# City of Ventura Special Studies:
# Estuary Subwatershed Study

*Final Year One Data Summary and Assessment*

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# 1 INTRODUCTION

## 1.1 Background

The City of San Buenaventura (City; also known as Ventura) owns and operates the Ventura Water Reclamation Facility (VWRF), which discharges treated municipal wastewater to the Santa Clara River Estuary (Estuary) just south of the City near the mouth of the Santa Clara River (Figure 1-1). With a design capacity of 14 million gallons per day (MGD), the VWRF currently treats approximately 9 MGD of municipal wastewater to tertiary standards (i.e., partial denitrification and filtration) under waste discharge requirements contained in Order No. R4-2008-0011, adopted by the California Regional Water Quality Control Board, Los Angeles Region (Regional Board), on March 6, 2008 (NPDES Permit No. CA0053651).

Under the Water Quality Control Policy for the Enclosed Bays and Estuaries of California (Enclosed Bay and Estuaries Policy), originally adopted by the State Water Resources Control Board in 1974 and updated as Resolution No. 95-84 on November 16, 1995, discharges of municipal wastewater to enclosed bays and estuaries are to be phased out except in circumstances "when the Regional Board finds that the wastewater in question would consistently be treated and discharged in such a manner that it would enhance the quality of receiving waters above that which would occur in the absence of the discharge." In discussions prior to the adoption of Order R4-2008-0011, a number of questions arose regarding the definition of enhancement, the benefits that the discharge provides to the Estuary and adjacent subwatershed, and how discharge practices could be modified over time to protect and enhance habitat and water quality of the portion of the Estuary directly affected by the VWRF discharge.

To address this issue regarding a finding of enhancement, the Regional Board required the City to complete a series of three Special Studies under Order R4-2008-0011. The Special Studies, described briefly below, are designed to assess the impacts and benefits of the VWRF discharge to the Estuary and to develop potential alternatives for the VWRF discharge.

- **Estuary Subwatershed Study** – evaluate the physical and biological function of the Estuary affected by the discharge to determine whether the discharge to the Estuary provides an ecological enhancement now or under different conditions such as a decreased discharge to the Estuary.
- **Treatment Wetlands Study** – determine how a constructed treatment wetland could further improve the water quality of the VWRF tertiary discharge by reducing copper, other metals, and nutrient concentrations to meet effluent limits and further promote receiving water quality improvements.
- **Recycled Water Market Study –** evaluate and quantify expansion the City's existing reclaimed water system through evaluation of potential users and uses within a five-mile radius of the VWRF.

The City submitted Workplans to the Regional Board for each of these studies on September 10, 2008 outlining the elements needed to address the information needs of the permit. The Workplans were approved on December 8, 2008 and form the foundation for the studies that will be submitted to the Regional Board by March 6, 2011.

## 1.2 Estuary Subwatershed Study Workplan

The Estuary Subwatershed Study will examine hydrology, water quality and biological resources within the lower Santa Clara River estuary ("Estuary"). For the purposes of this study, the Estuary extends north and south to the limits of the 500 year floodplain within the mainstem Santa Clara River, and extends eastwards to a 11.5 ft (NAVD88) contour corresponding to the measured water surface elevation during breaching events in October 2009 (approximately 2,500 ft east of the Harbor Blvd. bridge). In addition, for the purposes of habitat surveys, the Estuary study area extends north and south along McGrath State Beach from the Ventura Harbor inlet to near McGrath Lake.

The approved Workplan divides the Estuary Subwatershed Study into three primary investigations intended to supplement and synthesize existing information as follows:

1. **Estuary Water Balance.** The goals of the Estuary Water Balance are to identify the area of the Estuary that is influenced by the VWRF discharge, quantify the various inflows, and evaluate the dynamics of the surface and subsurface hydrology. This information allows examination of the dynamic relationship between flows, hydrologic conditions and the seasonal spatial extent of the lagoon as the different surface water elevations influence available habitat area. Tasks to reach this end include:
   a. Define the relevant extent of the Estuary that are influenced by the discharge spatially, hydrologically, and functionally by utilizing existing studies and reports to determine how the discharge may have altered conditions over time;
   b. Quantify the average monthly inflow from all quantifiable sources including; groundwater, Santa Clara River flows, VWRF discharges, and agriculture and urban surface water runoff;
   c. Define the relationship between inflows and Estuary habitat area, lagoon depth and volume under various discharge scenarios. Evaluate how different species require varied water depths, riparian habitats, and in-stream cover within the lagoon and the impact of altering the current discharge regime might have on these species.
   d. Evaluate breaching frequency and breaching types and their effect on the lagoon, backwater habitats, water quality, and how each impacts federal and state listed species present in the Estuary. Compile historic information to identify breaching changes over time considering activities such as dredge material management practices, mining, urbanization, agriculture, and other potential influences.
2. **Functionality of the Estuary and Subwatershed.** Using information from the Water Balance effort, this study element identifies the functionality of the Estuary as a single unit. In particular, effects of potential changes in the discharge volume upon water quality, overall habitat area, and changes habitat quality for birds, fish, flora, and human uses will be evaluated. These tasks include:
   a. Provide mapping of the various habitat types and their extent within the Estuary;
   b. Predict how changes to the amount of the VWRF discharge could alter water quality, side stream habitat, lagoon surface area, and groundwater influences;
   c. Investigate the role VWRF discharge plays in vegetation growth in the Estuary and whether this factor and any changes in riverbed vegetation and sediment management practices that may have occurred over time;
   d. Identify alternate VWRF discharge scenarios to the Estuary considering flow volumes, the quality of the various inflows, and treatment wetlands feasibility;

e. Under each scenario predict changes to spatial inundation characteristics of the Estuary and McGrath State Park including depth and volume;
f. Predict how groundwater quality could influence lagoon water quality under each scenario;
g. Identify how each VWRF discharge scenario changes breaching and those impacts on water quality and beach water quality in the area influenced by the discharge;
h. Identify how each scenario affects habitats for state and federally listed species including steelhead trout, tidewater goby, Western Snowy Plover, and critical habitat areas for birds such as the California least tern;
i. Evaluate the impacts of global warming on the potential increase on sea level elevation to the Estuary, sustainability of the current Estuary conditions and VWRF alternatives being evaluated, potential climate change impacts to the outcome of the special studies; and
j. Recommend a management strategy for the VWRF discharge in order to optimize the function of the Estuary affected by the discharge to demonstrate enhancement of the Estuary, or determine that no enhancement exists.

3. **Targeted Research Monitoring and Sampling.** This study element included a series of potential efforts to collect additional data to provide the evidence to support conclusions regarding the best practices to optimize the VWRF discharge.
    a. Identify existing and potential groundwater monitoring locations, appropriate sampling frequency, and proper constituents to determine water quality within the influence of the discharge;
    b. Conduct daily visual observations, record lagoon discharge volume to the ocean, and map by hand the extent of the lagoon from the point of discharge;
    c. Research existing LiDAR mapping to predict spatial Estuary inundation and available habitat areas under the various discharge scenarios pertaining to the McGrath State Park bird habitat areas;
    d. Conduct an inventory of existing and potential bird nesting and foraging habitats within the Estuary; and conduct four, one each quarter throughout a consecutive twelve-month period, inventories of bird species and their numbers within the Estuary;
    e. Conduct monthly sampling and monitoring to evaluate dissolved oxygen (DO) and nutrient concentrations in the lagoon taking into account seasonal and daily natural background DO levels and cycles. Prepare a DO trend analysis based on existing and new data as available;
    f. Conduct the annual Fish Survey and Macroinvertebrate Monitoring Plan; and
    g. Over a 12-month consecutive period, install and maintain a tidewater gage to determine actual periods of inundation, elevation of the impounded lagoon, lagoon water temperature, and conductivity.

## 1.3 Overall Monitoring Approach

The City hired Stillwater Sciences and Carollo Engineers to develop the Estuary Subwatershed Study. The Study synthesizes findings from previous work within and adjacent to the Estuary and incorporates new monitoring data to establish technically defensible linkages between flow regimes and Estuary habitat. The overall approach is to develop estimates of Estuary water surface areas and volumes as a function of water stage and Estuary inflows (e.g., river, groundwater, VWRF discharge) to allow for the evaluation of changes in inundated areas, water quality, and habitat suitability for various focal species, as well as human uses. An Estuary stage vs. area relationship will be extended to develop stage vs. suitable habitat area relationships using a habitat criteria mapping approach that includes important physical and water quality attributes for various focal species (e.g., tidewater goby, steelhead). Historical and up-to-date data on breaching will be combined with the Estuary Water Balance and water quality data to identify changes in suitable habitat areas and how these conditions may have changed over time in association with various factors (e.g., dredge material management practices, mining, urbanization, agriculture).

Once the stage relationships with inundation and suitable habitat areas have been developed along with the Estuary Water Balance and water quality assessment, a series of VWRF discharge scenarios will be identified. Using the stage vs. habitat relationships and simplified models of future water flows, water quality, and sea level rise, each scenario will be evaluated for changes in Estuary stage, breaching frequency, habitat area, water quality, and habitat suitability for focal species. As described in the approved Workplan, a management strategy will be developed to optimize VWRF discharge and Estuary functionality across a range of alternatives designed to either enhance existing beneficial uses or to completely divert the VWRF discharge if no enhancement exists.

## 1.4 Project Surveys and Sampling Events

To address identified data collection needs, we are conducting three surveys: (1) an Estuary Hydrology and Morphology Survey; (2) an Estuary Water Quality and Nutrient Survey; and (3) Upland and Tidal Vegetation and Aquatic Habitat Mapping. The Estuary Hydrology and Morphology Survey focuses on compiling Estuary stage and groundwater elevation data, the Estuary Water Quality and Nutrient Survey focuses on compiling Estuary surface water and adjacent groundwater quality data, and the Upland and Tidal Vegetation and Aquatic Habitat Mapping effort focuses on updating recent vegetation mapping and delineating suitable habitat areas. Detailed information regarding the process by which specific data needs for each survey were identified can be found in the project Monitoring Plan (Stillwater Sciences 2009).

A primary component of each of the surveys is collecting data that will be used to augment the existing data sources. Field data collection for this project occurs over a two-year monitoring period: Year One monitoring extended from late August 2009 through November 2009, with Year Two monitoring extending from January 2010 though fall. Over the course of the monitoring period, eight sampling events were scheduled that include instrument installation, field surveys and habitat mapping, and downloading data from installed instruments (Table 1-1). To date, we have conducted two of the eight surveys.

**Table 1-1.** Sampling schedule for the Estuary Subwatershed Study.

| Monitoring period | Sampling event | Estuary hydrology and morphology survey | Estuary water quality and nutrient survey | Upland and tidal vegetation and aquatic habitat mapping |
|---|---|---|---|---|
| Year One (2009) | Summer 2009 (8/31-9/1/09) | X | X | X |
| | Fall 2009 (11/16-11/18/09) | X | X | |
| Year Two (2010) | Winter 2010 (January)* | X | X | |
| | Winter 2010 (February)* | X | X | |
| | Spring 2010 (April)* | X | X | X |
| | Summer 2010 (July)* | X | X | |
| | Summer 2010 (August)* | X | X | |
| | Fall 2010 (October or November)* | X | X | X |

* Anticipated month to conduct sampling.

This document describes in detail the overall field data collection and analysis methods for each survey and presents the Year One data collected in 2009. This information will be used to determine the ability of current data collection/analysis techniques to help answer key questions regarding the impact of VWRF discharge on current and future Estuary physical and biological condition, and the subsequent need to update the data collection/analysis approach for the remaining monitoring period in 2010. The data collected during this study will be combined with historical data to address the task-specific goals outlined in the Board-approved Workplans.

# 2 ESTUARY HYDROLOGY AND MORPHOLOGY SURVEY

## 2.1 Goals and Objectives

The overall goals of the Estuary Hydrology and Morphology Survey are to determine (1) the contribution of groundwater flows relative to other components of the overall seasonal and average monthly water balance for the Estuary (i.e., VWRF inflows, SCR inflows, Estuary discharge, and evapotranspiration), and (2) the influence of Estuary stage upon local water table elevation, mouth breaching dynamics, and Estuary inundation extent.

To meet these goals, three study objectives were developed for the Hydrology and Morphology Survey to fill known data gaps and characterize physical conditions and the Estuary water balance for a range of conditions (mouth open, mouth closed, low river flow, high river flow) over multiple seasons:

- Measurement of an Estuary stage time series for use in: topographic modeling of inundation extent to be used to predict seasonal habitat availability; characterization of local groundwater gradient for estimation of groundwater discharge into and out of the Estuary; and the identification of thresholds for initiation of mouth breaching events.
- Measurement of a groundwater elevation time series along a transect for use in: characterizing effects of Estuary stage on local groundwater table elevation; and characterizing seasonal and average monthly groundwater gradients and associated groundwater flow rates.
- Compilation of high-resolution Estuary bed elevation data for use in: developing the current Estuary bathymetric surface; topographic modeling of inundation extent to be used to predict seasonal habitat availability; determining a time series of Estuary volume and helping construct the Estuary water balance.

These data will ultimately be combined with data collected during concurrent surveys (Water Quality and Nutrient Survey and Upland and Tidal Vegetation and Aquatic Habitat Mapping) and pre-existing information to determine the impact of VWRF discharge upon the Estuary water balance and the influence of potential VWRF discharge scenarios upon water quality, vegetation, overall habitat area, and habitat quality for birds, fish, and human uses.

## 2.2 Existing Information

There have been several studies conducted over the past 20 years and many past and on-going data collection efforts that provide hydrologic (e.g., river and groundwater discharge), hydraulic (e.g., stage and groundwater elevation), and morphologic (e.g., mouth condition) data for the Estuary, adjacent ocean, and contributing watershed. Existing studies and data sources for Estuary and lower Santa Clara River surface and groundwater hydrology/hydraulics, Estuary morphology and bathymetry, and tidal elevation data that will be used as references and will be used in conjunction with collected data are presented in Table 2-1.

**Table 2-1.** Existing information related to Estuary hydrology/hydraulics and morphology.

| Existing hydrology/hydraulics and morphology information | Tidal elevation | Estuary stage | Mouth breaching | Estuary bathymetry | Groundwater elevation and discharge | Surface flow discharge |
|---|---|---|---|---|---|---|
| **Studies** | | | | | | |
| Swanson et al. 1990 | | | X | | X | |
| Kennedy/Jenks Consultants 2002 | | | | | X | |
| ESA 2003 | | X | | | X | |
| URS 2004 | | | | | X | |
| URS 2005 | | | | | X | |
| Nautilus Environmental 2005 (including Entrix and KH&E studies) | | X | X | | | |
| KH&E 2007 | | X | X | | | |
| Barnard et al. 2009 | | | | X | | |
| **Data Sources** | | | | | | |
| NOAA tide elevation at Santa Monica, CA and Santa Barbara, CA | X | | | | | |
| City of Ventura daily mouth status and Estuary flow estimate (1984–present) | | | X | | | X |
| City of Ventura daily VWRF flow estimate (1984–present) | | | | | | X |
| City of Ventura daily Estuary inundation extent estimate (2001–present) | | X | X | | | |
| Bailard landfill groundwater data (2004–present) | | | | | X | |
| River discharge at Montalvo (USGS; 1955–2004) | | | | | | X |
| Ventura County LiDAR (2005) | | | | X | | |
| River discharge at Freeman Diversion (VCWPD; 2005) | | | | | | X |
| River discharge at Victoria Ave. (VCWPD; 2008–present) | | | | | | X |
| SCCWRP Bight 08 WQ monitoring program (in progress; 2009) | | X | | | | |

## 2.3 Survey Design

The overall design of the Estuary Hydrology and Morphology Survey is to use newly collected Estuary hydrologic, hydraulic, and morphologic data and pre-existing Estuary topographic information to determine the Estuary water balance, and the influence of Estuary stage upon local water table elevation, mouth breaching dynamics, and inundation extent for current (i.e., post-2005 floods) Estuary conditions. Newly collected data include Estuary water surface elevation (stage) at several locations (measured as part of this project and by SCCWRP as part of a larger coastal water quality monitoring program [see SCCWRP 2009]) and groundwater elevations in the adjacent floodplain under a range of Estuary conditions (e.g., open and closed mouth, low and high river flow) from summer 2009 through fall 2010. The pre-existing topographic data include high-resolution (<1 m [3 ft]) LiDAR of the Estuary bed surface taken by both Ventura County and the USGS (see Barnard et al. 2009) after the 2005 floods. Combined, these topographic data sources enable the construction of the current Estuary bathymetric surface.

For this project, Estuary stage is being recorded at two locations along the south bank of the Santa Clara River adjacent to McGrath State Beach (see Table 2-2 and Figure 2-1). The downstream location is in the Lower Estuary adjacent to the channel on the south bank of the Estuary at McGrath State Beach that originates in the McGrath State Beach campgrounds. The upstream location is in the Middle Estuary also along the south bank approximately 650 ft upstream of the downstream gage. These two locations were chosen for instrument installation for several reasons. First, measuring Estuary stage along the south bank allows for the full range of Estuary stage to be recorded as the stage recorders are installed near the Estuary main channel. Second, the south bank morphology provides small protected 'pockets' where the recorders are shielded from flow and are protected during storm events. Third, these locations are adjacent to McGrath State Beach trails and therefore are very easy to monitor and maintain.

**Table 2-2**. Site description and identification code for stage recorders and groundwater monitoring wells.

| Site description | Site code |
|---|---|
| Estuary stage recorders | |
| Lower Estuary | SR-1 |
| Middle Estuary | SR-2 |
| **Groundwater Wells** | |
| Floodplain west of McGrath State Beach campgrounds[a,b] | GW-1 |
| Floodplain west of McGrath State Beach campgrounds[a,c] | GW-2 |
| Floodplain south of McGrath State Beach campgrounds[a,d] | GW-3 |

[a] New groundwater well installed for the City of Ventura Estuary Subwatershed Study.
[b] Near well 2 from ESA (2003) study
[c] Near well 3 from ESA (2003) study
[d] Near well 5 from ESA (2003) study

In addition to Estuary water surface elevation, water table elevation is also being recorded adjacent to the Estuary along a transect extending through McGrath State Beach (Figure 2-1).

The transect is comprised of three monitoring wells installed near monitoring well locations from previous studies (i.e., ESA 2003 and URS 2005), allowing for direct comparison between pre-existing and newly collected water table elevation data. The three well locations were also chosen because of their close proximity to access roads, ensuring easy site access during the study period.

## 2.4 Methods

### 2.4.1 Instrument installation

#### 2.4.1.1 Estuary stage

Estuary stage is being recorded by two pressure transducers: the Lower Estuary stage is being recorded by an InSitu® miniTroll installed on 1 September 2009 and the Middle Estuary stage is being recorded by a Solinst® Levelogger installed on 5 October 2009. The pressure transducers record depth of water and were installed at an elevation low enough to record depth when the Estuary water volume is low, but high enough above the Estuary bed to ensure that the pressure transducers will not become buried with sediment during the course of the study. The Lower Estuary pressure transducer (SR-1) was installed horizontal to the Estuary bed in a 2-inch perforated PVC pipe approximately 5 ft from the adjacent bank. To ensure that the Estuary stage is constantly being recorded from a fixed elevation, the pressure transducers' pipe housing was anchored on the bed to limit potential movement due to scour and/or high flow velocity. The PVC pipe housing for the pressure transducers' data cable was secured to the ground surface and extended up the Estuary bank, terminating at an elevation above an anticipated flood stage approximately 40 ft from the pressure transducer. The Middle Estuary pressure transducer (SR-2) was installed vertically in a 2-inch perforated PVC pipe stilling well approximately 50 ft from the adjacent bank. The stilling well was secured to two fence posts driven deep into the Estuary bed and set at an elevation such that the well could be opened and the pressure transducer could be removed at the anticipated maximum Estuary stage. The pressure transducer was then suspended from the top of the stilling well with a metal cable to a position right above the adjacent bed. As the raw data from SR-2 need a correction for barometric pressure for conversion to water depth, a Solinst® Barologger was installed on the Estuary floodplain to record barometric pressure.

To convert the measured Estuary water depth, or relative stage, to actual Estuary water surface elevation, or Estuary stage, the pressure transducer elevations were surveyed in to an established local benchmark. Local temporary benchmarks were installed on the floodplain adjacent to each pressure transducer and the elevation difference between pressure transducer and temporary benchmark was recorded with an autolevel and stadia rod. Following this survey, the City used a survey-grade GPS to measure the actual elevation (in ft NAVD88) of the temporary benchmarks, thereby allowing for conversion of measured water depth to Estuary water surface elevation.

#### 2.4.1.2 Groundwater elevation

Groundwater elevation is being recorded by pressure transducers (Solinst® Levelogger) placed in monitoring wells installed on 26 October 2009. The wells are slotted 1-inch PVC pipe and were installed to a depth of approximately 25 ft below the adjacent ground surface (i.e., to a depth within the surface 'semi-perched' aquifer that will ensure continuous recording of the water table position). After well installation, sand was used to backfill the space between the augur hole and the well, clay was placed at the ground surface around the well to prohibit surface water infiltration into the sand adjacent to the well, and the wellheads were covered with steel casings set into cement. The wells were then drained using an electric pump and the time for the well to fill to a static level was measured to ensure that wells are functioning properly and capable of capturing short-term fluctuations in water table elevation. The pressure transducers were then suspended from the well cap with a metal cable to a position approximately 2 ft above the bottom of the well (i.e., depth adequate to capture continuous water table position and be above any fine sediment accumulation at the bottom of the well). Similar to the raw for SR-2, the data from the Solinst® Barologger installed on the Estuary floodplain is used for conversion to water depth above the well pressure transducers.

As with the Estuary stage recorders, the pressure transducer elevation was surveyed and tied to an established local benchmark to enable conversion of water depth to actual groundwater elevation. During the same survey effort for the Estuary stage recorder temporary benchmarks, the City used survey-grade GPS to measure the actual elevation (in ft NAVD88) of each well cap. This elevation combined with the known depth from each well cap to the pressure transducer enables the conversion of water depth to groundwater elevation.

### 2.4.2 Data collection and analysis

#### 2.4.2.1 Estuary stage

Estuary water depth (and subsequent Estuary stage) and barometric pressure is being recorded at a 30-minute time interval at SR-1 and SR-2, starting on 1 September 2009 and extending through November 2010 for both pressure transducers. The pressure transducers are also set-up to record surrounding temperature. Data has been downloaded 6 times in the first 2 months of data collection, however future data downloading will occur with less frequency, approximately once every 2–3 months. Each time stage data are downloaded, pressure transducer positions are assessed to determine if the there has been an elevation shift since the previous field visit. If it appears that there has been a change in position of the pressure transducer, the difference in elevation of the pressure transducer and the adjacent temporary benchmark is resurveyed for potential datum shifts.

As a quality assurance measure prior to leaving the field after downloading data, the pressure transducer elevations and Estuary stage data are reviewed and assessed for irregularities. The pressure transducer elevations are first compared to elevation recorded during the previous field visit. If the elevations differ by more than 5 mm, then it is assumed that the pressure transducer has moved and this shift is taken into account when determining water surface elevation (see below). The pressure transducer is then checked very closely to determine if it is currently at a secured elevation. Once the elevation is determined to be secure, the pressure transducer elevation is measured again. As an additional quality assurance review, Estuary stage data for the period between data downloads is examined for anomalous values. If the values are determined to be erroneous, the pressure transducer is assessed to determine if it is functioning properly and/or if there is any visible cause for the erroneous measurements (e.g., debris or sediment). Erroneous values are removed from the data set.

Following the initial stage data quality assessment, the sorted data are converted to ft NAVD88 (using the known elevation of the temporary benchmark) and added to the comprehensive Estuary water surface elevation data set. Where appropriate, the shift in pressure transducer elevation between field visits is included in determining the Estuary water surface elevation for a given time period. It is assumed that the elevation shift should be applied to the entire time period between field visits unless there is specific information indicating otherwise. The Estuary water depth recorded by two City water quality sondes installed in the Estuary will also be an important data source for use in this project. For example, the water depth from the sondes was used to determine Estuary water surface elevation before the pressure transducers for this study were installed, and is used to fill-in data gaps when the Estuary water surface is below the elevation of the pressure transducers installed for this study. Converting sonde water depth to Estuary water surface elevation was performed by correlating the sonde data with the data recorded by the pressure transducers installed for this study for the same time period, and using the resulting correlation equation with the sonde water depth.

#### 2.4.2.2 Groundwater elevation

Similar to the Estuary stage pressure transducers, the groundwater pressure transducers are recording groundwater depth (and subsequent groundwater elevation) and groundwater temperature at a 30-minute time interval, starting on 27 October 2009 and extending through November 2010 at all well locations. Data has been downloaded once since installation; however data downloading in the future will be at the same frequency as the Estuary stage pressure transducers, approximately every 2–3 months. Each time the data are downloaded, the depth to groundwater at each well is measured using a hand-held well level logger for comparison with the pressure transducer reading and the length of each metal cable that suspends the pressure transducer is re-measured to see if there has been any changed. The pressure transducers are also assessed to see if they are in good working order and the wells are assessed for sediment accumulation.

Prior to leaving the field after downloading groundwater elevation data and metal cable lengths, are assessed for irregularities. Metal cable length is first compared to lengths recorded during the previous field visit. If the cord lengths differ by more than 0.25 in, it is assumed that the cord length has changed and this shift is taken into account when determining actual water table elevation. As with the Estuary stage data above, the water table elevation and barometric pressure data for the period between data downloads are examined for erroneous values.

Following the initial groundwater elevation data assessment, the water table elevation data are corrected with barometric pressure, converted to ft NAVD88 (using the known elevation of the temporary benchmark), and added to the comprehensive ground water table elevation data set. Where appropriate, the shift in metal cable length between field visits is included in determining the Estuary water surface elevation for a given time period. It is assumed that the length change should be applied to the entire time period between field visits unless there is specific information indicating otherwise.

### 2.4.3 Estuary bathymetry

The current Estuary bathymetry was developed from a combination of two high-resolution LiDAR data sets collected after the 2005 flood events: LiDAR data collected in January 2005 by Ventura County and LiDAR data collected in October 2005 (see Barnard et al. 2009). For the purposes of this project, the post-2005 flood Estuary bathymetry is considered to be the “current” bathymetry. The January and February 2005 floods were two of the largest events on record in the watershed and noticeably changed the Estuary morphology and lateral extent. Anecdotal information suggests that Estuary physical processes operate differently now than before the 2005 flood events and subsequent flood events in the watershed have been of a lesser magnitude than the 2005 flood events. Therefore, assuming that the Estuary morphologic and hydraulic characteristics have changed considerably after the 2005 flood events and that the Estuary will remain in the current state for the foreseeable future seems appropriate.

