

# A STANDARD OPERATING PROCEDURES MANUAL FOR THE COASTWIDE REFERENCE MONITORING SYSTEM-*WETLANDS* AND THE SYSTEM-WIDE ASSESSMENT AND MONITORING PROGRAM:

Methods for Site Establishment, Data Collection, and Quality  
Assurance/Quality Control

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## CONVERSION FACTORS, NON-SI TO SI UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric units) as follows:

<b>Multiply</b>	<b>By</b>	<b>To Obtain</b>
acres	0.4047	hectares
Fahrenheit degrees	5/9	Celsius degrees <sup>1</sup>
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. statute)	1.6093	kilometers
square inches	6.4516	square centimeters

<sup>1</sup>To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula:  $C = (5/9) (F - 32)$ .



## ACRONYMS/ABBREVIATIONS USED IN DOCUMENT

Acronym/Abbreviation	Term/Concept it Represents
CA	Copper Azole
CCA	Chromate Copper Arsenate
CIMS	Coastal Information Management System
CIR	Color Infrared
CPRA	Coastal Protection and Restoration Authority
COC	Chain of Custody
CR	Continuous Recorder
CRMS	Coastwide Reference Monitoring System- <i>Wetlands</i>
CST	Central Standard Time
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
DBH	Diameter at Breast Height
DCA	Data Collection Area
DI	Deionized or Distilled
DOQQ	Digital Orthophoto Quarter-Quadrangles
EC	Electrical Conductivity
EPA	U.S. Environmental Protection Agency
FAV	Floating Aquatic Vegetation
GIS	Geographic Information System
GPS	Global Positioning System
LCZ	Louisiana Coastal Zone
LOI	Loss On Ignition
LRS	Land Rights Section
mNDWI	modified Normalized Difference Water Index
NAD83	North American Datum, 1983
NAVD88	North American Vertical Datum, 1988
NIR	Near Infrared
PDF	Portable Document Format
PSV	Preliminary Site Visit
PVC	Polyvinyl Chloride
QA/QC	Quality Assessment/Quality Control
RSET	Rod Surface Elevation Table
RTK	Real-Time Kinematic
SAV	Submerged Aquatic
SET	Surface Elevation Table
SM	Secondary Monument
SOP	Standard Operating Procedure
SWAMP	System Wide Assessment and Monitoring Program
TBM	Temporary Benchmark
USGS	United States Geological Survey
VA	Vertical Accretion
VNIR	Very-Near Infrared
WQMN	Water Quality Monitoring Network
UTM	Universal Transverse Mercator coordinate system

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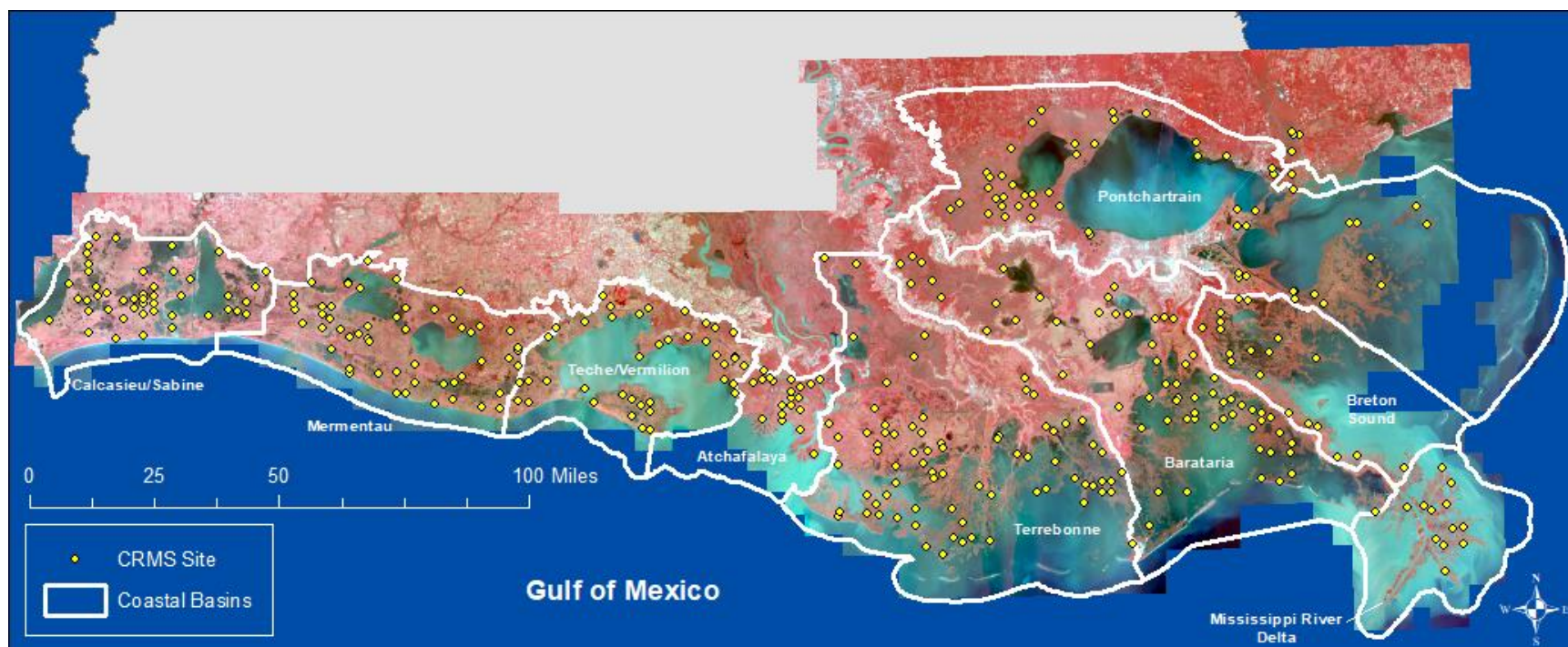
## 1. Introduction

Coastal Louisiana is experiencing a loss of more than 15 square miles of land per year. Since the 1930's, over 1,883 square miles of valuable wetland habitat have disappeared (Couvillion et al. 2011). In response to this loss, a multi-agency task force, comprised of federal and state government sponsors, created the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) of 1990 to conserve, restore, create, or enhance coastal wetlands. Through CWPPRA and various other funding sources, the Coastal Protection and Restoration Authority of Louisiana (CPRA) maintains a monitoring program with the mission of providing ecological data and research to support the planning, design, construction, evaluation, and adaptive management of Louisiana's wetland restoration projects.

In 2004 the Coastwide Reference Monitoring System-*Wetlands* (CRMS) was implemented to improve the monitoring program's capability to evaluate the effectiveness of individual restoration projects, as well as the combined effects of multiple projects, by providing a network of reference sites to compare to project sites (Figure 1.1) (Steyer et al. 2003). Because CRMS was designed to determine the ecological condition of all Louisiana wetlands, not just those affected by projects, CRMS also provides the opportunity to evaluate whether whole ecosystems are being restored. Thus, the effectiveness of landscape-scale restoration strategies can also be determined.

