site is located on the San Diego River channel, it is referred to as the Ocean Inlet Site throughout this document, to be consistent with the Lagoon Workplan terminology).

These locations are presented on Figure 2-1 and in Table 2-1.

Table 2-1. Continuous Monitoring Locations

Sampling Location	Longitude	Latitude	Site Description
MES	-117.2294361	32.74858471	Located within the trapezoidal storm drain channel at the end of Famosa Boulevard.
Slough Segment Site	-117.229096	32.75243665	Located adjacent to the northern pipe under West Point Loma Boulevard.
Ocean Inlet Site	-117.2287745	32.75615219	Located at the southern entrance of the three enclosed pipes under Interstate 8 at the north end of the channel.

Figure 2-1. Continuous Monitoring Locations in Famosa Slough

YSI 6920 Multiparameter Water Quality Sondes were deployed at these sites between October 2007 and October 2008 and were used to monitor water depth, temperature, turbidity, specific conductivity, pH, and DO (Table 2-2). Monthly maintenance and calibration was performed to ensure that the water quality sondes were functioning properly. The sondes were set up to log data at 15-minute intervals, and the recorded data was saved in the unit's internal memory until downloaded onto a portable laptop computer. Maintenance included removing biofouling organisms and algae, replacing batteries, and ensuring correct operation per manufacturer specifications.

In addition, flow monitoring was conducted at the MES between October 2007 and September 2008 using a Sigma 920 Flowmeter to measure stream velocity and stage. A flowmeter was also installed at the Ocean Inlet Site in August 2008 to measure tidal interactions.

Table 2-2. Continuously Measured Constituents at Each Sampling Location

Continuously Measured Analyte	Mass Emission Site	Famosa Slough Segment Site	Ocean Inlet Site
Flow	●	–	–*
Water level	●	●	●
Temperature	●	●	●
Conductivity	●	●	●
Turbidity	●	●	●
pH	●	●	●
DO	●	●	●

*A flowmeter was added at this site in August 2008 for a two-month period to monitor tidal influence from the San Diego River.

2.1.1 Mass Emission Site

Continuous monitoring equipment for the assessment of the MES was located at the southern end of the Slough's central basin at the cul-de-sac end of Famosa Boulevard. This is a monitoring location within the MS4 system designed to assess inputs into the Slough from the surrounding drainage area. The municipal separate storm sewer system (MS4) flows through this channel just upstream of the trash grate (located upstream of the location shown on Figure 2-2). Continuous monitoring at this site required the deployment of a water quality sonde and a flowmeter, installed in a protective housing at the base of the concrete channel.

Figure 2-2. Mass Emission Site

The stream flow rate at the MES was measured by stream stage (water level) sensors secured to the bottom of the channel. To quantify flow rates based on stream stage, a relationship between flow and stage was derived using standardized stream rating protocols developed by the United States Geological Survey (USGS) (Rantz, 1982; Oberg et al., 2005). Instantaneous flow measurements were taken at two stages at the inflow site. The measurements were combined with site-specific survey information to produce a rating curve for the inflow site.

To accurately measure flow in streams there are three critical elements needed to develop rating curves:

- An accurate survey of the stream channel cross section and longitudinal slope.
- Accurate level measurements based on a fixed point.
- Measurements of velocity and flows at several points throughout the rating curve including low flow, mid flow, and peak flow conditions.

To measure instantaneous flows during low storm event flow conditions and base flow conditions, a velocity measurement instrument was used. The instrument was a Marsh-McBirney Model 2000 Portable Flowmeter connected via a cable to an electromagnetic open channel velocity sensor.

The velocity sensor was attached to a stainless-steel, top-setting wading rod. To make an instantaneous flow measurement, a tape measure was stretched across the stream, perpendicular to flow, and was secured on both banks of the stream. The tape was positioned suspended approximately 1 ft above the surface of the water. The distance on the tape directly above the waterline (where the water met the bank) was recorded as the initial point. The first measurement was then made at the first point where there was adequate depth and measurable velocity. At this time, three measurements were made: water depth, velocity, and distance from the bank (i.e., the initial point). Subsequent depth, velocity, and distance measurements were made incrementally across the entire width of the channel, so a minimum of twenty points were measured at the site. Water depth was determined from calibrations on the wading rod in tenths of feet. Velocity measurements were made at each point along the transect by positioning the velocity sensor perpendicular to flow at 60% of the water depth (from the surface) to attain an average velocity. The top-setting wading rod was designed so that the sensor can be conveniently positioned at the appropriate depth. Water velocity was measured in feet per second.

Data from the field measurements were entered into a computer spreadsheet that calculates the stream's cross-sectional profile from the depth and distance-from-bank measurements. Total flow across the channel was determined by integrating the velocity measurements over the cross-sectional surface area of the stream channel. The result is an instantaneous flow measurement in cubic feet per second.

Rating curves were extended to high stream stages not measured using site-specific survey information and Manning's Equation (Linsley et al., 1982). Manning's Equation is an empirical formula for open channel flow, or flow driven by gravity:

$$Q = VA = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}} \sqrt{S}$$

where
Q = Flow
n = Manning Roughness coefficient
A= Cross sectional area
R = Hydraulic radius
S = Hydraulic slope

The hydraulic radius is derived as:

$R = A/P$

where
A = Cross sectional area of flow (ft^2)
P = Wetted perimeter (ft)

Manning's Equation was developed for conditions of uniform flow in which the water surface profile and energy gradient are parallel to the streambed and the area, hydraulic radius, and depth remain constant throughout the reach. Field surveys of the channel geometry of the inflow site were conducted to compute the channel characteristics for each site.

Channel cross-section surveys were conducted at each site to derive stream discharge using Manning's Equation. The cross-section surveys involve placing endpoints and a benchmark on the nearest overhead bridge structure or stretched line such that the endpoints are placed at the highest point of the channel on each bank. A tape is then stretched between the endpoints such that the zero end of the tape is attached to the endpoint on the left bank of the channel (looking downstream). Using a weighted tape measure, at least twenty vertical distance measurements from a standard level on the bridge or stretched line to the channel bottom are then recorded at equal horizontal distances across the creek. To survey the channel thalweg, a DeWalt transit level was used. A minimum of three elevations at increasing horizontal distances from the transit level were recorded in the channel bed. A minimum of five elevations were measured at sites with irregularly sloped or curved channel surfaces. The average channel slope was calculated from the survey data.

Channel survey data were used with Manning's Equation to produce a rating curve for the sampling site. Each rating curve was calibrated using instantaneous flow measurements by adjusting the formula roughness coefficient.

The MES in the Slough is located in a shallow, non-erosive concrete trapezoid channel. The following dimensions were used with Manning's Equation for water surface elevations measured every 15 minutes using a Sigma 920 Flowmeter to measure stream velocity and stage. A complete set of water surface elevation measurements were obtained during the monitoring season.

Top width = 19.6 ft.
Bottom width = 3.5 ft
Depth = 5.1 ft
Manning's n value = 0.025
Bed slope = 0.006 ft/ft

Estimates of continuous flow were made using a Sigma 920 Flowmeter with a pressure/level transducer. These measurements were downloaded monthly and verified to ensure accuracy and to identify maintenance or calibration needs. Continuous level data were converted to flow data using the site rating curve. Level and flow data were then entered into the data management system. All flow data were copied and archived.

2.1.2 Famosa Slough Segment Site

The Slough Segment Site was co-located with FoFS historical sampling Site 5 just below the West Point Loma Boulevard Bridge. The site consists of two 24-inch circular concrete pipes and a rectangular overflow pipe. In November 2007, a water quality sonde in PVC housing was deployed in the western concrete pipe. In December 2007, after one month of water quality data collection, the monitoring equipment was relocated to the eastern pipe in preparation for pipe reconstruction work.

Figure 2-3. Slough Segment Site Pre-Construction November 2007 (left) and Post-Construction January 2008 (right)

Pipe reconstruction at the West Point Loma Boulevard Bridge was performed by Merkel and Associates in late 2007. This work was to be undertaken as part of the long-term restoration and management strategy for the Slough. The original configuration of the dual pipes consisted of one eastern pipe, which was open and allowed flow from the main body of the Slough into the northern channel, and one western pipe, which was blocked with concrete and did not allow flow into the northern channel (Figure 2-3, left).

The reconfiguration consisted of removal of the concrete covering on the western pipe (Figure 2-3, right). To increase tidal flushing between the main body of the Slough and the Ocean Inlet Site, concrete infill was removed from the western concrete pipe linking the two segments, and the pipe was then opened at each end. In addition, both concrete pipes were extended on either side of West Point Loma Boulevard. Continuous data collection was not impaired by the reconstruction efforts.

2.1.3 Ocean Inlet Site

The Ocean Inlet Site was co-located with FoFS historical sampling Site 1 just south of Interstate 8. Under the northern edge of Interstate 8, flap gates remain open allowing for tidal exchange between the Slough and the Pacific Ocean by way of the San Diego River. A culvert consisting of three circular 5-ft diameter pipes runs 324 ft perpendicular to Interstate 8 and connects the river to the Slough channel (Figure 2-4). This configuration causes a tidal delay of between one and a half and two hours at the ocean inlet. A water quality sonde in PVC protective housing was installed in the opening of the eastern concrete pipe.

Figure 2-4. Ocean Inlet Site

Two significant tidal observations within the Slough were noted by field personnel, including a two-hour lag time between the ocean tide and the tide within the Slough and the fact that the water in the Slough didn't always ebb and flood according to the ocean's tidal cycle.

Tidal Lag – Anecdotal evidence[3] suggested that there was up to a two hour lag time between the forecast high tide and low tide and those observed at the ocean inlet and in the main body of the Slough. This discrepancy was attributed to the distance between the Pacific Coast and the Slough, the influence of the San Diego River flows, and the presence of the tidal flap gates. The delayed tidal pattern was observed in the field.

[3] Peugh, Pers Comm, 2007.

Ebb and Flood Discrepancy – During neap tides, the water was not observed to ebb and flood around the high tide. Instead, the water appeared to flow continuously out of the Slough at the Slough Segment Site and Ocean Inlet Site during smaller high tide events.

To help assess these tidal patterns, staff gauges were installed at the Slough Segment Site (Figure 2-5) and the Ocean Inlet Site (Figure 2-6) in February 2008. Water levels were recorded by field staff during index periods as well as during monthly equipment maintenance visits. The water level measurements confirmed the field observations, but more detailed measurements were necessary to properly assess the tidal cycle of the Slough.

Figure 2-5. Installation of Staff Gauge at the Famosa Slough Segment Site

Figure 2-6. Equipment Installation at Ocean Inlet

To further evaluate these two observations, a flowmeter was installed at the Ocean Inlet Site in early August 2008 (Figure 2-6). The sensor was placed 23 ft downstream of the ocean inlet continuous monitoring site, within the eastern pipe. The flowmeter was used to measure water level and velocity at the point where the Slough connects with the San Diego River. The purpose of the installation was to assess the timing and magnitude of ebb and flood tides at the most tidally influenced location of the Slough.

2.2 Storm Event Sampling

2.2.1 Pollutograph and Composite Sample Collection

Water sampling was performed throughout three storm events using Sigma SD 900 autosamplers. Prior to the arrival of a storm, autosamplers were placed at the MES, the Slough Segment Site, and the Ocean Inlet Site. Autosamplers were checked periodically throughout the sampling period to ensure proper sample collection. In the event of an autosampler malfunction, samples were collected manually using a grab pole and pre-cleaned sample containers.

Pollutograph sampling, consisting of eight or more discrete samples collected over the rise and fall of the hydrograph, was performed at the MES. In the event that more than eight samples were collected at the MES, samples were selected to undergo chemical analysis based upon their time of collection relative to the MES hydrograph.

During the first storm, sample collection began five hours after the first rainfall, and eight samples were collected. During the second storm, sample collection began one hour and 25 minutes before the first rainfall, and 11 samples were collected. For the last storm, sample collection began 30 minutes before the first rainfall, and 11 samples were collected.

Composite sampling was performed at the Slough Segment Site and at the Ocean Inlet Site at slack high and slack low tide such that two composite samples were collected per storm. The first composite sample was collected during the storm and the second was collected after the storm. Each composite sample consisted of collecting samples at a 15-minute interval over a period of three hours. During the first and second storm events, samples were collected in this manner. During the third storm event, two slack high tide data sets were collected in addition to a slack low tide data set. The rainfall began during the first slack high tide and continued through the slack low tide. Samples were collected during this first slack high tide; however, a field decision was made to collect a second set of slack high tide samples following the slack low tide once the rain ceased. Best efforts were made, using pre-storm forecasts, to sample storms with rainfall amounts between 0.2–1 inch or greater.

Table 2-3 lists the constituents analyzed during storm sampling at the MES, Slough Segment, and Ocean Inlet sites. A composite sample, comprised of water collected throughout the storm from a single sample location, was analyzed for particle size during one storm event.

Table 2-3. Constituents Measured during Storm Events at Each Sampling Location

Analyte	Mass Emission Site	Slough Segment Site	Ocean Inlet Site
Continuous Monitoring			
Flow	●	–	–
Water level	●	●	●
Temperature	●	●	●
Conductivity	●	●	●
Turbidity	●	●	●
pH	●	●	●
DO	●	●	●
Laboratory Measurements			
TSS	●	●	●
TN	●	●	●
TDN	●	●	●
Ammonium	●	●	●
Nitrate	●	●	●
Nitrite	●	●	●
TP	●	●	●
TDP	●	●	●
SRP	●	●	●
$CBOD_5$	●	●	●
Chlorophyll-a	–	●	●
%Fines or % sand/silt/clay	○	–	–

● : Measured in each storm
○ : Measured during one storm only
– : Analyte was not monitored

2.2.2 Particle-Size Analysis of Storm Samples

Time-weighted composite water samples from two storm events were collected and processed for particle-size analysis. The two storm events sampled were December 7, 2007 (second storm) and February 3, 2008 (third storm).

Particle-size samples were submitted to Core Laboratories in Bakersfield, California for analysis. The particle-size distribution of the sediment in each sample was determined using laser diffraction techniques modified from ASTM D4464. A Coulter LS200 laser particle size analyzer was used in the analysis. Each of the undiluted samples was loaded into the sample chamber and circulated through the system for approximately two minutes during which time the generated diffraction patterns were recorded by an array of detectors.

2.3 Post-Storm Sediment Sampling

The collection and analysis of post-storm event sediment samples was performed to calibrate the Slough sediment transport and water quality models, specifically with respect to the impact of a storm event on the spatial characteristics of Slough sediments. Post-storm event sampling occurred within two weeks after the third storm event monitored at the MES, Slough Segment Site, and Ocean Inlet Site. The third monitoring event of the program was recommended by Regional Board staff and SCCWRP during a meeting held at the City of Encinitas on December

6, 2007. A total of 14 sites were sampled throughout the Slough (Figure 2-7), and sediment samples were collected from the top 2 cm. These sites focused on areas of sediment deposition within the Slough (Table 2-4).

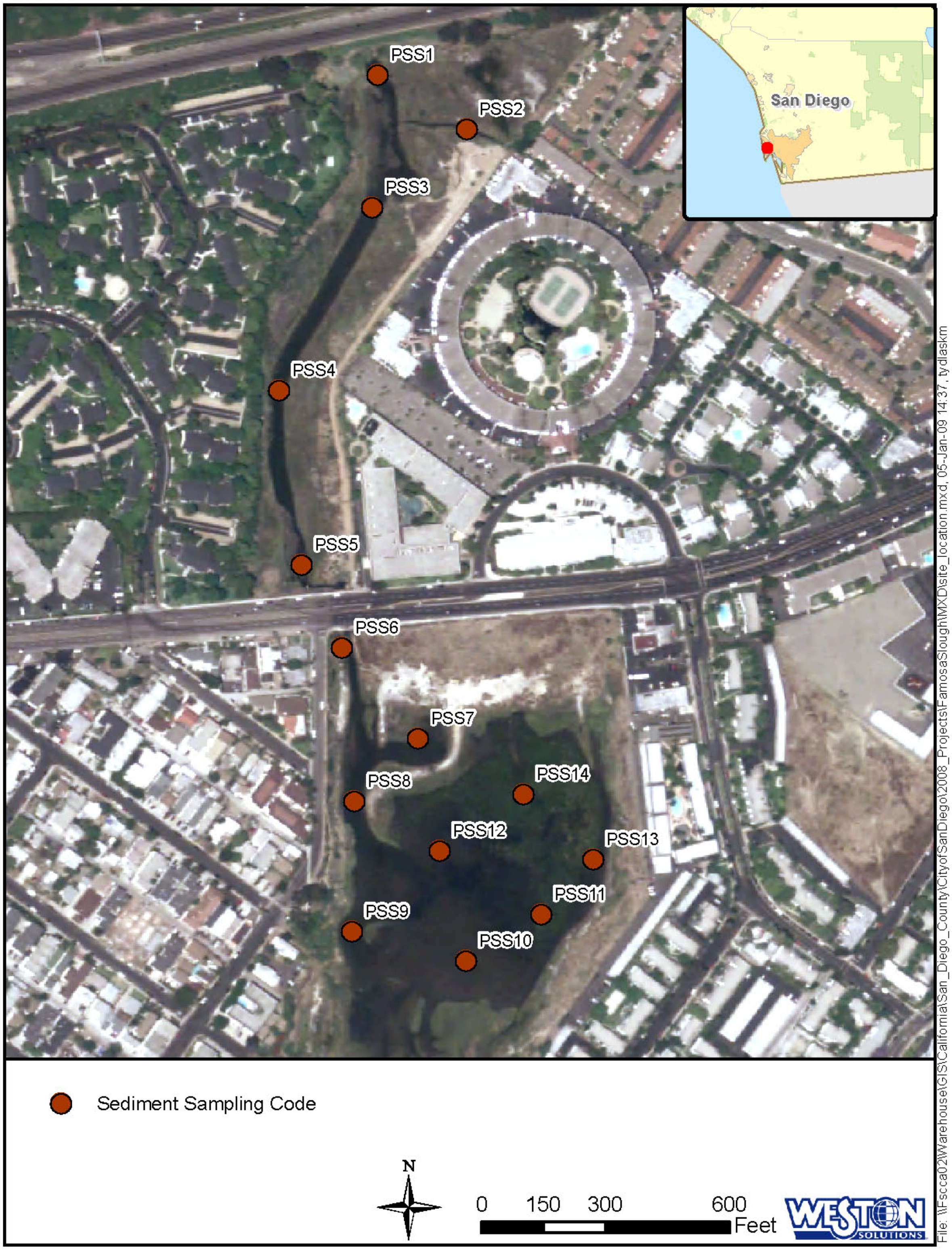

Figure 2-7. Map of Sediment Sampling Locations

Table 2-4. Sediment Sampling Locations

Sample Time	Site ID.	Water Depth	Latitude	Longitude	Comments
45	PSS-1	30 inches	32.75617	-117.22888	Shell hash.
12:05	PSS-2	NA (intertidal)	32.75580	-117.22818	Intertidal sample. Lots of horn snails present. Fine organic med. Brown to black mud.
12:15	PSS-3	30 inches	32.75528	-117.22892	Black, fine highly organic-anaerobic sediment.
12:30	PSS-4	8 inches	32.75407	-117.22965	Patchy brown algae spots on surface. Black fine sediment underneath algae.
12:45	PSS-5	NA (intertidal)	32.75290	-117.22947	Brown top layer comprises fine sand. Fine, black anaerobic underneath.
13:05	PSS-6	18 inches	32.75235	-117.22915	Taken on the side of the muddy bank near the Slough Segment Site.
13:15	PSS-7	NA (intertidal)	32.75175	-117.22855	Intertidal sample and duplicate taken.
13:25	PSS-8	8 inches	32.75133	-117.22905	Fine, black organic sediments.
13:45	PSS-9	5 inches	32.75047	-117.22907	Mud layer on top mixed with algae and is mostly suspended solids.
14:00	PSS-10	3 inches	32.75027	-117.22817	Shallow, algae layer on top with highly organic black fine sediments underneath.
14:15	PSS-11	8 inches	32.75058	-117.22758	Fine, black organic sediments.
14:45	PSS-12	9 inches	32.75100	-117.22838	Fine, black organic sediments.
14:25	PSS-13	NA (intertidal)	32.75095	-117.22712	Intertidal, very fine and loosely compacted sediments.. Hydrogen sulfide odor.
14:35	PSS-14	8 inches	32.75138	-117.22772	Fine, black organic sediments.

Sediment sample collection began on February 12, 2008, occurring within two weeks of the monitored storm event of February 3, 2008. Sediment samples were collected either by hand (Figure 2-8) or using an Ekman dredge (Figure 2-9) deployed from a kayak and consisted of surface grab samples, no more than 2 cm deep.

An Ekman dredge is a light-weight sampling apparatus recommended for collecting samples from a variety of semi-soft substrates, such as silt, silt mixed with clay, and silt mixed with some sand (USEPA, 2001). This allows for effective sample collection in various environments, including lakes, rivers, estuaries, and lagoons. WESTON's Ekman dredge collects 3.5 L of sediment and has two top doors that allow for access to visually inspect the grab sample and remove undisturbed surface sediment.

Figure 2-8. Manual Sediment Sampling

To prevent cross contamination of samples, all reusable sediment sampling equipment was scrubbed and rinsed with site water prior to sampling each station.

The following criteria were used to determine a sample's acceptability:

- The sampler was not overfilled with material to the point that the sediment surface is pressing against the top of the sampler or is extruded through the top of the sampler.
- Overlying water was present, indicating minimal leakage.
- The overlying water was not excessively turbid, indicating minimal disturbance.
- The sediment was relatively undisturbed with no sign of channeling or sample washout.
- The desired penetration depth was achieved.
- There was no sign of sediment loss or penetration at an angle.

If a sample failed to meet the above criteria, it was rejected and discarded away from the sampling station.

Penetration depth was determined by measuring the distance from the top of the sampler to the sediment interface using a clean stainless-steel ruler and subtracting this distance from the inside depth of the sampler. If the sample was uneven but the sediment surface was intact, an average of the measurements from opposite sides of the sampler was used in determining the penetration depth. A log book containing field data sheets was used to record the time, date, station coordinates, tide, water depth, sample depth, field crew, sample description, overlying water description, and other observations. Sample characteristics that were recorded included the following:

Figure 2-9. Sediment Sampling with an Ekman Dredge

- Sediment type (e.g., silt and sand).
- Texture (e.g., fine-grain, coarse, and poorly sorted sand).
- Color.
- Presence of shells.
- Percentage of organic debris.
- Stratification (if any).
- Presence of sheen.
- Odor.
- Presence of biological structures (e.g., worm tubes and shrimp molts).
- Percentage of water in sample.

After the sample had been characterized, the top 2 cm of sediment were removed using a stainless-steel scoop and was placed into a Ziplock™ bag. Unrepresentative material (e.g., large sticks, shells, or trash) were carefully removed and discarded. After the surface sediment was placed into a labeled Ziplock™ bag, the bag was placed into a cooler and stored on ice with a completed chain-of-custody (COC) form until they could be transported to the analytical laboratory. Samples were analyzed for percent fines, percent OC, percent ON, and percent OP.

2.4 Index Period Sampling

Index period sampling was performed quarterly to provide data for calibration and validation of the hydrodynamic and water quality models. This quarterly data collection was intended to capture seasonal cycles of algae blooms and associated variations in nutrient cycling activity within the Slough. Samples were analyzed as presented in Table 2-5. Index period sampling occurred at the MES, at the Slough Segment Site, at the Ocean Inlet Site, and at identified storm drains. Transect sampling was also conducted along longitudinal transects in the Slough and the adjoining channel. The four sampling periods occurred as follows:

- Index 1 – Winter (January 14–January 23, 2008).
- Index 2 – Spring (March 18–March 26, 2008).
- Index 3 – Summer (July 14–July 23, 2008).
- Index 4 – Fall (September 15–September 24, 2008).

Table 2-5. Index Period Sampling

Analyte	MES Sampling	Slough Segment Site Sampling	Ocean Inlet Site Sampling	Transect Sampling	Storm Drain Sampling
Temperature	●	●	●	●	●
Conductivity	●	●	●	●	●
Turbidity	●	●	●	●	●
pH	●	●	●	●	●
DO	●	●	●	●	●
TSS	●	●	●	●	●
TN	●	●	●	●	●
TDN	●	●	●	●	●
Ammonium	●	●	●	●	●
Nitrate	●	●	●	●	●
Nitrite	●	●	●	●	●
TP	●	●	●	●	●
TDP	●	●	●	●	●
SRP	●	●	●	●	●
$CBOD_5$	●	●	●	●	●
Chlorophyll-a	●	●	●	●	●

● : Analyte monitored

Sampling was conducted at the following locations:

- MES.
- Slough Segment Site.
- Ocean Inlet Site.
- Three transects within the Slough (one in the channel and two in the main body of the Slough).
- Contributing storm drains.

The four index period sampling events included seven days of sampling and occurred over a period of two consecutive weeks. Sampling occurred on the first three days of both the first and second week as illustrated in Table 2-6.