The two LiDAR datasets were necessary in developing the current Estuary bathymetry due to Estuary inundation and LiDAR coverage extent issues. The Ventura County LiDAR dataset covers the entire Estuary footprint, however the data were taken when the mouth was closed and Estuary was partially full, resulting in unusable elevation data for a large portion of the Estuary. The USGS LiDAR dataset was collected when the mouth was open and the Estuary was mostly drained, however the coverage only extends approximately 1,500 ft upstream from the mouth and covers only about 60% of the Estuary footprint. Therefore, combining these two data sets was necessary to obtain the best available Estuary bathymetry for use in this analysis.

Combining the two LiDAR datasets into a single bathymetric surface required several steps to reconcile both surfaces. The USGS LiDAR was re-projected and converted to the same units as the Ventura County LiDAR (ft NAVD88). Over 100 points were then randomly placed throughout the non-inundated area where the datasets overlapped to find the difference between both LiDAR datasets, and a linear relationship between both elevations in the area of overlap was obtained. This relationship was then used to 'fit' the USGS dataset to the Ventura County dataset. Both LiDAR surfaces were then merged and clipped into an Estuary boundary defined by the 11.5 ft NAVD88 elevation (maximum recorded closed-mouth Estuary water surface elevation, see Section 2.5.1). Three areas were then defined for further adjustment to remove infrastructure interference and to account for elevation differences due to the time lag between the flights (i.e., the Ventura County LiDAR dataset does not capture the impacts of the February 2005 flood). The Harbor Blvd. Bridge was removed from the combined LiDAR dataset by assigning each point on the bridge a Estuary bed elevation based on adjacent values. Approximately 1,000 ft downstream of the Harbor Blvd. Bridge, a parcel on the north bank was raised by 1.5 ft to match adjacent areas and account for apparent deposition associated with the February 2005 flood event. Just to the south, a parcel was lowered by 6.5 ft (based on matching adjacent side channel elevations) to account for bank erosion caused by the February 2005 flood event.

## 2.5 Results

The results from the initial hydrologic/hydraulic data collection effort and from compilation of existing Estuary topographic data are presented in the section below. The purpose of presenting these data are to provide an indication of the quality of the Estuary stage and groundwater elevation data that we are currently collecting, the quality of compiled topographic data used to generate the Estuary bathymetric surface, and the applicability of these data to for meeting project goals. A brief discussion of specific attributes of each data set is given in the section (Section 2.6 Data Assessment).

### 2.5.1 Estuary stage

The 30-minute time series of Estuary stage that starts in spring 2009 and extending into late fall 2009 and includes two mouth breaching events is shown in Figure 2-2. As stated previously, the time series is a combination of data recorded by the pressure transducers installed for this project and data recorded by the City water quality sondes. Initial data shown here suggest that the sonde data will be essential for use during low-flow, open-mouth conditions. For the first three months of the time series (20 May 2009–1 September 2009), the stage data are from the water depth record of the sonde installed near the south bank of the Estuary (Figure 2-1 Starting on 2 September 2009, the first pressure transducer installed for this study (SR-1) began recording Estuary stage. Shortly after the first recorded Estuary mouth breach (artificial breach on 11 September 2009), there was a rapid drop in Estuary stage of over 5 ft followed by tidal exchange until the mouth closed again over two weeks after the breach on 27 September 2009. During this time period and for several days following the mouth closure, the Estuary stage was below the initial SR-1 elevation, resulting in the need to use SCCWRP south sonde data for the Estuary stage time series. To help prevent this need in the future, SR-1 elevation was lowered by over 1 ft and SR-2 was installed at an elevation lower than SR-1 on October 5, 2009. The Estuary continued to fill until the stage reached 11.5 ft NAVD88 and the Estuary mouth breached for a second time (storm-induced breach on 14 October 2009), with SR-1 recording Estuary stage for that time period. Starting the day after the breach and continuing until the mouth closed on 25 October 2009, the Estuary stage dropped below elevation of both pressure transducers installed for this project (SR-1 and SR-2) and remained below both pressure transducers during for much of the 11-day tidal exchange period. During this time, the SCCWRP south sonde data was used to provide missing data from the stage time series. Following the mouth closure, both pressure transducers installed for this study were capable of recording stage as the Estuary continued to fill (Figure 2-2).

### 2.5.2 Groundwater elevation

The 30-minute time series of groundwater elevation during fall 2009 at each of the three monitoring wells installed in the surface 'semi-perched' aquifer is shown in Figure 2-3. These data capture a 20-day period of Estuary filling following mouth closure and show the interplay between Estuary stage and groundwater elevation south of the Estuary as the Estuary stage steadily rises. At the beginning of the time period, the Estuary mouth had been closed for two days and the groundwater gradient indicates an overall flow direction toward the Estuary (i.e., the water surface elevation is lowest in the Estuary and highest at GW-3). During the first eight days of Estuary filling (26 October 2009–2 November 2009), the Estuary stage and GW-1 groundwater elevation increased and Estuary stage rose above the GW-1 groundwater elevation on 2 November 2009, while the GW-2 groundwater elevation remained relatively unchanged and the GW-3 groundwater elevation decreases slightly. Over the next 10 days as the Estuary continued to fill (2–12 November 2009), the Estuary stage and GW-1 groundwater elevation rose above the groundwater elevation at both GW-2 and GW-3, and there was a relatively rapid rise in Estuary stage in one day (approximately 0.5 ft on November 3, 2009), possibly due to precipitation effects (verification with local precipitation and/or river discharge data is needed). During this 10-day time period, the groundwater flow gradient switched from an overall flow direction towards the Estuary to a situation where there were two local groundwater flow gradients: from the Estuary south towards GW-2 and from GW-3 north towards GW-2. After this 10-day period, the Estuary stage approached a constant elevation and the GW-1 groundwater elevation became higher than the Estuary stage and the groundwater elevation at Wells 2 and 3. During this period, local gradients indicate groundwater flow from GW-1 to the Estuary, from GW-1 towards GW-2, and from GW-3 towards GW-2. The indicates a time-lag between changes in estuary stage and groundwater elevation.

### 2.5.3 Estuary bathymetry

The compiled current (i.e., post-2005 flood) Estuary bathymetric surface is shown in Figure 2-4. These data show a current Estuary inundated area (i.e., area below 11.5 ft NAVD88) of approximately 260 acres, volume of approximately 1,135 acre-feet, an upstream Estuary boundary approximately 1,000 ft upstream of Harbor Boulevard bridge, and a minimum Estuary bed elevation at approximately 3 ft NAVD88 (excluding the elevation of the small inlet channel that existed when the USGS LiDAR data were collected). Analysis of this bathymetric data the reveals the way in which Estuary inundated area, volume, and depth relate to Estuary stage (Figures 2-5 to 2-7). At 3 ft NAVD88, inundated area and Estuary volume are both less than 1%

of the total values for the Estuary, with average Estuary water depth for the associated small Estuary area of approximately 0.6 ft. Between this minimum Estuary stage and the Estuary stage that is approximately half the value for a full Estuary (i.e., 6 ft NAVD88), the inundated area increases to 36% of the Estuary total, volume increases to 10% of the Estuary total, and the average Estuary water depth increases approximately 1.3 ft. Between 6 ft and 9 ft NAVD88 (i.e., the stages when the Estuary is approximately half full and three-quarters full, respectively), the inundated areas increases to 74% of the Estuary total, volume increases to 51% of the Estuary total, and the average Estuary water depth increases to approximately 3.0 ft. At 11.5 ft NAVD88 (i.e., the approximate stage of a full Estuary), all three bathymetric parameters are at their maximum values, with average Estuary water depth approaching a maximum value of approximately 4.5 ft.

## 2.6 Data Assessment

The approach to collecting and compiling Estuary hydrologic, hydraulic, and morphologic data collected during Year One of the Estuary Subwatershed Study yielded very informative results that will be essential for compiling an Estuary water balance for current conditions and determining the influence of Estuary stage on local water table elevation and mouth breaching dynamics, and inundation extent. The Estuary stage data show the steady-state Estuary stage during closed-mouth conditions, the Estuary stage that currently causes a natural mouth breach, the tidally-induced increase and decrease in water surface elevation when the mouth is open, and the amount of time it takes the mouth to close after breaching. The groundwater elevation data for the ‘semi-perched’ aquifer accurately capture the magnitude of and the response time to changes in Estuary stage, and reveal local groundwater gradient that exist along the Estuary’s southern floodplain. The compiled current Estuary bathymetric data provide a high-resolution continuous topographic surface from the best available data sources, which captures micro-habitat features including local scour zones, blind tidal sloughs, and side channels. In general, the quality and completeness of these data indicate a robust overall monitoring approach and suggests that data collected during Year Two will be equally as useful in addressing the Survey goals and answering the primary study questions related to the interaction between Estuary physical state and ecologic function

## 2.7 Estuary Water Balance

### 2.7.1 Introduction

One of the primary goals of the Estuary Hydrology & Morphology Survey is to develop an Estuary water balance and thereby determine the relative contribution of each water balance component under current Estuary conditions. This water balance will be used to understand the hydrologic/hydraulic, morphologic, and ecologic state of the Estuary, will help understand the future state of the Estuary under current conditions, and will be used to guide the development of alternatives for modifying VWRF discharge. Through combining data collected and compiled for this project (discussed above) with data provided from other sources (discussed below), a preliminary Estuary water balance will be compiled after the end of Year One data collection) and a finalized Estuary water balance will be compiled at the end of Year Two data collection. In this section we describe the overall approach to constructing the Estuary water balance. This discussion includes a presentation of the individual Estuary water balance components and an explanation of the data sources that will be used to estimate the relative contribution of each component. Values assigned to each water balance component will be detailed in a technical memorandum describing the conceptual models of current ecosystem drivers and biological response that will be submitted in July 2010.

### 2.7.2 Water balance approach and components

A water balance is a method for accounting for the inflows, outflows, and change in water stored in a specific reservoir over a given time period (Hornberger et al. 1998). The change in water volume stored over a given time period can be expressed by the equation

$$\frac{dV}{dt} = I - O$$

where $V$ is the reservoir volume, $t$ is time, $I$ is the volume of water input for the time step $dt$, and $O$ is the volume of water output for the time step $dt$. The volume of water stored at a given point in time can then be expressed by the equation

$$V(t+1) = V(t) \pm \frac{dV}{dt}$$

Essentially, the reservoir volume at any given time is equal to reservoir volume from the previous time step plus the amount of water put in minus the amount of water taken out over that time step. Also, if the reservoir volume at two time steps is known, it is possible to determine the volume of water gained/lost between the two time steps. Combining this information with known rates of water input and output between two time steps can help constrain discrete water input and output values for which little or no data are available.

For this project, the inflows and outflows to the Estuary are comprised of many different components. Water inflows into the Estuary include the following:

- Direct precipitation
- VWRF discharge
- Santa Clara River discharge
- Ocean exchange (surface flow in when the mouth is open)
- Ocean exchange (subsurface flow in across berm when the mouth is closed)
- Groundwater flow (inflow to the Estuary)

Water outflows from the Estuary include the following:

- Evaporation
- Ocean exchange (surface flow out when mouth is open)
- Ocean exchange (subsurface flow out across berm when the mouth is closed)
- Groundwater flow (outflow away from the Estuary)

Combining the inflow/outflow rates for each water balance component with the measured change in Estuary volume allows for a definitive determination of the Estuary water balance for a given time step, can be used to help constrain inflow/outflow values for individual components, and when compiled over a long time period (i.e., many successive time steps) can be used to determine average seasonal and annual contributions of individual water balance components.

The information used to develop the inflow/outflow rates and Estuary water volume estimates is being compiled from many different sources, including data being collected for this project and data being concurrently collected by others. A description of data that will be used to estimate each Estuary water balance component, along with the data sources for each component, is given below.

#### Estuary volume

The volume of water within the Estuary is being calculated on an hourly time step using the Estuary stage being recorded as part of this project (with sonde data when necessary) in conjunction with the relationship between Estuary stage and Estuary volume. For each time step, Estuary stage will be converted to Estuary volume, and the associated change in volume between time steps will be calculated. The measured volume change will then be used to determine the seasonal Estuary volume dynamics from fall 2009 through fall 2010.

#### Precipitation

The volume of direct precipitation onto the Estuary is derived from a combination of hourly precipitation at Ventura Harbor measured by the Ventura County Watershed Protection District (VCWPD gage 216C) and Estuary area derived from measured Estuary stage. This method ensures that as the Estuary area expands and receded during storm events, the volume of precipitation that falls directly onto the Estuary, and is therefore not accounted for in the surface and subsurface flow measurements discussed below, is accurately assessed.

#### Evaporation

The volume of Estuary water lost to evaporation is derived from a combination of daily pan evaporation (i.e., depth of water evaporated from an open volume of water) at the El Rio-UWCD Spreading Grounds (VCWPD station 239), approximately 6 miles east of the Estuary, and Estuary area. Pan evaporation is a function of air temperature, humidity, solar radiation, and wind, and the Estuary and the El Rio-UWCD spreading grounds are close proximity, it is assumed that these conditions are the same for both sites. The daily pan evaporation estimates are converted to average hourly estimates assuming a constant rate of evaporation throughout any given day, which is deemed appropriate for the purposes of constructing the water balance. This method ensures the accurate assessment of the volume of Estuary water loss to the atmosphere on an hourly basis as the Estuary expands and recedes.

#### VWRF discharge

The City currently records average daily VWRF discharge into the Estuary at the Wildlife Pond System outfall channel. The average daily discharge data for fall 2009 through fall 2010 is being compiled and will be used to determine an hourly discharge record by assuming the daily mean discharge and the average hourly discharge for a given day are the same. This converted data set will then be used to determine the VWRF discharge contribution to the Estuary water balance.

#### Santa Clara River discharge

The contribution of river discharge on the Estuary water balance is being determined by compiling data from two sources. The VCWPD records daily mean discharge at the Victoria Avenue Bridge (VCWPD station 723), approximately 1.5 miles upstream of the Estuary boundary. These data are being compiled for fall 2009 and fall 2010 and converted to an hourly time step for use in this analysis. Between the Victoria Avenue Bridge and the Estuary upstream boundary, the contribution of individual sub-basins on Santa Clara River discharge is being estimated using the Rational Method (Kuichling 1889). The Rational Method is a simple equation for calculating storm-induced discharge from small areas as a function of contributing watershed and precipitation characteristics and can be expressed as

$Q = CIA$

where $Q$ is discharge (cfs), $C$ is a dimensionless run-off coefficient based on contributing watershed land use/vegetation cover, $I$ is rainfall intensity (in/hr), and $A$ is contributing drainage area (acres). The run-off coefficient for each sub-basin is being estimated from land cover information for the region (from the 2001 National Landcover Dataset), rainfall intensity is being determined from rainfall data recorded at Ventura Harbor (VCWPD gage 216C), and contributing areas are being determined using the 2005 LiDAR dataset. The calculated discharge from individual subwatershed is then be combined with discharge measurements from the Victoria Avenue Bridge gage to determine hourly discharge into the Estuary from fall 2009 through fall 2010. It is assumed that there is little to no discharge coming from the sub-basins during dry conditions (i.e., mostly all discharge is from precipitation run-off); this assumption will be field-verified.

**Ocean exchange**

Water flow between the Estuary and the ocean is either surface or subsurface, depending on the condition of the Estuary mouth, and the flow magnitude is a function of the hydraulic gradient across the mouth. For open mouth conditions, the flow volume exchanged between the Estuary and ocean is being determined from tidal elevation recorded by nearby gages in conjunction with estimates of flow across the mouth made by the City. A time series of hourly tidal elevation data from Santa Monica, CA (NOAA gage 9410840) and Santa Barbara, CA (NOAA gage 9411340) are being compiled for fall 2009 to fall 2010. When the mouth is open, these data are being compared to hourly Estuary stage data to determine when tidal elevation is controlling Estuary stage and associated Estuary volume, and the associated volume of ocean flow to the Estuary during rising tides and out of the Estuary during falling tides. The City's daily estimates of surface flow into and out of the Estuary, calculated by visual estimates of width, depth and velocity, are being used to corroborate and help constrain the flow estimates derived by comparing tidal and Estuary stage data.

For closed mouth conditions, subsurface flow volume between the ocean and Estuary is being estimated by combining flow velocity and the physical dimensions of the flow exchange area. Subsurface flow velocity is being estimate by using Darcy's Law (Darcy 1856), which can be expressed as

$$V = -K\left(\frac{dh}{dl}\right)$$

where $V$ is flow velocity (ft/hr), $K$ is hydraulic conductivity (ft/hr), and $dh/dl$ is hydraulic gradient, or the ratio of the difference in elevation between the ocean and the Estuary ($dh$) and the surveyed width of the mouth berm ($dl$) over the hour time step. Flow velocity is towards the Estuary when velocity is positive and towards the ocean when velocity is negative. Combining hourly velocity with the mouth berm width (ft) and hourly estimate of flow depth (i.e., depth to the bottom of the 'semi-perched' aquifer, ft) results in an hourly estimate of the specific discharge of subsurface flow into or out of the Estuary. To arrive at the actual volume of water exchanged across the beach berm, the specific velocity is divided by porosity. Both hydraulic conductivity and porosity of the mouth berm is being estimated using a range of literature values for beach sand.

**Groundwater flow**

Estimates of groundwater flow into and out of the Estuary are being made through a combination of direct measurements and calculations of the residual volume (the difference between measured Estuary volume and the sum of all other water balance components) for each time step. Between the Estuary and the adjacent floodplain to the south, groundwater flow is being calculated at the downstream portion (west of Harbor Blvd. Bridge to the mouth) from data collected for this project and at the upstream portion (i.e., east of Harbor Blvd. Bridge to the Estuary boundary) by data concurrently collected at two landfill sites. Groundwater flow into and out of the Estuary for the southern floodplain west of Harbor Blvd. Bridge is being calculated using Darcy's Law and hourly elevation data at the three monitoring wells installed for this project, hourly Estuary stage measurements, estimates of hydraulic conductivity and porosity along the well transect, the width of the subsurface flow zone (the distance from the mouth to Harbor Blvd. Bridge), and the depth of groundwater flow (the depth to the bottom of the "semi-perched" aquifer for each time step). Hydraulic conductivity and porosity at each well are being estimated from literature values for sediment with similar particle size distributions as the sediment at each monitoring well (as determined from laboratory analysis of sediment samples taken during monitoring well installation). Groundwater flow into and out of the Estuary for the southern floodplain east of Harbor Blvd. Bridge is being determined from groundwater data recorded at the Bailard landfill just downstream of the Victoria Avenue Bridge in Oxnard, CA. Several wells at each landfill site monitor the 'semi-perched' aquifer water table elevation. In addition, both sites have estimates of local hydraulic conductivity and porosity. Combining these data with Darcy's Law, hourly Estuary stage data, the width of the subsurface flow zone (the distance from the Estuary extent to Harbor Blvd. Bridge), and the depth of groundwater flow gives an hourly estimate of groundwater flow for this portion of the adjacent southern floodplain.

Groundwater flow between the Estuary and the adjacent floodplain to the north is calculated on an hourly time step as the residual from the difference between measured Estuary volume and inflow/outflow volume associated with all other water balance components. As all other water balance components are well constrained (i.e., values come from direct measurements in or near the Estuary), solving for the groundwater flow between the Estuary and the floodplain to the north seems appropriate for "closing" the Estuary water balance. Should any semi-perched aquifer monitoring wells be installed on the floodplain to the north during the study period, we will make every effort to obtain that well dataset and incorporate it into the water balance analysis.

## 2.8 Future Work

### 2.8.1 Scheduled tasks

As stated above, the proposed approach for the Year Two monitoring is to collect data that complements the Year One monitoring dataset and helps finalize the Estuary water balance. Scheduled monitoring and data collection tasks (i.e., tasks outlined in the project Monitoring Plan and/or tasks that are required in determining Estuary water balance component values) include the following:

- continued measurement of Estuary stage on a 30-minute time step at SR-1 and SR-2 through November 2010;
- continued measurement of 'semi-perched' groundwater elevation on a 30-minute time step at GW-1, GW-2, and GW-3 through November 2010;

- compilation of all other appropriate datasets necessary for compiling the Estuary water balance (e.g., precipitation, evaporation, discharge, tide elevation, groundwater elevation); and
- determination of 'semi-perched' aquifer textural information and associated local hydraulic variables at the project monitoring wells.

### 2.8.2 Recommendations

There are a few tasks that did not occur in Year One that, if completed in Year Two, will help constrain Estuary water balance component values that require more information. These tasks include the following:

- Depth measurements – Water depth measurements at several Estuary locations can be used in conjunction with Estuary stage to determine local bed elevation (ft NAVD88). These elevations can be compared to elevations from the compiled Estuary bathymetric surface as an independent check on the presumption that there has not been much change in bed elevation since the 2005 storm events.
- Low-flow discharge estimates – Estimates of river discharge into the upstream end of the Estuary and out of small channels downstream of the Victoria Avenue Bridge during dry conditions can be used as a check on the low-flow gage readings from the Victoria Avenue Bridge gage (VCWPD 723) and as check on the presumption that small channels are dry except during storms.

## 2.9 References

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# 3 ESTUARY WATER QUALITY AND NUTRIENT SURVEY

## 3.1 Goals and Objectives

The overall goals of the water quality and nutrient survey are to determine (1) if water quality in the Estuary is affected by discharge from the VWRF, (2) the current trophic status of the Estuary, and (3) if the VWRF discharge currently enhances water quality in the Estuary or could provide an enhancement under a different discharge scenario (i.e., overall decreased discharge).

To meet the stated project goals, three study objectives were developed to characterize water quality and Estuary trophic status over multiple seasons and hydrologic conditions.

- Conduct quarterly synoptic surveys of *in situ* water quality (water temperature, DO, pH, conductivity), nutrients (nitrogen and phosphorus species) and chlorophyll-*a* in the Estuary and the lower Santa Clara River;
- Collect quarterly nitrate ($NO_3^-$) samples at up to four groundwater wells adjacent to the Estuary and lower Santa Clara River in order to characterize average seasonal groundwater nitrate contributions from the adjacent watershed to the Estuary;
- Conduct up to three synoptic surveys that pair open and closed mouth conditions during both seasonal low-flow (summer/fall) and high-flow (winter/spring) periods in order to elucidate the relative importance of inputs from the lower Santa Clara River, VWRF discharge, and groundwater on water quality in the Estuary.

## 3.2 Existing Information

Multiple studies and data collection efforts have characterized elements of surface water and groundwater quality in or near the Estuary and lower Santa Clara River, including efforts by federal and state agencies (e.g., USFWS, ACOE, CDFG, State Parks and Recreation) as well as regional and local entities (Southern California Coastal Water Research Project [SCCWRP], City of San Buenaventura). Existing studies and data sources for water quality in the Estuary and lower Santa Clara River are presented in Table 3-1. Ongoing monitoring efforts, including the City's monthly receiving water monitoring program, and the continuation of the continuous in situ data collection efforts by SCCWRP will be extended by the City through the 2009–2010 monitoring period to address identified data gaps.

**Table 3-1.** Existing studies and data sources for water quality.

| Existing water quality information | *In situ* surface water parameters (e.g., water temperature, DO, pH, salinity, conductivity) | Surface water nutrients (N, P, some speciation) | Groundwater parameters (e.g., elevation, contaminants) |
|---|---|---|---|
| **Studies** | | | |
| Swanson et al. 1990 | X | | |
| USFWS 1999 | X | | |
| URS 2005 | X[1] | | X[a] |
| Kennedy/Jenks Consultants 2002 | X[1] | | |
| Entrix 2002 (Metals Translator Study) | X | | |
| Nautilus Environmental 2005 (including Entrix and KH&E studies) | X | X | |
| Kelley 2008 | X | | |
| **Data Sources** | | | |
| City of Ventura Monthly WQ monitoring program (1997–present) | X | X | |
| Bailard and Coastal SC landfill groundwater data (2004–present) | | | X |
| SCCWRP Bight 2008 WQ monitoring program (in progress; 2009) | X | | |

[a] Available data are for McGrath Lake.

## 3.3 Study Design

To build upon existing and ongoing data collection efforts, additional *in situ* and analytical water quality data were collected at locations within the Estuary and lower Santa Clara River in September and November during 2009, with additional surveys planned for 2010. The study design is based upon our current understanding of Estuary configuration, which is derived from available Google Earth imagery (2006) and includes the prevailing channel network, vegetation cover, and location of the VWRF outfall channel. Using available imagery, the Estuary possesses a braided main channel flowing southwest from upstream of the Harbor Blvd. Bridge to a small mouth at the southwest corner of the Estuary (Figure 3-1). A narrow high-flow channel is also apparent, flowing roughly parallel to the main channel along the northern edge of McGrath State Beach. The VWRF outfall channel enters the Estuary from the north in a relatively more vegetated portion of the Estuary, flows southwest, and then turns directly south and flows along to enter the lower Estuary. The mouth is assumed to be in the southwest corner of the SCRE (shown by red line in Figure 3-1). Should Estuary configuration under current conditions vary significantly from that described above, the study design will be adjusted to accommodate updated information.

### 3.3.1 Monitoring sites

The current water quality monitoring sites were distributed amongst the channel network of the Estuary and lower Santa Clara River and on the adjacent floodplain, and include existing locations where water quality data has recently been or is currently being collected. Seven Estuary monitoring sites and one lower Santa Clara River site were identified as representative of either ambient conditions or waters potentially affected by permitted discharges of the VWRF to the Estuary (Figure 3-1, Table 3-2). The single river site is located upstream of the Harbor Blvd. crossing and is intended to characterize surface water conditions entering the Estuary from Reach 1 of the lower Santa Clara River (Stillwater Sciences 2008). The seven Estuary sites are located in the upper, middle, and lower zones of the Estuary, which are broadly defined using reported elevation above mean sea level (MSL) from 2001 McGrath State Beach mapping efforts (ESA 2003), as follows:

- Upper Estuary: ≥ 6 ft above MSL
- Middle Estuary: 4 ft to 5 ft above MSL
- Lower Estuary: 1 ft to 3 ft above MSL

In addition to the sites in the Estuary, groundwater water quality within and adjacent to the Estuary was measured along the three installed monitoring wells (Figure 3-1,Table 3-2). The wells were installed along a transect extending from the southern edge the Estuary through the McGrath State Beach campground, extending south towards McGrath Lake (see Section 2.4.1.2).