Developed in 2013, the System-Wide Assessment and Monitoring Program (SWAMP) encompasses several ongoing and proposed coastal data collection activities, including CRMS, which support the development, implementation, and adaptive management of the Louisiana coastal protection and restoration program. Data needs include additional parameters to support new predictive modeling tools and integrated program assessment to support the development, refinement, and implementation of the integrated coastal Master Plan. SWAMP components of expanded water quality and vegetative biomass data collection are included in this SOP.

The main purpose of this manual is to provide standardization of the scientific methods and quality control procedures used by the CPRA monitoring program and its contractors in order to produce high-quality, scientifically defensible data for the Coastwide Reference Monitoring System (Bass et al. 2003). In addition, it provides guidance for establishing, constructing, and maintaining CRMS field stations. This manual replaces Folse and West (2005) and its subsequent revisions (Folse et al. 2008 rev 2012, 2018). Even though the intended use of these methods and protocols is for CRMS and SWAMP, many of the same methods can be used in smaller-scale, more focused monitoring efforts related to specific restoration projects (i.e., project-specific monitoring).



**Figure 1.1** Map depicting sites in the CRMS monitoring network and Louisiana's nine coastal basins.

## 2. Site Establishment and Construction

The 392 CRMS sites were randomly selected from nearly 7,000 potential coastal wetland stations using a stratified random design (Steyer et al. 2003) where sites were allocated to major coastal wetland types (fresh, intermediate, brackish, saline, and swamp) according to distributions of those habitats (Visser and Sasser, 1998). CPRA, then Louisiana Department of Natural Resources, began establishing landrights for those sites and sites were rejected and reselected as needed.

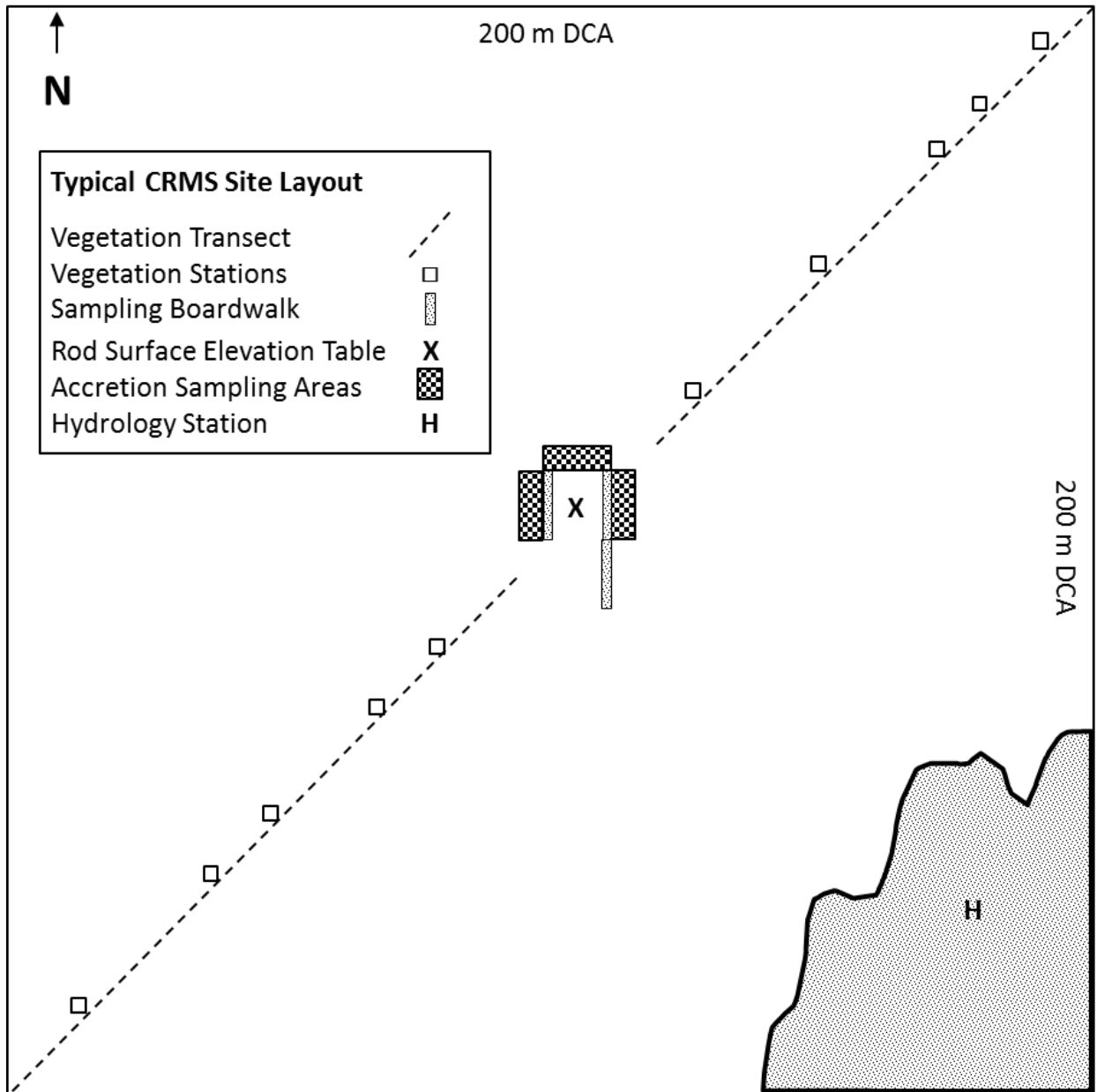
A typical CRMS site includes a hydrology station for measuring hourly water elevation and salinity, a boardwalk that provides access to stations used for measuring surface elevation change, vertical accretion, and soil porewater salinity, and a vegetation transect where vegetation community data are collected (Figure 2.1). At CRMS swamp sites, there are additional forest vegetation stations for measuring the canopy and understory along with the herbaceous layer. At CRMS floating marsh sites, the elevation change and accretion stations are typically absent and there are additional marsh mat inundation monitoring stations.

By 2009, the CRMS sites were established and stations constructed. The site construction procedures can be used for guidance on maintenance and/or replacement of constructed features.