Table 2-6. Index Period Sampling Schedule

	Week One	Week Two
Monday	MES once per day. Slough Segment and Ocean Inlet sites twice per day at ebb and flood.	MES once per day. Slough Segment and Ocean Inlet sites twice per day at ebb and flood.
Tuesday	MES once per day. Slough Segment and Ocean Inlet sites twice per day at ebb and flood.	MES once per day. Slough Segment and Ocean Inlet sites twice per day at ebb and flood.
Wednesday	MES once per day. Slough Segment and Ocean Inlet sites twice per day at ebb and flood.	MES once per day. Slough Segment and Ocean Inlet sites twice per day at ebb and flood.
Thursday	Transect sampling (ebb and flood tides) at 15 locations.	No sampling.
Friday/Saturday/Sunday	No sampling.	No sampling.

It should be noted that during the first three days of the first index period sampling, as well as during the transect sampling event of the first index period (winter), samples were collected at the low and high tides. All subsequent samples were collected at ebb and flood tides. To keep sample identification consistent throughout sample collection for QC, samples collected for the Slough Segment Site and Ocean Inlet Site were labeled as high tide and low tide to correspond with ebb tides or flood tides, respectively.

During each sampling event, one week would occur during a period of spring tides and another would occur during neap tides. During spring tides, the Slough would exhibit a semidiurnal tidal cycle, and the sampling was easily timed during the flood and ebb of the tides. Often, during the week of neap tides, the Slough exhibited a diurnal tidal cycle, and although the sampling would be scheduled around the tide flooding and ebbing, the observations indicated that the Slough was constantly ebbing during the sampling event.

To collect the samples during the flood and ebb of the tides, it was assumed that there was a two-hour lag time between the forecast high and low tides and those observed at the ocean inlet and in the main body of the Slough. To keep the index period sampling consistent, the flood samples were scheduled two hours before the estimated high tide within the Slough. The ebb samples were consistently collected two hours after the estimated high tide within the Slough.

2.4.1 Mass Emission Site, Slough Segment Site, and Ocean Inlet Site Sampling

Sampling at the Slough Segment and Ocean Inlet sites was comprised of three samples, collected every 15 minutes and composited over a 30-minute period. Composite samples were collected once at ebb tide and once at flood tide. Sampling at the MES consisted of 30-minute composite samples collected once each day of the first three days of both weeks during the two-week period.

2.4.2 Transect Sampling

Longitudinal transect sampling occurred on the fourth day of the first week of each index period. The purpose of this sampling was to provide spatial data by which the water quality could be calibrated and then validated within the Slough. Due to the highly silted nature of the Slough, transect sampling was performed using kayaks and grab-sampling techniques (Figure 2-10). One transect, comprising five samples, was collected in the northern channel section of the Slough. Two transects, comprising five samples each, were collected in the southern central basin. Sampling locations are presented in Table 2-7 and shown on Figure 2-11. Transects followed the channelized areas of the Slough and were collected once at ebb tide and once at flood tide.

Figure 2-10. Transect Sampling during Index Period

Table 2-7. Transect Codes and Locations

Transect	Sample Code	Latitude	Longitude
Transect 1	TR1	32.75038	-117.22816
Transect 2	TR2	32.75080	-117.22808
Transect 3	TR3	32.75090	-117.22806
Transect 4	TR4	32.75120	-117.22802
Transect 5	TR5	32.75153	-117.22800
Transect 6	TR6	32.75033	-117.22791
Transect 7	TR7	32.75059	-117.22783
Transect 8	TR8	32.75088	-117.22777
Transect 9	TR9	32.75121	-117.22769
Transect 10	TR10	32.75155	-117.22761
Transect 11	TR11	32.75336	-117.22956
Transect 12	TR12	32.75407	-117.22967
Transect 13	TR13	32.75485	-117.22920
Transect 14	TR14	32.75544	-117.22866
Transect 15	TR15	32.75616	-117.22888

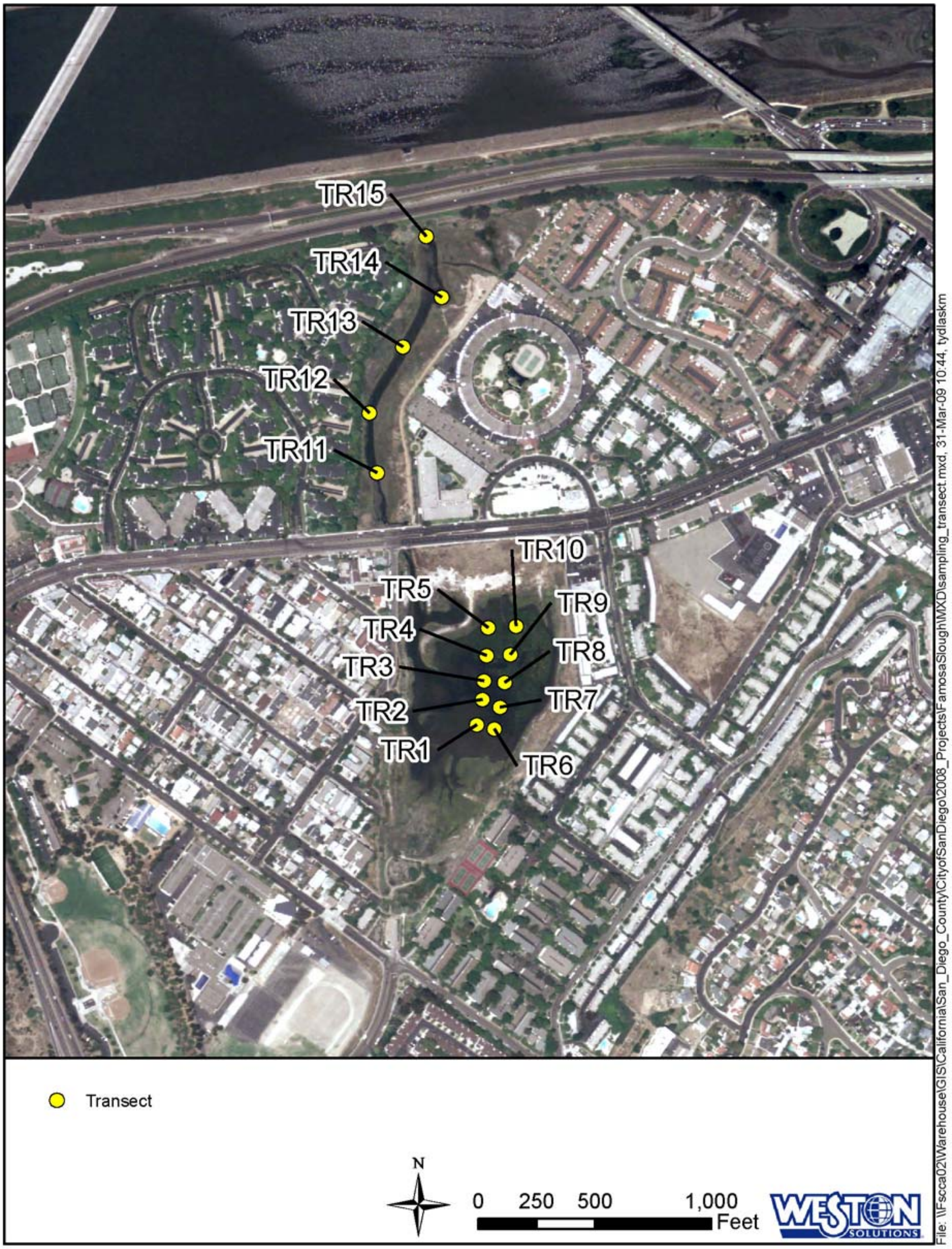

Figure 2-11. Transect Sampling Locations

2.4.3 Storm Drain Sampling

Flow rates and analyte concentration were measured once per index period at storm drains that represented 80% of the potential load into the Slough. Two storm drains near the ocean inlet were found to be the most representative of the dry weather flows into the Slough (Figure 2-12 and Table 2-8), in addition to the storm drain located at the MES sampling location. Samples were collected at the two storm drains during the second week of each index sampling period. It should be noted that during the first index period, SD1 was the only storm drain flowing, and samples were only collected at this site. During the second, third and fourth index periods, both of the selected storm drains (SD1 and SD3) were flowing and were sampled inside the pipe.

Figure 2-12. Storm Drain Sampling Sites SD1 (left) and SD3 (right)

Table 2-8. Storm Drain Sampling Locations and Dates Sampled

Site Number	Latitude	Longitude	Winter Sampling January 21, 2008	Spring Sampling March 19, 2008	Summer Sampling July 22, 2008	Fall Sampling September 23, 2008
SD1	32.75505	-117.22955	●	●	●	●
SD2 (SD3)	32.75570	-117.22792	○	●	●	●

● : Storm drain sampled
○ : Storm drain not sampled

2.5 Topography Survey

In Addendum No. 3 to the Order, the Regional Board requested that land elevation data be collected at the ocean inlet. The data were needed to configure accurate boundary conditions between the Slough and the ocean inlet in the lagoon models.

To meet this requirement, a land-based elevation survey was conducted at the ocean inlet of the Slough on December 19, 2007, immediately prior to the first index period sampling event. The survey documented the structure of the north side of the ocean inlet and was conducted by Southland Surveying, Inc. (Southland), a licensed California land surveyor. Due to the static, non-erosive nature of the ocean inlet, only one survey of the system was required.

2.6 Analytical Methods

Analytical methods used in this study, along with detection limits, reporting limits, and units, are presented in Table 2-9. Analytical analyses were performed by three laboratories:

- CRG Marine Laboratories, Inc. (based in Torrance California) performed analyses for TSS, chlorophyll-a, and $CBOD_5$.
- Odum School of Ecology, University of Georgia performed analyses for TN, TDN, TP, and TDP.
- Marine Science Institute, UCSB performed analyses for ammonia, nitrite, nitrate + nitrite, and SRP.

Table 2-9. Full Constituent List and Corresponding SWAMP-Compliant Method Detection and Reporting Limits

Constituent	Method	MDL	TRL	Units
Field Measurements				
Temperature	Data sonde	-5.0	0.1	°C
Conductivity	Data sonde	0	2.5	µS/cm
Turbidity	Data sonde	0	0.5	NTU
pH	Data sonde	0.0	0.2	pH Unit
DO	Data sonde	0	1.0	mg/L
Laboratory Measurements				
TSS*	SM 2540-D	0.5	0.5	mg/L
TN**	USGS I-4650-03	0.05	0.1	mg/L
TDN**	USGS I-2650-03	0.05	0.1	mg/L
Ammonia in water***	SM 4500-NH_3 F	0.01	0.05	mg/L
Nitrate in seawater***	SM 4500-NO_3 E	0.01	0.05	mg/L
Nitrite in seawater***	SM 4500-NO_2 B	0.01	0.05	mg/L
Nitrate in water***	EPA 300.1	0.01	0.05	mg/L
Nitrite in water***	EPA 300.1	0.01	0.05	mg/L
TP**	USGS I-4650-03	0.016	0.05	mg/L
TDP**	USGS I-2650-03	0.01	0.05	mg/L
SRP***	SM 4500-P E	0.016	0.05	mg/L
$CBOD_5$*	EPA 405.1	0.584	1.0	mg/L
Chlorophyll-a*	SM 10200-H	0.005	0.01	mg/m^3
Sediment*****				
% Fines	EPA 160.3	1%	1%	% dry weight
% OC	EPA 9060A	0.01%	0.01%	% dry weight
% TN	EPA 9060	0.01%	0.01%	% dry weight
% TP	Nelson (1987)****	0.01%	0.01%	% dry weight

MDL – Minimum detection limit
TDL – Target detection limit
* Processed by CRG Marine Laboratory
** Processed by UCSB
*** Processed by University of Georgia
**** Nelson, 1987
***** SCCWRP

3.0 RESULTS

This section presents a summary of the results of the monitoring conducted in the Slough. The section provides summaries on the following:

- QA (Appendix D).
- Rainfall and flow (Appendix E).
- Continuous monitoring (Appendix F).
- Storm water monitoring (Appendix G).
- Storm sediment grain size (Appendix H).
- Post-storm sediment sampling (Appendix I).
- Index period sampling (Appendix J).
- Topographic survey (Appendix K).

In addition, all raw data are provided as appendices to this report as noted.

3.1 Quality Assurance

This section presents the results of the QA procedures conducted throughout the monitoring period at the Slough. A number of different QA procedures were undertaken, in accordance with SWAMP Acceptance Criteria (provided in Appendix C). All QA data are provided in Appendix D.

3.1.1 Field Equipment Calibration

All continuous monitoring equipment was maintained and calibrated at least once every four weeks.

Continuous monitoring equipment was calibrated on the following dates:

- October 29, 2007
- November 20, 2007
- December 4, 2007
- December 18, 2007
- December 28, 2007
- January 30, 2008
- February 25, 2008
- February 28, 2008
- April 1, 2008
- May 7, 2008
- May 17, 2008
- June 2, 2008
- July 2, 2008
- July 14, 2008
- July 28, 2008
- August 20, 2008
- September 10, 2008
- October 7, 2008

Probes used during continuous monitoring were replaced as follows:

- DO and conductivity probes replaced on July 28, 2008, at the MES.
- Turbidity probe replaced on July 28, 2008, at the Slough Segment Site.
- Turbidity probe replaced on July 28, 2008, at the Ocean Inlet Site.
- pH probe replaced on August 20, 2008, at the Slough Segment Site.
- pH probe replaced on September 10, 2008, at the Slough Segment Site.

3.1.2 Holding Time Violations

The only holding time violation occurred with samples processed by UCSB from one day of sampling during the third index period. Samples were collected on July 17, 2008, delivered to UCSB on July 28, 2008, but were processed outside of holding time on August 26, 2008. Holding time for these samples was 28 days. The samples were processed three days past holding. While these data have been flagged and included in the calculations provided in this report, it is recommended that they are excluded from use in any TMDL calculations.

3.1.3 Broken Vials

Sediment samples were collected from the Slough on February 12, 2008, and sent to SCCWRP for analysis. All sediment samples were reported to arrive in intact containers to the SCCWRP facility. Two vials, containing samples FS-W3-PSS-10 and FS-W3-PSS-11, were broken during processing and subsequently no data are available for percent TP.

3.1.4 Field Duplicates

Field duplicates were collected at a rate of 5% of the total sample collection. Field duplicates were collected during each monitoring event by simultaneously collecting samples in separate sample bottles for processing by the laboratory. A total of 587 analyses were performed in the assessment of field duplicates. Duplicate samples were collected on 30 individual occasions throughout the monitoring period. Duplicate samples were matched, and the relative percent difference (RPD) was calculated. If the RPD was greater than 25%, then the sample was flagged.

The only exceptions to this were when analytical results were within 20% of the minimum detection limit (MDL) of the analytical method. The results of this analysis are presented in Table 3-1.

Table 3-1. Results of Field Duplicate Analysis

Analyte	Number of Duplicate Samples > 25% RPD	Total Number of Duplicate Samples	Percentage of Samples < 25% RPD
TSS	4	27	85.2%
TN	6	27	77.8%
TDN*	16	27	40.7%
Ammonia as N	3	27	88.9%
Nitrate + nitrite as N	3	18	83.3%
Nitrite as N	0	15	100%
TP	1	27	96.3%
TDP	1	27	96.3%
SRP	1	28	96.5%
$CBOD_5$	2	23	91.3%
Chlorophyll-a	7	21	66.8%

* Positive bias from filtration noted

The results of the field duplicate QA procedure suggest that most analytes were within the acceptable range of RPD stipulated in the SWAMP protocol. However, the majority of TDN duplicate samples exceeded the 25% RPD criterion. This suggests a wide variability in duplicate samples collected from the same temporal and spatial environment and subjected to the same analytical methods. Based on these results, the TDN and chlorophyll-a data should be used with caution.

3.1.5 Laboratory Duplicates

Laboratory duplicates were processed by each of the analytical laboratories. Samples were split in the laboratory and analyzed separately to assess the comparability of the sample analysis process. Laboratory duplicates were processed at a rate of 5% of the total sample collection. A total of 206 laboratory duplicates were processed by the analytical laboratories. All samples were reported as normal and within the laboratory QC method specifications for acceptance.

3.1.6 Laboratory Control Standard

A total of 216 laboratory control standard (LCS) samples were processed by the three analytical laboratories. All LCS samples met the acceptance criteria for percent recovery.

3.1.7 Laboratory Matrix Spikes

Matrix spike samples were processed in the laboratory by adding a known concentration of a specific analyte to a field sample. The sample was analyzed prior to addition of the spike and again after addition. A calculated analyte concentration was then prepared and compared against the analytical result. Matrix spike results are acceptable when the percent recovery is greater than 80%, depending on the method.

A total of 196 laboratory matrix spikes were performed using samples collected from the Slough. Only one sample was recorded as out of compliance. The sample was processed by the University of Georgia for analysis of TDP from the second index period. A total of 12 matrix spike samples were processed by this laboratory during the second index period; all other matrix spike samples were within acceptable ranges.

3.1.8 Laboratory Blanks

A total of 383 laboratory blank samples were processed. In total, 100% of analyzed samples resulted in analytical concentrations below the level of detection. This suggests no positive bias was introduced to the sample as a result of analytical techniques.

3.1.9 Field Blanks

Field blanks were collected in the field at a frequency of 5% of the total sample number. Field blank samples were collected using the same sample handling and equipment as field samples. Instead of site sample water, de-ionized water was added to each vial and was processed along with site sample water to assess potential contamination issues.

A total of 271 field blank samples were collected. The results are presented in Table 3-2.

Table 3-2. Results of Field Blank Analysis

Analyte	Number of Samples >MDL	Total Number of Samples	Percentage of Samples within Acceptable Range
TSS	0	21	100
TN	5	26	80.8
TDN	9	26	65.4
Ammonia as N	0	25	100
Nitrate + nitrite as N	1	26	96.2
Nitrite as N	0	27	100
TP	0	26	100
TDP	0	27	100
SRP	0	27	100
$CBOD_5$	0	20	100
Chlorophyll-a	1	19	94.7

These results suggest that all field blanks, with the exception of TDN, were within acceptable ranges. Based on these results, data associated with TDN analyses should be used with caution.

Investigation into Variability in Total Dissolved Nitrogen Results

To better understand the variability in TDN results, both from field duplicates and field blanks, a number of additional investigations and changes to sampling practices were undertaken during the course of the study. These experiments are detailed below.

Changes in Sample Processing

As directed by SCCWRP, the following protocol requirements were implemented during the fourth index period:

In the Field:

- Filter on a clean surface and always wear gloves.
- Use single syringe per sample.
- Make sure that the first plug (approximately 5 mL) of water filtered through the prepackaged filter is wasted.
- Make sure the sample receptacles are rinsed with the appropriate sample before filling.

In the Laboratory:

- Batch the samples so the TDP and TDN are run in the same digestion as TP and TN of the same sample.

Assessment of the Impact of Organic Compounds

The University of Georgia conducted an experiment to assess the potential for high concentrations of organic compounds in the sample water to inhibit reagent functioning during the persulfate digestion. In their analysis, they added higher volumes of oxidizing agent to the sample being analyzed for TN, while maintaining regular volumes of the oxidizing agent for the TDN analysis. The results showed that the addition of more oxidizing agent did not improve or impair the digestion process.

Evaluation of the Impact of Filters

Assessment of the field blank and field duplicate results suggested that the disposable 0.45-µm filters used in processing samples for the TDN analysis were potentially contaminating the samples. To assess this hypothesis, a sample process evaluation was conducted during the final index period (Table 3-3). All raw data collected in this analysis are provided in Appendix D. Samples of de-ionized water were processed using the following variables:

- Field and laboratory filtering of laboratory grade de-ionized water using a Whatman brand 0.4-µm filter to assess final TDN concentrations.
- Field and laboratory filtering of laboratory grade de-ionized water using a Fischer brand 0.45-µm filter to assess final TDN concentrations.

Table 3-3. Results of Filter Assessment

Filter Type	Sample Water	Location of Test	Total Dissolved Nitrogen (mg/L)		Total Dissolved Phosphorus (mg/L)	
			First 10 mL	Second 10 mL	First 10 mL	Second 10 mL
Fischer Filter	DI water	Field	0.032	0.045	0.004	0
	DI water	Lab	0.029	NA	0	NA
Whatman Filter	DI water	Field	0.092	0.0371	0.007	0
	DI water	Lab	0.106	NA	0.000	NA
Syringe	DI water	Field	0.024	NA	0.000	NA
Fischer Filter	Famosa sample water	Field	0.045	NA	0.009	NA
Whatman Filter	Famosa sample water	Field	0.099	NA	0.000	NA

The following conclusions can be made from this preliminary assessment:

- The use of Whatman filters, without pre-rinsing, led to an increase in the concentration of TDN in the resultant chemical analysis. This increase accounted for between 0.04 mg/L and 0.08 mg/L of the TDN recorded in a sample. No significant increases in TDP were observed.
- Pre-rinsing the filter (i.e., filtering and discarding approximately 10 mL of sample water) resulted in comparable TDN concentrations for both the Fischer or Whatman filters.
- There were no significant differences between samples filtered in the field versus the laboratory. This result indicated that environmental contamination from sampling in the field was unlikely to have been a factor.
- There was no significant difference in TDP concentrations regardless of filter type or pre-rinsing.

These results suggest that those samples collected and analyzed for TDN using Whatman filters without pre-rinsing may have led to artificially elevated concentrations. Pre-rinsing of filters was only initiated in the fourth index period sampling event. The same filter was also used to process both TDN and TDP samples, therefore approximately half the TDN samples, prior to index period 4, would be impacted by the filter contamination.

As a result of this filter contamination, data pertaining to TDN have not been included in this report.

3.2 Continuous Monitoring

This section presents the results of the continuous monitoring undertaken at the three Slough locations. Continuous monitoring occurred between October 2007 and October 2008 at the MES, the Slough Segment Site, and the Ocean Inlet Site.

3.2.1 Hydrology of the Slough

The Slough is tidally influenced by the Pacific Ocean by way of the San Diego River channel. Many areas on the western coast of North America often experience a mixed semidiurnal tidal cycle (NOAA, 2009) (Figure 3-1). An area has a mixed semidiurnal tidal cycle if it experiences two high tides and two low tides of different size every lunar day. During sampling events at the Slough, it was observed that during semidiurnal tidal cycles the Slough mirrored the tidal pattern of the ocean with an approximate lag time of two hours. However, when the tidal cycle was mixed semidiurnal, the Slough often didn't flood and ebb around the smaller of the high and low tides during the day. Ebb and flood tides were specified as sampling times in the Order, and precise understanding of the tidal patterns was needed to validate assumptions made during sampling and to assess daily tidal flux into and out of the Slough.

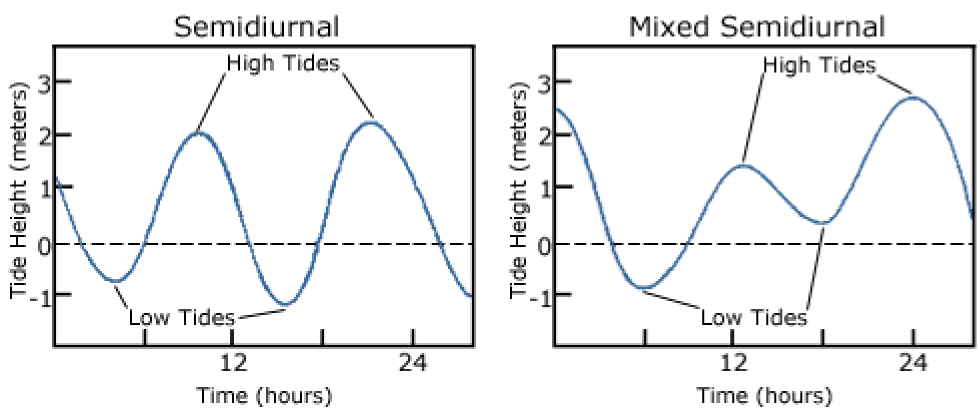

Figure 3-1. Example of Semidiurnal and Mixed Semidiurnal Tides

Observations and results of flow assessment at the Ocean Inlet Site indicated that the Slough often exhibited a diurnal tidal cycle of one high and one low corresponding to the higher high and lower low of the ocean's tides (Figure 3-2). Measuring the flow at the Ocean Inlet Site over two months showed that there were approximately eight days that the Slough had a diurnal tidal cycle. In addition, high and low tides lagged Pacific Coastline tidal cycles by approximately one and a half to two hours. The remainder of the month had the expected semidiurnal tidal cycle.