**Table 3-2.** Current monitoring sites in lower Santa Clara River and Estuary.

| Site description | Site code | GPS Coordinates | |
|---|---|---|---|
| **Lower Santa Clara River** | | | |
| Upstream of Harbor Blvd. Bridge | R-1 | 34° 14.172' | -119° 15.294' |
| **Santa Clara River Estuary** | | | |
| Upper Estuary main channel (d/s of Harbor Blvd. Bridge) | E-U1 | 34° 14.094' | -119° 15.550' |
| Upper Estuary high-flow channel | E-U2 | 34° 14.050' | -119° 15.478' |
| Upper Estuary d/s of VWRF Outfall | E-U3 | 34° 14.128' | -119° 15.779' |
| Middle Estuary main channel | E-M1 | 34° 13.984' | -119° 15.763' |
| Middle Estuary d/s of VWRF Outfall | E-M2 | 34° 14.035' | -119° 15.899' |
| Lower Estuary main channel | E-L1 | 34° 13.881' | -119° 15.924' |
| Lower Estuary at mouth[a] | E-L2 | 34° 13.772' | -119° 15.828' |
| **Groundwater Wells** | | | |
| Floodplain west of McGrath State Beach campgrounds[b] | GW-1 | 34° 13.622' | -119° 15.619' |
| Floodplain west of McGrath State Beach campgrounds[b] | GW-2 | 34° 13.473' | -119° 15.545' |
| Floodplain south of McGrath State Beach campgrounds[b] | GW-3 | 34° 13.204' | -119° 15.485' |

[a] Depending on mouth location, this site may be relocated to sample the south deepwater arm of SCRE depicted in the 2006 available imagery.
[b] New groundwater well installed for the City of Ventura Estuary Subwatershed Study.

### 3.3.2 Sampling timing

Two surveys were conducted in September and November 2009. During the surveys the Estuary mouth was closed, representing the condition when VWRF discharges are most likely to have an effect on Estuary water quality.

## 3.4 Methods

### 3.4.1 Sampling methods

#### 3.4.1.1 Estuary and lower Santa Clara River *in situ* sampling

All monitoring sites were located using Global Positioning System (GPS) units. Sampling during the closed mouth conditions required the use of a boat to access the monitoring sites.

*In situ* water quality parameters (Table 3-3) were measured using a portable multi-parameter probe (YSI 600XL, Yellow Springs Instruments, Yellow Springs, OH), including water temperature, pH, salinity, conductivity, and DO (temperature compensation, manual salinity correction, self-stirring probe). General sampling methodology followed SCCWRP (2009) and the California Surface Water Ambient Monitoring Program (SWAMP) protocols for calibration and sample collection. The YSI multi-parameter probe was calibrated before and after each field effort, with field calibration checks conducted on a daily basis. Winkler titrations were run pre- and post-calibration of the YSI DO probe, as an independent check on the internal instrument field calibration. For *in situ* measurements, the DO probe was allowed to equilibrate in-stream for at least 90 seconds before recording results to the nearest 0.1 mg/L. Temperature was measured to the nearest tenth of a degree centigrade. The pH was recorded to the nearest 0.1 of a pH unit. Lastly, turbidity was measured in triplicate for each site using a grab sample collected in a clean, rinsed sample bottle and a portable Hach 2100 P turbidimeter. A field calibration check of the turbidimeter occurred daily.

**Table 3-3.** *In situ* water quality parameter methods and instrument accuracy levels.

| Parameter | Method No. | Specified instrument accuracy | Reference |
|---|---|---|---|
| Temperature | 170.1 | 0.1 C | USEPA 2003 |
| DO | 4500-O | 0.03 mg/L (0.03 %) | APHA 1998 |
| Conductivity | 2510-B | 1.0 umhos/cm | APHA 1998 |
| pH | 4500-H | 0.1s.u. | APHA 1998 |
| Turbidity | 2130 B | 0.1 NTU | APHA 1998 |

At the lower Estuary monitoring sites, representative sample depths for analytical parameters were determined by *in situ* conductivity profiles to determine the extent of vertical mixing in the water column. If stratification was observed, as either the result of a pycnocline[1] or a freshwater thermal density gradient, remaining *in situ* parameters were measured at 0.5 m (1.6 ft) depth increments.

[1] A density gradient, or pycnocline, is formed in the estuary when marine water moves inland on and near the bottom and lighter fresh water moves seaward on top.

#### 3.4.1.2 Estuary and lower Santa Clara River analytical sample collection

Grab samples for nutrients and chlorophyll-*a* (Table 3-4) were collected at the surface for each monitoring site. If stratification was observed (see above), analytical samples were measured at the surface and at one location below the depth of the pycnocline. For each survey effort, duplicate samples were collected at one site and sent to the laboratory as a quality control measure. Equipment blank samples were collected in the field where necessary and then shipped along with the rest of the samples. All nutrient and chlorophyll-*a* samples were packaged with ice in coolers and shipped overnight to Sierra Environmental Laboratories (Reno, NV). Analytical laboratory methods are shown in Table 3-4.

**Table 3-4.** Analytical methods with reporting and detection limits.

| Parameter/Constituent | Method | Units | MDL[a] | MRL[b] |
|---|---|---|---|---|
| Total Kjeldahl Nitrogen as N | SM4500 N(org) | mg/L | 0.03 | 0.1 |
| Total Ammonia as N | EPA 350.3 | mg/L | 0.03 | 0.1 |
| Nitrate + Nitrite as N | EPA 300.0 | mg/L | 0.05 | 0.0076 |
| Orthophosphate as P | EPA 365.3 | mg/L | 0.02 | 0.05 |
| Total Phosphorous | EPA 365.3 | mg/L | 0.02 | 0.008 |
| Chlorophyll-*a* | SM 10200H | mg/L | 0.0005 | 0.002 |

[a] The MDL (Method Detection Limit) is defined as the concentration at which the laboratory can report with 99 percent confidence that the analytical result is not actually zero.
[b] The MRL (Method Reporting Limit) is defined by the laboratory for each method, and is an estimate of the minimum concentration at which the laboratory is confident in reporting a numerical value.

#### 3.4.1.3 Groundwater sample collection

Water collected from the groundwater wells at McGrath State Beach was measured for *in situ* conductivity (Table 3-3) and samples were collected for laboratory analysis of $NO_3$+$NO_2$ (Table 3-4). A 12-volt submersible pump deployed in the 2-inch diameter well casing was used to extract groundwater samples. At least three well volumes were purged prior to sampling to ensure that the sample is representative of groundwater conditions. Follow-up sampling will be conducted in 2010 for *in situ* water quality, nutrients, and targeted contaminants (e.g., total metals, cyanide, PCBs, pesticides, and VOCs) that may be transported in the groundwater to the Estuary under low Estuary stage conditions.

### 3.4.2 Analysis methods

Quality control review was performed on all analytical data, using blank and duplicate laboratory results. There were no errors found in the analytical data, so no corrections were made to the dataset. The accuracy of the analytical methods will be estimated using the results from duplicate samples collected during the planned 2009–2010 survey period.

*In situ* and chlorophyll-*a* results from the eight designated water quality monitoring sites were analyzed to identify spatial patterns indicating a potential change in water quality between the river, VWRF discharge, and the Estuary. As more data are collected, water quality data along the transect from the Santa Clara River site to the upper, middle, and lower Estuary sites will be analyzed for possible trends on a seasonal basis, as will data along the high-flow channel and VWRF discharge channel transects. While analysis of $NO_3$+$NO_2$ data also included the identification of potential concentration gradients in groundwater and Estuary sites, in general, nutrient data has been collected for later use in a mass balance approach to include the effects of flow volume on the Estuary. A seasonal nutrient mass balance will be calculated using a simplified box model, parameterized with measured concentration data and results from the Estuary Water Balance (See Section 1.3.1) along with literature based values for denitrification, settling of particulate forms, and biomass nutrient uptake.

Estuarine trophic status will be assessed using multiple indicators of estuarine eutrophication including DO, pH (Bricker et al. 2003), and the biological response indicators, chlorophyll-*a*, macro algae, and submerged aquatic vegetation (SAV). Note that very little macro-algae or SAV was observed during the 2009 surveys, as discussed in the Tidal & Upland Vegetation and Aquatic Habitat Mapping Surveys (Section 4). Measured chlorophyll-*a* and DO concentrations at all sample sites will be compared with thresholds for primary and secondary symptoms of estuarine eutrophication (Bricker et al. 2003). Results will be compared with data from the 2008–2009 SCWWRP surveys (SCCWRP 2009), assuming data for the latter is available prior to December 2010.

## 3.5 Results

Results from the initial water quality data collection effort are presented below. The purpose of presenting these data is to provide an indication of the quality of the *in situ* and analytical data that we are currently collecting and the applicability of these data for meeting project goals. A brief interpretation of the water quality data is also provided (Section 3.6 Data Assessment).

The sample date, sample time, sample depth, and bottom depth for the summer (September) and fall (November) surveys are presented in Tables 3-5 and 3-6. As planned, the Estuary mouth was closed during both surveys. However, in the interim between surveys, the Estuary mouth opened and closed twice, once between 11 and 27 September 2009 and again between 14 and 25 October 2009. By the November survey, the Estuary elevation returned to near the level that it was at during the September survey. Because of high Estuary stage during the September surveys, the lower Santa Clara River (R-1) sample site was located further upstream than anticipated, approximately 2,300 ft east of the Harbor Blvd. Bridge.

**Table 3-5.** Water quality metadata for summer 2009 survey.

| Site code | Site description | Sample date | Sample time | Sample depth (ft) | Bottom depth (ft) |
|---|---|---|---|---|---|
| R-1 | Upstream of Harbor Blvd. Bridge | 1 Sep | 13:45 | 0.5 | 0.6 |
| E-U1 | Upper Estuary main channel (d/s of Harbor Blvd. Bridge) | 1 Sep | 13:00 | 0.5 | 3.1 |
| E-U2 | Upper Estuary high-flow channel | 1 Sep | 13:15 | 0.5 | 1.2 |
| E-U3 | Upper Estuary d/s of VWRF Outfall | 1 Sep | 12:10 | 0.5 | 5.0 |
| E-M1 | Middle Estuary main channel | 1 Sep | 12:30 | 0.5 | 3.1 |
| E-M2 | Middle Estuary d/s of VWRF Outfall | 1 Sep | 11:55 | 0.5 | 5.5 |
| E-L1 | Lower Estuary main channel | 1 Sep | 11:25 | 0.5 | 5.5 |
| E-L2 | Lower Estuary at mouth | 1 Sep | 11:05 | 0.5 | 6.1 |

**Table 3-6.** Water quality metadata for fall 2009 survey.

| Site code | Site description | Sample date | Sample time | Sample depth (ft) | Bottom depth (ft) |
|---|---|---|---|---|---|
| R-1 | Upstream of Harbor Blvd. Bridge | 17 Nov | 11:25 | 0.5 | 0.7 |
| E-U1 | Upper Estuary main channel (d/s of Harbor Blvd. Bridge) | 17 Nov | 12:20 | 0.5 | 2.5 |
| E-U2 | Upper Estuary high-flow channel | 17 Nov | 10:30 | 0.5 | 2.1 |
| E-U3 | Upper Estuary d/s of VWRF Outfall | 17 Nov | 13:05 | 0.5 | 5.2 |
| E-M1 | Middle Estuary main channel | 17 Nov | 12:36 | 0.5 | 2.1 |
| E-M2 | Middle Estuary d/s of VWRF Outfall | 17 Nov | 13:30 | 0.5 | 4.2 |
| E-L1 | Lower Estuary main channel | 17 Nov | 14:05 | 0.5 | 4.8 |
| E-L2 | Lower Estuary at mouth | 17 Nov | 14:15 | 0.5 | 3.1 |
| GW-1 | Floodplain west of McGrath State Beach campgrounds | 16 Nov | 15:15 | 5.6[a] | NA |
| GW-2 | Floodplain southwest of McGrath State Beach campgrounds | 16 Nov | 15:45 | 5.1[a] | NA |
| GW-3 | Floodplain south of McGrath State Beach campgrounds | 16 Nov | 16:35 | 8.6[a] | NA |

[a] Distance between ground elevation and water surface elevation. Sample collected near bottom of well casing.

### 3.5.1 *In situ* parameters

The results of the *in situ* water quality sampling in the lower Santa Clara River, the Estuary, and the adjacent groundwater wells during summer and fall 2009 are presented in Tables 3-7. During the summer 2009 surveys, water temperature and conductivity were relatively uniform throughout the Estuary, consistent with wind mixing of the shallow estuary. Both pH and DO levels were very high, consistent with algal photosynthesis, and exhibited large diel variations, as shown by the continuous recording multi-parameter sondes deployed by the City (Figure 3-2). In addition, turbidity levels were elevated at all locations possessing high DO, consistent with algal production. Lower levels of DO were found within and downstream of the outfall channel (Sites E-U3 and E-M2). In contrast, water entering the Estuary via the lower Santa Clara River (Site R-1) was cooler, had slightly higher conductivity and was much clearer than water in the Estuary (Table 3-7). DO levels at this site were also high, potentially due to photosynthesis within the benthic algal mats established at groundwater upwelling locations. There was no detectable density stratification in the outfall channel (Figure 3-3).

*In situ* water quality observations following two estuary breaching events in fall 2009 showed the Estuary to have substantially higher conductivity, lower temperature, lower DO concentration, and lower turbidity than during the summer survey (Table 3-7). No longitudinal gradient was apparent among the sample locations within the estuary, consistent with wind mixing, and diel fluctuations in DO were likely smaller than observed during summer. At the locations nearest the outfall channel (Sites E-U3 and E-M1), the DO was low, especially along the bottom. Larger differences in temperature and conductivity between the surface and bottom within the outfall channel indicate density stratification with fresh water from the VWRF outfall overlying the higher salinity ocean water (Figures 3-4 and 3-5). Although the lower Santa Clara River (Site R-1) had lower conductivity due to fresh water inputs from upstream, DO levels were higher, consistent with benthic algal photosynthesis within the mats observed during the summer 2009 surveys.

### 3.5.2 Analytical chemistry parameters

The results of the analytical chemistry sampling in the lower Santa Clara River, the Estuary, and the adjacent groundwater wells during summer and fall 2009 are presented in Tables 3-8. Levels of nutrients ($NH_3$, $NO_3$+$NO_2$, TKN, $PO_4$, TP) were uniform throughout the estuary, with increased levels found at the outfall channel (Sites E-U3 and E-M2). An inverse relationship between nutrients and phytoplankton production is apparent in that chlorophyll-*a* concentrations were extremely high in the Estuary but very low in the outfall channel. For example TKN levels and chlorophyll-*a* were generally low in the outfall channel sites and higher in the greater estuary, whereas $NO_3$+$NO_2$ and $PO_4$ were generally higher in the outfall channel sites, and lower in the greater Estuary. The results from the lower Santa Clara River (Site R-1) show lower chlorophyll-*a* concentration and a low level of nutrients, except for $NO_3$+$NO_2$, which has a concentration similar to that of the main Estuary sample locations. However, high DO at this location (Table 3-7) suggests algal photosynthesis from benthic algae observed at the sampling location.

During the fall, nutrient levels in the Estuary were generally higher than found in summer, whereas chlorophyll-*a* levels were generally lower than in summer (Table 3-8). For example, $NO_3$+$NO_2$ levels were higher in both the Estuary and the outfall channel than in the summer, ammonia and the phosphorous species exhibited increases at the Estuary locations but decreases at the sample sites nearest the outfall channel, and total Kjeldahl nitrogen generally decreased between the summer and fall. Fall nutrient concentrations in the lower Santa Clara River (Site R-1) were all below the MRL, except for $NO_3$+$NO_2$ which was slightly higher in fall as compared with summer, but was significantly less than fall concentrations observed in the Estuary. Chlorophyll-*a* concentrations were very low throughout the Estuary as well as in the lower Santa Clara River. In the groundwater wells adjacent to McGrath State Beach, $NO_3$+$NO_2$ concentrations were above the MRL at only the southernmost site, GW-3.

**Table 3-7.** *In-situ* water quality parameters from summer and fall 2009.

| Site code | Site description | Depth (ft) | Temperature °C | | Specific conductivity µs/cm | | pH s.u. | | DO mg/L | | DO % | | Turbidity NTU | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ***Summer*** | ***Fall*** | ***Summer*** | ***Fall*** | ***Summer*** | ***Fall*** | ***Summer*** | ***Fall*** | ***Summer*** | ***Fall*** | ***Summer*** | ***Fall*** |
| **Lower Santa Clara River** | | | | | | | | | | | | | | |
| R-1 | Upstream of Harbor Blvd. Bridge | 0.5 | 20.3 | 16.3 | 3,210 | 3,140 | 8.3 | 7.5 | 11.4 | 13.3 | 127 | 137 | 0.9 | 3.9 |
| **Santa Clara River Estuary** | | | | | | | | | | | | | | |
| E-U1 | Upper Estuary main channel (d/s of Harbor Blvd. Bridge) | 0.5 | 25.0 | 16.3 | 2,550 | 9,440 | 9.7 | 8.5 | 21.2 | 7.8 | 259 | 81 | 21.4 | 14.8 |
| | | Bottom[a] | 23.3 | 15.8 | 2,650 | 9,740 | 9.3 | 8.5 | 20.4 | 7.1 | 241 | 74 | - | - |
| E-U2 | Upper Estuary high-flow channel | 0.5 | 25.4 | 15.3 | 2,540 | 9,440 | 9.7 | 8.6 | 20.9 | 9.2 | 257 | 95 | 22.3 | 15.8 |
| | | Bottom[a] | 25.1 | 14.6 | 2,540 | 9,600 | 9.7 | 8.6 | 21.0 | 9.1 | 258 | 94 | - | - |
| E-U3 | Upper Estuary d/s of VWRF Outfall | 0.5 | 24.5 | 18.4 | 2,280 | 2,990 | 7.8 | 7.6 | 5.1 | 7.9 | 61 | 84 | 5.0 | 6.6 |
| | | Bottom[a] | 21.2 | 17.1 | 2,430 | 17,580 | 7.6 | 8.4 | 4.5 | 2.1 | 51 | 18 | - | - |
| E-M1 | Middle Estuary main channel | 0.5 | 24.7 | 16.3 | 2,540 | 9,710 | 9.6 | 8.5 | 21.1 | 7.0 | 257 | 73 | 22.1 | 20.5 |
| | | Bottom[a] | 24.0 | 16.3 | 2,540 | 9,720 | 9.6 | 8.5 | 20.4 | 6.9 | 245 | 74 | - | - |
| E-M2 | Middle Estuary d/s of VWRF Outfall | 0.5 | 23.2 | 18.1 | 2,400 | 6,000 | 8.2 | 7.9 | 6.8 | 6.4 | 81 | 69 | 3.8 | 5.3 |
| | | Bottom[a] | 21.5 | 16.0 | 2,480 | 11,280 | 7.9 | 8.5 | 5.3 | 4.7 | 67 | 50 | - | - |
| E-L1 | Lower Estuary main channel | 0.5 | 24.0 | 16.2 | 2,540 | 9,970 | 9.5 | 8.6 | 18.1 | 7.7 | 216 | 81 | 18.3 | 15.1 |
| | | Bottom[a] | 23.1 | 16.3 | 2,540 | 10,070 | 9.3 | 8.6 | 12.0 | 7.2 | 141 | 74 | - | - |
| E-L2 | Lower Estuary at mouth | 0.5 | 23.9 | 16.3 | 2,540 | 9,780 | 9.5 | 8.6 | 15.4 | 7.6 | 184 | 82 | 17.5 | 16.5 |
| | | Bottom[a] | 23.1 | 16.3 | 2,550 | 9,790 | 9.3 | 8.6 | 11.9 | 7.9 | 142 | 83 | - | - |
| **Groundwater Wells** | | | | | | | | | | | | | | |
| GW-1 | Floodplain west of McGrath State Beach campgrounds | 5.6[b] | - | - | - | 6,430 | - | - | - | - | - | - | - | - |
| GW-2 | Floodplain southwest of McGrath State Beach campgrounds | 5.1[b] | - | - | - | 3,510 | - | - | - | - | - | - | - | - |
| GW-3 | Floodplain south of McGrath State Beach campgrounds | 8.6[b] | - | - | - | 3,260 | - | - | - | - | - | - | - | - |

[a] The bottom *in-situ* sample was taken at approximately 1 ft above the substrate depth (see Tables 3-5 and 3-6).
[b] Distance between ground elevation and water surface elevation. Sample collected near bottom of well casing.

**Table 3-8.** Analytical water quality parameters from surface grab samples during summer and fall 2009.

| Site code | Site description | Ammonia-N mg/L N | | NO3 + NO2 mg/L N | | Kjeldahl Nitrogen mg/L N | | Phosphorus - Ortho mg/L | | Phosphorus - Total mg/L | | Chlorophyll a µg/L | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Summer* | *Fall* | *Summer* | *Fall* | *Summer* | *Fall* | *Summer* | *Fall* | *Summer* | *Fall* | *Summer* | *Fall* |
| **Lower Santa Clara River** | | | | | | | | | | | | | |
| R-1 | Upstream of Harbor Blvd. Bridge | <0.1 | <0.1 | 3.3 | 5 | 1.1 | <0.1 | <0.02 | <0.02 | 0.05 | <0.02 | 13 | 5 |
| **Santa Clara River Estuary** | | | | | | | | | | | | | |
| E-U1 | Upper Estuary main channel (d/s of Harbor Blvd. Bridge) | 0.1 | 0.3 | 2.7 | 9.3 | 3.5 | 1.7 | 0.2 | 0.8 | 0.7 | 1.0 | 170 | 3 |
| E-U2 | Upper Estuary high-flow channel | <0.1 | 0.4 | 2.9 | 9.7 | 3.1 | 1.1 | 0.2 | 0.8 | 0.5 | 0.8 | 200 | 2 |
| E-U3 | Upper Estuary d/s of VWRF Outfall | 0.9 | 0.2 | 16 | 19 | 2.6 | 1.5 | 3.0 | 2.1 | 3.2 | 2.8 | 8 | 9 |
| E-M1 | Middle Estuary main channel | 0.3 | 0.3 | 3.4 | 11 | 3.3 | 1.9 | 0.4 | 1.1 | 0.6 | 1.4 | 150 | 3 |
| E-M2 | Middle Estuary d/s of VWRF Outfall | 0.7 | 0.4 | 11 | 16 | 1.6 | 1.7 | 2.2 | 2.5 | 2.7 | 2.2 | <2 | 9 |
| E-L1 | Lower Estuary main channel | 0.6 | 0.3 | 3.0 | 11 | 2.8 | 2.2 | 0.3 | 1.1 | 0.7 | 1.3 | 260 | 2 |
| E-L2 | Lower Estuary at mouth | 0.4 | 0.3 | 2.9 | 12 | 3.5 | 2 | 0.3 | 1.2 | 0.8 | 1.1 | 170 | <2 |
| **Groundwater Wells** | | | | | | | | | | | | | |
| GW-1 | Floodplain west of McGrath State Beach campgrounds[a] | - | - | - | <0.5 | - | - | - | - | - | - | - | - |
| GW-2 | Floodplain southwest of McGrath State Beach campgrounds[a] | - | - | - | <0.5 | - | - | - | - | - | - | - | - |
| GW-3 | Floodplain south of McGrath State Beach campgrounds[a] | - | - | - | 2 | - | - | - | - | - | - | - | - |

[a] Groundwater samples were collected using a submersible pump deployed into the well.

## 3.6 Data Assessment

Preliminary analysis of *in situ* and analytical water quality parameters suggest that the Estuary water quality may be affected by sources other than the lower Santa Clara River. In particular, the levels of ammonia, phosphorous, and $NO_3$+$NO_2$ are highest at the sites adjacent to the VWRF outfall channel (E-U3, E-M1). Additionally, the groundwater wells adjacent to the Estuary exhibited low levels of $NO_3$+$NO_2$, indicating that the nutrient inputs from groundwater sources were small during the survey period.

High DO and chlorophyll-*a* levels were observed during the daytime surveys in the Estuary in summer 2009. These observations, combined with a lack of submerged aquatic vegetation, represent levels above the threshold for primary and secondary symptoms of estuarine eutrophication, as defined by Bricker et al. (2003). During the fall survey, observed chlorophyll-*a* and DO levels were below the thresholds indicative of estuarine eutrophication. A more detailed analysis of nutrient mass balance and assessment of nutrient limiting conditions and trophic status will be conducted using data collected in 2010.

## 3.7 Future Work

As described in the Monitoring Plan (Stillwater Sciences 2009), the approach for the Year Two monitoring is to collect additional data to capture both open and closed mouth conditions as well as to examine the influences of tidal exchange. These data will be combined with the Estuary Water Balance (Section 2) to examine the relative contributions from the lower Santa Clara River, the City's discharge, as well as local groundwater, with the overall goal of determining how water quality in the estuary is affected by these sources and to evaluate whether water quality conditions in the estuary represent habitat enhancement or could be improved under different discharge scenarios through a combination of recycling and wetlands treatment.

Scheduled monitoring and data collection tasks outlined in the project Monitoring Plan include the following:

- Continued measurement of *in situ* and analytical water quality during winter, spring, summer, and fall 2010
- Targeted sampling at the recently installed groundwater wells at McGrath State Beach.
- Compilation of other appropriate water quality datasets for comparisons to water quality criteria, trophic status, and assessment of aquatic habitat suitability.

*In situ* and analytical water quality monitoring will continue through November 2010 in accordance with the study design, including the paired open mouth and closed mouth surveys during the winter/spring and summer/fall seasons. Surveys during the open mouth period should provide more information regarding the influence of the lower Santa Clara River, especially during the winter/spring when seasonal run-off may provide a different source of nutrient loads to the Estuary. Continued analysis of water quality data, chlorophyll-*a* levels, and nutrient availability will provide information about the effect of VWRF effluent on the Estuary.

## 3.8 References

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# 4 UPLAND & TIDAL VEGETATION AND HABITAT MAPPING

## 4.1 Goals and Objectives

The overall goal of assessing the biological condition of the Estuary and surrounding habitats is to provide current information to help evaluate the relationship between Estuary stage and the extent of suitable habitat for aquatic and terrestrial focal species.

To meet this goal, the following two study objectives have been developed:

- delineate the type and extent of upland, tidal, and subtidal vegetation under varying Estuary stage and hydrologic conditions (i.e., mouth open, mouth closed, low river flow, high river flow); and
- determine the area of suitable habitat for focal species in the Estuary.

These data will ultimately be combined with additional data collected during concurrent surveys (Sections 2 and 3) and pre-existing information to determine the impact of VWRF discharge upon suitable habitat for aquatic and terrestrial focal species and the influence of potential VWRF discharge scenarios upon water quality, overall habitat area, and habitat quality for birds, fish, flora, and humans.

## 4.2 Existing Information

Recently, there have been several studies and data collection efforts that describe upland and tidal vegetation and focal species abundance and habitat for the Estuary and adjacent areas. These existing studies and data sources for the Estuary and lower Santa Clara River, which were essential for completing this task, are presented in Table 4-1.[2]

Ongoing monitoring efforts, including the annual benthic macroinvertebrate sampling and tidewater goby surveys conducted by the City will be extended through the 2009–2010 monitoring period to address identified data gaps on habitat use under a range of Estuary conditions. Additional bird survey data collected by the Ventura Audubon society will also be integrated with the habitat mapping surveys.

[2] It should be noted that California State Parks 2009 vegetation mapping in McGrath State Beach was not available, as previously anticipated, for Year One of the Upland and Tidal Vegetation and Aquatic Habitat Mapping task.