### 2.1 Site Establishment Procedure

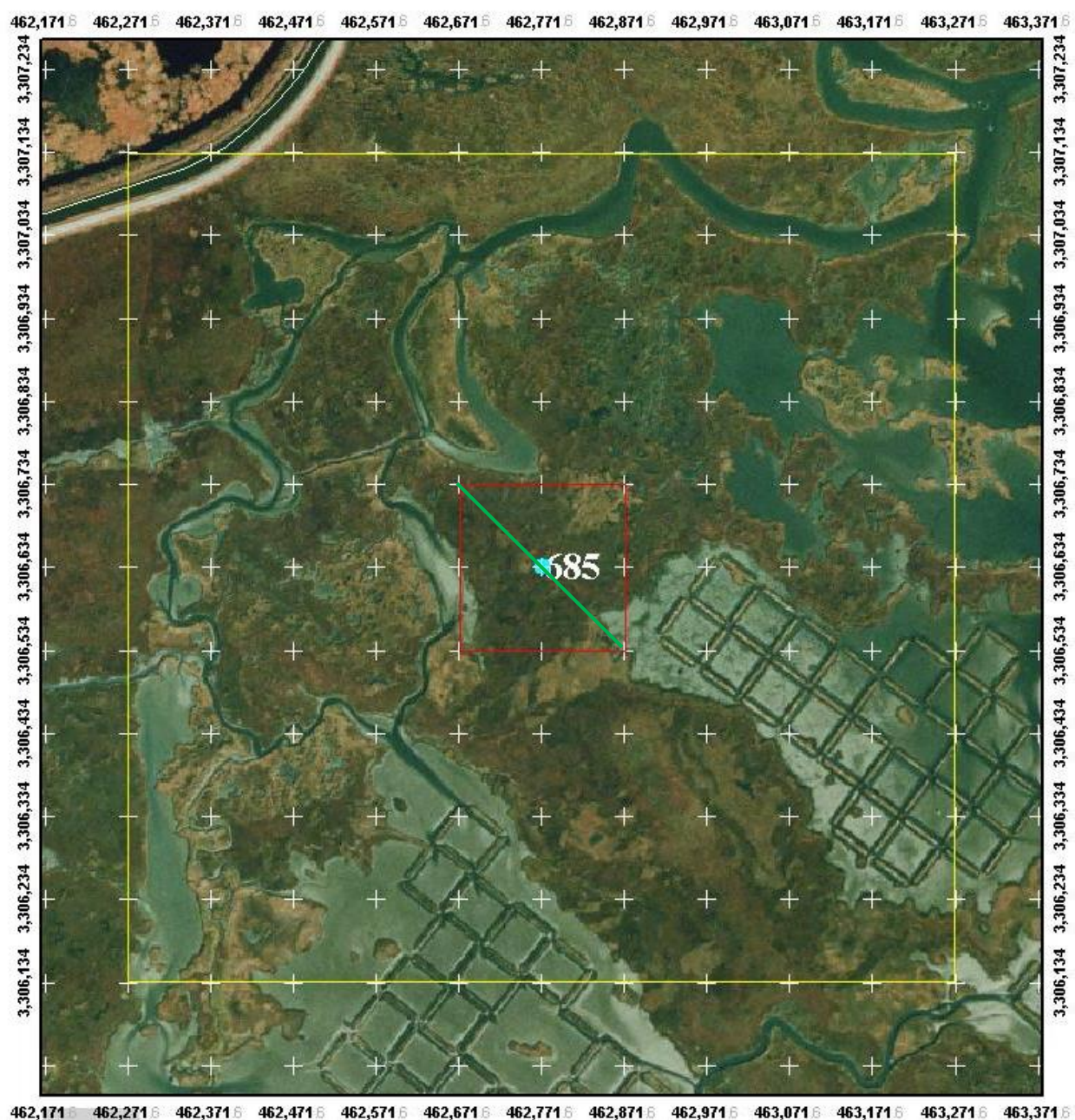
CRMS sites were established between 2006 and 2009. The CRMS program is designed for 392 sites. Sites are only moved when land rights have become compromised. The following information is a description of how sites were originally selected and constructed. A CRMS site comprises a 1-km<sup>2</sup> area (Figure 2.2) which serves as the boundary for land/water analysis. A 200-m<sup>2</sup> Data Collection Area (DCA) is identified within the 1-km<sup>2</sup> site area by utilizing the following site establishment procedures (Figure 2.1).

The original CRMS site design was for all of the data stations to be distributed across the 1-km<sup>2</sup> area. Land rights complications made it necessary to focus on a 200-m<sup>2</sup> data collection area (DCA) within the 1-km<sup>2</sup>. During site selection, attempts were made to locate the hydrology equipment and all of the monitoring stations within the 200-m<sup>2</sup> DCA as described below. Originally, if hydrology sites could not be located in “open water” here defined as a bayou, pond, lake, bay, canal, or other location hydrologically connected to the boardwalk monitoring stations, marsh wells were installed at the boardwalk in the middle of the original 1-km<sup>2</sup> area. Well data proved to be much less desirable than “open water” data, so most wells were moved to open water areas even if that meant that they were located outside of the 200-m<sup>2</sup> DCA or, in some cases, outside of the 1-km<sup>2</sup> area. Currently, 24 marsh wells remain in the CRMS network for which no alternative open-water site has been chosen.



**Figure 2.1.** Schematic of a typical CRMS site depicting the vegetation transect and vegetation stations, the sampling boardwalk with elevation change and accretion stations, and the hydrology station in an adjacent pond.





**Figure 2.2.** The 1-km<sup>2</sup> grid of 100-m squares. The yellow box represents the 1-km<sup>2</sup> area used to evaluate and choose a smaller 200-m<sup>2</sup> data collection area (DCA; red square). The green line represents a northwest to southeast vegetation transect.

After sites are randomly selected using GIS software and a land rights agreement has been established, Preliminary Site Visits (PSVs) are conducted. The purpose of the PSV is to:

- A. determine the location of a 200-m<sup>2</sup> DCA within the 1-km<sup>2</sup> site;
- B. verify marsh community type according to most recent assessment (ex. Visser and Sasser (1998)) within the 200-m<sup>2</sup> DCA;
- C. determine the station type and layout within the 200-m<sup>2</sup> DCA;
- D. document the logistics needed to access the site.

The general procedure is to investigate the site in the office using GIS software and site-specific documents (e.g., land rights and access agreements) to choose a number of potential locations for the DCA. This is done to make the field portion of the PSV more efficient. Field procedures consist of verifying the parameters above and making the final DCA selection.

**ACCESS AND LAND RIGHTS AGREEMENTS:** Travel logistics and proposed site locations can be found in the land rights packet supplied by the Land Rights Section (LRS) of the Coastal Protection and Restoration Authority (CPRA). The land rights packet includes a list of landowners and their contact information, site restrictions, directions to the site, and maps of each site. The LRS has only acquired access permission for the suggested route, and travel should be restricted to the directions and paths outlined in the packet. The LRS provides maps such as but not limited to digital orthophoto quarter-quadrangles (DOQQ) or SPOT (Système Pour l'Observation de la Terre) imagery and Tobin plat maps. These maps provide the location of the site and the surrounding land rights. In some cases, the land rights may not be determined and/or secured at the time of the visit; however, these packages must be reviewed to confirm the secured access route. It may be advantageous to utilize the most current geo-rectified imagery to supplement the maps provided by the LRS. Using this imagery in a GIS software package will enable field personnel to look more closely at the secured access route and print out maps.

### 2.1.1 Site Establishment Methods

#### 2.1.1.1 Establishing Site Location (in office)

1. Locate the potential CRMS site on a GIS map using the most current imagery and overlay the 1-km<sup>2</sup> grid of 200-m squares (Figure 2.1).

2. Determine if land rights are an issue.

Note: Some sites have two (2) or more landowners within the 1 km<sup>2</sup> but only one (1) landowner has signed an agreement. Therefore, the site must go on that owner's property.

