1. INTRODUCTION

1.1 PROJECT DESCRIPTION

The Sonoma Baylands Wetland Demonstration Project (Sonoma Baylands) is located on 348 acres of formerly diked farmland in southwestern Sonoma County, California. The project site is on the northern shoreline of San Pablo Bay just east of the mouth of the Petaluma River (Figure 1).

The 289-acre interior of the restoration site was designed to restore the ecological function of a tidal marsh habitat. The Sonoma Baylands site was once part of an extensive tidal wetland system along the north margin of San Pablo Bay. It had an original elevation of approximately Mean Higher-High Water (MHHW = 3.43 feet National Geodetic Vertical Datum of 1929 [NGVD]). The area was diked and drained for agriculture in the late 1800's. Since then, up to 6 feet of subsidence has occurred at the site. Before opening the Sonoma Baylands to tidal action, clean dredged materials were used to raise the surface elevation in order to speed the geologic and biologic evolution of the marsh.

The design approach for Sonoma Baylands was to create the appropriate conditions whereby a marsh would evolve in response to natural processes occurring at the site. This meant taking advantage of natural sedimentation to raise the marshplain above the dredged material placed on the site. Slough channels will form as tidal exchange is increased, sedimentation occurs, and marsh vegetation is established within the restoration area. More complete information on project design is contained in U.S. Army Corps of Engineers (USACE, 1994), Williams and Florsheim (1994), and ENTRIX (1991).

The design features of the project can be seen in Figure 2. The bayfront levee has two breaches that restore the site to tidal action. In addition, the bayfront levee has been graded lower to permit overtopping of the levee during higher tides. An 11,600 feet peripheral levee provides flood protection to the contiguous low-lying agricultural lands, highway, and railroad. The interior levee, which provides maintenance access to two high voltage electrical transmission line towers, also divides the restoration site into the functionally independent areas of the west side Pilot Unit and east side Main Unit. The series of low interior berms or “peninsulas” throughout the marsh restoration area were built to limit the length of wind-wave fetches across the site. The peninsulas also direct the formation of major tidal channels away from the toe of the peripheral levee.

Placement of dredged material from the Petaluma River Navigation channel in the Pilot Unit was completed in November 1994. The 29-acre Pilot Unit was opened to tidal action on January 24, 1996. The 260-acre Main Unit received dredged material from the Oakland Harbor, and the levee was breached on October 25, 1996. This provided the opportunity to monitor the evolution of the Pilot Unit prior to breaching the Main Unit. Because of the difference in the date of tidal inundation, each unit is in a different stage of evolution. This monitoring report separates the monitoring results for the Pilot Unit and the Main Unit.
Sonoma Baylands Vicinity Map

Figure 1

San Francisco
Pacific Ocean
Petaluma River
Napa River
San Pablo Bay
Sonoma Baylands
San Francisco
South San Francisco Bay
Figure 2

Sonoma Baylands
Base Map

N
0 250 500
FEET

San Pablo Bay
Outboard Marsh
Levee Road
Interior Staffs
Interior Peninsulas
Interior Levee
Pilot Unit
Main Unit
Perimeter Levee
Pilot Unit Breach
Main Unit Breach
Main Unit Outboard Tide Channel
Pilot Unit Outboard Tide Channel
Outboard Marsh
San Pablo Bay

PWA
1.2 MONITORING PROGRAM

The Congressional authorization for the Sonoma Baylands Wetland Demonstration Project includes monitoring of the development of the restored tidal marsh. Implementation of the monitoring program is required by the Project Cooperation Agreement for the Sonoma Baylands project between the USACE and the California State Coastal Conservancy (Conservancy), the Dredged Materials Re-use Requirements issued for the project by the San Francisco Bay Regional Water Quality Control Board (RWQCB), and the conditions of the endangered species consultations for the project (USACE, 1995). The project authorization also includes a provision for remediation (adaptive management and monitoring) if the monitoring results indicate that the project requires corrective action.

The USACE and the Conservancy approved the Sonoma Baylands Wetland Demonstration Project Monitoring Plan in October 1996, with the concurrence of the U.S. Fish and Wildlife Service (FWS), RWQCB, and the National Marine Fisheries Service. This report constitutes the seventh annual monitoring report, which documents monitoring results from the 2002 Spring and Fall monitoring programs carried out by Philip Williams & Associates, Ltd. (PWA), under contract to the USACE (Table 1).

Table 1. Monitoring Report History

<table>
<thead>
<tr>
<th>Report No.</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>October 1994 - July 1996</td>
</tr>
<tr>
<td>2</td>
<td>July 1996 - June 1997</td>
</tr>
<tr>
<td>3</td>
<td>March 1997 - April 1998</td>
</tr>
<tr>
<td>4</td>
<td>August 1998 – October 1999</td>
</tr>
<tr>
<td>5</td>
<td>March 2000 – December 2000</td>
</tr>
<tr>
<td>6</td>
<td>March 2001 – December 2001</td>
</tr>
<tr>
<td>7</td>
<td>January 2002 – December 2002</td>
</tr>
</tbody>
</table>

1.2.1 Year 2002 Monitoring Program Changes

The approved monitoring plan for the project, requires information on tidal hydrology and tide elevations; current benchmark elevations and position of the 21 resistivity staffs; tidal sedimentation and establishment of tidal marsh vegetation; and the taxa occurrence, density, and standing stock of benthic macroinvertebrate in fauna and fish.