**Table 4-1.** Existing information on Estuary vegetation and aquatic and terrestrial habitat.

| Existing vegetation and habitat information | Upland and tidal vegetation mapping | Upland and tidal vegetation classification | Subtidal vegetation mapping | Steelhead abundance and location | Tidewater goby abundance and location | Snowy plover and least tern abundance and location |
|---|---|---|---|---|---|---|
| **Studies** | | | | | | |
| ESA 2003 | X | X | X | | | |
| CDFG and CNPS 2006 | | X | | | | |
| Evens and San 2005 | | X | | | | |
| Entrix 2002 | | | | X | X | |
| Entrix 2004 | | | | | X | |
| Kelley 2004 | | | | X | | |
| Kelley 2008 | | | | X | | |
| Klein and Evens 2005 | | X | | | | |
| More 2008 | | | | | | X |
| Nautilus Environmental 2005 | | | | | X | |
| Nautilus Environmental 2009 | | | | | X | |
| B. Orr, unpublished data | | X | | | | |
| Sawyer et al. 2009 | | X | | | | |
| Smith 2008 | | | | | | X |
| Smith 2009 | | | | | | X |
| Stillwater Sciences and URS 2007 | X | X | | | | |
| **Data Sources** | | | | | | |
| Ventura County 2005 digital orthophotography and LiDAR | X | | X | | | |
| USDA 2009 digital orthophotography | X | | X | | | |
| Ventura Audubon Society nesting data | | | | | | X |

## 4.3 Study Area

The Study Area for the upland and tidal vegetation and aquatic habitat mapping is a subset of the area mapped by Stillwater Sciences and URS (2007) (Figure 4-1). Downstream of Harbor Blvd., vegetation was mapped within the 500-yr floodplain (as defined by the Federal Emergency Management Agency [FEMA]) including the vegetated area through which the VWRF outfall channel flows and McGrath State Beach. Upstream of Harbor Blvd., vegetation was mapped within the 'active' Santa Clara River channel between adjacent floodplain levees. The upstream boundary of the mapping extent was defined by the 2009 extent of inundation during closed-mouth, low-flow conditions (as defined by daily observations by the City) in combination with the upstream extent of the City's benthic macroinvertebrate sampling program.

Aquatic habitat was mapped in the open water area of the Estuary extending from the point where the lower Santa Clara River enters the Estuary, downstream to the mouth. The upstream boundary of the aquatic mapping area is defined by the location of the estuary/river boundary during summer 2009 (see Figure 2-4).

## 4.4 Methods

Field based mapping is being used to delineate the upland, tidal, subtidal, and wetland vegetation alliances, updating detailed vegetation mapping by Stillwater Sciences and URS (2007) to current (2009) conditions. In addition, data collected during concurrent surveys (Hydrology and Morphology Survey and Water Quality and Nutrient Survey), and additional targeted surveys is being to determine the quantity of suitable habitat within the Estuary for California least tern (*Sterna antillerum browni*), western snowy plover (*Charadrius alexandrinus nivosus*), steelhead (*Oncorhynchus mykiss*), and tidewater goby (*Eucycloglobius newberryi*) over a range of Estuary conditions (open mouth, closed mouth, low river flow, high river flow) from summer 2009 (late August) through fall 2010 (October or November).

### 4.4.1 Data collection

#### 4.4.1.1 Existing information review and preliminary mapping

Existing information was gathered and reviewed to generate an initial list of the upland and tidal vegetation alliances and habitat types that occur in the Study Area. Stillwater Sciences and URS (2007) captured summer 2005 conditions in the Estuary (after the high-flow events of January and February 2005). Their map served as the preliminary field base map for tidal wetland and upland areas; however, mudflat and channel areas—referred to as subtidal areas—in the Estuary were not mapped by Stillwater Sciences and URS (2007).

This base map of the Estuary was used to stratify the Study Area and identify preliminary vegetation sampling sites. Preliminary sample sites were selected to increase the likelihood that every previously mapped vegetation type in the Study Area was sampled at least once (although this would ultimately be dependent on the ability of field crews to access each vegetation type), and ideally to sample each vegetation type in proportion to its relative abundance in the Study Area.

Focal species habitat was described according to key vegetative, physical, and water quality (e.g., water temperature, salinity, and DO for aquatic focal species) characteristics identified from detailed reviews of peer-reviewed literature, previous reports, and other relevant information.

#### 4.4.1.2 Field-based mapping

From 1 to 3 September 2009, the entire accessible portion of the Study Area was traversed by foot and/or boat by two plant ecologists, in an attempt to visit as many vegetation sample sites as possible. Sample sites were surveyed using the CNPS rapid assessment protocol (CNPS Vegetation Committee 2004). At each sample site, the occurrence and percent cover of dominant and characteristic plant species in three height strata—low (<0.5 m [1.6 ft]), medium (0.4–5 m

[1.3–16 ft]), and high (>5 m [16 ft])—were recorded. Per the CNPS rapid assessment protocol, additional information on site history and physical conditions, as well as sample site location (using a Geographic Positioning System [GPS]), were also recorded. Each sample site was assigned a preliminary vegetation alliance determination, based on a cursory review of the species occurrence and percent cover data in the field, which was ultimately finalized in the office (see Section 4.4). The boundaries of each preliminary vegetation alliance were delineated on the field base map (because this was such a localized effort, a minimum map unit standard was not used).

In areas where sample points were not taken, the vegetation types previously mapped by Stillwater Sciences and URS (2007) were ground-truthed where possible; the previous vegetation type was confirmed or revised, and vegetation type boundaries were confirmed or modified on the base map as necessary to more accurately reflect current conditions. A quality assurance/quality control (QA/QC) check for completeness and errors was performed on all field data, including data forms and mapping unit boundaries, shortly after collection and before leaving the field.

Because of the limited existing information on subtidal habitat within the Estuary, subtidal habitat was assessed in the field in August and November 2009 as a preliminary mapping effort. A field crew followed the open-water edge of the Estuary by boat and measured key physical (substrate, water depth, and velocity) and water quality parameters (salinity, DO, and temperature) at various locations along the margin and throughout the Estuary. Although the Estuary contained a large amount of inundated vegetation due to the high water levels during the field visits, access issues prevented accurate quantification of this type of aquatic habitat in the field.

### 4.4.2 Data analysis

The completed CNPS rapid assessment data forms were entered into a Microsoft® Access database shortly after returning from the field to store, organize, and analyze the vegetation sampling data. All entered data were checked for errors and corrected as necessary. The database was queried to derive the full list of preliminary vegetation alliances mapped in the field and the vegetation composition data associated with each alliance. Using the vegetation composition data, each preliminary vegetation alliance was keyed using the second edition of *A Manual of California Vegetation* (Sawyer et al. 2009) to determine final vegetation alliances. The database was then updated with these final vegetation alliance names.

The field mapping was integrated into GIS by scanning the field maps at 600 dpi resolution, digitizing the field-delineated mapping boundaries, and entering GPS point data for vegetation, sample points. Although 2005 aerial photography was used as the basis of the field mapping, all mapping boundaries and GPS points were geo-referenced to recently acquired USDA-FSA (2009) orthophotography. Digitized mapping boundaries were checked for accuracy by the field plant ecologists and corrected as necessary. The Stillwater Sciences and URS (2007) designated vegetation type was retained for all mapping units not directly surveyed or observed during the field mapping, and photo-interpretation of the 2009 orthophotography was used to adjust the boundaries of these mapping units to 2009 conditions. Finally, each mapping unit was designated with a final vegetation alliance name or land cover type (e.g., developed) in GIS. (This map development effort will be repeated in Year Two for the subtidal sampling effort and any areas below the most recent peak in Estuary water levels that are remapped.)

The Access database and GIS were linked using the final vegetation alliance names and sample site GPS data. Both databases were used to calculate the extent of each vegetation alliance mapped during the 2009 survey effort, and to compare vegetation composition and extent with conditions in 2006.

## 4.5 Results

### 4.5.1 Year One upland and tidal vegetation mapping

A total of 28 vegetation sample sites were surveyed and the entire 866-acre Study Area was mapped, either in the field or through photo-interpretation. The Study Area includes 498 acres of upland and tidal vegetation. The remaining area is composed of disturbed and/or developed lands associated with the McGrath State Beach campground and related facilities and access roads (145 acres), open water (127 acres), open beach (87 acres), and unidentified aquatic vegetation in McGrath Lake (10 acres). The Year One upland and tidal vegetation map is presented in Figures 4-2a, b, and c and summarized in Table 4-2. Appendix A provides additional details on individual mapping units in Figures 4-2a, b, and c, including whether it was mapped in the field or through photo-interpretation.

**Table 4-2.** Year One upland and tidal vegetation mapping units.

| Map unit | Classification level | Vegetation form | Acres |
|---|---|---|---|
| *Abronia* spp. - *Ambrosia chamissonis* | Alliance | Herbaceous | 120.7 |
| *Ambrosia psilostachya* | Provisional Alliance | Herbaceous | 2.1 |
| Aquatic vegetation | Map unit | n/a | 10.3 |
| *Argentina egedii* | Alliance | Herbaceous | 1.3 |
| *Arundo donax* | Semi-Natural Stands | Herbaceous | 16.4 |
| *Baccharis pilularis* | Alliance | Shrubland | 8.6 |
| *Baccharis salicifolia* | Alliance | Shrubland | 23.7 |
| *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | 51.3 |
| Developed | Map unit | n/a | 65.5 |
| *Distichlis spicata* | Alliance | Herbaceous | 1.9 |
| Disturbed | Map unit | n/a | 79.1 |
| *Leymus triticoides* | Alliance | Herbaceous | 1.5 |
| *Myoporum laetum* | Semi-Natural Stands | Shrubland | 2.7 |
| Non-native grasses and forbs | Provisional Alliance | Herbaceous | 7.1 |
| Open beach | Map unit | n/a | 86.9 |
| Open water | Map unit | n/a | 126.7 |
| *Persicaria hydropiperoides–Melilotus alba* | Provisional Alliance | Herbaceous | 1.0 |
| *Salix lasiolepis* | Alliance | Shrubland | 32.0 |
| | | Woodland | 150.9 |
| *Salix lucida* | Alliance | Woodland | 16.0 |
| *Schoenoplectus californicus* | Alliance | Herbaceous | 58.2 |
| *Typha domingensis* | Alliance | Herbaceous | 1.3 |
| *Urtica dioica* | Provisional Alliance | Herbaceous | 1.1 |
| **Total** | | | **866.3** |

Overall, the composition and extent of upland and tidal vegetation mapped during Year One is very similar to or the same as that mapped by Stillwater Sciences and URS (2007). In a few instances, alliance names were changed from those in 2006 to conform to recent changes in plant species nomenclature (e.g., *Potentilla anserina* to *Argentina egedii*, and *Scirpus* spp. to *Schoenoplectus californicus*) and the vegetation alliance and association names in the recently published second edition of *A Manual of California Vegetation* (Sawyer et al. 2009) (e.g., Mixed Willow Forest to *Salix lucida* Woodland). In other instances, the composition of vegetation mapping units did not change between 2006 and 2009, but the boundaries of the mapping units were modified slightly based on the field mapping or photo-interpretation of the USDA (2009) orthophotography.

The primary, substantive changes in vegetation composition or distribution between 2006 and 2009 occurred on the lower floodplain of the Santa Clara River, upstream of the Harbor Blvd. Bridge. In this area, we documented a general shift in vegetation successional stage, reflecting the recovery of riparian vegetation from the 2005 flood. The vast majority of this area was mapped as Riverwash Herbaceous Super-Alliance in 2006, defined by Stillwater Sciences and URS (2007) as:

> The majority of the area mapped under this super-alliance was bare riverwash following the large floods in January and February 2005. At the time of the field surveys in summer 2005 and 2006, these areas were typically dominated by white sweetclover (*Melilotus alba*), generally ranging from 10–35% cover. In many areas, seedlings of willows (*Salix exigua, S. laevigata, S. lucida* ssp. *lasiandra,* and *S. lasiolepis*) and mulefat (*Baccharis salicifolia*), and occasionally Fremont cottonwood (*Populus fremontii*), were common (at up to 10% cover). In addition, low levels of giant reed (*Arundo donax*) were often present (at up to 10% cover). This suggests that the dominance of these stands by herbaceous vegetation is likely to be short-lived, with transformation into willow-dominated or *Arundo*-dominated stands likely occurring within a few years unless another large flood scours out the established vegetation and resets these areas.

This predicted transformation was demonstrated in the Year One upland and tidal vegetation mapping: floodplain areas previously mapped as Riverwash Herbaceous Super-Alliance have transitioned to shrub-dominated *Salix lasiolepis* and *Baccharis salicifolia* alliances (Figure 4-2b).

In their description of the Riverwash Herbaceous Super-Alliance, Stillwater Sciences and URS (2007) noted that:

> Many stands have wetter margins near the summer low flow channel that support a greater diversity of herbaceous species more common in the Floodplain Wetland Super-Alliance, including barnyard grass (*Echinochloa crus-galli)*, sprangletop (*Leptochloa uninervia*), knotweed (*Polygonum* spp. [now *Persicaria* spp.]), annual rabbitsfoot grass (*Polypogon monspeliensis*), watercress (*Rorippa nasturtium-aquaticum* [now *Nasturtium officinale*]), and water speedwell (*Veronica anagallis-aquatica*).

This same high-diversity herbaceous vegetation along the low-flow channel margin was also observed in 2009, but separated into discrete mapping units such as the *Schoenoplectus californicus*, *Typha domingensis*, and *Persicaria hydropiperoides-Melilotus alba* herbaceous alliances (Figure 4-2b).

### 4.5.2 Year One upland and tidal vegetation alliance descriptions

Sixteen different vegetation alliances, semi-natural stands, or provisional alliances or association (i.e., those alliances or associations which have not been sampled or described sufficiently to determine if they meet the formal requirements for classification as an accepted vegetation alliance or association), were mapped in the Study Area. These vegetation alliances and semi-natural stand types are summarized in Table 4-2 above and described in terms of distribution and composition in the sections below (mapping units other than vegetation alliances and semi-natural stand types, such as open water and developed, that appear in the vegetation map [Figures 4-2a, b, and c] are not described). A list of all species observed during the Year One Upland and Tidal Vegetation Mapping effort is provided in Appendix B.

***Abronia* spp.-*Ambrosia chamissonis* Alliance**

This alliance typically has a sparse to moderate cover of perennial forbs in the ground layer, and may occur with grasses and occasional emergent shrubs. It occurs in sandy coastal foredune areas. In our mapping area, the common species are red sand-verbena (*Abronia maritima*), beach bursage (*Ambrosia chamissonis*), and beach evening primrose (*Camissonia cheiranthifolia* ssp. *suffruticosa*), as well as pink sand-verbena (*Abronia umbellata*), seacliff buckwheat (*Eriogonum parvifolium*), European searocket (*Cakile maritima*), and lotus (*Lotus junceus*). Non-native iceplants (*Carpobrotus* spp.) are also common species, and can range from low to relatively high percent cover. This alliance most closely corresponds with *A Manual of California Vegetation*'s *Abronia latifolia-Ambrosia chamissonis* Herbaceous Alliance (Sawyer et al. 2009). It was previously described in the Study Area by ESA (2003) (as Sand verbena-beach bursage series) and Stillwater Sciences and URS (2007).

The *Abronia* spp.–*Ambrosia chamissonis* Alliance is found along the coastal strand on both sides of the mouth of the Santa Clara River (Figures 4-2a and c).

***Ambrosia psilostachya* Provisional Alliance**

This provisional alliance has dense (100%) vegetative cover, with western ragweed (*Ambrosia psilostachya*) (60% cover) and western goldentop (*Euthamia occidentalis*) (25% cover) as co-dominants. California bulrush (*Schoenoplectus californicus*) and curly dock (*Rumex crispus*) occur at lower densities (5–10% cover). This alliance corresponds somewhat to *A Manual of California Vegetation*'s *Ambrosia psilostachya* Provisional Herbaceous Alliance (Sawyer et al. 2009). It was previously described in the Study Area by Stillwater Sciences and URS (2007). Further study is required to determine if this is a valid alliance (or association), or if it would better fit under some other herbaceous alliance.

The *Ambrosia psilostachya* Provisional Alliance is found on the sloped banks along the perimeter of two the VWRF Ponds (Figure 4-2a).

***Argentina egedii* Alliance**

This alliance is a dense herbaceous vegetation type, primarily composed of pacific silverweed (*Argentina egedii*) (20% cover), swamp smartweed (*Persicaria hydropiperoides*) (15% cover), and pickleweed (*Sarcocornia pacifica*) (10% cover). Curly dock (*Rumex crispus*), alkali bulrush (*Bolboschoenus maritimus*), marsh jaumea (*Jaumea carnosa*), and saltgrass (*Distichlis spicata*) may all be present, but are sparse (<1% cover). This alliance corresponds with *A Manual of California Vegetation*'s *Argentina egedii* Herbaceous Alliance (Sawyer et al. 2009). It was previously described in the Study Area by ESA (2003) (as Silverweed series) and Stillwater Sciences and URS (2007) (using the dominant species' old scientific name, *Potentilla anserina)*.

One stand of the *Argentina egedii* Alliance occurs in estuarine wetland habitat immediately north of the McGrath State Beach campground (Figure 4-2a).

#### *Arundo donax* Semi-Natural Stands

The *Arundo donax* Semi-Natural Stands includes areas where giant reed (*Arundo donax)* dominates (generally >50% relative cover, and often >50% total cover). Stands of this map unit type usually have a dense, continuous herbaceous layer, typically 2–5 m (7–16 ft) tall. Woody shrubs when present are interspersed or present in smaller inclusions within the stand, but never at cover levels sufficient to be co-dominant with giant reed. Trees may occur as emergents (<10% cover), including primarily cottonwoods and willows. Although giant reed is herbaceous, it commonly reaches heights of 4–5 m (13–16 ft) along the Santa Clara River (and occasionally extends up to 6 m [20 ft]). Because of its height, dense growth pattern, and general physical structure it commonly dominates the middle stratum (0.5–5 m [1.6–16 ft], also known as the shrub stratum), or co-dominates with woody shrubs. This map unit type corresponds with *A Manual of California Vegetation*'s *Arundo donax* Semi-Natural Herbaceous Stands (Sawyer et al. 2009). It was previously described in the Study Area by ESA (2003) (as Giant Reed series) and Stillwater Sciences and URS (2007).

*Arundo donax* Semi-Natural Stands occur primarily in large patches south of the VWRF Ponds (Figure 4-2a), but giant reed is also a common sub-dominant or component species in many other vegetation alliances (Stillwater Sciences and URS 2007). Giant reed is listed as one of the most widespread invasive plants in California (Cal-IPC 2007). Its great extent in the Santa Clara River watershed, rate of spread, and impacts to the ecology of riparian areas have made it the focus of eradication efforts throughout the watershed.

#### *Baccharis pilularis* Alliance

This alliance has a moderate cover of shrubs (30–50% cover), dominated by coyote brush (*Baccharis pilularis*) (5–50% cover), with a generally sparse herbaceous understory (0–19% cover). Mulefat (*Baccharis salicifolia*) and giant reed may also be present and can sometimes co-dominate (0–20% cover). This alliance corresponds with *A Manual of California Vegetation*'s *Baccharis pilularis* Shrubland Alliance (Sawyer et al. 2009) and was previously described in the Study Area by ESA (2003) (as Coyote brush series) and Stillwater Sciences and URS (2007).

The *Baccharis pilularis* Alliance is found in several patches in the southern portion of the Study Area (Figure 4-2c).

#### *Baccharis salicifolia* Alliance

This alliance typically has moderate to dense cover of shrubs (25–70% cover), dominated by mulefat, and low to moderate herbaceous cover (0–45% cover). Trees are only rarely present in the alliance. In addition to mulefat, giant reed is frequently found in the alliance; although with variable cover when present (1–40% cover). Tamarisk (*Tamarix ramosissima*), arrowweed (*Pluchea sericea*), narrowleaf willow (*Salix exigua*) and tree tobacco (*Nicotiana glauca*) are sometimes present in the shrub layer. The following species can be common in the understory: saltgrass, shortpod mustard (*Hirschfeldia incana*), ripgut grass (*Bromus diandrus*), and milkthistle (*Silybum marianum*). This alliance corresponds with *A Manual of California Vegetation*'s *Baccharis salicifolia* Shrubland Alliance (Sawyer et al. 2009) and was previously described in the Study Area by Stillwater Sciences and URS (2007).

Two bands of the *Baccharis salicifolia* Alliance are found in the Study Area, upstream of the Harbor Blvd. Bridge, on the exposed floodplain immediately adjacent to the Santa Clara River channel (Figure 4-2b).

#### *Carpobrotus* spp. Semi-Natural Stands

This semi-natural herbaceous stand type contains one or more of three low-growing (generally <0.5 m [1.6 ft]), succulent iceplant species: *Carpobrotus edulis*, *C. chilensis*, and *Mesembryanthemum crystallinum*. Other species found in this map unit type include pink sand-verbena, beach bursage, seacliff buckwheat, common sand aster (*Corethrogyne filaginifolia* var. *filaginifolia*), and Bermudagrass (*Cynodon dactylon*). Coyote brush can occur at low percent cover (10% or less), but trees are generally absent. This map unit type corresponds with *A Manual of California Vegetation*'s *Carpobrotus* spp. Semi-Natural Herbaceous Stands (Sawyer et al. 2009) and was previously described in the Study Area by ESA (2003) (as Iceplant series) and Stillwater Sciences and URS (2007).

Iceplant species are listed as moderate to highly invasive in coastal California habitats, particularly sand dunes (Cal-IPC 2007). *Carpobrotus* spp. Semi-Natural Stands, which generally occur on coastal bluffs and dunes throughout California, are found along the beach and Santa Clara River estuary in and near McGrath State Beach (Figures 4-2a and c).

#### *Distichlis spicata* Alliance

The *Distichlis spicata* Alliance stands in the Study Area have only a dense herbaceous layer (>70% cover). The dominant species is saltgrass, with alkali heath (*Frankenia salina*), Bermudagrass, curly dock, and cocklebur (*Xanthium strumarium*) as common co-occurring species. Mulefat seedlings and saplings can occur but are not common (Stillwater Sciences and URS 2007). This alliance corresponds with *A Manual of California Vegetation*'s *Distichlis spicata* Herbaceous Alliance (Sawyer et al. 2009) and was previously described in the Study Area by ESA (2003) (as Saltgrass series) and Stillwater Sciences and URS (2007).

One patch of the *Distichlis spicata* Alliance occurs in estuarine wetland habitat immediately north of the McGrath State Beach campground (Figure 4-2a).

#### *Leymus triticoides* Alliance

This herbaceous alliance is densely vegetated (>90% cover) with grasses and forbs, although shrubs can occasionally be present (<5% cover). Creeping wildrye (*Leymus triticoides*) is the dominant species, sometimes occurring as a nearly mono-specific stand. In the Study Area, pickleweed and alkali heath also occur at very low cover (<1%), and western ragweed and yerba mansa (*Anemopsis californica*) can be common co-dominant or sub-dominant species elsewhere along the Santa Clara River (Stillwater Sciences and URS 2007). This alliance corresponds with *A Manual of California Vegetation*'s *Leymus triticoides* Herbaceous Alliance (Sawyer et al. 2009) and was previously described in the Study Area by ESA (2003) (as Creeping ryegrass series) and Stillwater Sciences and URS (2007).

Several patches of the *Leymus triticoides* Alliance occurs in estuarine wetland habitat immediately north of the McGrath State Beach campground (Figure 4-2a).

#### *Myoporum laetum* Semi-Natural Stands

This semi-natural stands type is characterized by an overstory canopy dominated by shrubs or small trees (generally 3–10 m [10–33 ft] tall) of myoporum (*Myoporum laetum)*, a woody evergreen species native to New Zealand that has become naturalized in many coastal areas in Southern California. In the Study Area, myoporum stands may have an understory of species found in the *Baccharis pilularis* Alliance and Non-native Grasses and Forbs Provisional Alliance. This map unit type corresponds with *A Manual of California Vegetation*'s *Schinus (molle, terebinthifolius)-Myoporum laetum* Semi-Natural Woodland Stands (Sawyer et al. 2009). It was previously described in the Study Area by ESA (2003) (as Myoporum association) and Stillwater Sciences and URS (2007) (as *Schinus molle-Myoporum laetum*). Further study is required to determine if this is a valid semi-natural stand, or if it would better fit under some other woodland alliance.

Myoporum is rated as a moderately invasive species in riparian areas in southern coastal California (Cal-IPC 2007). This semi-natural stand occurs in several patches north and south of the McGrath State Beach campground (Figure 4-2c). Myoporum also occurs as a co-dominant species in much of the *Salix lasiolepis* Alliance mapped primarily around the VWRF Ponds, and throughout the McGrath State Beach campground in areas mapped as disturbed or developed (Figures 4-2a and c).

#### Non-native Grasses and Forbs Provisional Alliance

The Non-native Grasses and Forbs Provisional Alliance is a mapping unit that includes a number of herbaceous alliances and associations. Many stands are dominated by shortpod mustard or by non-native bromes (*Bromus* spp.). In other sites, these two species are co-dominants. White sweetclover (*Melilotus alba*) and tocolote (*Centaurea melitensis*) are common associated species. Emergent shrubs and trees may be present but at low levels (<10% cover). This alliance most closely corresponds with *A Manual of California Vegetation*'s *Bromus (diandrus, hordeaceus)-Brachypodium distachyon* Semi-Natural Herbaceous Stands (Sawyer et al. 2009). It was previously described in the Study Area by ESA (2003) (as California annual grassland series) and by Stillwater Sciences and URS (2007) (as Non-native Grasses and Forbs Super-alliance). Further study is required to determine if this is a valid alliance (or association), or if it would better fit under some other herbaceous alliance.

Several patches of the Non-native Grasses and Forbs Provisional Alliance occur along Harbor Blvd. in the southern portion of the Study Area (Figure 4-2c).

#### *Persicaria hydropiperoides-Melilotus alba* Provisional Alliance

This provisional alliance has moderate (80%) vegetative cover, with swamp smartweed (*Persicaria hydropiperoides*) (20% cover) and white sweetclover (20% cover) as co-dominants. Watercress (*Nasturtium officinale*), rabbitsfoot grass (*Polypogon monspeliensis*), southern cattail (*Typha domingensis*), and duckweed (*Lemna* spp.) also occur in the herbaceous layer. Giant reed, narrowleaf willow, and arroyo willow (*Salix lasiolepis* var. *lasiolepis*) occur in very low density (1–2% cover) in the shrub layer. This alliance most closely corresponds with *A Manual of California Vegetation*'s *Persicaria lapathifolia-Xanthium strumarium* Provisional Herbaceous Alliance (Sawyer et al. 2009). It has not been previously described in the Study Area, but similar suites of species were included in the Riverwash Herbaceous and Freshwater Wetland Super-Alliances described by Stillwater Sciences and URS (2007). Further study is required to determine if this is a valid alliance (or association), or if it would better fit under some other herbaceous alliance.