- A. If land rights are denied or restricted:
  - a. Follow landowner restrictions and proceed to step 3.



OR

b. Reselect CRMS site following established methods.

B. If land rights are accepted, proceed to step 3.

3. Determine consistency of access to the site. Can the center point of the 1 km<sup>2</sup> be consistently accessed? Is the 200-m square >55% land, and is the center point over land? Consistent access is defined by the ability to reliably reach the beginning of the access boardwalk at least once each month by a route that will cause minimum or no long-term irreversible damage to the marsh.

A. If YES to these questions, proceed to step 4.

B. If the center point cannot be consistently accessed, proceed to step 5, "Moving the 200-m square."

C. If the center of the square is not over land or the square is not >55% land, proceed to step 5, "Moving the 200-m square."

4. Determine availability of water. Is open water available in the 200-m square for the continuous recorder? Is the water characteristic of what is influencing the marsh that will be sampled? Is it hydrologically connected to the marsh?

A. If YES to these questions, use the center 200-m square. Proceed to step 5 for backup points.

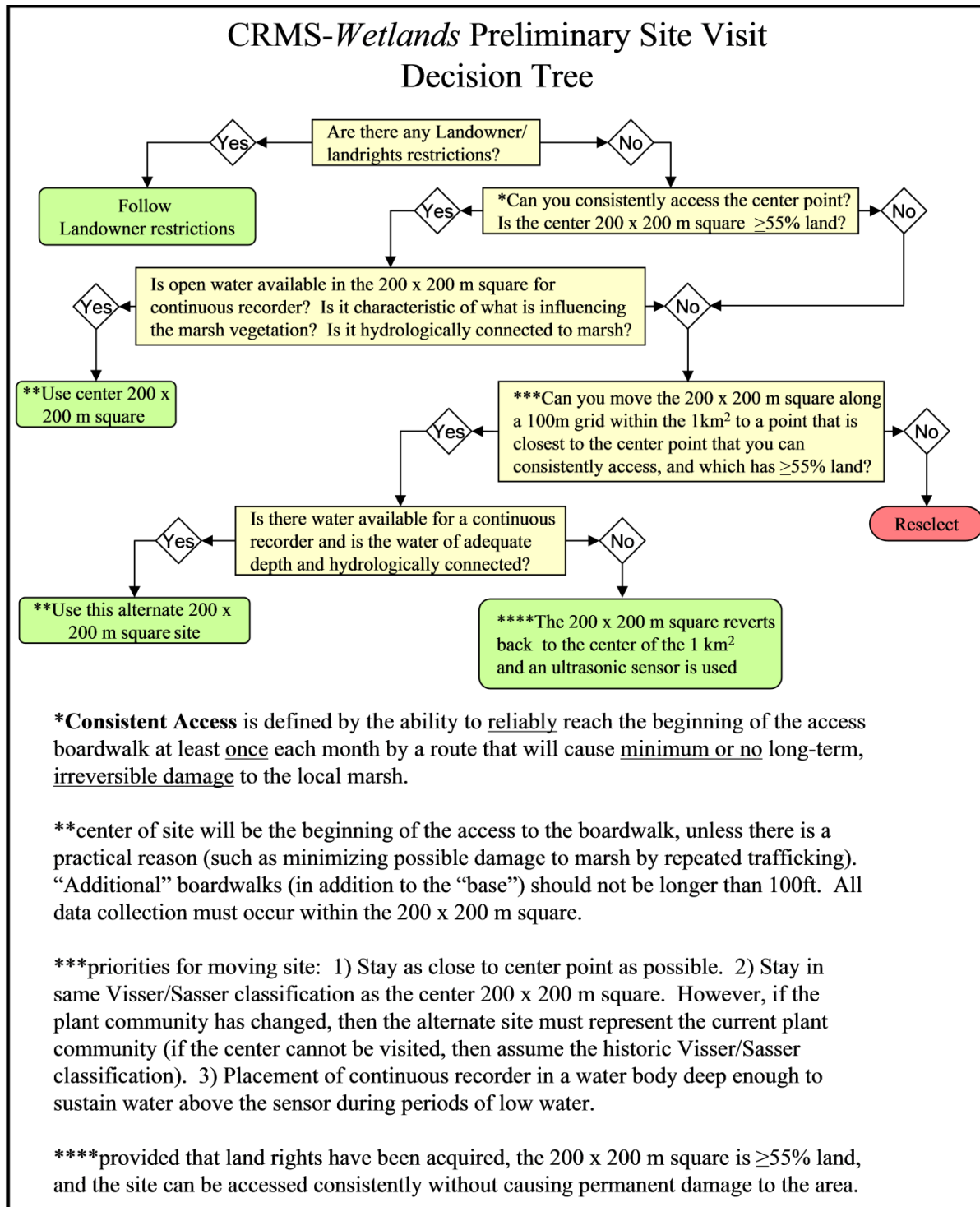
B. If there is no open water, it is not characteristic, or it is not connected, proceed to step 5, "Moving the 200-m square."

5. "Moving the 200-m square"

1. Examine the 100-m grid on the current photography (Figure 2.1).
2. Record the GPS point for the original center point of the CRMS site.
3. Select the next four possible center point locations. These center points should fall on grid nodes or be located as directed by the CPRA
4. The first attempt should be to move in the four cardinal directions from the original center point. Upon selecting any potential points, follow the above decision tree (Figure 2.3).
5. If all of these do not qualify:
  - c. The next attempt should be the diagonals connected to the original center point.
  - d. Continue outwards, selecting points that are closer to the original center first.
6. Before a new point is accepted it must fall under the same Visser/Sasser classification as the original center point or the land that is closest to it. If the original center point is no longer the same as the listed classification, then it must be reclassified.
7. Priorities for choosing a site are as follows:

## 2. Site Establishment and Construction

- a. Same Visser/Sasser classification as the original center point
    - b. Available water for sonde deployment
    - c. Minimum distance to center point
  8. If points are accepted, record their GPS location data.
  9. The four new points should be in a priority list of 1–4, with 1 being the closest to the center point and proceeding outward.
  10. If a location is acceptable except for water availability, return to the grid node that is closest to the center point and use the modified well installation.
  11. Note: Sites originally established as wells have been moved to open water sites even if those sites were located outside of the 200 m square or the 1 km<sup>2</sup> in some instances if the location was judged to be representative of site hydrology. If there are no acceptable 200-m squares within the 1 km<sup>2</sup>, reject and reselect the CRMS site location following established methods. STOP.
6. When proceeding to the field, take all five points that have been selected (the original center point and the four most acceptable alternates). Use these locations when scouting in case of land/marsh alterations that may have occurred since the photography was taken.



**Figure 2.3.** CRMS-Wetlands Site Decision Tree used to determine the placement of the 200 x 200-m site within the 1-km square.

### **2.1.1.2 Selecting Site Location (in field)**

Landowners should be contacted and permission to access granted prior to any site visit. Field personnel should approach the site with great care to maintain site and future data integrity.