Due to contracting issues during the beginning of this monitoring period, certain data were not collected. Sedimentation data as reported by the 21 resistivity staffs were not collected, bird surveys were not conducted and data on benthic and fish communities were not collected during the fall 2002 sampling
period; however, benthic and fish usage data were collected during the spring 2002 period as part of the 2001 budget.

Despite the lack of resistivity data, sedimentation rates and trends for this monitoring period are characterized through the analysis of topographic survey data from the interior elevation transects (Section 4.0).

The 2002 monitoring scope was extended to include a detailed digital terrain model (DTM) of both the Pilot and Main Units, and data regarding vegetation establishment included extensive cordgrass mapping.

Year 2002 monitoring data is used to characterize the rate and pattern of outboard slough channel erosion; changes in tidal prism within the units; sediment deposition and consolidation; constructed levee and peninsula subsidence; vegetation establishment; and the development of benthic communities and fisheries and their value as a food source for higher trophic levels of organisms.

Table 2 outlines the data sets collected and the team member responsible for the collection, analysis and quality control. A history by report number of all Sonoma Baylands monitoring to date is summarized in Table 3.

Table 2. Monitoring Team Tasks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Team Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Hydrology</td>
<td>PWA</td>
</tr>
<tr>
<td>Tidal Elevations</td>
<td>PWA</td>
</tr>
<tr>
<td>Outboard Slough Channel Geometry Surveys</td>
<td>PWA</td>
</tr>
<tr>
<td>Control Point Surveys</td>
<td>Gahagan &amp; Bryant Assoc.</td>
</tr>
<tr>
<td>Position of Resistivity Staffs</td>
<td>Gahagan &amp; Bryant Assoc.</td>
</tr>
<tr>
<td>Tidal Sedimentation via Resistivity Staff Data*</td>
<td>SP Surveys*</td>
</tr>
<tr>
<td>Tidal Sedimentation via Interior Mudflat Transects</td>
<td>PWA</td>
</tr>
<tr>
<td>Subsidence Surveys</td>
<td>PWA</td>
</tr>
<tr>
<td>Establishment of Marsh Vegetation</td>
<td>Phyllis Faber and Associates</td>
</tr>
<tr>
<td>Presence and Abundance of Bird Species</td>
<td>Avocet Research Associates*</td>
</tr>
<tr>
<td>Benthic Macroinvertebrate Establishment</td>
<td>Entrix Inc.</td>
</tr>
<tr>
<td>Fish Usage</td>
<td>Entrix Inc.</td>
</tr>
</tbody>
</table>

*data collection did not occur during the monitoring period
Table 3. Sonoma Baylands Monitoring Report History

<table>
<thead>
<tr>
<th>Report No.</th>
<th>Monitoring Period</th>
<th>Data Collected</th>
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</thead>
<tbody>
<tr>
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<td>OCTOBER 1994 – JULY 1996</td>
<td>EXTERIOR CROSS SECTIONS</td>
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<td></td>
<td>Tidal Monitoring</td>
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<tr>
<td></td>
<td></td>
<td>Water Quality Monitoring</td>
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<tr>
<td></td>
<td></td>
<td>Vegetation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aerial Photographs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>START SP Surveys Resistivity Monitoring (reported directly to ACOE)</td>
</tr>
<tr>
<td>2</td>
<td>JULY 1996 – SEPTEMBER 1997</td>
<td>EXTERIOR CROSS SECTIONS</td>
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<tr>
<td></td>
<td></td>
<td>START Interior Transect Monitoring</td>
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<tr>
<td></td>
<td></td>
<td>Tidal Monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water Quality Monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>START Photo Documentation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gahagan &amp; Bryant Surveys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Faber Vegetation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Avocet Birds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Entrix Benthic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO SP Surveys Resistivity</td>
</tr>
<tr>
<td>3</td>
<td>MARCH 1998 – JUNE 1998</td>
<td>Exterior Cross Sections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interior Transect Monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>START Peninsula Centerline Surveys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tidal Monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STOP Water Quality Monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Photo Documentation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO Aerial Photographs</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Entrix Benthic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO SP Surveys Resistivity</td>
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</tbody>
</table>

Final to ACOE and Coastal Conservancy in September 1998.