One patch of the *Persicaria hydropiperoides- Melilotus alba* Provisional Alliance occurs in the Study Area, just upstream of the Harbor Blvd. Bridge, on the exposed floodplain of the Santa Clara River channel (Figure 4-2b).

#### *Salix lasiolepis* Alliance

The *Salix lasiolepis* Alliance occurs in both shrubland and woodland forms in the Study Area. In its woodland form, vegetation coverage is generally dense in the tree layer (50–100% cover), variable in the shrub layer (5–100% cover), and absent from the herbaceous layer (<5% cover). Arroyo willow is the dominant species in the tree layer and is dominant or co-dominant in the shrub layer. Black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), red willow (*Salix laevigata*), and/or occasionally myoporum trees are also present in the tree layer, but generally at much lower abundance (<30% cover). Giant reed and poison oak (*Toxicodendron diversilobum*) are common co-dominant or sub-dominant components of the shrub layer, with myoporum, red willow, and California blackberry (*Rubus ursinus*) also commonly present.

In its shrubland form, total vegetation coverage is generally dense (80–100%), with variable shrub (40–100% cover) and herbaceous (0–60% cover) layers (a tree layer is typically absent). Arroyo willow is the dominant or co-dominant species in the shrub layer, with red willow, narrowleaf willow, and giant reed as co-dominant or component species. Cattail, smartweed, and cocklebur can occur in the herbaceous layer.

Both forms of the alliance correspond with *A Manual of California Vegetation*'s *Salix lasiolepis* Shrubland Alliance (Sawyer et al. 2009). This alliance was previously described in the Study Area by ESA (2003) (as Arroyo willow series) and by Stillwater Sciences and URS (2007).

The *Salix lasiolepis* Alliance is the most abundant in the Study Area. It is found in bands adjacent to levees along the Santa Clara River, throughout the VWRF Pond area, and in large and small patches around McGrath State Beach campground and McGrath Lake (Figures 4-2a, b, and c).

#### *Salix lucida* Alliance

This alliance can have highly variable tree canopy (0–75% cover) and shrub (0–75% cover) layers, and a sparse understory (<5% cover). Shining willow (*Salix lucida* ssp. *lasiandra*) is the dominant or a co-dominant species (10–75% cover). Other species of willow are common components of the tree and/or shrub layers and giant reed is often present. In wetter sites, cattail or bulrush may occur in the understory. This alliance corresponds with *A Manual of California Vegetation*'s *Salix lucida* Woodland Alliance (Sawyer et al. 2009) and was previously described upstream of the Study Area by Stillwater Sciences and URS (2007).

One large strand of the *Salix lucida* Alliance occurs along the southern bank of the Santa Clara River, upstream of the Harbor Blvd. Bridge (Figure 4-2b).

#### *Schoenoplectus californicus* Alliance

The *Schoenoplectus californicus* Alliance is a densely vegetated alliance dominated by California bulrush (>10% cover). A tree layer is absent and one of the other bulrush species (*S. americanus, S. acutus,* and *Bolboschoenus maritimus*) may also be present to co-dominant. Other associated species may include: curlytop knotweed, dotted smartweed (*Persicaria punctatum*), cattail, and giant reed. This alliance corresponds with *A Manual of California Vegetation*'s *Schoenoplectus acutus* Herbaceous Alliance (Sawyer et al. 2009) and was previously described in the Study Area by ESA (2003) (as Bulrush series) and Stillwater Sciences and URS (2007) (using the dominant species' old scientific name, *Scirpus* spp.).

The *Schoenoplectus californicus* Alliance typically occurs in sites experiencing extended periods of inundation by fresh or brackish water, and in the Study Area is found primarily along the margins of the Estuary and Santa Clara River channel, and in ponded dune swales at McGrath State Beach (Figures 4-2a, b, and c).

#### *Typha domingensis* Alliance

The *Typha domingensis* Alliance is a densely vegetated alliance (95% cover in the Study Area) dominated by southern cattail, with one of the other cattail species general co-dominant. A tree layer is absent and the low (<1.5 m [5 ft]) herbaceous understory is moderate to sparse. Other associated species may include: curlytop smartweed, dotted smartweed, American bulrush, and California bulrush. Willow species may be present at low cover, as well as giant reed. This alliance corresponds with *A Manual of California Vegetation*'s *Typha (angustifolia, domingensis, latifolia)* Herbaceous Alliance (Sawyer et al. 2009). It has not been previously described in the Study Area, but similar suites of species were included in the Freshwater Wetland Super-Alliances described by Stillwater Sciences and URS (2007).

The *Typha domingensis* Alliance typically occurs in sites experiencing extended periods of inundation by fresh water, and in the Study Area is found in two areas along the margins of the Estuary (Figure 4-2a).

#### *Urtica dioca* Provisional Alliance

The *Urtica dioca* Provisional Alliance is dominated by stinging nettle (*U. dioca)* (30%), with western goldentop (20%) and California bulrush (20%) as associated species. Tree and shrub layers are absent and the herbaceous layer is moderate to dense. This alliance has not been previously described in the Study Area. Further study is required to determine if this is a valid alliance (or association), or if it would better fit under some other herbaceous alliance.

One occurrence of the *Urtica dioca* Provisional Alliance is found on the sloped banks along the perimeter of one of the VWRF Ponds (Figure 4-2a).

### 4.5.3 Year One aquatic and subtidal habitat mapping

Figure 4-3 shows the extent of approximately 100 acres of aquatic and subtidal habitat mapped during the September and August 2009 field efforts, and the location of habitat measurements taken in September and November 2009. *In situ* water quality data and physical habitat parameters recorded throughout the Estuary are presented in Appendix C.

Despite the relatively shallow water depths observed at many sites (< 1 to 3 ft), the large amount of fine sediment entering the Estuary has created large expanses of sand and silt substrates and a general lack of submerged and subtidal aquatic vegetation that could be used as in-water cover habitat for aquatic species. An exception to the general lack of vegetative cover exists in the upper portion of the Estuary, where coarse substrates and small amounts (~5% cover) of instream cover (e.g., wood, flooded terrestrial vegetation) were observed. Further, throughout the Estuary and lower Santa Clara River, large stands of emergent marsh and flooded riparian vegetation bordering the open water zones (see Section 4.5.2) do provide overhead cover along the margins for local fish species.

Under the closed-mouth conditions during which both the September and November 2009 surveys occurred, water temperatures were fairly uniform, with large variations in DO on a diel basis (Section 3.5.1). Water velocities were generally low, with some flow being observed at upwelling locations approximately 2,300 ft above the Harbor Blvd. Bridge.

## 4.6 Fish and Avian Community Characterization

The Estuary provides habitat for a variety of fish and avian species. Bird species utilizing the Estuary include herons, egrets, ducks, plovers, stilts, sandpipers, phalaropes, and gulls. Additionally, riparian forest and emergent freshwater marsh habitats at the Ventura Water Reclamation ponds provide habitat for rails, flycatchers, vireos, warblers, and sparrows. Fish species in the Estuary include tidewater goby (*Eucyclogobius newberryi*), steelhead (*Oncorhynchus mykiss*), staghorn sculpin (*Leptocottus armatus*), prickly sculpin (*Cottus asper*), mosquitofish (*Gambusia affinis*), arroyo chub (*Gila orcutti*), stickleback (*Gasterosteus aculaeatus*), common carp (*Cyprinus carpio*), green sunfish (*Lepomis cyanellus*), and fathead minnow (*Pimephales promelas*). This section describes the aquatic and terrestrial focal species for the Estuary Subwatershed study based upon available recent monitoring data from Ventura Audubon Society bird monitoring (More 2008, Smith 2008, 2009) as well as recent fish monitoring (Entrix 2004, Kelley 2008, Nautilus Environmental 2009).

### 4.6.1 Aquatic focal species

The two aquatic focal species for the Estuary Subwatershed Study are steelhead and tidewater goby. Information regarding their habitat requirements and life history are described below. The habitat requirements and life history information is provided only as it pertains to the estuarine environment. For tidewater goby, this includes all life stages; for steelhead, only adult migration and estuarine rearing are discussed.

#### 4.6.1.1 Steelhead

**Status and distribution**

Steelhead occur throughout the North Pacific Ocean and historically spawned in freshwater streams along the west coast of North America from Alaska to northern Baja California. Historically, *O. mykiss* occurred at least as far south as Rio del Presidio in Mexico, although spawning populations of steelhead did not likely occur that far south (NMFS 1997). At present, the southernmost stream used by steelhead for spawning is generally considered to be Malibu Creek, California; however, in years of substantial rainfall, spawning steelhead may be found as far south as the Santa Margarita River, in northern San Diego County (NMFS 1997). The Steelhead population found in the Santa Clara River is federally listed as endangered and is part of the Southern California steelhead Distinct Population Segment (DPS), which extends from the Santa Maria River in San Luis Obispo County to the U.S-Mexico border (NMFS 2006).

Historically (before 1946), steelhead likely spawned and reared in the major tributaries within the lower portion of the Santa Clara River, west of the Piru Creek confluence (Kelley 2004, Harrison 2006). These major tributaries included primarily Sespe and Piru creeks; Santa Paula and Hopper creeks likely provided significant steelhead habitat as well. The present-day distribution of anadromous *O. mykiss* in the Santa Clara River watershed is limited by a number of migration barriers that restrict upstream passage of adult steelhead, both in the lower mainstem river and most major tributaries (Titus et al., in press).

**Threats**

Estuary conditions may have an important influence on anadromous fish survival, since anadromous fish must pass through these areas during upstream and downstream migration and since estuarine rearing prior to ocean entry is a life history strategy used by many juvenile anadromous fish to increase marine survival (Giger 1972, Healey 1991, McMahon and Holtby 1992). Kelley (2008) determined that the potential threats to steelhead smolts in the Estuary are high turbidity, high water temperatures, a lack of cover to avoid predation, and the prevalence of resident avian predators.

**Life history**

The life history patterns of southern California steelhead depend more strongly on rainfall and flow than steelhead populations found farther north (NMFS 1997; Titus et al., in press). In southern California, average rainfall is substantially lower and more variable than in regions to the north, resulting in increased duration of sand berms across the mouths of streams and rivers and, in some cases, complete dewatering of the lower reaches of these streams from late spring through fall (NMFS 1997, Entrix 2002). Steelhead in southern California appear to withstand higher temperatures than populations to the north (NMFS 1997). Although there is limited specific life history information for southern California steelhead, several unique traits have been identified, including increased temperature tolerance, duration and timing of life stages, and environmental flexibility (Stoecker and Kelley 2005, Titus et. al., in press).

Adult steelhead return to spawn in their natal stream, usually in their fourth or fifth year of life (Shapovalov and Taft 1954, Behnke 1992). Access to natal streams is often impaired or blocked because of low flow conditions so Southern steelhead time their upstream migration to follow sizable rainfall events in the fall (Stoecker 2002). A unique adaptation of southern steelhead is the ability to delay the upstream migration until adequate flows exist, or by straying to another accessible and suitable stream in a nearby watershed (Stoecker 2002).

Juvenile steelhead (parr) rear in freshwater before outmigrating to the ocean as smolts. Juvenile southern steelhead have extremely variable residence time due to the highly unpredictable and often stochastic environmental conditions that exist in watersheds in southern California (Stoecker and Kelley 2005). Some juvenile steelhead may never migrate, remaining in freshwater as coastal rainbow trout for their entire life cycle (Stoecker and Kelley 2005).

At the end of the freshwater rearing period, juvenile steelhead migrate downstream to the ocean as smolts. Evidence suggests that photoperiod is the most important environmental variable stimulating the physiological transformation from parr to smolt (Wagner 1974). Southern steelhead smolts may spend a considerable amount of time in lagoons and estuaries in order to acclimate to saltwater before outmigrating (Stoecker 2002). These lagoons and estuaries also provide a holding area where smolts can feed while waiting for adequate flow conditions to open the streams and lagoons to the ocean (sandbars build up and seal off many confluences in low flow conditions) (Stoecker 2002).

Estuarine rearing may be more important to steelhead populations in the southern half of the species' range due to greater variability in ocean conditions and lack of high quality near-shore habitats in this portion of their range (NMFS 1996). Estuaries may also be more important to populations spawning in smaller coastal tributaries due to the more limited availability of rearing habitat in the headwaters of smaller stream systems (McEwan and Jackson 1996). Most marine mortality of steelhead occurs soon after they enter the ocean and predation is believed to be the primary cause of this mortality (Pearcy 1992, as cited in McEwan and Jackson 1996). Because predation mortality and fish size are likely to be inversely related (Pearcy 1992, as cited in McEwan and Jackson 1996), the growth that takes place in estuaries may be very important for increasing the odds of marine survival (Pearcy 1992 [as cited in McEwan and Jackson 1996], Simenstad et al. 1982 [as cited in NMFS 1996a], Shapovalov and Taft 1954).

**Habitat Needs within the Santa Clara River Estuary**

Adult migratory steelhead need water with a minimum depth of 0.6 ft (18 cm) for successful upstream migration with velocities below 8 ft/s (240 cm/s) (Thompson 1972, as cited in Everest et al. 1985). Relatively cool water temperatures (between 50 and 59°F [$10^{o}$ and 15°C]) are preferred by adults, although they may survive temperatures as high as 80.6°F (27°C) for short periods (Moyle et al. 1989).

Although spawning, egg incubation, and early juvenile rearing life stages occur in Santa Clara River tributary habitats well upstream of the estuary, steelhead juveniles may spend a considerable amount of time in lagoons and estuaries in order to acclimate to saltwater before outmigrating as smolts (Stoecker 2002). Although optimal temperature for steelhead growth has been reported at a range of 15–19°C (59–66.2°F) (Myrick and Cech 2005), the highest growth rates of juvenile steelhead were observed at temperatures between 15–24°C (59–75.2°F) in the Scott Creek estuary along the central California coast (Hayes et al. 2008). Dissolved oxygen concentrations near saturation are generally required for steelhead growth, but they can survive with oxygen concentrations as low as 1.5–2.0 mg/L (Moyle 2002).

There has been limited research documenting habitat use of the estuary or habitat associations of steelhead (Kelley 2004, 2008). During periods when sand bars block the river mouths and form fresh or brackish water lagoons, these habitats may be used by smolts while waiting for adequate flow conditions to open the streams and lagoons to the ocean (Stoecker 2002). Although woody debris, overhanging vegetation, man-made objects, and overhanging vegetation provide some degree of cover for juvenile life stages regardless of water level, the major source of cover within the Estuary is due too low water clarity resulting from turbidity and periodic blooms of suspended algae (Kelley 2008).

**Occurrence in and around study area**

Although the Estuary provides potential rearing habitat for steelhead smolts as they continue their migration to the ocean, little is known regarding juvenile steelhead use of the Santa Clara Estuary. Kelley (2008) captured 133 steelhead smolts at the Freeman Diversion Dam operated by United Water District and tagged 81 of them with acoustic and PIT tags prior to release in the estuary in order to determine their survival and ocean movement. Acoustic receivers were placed in the nearshore ocean outside of the Estuary in order to detect fish that reached the ocean. Of the 81 tagged smolts, 48 (59%) were later detected in the ocean (Kelley 2008). No steelhead have been documented in routine seining surveys conducted by the City (Nautilus Environmental 2009).

#### 4.6.1.2 Tidewater goby

**Status and distribution**

Tidewater goby are an estuarine/lagoon adapted species that are endemic to California coast, mainly in small lagoons and near stream mouths in the uppermost brackish portion of larger bays (SCR Project Steering Committee 1996). The population in the Santa Clara River Estuary belong to the Central California Coast ESU and is federally listed as threatened under the Endangered

Species Act (62 FR 43937). Historically this species ranged from the mouth of the Smith River, Del Norte County near the Oregon border to Agua Hedionda Lagoon in northern San Diego County (USFWS 2005). Tidewater gobies have been observed in the Santa Clara River as far as three miles from the estuary/lagoon, between Ventura and Oxnard (SCR Project Steering Committee 1996).

Tidewater gobies often migrate upstream into tributaries, as far as 1.0 km (0.5 mi) from the estuary (SCR Project Steering Committee 1996). However, in the Santa Ynez River, Santa Barbara County, tidewater gobies have been found as far as 5–8 km (3–5 mi) upstream of tidal lagoons areas, sometimes in sections of stream impounded by beavers (*Castor canadensis*) (SCR Project Steering Committee 1996, USFWS 2005).

#### Threats

Gobies are sensitive to impacts such as lack of freshwater due to diversions, pollution, siltation, and invasion of non-native species, such as the western mosquitofish (*Gambusia affinis*), which is a competitor, and the African clawed frog (*Xenopus laevis*), which is a predator (USFWS 2005, Lafferty et. al 1999a). According to the U.S. Fish and Wildlife Service, which has prepared a final recovery plan for the tidewater goby, the key threats to the goby that are relevant to the Santa Clara River watershed include agricultural discharges, sewage treatment effluent, water diversions, and exotic species (USFWS 2005).

#### Life history

Although tidewater goby are short-lived (generally 1 year), they have relatively high fecundity (females produce 300–500 eggs/batch and spawn multiple times per year), with males defending eggs in burrows. Reproduction and spawning typically occurs during the spring and summer (April to June) in slack shallow waters of seasonally disconnected or tidally muted lagoons, estuaries, and sloughs. Males dig burrows vertically into sand, 100–200 mm [4–8 in] and guard eggs (SCR Project Steering Committee 1996). Juveniles and adults can be found year-round, although they are most abundant in summer/fall.

Tidewater goby standard length at hatching is approximately 4–5 mm (0.17–0.25 in), and are planktonic (unable to swim freely) for 1–3 days before they become benthic (USFWS 2005). The average size of tidewater gobies tends to be significantly larger in marshes (43–45 mm [1.7–1.8 in] standard length) when compared to tidewater gobies from lagoons or creek habitats (USFWS 2005, Swenson 1999). This may be because the more stable physical conditions of the marsh foster improved growth or a more consistent or abundant supply of prey (USFWS 2005, Swift et al. 1997).

Flood and breaching events can result in dispersal of tidewater gobies between estuarine/lagoon habitats, although survival is likely low and dispersal is limited. Gobies can persist in habitats that flood as long as a velocity refuge is present (Moyle 2002, Lafferty et al. 1999b). When lagoons are breached due to flood events during the rainy seasons, populations of tidewater gobies generally decrease and then recover during the following summer (USFWS 2005). The life stages that are likely most sensitive to changes in habitat conditions associated with flooding and breaching are eggs in burrows and pelagic larvae (Chamberlain 2006).

#### Habitat needs within the Santa Clara River Estuary

Tidewater gobies inhabit discrete lagoons, estuaries, or stream mouths separated by mostly marine conditions, and are generally absent from areas where the coastline is steep and streams do not form lagoons or estuaries (USFWS 2005). Gobies require stable lagoon or off-channel habitats, particularly during their relatively short larval stage (Lafferty et al. 1999, Chamberlain 2006). Generally, they are found in areas where water temperatures are 4–21.5°C (39.2–70.7°F) water salinity is 12 parts per thousand (ppt) or less, but can tolerate salinities of up to 28 ppt (USFWS 2005). Tidewater gobies spawn regularly in water with salinities 8–15 ppt and temperatures 17–22°C (62–71°F) (USFWS 2005). Tidewater gobies are usually collected in areas with water less than 1 meter (3.3 feet) deep (USFWS 2005). Preferred substrates are sand, mud, gravel, and silt, particularly associated with submerged vegetation that is likely used for cover (USFWS 2005). Tidewater gobies feed mainly on small animals, usually mysid shrimp (*Mysidopsis bahia*), gamarid amphipods (*Gammarus roeseli*), and aquatic insects, particularly chironomid midge (Diptera: *Chironomidae*) larvae (Swift et al. 1989; Swenson 1995; Moyle 2002).

**Occurrence in and around study area**

Tidewater goby represent the most common and widespread fish species in the Estuary and have been observed using all parts of the Estuary, including the main channel area, backwater areas, and the VWRF outfall channel (Entrix 2004). Higher densities within the VWRF outfall channel following high flow events suggests the use of this area as a refuge and allows the population to quickly rebound following breaching events (Entrix 2004). Ongoing tidewater goby surveys during the spring and fall use seine hauls to monitor the population within the Estuary. The most recent surveys have found tidewater gobies to be common and the population is stable, although the populations are higher in the fall following the spawning period (Nautilus Environmental 2009).

### 4.6.2 Avian focal species

The two avian focal species for the Estuary Subwatershed Study are western snowy plover (*Charadrius alexandrinus nivosus*) and California least tern (*Sternula antillarum browni*). Western snowy plover and California least tern populations have been monitored at McGrath State Beach for over 25 years (R. Smith, Ventura Audubon Society, pers. comm, 2010). Ventura Audubon Society has been conducting annual monitoring for these two species in recent years. Information regarding their habitat requirements and life history is described below.

#### 4.6.2.1 Western snowy plover

**Status, distribution, and habitat**

The western snowy plover is a small shorebird closely associated with sandy beaches. Pacific coastal populations of western snowy plover are federally listed as threatened, while interior populations are a state species of special concern. The Pacific Coast breeding population of western snowy plover ranges from Washington to Baja California, Mexico. Nesting takes place on the ground above the high tide line on barren to sparsely-vegetated beaches. In California, breeding habitat primarily includes coastal dune-backed beaches, barrier beaches, and salt-evaporation ponds, and less commonly bluff-backed beaches, dredged material disposal areas, salt ponds, and river bars (Page et al. 2009, USFWS 2007). Wintering habitat includes the same beaches used for nesting, as well as non-nesting beaches and flats. Many inland nesting western snowy plovers migrate west and spend winters along the coast. This species forages on invertebrates found in sand, in organic matter on the beach, or from low-growing plants.

**Threats**

Primary threats to the western snowy plovers include human disturbance (e.g., off-road vehicles, pets, or direct harassment of eggs or chicks), loss of breeding and wintering habitat from development, expanding predator populations, and introduced beachgrass (*Ammophila* spp.) (USFWS 2007).

**Life history**

In California, western snowy plover breeding and nesting begins in March, peaks from mid-April to mid-June, and ends by late September (USFWS 2007). Hatching occurs from early April through mid-August, and chicks take approximately one month to fledge (USFWS 2007). A nest site consists of a shallow scrape or depression created by the male during courtship; the female chooses the scrape in which to lay her eggs (Page et al. 2009). Often the nest scrape is lined with bits of debris such as small pebbles, shell fragments, or plant debris. After either successful hatching or loss of a nest, both sexes may double brood and females may even triple brood (Page *et al*. 2009). There may be some correlation for plover hatching success related to nests occurring within active least tern colonies; least terns may provide protection from certain predators such as American crows (Powell 2001). In addition to disturbance from humans or predators, nesting success may depend on tides or weather.

**Occurrence in and around study area**

McGrath State Beach and the beach northwest of the Estuary provide both nesting and wintering habitat for western snowy plovers. In the winter, numbers of western snowy plover increase because of inland nesting populations migrating to the coast to spend the winter. In the context of the upland habitat mapping effort described above in Section 4.3, western snowy plovers are associated with open beach and *Abronia* spp. - *Ambrosia chamissonis* Alliance.

The Channel Coast District (CCD) began a Western Snowy Plover Protection Program in 2001–2002, whose goal is to increase the amount of suitable habitat on CCD beaches, reduce disturbance to nesting and wintering plovers, prevent the take of nests and chicks, and simultaneously provide recreational and educational opportunities for visitors (More 2008). The CCD supports comprehensive nesting surveys, which involves collection of breeding data as well as winter foraging and roosting data. A permanent fence was installed around McGrath Lake by CCD staff in March 2002 (More 2008). In addition, anti-predator exclosures have been used on a subset of nests at McGrath Beach to protect the nests from predation.

**Recent survey protocol and results**

Recent western snowy plover visual nest surveys have been conducted once or twice weekly by a USFWS 10(a)(1)(A) recovery permit holder, who walked meandering transects throughout the study area in search of nests or sign (More 2008, Smith 2009). Nesting surveys were typically initiated in March and finished after nesting was complete, typically around August. Efforts were made to minimize any disturbance to nests. The survey area for McGrath State Beach included McGrath Lake, "McGrath North" near the campground, and the Estuary bar. General population surveys were conducted the rest of the year.

The number of nests at McGrath State Beach between 2003 and 2009 has ranged between 10 and 23 (Smith 2009). Western snowy plover nesting activity in this area usually peaks in May, though in 2009 the peak was in June followed closely by July (Smith 2009). Over the last 4 years, nest locations have shifted from next to McGrath Lake, to along the outer beach from the lake to opposite the campground (Smith 2009). In 2009, the primary cause of nest failure was human disturbance; people taking, moving, or stepping on eggs, or people vandalizing nest exclosures placed by biologists for protection from predators (Smith 2009). Other documented causes of failed nest sites at McGrath State Beach include: dogs, predators (coyotes, crows, gulls, ravens, red-tailed hawks, northern harriers, great blue herons, American kestrels, merlins, coyotes, ground squirrels, and loggerhead shrikes), and fluctuating water (More 2008, Smith 2009).

#### 4.6.2.2 California least tern

**Status, distribution, habitat**

The California least tern, a small seabird generally associated with lagoons, estuaries, rivers, and the coast, is the smallest of North American terns. It is federally and state listed as endangered, and the only subspecies of least tern found in California. During the summer breeding season California least terns range from the San Francisco Bay area along the Pacific coast to Baja California, Mexico. Nesting habitat is typically sand or gravel beaches above high tide though relatively free of vegetation as a result of scour from periodic high storm tides (Thompson et al. 1997, USFWS 2006). Little is known about winter habitats, though is thought be primarily along marine coasts in Central America (Thelander 1994). Least terns feed in shallow estuaries, lagoons, coastal ponds, or near shore waters where small bait fish, such as anchovies, smelts, or silversides, are abundant. They hover above water and then plunge to feed after spotting fish.

**Threats**

Primary threats to the species include loss of breeding and wintering habitat from development, human-related disturbance (e.g., direct harassment of eggs or chicks, off-road vehicles, pets, or noise), and expanding predator populations (USFWS 2007). Nesting success may also depend on tides or weather.

**Life history**

California least terns nest in loose colonies of around 30–50 pairs, and breeding begins as early as late April or May. They locate their breeding colonies near an abundance of very small fish (Thleander 1994). Nest sites are a bowl-shaped depression in the sand or shell fragments. Eggs hatch after 20–25 days (Thelander 1994), and are fed by both parents. After the first young fledge, there is generally a second wave of nesting. In addition to disturbance from humans or predators, nesting success may depend on tides or weather. Fall migration begins in late July or early August (USFWS 2006).

**Occurrence in and around study area**

Documented primary summer nesting areas for California least terns have included: (1) just north of the Santa Clara River Estuary, (2) west of the campground and inland of the south arm of the Santa Clara River Estuary, (3) the strip of beach west of the south arm of the Santa Clara River Estuary, near the surf zone and (4) near McGrath Lake; though not all areas have been populated each year (Smith 2008, Smith 2009). Many nests occurred on a wide, level, sandy area inland of small (1–3 foot high) dunes on the ocean side (Smith 2008). In the context of the upland habitat mapping effort described above in Section 4.3, California least terns are associated with open beach and *Abronia* spp. - *Ambrosia chamissonis* Alliance. Sparse vegetation provides least tern chicks shelter from the sun and predators (Smith 2008).