During the site visit, field personnel should complete the “Site Characterization Sheet” (Figure 2.4a and 2.4b) and “Site Sketch Sheet” (Figure 2.4c) and photograph the area. The information provided on this data sheet will characterize the proposed site to determine if the site is suitable for the project’s overall goals and objectives. This information can also be used in the event that a site is completely destroyed and must be reestablished.

The following section provides a list of the minimum materials/equipment necessary to perform an adequate preliminary site visit and evaluation.

#### *Minimum Materials:*

1. Compass: 0° to 360° azimuth dial with 2° graduations
2. Digital camera with date stamp capabilities. Photographs should be at least 8 megapixels.
3. Measuring tape: capable of measuring 100 m (~328.1 ft)
4. GPS with sub-meter accuracy.
5. Maps
6. “Site Characterization Sheet” (Figure 2.4a and 2.4b)
7. “Site Sketch Sheet” (Figure 2.4c)
8. Pencils and pens
9. PVC poles to mark locations for infrastructure installation (e.g., boardwalk(s), continuous recorders)
10. Soil corer for floating marshes
11. Survey rod
12. Salinity meter

The following steps describe specific procedures necessary to select a site location in the field:

1. Using the LRS land rights packet, GPS coordinates, and/or other maps, travel to the center of the 200 x 200-m square site (center point), if logistically possible. Be careful not to damage the site and compromise future data.
2. Using the CRMS-*Wetlands* Preliminary Site Visit Decision Tree (Figure 2.3), determine if the proposed 200 x 200-m site is sufficient for the goal of the project. If the site is sufficient for the goal of the project, then continue to collect the necessary information needed to complete the “Site Characterization Sheet.” If the 200 x 200-m site is not sufficient, continue using the decision tree until a site is selected. The site shall be moved in 100-m increments away from

its original position while trying to keep it close to the center of the 1-km square, within the same vegetation community, and having a water body that is deep enough to continually submerge the sensors during periods of low water. Once a site has been selected, complete the “Site Characterization Sheet.”

Note: The decision tree was strictly followed when CRMS sites were constructed in 2006-2009; and, if there was no location within the 1-km sq to place the hydrology equipment in ‘open water’, then wells were deployed. Well data quality was found to be unsatisfactory, so the requirement that the sonde be within the 200-m sq was relaxed and if surface water could be identified that was hydrologically connected to the DCA, then the wells were removed and ‘open water’ stations were installed. Some CRMS sondes are outside of the 200-m<sup>2</sup> DCA and some are even outside of the 1-km<sup>2</sup> site area.

- a. Use the GPS with sub-meter accuracy unit to document the coordinates of the center point (the beginning of the base boardwalk, if the center point is relocated) and the beginning of the access boardwalk if applicable.
- b. Record the GPS coordinates (in UTM [Universal Transverse Mercator coordinate system], NAD83 [North American Datum of 1983], meters).
- c. Determine the bearing (in degrees) of the boardwalk from the access point (the access point is the center point if there is no access boardwalk and the beginning of the access boardwalk if there is one).
- d. Determine the approximate length (in feet) that the boardwalk will extend, if there will be an access boardwalk. Document this in Section 3 of the “Site Characterization Sheet.”

Note: The maximum distance of access boardwalk is 100 ft.; however, there may be exceptions with CPRA approval.

Note: PVC markers may be left at the site to mark the exact location; however, enough descriptive information should be obtained to not rely solely on the markers. It is possible that the markers may be removed by others before construction of the site begins.

Note: Sites accessed with airboats shall have a 10-ft access boardwalk to prevent or reduce the chances of damage occurring to the data collection stations.

3. Determine the orientation of the vegetation transect, northwest to southeast or northeast to southwest, and document the decision in Section 4 of the “Site Characterization Sheet.” If the transect can be placed in either direction, its orientation should be decided randomly (using flip of a coin or some other random method). Vegetation transects should not parallel any geologic feature, human-induced feature (e.g., spoil banks), or a uniform vegetation community.
4. At the center point, take a few pictures from an elevated position in various directions (N, E, S, and W) to provide a reference prior to site construction. Note each picture’s number, direction, and time stamp in Section 5 of the “Site

- Characterization Sheet.” Record the dominant vegetation species of the site in Section 6 of the “Site Characterization Sheet” and characterize the marsh condition (e.g., any notable ecological/biological attributes, evidence of nutria herbivory, noticeable causes of degradation such as saltwater intrusion, etc.) in Section 7.
5. If the site is a floating marsh, then the marsh mat must be measured to determine its thickness and the depth from the surface to the firm clay layer below the mat by coring through the marsh mat. Document these measurements in Section 8 of the “Site Characterization Sheet.” Describe any other characteristics of the mat that may be beneficial for construction and/or historical records.
  6. Briefly describe any potential problems that may arise during initial site construction or during routine sampling of the site and make any recommendations for subsequent site visits in Section 9 of the “Site Characterization Sheet.” Also, if the center point of the 1 km<sup>2</sup> is not being used, then document the reason for moving the center point and the justification for the new center point.
  7. Before leaving the site, sketch the major landscape features such as ponds, waterways, marsh/swamp, etc. (Figure 2.4c) within the 200 x 200-m square, and any other important features that would assist the construction crew in identifying the proper location for the station to be constructed. Also sketch the layout of the boardwalk and placement of stations within the square in the proper directions. Any features that are outside of the square that are relevant to the site should be placed outside of the square on the sketch.
  8. Determine the best location for the continuous recorder. Document the coordinates for its location, recommend the type of set-up needed to deploy the instrument, and describe the location (size and depth of the water body, consistency of the bottom, distance from edge of emergent vegetation, etc.). When determining the location for a continuous salinity and water level recorder, it is imperative that the water body maintains a depth that will continually submerge the sensor during periods of low water, especially during the winter months.

Upon return from the PSV, GIS software should be used to upload the sub-meter GPS coordinates for all points that were collected in the field. A map should be produced showing the site layout and locations of the sampling stations to facilitate the construction phase.

## 2. Site Establishment and Construction

<b>Site Characterization Sheet (Page 1 of 2)</b>					
Site: _____			Basin: _____		
Date and Time (CST) of Site Visit: _____			Agency: _____		
Field Personnel: _____					
Weather: _____					
<b>1. Site Location and Access:</b>					
Site Coordinates (Center Point; UTM, NAD83 Meters)			Easting: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	Northing: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	
Access: Nearest City: _____			Highway Access: _____		
Boat Ramp: _____					
Type of Water Vessel: _____					
Directions from field office: _____					
_____					
_____					
Direction from boat ramp to site: _____					
_____					
Site Restrictions: _____					
Location of Secondary Benchmark: _____					
Other: _____					
<b>2. Continuous Recorder Details:</b>					
Coordinates of Location (UTM, NAD 83 Meters)			Easting: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	Northing: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	
Recommended Set-up (Wooden post, Mono-pole, Well): _____					
Description of area [describe water body (size, depth, consistency of bottom), distance from edge, salinity]: _____					
<b>3. Boardwalk Details:</b>					
Coordinates of Access Point (UTM, NAD83 Meters)			Easting: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	Northing: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	
Direction/Bearing of Boardwalk (degrees) _____					
Approximate length of Access (Additional) Boardwalk (ft) _____					
<b>4. Site Layout Details:</b> (airboat access direction, vegetation transect orientation, RSET location, etc)					
_____					
_____					
_____					
<b>5. Photos:</b>					
<u>Number</u>	<u>Direction</u>	<u>Time Stamp</u>	<u>Number</u>	<u>Direction</u>	<u>Time Stamp</u>
_____	N	_____	_____	_____	_____
_____	E	_____	_____	_____	_____
_____	S	_____	_____	_____	_____
_____	W	_____	_____	_____	_____