Note odd monitoring period coverage up to this point. ACOE starts “regular scheduled monitoring periods at this point.”
<table>
<thead>
<tr>
<th>Report No.</th>
<th>Monitoring Period</th>
<th>Data Collected</th>
</tr>
</thead>
</table>
| 4          | MARCH 1999 – OCTOBER 1999 (Includes Fall 1998 data) | EXTERIOR CROSS SECTIONS
Interior Transect Monitoring
Peninsula Centerline Surveys
Tidal Monitoring
PHOTO DOCUMENTATION
Aerial Photographs
Pilot Unit Channel Excavation
Gahagan & Bryant Surveys
Faber Vegetation
Avocet Birds
Entrix Fish and Benthic
SP SURVEYS RESISTIVITY |
| 5          | MARCH 2000 – DECEMBER 2000 | EXTERIOR CROSS SECTIONS
START Main Unit Exterior Mudflat Cross Section
Interior Transect Monitoring
Peninsula Centerline Surveys
Tidal Monitoring
PHOTO DOCUMENTATION
NO Aerial Photographs
Gahagan & Bryant Surveys
Faber Vegetation
Avocet Birds
Entrix Fish and Benthic
SP SURVEYS RESISTIVITY |
| 6          | MARCH 2001 – DECEMBER 2001 | EXTERIOR CROSS SECTIONS
Main Unit Exterior Mudflat Cross Section
Interior Transect Monitoring
STOP Peninsula Centerline Surveys
Tidal Monitoring (START year round monitoring)
Photo Documentation
NO Aerial Photographs
Gahagan & Bryant Surveys
Faber Vegetation
Avocet Birds
Entrix Fish and Benthic (Fall monitoring only, due to late contract signing with ACOE)
NO SP Surveys Resistivity |
<table>
<thead>
<tr>
<th>Report No.</th>
<th>Monitoring Period</th>
<th>Data Collected</th>
</tr>
</thead>
</table>
| 7         | JANUARY 2002 – DECEMBER 2002 | Exterior Cross Sections  
Main Unit Exterior Mudflat Cross Section  
Interior Transect Monitoring  
Tidal Monitoring (year round monitoring)  
Photo Documentation  
Aerial Photographs  
Gahagan & Bryant Surveys  
Faber Vegetation  
NO Avocet Birds  
Entrix Fish and Benthic (Spring monitoring only, as part of 2001 budget)  
NO SP Surveys Resistivity |

Draft to ACOE in April 2003.
2. TIDAL CHANNEL GEOMETRY SURVEYS

The primary objectives of the outboard tidal channel geometry surveys are:

- To characterize the current geometry of the outboard slough channels and relate changes in width and depth to tidal prism changes and marsh formation within both sites.
- To characterize the rate and pattern of channel erosion within these slough channels.
- To identify areas which are not eroding at expected rates.

2.1 METHODS

Each cross section is tied into a local benchmark for elevation control. The local cross section benchmarks are resurveyed annually, prior to each cross section survey (see Section 5 for more detail on site control points [Figure 12]). Each cross section is marked by a monumented endpoint (at each end of the cross section), which consists of a pipe driven into the marshplain with a flange attached at the top.

Cross section elevations (marshplain, slope breaks, channel banks and bottom) are recorded using a multi-parameter recording total station that records elevation and stationing as the rod-person traverses the cross section.

2.2 SURVEY LOCATIONS AND DATES

2.2.1 Pilot Unit

To document changes in slough channel geometry, PWA surveyed pre-breach cross sections at three locations between the breach and the Petaluma River (XS 1, 9 and 6; Figure 3) on the outboard tidal slough channel. Tidal action from San Pablo Bay enters the Pilot Unit through this 1,800-foot tidal slough channel. PWA also surveyed cross sections of other slough channels that might be affected by the Pilot Unit restoration (XS 2, 4, 5a and 5b; Figure 3) and a nearby reference slough channel unaffected by the restoration (XS 7; Figure 3). Cross sections along the outboard tidal slough channel and on nearby control channels in the outboard marsh were surveyed in April/May 2002 and September 2002 (Table 4). Resurveys of these outboard slough channels (Pilot and Main units) have been conducted since monitoring began in 1994.
### Table 4. Tidal Channel Survey Summary

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</thead>
<tbody>
<tr>
<td><strong>Pilot Unit</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>ndc</td>
<td>2/12, 7/16</td>
<td>2/13</td>
<td>6/10, 9/22</td>
<td>3/19, 10/24</td>
<td>4/9, 9/10</td>
<td>3/24, 10/18</td>
<td>4/11, 9/13</td>
<td></td>
</tr>
<tr>
<td>11 (Breach)</td>
<td>ndc</td>
<td>ndc</td>
<td>ndc</td>
<td>3/29, 8/6</td>
<td>6/10, 9/30</td>
<td>3/24, 10/28</td>
<td>4/9, 10/7</td>
<td>3/24, 10/31</td>
<td>4/24, 10/18</td>
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<td>ndc</td>
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<td>4/17, 10/18</td>
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<tr>
<td><strong>Main Unit</strong></td>
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</tr>
<tr>
<td>8</td>
<td>ndc</td>
<td>8/6</td>
<td>3/14, 9/22</td>
<td>3/31, 10/13</td>
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<tr>
<td>12</td>
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<td>11/4</td>
<td>3/14, 9/30</td>
<td>3/26, 10/23</td>
<td>4/7, 10/6</td>
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<td>ndc</td>
<td>8/6</td>
<td>3/14, 9/30</td>
<td>3/31, 10/13</td>
<td>4/7, 10/6</td>
<td>3/29, 10/16</td>
<td>4/10, 10/2</td>
<td>4/12, 10/9</td>
</tr>
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<td>3/14, 9/30</td>
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<td>3/29, 10/18</td>
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<td>4/16, 10/9</td>
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<td>3/14, 9/30</td>
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<td>4/4, 11/01</td>
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<td>4/16</td>
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<td>3/31, 10/23</td>
<td>4/7, 10/6</td>
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<td>4/12, 10/9</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** ndc = No Data Collected

In addition to tidal channel cross sections, one cross section through the breach (XS 11) was established to monitor breach geometry changes as the site evolves and reaches an equilibrium.