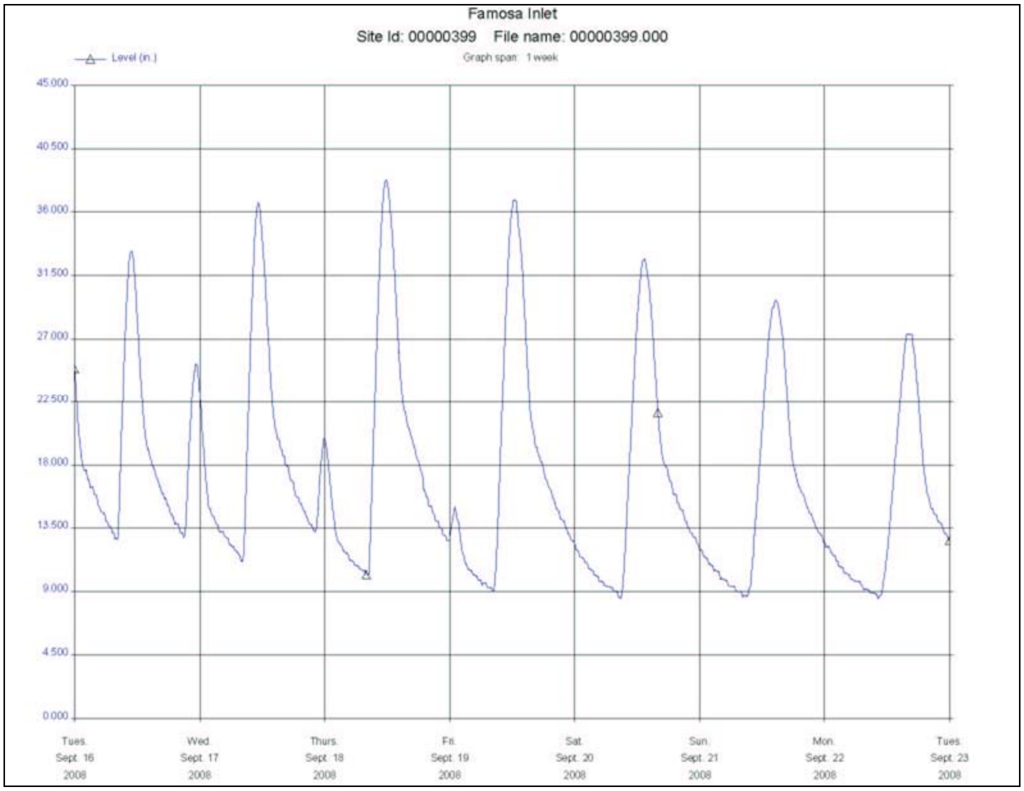

Figure 3-2. Results of Flow Measurement at the Ocean Inlet Site (September 16–23, 2008)

3.2.2 Rainfall and Flow

Rainfall and flow data were collected continuously throughout the monitoring period from October 2007 through October 2008. Rainfall and flow data are presented in Appendix E.

Three storm events were monitored at the Slough during the wet weather monitoring period. Samples were collected on November 30, 2007; December 7, 2007; and February 3, 2008. Table 3-4 presents the summary of rainfall data from the three storm events monitored at the Slough, while Figure 3-3 illustrates the duration of sampling during each hydrograph.

Table 3-4. Famosa Slough Mass Emission Site Rainfall Summary

Date of Storm Event	Number of Previous Dry Days	Duration of Storm (hours)	Rainfall (inches)	Average Intensity of the Storm (inch/hour)
November 30, 2007	220	13	1.12	0.09
December 7, 2007	8	5	0.24	0.05
February 3, 2008	7	9	0.36	0.04

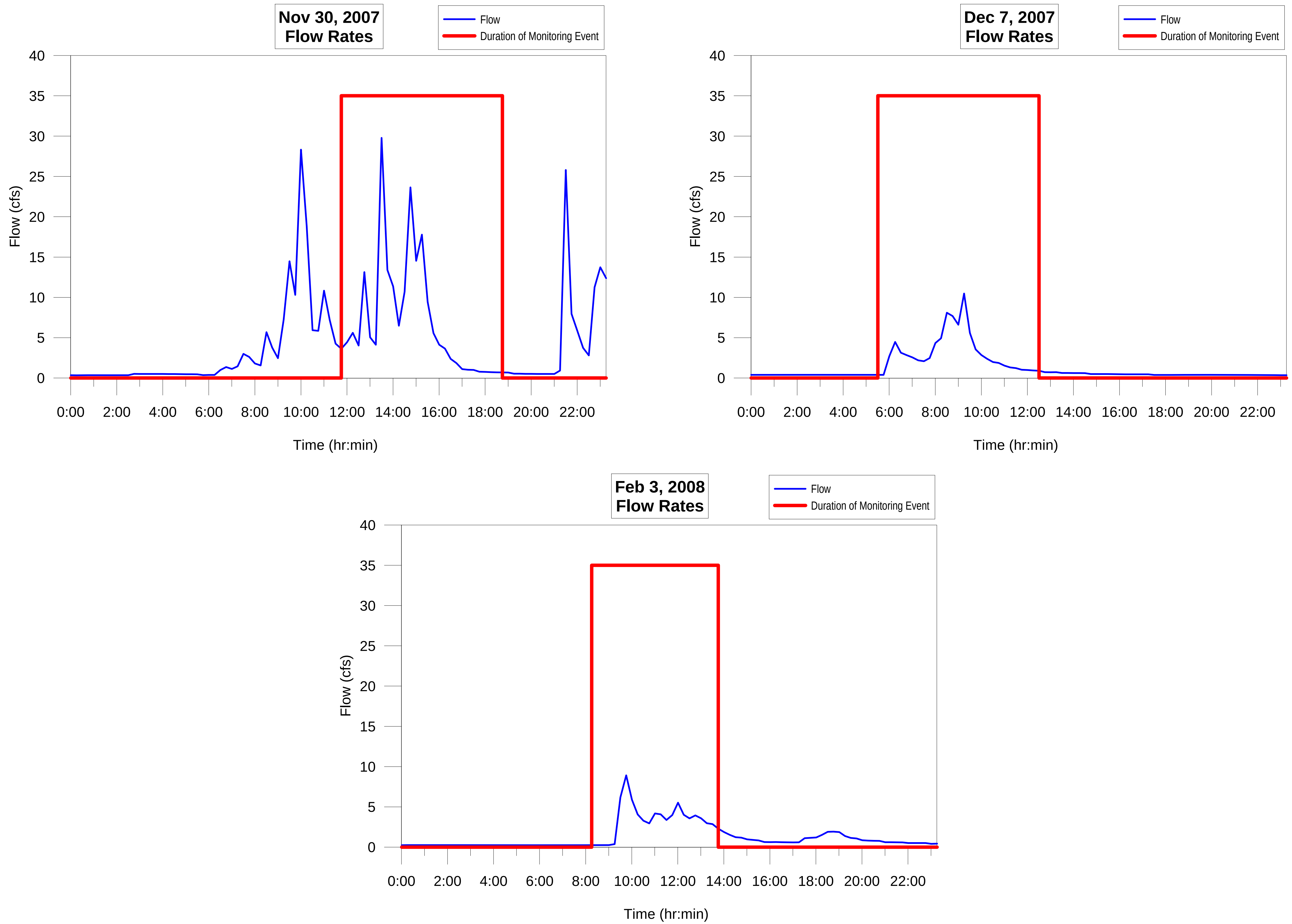

Figure 3-3. Hydrograph Data from the Mass Emission Site for the Three Storm Events Showing Monitoring Period

The first storm on November 30, 2007, recorded 1.12 inches of precipitation and was the largest of the three monitored wet weather events. It should be noted that total rainfall for this date was 1.33 inches, however two distinct bands of rain featured in this storm and the latter band was attributed to the December 1 rain event and was not included in the flow assessments used in this report. This first storm was proportionally larger than the second and third storms, which had 0.24 inch and 0.36 inch of precipitation, respectively.

Analysis of the rainfall data collected between October 12, 2007 and June 2, 2008, indicated that a total of 7.02 inches of rain was recorded at the Slough MES sampling location.

A complete data set containing flows at the MES was compiled from October 2007 through October 2008. Averages from this compiled data set are presented in Table 3-5. The data were then analyzed by separating wet weather flows (i.e., flows influenced by rain events) from dry weather flows (i.e., flows that occurred at times with no measurable precipitation). These data were then used in load calculations for both dry weather conditions and wet weather conditions (Section 4.0).

Dry weather baseline flow averaged approximately 0.37 cfs, whereas the average wet weather flows were approximately 3.6 cfs. The maximum wet weather flows were recorded as 34.7 cfs on February 22, 2008, and the highest dry weather flows were recorded as 24.2 cfs on November 16, 2007. Flows on this one day were significantly higher than any other recorded dry weather flows. The second highest dry weather flows were recorded as 4.4 cfs on June 21, 2008. These results suggest that there was one significant episodic dry weather discharge into the Slough.

Table 3-5. Flow Statistics at the Mass Emission Site (October 2007–September 2008)

Month	Flow (cubic feet per second)			
	Mean	Minimum	Maximum	Standard Deviation
October	0.48	0.17	12.03	0.59
November	0.53	0.26	29.78	1.51
December	0.54	0.30	28.57	1.05
January	0.85	0.31	30.21	2.33
February	0.53	0.20	34.73	1.42
March	0.33	0.22	1.50	0.08
April	0.39	0.26	0.69	0.06
May	0.37	0.24	13.11	0.31
June	0.41	0.20	4.47	0.36
July	0.43	0.20	3.02	0.39
August	0.38	0.18	1.28	0.09
September	0.25	0.15	0.52	0.05

3.2.3 Continuous Monitoring of Water Quality Parameters

Monitoring of hydrology and core chemical parameters was conducted continuously from October 2007 through October 2008 via in situ water quality sondes (raw data are presented in Appendix F). Sondes were installed at three locations, one at the MES, one at the Slough Segment Site, and one at the Ocean Inlet Site. The continuously monitored core parameters included water depth, temperature, turbidity, specific conductivity, pH, and DO. The goal of the continuous monitoring was to better understand the physical factors controlling the Slough hydrodynamics and sediment transport. The data provided by the water quality sondes will ultimately be used to calibrate and validate watershed hydrology and lagoon hydrodynamic models. The continuous monitoring also provided data to determine daily, monthly, and seasonal patterns of the water quality parameters.

Temperature – Figure 3-7 presents monthly temperature at the three monitoring locations in the Slough. The data indicate seasonal patterns, with warmer water temperatures occurring during the summer months May through August. The warmest temperature (33.9 ºC) was recorded at the Ocean Inlet Site on June 22, 2008. The coldest temperature (2.8 ºC) was recorded on December 28, 2007 at the Ocean Inlet Site.

Conductivity – Table 3-6 presents monthly conductivity measurements at the three monitoring locations in the Slough. Conductivity results indicate the MES is primarily freshwater influenced with average annual results of approximately 1.25 mS/cm. Conductivity at the Slough Segment Site and at the Ocean Inlet Site was indicative of saltwater and was observed to be lowest during periods of rainfall in December, January, and February. The lowest conductivity concentrations (0.003 mS/cm) were recorded at the Slough Segment Site on May 7, 2008. The highest conductivity concentrations (57.4 mS/cm) were recorded at the Slough Segment Site on August 24, 2008.

Table 3-6. Mean Monthly Conductivity (mS/cm) in Famosa Slough

	October 2007	November 2007	December 2007	January 2008	February 2008	March 2008	April 2008	May 2008	June 2008	July 2008	August 2008	September 2008	October 2008
MES	0.92	1.02	0.66	0.98	0.69	1.65	2.09	1.11	0.39	2.17	1.29	1.55	1.70
Slough Segment Site	47.04	47.86	41.24	35.15	38.01	35.44	39.80	45.86	42.03	37.99	45.24	49.03	45.89
Ocean Inlet Site	48.87	43.64	30.34	32.74	39.03	42.32	36.84	33.34	38.84	46.53	46.75	48.57	47.40

Dissolved Oxygen – DO is influenced by temperature and salinity and tends to vary seasonally. In addition, daily DO concentrations follow a diurnal pattern over a 24-hour period. Oxygen is supplied to the water column through photosynthesis during daylight hours. Oxygen is continually consumed by bacteria, fungi, and other organisms; when photosynthetic capability is low (i.e., during nighttime), DO decreases in the water column (NOAA, 2004). Both these trends are apparent at the Slough Segment Site and the Ocean Inlet Site (Figure 3-4). DO concentrations were lowest between midnight and 9am at both the Slough Segment Site and Ocean Inlet Site. DO concentrations increased sharply between 9am and noon, generally peaking between 1pm and 3pm before declining through the afternoon and evening. Seasonal analysis demonstrates that the highest DO concentrations occurred during the summer months, whereas lower concentrations were apparent during winter. The Ocean Inlet Site had slightly more variable DO concentrations particularly in May and March.

The Basin Plan WQO for DO states that DO shall be above or not less than 5 mg/L. Figure 3-5 and Figure 3-6 present the percentage of DO exceedances observed at the Slough Segment Site and Ocean Inlet Site. The graph displays DO exceedances by month and hour. Those areas in red signify periods of the day and month when DO was consistently below the WQO. The majority of DO exceedances in the Slough Segment occurred between midnight and 8am. While more frequent exceedances were observed between April and November, DO concentrations were not observed to fall below the WQO for prolonged periods of time.

At the Ocean Inlet Site, DO concentrations decreased below the WQO between midnight and 8am also, in a pattern similar to the Slough Segment Site. An increased period of DO exceedances was observed at this site in March, where DO concentrations were lower than the WQO from 6pm through to 10am.

Figure 3-8 presents monthly DO concentrations at the three monitoring locations in the Slough. DO results at the MES were indicative of eutrophic conditions with average results of less than 2 mg/L. The Slough Segment Site (indicative of the overall Slough) had average results of 6.9 mg/L. The results of the DO analysis within the Slough indicate that concentrations were influenced by seasonal variation and spatially. Lower DO concentrations were more frequently below the WQO of 5 mg/L during the months of September and October at the Ocean Inlet Site and during the summer and fall months of June through October at the Slough Segment Site. The highest potential for eutrophication in the Slough would therefore be during summer and fall, coinciding with warmer water temperatures. The lowest DO concentrations (0 mg/L) were recorded at the Ocean Inlet Site on April 2, 2008. The highest DO concentrations (26.0 mg/L) were recorded at the Ocean Inlet Site on May 13, 2008.

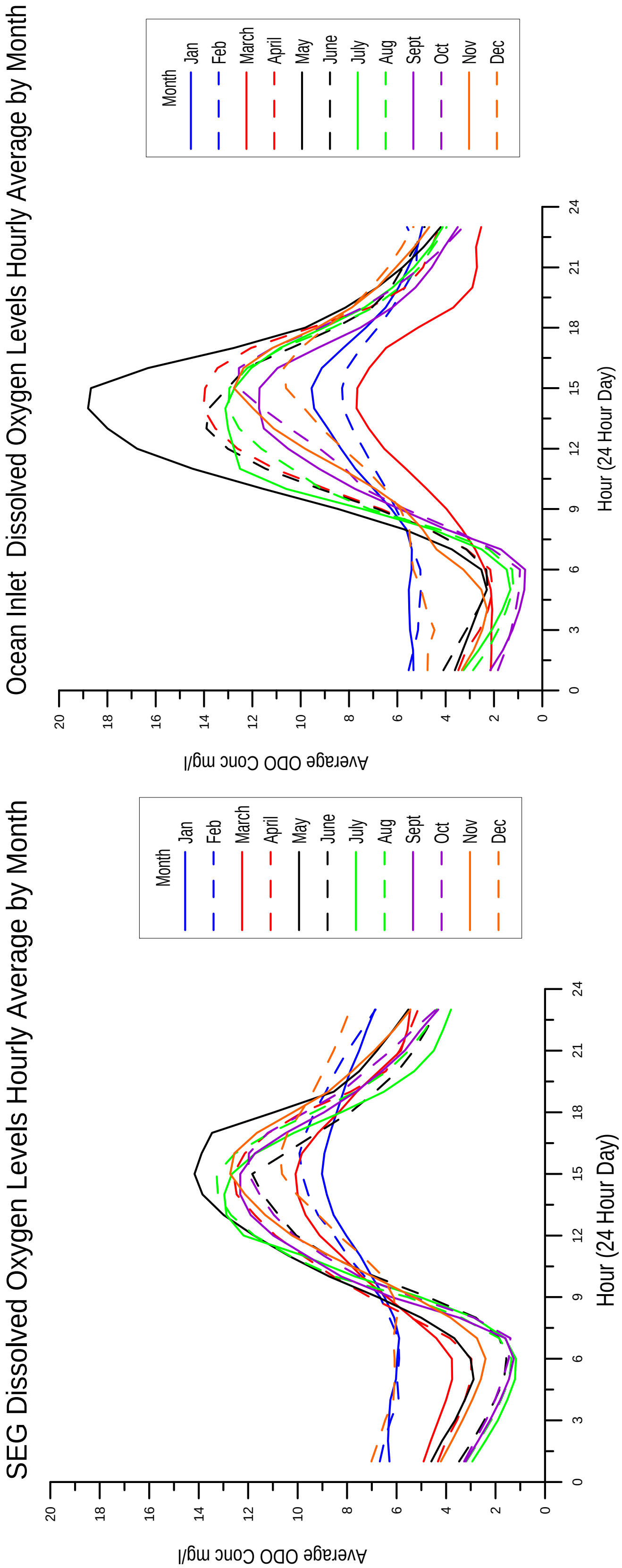

Figure 3-4. Average Monthly Dissolved Oxygen Concentrations at Slough Segment Site and Ocean Inlet Site

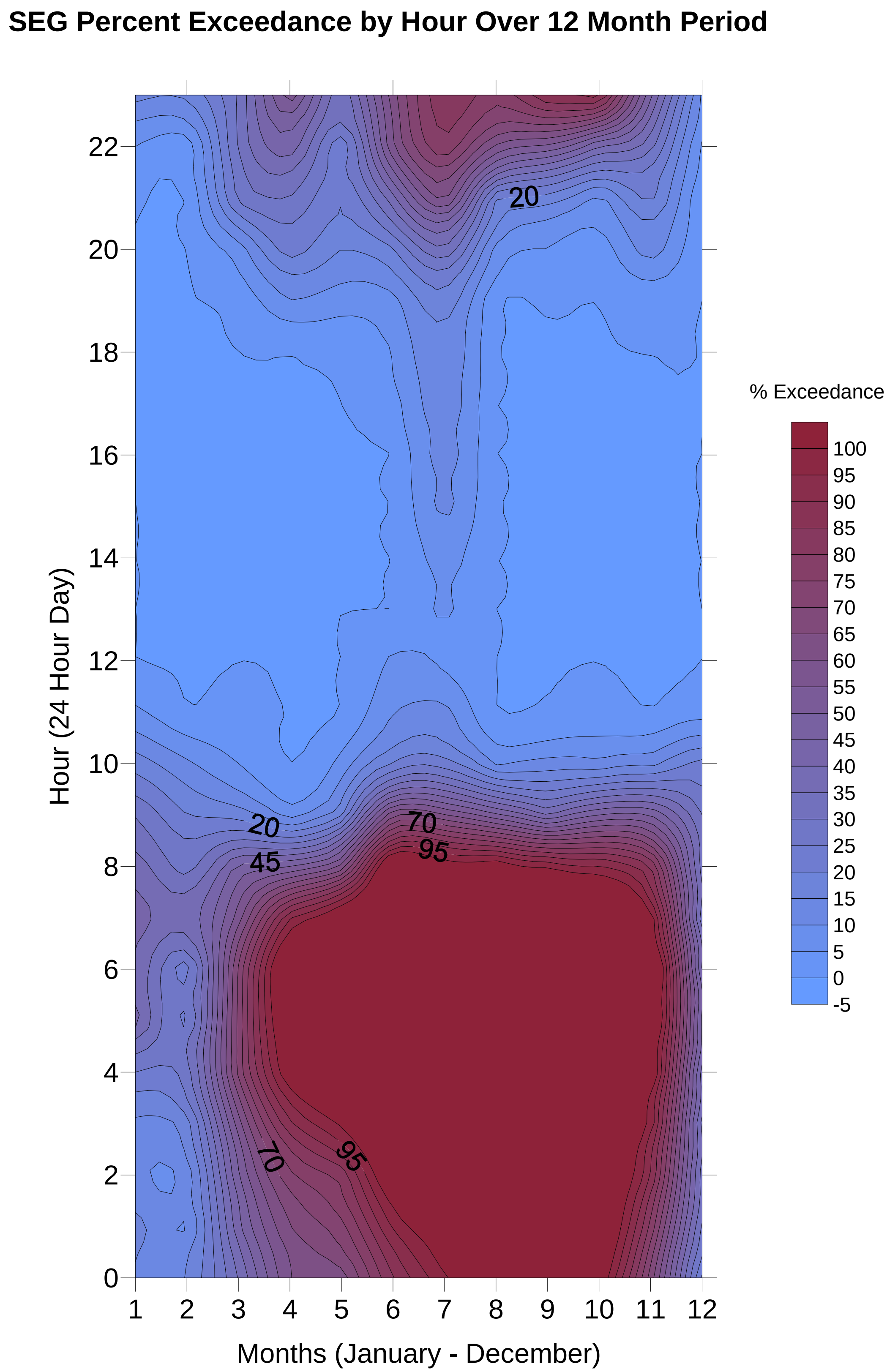

Figure 3-5. Percentage Exceedances of Dissolved Oxygen at the Slough Segment Site

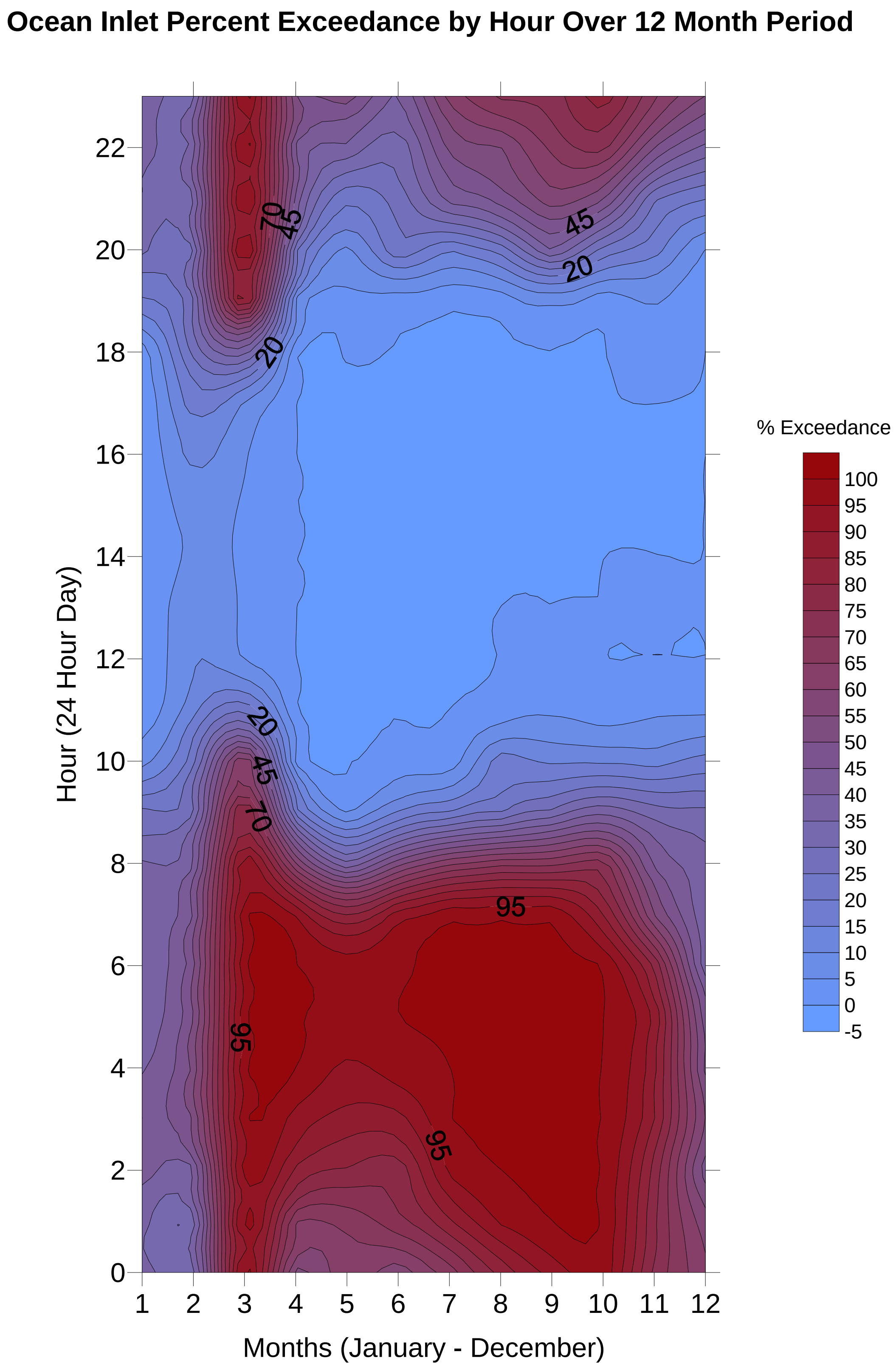

Figure 3-6. Percentage Exceedances of Dissolved Oxygen at Ocean Inlet Site

Figure 3-7. Monthly Temperature at the Three Continuous Monitoring Locations in Famosa Slough

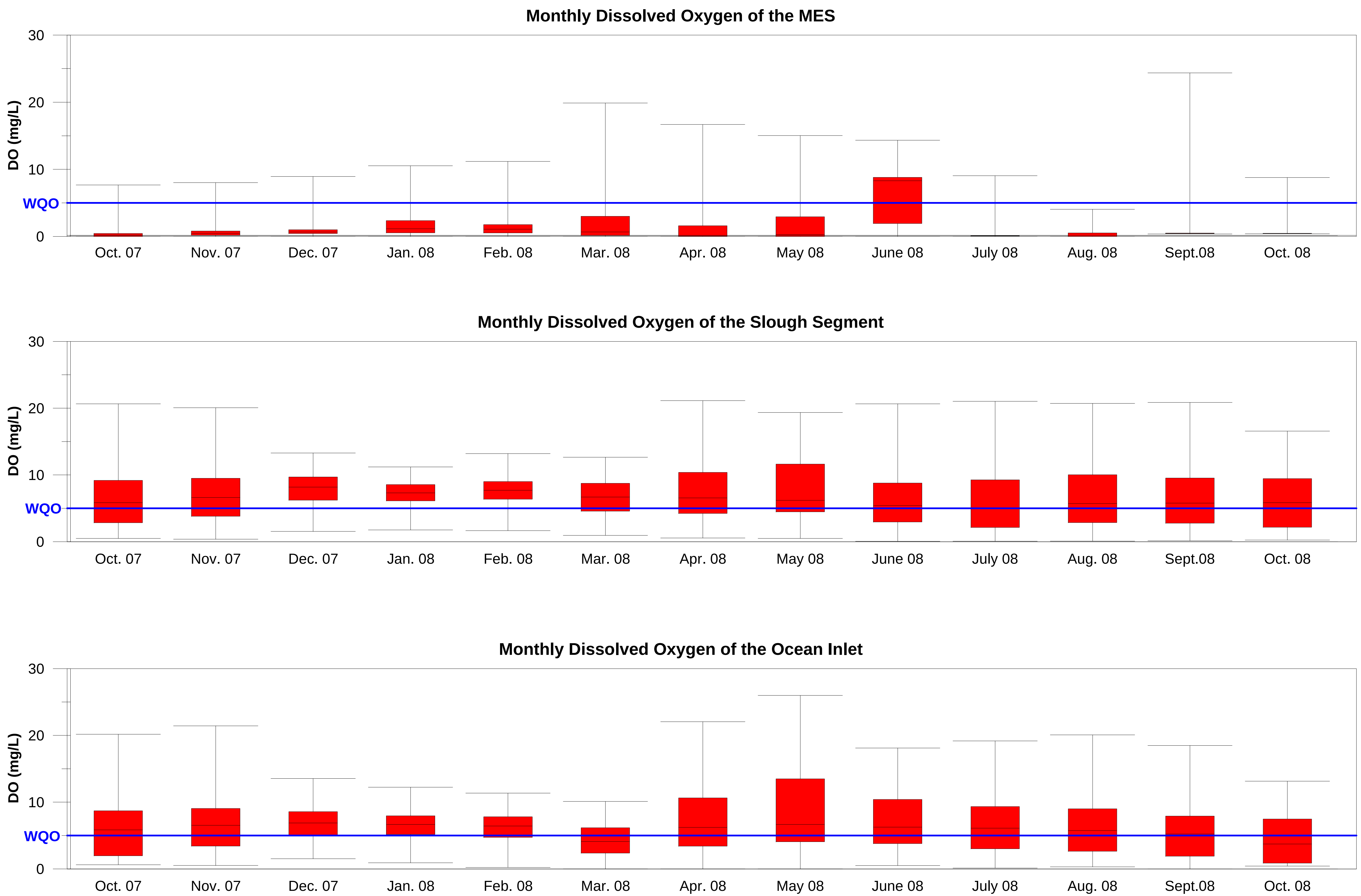

Figure 3-8. Monthly Dissolved Oxygen at the Three Continuous Monitoring Locations in Famosa Slough

3.3 Storm Water Monitoring

This section presents a summary of the wet weather monitoring results and analysis for contaminants of concern conducted throughout the Slough between November 2007 and February 2008. Raw wet weather analytical data are presented in Appendix G. The wet weather results are presented in Section 3.3.1 for the MES and in Section 3.3.2 for the Slough Segment Site and Ocean Inlet Site.