**Figure 2.4a.** Site characterization sheet used during the preliminary site visit (PSV).  
Page 1 of 2.

<b>Site Characterization Sheet (Page 2 of 2)</b>	
Site: _____	Basin: _____
Date and Time (CST) of Site Visit: _____	Agency: _____
<b>6. Vegetation:</b> Dominant Species: _____ _____ Current Marsh Type: _____ Visser/Sasser Marsh Type: _____	
<b>7. Marsh Characteristics:</b> Other Species Present: _____ _____ _____ Vegetation Characteristics (average height, grazing, burning, herbivory, wrack deposition, etc): _____ _____ _____ Marsh Stability (brokenness, soil consolidation, edge shearing): _____ _____ _____ Water on Marsh (depth, salinity): _____ _____ Other: _____ _____ _____	
<b>8. Floating Marsh:</b> Recommended Set-up (Floating or Static): _____ Mat thickness (ft): _____ Distance from mat surface to firm substrate: _____ Mat characteristics: _____	
<b>9. Potential Site Problems:</b> _____ _____ _____ _____	

**Figure 2.4b.** Site characterization sheet used during the preliminary site visit (PSV).  
Page 1 of 2.

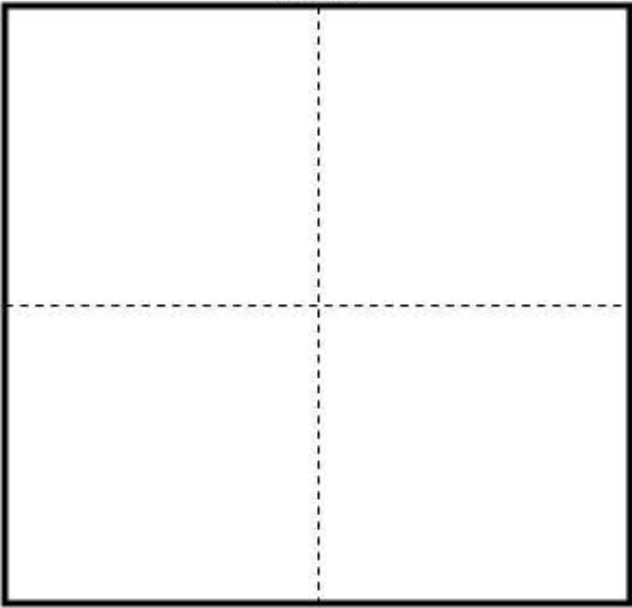


## 2. Site Establishment and Construction

**Site Sketch Sheet**

CRMS Site: \_\_\_\_\_  
 Date & Time: \_\_\_\_\_  
 Personnel: \_\_\_\_\_

Center Coordinates: Easting \_\_\_\_\_  
 Northing \_\_\_\_\_

**N**  

  
**S**

Checklist

- ☐ Compass
- ☐ Camera
- ☐ GPS
- ☐ Survey Rod
- ☐ Permanent Marker

Site Description: (Location and orientation of access route, boardwalk, SET, continuous recorder, and vegetation transect)

Notes: <div style="height: 100px; border: 1px solid black;"></div>	<div style="text-align: center; font-weight: bold; font-size: small;">LEGEND</div> <ul style="list-style-type: none"> <li>△ - Access Point</li> <li>● - Center Point</li> <li>▲ - Marsh Well</li> <li>⊗ - RSET</li> <li>■ - Continuous Recorder</li> <li>— — - Vegetation Transect</li> <li>→ → Access Route</li> <li>AB - Access Boardwalk</li> <li>BB - Base Boardwalk</li> </ul>
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**Figure 2.4c.** Site sketch sheet used to draw the layout of the proposed data collection area (DCA).

### 2.1.2 Site Establishment Deliverables

The deliverable will be a single PDF per site that is created from several sources:

1. The field-completed “Site Characterization Sheet” (Figures 2.4a and 2.4b) shall be transcribed into the Excel file used in the site selection process along with any other pertinent information obtained from the field or during the site location selection process. The Excel file shall then be converted to a PDF.
2. All downloaded pictures (.jpg images) from the field shall be viewed and the file names shall be renamed to describe the site number and direction and date of the picture (e.g., CRMS0395\_N\_03112004.jpg). The pictures shall be inserted into the PDF.
3. The field-completed “Site Sketch Sheet” (Figure 2.4c) shall be scanned and saved as a PDF. The scanned copy shall then be inserted into the PDF containing items from 1 and 2 above.
4. A layout map shall be created of the 1-km<sup>2</sup> area to a scale of 1:6,000 that shows the location of the 200-m square, the continuous recorder, orientation of the vegetation transect, the access boardwalk, and the base boardwalk. The map shall also include a north arrow, scale bar, site number, imagery information, and a unique map identification number for reproduction. The map shall be inserted into the PDF.
5. A route map shall be prepared that shows the route to be taken from the landing to the site or from another site near-by. The map shall also include a north arrow, scale bar, site number, imagery information, and a unique map identification number for reproduction. The map shall be inserted into the PDF.
6. The original field “Site Characterization Sheet” shall be scanned and inserted at the end of the PDF.
7. An electronic GPS track log shall be provided from the launch to the site. This track log shall include the entire day’s travel record.

**APPROVAL:** Once the PSV deliverable is received, the CPRA will review the land rights information, location, and site logistics. The PSV information will then be sent to the landowner for approval of the final site location. Once the PSV is approved by the CPRA and the landowner, the contractor will be given permission to begin construction of the boardwalk and install the hydrologic stations. Update CPRA with any changes in site logistics, routes, or land rights information shall be updated.

## 2.2 Site Construction

By 2009, the CRMS sites and stations were established. CRMS station construction followed these protocols which should be referenced for maintenance or replacement. Contact CPRA for updates or permission for modifications.

### *Minimum Materials:*

All lumber used for the construction of data collection structures for the CPRA shall be treated with the chromate copper arsenate (CCA) preservative, which is the only preservative recommended for brackish and saltwater usage. When considering the quantity of materials needed and the levels of retention required, the CPRA requires the following retention levels: (1) materials being placed into the soil and/or water in a brackish or saline environment shall be treated with the maximum level of retention, i.e., 2.5 pcf for saltwater environments, and (2) materials being used for decking (2" x 12") and all material being used in freshwater environments shall be treated with a 0.6 pcf rating for salt splash. For replacement, repairs, or additions to station infrastructure, follow the previous guidance for material placed into the soil and water (2.5 or 0.6 pcf CCA treated material); however, decking material (typically 2" x 12" planks) should be Copper Azole (CA) treated for Ground Contact (at least 0.15 pcf) to avoid arsenic on touched surfaces.