A thalweg profile was established to track the channel bottom elevation from the San Pablo Bay Mudflat, and up into each site. A survey point is recorded approximately every 50 feet along the channel to track the rate of scour (or deposition) as the tidal prism increases with the natural evolution of the site.

#### 2.2.2 Main Unit

Tidal action enters the Main Unit through a 1,000-foot natural tidal slough channel that flows directly to San Pablo Bay across the outboard marsh (Figure 2). To document changes in slough channel geometry, PWA surveyed pre-breach cross sections at three locations between the breach and San Pablo Bay (XS 8, 15 and 13; Figure 3). PWA also established cross sections on other slough channels that might be affected by the restoration (XS 12 and 14). All cross sections along this channel and on nearby control
channels in the outboard marsh were surveyed in April 2002, and October 2002 (Table 4). The location of the breach cross section (XS 16) and the slough channel thalweg longitudinal profile is also shown in Figure 3. The first survey of the longitudinal profile established baseline conditions and was performed before the breach on October 1, 1996.

Before this monitoring period, these surveys last occurred on October 2, 2001; a detailed description and analysis of this data is located in the “2001 Final Annual Monitoring Report #6”. Table 4 outlines the history of surveys at each monitoring location.
3. TIDE ELEVATIONS

The primary objectives of measuring and recording tidal elevations within both units and in San Pablo Bay are:

- To compare tidal elevations within the sites to tidal elevations in San Pablo Bay and relate these data to the hydraulic conveyance of the tidal channels.

- To relate tidal elevations within the sites to marshplain formation.

- Eventually to relate tidal elevations to vegetation establishment within the sites.

3.1 METHODS

Continuous water level measuring stations consisted first, of an Instrumentation Northwest (INW) stainless-steel submersible pressure transducer (model #PS9800), and then a transition to a Druck titanium submersible pressure transducer (model #PTX 1830), inside a 3-inch, perforated aluminum stilling well. The stilling well was vibrated into the mud until refusal and a lock box was bolted to the top of the well, above the highest water level. The pressure transducer was placed inside the stilling well and connected by cable to the data logger, which was located within the lock box. The data loggers were programmed to record one sample every ten minutes.

Typically, the data loggers were downloaded after one month of recording; a spreadsheet program was used to tabulate and plot the accumulated data. Quality control of the electronic measurements were made at the time of downloading and included a visual observation of the tide gage to check for equipment degradation, an open air calibration reading, and a water surface elevation survey to check for instrument drift.

The elevation of the pressure transducers were surveyed into the 1929 NGVD datum from the site vertical control described in Section 5. For each data record, all measurements were adjusted by the difference between the gage datum and NGVD in order to convert the measurements to feet NGVD.

Over the years, several problems were encountered during the sampling periods that resulted in data loss. The most common problems were the clogging of the stilling well with sediment and the fouling of the sensor heads. Suspended sediment in the water column, deposition in the station location, channel migration and small aquatic organisms repeatedly clogged the sensor heads at several of the stations. Furthermore, the salinity levels in the marsh are significant enough that over the long time periods of sampling, corrosion of the sensor heads had occurred. In order to eliminate these issues, PWA field personnel transitioned from the INW stainless-steel models to a more robust titanium-based sensor (Druck) for long term monitoring. This type of sensor carries a five-year warranty against salt-water corrosion.
corrosion. In addition to this monitoring change, PWA field personnel increased site visits to service and clean the sensor heads.

During the 2000 and 2001 monitoring seasons, PWA experimented with the use of a non-contact acoustic water level sensor at the main unit breach. This monitoring device eliminates fouling due to sediment, aquatic organisms and salinity corrosion. However, it was found that the acoustic sensor was affected by changes in the ambient air temperature. It was then decided to resume tidal monitoring with submersible pressure transducers. Data collected between the dates of 4/6/2000 and 6/5/2001 were included within the results provided in Figure B-21. However, data collected between the dates of 6/6/2001 through 8/2/2001 were not included in the final results due to temperature fluctuations in the data.

3.2 TIDE STATION LOCATIONS AND DATES

2002 was the first year of continuous, year round tide monitoring. Throughout the year, a total of three stations were used to collect water surface measurements. The locations of all measuring stations are shown in Figure 8. Table 5 lists the dates of deployment for each location. One of the locations, the Railroad (RR) bridge station, was located outside the site at the mouth of the Petaluma River. Tide data was collected for two weeks during spring and fall monitoring.

3.2.1 Pilot Unit

There is one measuring station in the Pilot Unit, located near the breach (Figure 8). This is now a permanently maintained station.