3.3.1 Wet Weather Water Quality Entering the Slough from the Watershed

Three storm events were monitored as pollutograph samples at the MES. During each event, up to ten grab samples were collected and analyzed for a range of constituents. A summary of the monitoring results is presented in Table 3-7.

Table 3-7. Summary of Mass Emission Site Data – Means, Standard Deviations, Minimums, and Maxima by Analyte for All Storm Events

All Storms	TSS (mg/L)	TN (mg/L)	Ammonia as N (mg/L)	Nitrate + Nitrite as N (mg/L)	Nitrite as N (mg/L)	TP (mg/L)	TDP (mg/L)	SRP (mg/L)	$CBOD_5$ (mg/L)
WQO*	<100 ***	–	Varied*	<10**	<1**	<2 ***	<2 ***	–	–
Mean	30.04	1.54	0.26	0.55	0.03	0.35	0.31	0.22	6.79
Minimum	7	0.66	0.11	0.2	0.01	0.15	0.13	0.12	1.1
Maximum	109	5.27	0.64	1.86	0.06	0.98	0.82	0.68	32.6

* USEPA (1989)
** Basin Plan (SDRWQCB, 1994)
*** Multi-Sector General Permit (USEPA, 2000b)

The hydrographs, together with analytical results, are presented on Figure 3-9 through Figure 3-12.

It should be noted that a rain gauge malfunction occurred during the storm event of February 3, 2008. As a result, no rainfall data were collected for the third (i.e., final) storm event. Hourly rainfall from the Lindberg station was used in the graphs and in load calculations.

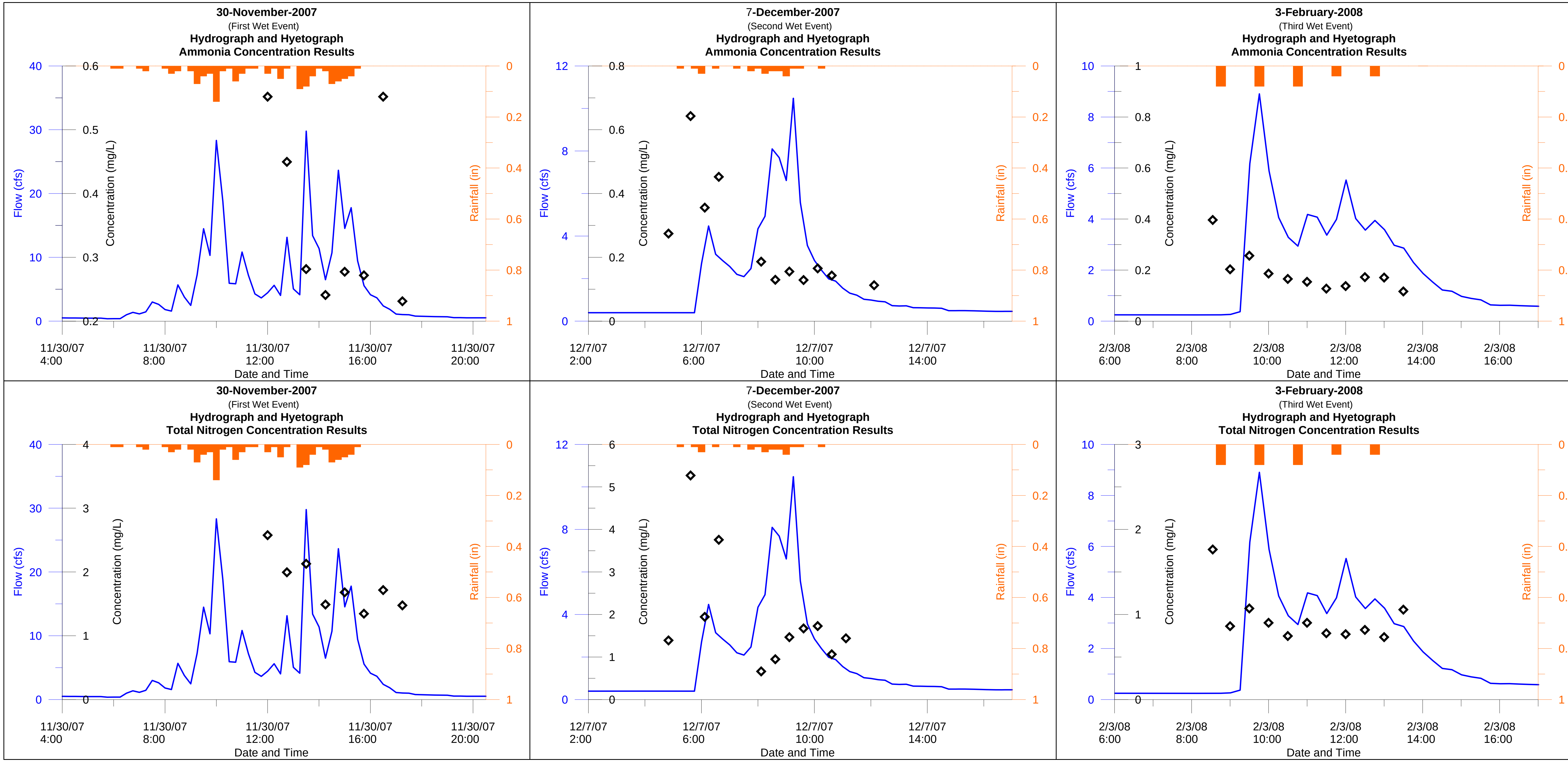

Figure 3-9. Concentrations of Ammonia and Total Nitrogen at the Mass Emission Site during Three Storm Events

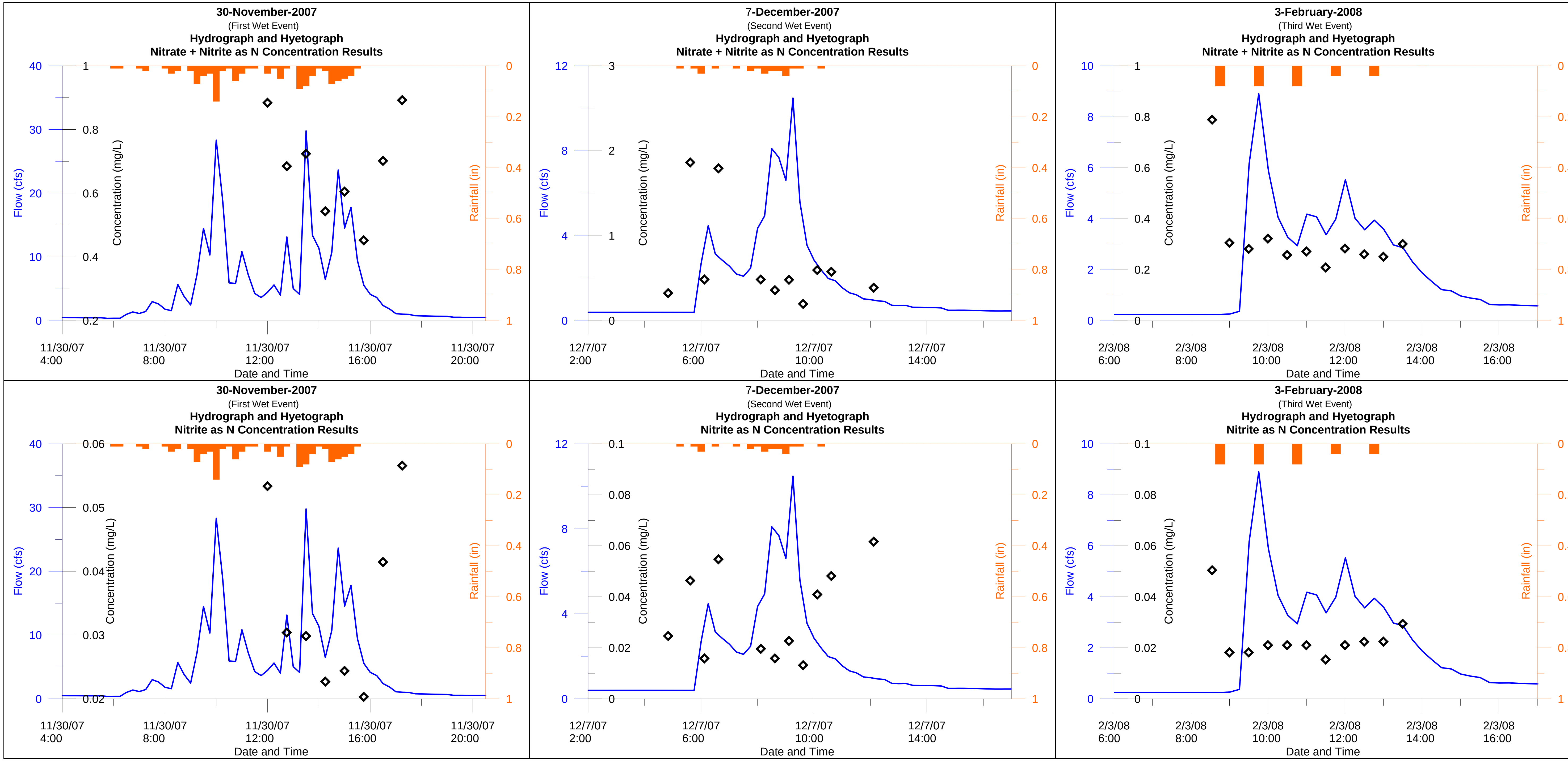

Figure 3-10. Concentrations of Nitrate and Nitrite as N and Nitrite as N at the Mass Emission Site during Three Storm Events

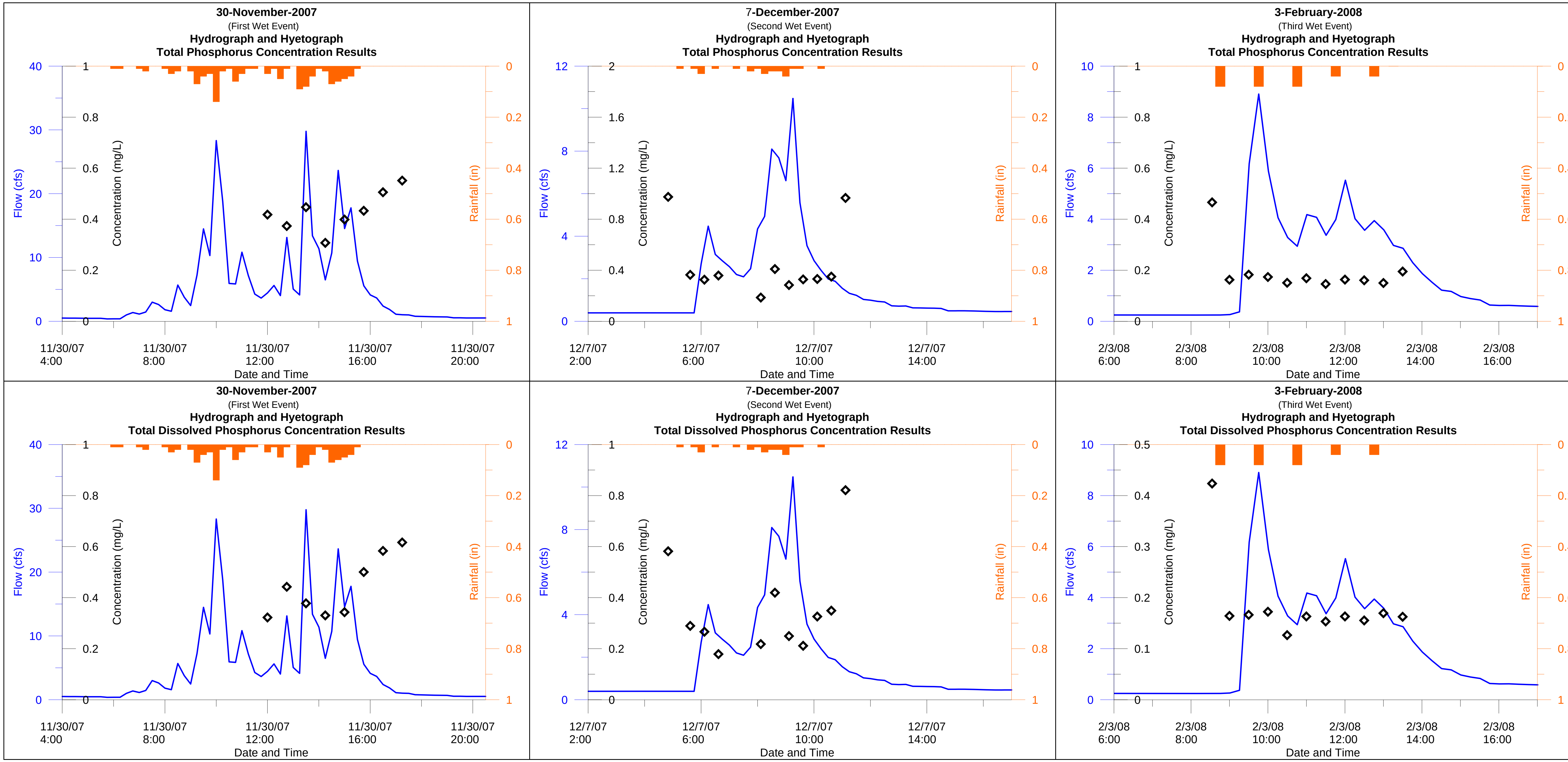

Figure 3-11. Concentrations of Total Phosphorus and Total Dissolved Phosphorus at the Mass Emission Site during Three Storm Events

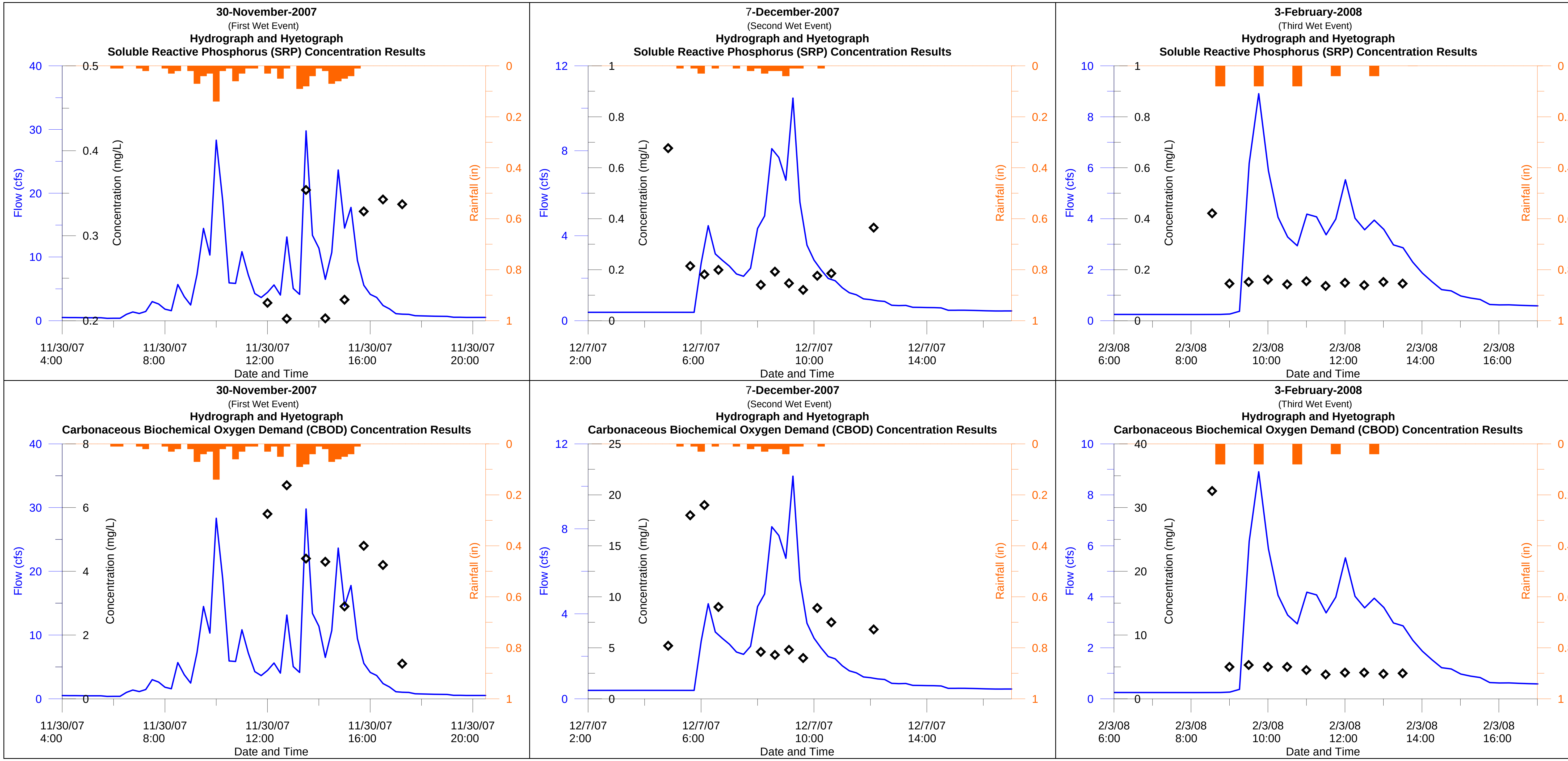

Figure 3-12. Concentrations of Soluble Reactive Phosphorus and Carbonaceous Biological Oxygen Demand at the Mass Emission Site during Three Storm Events

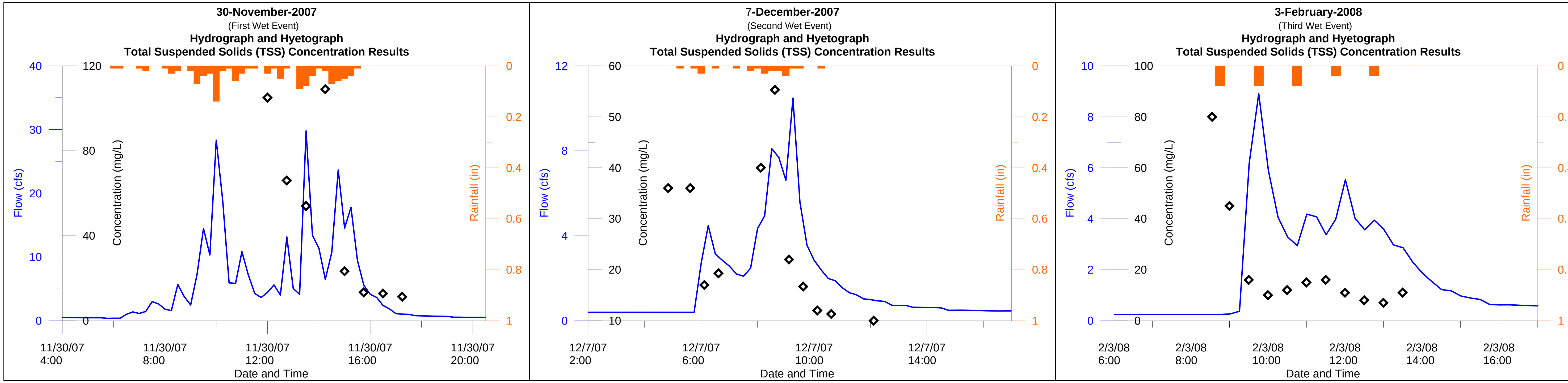

Figure 3-13. Concentrations of Total Suspended Solids at the Mass Emission Site during Three Storm Events

3.3.2 Wet Weather Water Quality in the Slough Segment and Ocean Inlet during Storm Events

Slough Segment and Ocean Inlet water samples were collected as three-hour composite samples taken over slack high and slack low tides after each storm event. These data are presented as means for all three storm events (Table 3-8).

Table 3-8. Analyte Concentrations at the Ocean Inlet and Slough Segment Sampling Locations during Wet Weather (mean of three storms)

Sampling Location	Tide	Ammonia as N	Carbonaceous Biochemical Oxygen Demand	Chlorophyll-a	Nitrate + Nitrite as N	Nitrite as N	SRP	TDP	TN	TP	TSS
Slough Segment	High	0.17	0.48	4.25	0.10	0.02	0.05	0.09	0.80	0.10	13.48
	Low	0.18	1.10	4.47	0.20	0.02	0.07	0.08	0.68	0.07	11.27
Ocean Inlet	High	0.19	0.45	4.05	0.13	0.02	0.06	0.03	0.54	0.06	17.65
	Low	0.20	1.83	4.33	0.17	0.02	0.06	0.19	0.94	0.12	19.40

To assess the impact of the San Diego River on the Slough during periods of wet weather, the high and low tides at the Ocean Inlet Site were compared. Analysis of the comparison suggested no significant differences between the high and low tide concentrations of analytes.

3.3.3 Storm Sediment Grain Size Analysis

Two time-weighted composite water samples were collected at the Slough during wet weather on December 7, 2007 (Figure 3-14) and February 3, 2008 (Figure 3-15).

The water samples were analyzed for particle-size distribution using laser diffraction techniques modified from ASTM D4464. The results of this analysis are presented in Appendix H.

The results of the particle-size distribution show that the majority of sediment in the storm water flows is made up of silt (0.0625–0.002 mm). A small proportion of the particles were very fine sand (0.125–0.0625 mm) or clay (0.002 mm or smaller).