Recommended tools for construction include: hand saw or skill saw to cut boards, cordless drill with various size wooden bits and screwdriver heads, crescent wrenches, socket wrenches, sledgehammer, tape measure, gloves, and hammer. Note: Personal protective equipment shall be worn during all phases of material handling.

**Table 2.1.** Minimum materials list for the base boardwalks; attached and floating marsh boardwalks are a minimum of 30 feet long.

Material Type	Quantity for Attached Marsh	Quantity for Floating Marsh
2" x 4" x 8' treated board (teeth piles)	10	8
2" x 4" x 2' treated board (teeth cross pieces)	15	12
2" x 4" x 8' treated board (strong-backs)	6	6
2" x 12" x 10' treated board (deck planks)	6	6
3/8" x 4" hot-dipped galvanized bolt assemblies (screw, nut, 2 washers)	10	8
3/8" x 6" hot-dipped galvanized bolt assemblies (screw, nut, 2 washers)	10	8
3" Exterior deck screws (teeth)	36	36
3" Exterior deck screws (strong-backs)	48	48

### 2.2.1 Site Construction Methods

The main support of the boardwalk platform is called a tooth (Figures 2.5a-c) and is comprised of two (2) legs (2" x 4" x 8' or 10') attached to three (3) crosspieces with the hot-dipped galvanized carriage bolts. This part of the boardwalk can be assembled before constructing the boardwalk in the field. If the water vessel is not large enough to safely handle the assembled teeth, it is highly recommend that the teeth be disassembled.

Using the CPRA-approved "Preliminary Site Visit" (PSV) deliverable packet, enter the 200 x 200-m site using the pre-determined route access. When accessing the area for the base boardwalk construction, a 10-m (32.8-ft) buffer zone shall be observed. In this buffer zone, there shall be neither airboat travel nor any foot traffic except at the point of accessing the boardwalk. Once the access point has been established, there shall be no access from the other side of the boardwalk. The boardwalk shall be accessed from the same location during every site visit. This will ensure that the site will not be compromised by the construction personnel or any personnel visiting the site for future data collection efforts. Other stations will be established adjacent to the boardwalk; therefore, the access route must be followed at all times. Upon arrival at the access point of the boardwalk, the construction personnel shall begin the construction of the boardwalk from the water vessel. This will prevent any disturbance to the site.

The following procedures shall be followed to assure proper installation without damaging the marsh or swamp surface.

1. Using the approved PSV deliverable packet, the construction crew shall arrive at the coordinates designated for the beginning of the boardwalk (access point).
2. Determine the orientation/direction of the boardwalk from the water vessel using the provided information.
3. Place the sharpened end of the tooth onto the marsh/swamp surface.
4. Drive the tooth into the surface of the marsh/swamp by standing or hammering.  
Note: To facilitate the installation, the four 3/8" carriage bolts should be loosened to allow the legs to penetrate into the marsh surface independently.
5. The bottom support piece shall rest on the marsh surface or to a maximum of eight (8) inches above the surface.
6. Tighten all four carriage bolts once the tooth has been driven to the proper position above the marsh surface to secure the tooth from horizontal movement.
7. Once the tooth has been installed, lay one end of a 2" x 12" x 10' board with strong-back brace attached (Figure 2.6) on the tooth (preferably on the cross piece closest to the marsh surface) with the other end placed on the marsh where the next tooth will be installed.
8. Standing on the end of the board and not on the surface of the marsh, install the next tooth.
9. Place two, 2" x 12" x 10' boards with strong-back braces between the two teeth. Secure the boards to the teeth using the 3" screws. Note: Only a portion or none of the boards may be left in place to reduce the risk of vandalism.

10. Repeat steps 3 through 9 until the boardwalk is constructed to the desired length.

Due to the span length (10 ft) with no support, strengthen the 2" x 12" x 10' planks by attaching a 2" x 4" x 8' strong-back brace on the 2" edge parallel along the underside of the plank (Figures 2.6, 2.7a, and 2.8a). This prevents the boards from flexing and reduces the flexibility of the boards, providing for a more stable platform to traverse.

When constructing base boardwalk in an attached marsh or swamp, a 10-ft boardwalk shall be constructed parallel to the previously constructed 20-ft section on either side (Figures 2.7a-d) as detailed by the PSV deliverable packet.

1. From the middle tooth of the base boardwalk (2<sup>nd</sup> tooth from the end) place a 2" x 12" x 10' board perpendicular to the boardwalk on the appropriate side of the marsh/swamp surface.
2. Place the tooth such that the inside of the tooth is approximately 7.5 ft from the tooth of the constructed boardwalk. Orient the tooth such that the 10-ft section will parallel the longer section.
3. Construct the boardwalk following steps 3–9 above.

In a floating marsh, the boardwalk will consist of one long boardwalk with no flanking boardwalk or RSET area (Figure 2.8a). The 30-ft base boardwalk will be similar to an attached boardwalk; however, an extra 10 ft will be added off the end of the base boardwalk (Figure 2.8b). These 10 ft of boardwalk will be free of any teeth and will float on top of the marsh surface (Figures 2.9 a and b).