As part of the regular maintenance program for this tide station, periodic location adjustments are necessary due to the evolving interior tidal channel. The PWA field team made an effort to maintain the tide gage within the deeper waters of the channel. Due to channel migration, the location of the station has been moved to keep the station within the channel thalweg.

3.2.2 Main Unit

There are currently two measuring stations in the Main Unit: the northeast station and the new Main Unit breach station (Figure 8). The new Main Unit breach station was relocated approximately 150 yards north of the old location in November 1998. This relocation was necessary due to sedimentation that had occurred at the old location. The USGS bridge station was abandoned in 2002 because the channel has widened sufficiently to destroy the bridge.

3.2.3 Control

A tide gage is installed outside of the project site on the Petaluma River railroad bridge to show the amount of tidal dampening within the project site. Predicted tides from the Presidio Gage located on the Golden Gate Bridge (station ID 9414290) are also used as control. During Spring monitoring the RR bridge station stilling well became clogged with sediment thereby corrupting the data set.
Sonoma Baylands
Water Level Recording Stations

= water level recording stations

northeast station

Main Unit

Pilot Unit

new main unit breach station

old main unit breach station

USGS bridge station

Outboard Marsh

San Pablo Bay

Petaluma River

RR bridge station
<table>
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<tr>
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<td>9/3 - 10/12</td>
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<tr>
<td>Main Unit</td>
<td>150' N of breach in thalweg of developing M.U. interior channel</td>
<td>11/5 - 12/12</td>
<td>1/17 - 2/14</td>
<td>1/1 - 1/21</td>
<td>5/11 - 7/1</td>
<td>4/22 - 6/4</td>
<td>1/23 - 5/18</td>
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<tr>
<td>RR Bridge</td>
<td>On Petaluma River RR bridge, 8th trestle from riverleft.</td>
<td>11/4 - 12/31</td>
<td>1/1 - 2/14</td>
<td>1/1 - 1/25</td>
<td>3/26 - 7/1</td>
<td>5/10 - 7/20</td>
<td>1/1 - 2/7</td>
<td>4/5 - 5/9 (data corrupted) 9/11 - 10/1</td>
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<td>12/6 - 12/31</td>
<td>2/12 - 3/30</td>
<td>12/4 - 12/21</td>
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<td>11/24 - 12/31</td>
<td>4/3 - 5/4</td>
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<td>12/4 - 12/21</td>
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<tr>
<td>Pilot Unit</td>
<td>In thalweg of P.U. interior channel near breach.</td>
<td>2/5 - 11/1</td>
<td>12/31 - 3/3</td>
<td>1/1 - 1/21</td>
<td>1/29 - 3/9</td>
<td>3/24 - 6/6</td>
<td>1/23 - 5/18</td>
<td>1/1 - 12/31</td>
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<td>12/6 - 12/31</td>
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<td>11/25 - 12/21</td>
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4. SEDIMENTATION AND SUBSIDENCE

Twelve interior transects (Figure 11) were established to determine the amount of sedimentation and/or erosion occurring on the interior mudflats. The primary objective of the interior mudflat surveys is to track the evolution (sedimentation) of the mudflats, which ultimately control the evolution of the tidal drainage system, vegetation establishment and, in the end, biotic usage.

There are currently enough surveys in the database to start tracking seasonal patterns in sedimentation/erosion.

4.1 METHODS

Elevations and horizontal position data were collected with a total station set up over a known benchmark on the levee crest near each transect. Eastings, northings and elevations were recorded for each position along the transect (refer to Section 5).

A two-person rod crew in a small boat utilized a rigid 12-inch diameter disk fitted to the bottom of the prism rod to reduce penetration of the rod into the soft sediment. Flagged range poles and resistivity staffs were used to keep the rod crew in line along each transect.

4.2 SURVEY LOCATIONS AND DATES

Table 6 lists the dates of all interior transect surveys for the Pilot Unit and Main Unit. Figure 11 shows the locations of each transect.

4.2.1 Pilot Unit

Interior Transects 1, 3 and 6 within the Pilot Unit, have been measured since 1997. Interior Transect 6 crosses the recently formed interior tidal channel within the Pilot Unit.

4.2.2 Main Unit

The Main Unit contains three transects, Interior Transects 12, 16 and 20, that have been monitored twice a year since 1997. Six new transects, Interior Transects 7, 12a, 13s, 13n, 20a, and 20b, were added to the comprehensive monitoring program in the Main Unit in 1998.
Table 6. Interior Transect Survey Summary

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<tbody>
<tr>
<td><strong>Pilot Unit</strong></td>
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<tr>
<td><strong>Main Unit</strong></td>
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<tr>
<td>13n+s</td>
<td>ndc</td>
<td>ndc</td>
<td>ndc</td>
<td>ndc</td>
<td>October</td>
<td>April, Oct.</td>
<td>ndc</td>
<td>April</td>
<td>May, Sept.</td>
</tr>
</tbody>
</table>
Figure 11

Sonoma Baylands
Interior Transects

= interior transects location
= resistivity staffs location

San Pablo Bay
Outboard Marsh
Pilot Unit
Interior Levee
Main Unit
Levee Road
Perimeter Levee

SONOMA BAYLANDS 1998 interior transects .cdr
5. BENCHMARK AND RESISTIVITY STAFF ELEVATIONS

The Sonoma Baylands site has seven elevation control points throughout the site (Figure 12). All surveys (outboard marsh cross sections, thalweg profiles and interior transects) and tidal elevation data are tied into these elevation control points.