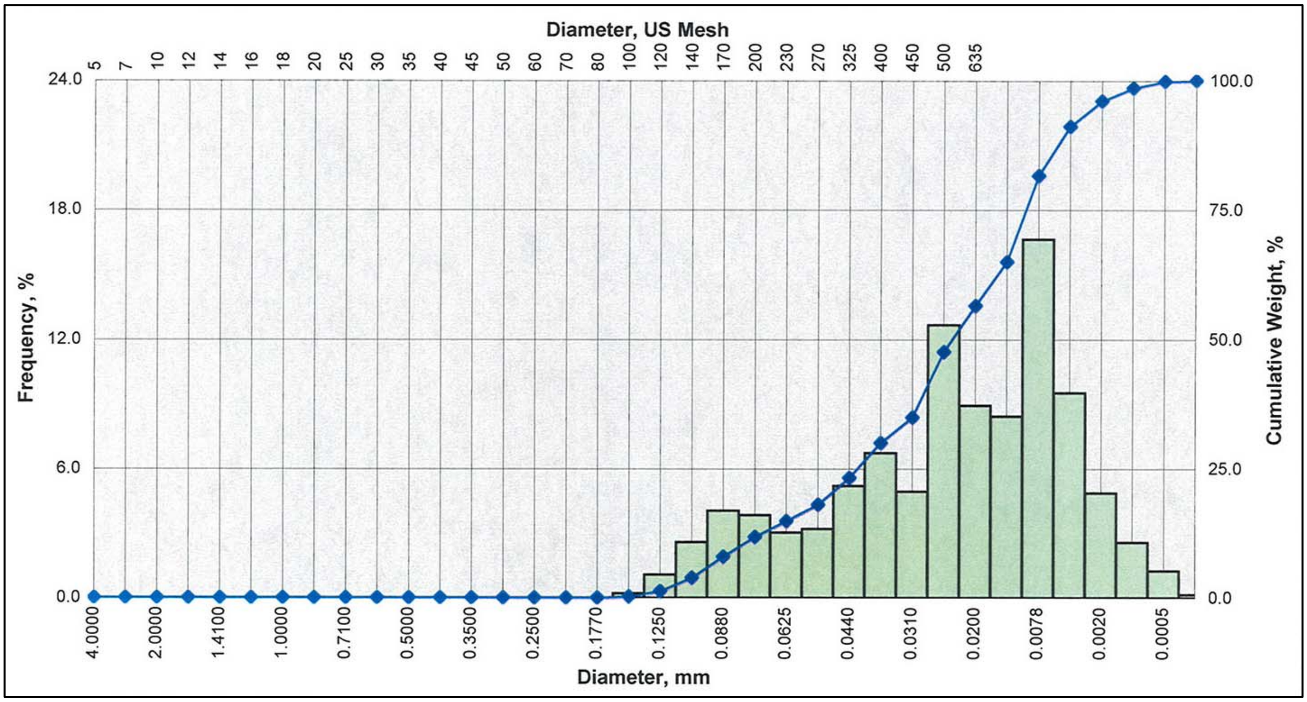

Figure 3-14. Laser Particle Size Analysis Results from the December 7, 2007 Storm Event

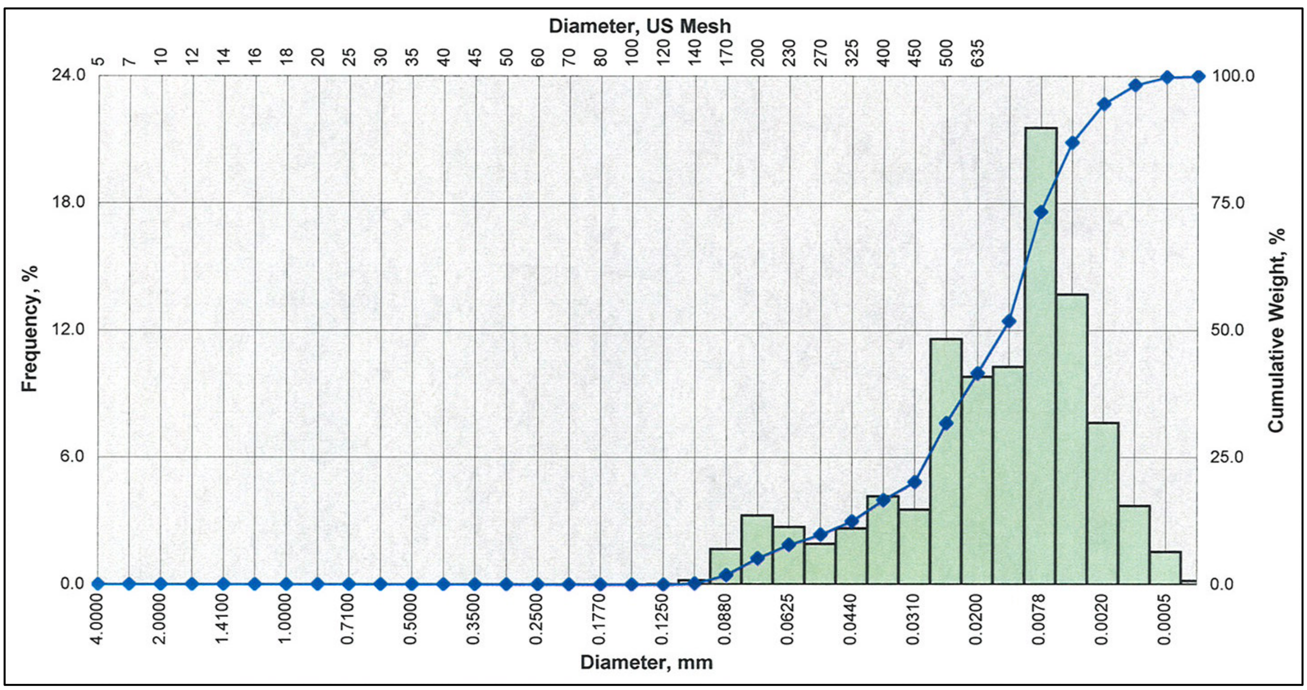

Figure 3-15. Laser Particle Size Analysis Results from the February 3, 2008 Storm Event

3.4 Post-Storm Sediment Sampling

Post-storm sediment sampling was conducted on February 12, 2008. Sediments were collected from nine locations around the Slough and from five locations in the adjoining channel. Samples were analyzed by SCCWRP for the following:

- Percent of fines or sand/silt/clay.
- Percent of OC.
- Percent of TN.
- Percent of TP.

The results of this analysis, as provided by SCCWRP, are presented in Table 3-9. Raw data are presented in Appendix I. It should be noted that analysis results were not provided for percent of OC or percent of TN for Site FS-W3-PSS-2. In addition, technician error during processing by SCCWRP resulted in vial breakage during analysis for percent of TP in samples FS-W3-PSS-10 and FS-W3-PSS-11.

The results indicate that sediment grain size varied considerably with the lowest sand fraction reported at 15.18% and the highest at 91.86%. The site with the largest grain size (Site PSS-6) was also associated with the lowest TN and TP concentrations. The smallest grain size (Site PSS-1) also had very low associated nutrient concentrations.

Table 3-9. Results of Post-Storm Sediment Analysis in Famosa Slough

Site ID	% OC	% Sand	% TN	% TP
PSS-1	0.69	15.18	0.12	0.04
PSS-2	–*	55.05	–*	0.07
PSS-3	3.3	55.40	0.42	0.06
PSS-4	4.5	37.21	0.47	0.08
PSS-5	2.3	58.51	0.22	0.05
PSS-6	0.76	91.86	0	0.02
PSS-7	2.1	76.7	0.28	0.06
PSS-8	3.9	48.51	0.44	0.08
PSS-9	5.5	60.29	0.73	0.11
PSS-10	4.4	88.62	0.55	Vial broken**
PSS-11	5.2	61.67	0.66	Vial broken**
PSS-12	5.3	54.07	0.54	0.09
PSS-13	7.6	71.11	1.1	0.13
PSS-14	4.7	72.35	0.59	0.09
Mean	**3.87**	**63.15**	**0.47**	**0.07**
Std. deviation	**1.99**	**24.28**	**0.28**	**0.03**

* No data were provided by SCCWRP.
**The vial used to perform the nutrient digestion was broken during processing at the SCCWRP facility.
Minimum result – yellow highlight
Maximum result – green highlight

3.5 Index Period Sampling

Dry weather sampling was conducted in several areas of the Slough during quarterly index periods. Samples were collected from the MES, the Slough Segment Site, and the Ocean Inlet Site during four two-week periods (Table 3-10). The index period sampling provides a representative data set of the seasonal cycles and trends of physical forcing and biological activity in the Slough. Index period data are presented in Appendix J.

It should be noted that for this report, non-detect results were reported as half their minimum detection limits.

Table 3-10. Index Period Sampling

Season	Index Period	Start Date	End Date
Winter	1	January 14, 2008	January 23, 2008
Spring	2	March 18, 2008	March 26, 2008
Summer	3	July 14, 2008	July 23, 2008
Fall	4	September 15, 2008	September 24, 2008

The primary constituents of concern in the Slough are nutrients, CBOD, TSS, and chlorophyll-a. Nutrients in excessive amounts can cause eutrophication, which results in overgrowth of plant life and a decline of the biological activity. Elevated concentrations of nutrients can lead to low DO levels, fish kills, algal blooms, increased sedimentation, and species shifts in both flora and fauna.

The MES is the largest input of freshwater runoff into the Slough. Data from this site were averaged by index period to assess seasonal variability (Table 3-11).

Chemistry concentrations of the constituents of concern were consistently higher at the MES (Table 3-11) compared with the Slough Segment Site (Table 3-12) and Ocean Inlet Site (Table 3-13). The low flows at the MES were observed to provide ideal conditions for algal growth which may explain the higher concentrations. The highest chlorophyll-a results were observed during spring and summer at the MES. The highest chlorophyll-a concentrations at the Slough Segment Site were recorded in Fall 2008. The highest chlorophyll-a results recorded at the Ocean Inlet Site were recorded during the winter. In addition, it should be noted that dry weather loads (as opposed to concentrations) from the MES present a relative proportion of the inputs to the Slough (Section 4.2.2).

Table 3-11. Mean Dry Weather Concentrations at the Mass Emission Site

Parameter	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
TSS (mg/L)	12.67	20.78	12.85	30.55
TN (mg/L)	0.66	1.11	1.23	0.75
Ammonia as N (mg/L)	0.26	0.15	0.20	0.16
Nitrate + nitrite as N (mg/L)	0.04	0.08	0.02	0.00
Nitrite as N (mg/L)	0.01	0.02	0.01	0.00
TP (mg/L)	0.42	0.50	0.78	0.62
TDP (mg/L)	0.41	0.46	0.72	0.60
SRP (mg/L)	0.36	0.29	0.50	0.47
$CBOD_5$ (mg/L)	2.58	4.23	2.82	2.68
Chlorophyll-a (mg/m^3)	23.83	204.48	58.22	40.05

Table 3-12. Mean Dry Weather Concentrations at the Slough Segment Site

Parameter	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
TSS (mg/L)	9.84	7.06	8.56	7.55
TN (mg/L)	0.42	0.44	0.52	0.31
Ammonia as N (mg/L)	0.13	0.06	0.03	0.01
Nitrate + nitrite as N (mg/L)	0.03	0.03	0.01	0.00
Nitrite as N (mg/L)	0.01	0.00	0.00	0.00
TP (mg/L)	0.03	0.04	0.07	0.06
TDP (mg/L)	0.04	0.04	0.05	0.01
SRP (mg/L)	0.02	0.02	0.02	0.02
$CBOD_5$ (mg/L)	0.00	0.10	0.66	0.38
Chlorophyll-a (mg/m^3)	5.42	5.57	4.04	11.08

Table 3-13. Mean Dry Weather Concentrations at the Ocean Inlet Site

Parameter	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
TSS (mg/L)	8.45	11.08	8.67	5.04
TN (mg/L)	0.38	0.40	0.41	0.22
Ammonia as N (mg/L)	0.13	0.06	0.03	0.05
Nitrate + nitrite as N (mg/L)	0.03	0.03	0.01	0.00
Nitrite as N (mg/L)	0.01	0.00	0.00	0.00
TP (mg/L)	0.03	0.04	0.06	0.02
TDP (mg/L)	0.03	0.03	0.04	0.02
SRP (mg/L)	0.02	0.02	0.03	0.03
$CBOD_5$ (mg/L)	0.00	0.08	0.14	0.00
Chlorophyll-a (mg/m^3)	5.19	4.47	3.07	1.98

The results presented on Figure 3-16 through Figure 3-23 show that certain analyte values at the MES were significantly greater than the values at the Slough Segment Site and the Ocean Inlet Site. However, no water quality exceedances were recorded within the Slough at the Slough Segment Site or at the Ocean Inlet Site to indicate that inputs from the MES were adversely affecting receiving water quality[4].

The presence of chlorophyll-a can be a biological response to high levels of nutrients. The low velocities and excess nutrients at the MES may be facilitating or promoting the growth of algae within the Slough. Nutrients can stimulate the growth of algae, which in turn die and decay in the sediment layer while consuming oxygen through this process. Algal growth may be a significant factor in the low DO levels continuously recorded at the MES. However, DO levels within the Slough at the Slough Segment Site and the Ocean Inlet Site were consistently above 5 mg/L, suggesting no impairment.

[4] The WQO for ammonia was calculated using the pH, salinity, and temperature (based on parameters presented in Table 2 of the United States EPA Ambient Water Quality Criteria for Ammonia (Saltwater) – 1989). Using these criteria, it was shown that ammonia concentrations did not exceed WQOs.

3.5.1 Mass Emission Site Contaminant Concentrations during Index Period Sampling

This section presents the concentrations of analytes discharging from the MES into the Slough during each of the four index periods. Nitrogen species are presented in Figure 3-16. This comparison shows that most nitrogen species were highest in the second index period (spring). Concentrations of nitrogen species were significantly higher at this MS4 discharge point than at the Slough Segment Site and Ocean Inlet Site (Figure 3-19 through Figure 3-21). However, flows from the MS4 were very low during dry weather, and as such the annual loads, as calculated in Section 4.2, were not found to contribute significantly to the Slough.

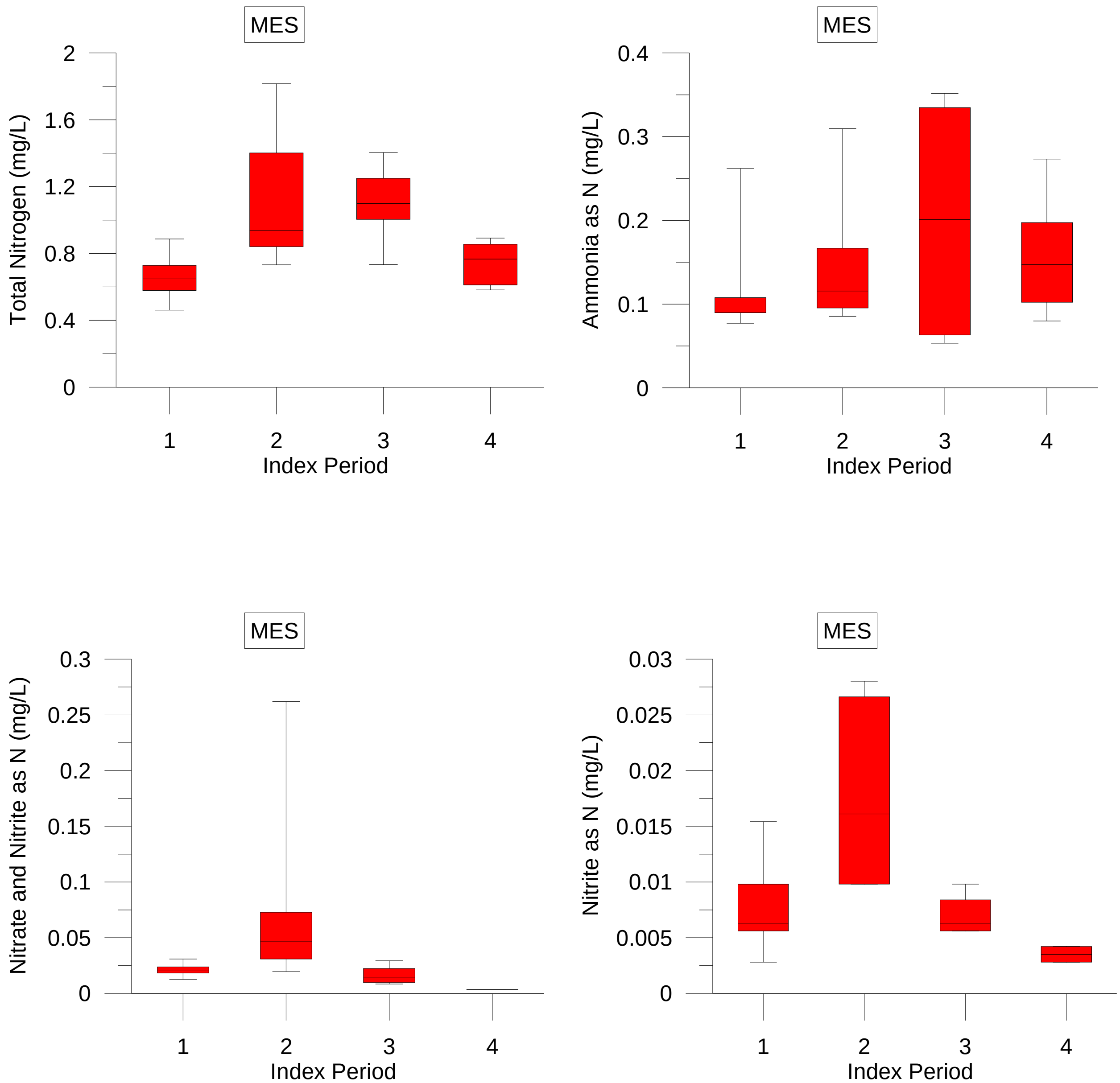

Figure 3-16. Concentrations of Total Nitrogen, Ammonia, Nitrate and Nitrite, and Nitrite at the Mass Emission Site during Index Period Sampling

Total phosphorus, TDP, and SRP concentrations for each index period are presented in Figure 3-17. The highest average TP and TDP concentrations were observed in the third index period (summer).

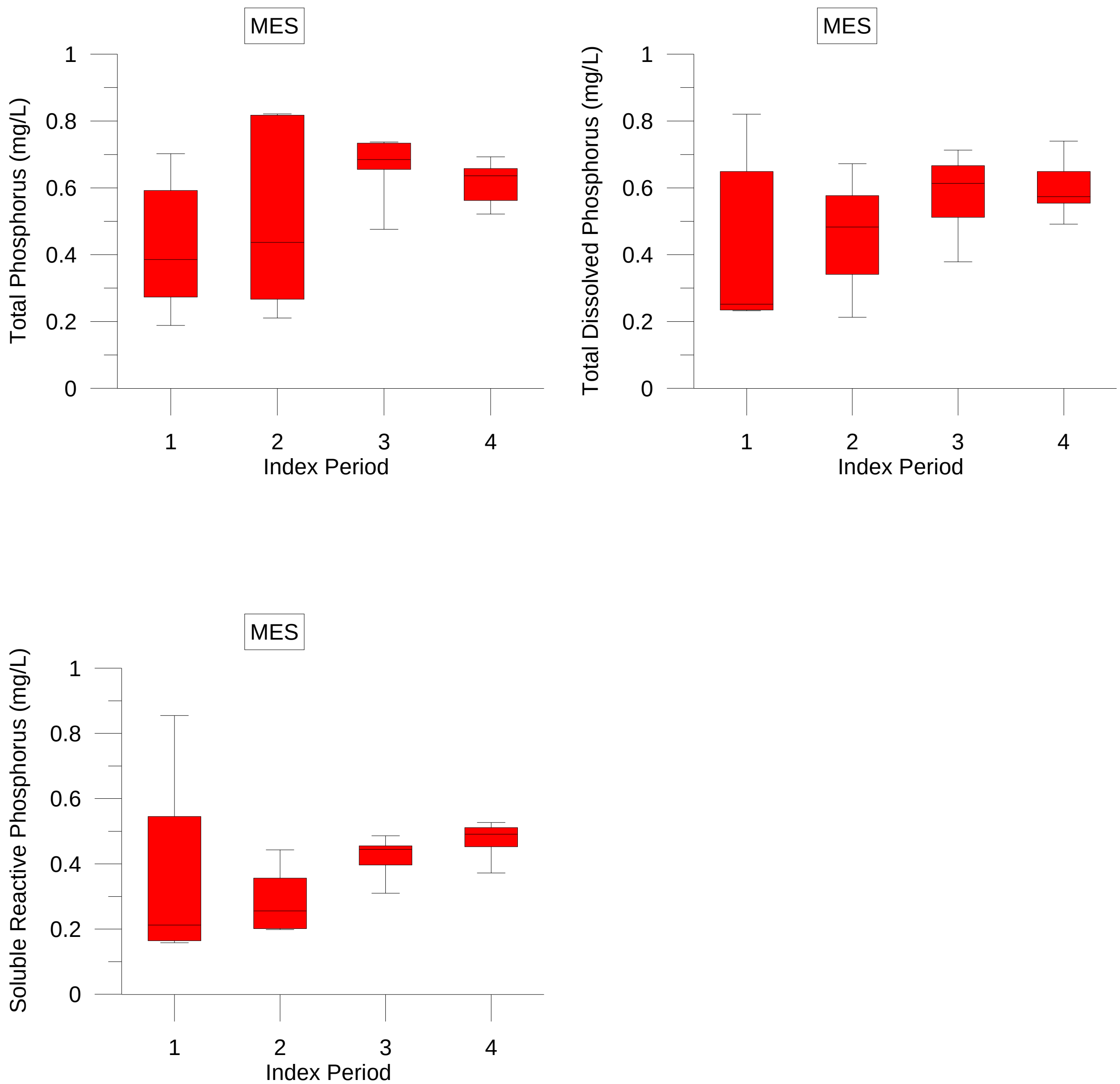

Figure 3-17. Concentrations of Total Phosphorus, Total Dissolved Phosphorus, and Soluble Reactive Phosphorus at the Mass Emission Site during Index Period Sampling

Concentrations of CBOD, chlorophyll-a, and TSS from each index period are presented in Figure 3-18. Chlorophyll-a concentrations were highest in the MES during the second index period (spring) corresponding with the greatest potential for algal growth in the MES's open drainage system leading into the Slough. TSS concentrations averaged between 5 mg/L and 20 mg/L throughout the four index periods.

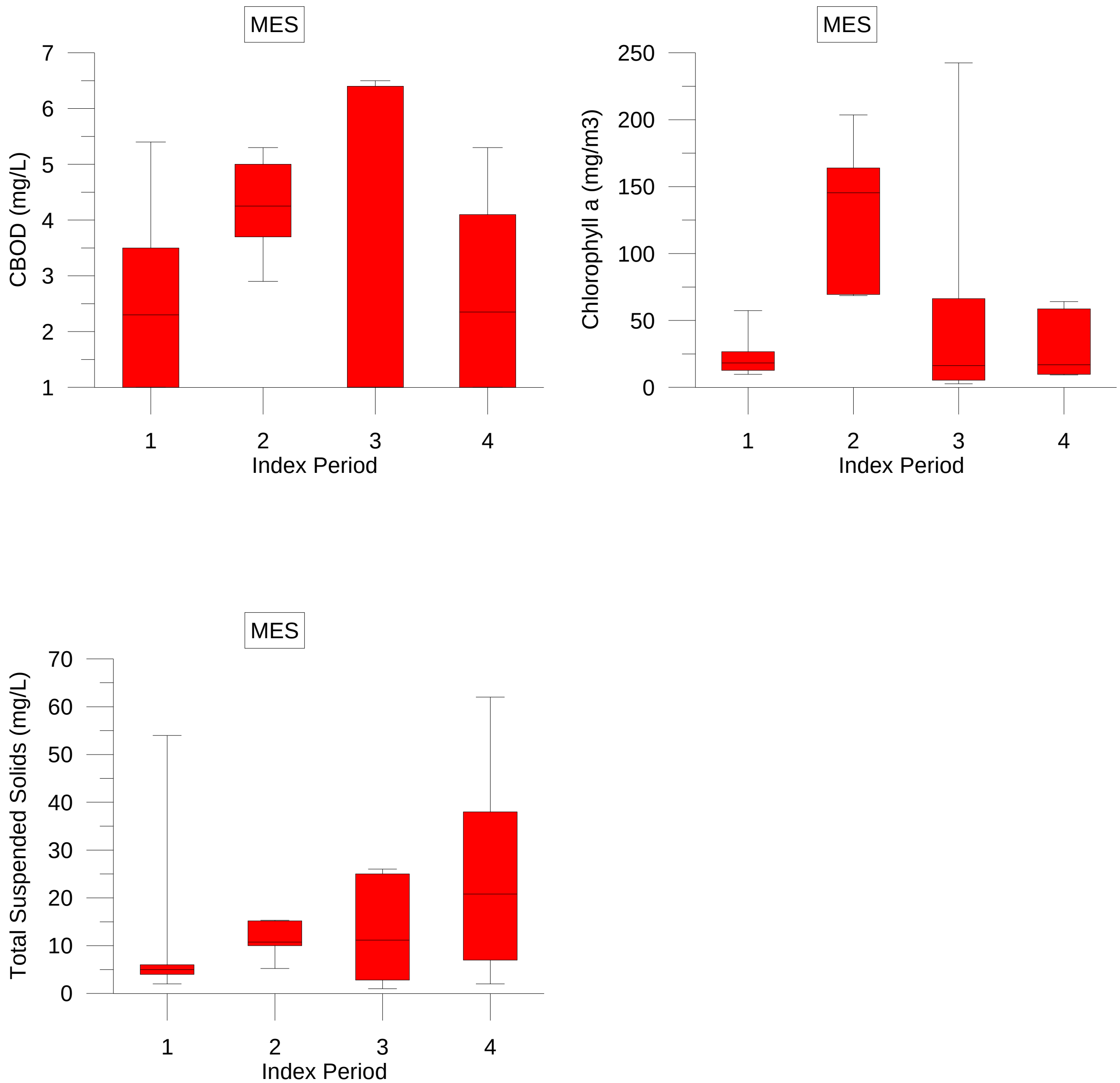

Figure 3-18. Concentrations of Carbonaceous Biochemical Oxygen Demand, Chlorophyll-a, and Total Suspended Solids at the Mass Emission Site during Index Period Sampling

3.5.2 Slough Segment and Ocean Inlet Contaminant Concentrations during Index Period Sampling

This section presents the concentrations of analytes at both the Slough Segment Site and the Ocean Inlet Site during the four index periods.