**Recent survey protocol and results**

Recent California least tern nest surveys have been conducted once weekly by a USFWS 10(a)(1)(A) recovery permit holder, who walked meandering transects throughout the study area in search of nests or sign (Smith 2008, Smith 2009). California least tern nesting surveys were initiated in spring as early as late April, and completed after nesting was complete, typically around August or September (Smith 2008, Smith 2009). Efforts were made to minimize any disturbance to nests. The survey area for McGrath State Beach included McGrath Lake, “McGrath North” near the campground, and the Estuary bar.

The number of nests at McGrath State Beach between 2000 and 2009 has ranged between 3 and 97, with a general upward trend in the number of nests, especially in recent years (Smith 2008, Smith 2009). In this area, California least tern nesting activity usually peaks between June and July (Smith 2008, Smith 2009). Documented causes of failed tern nest sites at McGrath State Beach include human disturbance, abandonment, and predation by coyotes, opossums, American crows, and possibly ground squirrels (Smith 2008). Efforts to protect least tern nesting have been ongoing for over 20 years by the Ventura Audubon Society (Smith 2008). Various types of protective fencing have been placed in the spring and removed in the fall particularly to discourage disturbance by humans or their dogs.

## 4.7 Data Assessment

The methods used for Year One of the Tidal and Upland Vegetation and Aquatic Habitat Mapping effort are based upon established vegetation sampling, photo-interpretation, classification, and mapping protocols. This has facilitated the comparison of Year One data with previous mapping efforts in and around the Estuary (e.g., ESA 2003, Stillwater Sciences and URS 2007). Year Two data will be collected using the same methods to further enable between-year comparisons of vegetation and habitat conditions.

Access to a small portion of the Study Area was not feasible because it required traversing private property or was unsafe. This lack of access to all portions of the Study Area does not undermine the quality of the vegetation mapping, since vegetation mapping protocols assume some level of photo-interpretation, but it did limit the number of sample points that could be surveyed in individual mapping units.

Lastly, although no direct sampling for tidewater gobies or Southern California steelhead was planned for this study, aquatic habitat mapping identified very little variation in the availability of cover for fish species or variations in substrates necessary to support a variety of other aquatic species.

## 4.8 Future Work

### 4.8.1 Vegetation mapping

A streamlined, follow-up vegetation mapping effort will occur in 2010 when the river mouth is open (most likely fall or winter 2010) to document subtidal vegetation and any tidal wetland or upland areas inundated during the 2009 surveys, and to document any changes in tidal and upland vegetation and habitats associated with high flows that may occur during winter 2010.

Field efforts to continue mapping the subtidal habitat will continue through 2010. The subtidal and aquatic mapping data were used to measure the open-water area and make a preliminary assessment of the location and quality of habitat within the Estuary for each focal species (e.g., steelhead and tidewater goby). The maps developed from the initial field visits will be used to quantify the general extent of aquatic and subtidal habitat. Further map updates will be made following surveys under varying Estuary conditions. Changes to suitable habitat area as a result of lagoon bar breaching and buildup will be documented through fall 2010, taking place over four efforts consisting of two open-mouth surveys and two-closed mouth surveys. Fluctuations in the area of suitable habitat related to changes in environmental conditions will be quantified and evaluated to identify relationships between focal species habitat, water quality, hydrology, and Estuary mouth closure status.

### 4.8.2 Aquatic habitat mapping

Recommended modifications to the sampling plan for 2010 include the elimination of SAV collection at the sample sites due to absence at all locations, and relocating the Lower Estuary at Mouth site (E-L2) to a point further south to better represent the current configuration of the Estuary (Figure 3-1).

In order to better understand the distribution and quality of aquatic habitat, a detailed bed sediment facies map should be compiled when the Estuary is empty. A facies map delineates areas of distinct bed sediment size distribution, which when combined with other parameters can better define the zones of suitable habitat for focal aquatic species.

### 4.8.3 Bird surveys

Spring and summer nesting surveys for the two focal bird species, western snowy plover and California least tern, will continue to be conducted annually by the Ventura Audubon Society according to established protocols. In addition, a comprehensive quarterly avian monitoring study effort will be conducted for all habitats in and around the Estuary, including open water, coastal dune, emergent freshwater marsh, and riparian forest. In total, four comprehensive seasonal bird surveys are planned for 2010, including:

- early spring surveys to monitor migrating, resident, and nesting species;
- summer surveys to monitor resident and nesting species;
- fall surveys to monitor migrating and resident species; and
- winter surveys to monitor wintering and resident species.

The study area for all surveys would include Ventura Wastewater Reclamation ponds and the Santa Clara River Estuary upstream to Harbor Blvd. bridge and south to McGrath State Beach (Figure 1-1). Objectives of avian monitoring are to provide species composition, abundance, distribution, nesting, and habitat use data under current estuary conditions. Surveys will be conducted on foot, and will combine visual and bird song identification protocols, as necessary. Summer nesting season protocols would be similar to those used by the Ventura Audubon Society for focal species, as described in Section 4.4.2, though broadened to include habitats occurring in the study area other than coastal dunes.

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# Figures


**Figure 1-1. Location of Study Area, Santa Clara River Estuary near Ventura, CA.**


**Figure 2-1. Location of Estuary stage recorders and groundwater monitoring wells.**

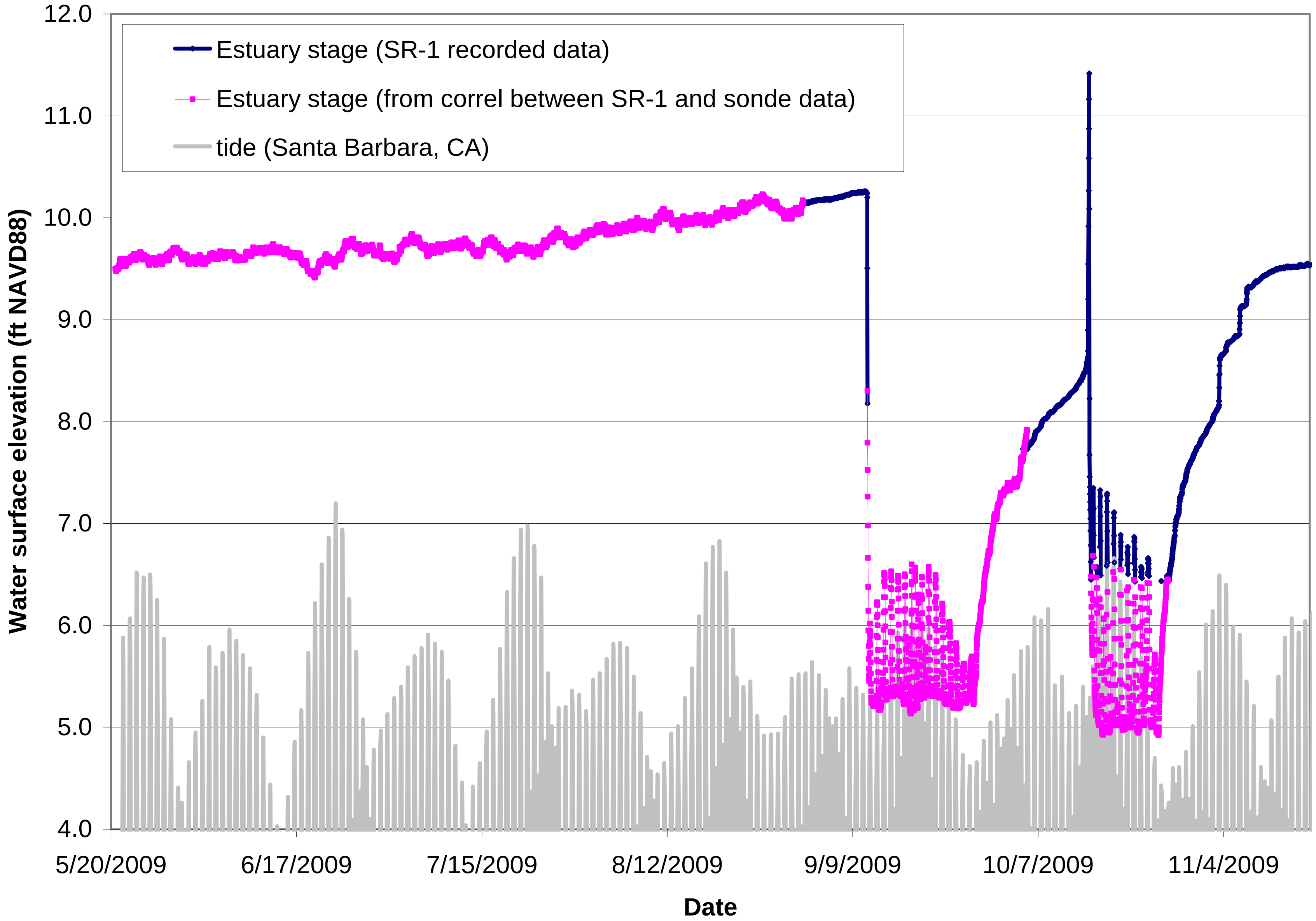


**Figure 2-2. Estuary stage (SR-1) and adjacent tidal elevation: Year One (5/20/09 – 11/17/09).**

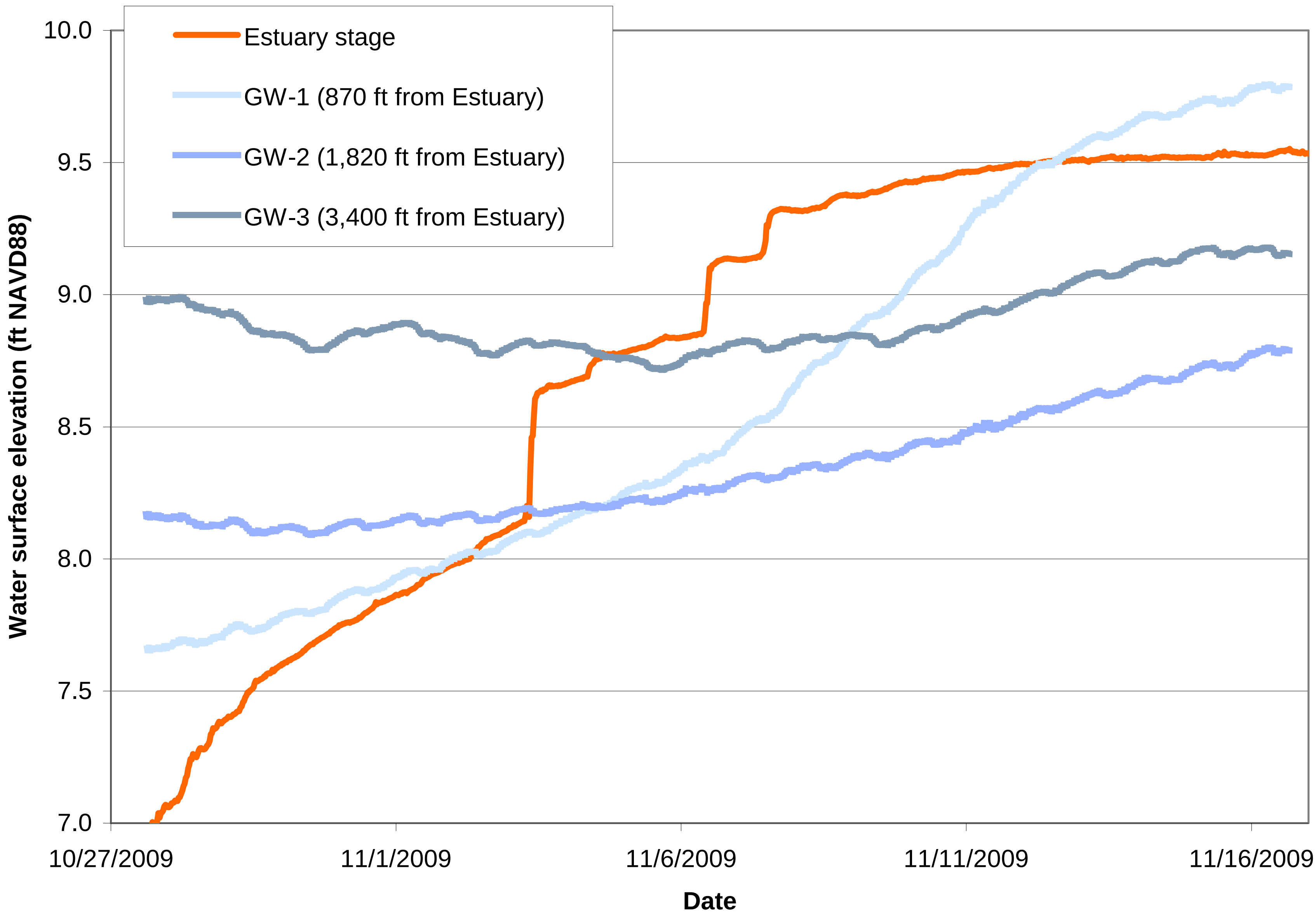


**Figure 2-3. Groundwater elevation and Estuary stage: Year One (10/27/09 – 11/16/09).**

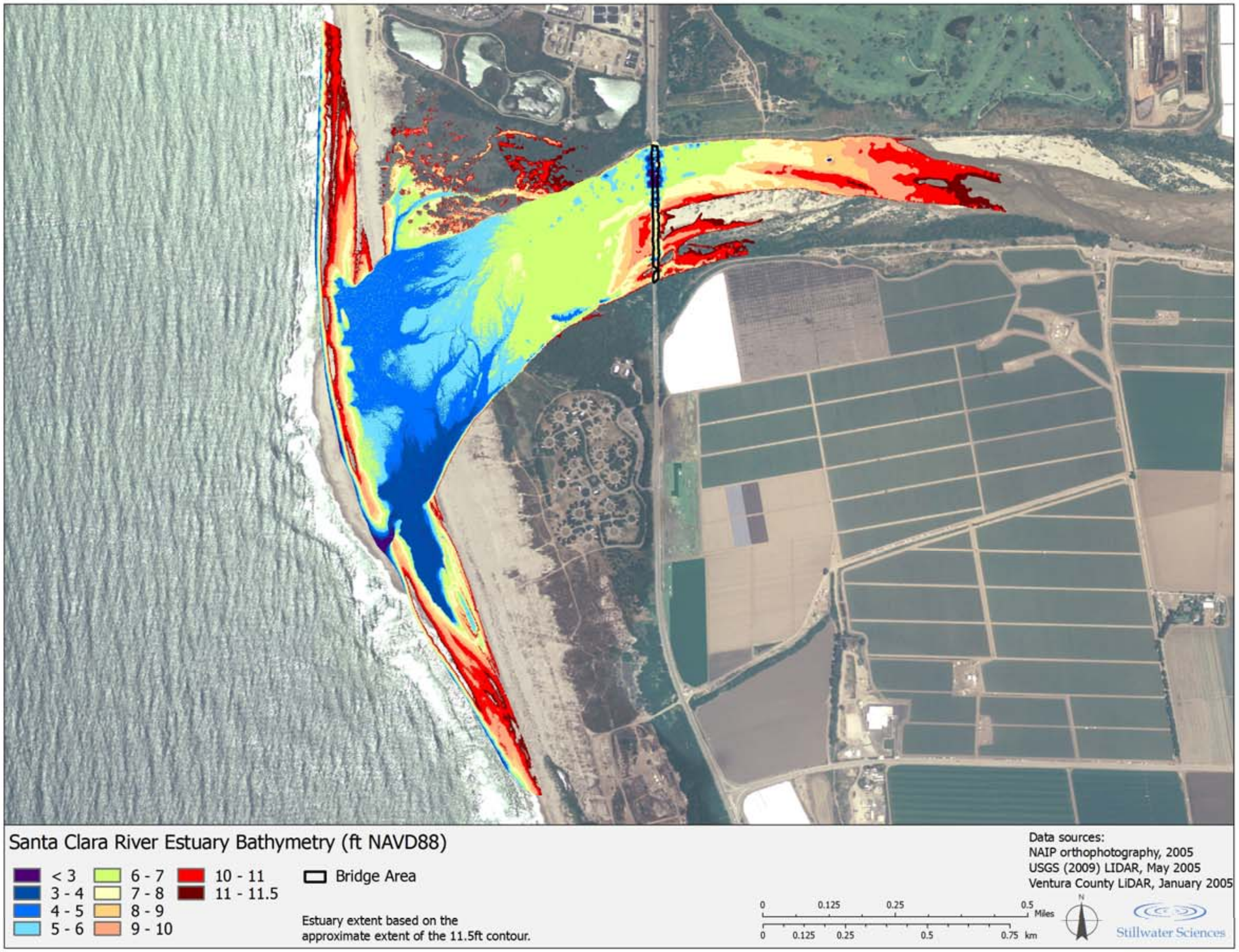


**Figure 2-4. Current (i.e., post-2005 flood) Estuary bathymetry.**

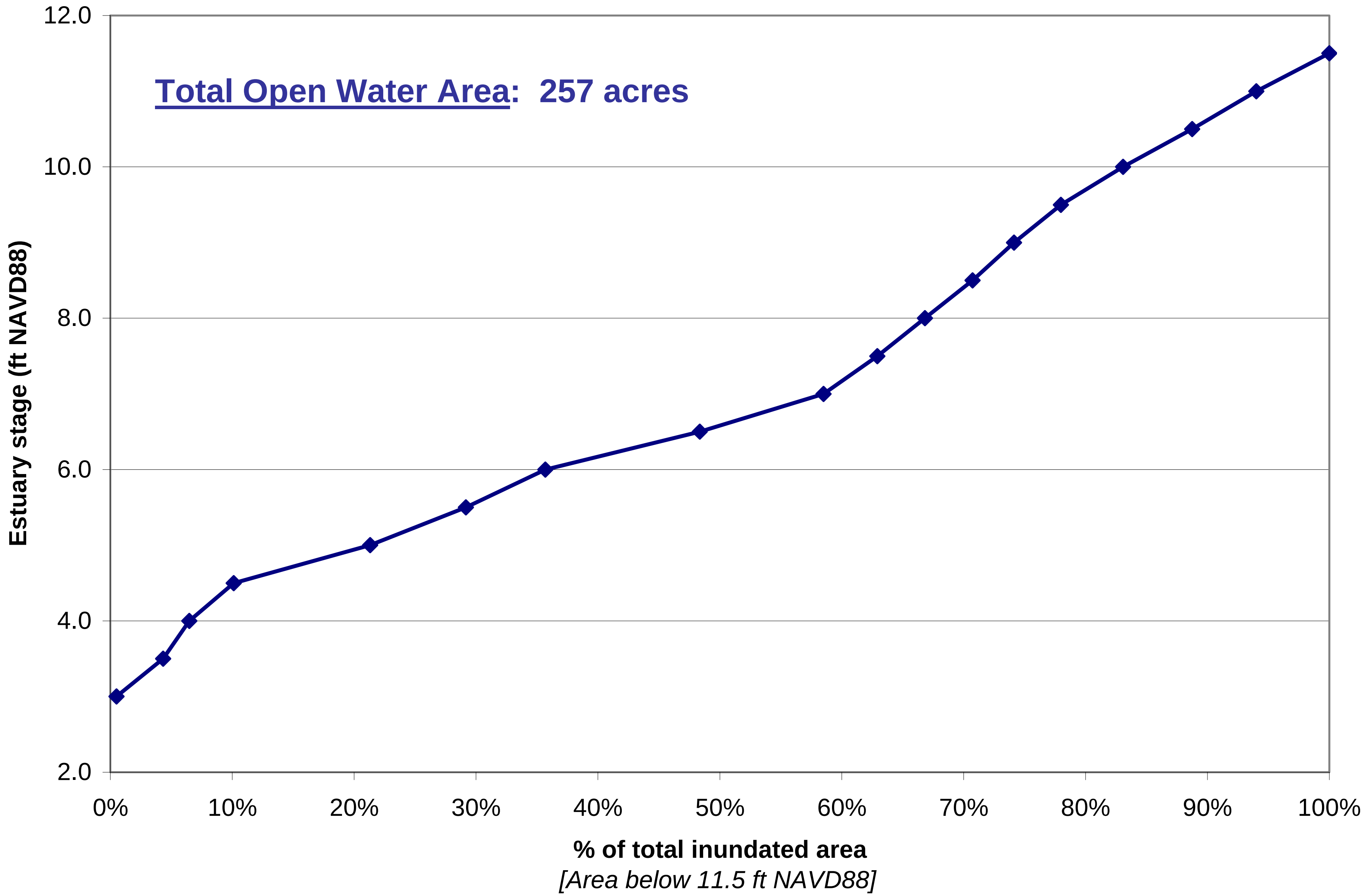


**Figure 2-5. Relationship between Estuary stage and Estuary inundated area (data collected between 5/20/09 and 11/17/09).**

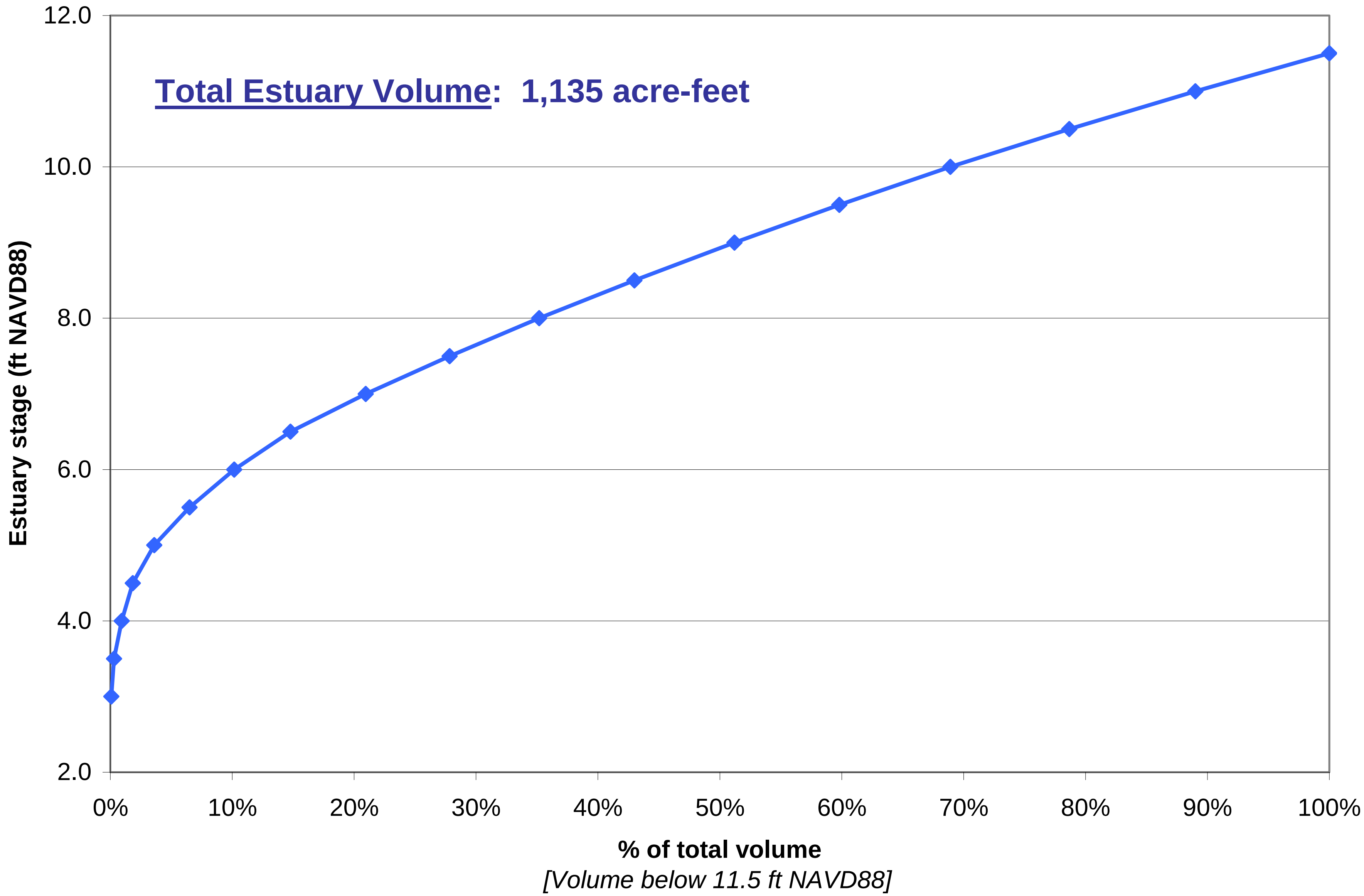


**Figure 2-6. Relationship between Estuary stage and Estuary volume (data collected between 5/20/09 and 11/17/09).**

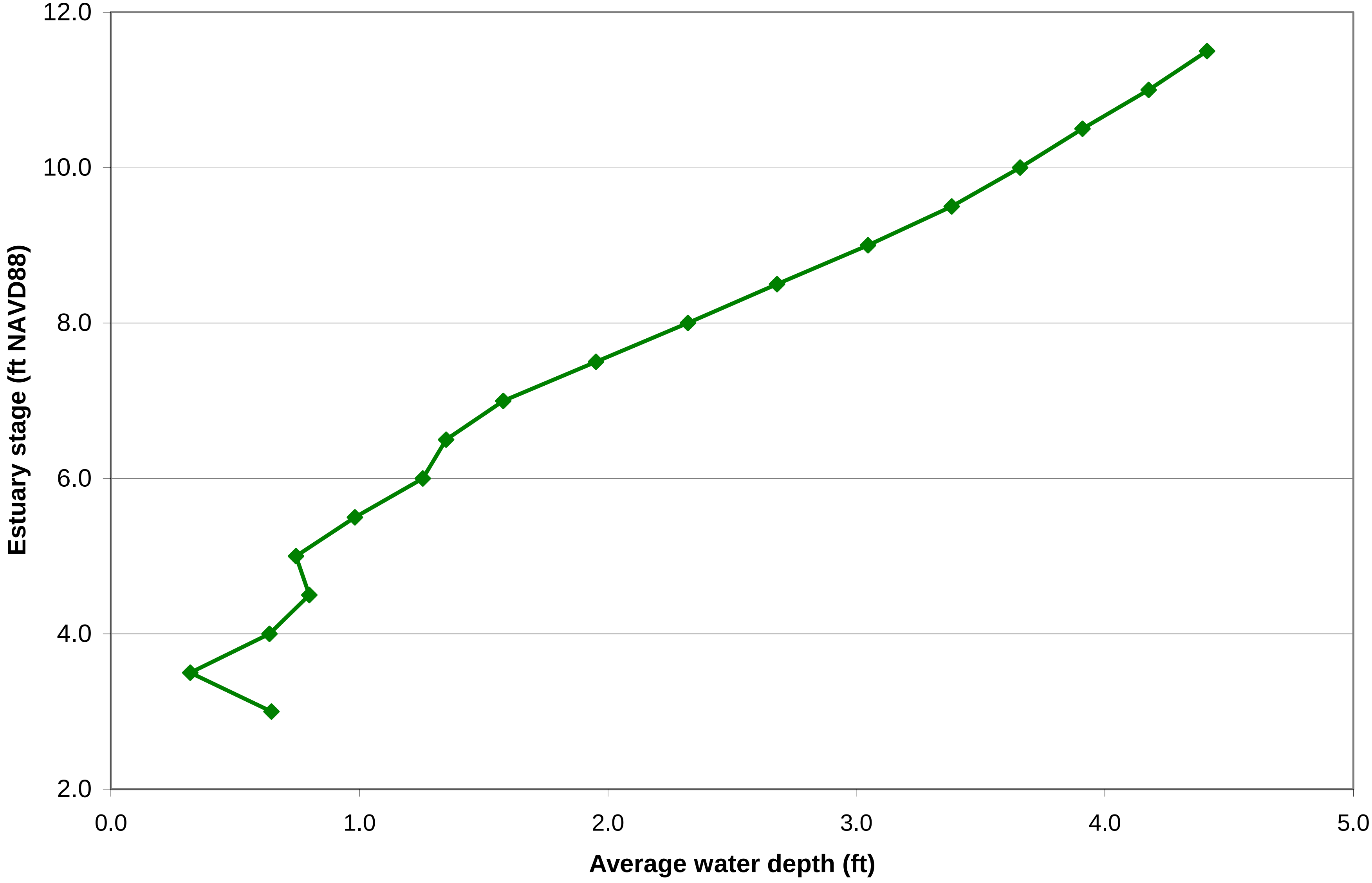


**Figure 2-7. Relationship between Estuary stage and average Estuary water depth (data collected between 5/20/09 and 11/17/09).**