Once a year, these control points are re-leveled to establish new elevations; control points in this area are subject to either subsidence or upheaval.

5.1 BENCHMARKS

5.1.1 Methods

On January 31 and February 1, 2002, Gahagan & Bryant Associates, Inc., in conjunction with their joint venture partner, NorthStar Engineering, performed a survey of these seven permanent elevation benchmarks to establish the current elevations. The seven existing benchmarks and the corresponding locations and elevations are listed in Table 7.

The basis of the survey used to establish elevations at the seven benchmarks was the US Coast and Geodetic Survey benchmark ("Tidal 8", elevation +6.16 feet NGVD 29) located at the east abutment of the Petaluma River Railroad Bridge (Figure 12). A differential level circuit was performed, tying the seven benchmarks into the “Tidal 8” benchmark.

Cross sections, channel thalweg profiles, interior transects, and tidal heights were referenced to feet NGVD 1929 using these seven benchmarks and control points established by Gahagan and Bryant during their level circuit. As the DTM (Section 11) also required horizontal control, PWA survey crews set up a network of control points within the site based on the Gahagan and Bryant surveys. All horizontal coordinates were founded on the State of California Coordinate System, Lambert Conformal Projection, Zone III.

Section 2.1 describes the process of leveling an elevation to all cross sections, interior transects, and tidal monitoring stations at the time of each bi-annual survey. Figure 12 illustrates the line of levels taken from the main site control points to all of the monitoring locations.

5.1.2 Results

Table 7 shows the results of the Gahagan and Bryant 2002 level-line survey of all site control points. The power tower footing control points continue to subside. Monuments A, B and C were disturbed due to the railroad right-of-way maintenance between the 1999 and 2000 surveys.
Sonoma Baylands
Site Benchmarks

* Dashed lines indicate level loops from primary to secondary benchmarks
Table 7. Sonoma Baylands Wetland Demonstration Project — Control Benchmarks
Basis of Survey: US Coast and Geodetic Survey Benchmark "Tidal 8", el. +6.16 feet NGVD29; located at the east abutment of the railroad bridge over the Petaluma River. All elevations have been corrected to this survey benchmark elevation.

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</thead>
<tbody>
<tr>
<td>A</td>
<td>596052.749</td>
<td>1427288.959</td>
<td>1.15</td>
<td>1.12</td>
<td>-1.20</td>
<td>-1.19</td>
<td>2.34</td>
<td>Bronze disk set in concrete adjacent to and north of railroad tracks; on east side of western road crossing into Sonoma Baylands site; stamped “G.B. Star Point A”</td>
</tr>
<tr>
<td>B</td>
<td>596832.358</td>
<td>1428718.067</td>
<td>0.96</td>
<td>1.03</td>
<td>0.88</td>
<td>0.96</td>
<td>0.00</td>
<td>Bronze disk set in concrete adjacent to and north of railroad tracks; near drainage culvert approximately 1,620 feet east of Monument A; stamped “G.B. Star Point B”</td>
</tr>
<tr>
<td>C</td>
<td>598952.334</td>
<td>1433276.033</td>
<td>1.12</td>
<td>1.03</td>
<td>0.88</td>
<td>0.91</td>
<td>0.21</td>
<td>Bronze disk set in concrete adjacent to and south of railroad tracks; on east side of the road crossing into Sonoma Baylands site; stamped “G.B. Star Point C”</td>
</tr>
<tr>
<td>SB1</td>
<td>594257.747</td>
<td>1426747.361</td>
<td>8.36</td>
<td>ndc</td>
<td>8.19</td>
<td>8.21</td>
<td>0.15</td>
<td>Bronze disk set in concrete on bayfront levee crest; southwest of pump station at south end of western drainage channel at Sonoma Baylands site; stamped “6 TRONOFF”</td>
</tr>
<tr>
<td>North PG&amp;E Tower</td>
<td>13.08</td>
<td>12.85</td>
<td>12.69</td>
<td>12.56</td>
<td>0.52</td>
<td>Scribed 2” x 2” cross on top of concrete cross brace on south side of transmission tower located on Peninsula 5 within the Sonoma Baylands site.</td>
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<tr>
<td>Middle PG&amp;E Tower</td>
<td>13.04</td>
<td>12.81</td>
<td>12.66</td>
<td>12.53</td>
<td>0.51</td>
<td>Scribed 2” x 2” cross on top of concrete cross brace on southwestern side of transmission tower located on Interior Levee within the Sonoma Baylands site.</td>
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<tr>
<td>South PG&amp;E Tower</td>
<td>12.09</td>
<td>11.83</td>
<td>11.65</td>
<td>11.49</td>
<td>0.60</td>
<td>Scribed 2” x 2” cross on top of concrete cross brace on south side of transmission tower located on Interior Levee (marked “Elev. = 12.69”) within the Sonoma Baylands site.</td>
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</table>
It should be noted that the PWA Field Team did not use the Monument A or B control points for year 2002 surveys.