Total nitrogen concentrations are presented in Figure 3-19. The results indicate that the Ocean Inlet Site generally had slightly higher nitrogen concentrations than the Slough Segment Site.

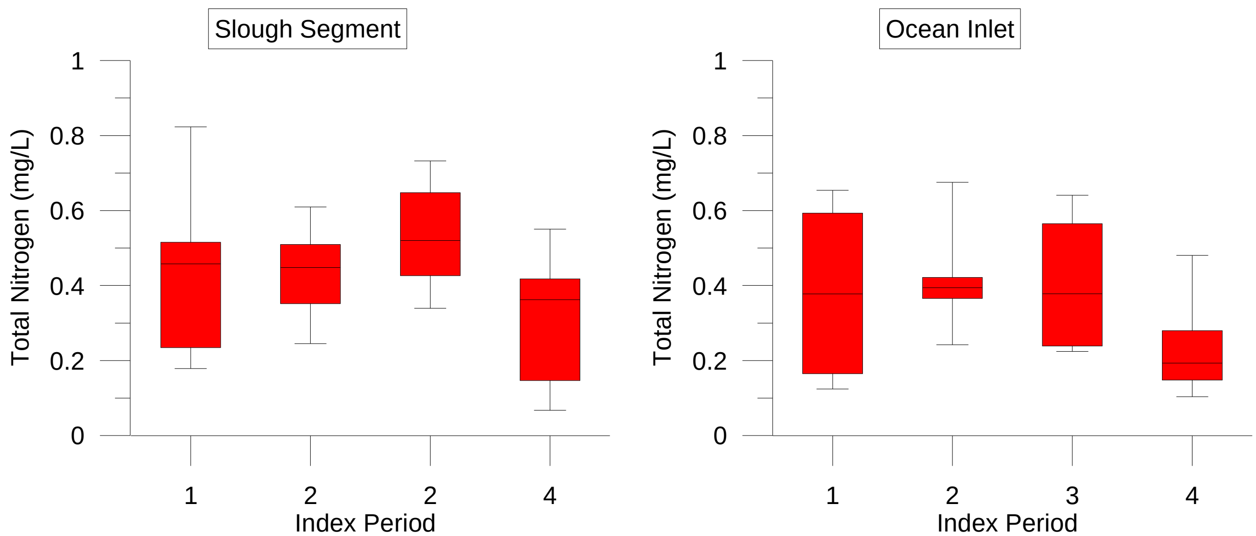

Figure 3-19. Concentrations of Total Nitrogen at the Slough Segment and Ocean Inlet Sites during Index Period Sampling

Figure 3-20 illustrates the difference in concentrations of nitrate and nitrite, and nitrite between the Slough Segment and the Ocean Inlet. The highest concentrations were observed during the first index period (winter), with concentrations decreasing over time. Higher concentrations were generally observed at the Ocean Inlet Site.

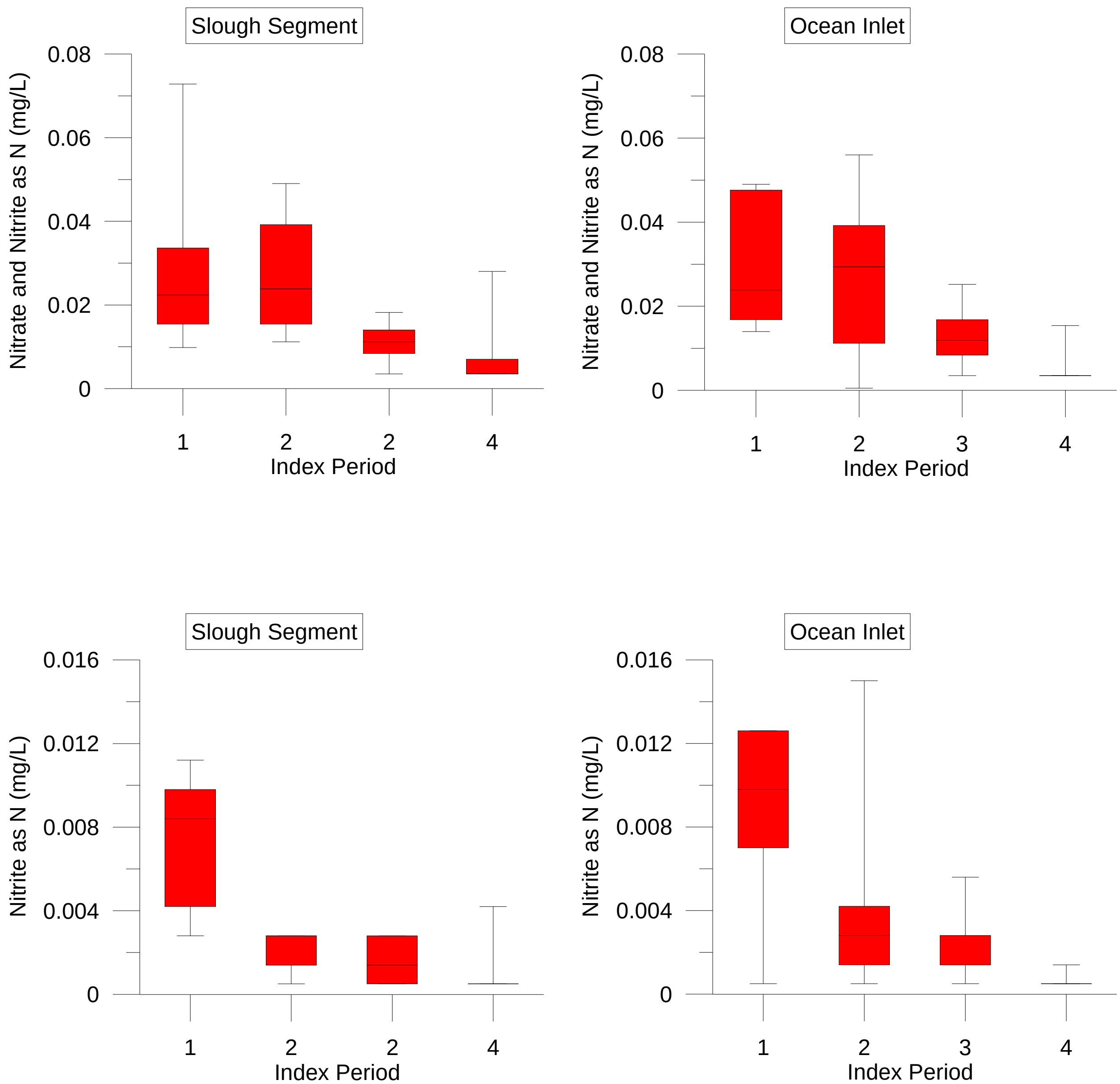

Figure 3-20. Concentrations of Nitrate and Nitrite and Nitrite at the Slough Segment and Ocean Inlet Sites during Index Period Sampling

Figure 3-21 presents the ammonia and SRP concentrations at both the Slough Segment Site and the Ocean Inlet Site. Ammonia concentrations showed a similar trend to those observed in other nitrogen species, with highest concentrations occurring in the first index period (winter) and higher observed concentrations at the Ocean Inlet Site.

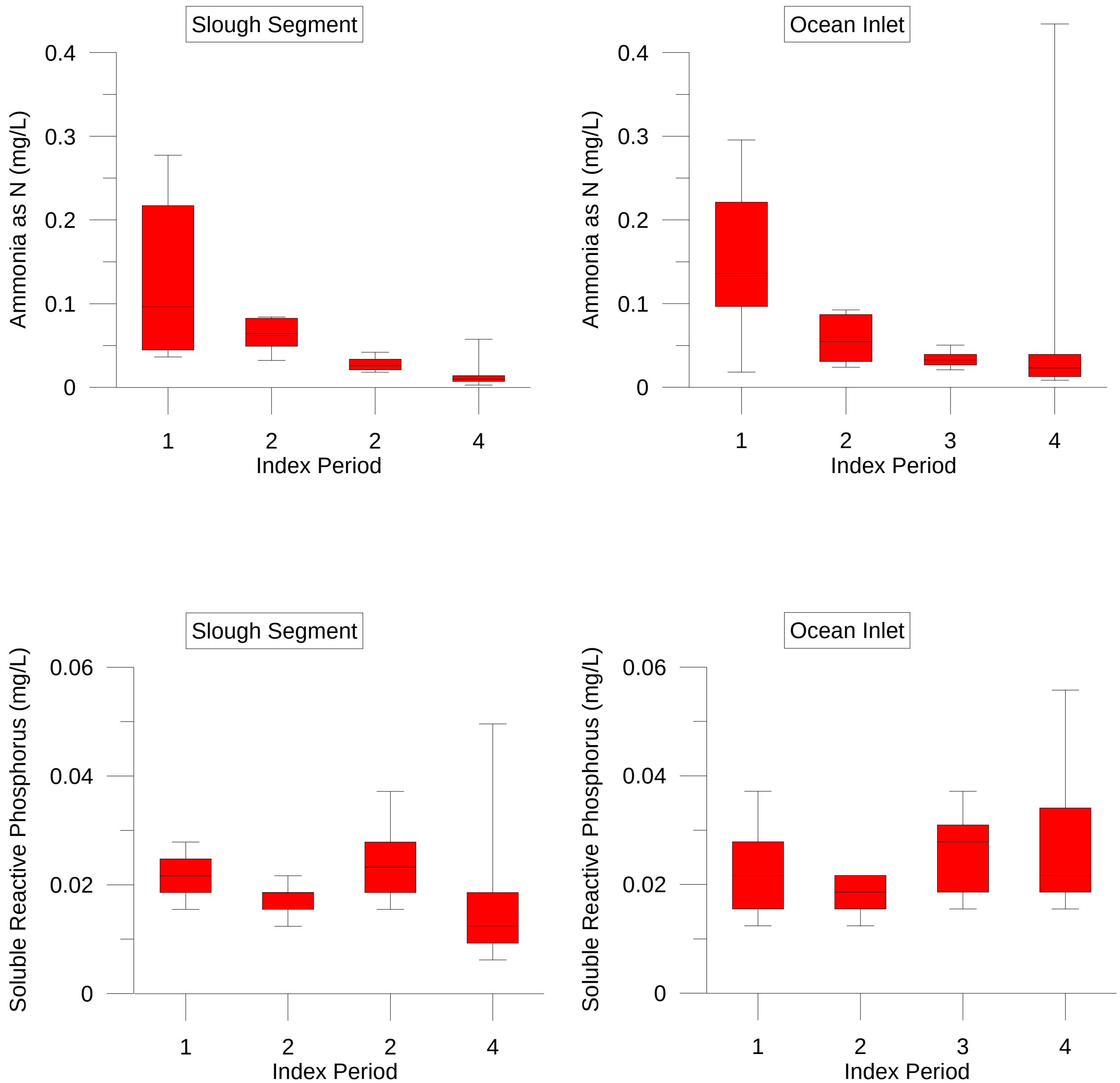

Figure 3-21. Concentrations of Ammonia and Soluble Reactive Phosphorus at the Slough Segment and Ocean Inlet Sites during Index Period Sampling

Figure 3-22 shows the average temporal changes in TP and TDP at the Slough Segment Site and at the Ocean Inlet Site. Both sites showed slightly higher concentrations during the third index period (summer). The Ocean Inlet Site also showed higher concentrations of TP and TDP than the Slough Segment Site.

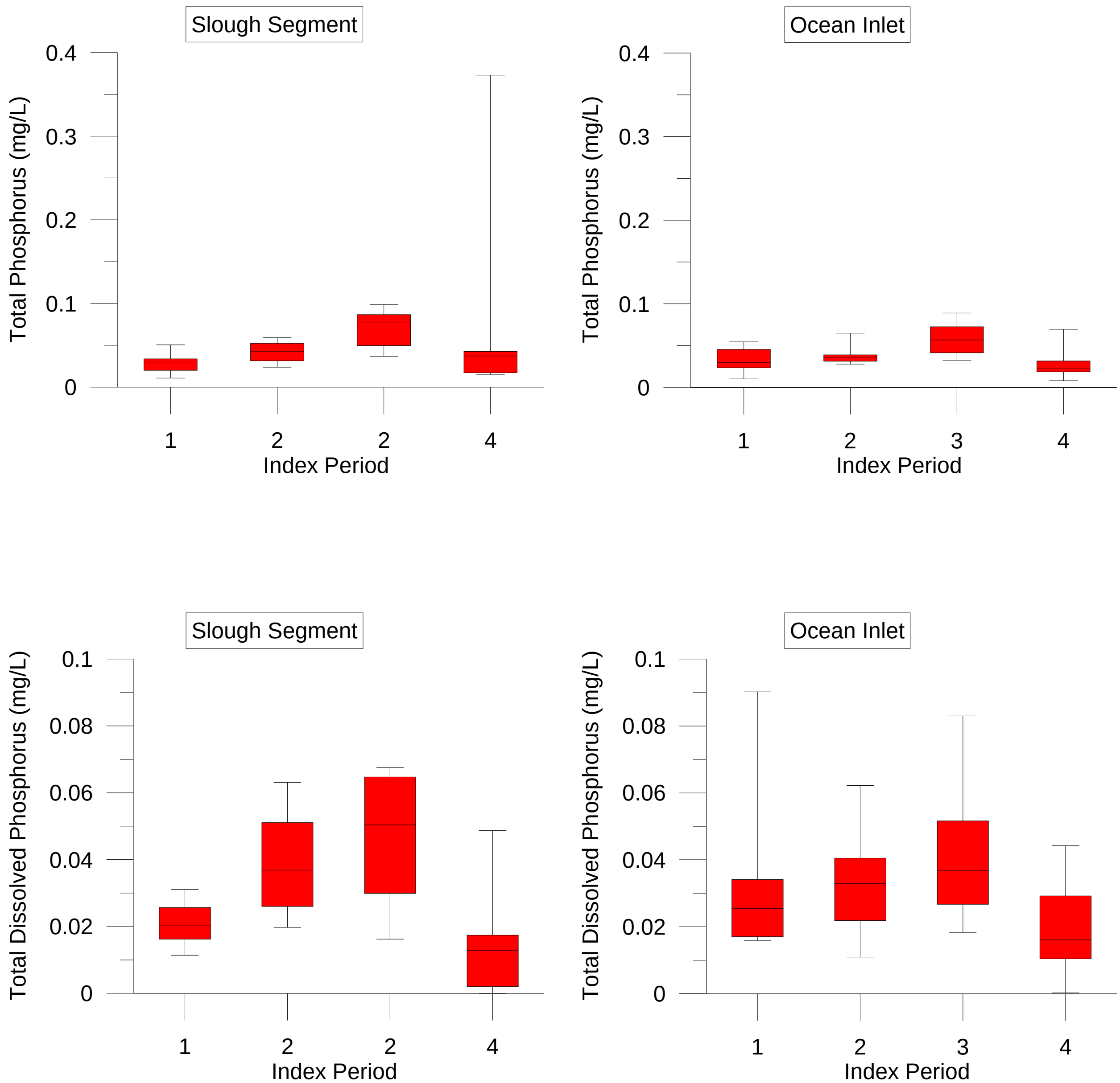

Figure 3-22. Concentrations of Total Phosphorus and Total Dissolved Phosphorus at the Slough Segment and Ocean Inlet Sites during Index Period Sampling

Figure 3-23 presents the chlorophyll-a and TSS concentrations at the Slough Segment Site and at the Ocean Inlet Site. Chlorophyll-a concentrations were on average slightly higher at the Ocean Inlet Site with the exception of the fourth index period (fall) when significantly higher concentrations were observed at the Slough Segment Site. TSS concentrations were consistent at the Slough Segment Site averaging around 10 mg/L. Overall average TSS concentrations at the Ocean Inlet Site were slightly higher and more variable.

Concentrations of $CBOD_5$ were consistently reported as non-detects in the Slough Segment Site and Ocean Inlet Site. As such, these results are not reported here.

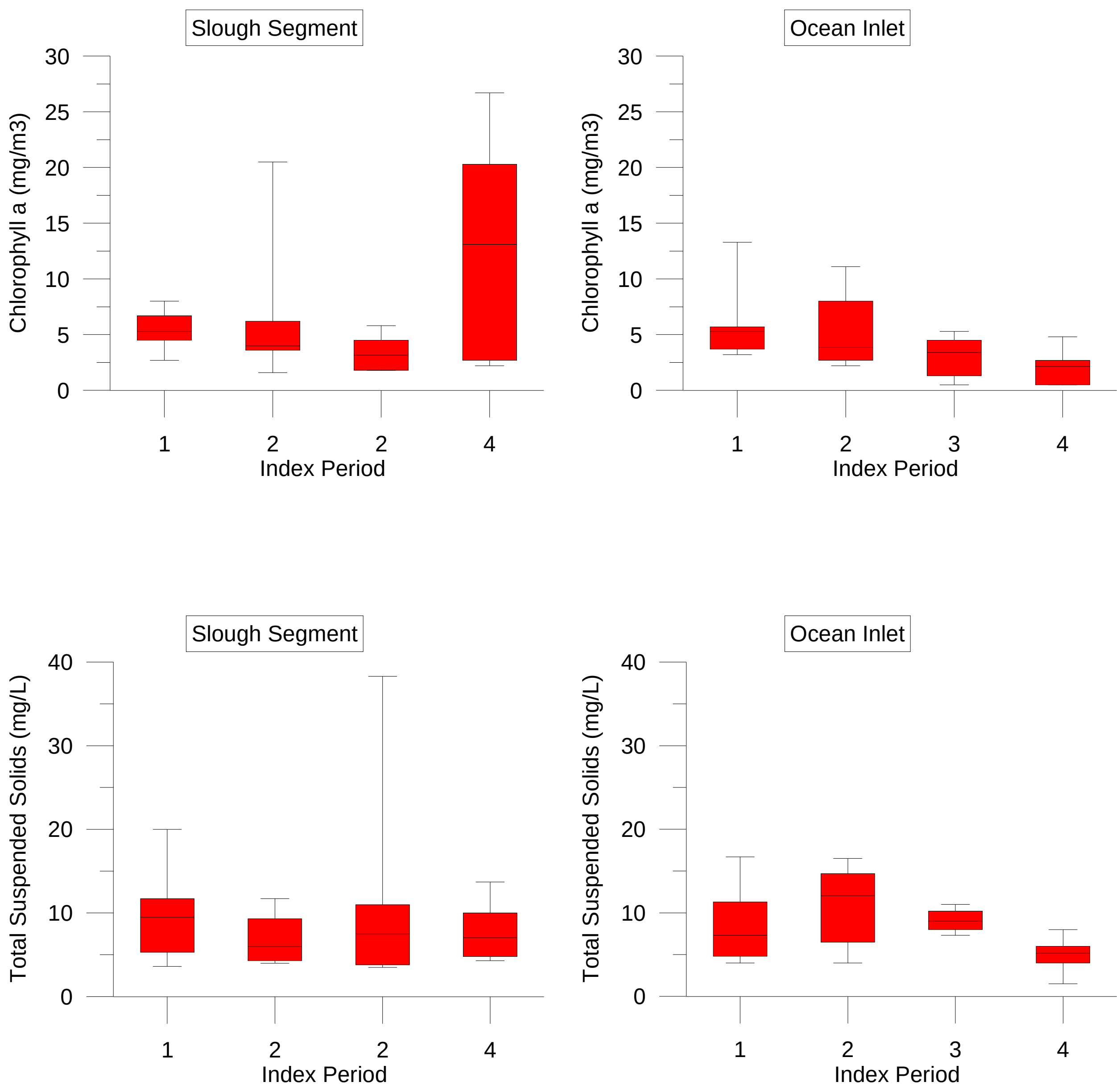

Figure 3-23. Concentrations Chlorophyll-a and Total Suspended Solids at the Slough Segment and Ocean Inlet Sites during Index Period Sampling

3.5.3 Transect Sampling

Longitudinal transect sampling occurred on the fourth day of the first week of each index period. During this sampling, three transects were collected during ebb tides and flood tides. This sampling provided spatial water quality data within the Slough. Analysis of these data showed no significant difference between ebb and flood concentrations during each index period. Therefore, data from each transect were averaged to illustrate seasonal differences (Table 3-14). Concentrations of TN, TP, chlorophyll-a, and TSS were higher in the summer and fall months. These results are consistent with observations of increased biological activity and algal growth in the Slough during the summer.

Table 3-14. Mean Transect Analyte Result during Each Index Period

Analyte	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
TSS (mg/L)	10.29	9.37	15.21	13.36
TN (mg/L)	0.46	0.41	0.62	0.31
Ammonia as N (mg/L)	0.10	0.05	0.02	0.01
Nitrate + nitrite as N (mg/L)	0.02	0.01	0.01	0.00
Nitrite as N (mg/L)	0.01	0.01	0.00	0.00
TP (mg/L)	0.04	0.03	0.08	0.02
TDP (mg/L)	0.02	0.03	0.03	0.00
SRP (mg/L)	0.02	0.01	0.01	0.01
$CBOD_5$ (mg/L)	0.50	1.10	–	3.08
Chlorophyll-a (mg/m^3)	6.38	4.80	26.58	20.17

Physical water quality parameters at each transect sampling location were recorded both temporally and spatially with differences observed between both ebb and flood tides. Results are presented graphically for DO (Figure 3-24 and Figure 3-25), salinity (Figure 3-26 and Figure 3-27), and temperature (Figure 3-28 and Figure 3-29). The results show that each variable is influenced by both season and by tidal flow.

3.5.4 Dissolved Oxygen

The DO concentrations varied throughout the Slough during each index period. The concentrations were consistently above the WQO of 5 mg/L, and only one outlying measurement was below the benchmark. The average DO concentrations were higher during the flood tides of each index period.