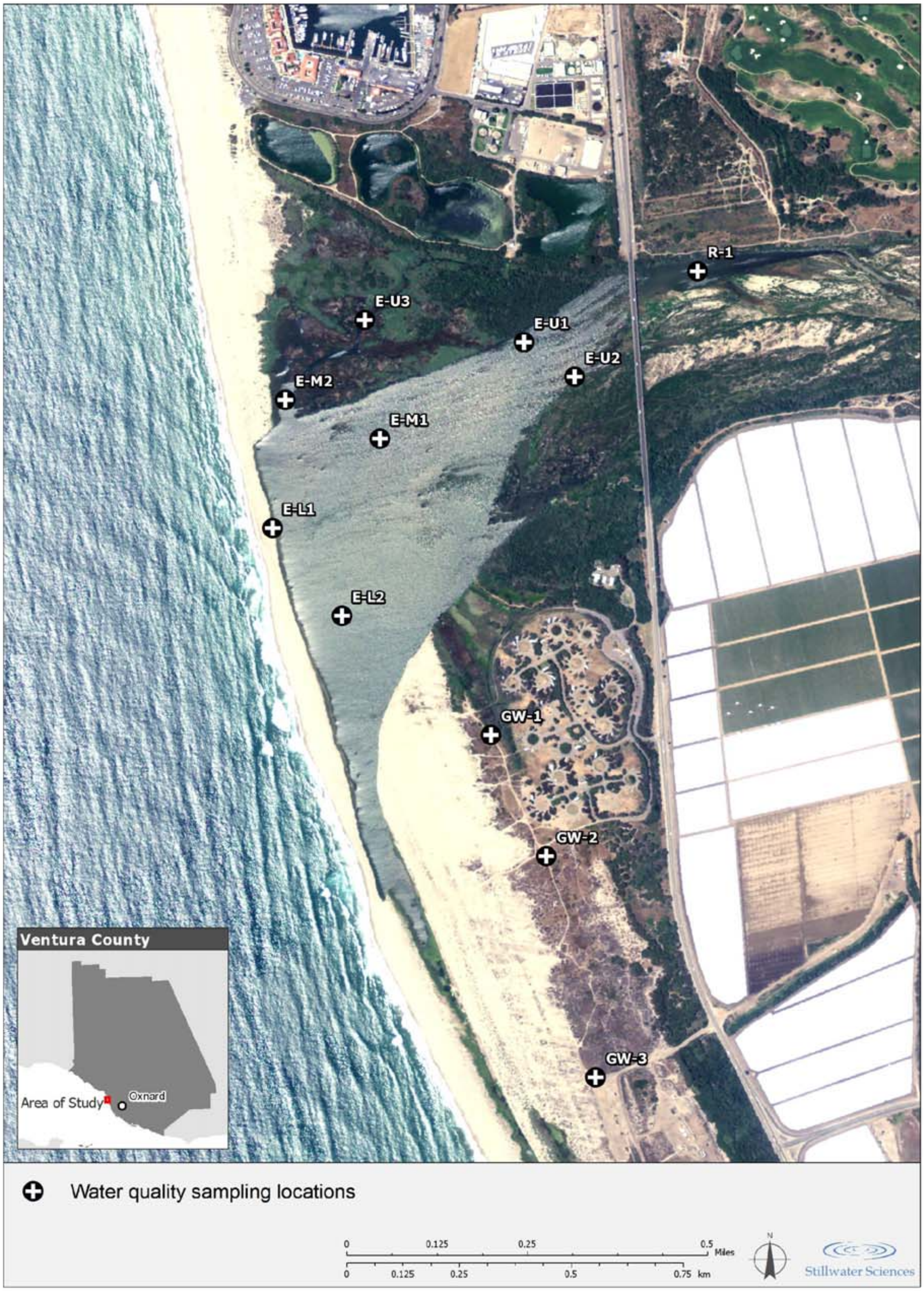


**Figure 3-1. Approximate water quality sampling locations in the Santa Clara River Estuary and adjacent floodplain.**

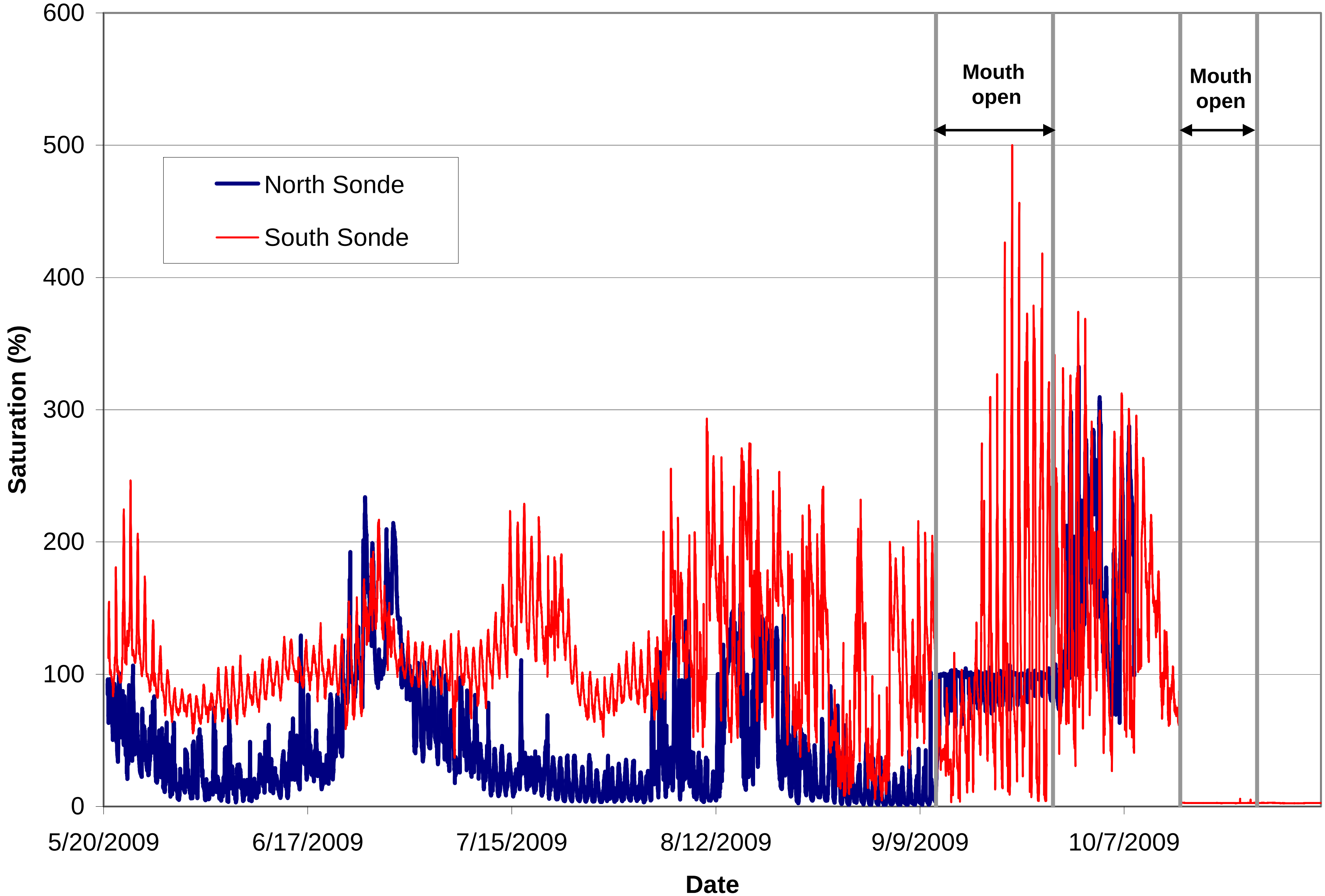


**Figure 3-2. Dissolved oxygen concentration in the Santa Clara River Estuary from May through November 2009. Data source is the continuous recording multiparameter sonde deployed by the City. Also shown are the periods in which the Estuary mouth was open.**

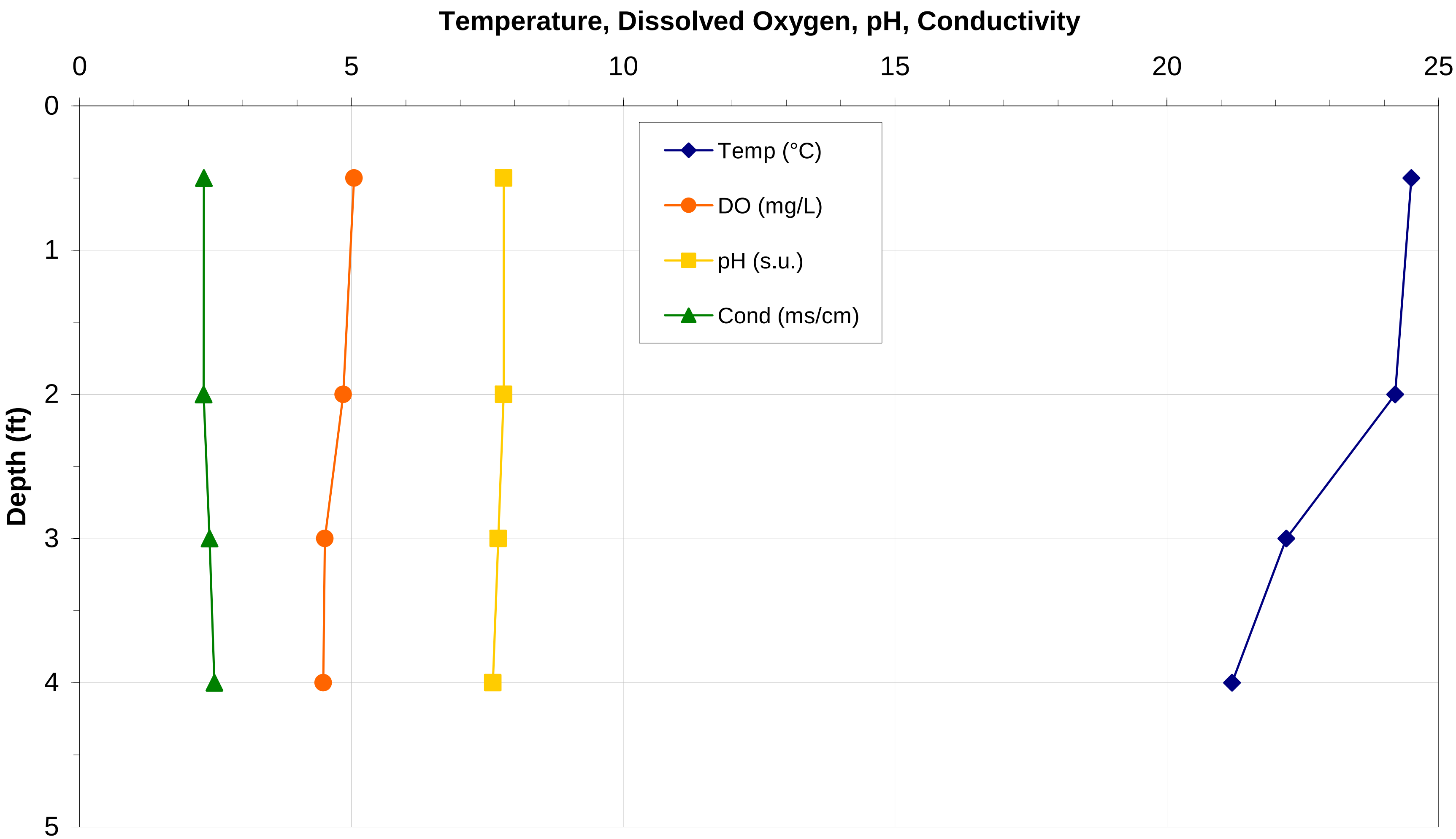


**Figure 3-3. Vertical profile of *in situ* water quality parameters at Upper Estuary downstream of outfall channel site (E-U3) during September 2009 survey.**

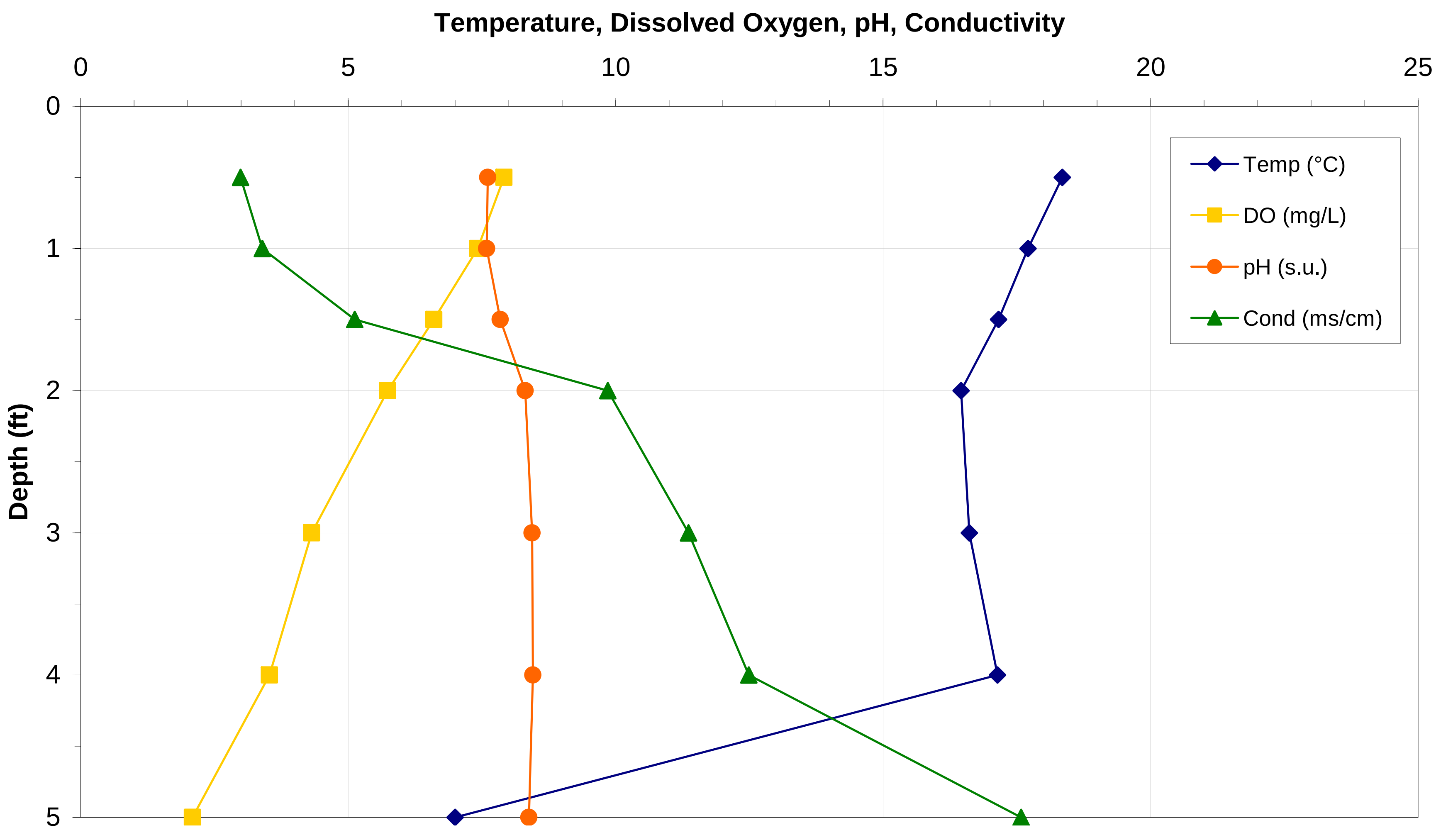


**Figure 3-4. Vertical profile of *in situ* water quality parameters at Upper Estuary downstream of outfall channel site (E-U3) during November 2009 survey.**

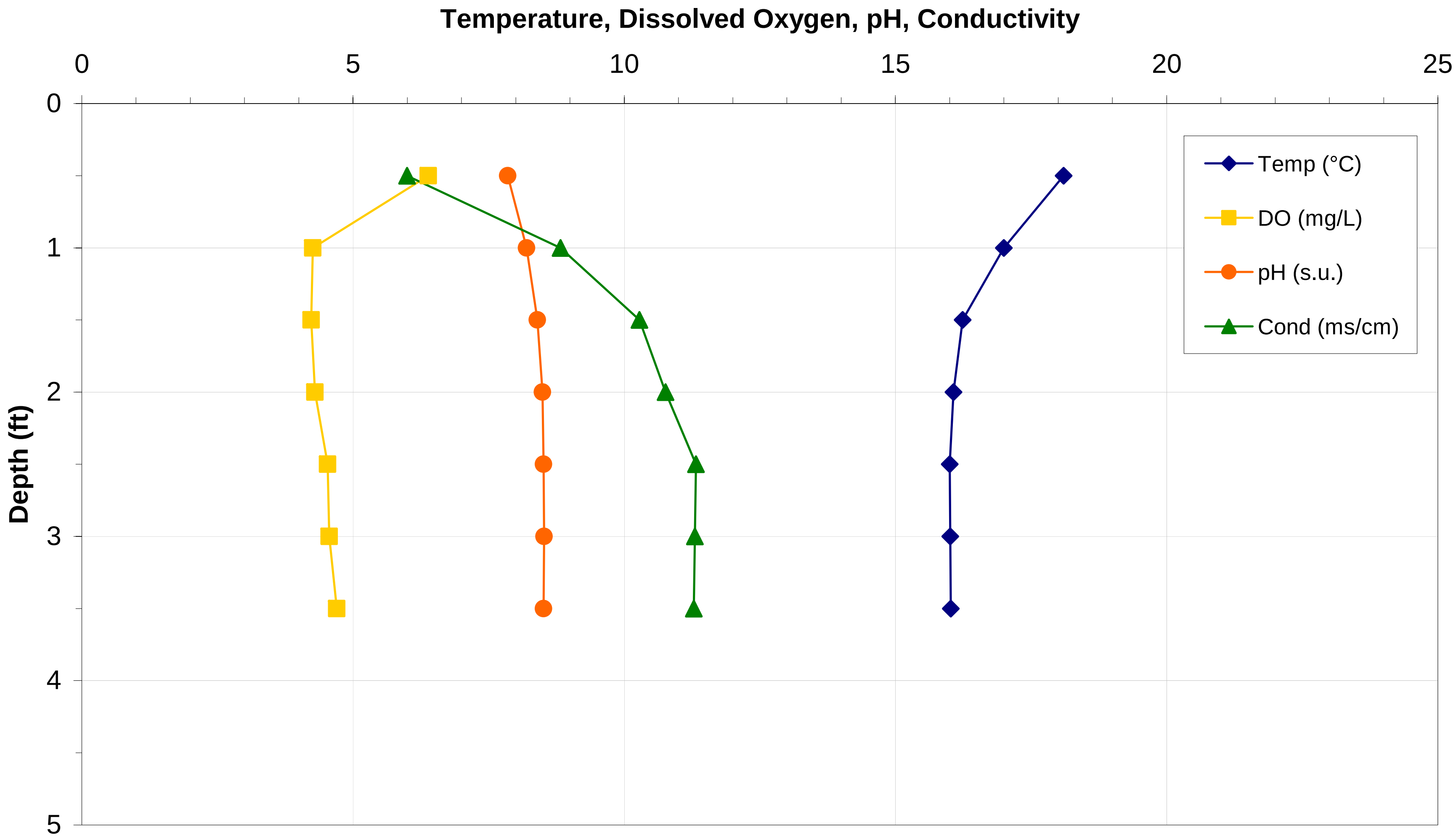


**Figure 3-5. Vertical profile of *in situ* water quality parameters at Middle Estuary downstream of outfall channel site (E-M2) during November 2009 survey.**


**Figure 4-1. Study area for upland and tidal vegetation and aquatic habitat mapping.**


**Figure 4-2a. Upland and tidal vegetation map for northern section, Year One (2009).**

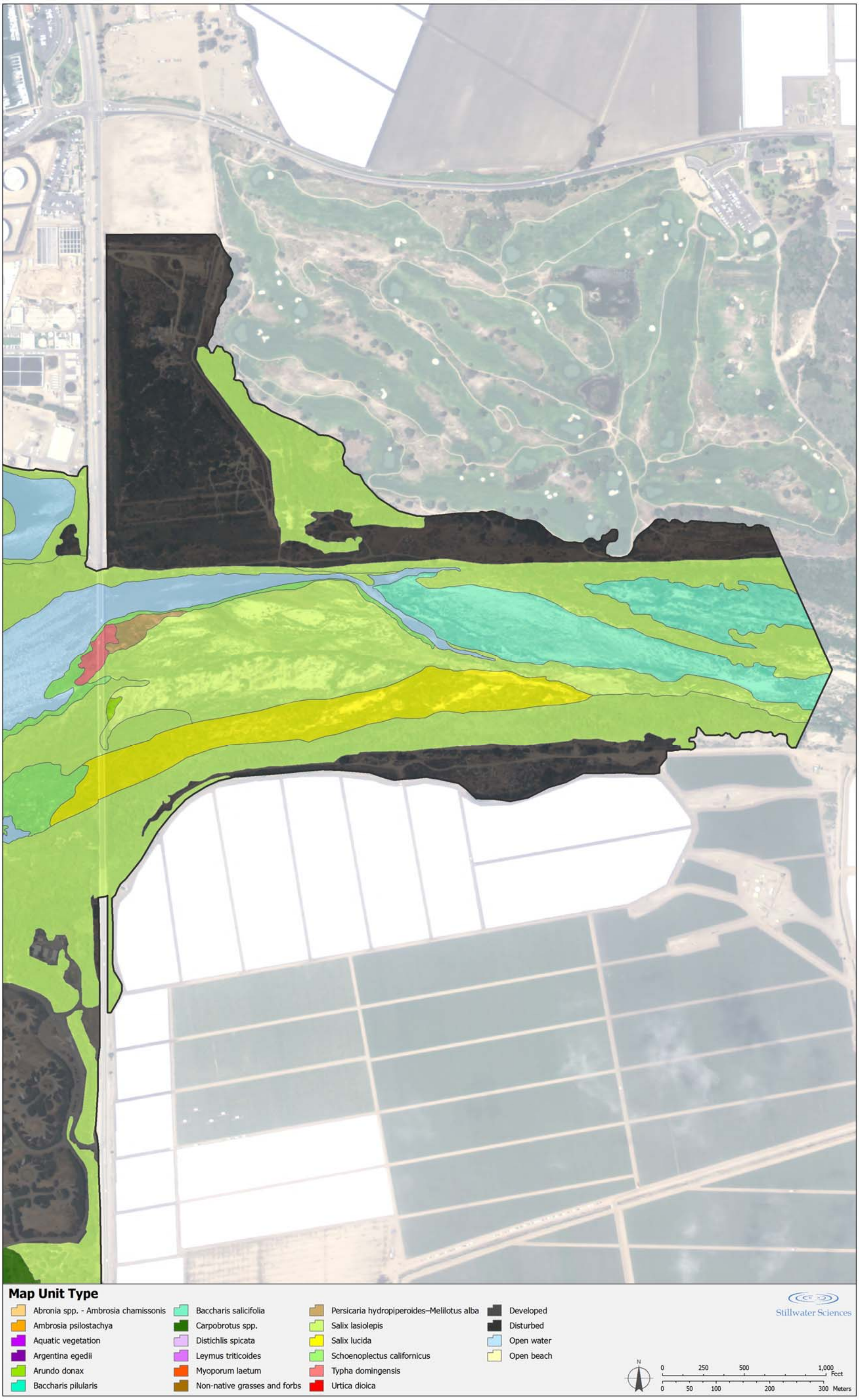


**Figure 4-2b. Upland and tidal vegetation map for eastern section, Year One (2009).**


**Figure 4-2c. Upland and tidal vegetation map for southern section, Year One (2009).**

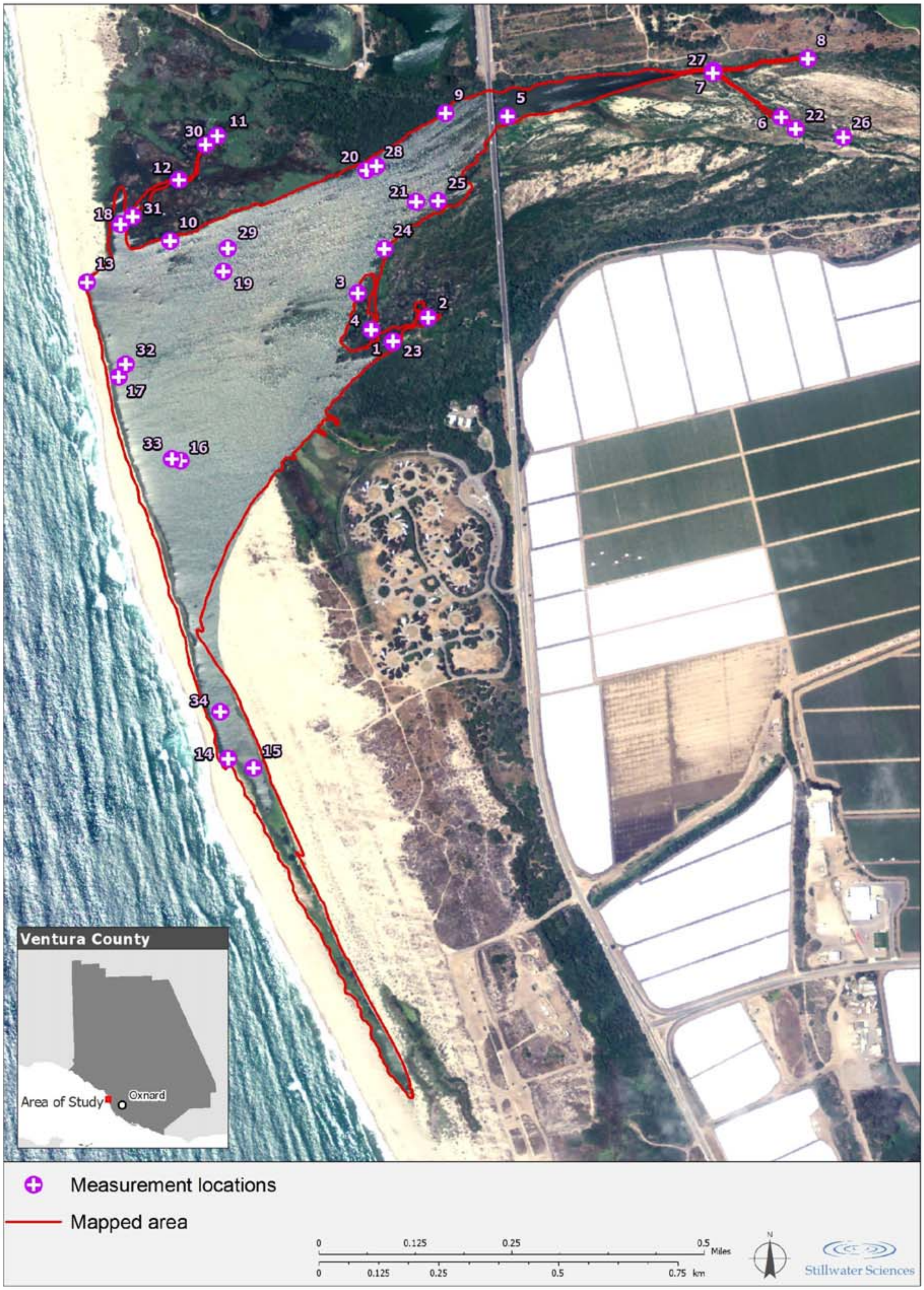


**Figure 4-3. Mapped aquatic habitat area (indicated by line) and locations of habitat parameter measurements (indicated by points) within the Santa Clara River Estuary. Associated habitat data is found in Appendix C.**