These elevation changes do not have an impact on site surveys because the basis for all site control, Tidal benchmark “8”, is on a stable concrete pylon which is normally not subject to subsidence. These elevation losses are typical for a newly constructed site and are expected to stabilize over time (Jack Fink, Pers. Com., 1999).

5.2 RESISTIVITY STAFF ELEVATIONS

5.2.1 Methods

In addition to the seven benchmarks, the current vertical position of the 21 resistivity staffs within the project area were also surveyed (Figure 11). Using the previously established benchmark elevations, elevation readings of the 10-foot markings of the staff gauge strips were taken, using a small, shallow draft boat.
6. FISH SAMPLING

6.1 METHODS AND SAMPLING LOCATIONS

Fish surveys were conducted in the tidal channels to the Pilot Unit and Main Unit on April 15, 2002. Collections were made using a beach seine (4 feet x 20 feet) with a 1/8\textsuperscript{th}-inch mesh size. At each of the sample sites, replicate seine hauls were collected until no additional species were collected in the site area. During ebb tides, to the extent practicable, seine hauls were made at slack tide. When this was not practicable, seine hauls were made in an “upcurrent” direction. The catch was identified to the lowest possible taxonomic level, enumerated and returned to the water from which it was collected.

6.1.1 Pilot Unit

The tidal channel for the Pilot Unit is approximately 35 feet wide and 1,800 feet long. The channel flows south and enters a ditch that runs roughly in an east-west direction. At the southern end of the channel, it becomes too deep (>6 feet) to sample effectively.

The Pilot Unit channel was sampled from 1215 to 1305 hours using two replicate tows averaging 35 feet in length. Sampling in this channel was complicated by fine soft substrate that made walking difficult. Sampling was confined to the end of the channel nearest the pilot unit, because the more downstream end of this channel tended to overtop the net. The channel here was approximately 30 feet wide and could not be sampled in its entirety.

6.1.2 Main Unit

The tidal channel into the Main Unit is now approximately 30 feet wide, with an approximate depth of 8 feet at mean higher high tide. The channel banks are actively sloughing, leaving large (3 – 6 foot) clods both submerged and emergent in the channel.

The Main Unit channel was sampled from 1115 to 1200 hours using two replicate tows averaging 45 feet in length. Conditions for seining were poor, due to large chunks of bank that had fallen into the channel creating an irregular bottom and a varying width of channel that could be seined. Soft silt and slick clays along the bottom also hampered sampling.
7. BENTHIC MACROINVERTEBRATE SURVEY

7.1 METHODS AND SAMPLING LOCATIONS

Benthic macroinvertebrate samples were collected within the Pilot Unit near water quality Stations 1 and 3 on April 15, 2002 and near station 6 on April 24, 2002 (Figure 13). On April 15, 2002, the sampling crew arrived before the low tide to attempt to collect benthic samples. At 0845 hours, there was sufficient water at Stations 1 and 3 to collect the samples, but by the time Station 3 was completed (1045), Station 6 was exposed. The sampling crew then returned on April 24th, to collect the benthic samples at Station 6.

Station 6 is located closest to the inlet of the tidal channel to the pilot unit, while Station 1 is located most distant from the tidal channel inlet (Figure 13). Near each water quality station, six core samples were collected at randomly selected locations within 16 feet of the designated water quality station. The cores were 2 inches in diameter and taken to a depth of 8 inches. Samples were collected near water quality Stations 1 and 3 at about 0845 hours and 1000 hours respectively on April 15th. Samples were collected near Station 6 at about 0840 hours on April 24th. The cores were sieved on site through a 1 millimeter (mm) mesh screen, and the first three cores to contain invertebrates were retained. Invertebrates from these cores were then preserved in a 10% buffered formalin solution and later transferred to a 70% ethanol solution and placed in storage. The samples were shipped to Dr. Howard Jones of Marine Taxonomic Services for identification.

For each station (1, 3, and 6), the densities (#/0.1 m$^2$) of each species and phyletic group, total density of invertebrates (sum of species densities), total standing stock (total wet weight [grams/0.1 m$^2$]), standing stock of each phyletic group, and number of species (species richness) collected were calculated. Indices for species diversity (Shannon-Weaver H’) and evenness (Pielou’s J’) (1966) were calculated according to the following formulas (Zar 1974):

$$H' = n \log n - \sum f_i \log f_i \over n$$

where,  $H'$ = Shannon-Weaver Diversity Index

$f_i$ = observed frequencies of individuals

$n$ = total number of individuals

and

$$J' = H'/\log N$$

where,  $J'$ = Pielou’s Index of Evenness

$N$ = number of species
Figure 13

Sonoma Baylands
Benthos Stations

San Pablo Bay
Outboard Marsh

Benthos Station #2
Benthos Station #6
Benthos Station #5
8. VEGETATION

8.1 METHODS AND SAMPLING LOCATIONS

Six PWA interior transects were examined for the presence of vascular vegetation (Table 18). The perimeter of the Pilot and Main project units were examined for wetland vegetative cover, and extensive cordgrass mapping was performed. Counts were made only on plants in bloom, however many small clones were visible and will likely become large enough to be included in future counts. Species distribution and condition were noted.