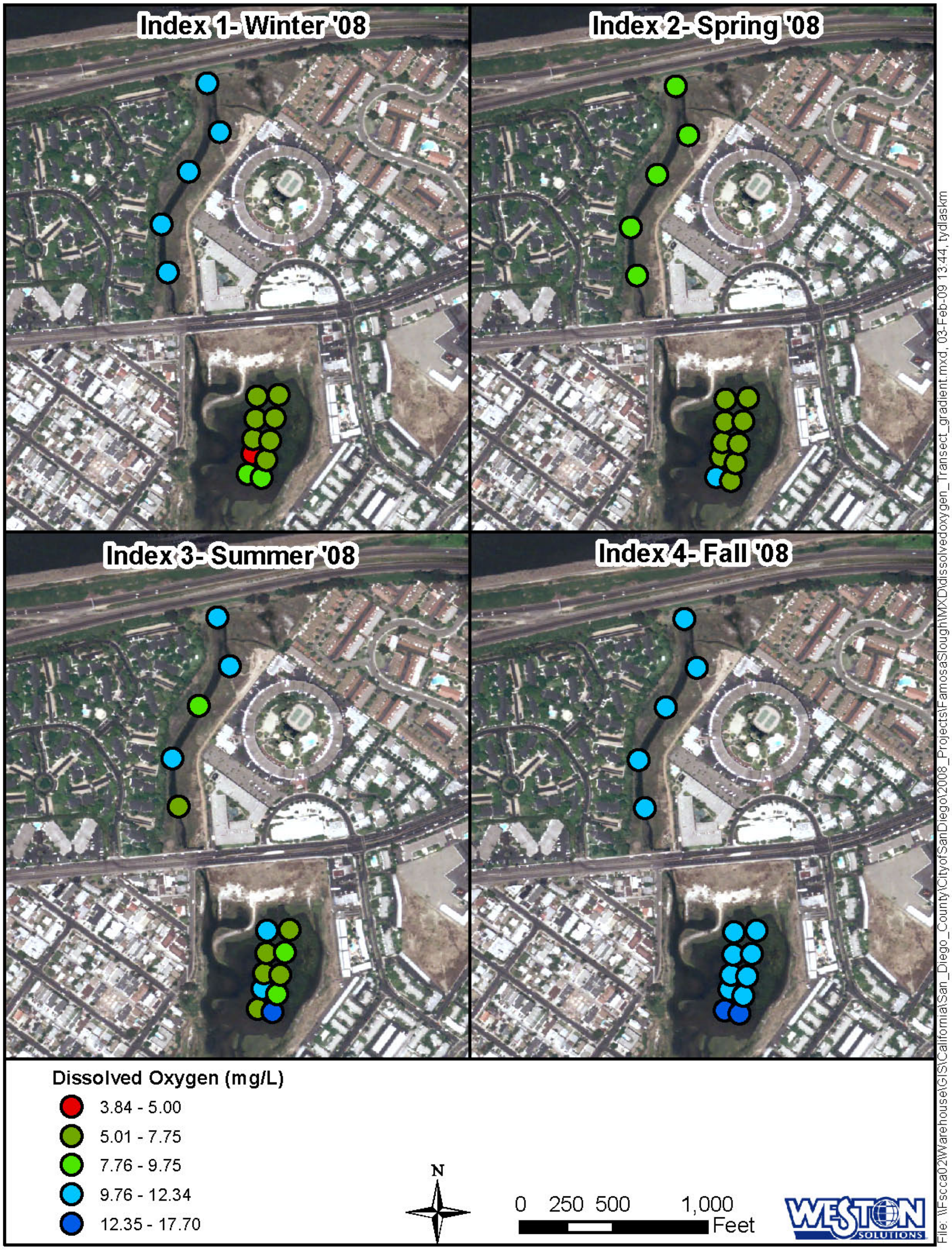

Figure 3-24. Mean Dissolved Oxygen Concentrations – Ebb Tide

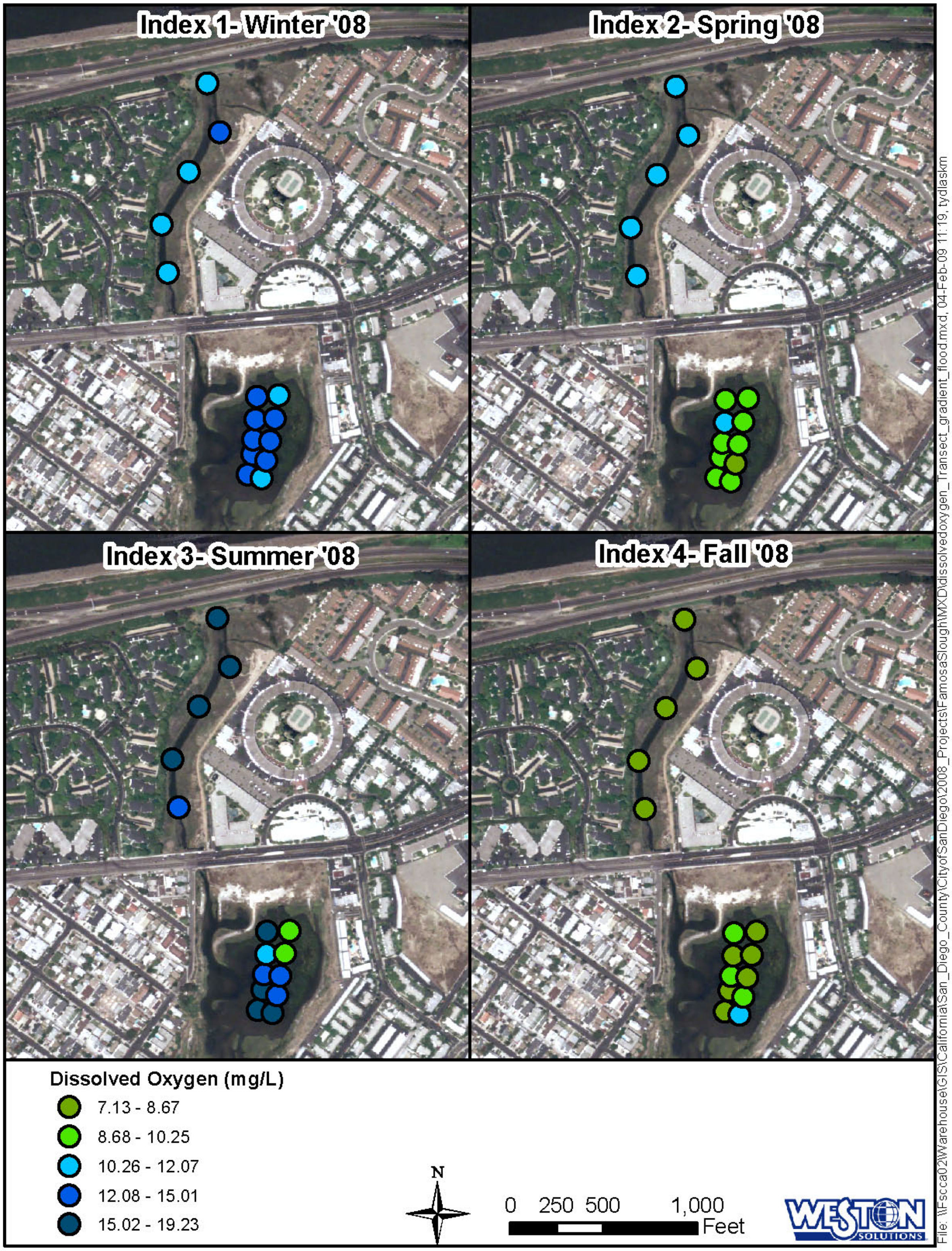

Figure 3-25. Mean Dissolved Oxygen Concentrations – Flood Tide

3.5.5 Salinity

The average salinity in the Slough did not vary greatly between seasons and was consistent throughout the ebb and flood of the tide for each index period. Salinity increased slightly throughout the year and peaked during the fall index period. Salinity was consistently higher in the channel portion of the Slough north of the main body of the Slough. This channel is closest to the San Diego River channel and is therefore more influenced by saltwater.

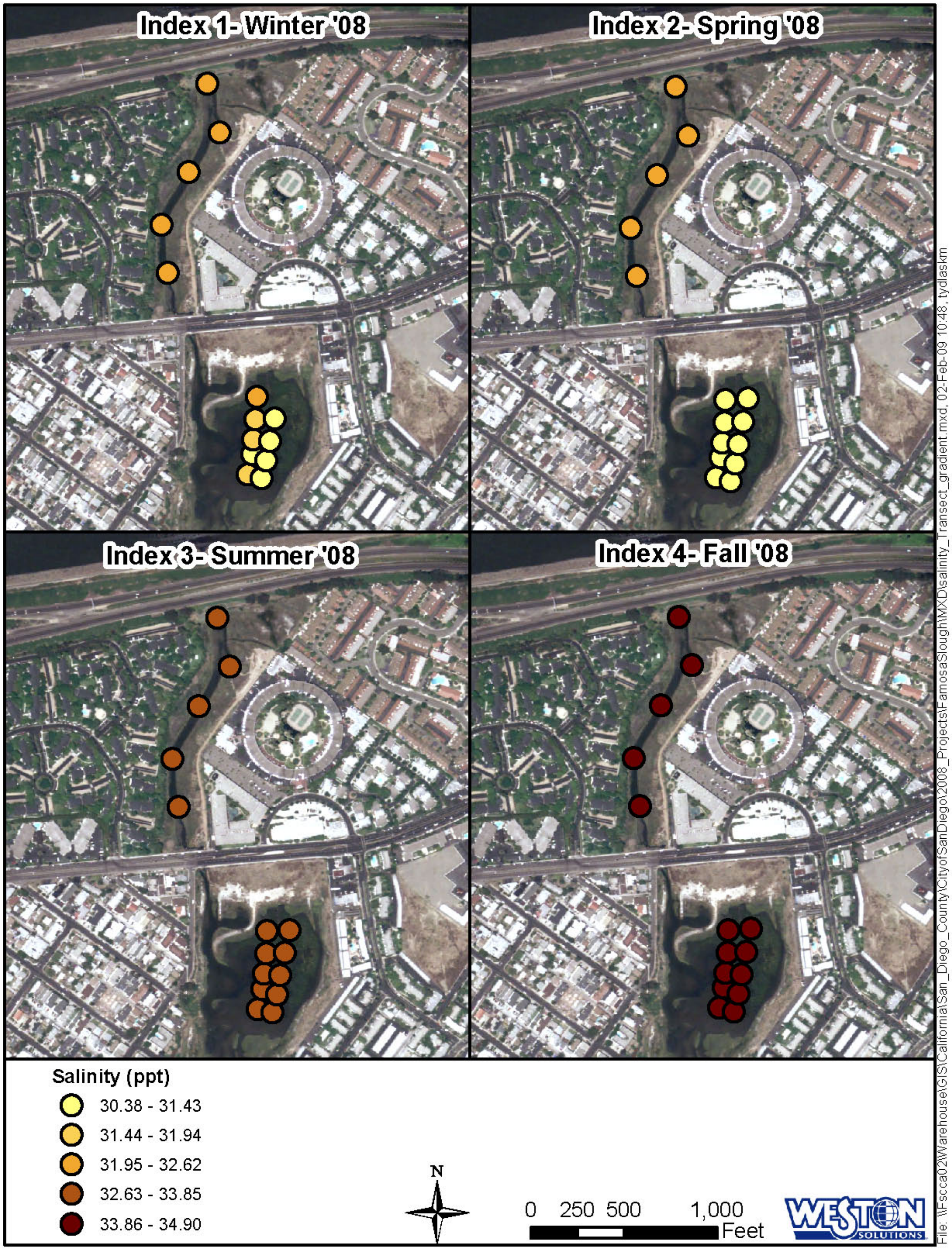

Figure 3-26. Mean Salinity – Ebb Tide

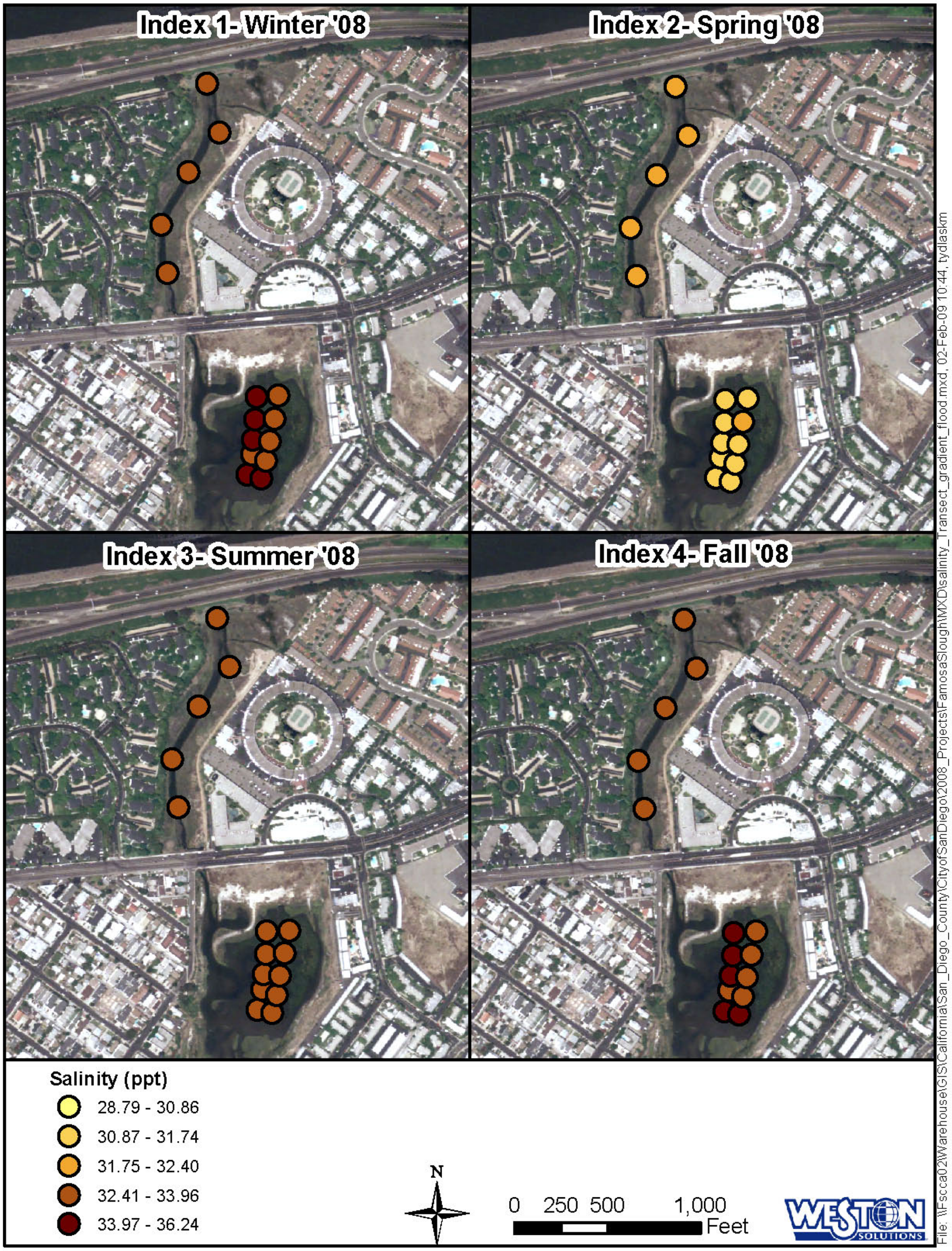

Figure 3-27. Mean Salinity – Flood Tide

3.5.6 Temperature

Temperatures in the Slough were highest during the summer index period, often above 26 ºC in the inner Slough area. Temperatures were lowest during the winter index period, most likely corresponding to lower temperatures of the Pacific Ocean and the San Diego River during the winter.

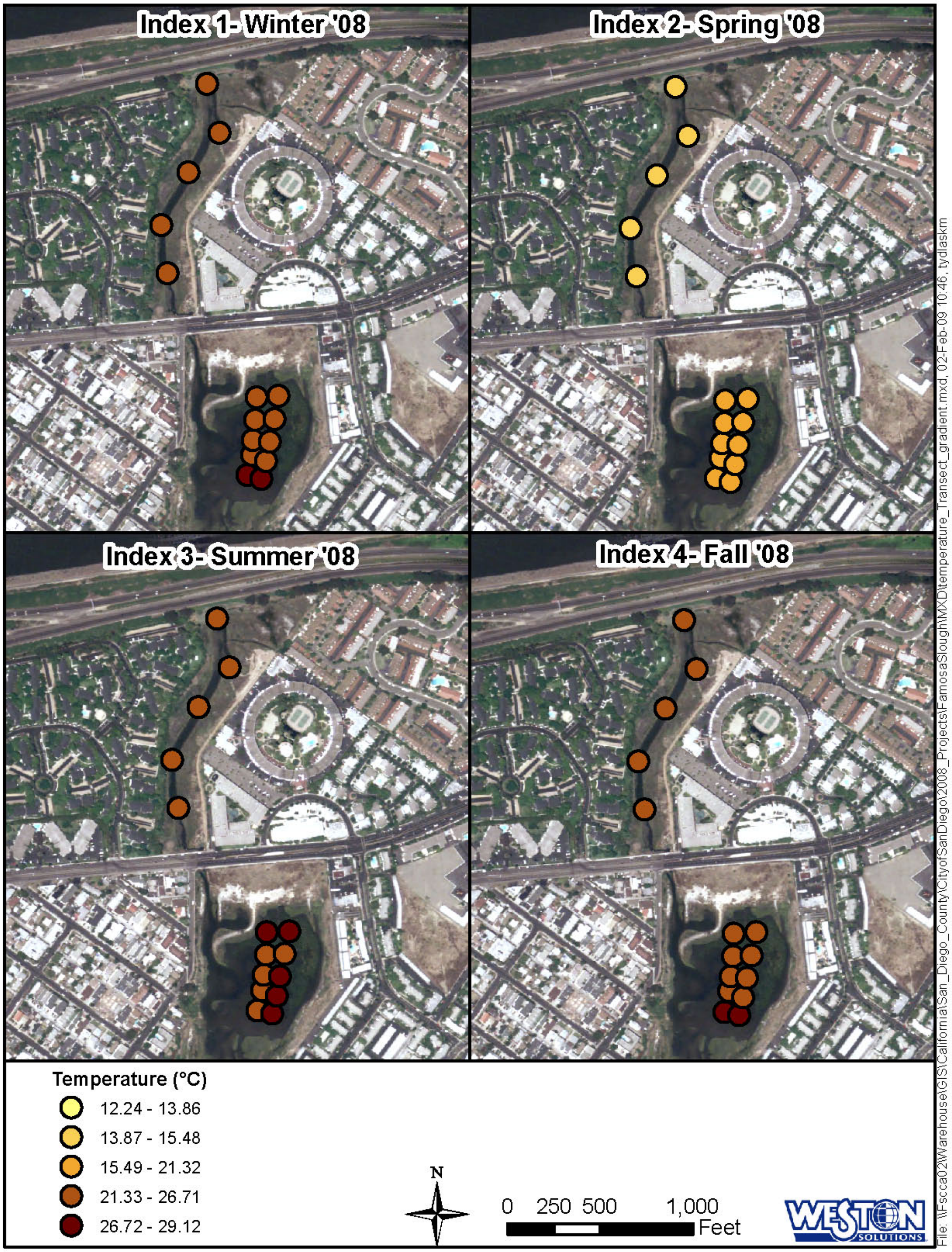

Figure 3-28. Mean Temperature – Ebb Tide

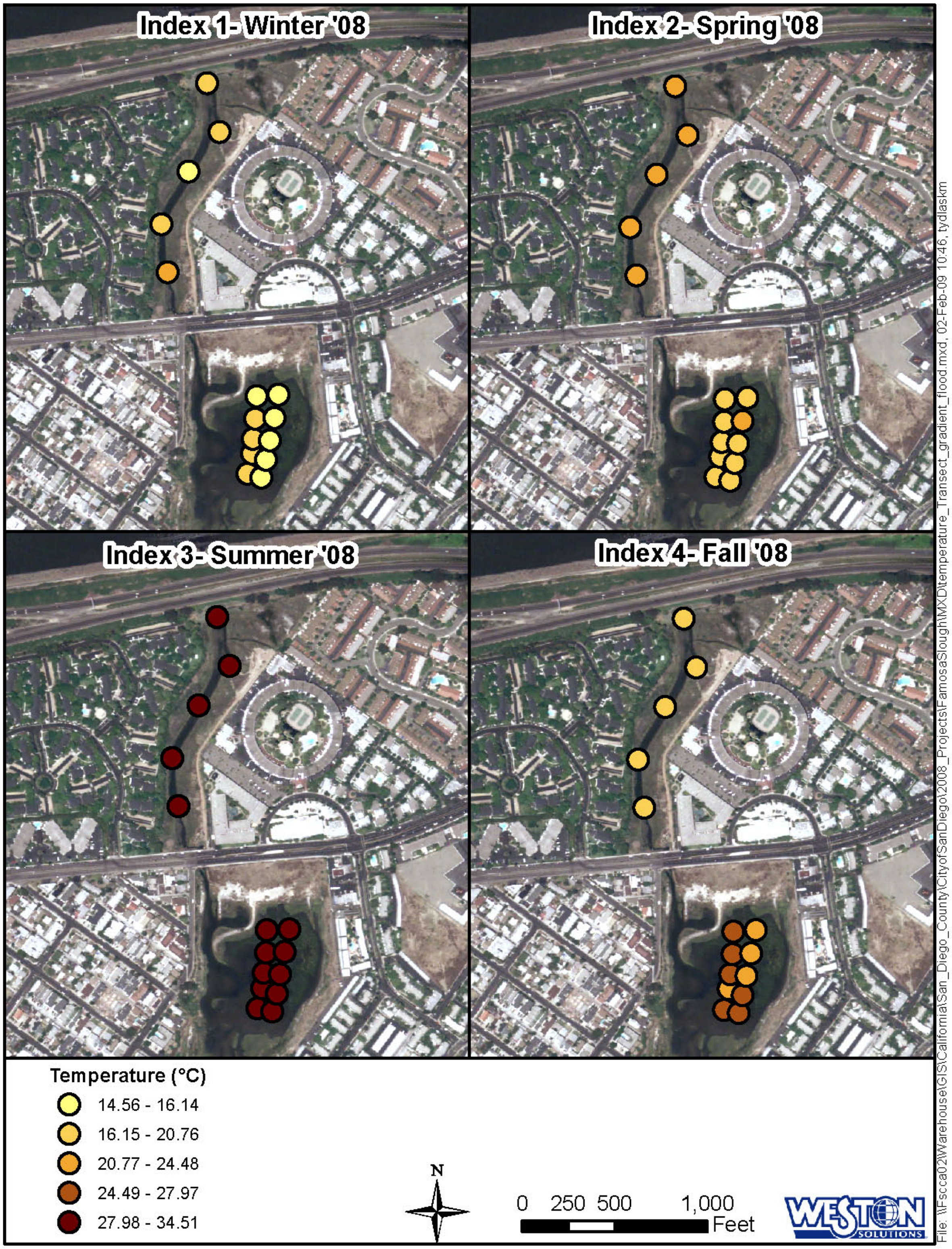

Figure 3-29. Mean Temperature – Flood Tide

3.6 Topographic Survey

The land-based elevation survey was conducted at the ocean inlet of the Slough on December 19, 2007, immediately prior to the first index period sampling event. Prior to the survey, the contractor, Southland, reviewed previous bathymetry survey information provided by Merkel and Associates. Southland obtained a horizontal location for the storm drain headwall just north of West Point Loma Boulevard to orient the Merkel and Associates topographic mapping to the only existing improvements found on their exhibit. The closest "fit" was to use the midpoint of the headwall on the north from the data and their exhibit, then rotate the Merkel and Associates exhibit to that located headwall on the south. The raw location, based on Southland's NAD83 datum and the Merkel and Associates exhibit, differs by 5–10 ft depending on orientation. Survey reports and elevation maps were then produced which summarize the results of the survey (Figure 3-30). Full reports on the topographic survey are presented in Appendix K. Due to the static nature of the concrete infrastructure at the Slough ocean inlet, only one topographic survey was undertaken.

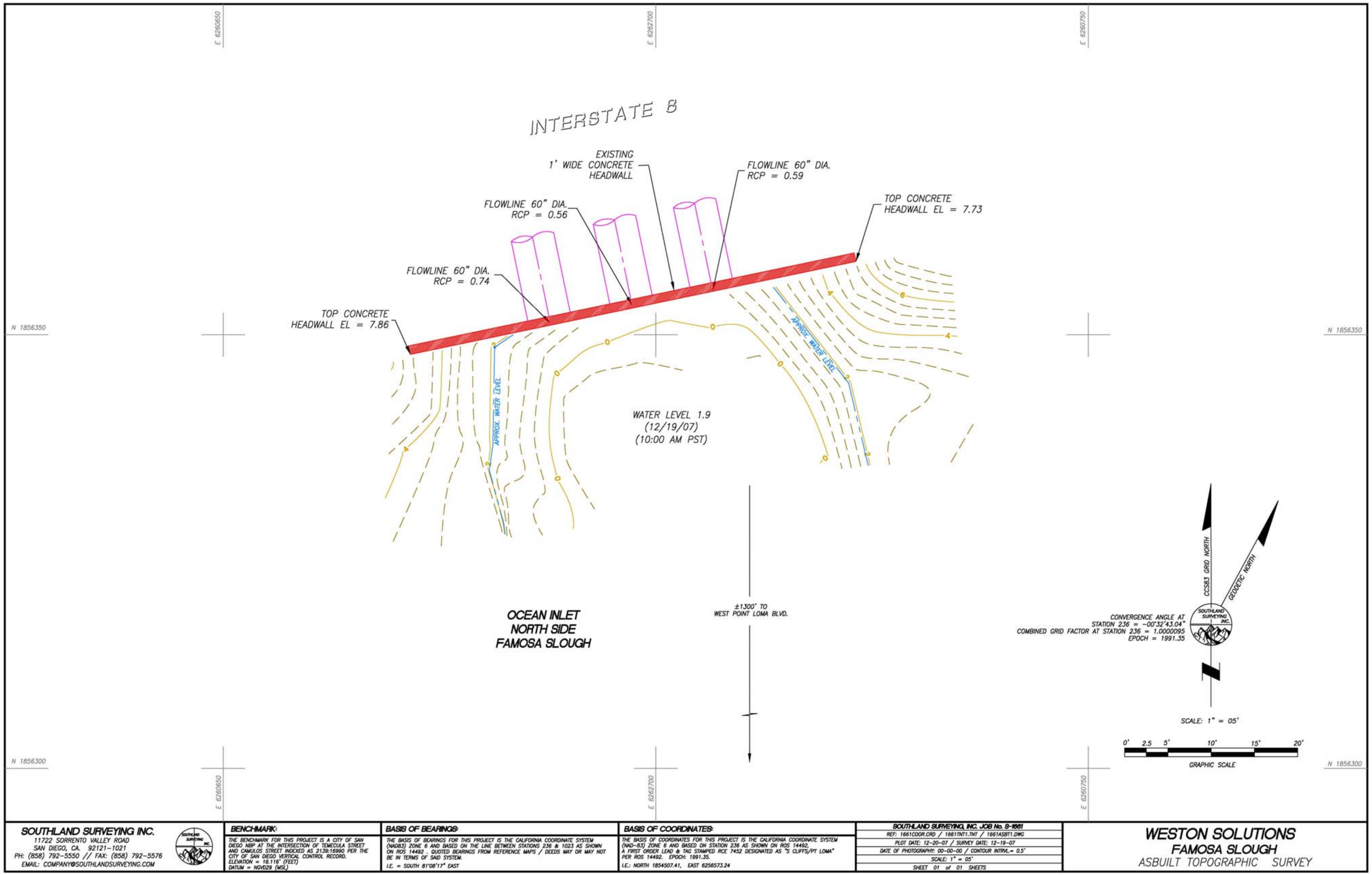

Figure 3-30. Topographic Survey of the Famosa Slough Ocean Inlet

4.0 LOAD ANALYSIS

Both dry weather loads and wet weather loads were estimated using flow data collected from the MES in the Slough together with nutrient data collected from the three wet weather sampling events and the four index periods. The results of this analysis are presented in the sections below.