# Appendices

# Appendix A

# Vegetation Map Unit Details

| Map unit no. | Map unit | Classification level | Vegetation form | Source of map unit identification* | Acres |
|---|---|---|---|---|---|
| 1 | *Abronia* spp. - *Ambrosia chamissonis* | Alliance | Herbaceous | 2009 field survey – Sample point V20 | 5.59 |
| 2 | *Abronia* spp. - *Ambrosia chamissonis* | Alliance | Herbaceous | Photo-interpretation | 2.71 |
| 3 | Developed | Mapunit | n/a | Photo-interpretation | 0.99 |
| 4 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | Photo-interpretation | 2.67 |
| 5 | *Myoporum laetum* | Semi-Natural Stands | Shrubland | Photo-interpretation | 0.32 |
| 6 | Aquatic vegetation | Mapunit | n/a | Photo-interpretation | 5.57 |
| 7 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 8.02 |
| 8 | Disturbed | Mapunit | n/a | Photo-interpretation | 10.42 |
| 9 | *Myoporum laetum* | Semi-Natural Stands | Shrubland | Photo-interpretation | 1.94 |
| 10 | Developed | Mapunit | n/a | Photo-interpretation | 24.39 |
| 11 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | 2009 field survey – Sample point V19 | 5.99 |
| 12 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | 2009 field survey - Obs. + Photo-interp | 0.96 |
| 13 | *Arundo donax* | Semi-Natural Stands | Herbaceous | 2009 field survey - Obs. + Photo-interp | 0.42 |
| 14 | *Arundo donax* | Semi-Natural Stands | Herbaceous | Photo-interpretation | 6.96 |
| 15 | *Myoporum laetum* | Semi-Natural Stands | Shrubland | 2009 field survey – Sample point V25 | 0.40 |
| 16 | *Salix lasiolepis* | Alliance | Shrubland | 2009 field survey – Sample points V8, V10, V11, V14 | 31.98 |
| 17 | *Salix lasiolepis* | Alliance | Woodland | 2009 field survey – Sample points V16, V27-V28 | 43.84 |
| 18 | *Abronia* spp. - *Ambrosia chamissonis* | Alliance | Herbaceous | 2009 field survey – Sample points V26 | 106.37 |
| 19 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | 2009 field survey – Sample point V18 | 31.47 |
| 20 | Developed | Mapunit | n/a | Photo-interpretation | 0.82 |
| 21 | *Salix lasiolepis* | Alliance | Woodland | 2009 field survey – Sample point V5 | 15.09 |
| 22 | Open water | Mapunit | n/a | 2009 field survey - Obs. + Photo-interp | 104.07 |
| 23 | *Baccharis salicifolia* | Alliance | Shrubland | Photo-interpretation | 7.34 |
| 24 | *Baccharis salicifolia* | Alliance | Shrubland | 2009 field survey – Sample point V9 | 16.38 |
| 25 | *Salix lucida* | Alliance | Woodland | 2009 field survey – Sample point V15 | 16.04 |
| 26 | *Schoenoplectus californicus* | Alliance | Herbaceous | 2009 field survey - Obs. | 10.10 |
| 27 | *Argentina egedii* | Alliance | Herbaceous | 2009 field survey – Sample point V22 | 0.36 |

| Map unit no. | Map unit | Classification level | Vegetation form | Source of map unit identification* | Acres |
|---|---|---|---|---|---|
| 28 | Disturbed | Mapunit | n/a | 2009 field survey - Obs. + Photo-interp | 11.30 |
| 29 | Disturbed | Mapunit | n/a | Photo-interpretation | 0.38 |
| 30 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 1.72 |
| 31 | *Leymus triticoides* | Alliance | Herbaceous | Photo-interpretation | 0.58 |
| 32 | *Leymus triticoides* | Alliance | Herbaceous | 2009 field survey – Sample point V24 | 0.60 |
| 33 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 3.13 |
| 34 | *Argentina egedii* | Alliance | Herbaceous | 2009 field survey - Obs. + PhotoInterp | 0.95 |
| 35 | *Distichlis spicata* | Alliance | Herbaceous | 2009 field survey – Sample point V23 + Photo-interp | 1.24 |
| 36 | Developed | Mapunit | n/a | Photo-interpretation | 36.78 |
| 37 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.73 |
| 38 | Non-native grasses and forbs | Provisional Alliance | Herbaceous | Photo-interpretation | 1.18 |
| 39 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 13.13 |
| 40 | *Schoenoplectus californicus* | Alliance | Herbaceous | 2009 field survey - Obs. | 5.74 |
| 41 | *Schoenoplectus californicus* | Alliance | Herbaceous | 2009 field survey – Sample point V17 + Photo-interp | 8.33 |
| 42 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 0.61 |
| 43 | *Baccharis pilularis* | Alliance | Shrubland | Photo-interpretation | 0.51 |
| 44 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 12.76 |
| 45 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 1.85 |
| 46 | Non-native grasses and forbs | Provisional Alliance | Herbaceous | Photo-interpretation | 5.91 |
| 47 | Open water | Mapunit | n/a | Photo-interpretation | 4.63 |
| 48 | *Distichlis spicata* | Alliance | Herbaceous | Photo-interpretation | 0.62 |
| 49 | Open water | Mapunit | n/a | Photo-interpretation | 0.52 |
| 50 | Aquatic vegetation | Mapunit | n/a | Photo-interpretation | 4.69 |
| 51 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 1.38 |
| 52 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 6.41 |
| 53 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 2.89 |
| 54 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | Photo-interpretation | 1.21 |
| 55 | *Baccharis pilularis* | Alliance | Shrubland | Photo-interpretation | 5.04 |
| 56 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | Photo-interpretation | 0.57 |
| 57 | *Abronia* spp. - *Ambrosia chamissonis* | Alliance | Herbaceous | Photo-interpretation | 6.07 |
| 58 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | Photo-interpretation | 0.52 |
| 59 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 1.96 |
| 60 | *Salix lasiolepis* | Alliance | Woodland | 2009 field survey – Sample point V6 + Photo-interp | 14.90 |

| Map unit no. | Map unit | Classification level | Vegetation form | Source of map unit identification* | Acres |
|---|---|---|---|---|---|
| 61 | Open water | Mapunit | n/a | Photo-interpretation | 4.77 |
| 62 | Disturbed | Mapunit | n/a | Photo-interpretation | 0.46 |
| 63 | *Salix lasiolepis* | Alliance | Woodland | 2009 field survey - Obs. + Photo-interp | 4.48 |
| 64 | *Salix lasiolepis* | Alliance | Woodland | 2009 field survey – Sample point V4 | 4.39 |
| 65 | Disturbed | Mapunit | n/a | Photo-interpretation | 0.96 |
| 66 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 2.15 |
| 67 | *Urtica dioica* | Provisional Alliance | Herbaceous | 2009 field survey – Sample point V3 | 1.14 |
| 68 | Open water | Mapunit | n/a | Photo-interpretation | 3.95 |
| 69 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | 2009 field survey - Obs. + Photo-interp | 1.01 |
| 70 | Open water | Mapunit | n/a | Photo-interpretation | 8.77 |
| 71 | *Ambrosia psilostachya* | Provisional Alliance | Herbaceous | 2009 field survey – Sample point V2 | 2.14 |
| 72 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.73 |
| 73 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.17 |
| 74 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.33 |
| 75 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.22 |
| 76 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | Photo-interpretation | 0.97 |
| 77 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 8.54 |
| 78 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 6.07 |
| 79 | *Arundo donax* | Semi-Natural Stands | Herbaceous | Photo-interpretation | 3.38 |
| 80 | *Arundo donax* | Semi-Natural Stands | Herbaceous | Photo-interpretation | 0.81 |
| 81 | *Arundo donax* | Semi-Natural Stands | Herbaceous | Photo-interpretation | 1.88 |
| 82 | *Typha domingensis* | Alliance | Herbaceous | 2009 field survey – Sample point V21 | 0.42 |
| 83 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 0.27 |
| 84 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 0.82 |
| 85 | *Arundo donax* | Semi-Natural Stands | Herbaceous | Photo-interpretation | 1.05 |
| 86 | *Arundo donax* | Semi-Natural Stands | Herbaceous | Photo-interpretation | 1.23 |
| 87 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 0.70 |
| 88 | Developed | Mapunit | n/a | Photo-interpretation | 2.50 |
| 89 | Disturbed | Mapunit | n/a | Photo-interpretation | 1.58 |
| 90 | Disturbed | Mapunit | n/a | 2009 field survey - Obs. + Photo-interp | 53.40 |
| 91 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 10.99 |
| 92 | *Leymus triticoides* | Alliance | Herbaceous | Photo-interpretation | 0.32 |
| 93 | Disturbed | Mapunit | n/a | Photo-interpretation | 0.55 |
| 94 | *Typha domingensis* | Alliance | Herbaceous | 2009 field survey – Sample point V1 | 0.90 |

| Map unit no. | Map unit | Classification level | Vegetation form | Source of map unit identification* | Acres |
|---|---|---|---|---|---|
| 95 | *Persicaria hydropiperoides–Melilotus alba* | Provisional Alliance | Herbaceous | 2009 field survey – Sample point V12 | 1.02 |
| 96 | *Salix lasiolepis* | Alliance | Woodland | 2009 field survey – Sample point V7 | 7.37 |
| 97 | Open beach | Mapunit | n/a | 2009 field survey - Obs. + Photo-interp | 86.85 |
| 98 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 1.77 |
| 99 | *Schoenoplectus californicus* | Alliance | Herbaceous | 2009 field survey - Obs. + Photo-interp | 0.37 |
| 100 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 1.27 |
| 101 | *Schoenoplectus californicus* | Alliance | Herbaceous | Photo-interpretation | 0.85 |
| 102 | *Arundo donax* | Semi-Natural Stands | Herbaceous | Photo-interpretation | 0.53 |
| 103 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 3.00 |
| 104 | *Carpobrotus* spp. | Semi-Natural Stands | Herbaceous | Photo-interpretation | 0.31 |
| 105 | *Baccharis pilularis* | Alliance | Shrubland | Photo-interpretation | 0.57 |
| 106 | *Baccharis pilularis* | Alliance | Shrubland | Photo-interpretation | 2.51 |
| 107 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.35 |
| 108 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.13 |
| 109 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.15 |
| 110 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.17 |
| 111 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.08 |
| 112 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.63 |
| 113 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.14 |
| 114 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.20 |
| 115 | *Carpobrotus* spp. | Alliance | Herbaceous | Photo-interpretation | 5.58 |
| 116 | *Salix lasiolepis* | Alliance | Woodland | Photo-interpretation | 0.14 |
| 117 | *Arundo donax* | Semi-Natural Stands | Herbaceous | 2009 field survey – Sample point V13 | 0.17 |

* Source of Map Unit Identification

| | |
|---|---|
| Photo-interpretation | 2006 map unit name was retained, but map unit boundaries were revised based on photo-interpretation of USDA (2009) orthophotography. |
| 2009 field survey | the map unit was assessed during the 2009 field mapping. |
| Sample point # | the map unit name is based upon the results of a 2009 CNPS rapid assessment sample point. |
| Obs. | the map unit name was confirmed during the 2009 field mapping |
| + Photo-interp | the map unit boundaries were revised based on photo-interpretation of USDA (2009) orthophotography. |

# Appendix B

# Plant Species List

| **Name[a]** | **Common name** | **Family** | **Native?** |
|---|---|---|---|
| *Abronia maritima* | red sand-verbena | Nyctaginaceae | Y |
| *Abronia umbellata* | pink sand-verbena | Nyctaginaceae | Y |
| *Ambrosia chamissonis* | beach bursage | Asteraceae | Y |
| *Ambrosia psilostachya* | western ragweed | Asteraceae | Y |
| *Anemopsis californica* | yerba mansa | Saururaceae | Y |
| *Argentina egedii* | Pacific silverweed | Rosaceae | Y |
| *Arundo donax* | giant reed | Poaceae | N |
| *Atriplex lentiformis* | big saltbush | Chenopodiaceae | Y |
| *Atriplex triangularis* | spearscale | Chenopodiaceae | Y |
| *Azolla* sp. | mosquitofern | Azollaceae | |
| *Baccharis pilularis* | coyotebrush | Asteraceae | Y |
| *Baccharis salicifolia* | mule fat | Asteraceae | Y |
| *Bolboschoenus maritimus* | alkali bulrush | Cyperaceae | Y |
| *Bromus diandrus* | ripgut grass | Poaceae | N |
| *Cakile maritima* | European searocket | Brassicaceae | N |
| *Camissonia cheiranthifolia* | beach evening primrose | Onagraceae | Y |
| *Carpobrotus chilensis* | sea fig | Aizoaceae | N |
| *Carpobrotus edulis* | hottentot fig | Aizoaceae | N |
| *Chenopodium ambrosioides* | Mexican tea | Chenopodiaceae | N |
| *Clematis ligusticifolia* | virgin’s bower | Ranunculaceae | Y |
| *Conium maculatum* | poison hemlock | Apiaceae | N |
| *Convolvulus soldanella* | seashore false bindweed | Convolvulaceae | Y |
| *Conyza canadensis* | Canadian horseweed | Asteraceae | Y |
| *Corethrogyne filaginifolia* var. *filaginifolia* | common sandaster | Asteraceae | Y |
| *Cortaderia jubata* | purple pampas grass | Poaceae | N |
| *Cotula coronopifolia* | common brassbuttons | Asteraceae | N |
| *Cuscuta* sp. | dodder | Cuscutaceae | |
| *Cynodon dactylon* | Bermudagrass | Poaceae | N |
| *Cyperus esculentus* | yellow nutsedge | Cyperaceae | Y |
| *Distichlis spicata* | saltgrass | Poaceae | Y |
| *Echinochloa crus-galli* | barnyardgrass | Poaceae | N |
| *Equisetum* sp. | horsetail | Equisetaceae | |
| *Eriogonum parvifolium* | seacliff buckwheat | Polygonaceae | Y |
| *Euthamia occidentalis* | western goldentop | Asteraceae | Y |
| *Foeniculum vulgare* | sweet fennel | Apiaceae | N |
| *Frankenia salina* | alkali seaheath | Frankeniaceae | Y |
| *Heliotropium curassavicum* | salt heliotrope | Boraginaceae | Y |
| *Heterotheca grandiflora* | telegraphweed | Asteraceae | Y |
| *Hirschfeldia incana* | shortpod mustard | Brassicaceae | N |
| *Isocoma menziesii* var. *vernonioides* | Menzies' goldenbush | Asteraceae | Y |
| *Jaumea carnosa* | marsh jaumea | Asteraceae | Y |
| *Juncus acutus* | spiny rush | Juncaceae | Y |
| *Juncus torreyi* | Torrey's rush | Juncaceae | Y |
| *Lemna sp.* | duckweed | Lemnaceae | |
| *Leymus triticoides* | beardless wildrye | Poaceae | Y |
| *Ludwigia sp.* | primrose-willow | Onagraceae | |
| *Melilotus albus* | white sweetclover | Fabaceae | N |
| *Myoporum laetum* | myoporum | Myoporaceae | N |
| *Nasturtium officinale* | watercress | Brassicaceae | Y |

| Name[a] | Common name | Family | Native? |
|---|---|---|---|
| *Nicotiana glauca* | tree tobacco | Solanaceae | N |
| *Oenothera elata* | Hooker's evening-primrose | Onagraceae | Y |
| *Opuntia* sp. | pricklypear | Cactaceae | |
| *Persicaria hydropiperoides* | swamp smartweed | Polygonaceae | Y |
| *Persicaria lapathifolium* | curlytop knotweed | Polygonaceae | Y |
| *Pluchea odorata* | salt marsh fleabane | Asteraceae | Y |
| *Polypogon monspeliensis* | annual rabbitsfoot grass | Poaceae | N |
| *Populus balsamifera* ssp. *trichocarpa* | black cottonwood | Salicaceae | Y |
| *Populus fremontii* ssp. *fremontii* | Fremont cottonwood | Salicaceae | Y |
| *Ricinus communis* | castorbean | Euphorbiaceae | N |
| *Rubus ursinus* | California blackberry | Roseaceae | Y |
| *Rumex crispus* | curly dock | Polygonaceae | N |
| *Rumex* sp. | dock | Polygonaceae | |
| *Sarcocornia pacifica* | pickleweed | Chenopodiaceae | Y |
| *Salix exigua* | narrow-leaved willow | Salicaceae | Y |
| *Salix laevigata* | red willow | Salicaceae | Y |
| *Salix lasiolepis* | arroyo willow | Salicaceae | Y |
| *Salix lucida* ssp. *lasiandra* | shining willow | Salicaceae | N |
| *Schoenoplectus acutus* var. *occidentalis* | hardstem bulrush | Cyperaceae | Y |
| *Schoenoplectus americanus* | chairmaker's bulrush | Cyperaceae | Y |
| *Schoenoplectus californicus* | California bulrush | Cyperaceae | Y |
| *Spergularia* sp. | sandspurry | Caryophyllaceae | |
| *Tamarix* sp. | tamarisk | Tamaricaceae | N |
| *Toxicodendron diversilobum* | poison oak | Anacardiaceae | Y |
| *Typha domingensis* | southern cattail | Typhaceae | Y |
| *Typha latifolia* | broadleaf cattail | Typhaceae | Y |
| *Urtica dioica* | stinging nettle | Urticaceae | Y |
| *Washingtonia filifera* | California fan palm | Arecaceae | N[b] |
| *Xanthium strumarium* | cockleburr | Asteraceae | Y |
| *Yucca* sp. | yucca | Agavaceae | |

[a] Nomenclature follows: Jepson (2009): Online Interchange of California Floristics, University of California, Berkeley. Online database. http://ucjeps.berkeley.edu/interchange/index.html.

[b] This species is native to California, but not to Ventura County.

# Appendix C

# Recorded Habitat Parameters (Summer/Fall 2009)

| ID | Date | Average depth | Average velocity | Surface water quality parameters | | | | Substrate (>5% increments to 100%) | | | | | | | Cover (>5% increments to 100%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Water temp-surface | DO (ppm) surface | DO (%) surface | Cond surface | Bedrock | Boulder | Cobble | Gravel | Sand | Silt | Organic | Wood | Ovrhng veg | Flood terr veg | Emergent veg | Aquatic veg | Open water | Other |
| 1 | 31-Aug | 2.7 | 0 | 24.1 | 17.0 | 203.8 | 2,630 | | | | | 80 | 10 | 10 | | | | 20 | 10 | 70 | |
| 2 | 31-Aug | 3.4 | 0 | 24.1 | 5.0 | 59.6 | 2,680 | | | | | 80 | 10 | 10 | | | | 20 | 10 | 70 | |
| 3 | 31-Aug | 3.6 | 0 | 24.1 | 17.5 | 210.2 | 2,620 | | | | | 80 | 10 | 10 | | | | 20 | 10 | 70 | |
| 4 | 31-Aug | 3.9 | 0 | 25.1 | 9.8 | 119.1 | 2,670 | | | | | 80 | 10 | 10 | | | | 20 | 10 | 70 | |
| 5 | 31-Aug | 2.1 | 0 | 25.0 | 17.6 | 216.3 | 2,630 | | | | | 100 | | | | | | | | 100 | |
| 6 | 31-Aug | 1.2 | 0.1 | 20.9 | 9.1 | 103.2 | 3,380 | | | | | 95 | | 5 | | | | 75 | 5 | 25 | |
| 7 | 31-Aug | 2.4 | 0 | 23.8 | 21.5 | 259.5 | 2,960 | | | | | 70 | 10 | 20 | | | | 75 | 5 | 25 | |
| 8 | 31-Aug | 2.8 | 0 | 21.1 | 14.7 | 177.3 | 3,900 | | | | | 70 | 10 | 20 | | 20 | | 50 | 20 | 10 | |
| 9 | 31-Aug | 3.9 | 0 | 25.7 | 20.9 | 257.0 | 2,640 | | | | | 90 | 10 | | | | | 10 | | 90 | |
| 10 | 31-Aug | 3.4 | 0 | 25.6 | 20.4 | 250.8 | 2,650 | | | | | 20 | 60 | 20 | | | | 70 | 20 | 10 | |
| 11 | 31-Aug | 5.9 | 0 | 24.9 | 4.2 | 493.7 | 2,360 | | | | | 20 | 60 | 20 | | | | 70 | 20 | 10 | |
| 12 | 31-Aug | 3.3 | 0 | 25.2 | 5.0 | 60.0 | 2,370 | | | | | 20 | 60 | 20 | | | | 70 | 20 | 10 | |
| 13 | 31-Aug | 1.9 | 0 | 23.7 | 8.7 | 103.8 | 2,500 | | | | | 100 | | | | | | | | 100 | |
| 14 | 31-Aug | 2.0 | 0 | 25.9 | 15.4 | 191.0 | 2,640 | | | | | 95 | | 5 | | | | | | 100 | |
| 15 | 31-Aug | 3.0 | 0 | 26.1 | 16.7 | 208.0 | 2,640 | | | | | | | | | | | | | | |
| 16 | 1-Sep | 6.2 | 0 | 23.9 | 15.3 | 183.1 | 2,540 | | | | | 100 | | | | | | | | 100 | |
| 17 | 1-Sep | 5.6 | 0 | 24.0 | 18.1 | 216.1 | 2,540 | | | | | 100 | | | | | | | | 100 | |
| 18 | 1-Sep | 5.7 | 0 | 23.2 | 6.8 | 80.6 | 2,400 | | | | | 60 | 20 | 20 | | | | | | 100 | |
| 19 | 1-Sep | 3.1 | 0 | 24.7 | 21.7 | 259.8 | 2,540 | | | | | 85 | 10 | 5 | | | | | | 100 | |
| 20 | 1-Sep | 12.7 | 0 | 25.0 | 21.2 | 258.8 | 2,550 | | | | | 100 | | | | | | | | 100 | |
| 21 | 1-Sep | 1.5 | 0 | 25.4 | 20.9 | 253.8 | 2,540 | | | | | 90 | 10 | | | | | | | 100 | |
| 22 | 1-Sep | 0.6 | 0.1 | 20.3 | 11.4 | 127.0 | 3,210 | | | | | | | | | | | | | | |
| 23 | 17-Nov | 2.8 | 0 | 14.5 | 8.4 | 82.8 | 3,340 | | | | | 100 | | | | | | | | 100 | |
| 24 | 17-Nov | 3.3 | 0 | 15.0 | 7.9 | 80.0 | 10,040 | | | | | 100 | | | | 5 | | 5 | | 90 | |
| 25 | 17-Nov | 2.1 | 0 | 15.3 | 9.2 | 95.0 | 9,350 | | | | | 100 | | | | | | | | 100 | |
| 26 | 17-Nov | 0.7 | 0.2 | 16.3 | 13.3 | 137.5 | 3,140 | | | 15 | 25 | 60 | | | 5 | 5 | | | 10 | 80 | |
| 27 | 17-Nov | 2.8 | 0 | 14.5 | 8.4 | 82.8 | 3,340 | | | | | 100 | | | | | 5 | 5 | | 90 | |
| 28 | 17-Nov | 2.8 | 0 | 16.3 | 7.8 | 81.1 | 9,440 | | | | | 100 | | | | | | | | 100 | |
| 29 | 17-Nov | 2.1 | 0 | 16.3 | 7.0 | 73.3 | 9,710 | | | | | 100 | | | | | | | | 100 | |
| 30 | 17-Nov | 5.2 | 0 | 18.4 | 7.9 | 84.7 | 2,990 | | | | | 100 | | | | | | 50 | | 50 | |
| 31 | 17-Nov | 4.8 | 0 | 18.1 | 6.4 | 68.6 | 6,000 | | | | | 100 | | | | | | 25 | | 75 | |
| 32 | 17-Nov | 4.8 | 0 | 16.2 | 7.7 | 81.3 | 9,970 | | | | | 100 | | | | | | | | 100 | |
| 33 | 17-Nov | 3.1 | 0 | 16.3 | 7.6 | 81.8 | 9,780 | | | | | 100 | | | | | | | | 100 | |
| 34 | 18-Nov | 1.0 | 0 | 14.1 | 8.4 | 84.4 | 9,354 | | | | | 100 | | | | | 5 | 5 | | 90 | |