Sampling locations included the six transects at the perimeter of the land/water interface of the Pilot and Main Units (Figure 11) along with the cordgrass counts along the perimeter of the Pilot and Main Units.
9. PHOTO DOCUMENTATION

9.1 METHODS

A series of 46 (22 for the Pilot Unit and 24 for the Main Unit) photographic benchmarks were established to photographically document the evolution of the channels and embayments of both the Pilot and Main Units of Sonoma Baylands. The techniques used in this year’s photographic documentation were based on the principals of re-photography, also known as repeat photography—a “technique of landscape study in which a scene depicted in an earlier photograph is ‘re-photographed,’ generally after an interval of some months or years, to determine the nature of the changes that have occurred between the time of the original photograph and the time of the repeat photograph (Lambert, 1984).”

In order to provide for the opportunity of a re-photographic survey at Sonoma Baylands, detailed records were kept for each of the benchmarks and the photographs. For each benchmark the GPS latitude, longitude and elevation were recorded. In addition, a photograph was taken of the tripod set up over the benchmark to further facilitate its relocation. For each photograph the following information was recorded:

1. **Equipment**: This included the makes and models of the camera, lenses and tripod as well as the format, manufacturer, ISO and type of film;

2. **Camera Orientation**: This included the magnetic bearing, zenith and roll angles as well as the height of the camera above the benchmark (on the levees) or above the ground (in the marshplain); and

3. **Camera Settings**: This included the focal length of the lens, aperture and shutter speed.

9.2 PHOTO DOCUMENTATION STATIONS

Figure 14 displays the locations of the photographic benchmarks and the photographs that are presented in this report.
**figure 14**

Sonoma Baylands
Photographic Benchmarks

- **PBM PUP 1** = photographic benchmark - photographs presented in Appendix G
- **XS3** = outboard cross section location

Pilot Unit

Main Unit

Interior Levee

Perimeter Levee

San Pablo Bay

Outboard Marsh

Sonoma Baylands

Photographic Benchmarks
10. DIGITAL TERRAIN MODEL (DTM)

Year 2002 Monitoring was extended to include the production of a Digital Terrain Model (DTM). The primary objective of the DTM is to calculate volumetric changes of sediment over time. This gives us an estimate of the amount of accretion or erosion of sediment throughout the site, which can be invaluable when looking at vegetation establishment and channel formation. The Year 2002 DTM is the first step in this process; this survey will be compared to future DTM’s to calculate changes in sediment volumes.

10.1 METHODS

Creation of the DTM began with an extensive elevation survey of all existing benchmarks within the site (Section 5). As the DTM also required horizontal control, PWA survey crews set up a network of control points based on the Gahagan and Bryant surveys. All horizontal coordinates were founded on the State of California Coordinate System, Lambert Conformal Projection, Zone III.

10.1.1 Pilot Unit Surveys

Detailed surveys of the Pilot Unit included interior transect surveys (Section 4), contours of levees, peninsulas, scarps, pickleweed and cordgrass transitions, random mudflat shots and mapping the exterior tide channel. PWA survey crews also followed the exterior tide channel into the site to define the reaches of the evolving interior channel.

10.1.2 Main Unit Surveys

Due to the size of the Main Unit and budget restrictions, the Main Unit DTM survey was not nearly as detailed as that in the Pilot Unit. Main Unit interior transect surveys (Section 4) were supplemented with additional survey points on the mudflats and along the peninsulas. A concentrated effort was made in the vicinity of the breach where channelization of the mudflat is beginning.

10.1.3 DTM Development

PWA DTM surveys were imported into CAD graphing software. According to survey notes, selected survey points at grade breaks were connected by 3-dimensional lines to form break lines which facilitated generation of the DTM. The remaining survey points acted as spot elevations to further refine the DTM network.

2002 infrared aerial photography was scanned and overlayed in the CAD survey file. The infrared photo was then rubbersheeted to match the ground survey. It should be noted that raw aerial photo data was not rectified to the geographic coordinate system and contains inherent errors due to camera lens distortion and image centering. This rubbersheeting technique uses multiple match points to stretch the image and match known ground points, contorting individual pixels in the image like a rubber sheet, resulting in an
approximate correlation to the geographic coordinate system. Water surface elevations (Section 10) were digitized from the aerial photo and used as additional break lines in the DTM.

Using the above survey and photo data, the DTM was compiled and draft contours were generated. The draft contours were inspected to identify anomalies and provide feedback to locate additional required break lines. DTM compilation and contour generation was iterated until the topography smoothed out to natural landforms.

The DTM in the Pilot Unit had a much more extensive ground survey and is considered more accurate than the Main Unit DTM. The Main Unit DTM provides a good approximation of the topography, which utilized interpolated cross section data and approximate aerial photography data. Also note the development of the DTM was more focused on accurately showing the elevations of the tidal flats and the channels within the tidal flats. Elevations and shapes of the tops of peninsulas were estimated.
11. REFERENCES


National Weather Service website @ www.nws.mbay.net/sf_rain1.html (download date: 4/28/98).


11/12/03