4.1 Wet Weather Load Estimate

Three storm events were monitored for the Famosa Slough TMDL Monitoring Study between October 1, 2007 and March 31, 2008. Estimates for constituent loads per storm were derived using the event mean concentration (EMC) of the collected samples and the observed storm water runoff during the storm event. The EMC values are based on the duration of the storm event.

4.1.1 Flow Calculations

Flow values during each event were calculated using Manning's Equation for open channel flow from observed water surface elevations in the concrete trapezoidal channel. Flow was calculated for the observed water surface elevations to produce a stream flow hydrograph at the mass loading station. Figure 4-1 presents the stream flow hydrograph for each of the monitored storm events.

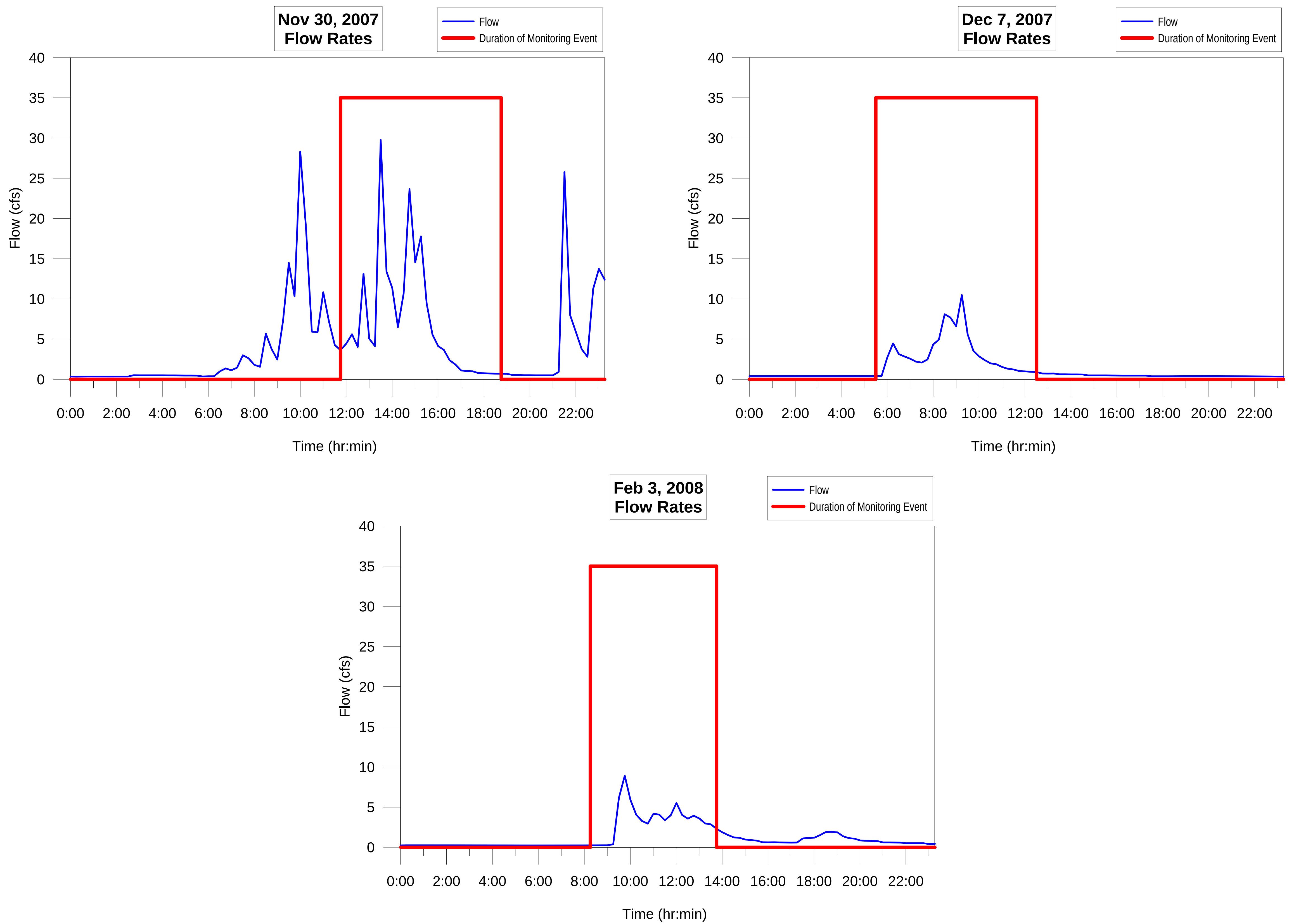

Figure 4-1. Hydrograph Data from the Mass Emission Site for the Three Storm Events Showing Monitoring Period

4.1.2 Calculation of Event Mean Concentrations

The EMC for each parameter was calculated by applying the observed concentrations of each parameter to the incremental volume of flow between observations using the following equation:

$$Li = Vi \times C \times CF$$

where

Li = incremental load (lbs)
Vi = incremental flow volume (cubic ft)
C = observed concentration (mg/L)
CF = Conversion factor to convert mg/L to lbs
1 lb/453592.37 mg
28.3168 L/ft^3

A flow-weighted EMC was developed for each parameter by dividing the sum of the incremental loads by the sum of the incremental volumes for the elapsed time of the water quality monitoring effort. The results of the EMC calculations are presented in Table 4-1. In the case of the November 30, 2007 storm event, the time duration of the monitoring event was a portion of the duration of the total storm hydrograph. The duration of the total runoff event was determined to be the time when flows exceeded base flow levels in the channel (13.5 hours for the November 30, 2007 event). The EMC, which was developed based on the duration of the monitoring effort, was then applied to the total storm event runoff volume to develop wet weather loads for each event. An arithmetic mean of the EMCs from the three monitored events will be applied to a summation of all storm water runoff flows to develop an average load estimate for each parameter.

Table 4-1. Estimated Mean Wet Weather Loading Rate for Famosa Slough

Storm Event (date)	Runoff Duration (hrs)	Flow-Weighted EMC (mg/L)	Mean Load Rate (lbs/storm event)
Storm Event 1 (November 30, 2007) – Precipitation 1.12 inches			
TSS	13.5	52.04	1,004
TN		1.90	36.67
Ammonia		0.32	6.18
Nitrate + nitrite as N		0.67	12.93
Nitrite as N		0.03	0.58
TP		0.41	7.91
TDP		0.39	7.53
SRP		0.28	5.40
$CBOD_5$		4.54	87.62
Storm Event 2 (December 7, 2007) – Precipitation 0.24 inch			
TSS	11.25	29.94	170.39
TN		1.41	8.02
Ammonia		0.19	1.08
Nitrate + nitrite as N		0.54	3.07
Nitrite as N		0.03	0.17
TP		0.35	1.99
TDP		0.31	1.76
SRP		0.18	1.02
$CBOD_5$		6.30	35.85
Storm Event 3 (February 3, 2008) – Precipitation 0.36 inch			
TSS	13.75	12.61	78.57
TN		0.88	5.48
Ammonia		0.17	1.06
Nitrate + nitrite as N		0.28	1.74
Nitrite as N		0.02	0.12
TP		0.17	1.06
TDP		0.16	1.00
SRP		0.15	0.93
$CBOD_5$		4.68	29.16
Mean of Three Events			
TSS	**12.83**	**31.53**	**420**
TN		**1.40**	**17**
Ammonia		**0.23**	**2.8**
Nitrate + nitrite as N		**0.49**	**5.90**
Nitrite as N		**0.03**	**0.29**
TP		**0.31**	**3.7**
TDP		**0.29**	**3.4**
SRP		**0.20**	**2.5**
$CBOD_5$		**5.17**	**51**

4.2 Dry Weather Load Estimate

Dry weather discharge volume was monitored in the Slough from October 10, 2007–October 7, 2008. Flow volume was recorded in 15-minute intervals during the monitoring period. Dry weather water quality grab samples were taken on six dry weather days during each index period throughout the year. This section presents a determination of the dry weather loading for each water quality parameter from the Slough.

4.2.1 Flow Calculations

Flow calculations were determined as described above in Section 4.1.1.

4.2.2 Calculation of Dry Weather Loads

An average value for each parameter was used to represent the dry weather concentration for each index period. Table 4-2 includes the average value for the six observed concentrations of each water quality constituent.

Table 4-2. Mean Dry Weather Concentrations at the Mass Emission Site

Parameter	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
TSS (mg/L)	12.67	20.78	12.85	30.55
TN (mg/L)	0.66	1.11	1.23	0.75
Ammonia as N (mg/L)	0.26	0.15	0.20	0.16
Nitrate + nitrite as N (mg/L)	0.04	0.08	0.02	0.00
Nitrite as N (mg/L)	0.01	0.02	0.01	0.00
TP (mg/L)	0.42	0.50	0.78	0.62
TDP (mg/L)	0.41	0.46	0.72	0.60
SRP (mg/L)	0.36	0.29	0.50	0.47
$CBOD_5$ (mg/L)	2.58	4.23	2.82	2.68
Chlorophyll-a (mg/m^3)	23.83	204.48	58.22	40.05

Flow in the Slough was separated into wet weather flow (storm water runoff hydrographs) and dry weather flow. The periods of dry weather flow were separated as presented in the table below.

Table 4-3. Dry Weather Flow Periods

	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
Start	October 2007	January 2008	April 2008	July 2008
End	December 2007	March 2008	June 2008	September 2008

Dry weather flow volume was calculated by multiplying the observed flow rates by the time within each 15-minute increment. The average parameter concentration in each index period was multiplied by the incremental volume of water, and the incremental load was totaled for the index period. Table 4-4 presents the total dry weather loadings for each index period.

Table 4-4. Estimated Dry Weather Loading Summary

Parameter (pounds)	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall	Estimated Total Annual Load*
TSS	2,100	3,300	2,400	10,100	18,000
TN	110	179	230	246	770
Ammonia as N	44	24	38	52	160
Nitrate + nitrite as N	6.5	12.8	3.1	1.2	24
Nitrite as N	1.9	2.9	1.4	1.2	7.0
TP	70	80	145	204	500
TDP	68	74	135	197	470
SRP	60	46	93	157	360
$CBOD_5$	431	680	527	887	2,500
Chlorophyll-a (mg/m^3)	3,800	38,200	10,200	13,700	66,000

5.0 DISCUSSION

Conclusions and recommendations provided in this report are based on results of both dry weather and wet weather monitoring from October 2007 through October 2008. This discussion is provided using the original study questions posed in the Order (Table 1-2). Responses to those study questions are limited to the scope of this component of the Order and do not include those elements that require modeling or supplemental data from SCCWRP.

5.1 Question 1 – What are the Concentrations of Contaminants at the Base of the Watershed?

Contaminant concentrations were recorded at the base of the watershed (i.e., at the MES) during both wet weather (Section 3.3.1) and dry weather (Section 3.5).

During wet weather, only one sample was above relevant WQOs. One TSS wet weather sample was above the Multi-Sector General Permit WQO of 100 mg/L (Table 5-2). Ammonia concentrations were below WQOs calculated using temperature, pH, and salinity per the United States Environmental Protection Agency (EPA) (1989) guideline[5].

Table 5-1. Summary of Mass Emission Site Data – Means, Standard Deviations, Minimums, and Maxima by Analyte for All Storm Events

All Storms	TSS (mg/L)	TN (mg/L)	Ammonia as N (mg/L)	Nitrate + Nitrite as N (mg/L)	Nitrite as N (mg/L)	TP (mg/L)	TDP (mg/L)	SRP (mg/L)	$CBOD_5$ (mg/L)
WQO*	100 ***	–	Varied*	10**	1**	2 ***	2 ***	–	–
Mean	30.04	1.54	0.26	0.55	0.03	0.35	0.31	0.22	6.79
Minimum	7	0.66	0.11	0.2	0.01	0.15	0.13	0.12	1.1
Maximum	109	5.27	0.64	1.86	0.06	0.98	0.82	0.68	32.6

* USEPA (1989)
** Basin Plan (SDRWQCB, 1994)
*** Multi-Sector General Permit (USEPA, 2000b)

During the four dry weather index period sampling events, contaminant concentrations were recorded at the MES and averaged (Table 5-2). The results indicated some seasonal variability.

[5] It should be noted that Basin Plan WQOs for un-ionized ammonia are 0.025mg/L. However, for ammonia in saline receiving waters, comparison against the United States EPA criteria are more accurate.

Table 5-2. Mean Dry Weather Concentrations at the Mass Emission Site

Parameter	WQO	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
TSS (mg/L)	<100***	12.67	20.78	12.85	30.55
TN (mg/L)	–	0.66	1.11	1.23	0.75
Ammonia as N (mg/L)	Varied*	0.26	0.15	0.20	0.16
Nitrate + nitrite as N (mg/L)	<10**	0.04	0.08	0.02	0.00
Nitrite as N (mg/L)	<1**	0.01	0.02	0.01	0.00
TP (mg/L)	<2***	0.42	0.50	0.78	0.62
TDP (mg/L)	<2***	0.41	0.46	0.72	0.60
SRP (mg/L)	–	0.36	0.29	0.50	0.47
$CBOD_5$ (mg/L)	–	2.58	4.23	2.82	2.68
Chlorophyll-a (mg/m^3)	–	23.83	204.48	58.22	40.05

* USEPA (1989)
** Basin Plan (SDRWQCB, 1994)
*** Multi-Sector General Permit (USEPA, 2000b)

5.2 Question 2 – What is the Daily Rainfall?

Rainfall was monitored continuously throughout a 12-month period from October 2007 through October 2008. A total rainfall of 7.02 inches was recorded during this period. Daily rainfall was generally zero with the exception of the dates provided in Table 5-3. Average daily rainfall for days with recorded precipitation was 0.03 inch.

Table 5-3. Summary of Daily Rainfall in Famosa Slough

Date	Total Daily Rainfall (inches)
10/19/2007	0.06
11/11/2007	0.03
11/30/2007	1.33
12/01/2007	0.28
12/05/2007	0.01
12/07/2007	0.24
12/08/2007	0.28
12/09/2007	0.19
12/11/2007	0.02
12/19/2007	0.19
12/20/2007	0.01
12/28/2007	0.03
12/29/2007	0.02
01/05/2008	1.62
01/06/2008	0.27
01/07/2008	0.5
01/11/2008	0.01
01/12/2008	0.01
10/19/2007	0.06
11/11/2007	0.03

Date	Total Daily Rainfall (inches)
01/12/2008	0.01
01/13/2008	0.01
01/21/2008	0.02
01/22/2008	0.06
01/23/2008	0.53
01/24/2008	0.1
01/26/2008	0.12
01/27/2008	0.33
01/29/2008	0.01
02/01/2008	0.01
02/03/2008	0.36
02/04/2008	0.01
02/08/2008	0.01
02/14/2008	0.01
02/22/2008	0.01
02/26/2008	0.06
03/12/2008	0.01
03/16/2008	0.04
05/23/2008	0.06
05/24/2008	0.16

5.3 Question 3 – What is the Total Annual Flow and Mass Loads of Contaminants from the Watershed into the Slough?

Mass loads and flows have been calculated and are provided in full detail in Section 4.0. In summary, the average wet weather load rates from the MES, based on the three storm events, are presented in Table 5-4, whereas estimated dry weather loads from the MES are presented in Table 5-5.

Table 5-4. Mean Wet Weather Loads at the Mass Emission Site Based on a Mean Rainfall Duration of 12.8 Hours

Parameter	Mean Storm Event Load (pounds)
TSS	417.78
TN	16.73
Ammonia as N	2.77
Nitrate + nitrite as N	5.92
Nitrite as N	0.29
TP	3.65
TDP	3.43
SRP	2.45
$CBOD_5$	50.88

Table 5-5. Total Annual Dry Weather Load Estimate (2007–2008)

Parameter	Total Annual Load (pounds)
TSS	17,960
TN	765
Ammonia as N	157
Nitrate + nitrite as N	23.59
Nitrite as N	7.32
TP	500
TDP	474
SRP	355
$CBOD_5$	2,526
Chlorophyll-a	60,990

5.4 Question 4 – What are the Concentrations of Contaminants at the Ocean Inlet Before it Enters Famosa Slough?

Data from both wet weather events and dry weather events were compared to assess potential impacts of the San Diego River channel on the water quality within the Slough.

The wet weather results (Table 5-6) indicated that there were no observed differences between water quality at the Ocean Inlet Site and water quality at the Slough Segment Site.

Table 5-6. Mean Analyte Concentrations at the Ocean Inlet and Slough Segment Sites during Wet Weather

Tide	Sample Site	Ammonia as N (mg/L)	Carbonaceous Biochemical Oxygen Demand (mg/L)	Chlorophyll-a (mg/m^3)	Nitrate + Nitrite as N (mg/L)	Nitrite as N (mg/L)	SRP (mg/L)	TDP (mg/L)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
High	Ocean Inlet	0.19	0.45	4.05	0.13	0.02	0.06	0.03	0.54	0.06	17.65
	Slough Segment	0.17	0.48	4.25	0.10	0.02	0.05	0.09	0.80	0.10	13.48
Low	Ocean Inlet	0.20	1.83	4.33	0.17	0.02	0.06	0.19	0.94	0.12	19.40
	Slough Segment	0.18	1.10	4.47	0.20	0.02	0.07	0.08	0.68	0.07	11.27

Table 5-7 demonstrates the difference in contaminant concentrations between the Slough Segment Site and the Ocean Inlet Site during dry weather. The results of both sites were similar, with the exception of chlorophyll-a during the spring, summer, and fall index periods. Chlorophyll-a concentrations were higher at the Slough Segment Site than at the Ocean Inlet Site. This could be attributed to the larger photosynthetic capacity of the main body of the Slough which would allow for greater phytoplankton growth.

In assessment of all other constituents of concern, the dry weather water quality from the San Diego River does not appear to impact the Slough.

Table 5-7. Mean Analyte Concentrations at the Slough Segment and Ocean Inlet Sites during Dry Weather

Parameter	Index Period 1 – Winter		Index Period 2 – Spring		Index Period 3 – Summer		Index Period 4 – Fall	
	Slough Segment	Ocean Inlet	Slough Segment	Ocean Inlet	Slough Segment	Ocean Inlet	Slough Segment	Ocean Inlet
Ammonia as N (mg/L)	0.13	0.13	0.06	0.06	0.03	0.03	0.01	0.05
$CBOD_5$ (mg/L)	0.00	0.00	0.10	0.08	0.66	0.14	0.38	0.00
Chlorophyll-a (mg/m^3)	5.42	5.19	5.57	4.47	4.04	3.07	11.08	1.98
Nitrate + nitrite as N (mg/L)	0.03	0.03	0.03	0.03	0.01	0.01	0.00	0.00
Nitrite as N (mg/L)	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
SRP (mg/L)	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03
TDP (mg/L)	0.04	0.03	0.04	0.03	0.05	0.04	0.01	0.02
TN (mg/L)	0.42	0.38	0.44	0.40	0.52	0.41	0.31	0.22
TP (mg/L)	0.03	0.03	0.04	0.04	0.07	0.06	0.06	0.02
TSS (mg/L)	9.84	8.45	7.06	11.08	8.56	8.67	7.55	5.04

5.5 Question 5 – What are the Concentrations of Contaminants in Famosa Slough? Do They Exceed Water Quality Objectives?

Contaminant concentrations with the main body of the Slough were measured during four index period sampling events and are summarized in Table 5-8. There were no WQO exceedances recorded within the Slough during this monitoring period.

Table 5-8. Mean Transect Analyte Result during each Index Period

Parameter	WQO	Index Period 1 – Winter	Index Period 2 – Spring	Index Period 3 – Summer	Index Period 4 – Fall
Ammonia as N (mg/L)	Varied*	0.10	0.05	0.02	0.01
$CBOD_5$ (mg/L)	–	0.50	1.10	–	3.08
Chlorophyll-a (mg/m^3)	–	6.38	4.80	26.58	20.17
Nitrate + nitrite as N (mg/L)	<10**	0.02	0.01	0.01	0.00
Nitrite as N (mg/L)	<1**	0.01	0.01	0.00	0.00
SRP (mg/L)	–	0.02	0.01	0.01	0.01
TDP (mg/L)	<2***	0.02	0.03	0.03	0.00
TN (mg/L)	–	0.46	0.41	0.62	0.31
TP (mg/L)	<2***	0.04	0.03	0.08	0.02
TSS (mg/L)	<100***	10.29	9.37	15.21	13.36

* USEPA (1989)
** Basin Plan (SDRWQCB, 1994)
*** Multi-Sector General Permit (USEPA, 2000b)

Acute and chronic ammonia WQOs were calculated based on Table 2 and Table 3, respectively, of the United States EPA Ambient Water Quality Criteria for Ammonia (Saltwater) – 1989. Under these criteria, WQOs are assessed by comparing salinity, pH, and temperature. A summary comparison of the calculations used for assessment of chronic and acute toxicity is provided in Table 5-9. With elevated salinity, temperature, and/or pH, the WQO for ammonia decreases. The results of this analysis show that under worst case conditions, along with high pH, high temperature, and high salinity, ammonia concentrations were still well below WQOs.

Table 5-9. Assessment of Acute and Chronic Ammonia Exceedances during Index Period Sampling

Salinity (ppt)	pH	Temperature (ºC)	Ammonia Concentration Recorded in Slough (mg/L)	Acute WQO for Ammonia (mg/L)	Chronic WQO for Ammonia (mg/L)
36.24	7.98	25.85	0.02	3.5	0.75
33.91	9.15	33.54	0.01	0.46	0.07
33.42	8.74	34.51	0.01	0.58	0.09

* Shading denotes the highest recorded level for this parameter.

The highest recorded ammonia concentration found in the Slough during index period sampling was 0.17 mg/L with a pH of 7.94, a temperature of 12.73 ºC, and salinity of 30.38 mS/cm. The corresponding acute WQO for ammonia is 2.2 mg/L.

During wet weather, the highest ammonia concentrations were found at the Slough Segment Site and at the Ocean Inlet Site during the first storm event on November 30, 2008. Analysis of the pH, temperature, and salinity during these times indicated that ammonia concentrations at the Slough Site and at the Ocean Inlet Site during wet weather were less than the chronic WQOs (Table 5-10).

Table 5-10. Assessment of Acute and Chronic Ammonia Exceedances during Wet Weather Sampling

Sample Site	Storm Event Date	Ammonia Concentration (mg/L)	Temperature (°C)	pH	Acute WQO for Ammonia (mg/L)	Chronic WQO for Ammonia (mg/L)
Slough Segment	11/30/2007	0.27	16.41	7.77	16	2.4
Slough Segment	12/07/2007	0.06	15.75	7.95	10	1.1
Slough Segment	02/03/2008	0.21	13.50	8.02	10	1.6
Ocean Inlet	11/30/2007	0.28	16.14	7.64	25	2.4
Ocean Inlet	12/07/2007	0.06	15.83	7.90	10	1.6
Ocean Inlet	02/03/2008	0.28	13.61	7.74	16	2.4

5.6 Question 6 – What are the Dissolved Oxygen Concentrations in Famosa Slough?

DO was recorded within the Slough during each index period as well as at the Slough Segment Site and at the Ocean Inlet Site. The Basin Plan WQO for DO states that DO shall be 5 mg/L or above (SDRWQCB, 1994).

The DO concentrations were lowest at the MES, with approximately 88% of all recorded DO below 5 mg/L. The average DO concentration at the MES was 1.54 mg/L. However, the MES is only representative of flows entering the Slough from the storm drain system and are not representative of the overall receiving water condition; therefore, comparison against the DO WQO is not appropriate.

The DO concentrations at the Slough Segment Site and at the Ocean Inlet Site were similar, with DO below the WQO during the night but elevated above the WQO during daylight hours. There were no prolonged periods of reduced DO, indicating that DO levels were maintained within the Slough.

DO can be influenced by water quality, hydraulics, the presence of nutrients, sunlight, and plants as well as diurnal effects. Diurnal effects were apparent both at the Slough Segment Site and at the Ocean Inlet Site, with the highest DO generally occurring in the mid to late afternoon and lowest DO occurring during the middle of the night.

6.0 RECOMMENDATIONS

As a result of the monitoring and investigation conducted in the Slough to comply with the Order, the following is recommended:

- The TDN data should not be used for assessment modeling due to observed filter contamination.
- Samples processed by UCSB that exceeded holding times should not be used in TMDL calculation
- All other data collected between October 2007 and October 2008 meet the QC/QA requirements set forth in the approved QAPP and can therefore be used by the Regional Board for calibration and validation of watershed and hydrological models.
- Periodic monitoring of the Slough and coordination with the FoFS would be beneficial to monitor the long-term condition of the Slough.
- Certified laboratories should be used for any future TMDL monitoring.

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