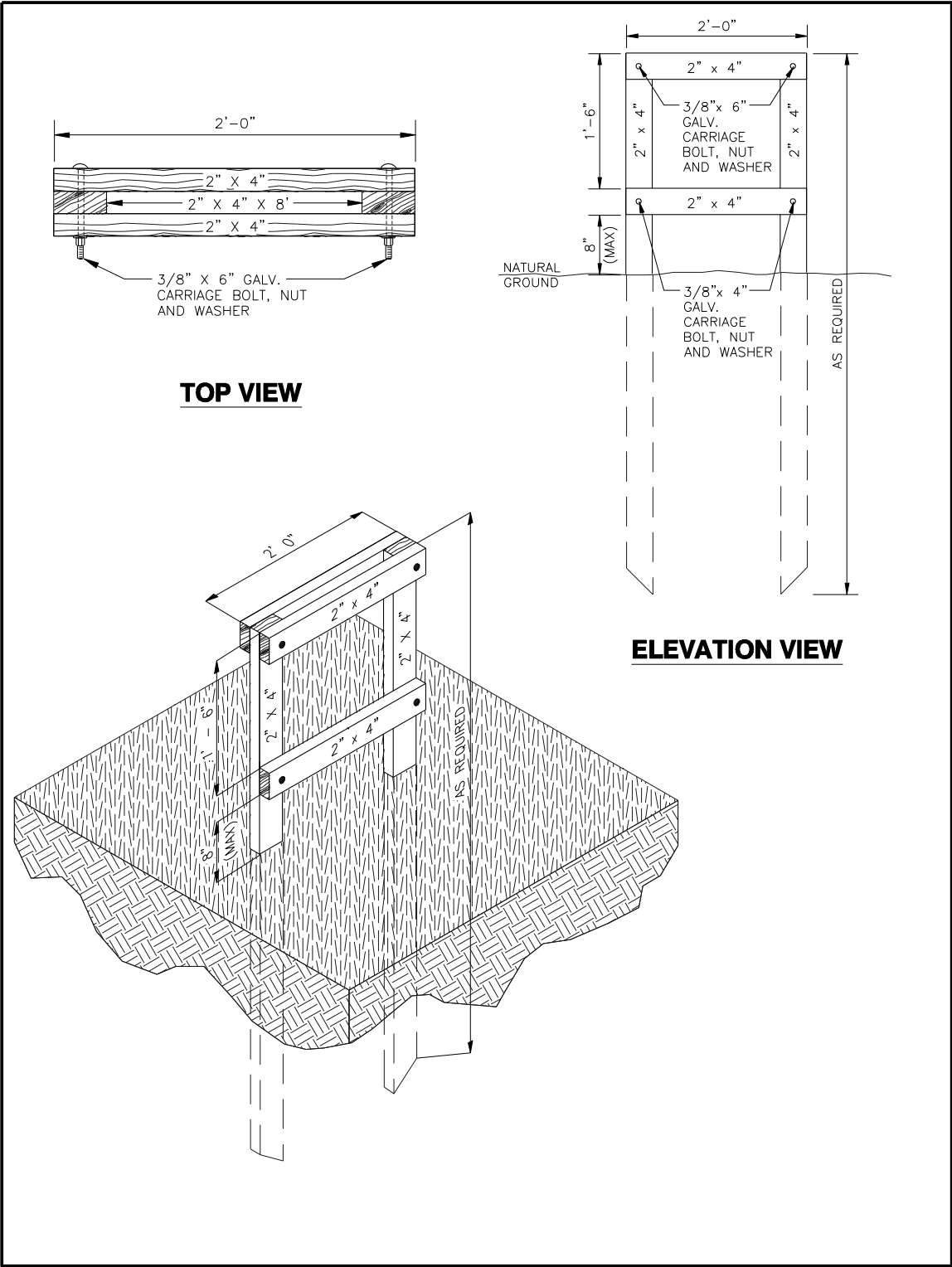
During the construction of the site, no one should walk on the surface of the marsh/swamp at any time. The integrity of the data collected that will be collected depends on the wetland functioning naturally in an undisturbed manner. Failure to follow this guideline will result in the construction of another site at another location at the expense of the contractor. The replacement site would be determined by the CPRA.

Over time, sites and boardwalk areas may convert from one coastal habitat type to another. When sites convert from floating to attached marshes, the flanking boardwalk shall be added to ready the sample area for RSET and accretion stations. When sites convert from attached marsh to floating marsh, no modifications shall be made.

### **2.2.2 Site Construction Deliverables**

The deliverable will be a single PDF of the construction report (Figures 2.10a-c) filled out following the construction of each boardwalk. This report will contain the exact coordinates of the boardwalk, specific boardwalk measurements, and other pertinent information regarding the final construction of the boardwalk.

2. Site Establishment and Construction



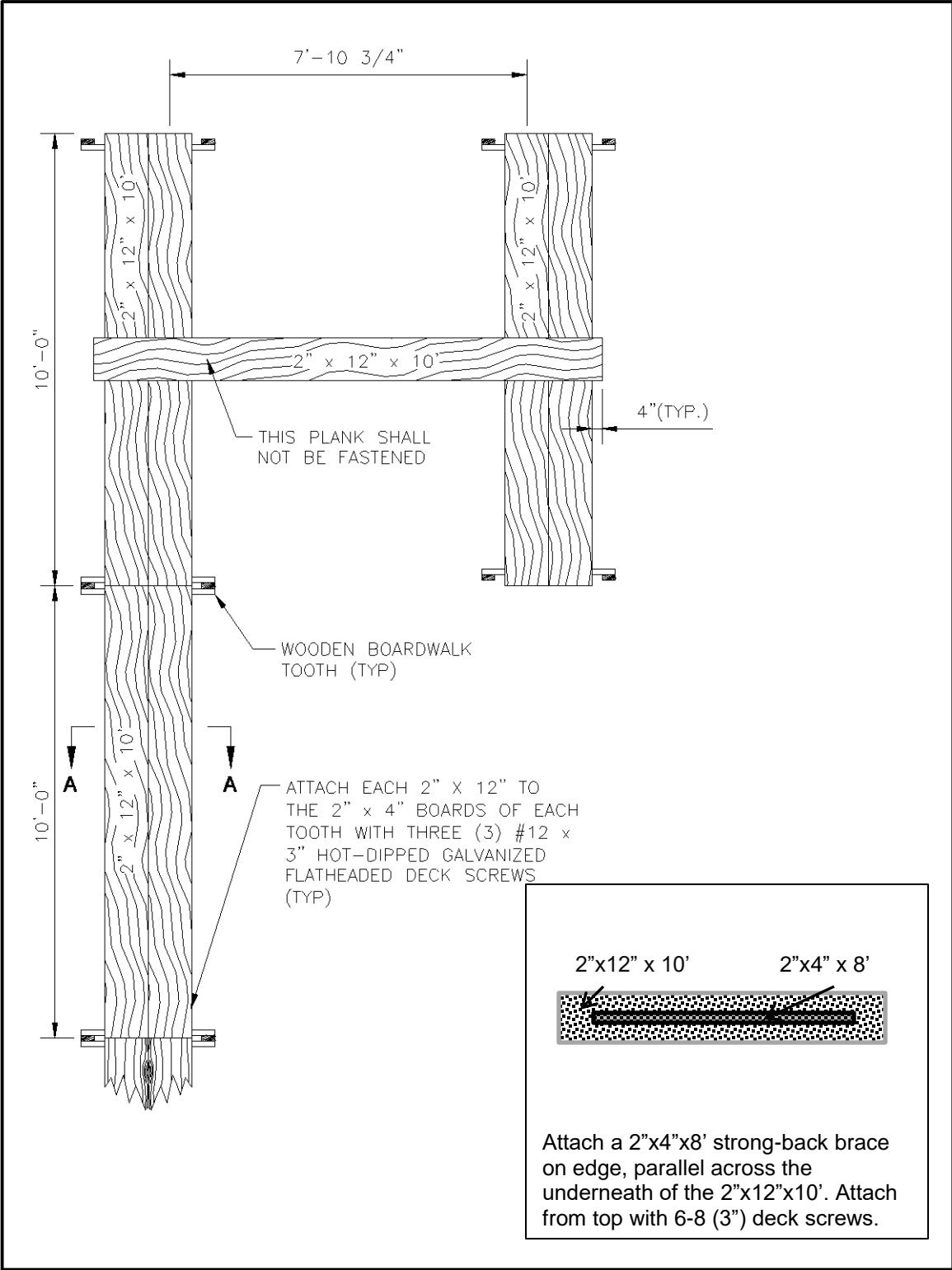
**Figure 2.5a.** Tooth construction diagram used to support the boardwalk for access to the data collection stations.



**Figure 2.5b.** Photograph of a boardwalk in a marsh that washed away. The portion of the teeth that is normally beneath the surface is exposed.



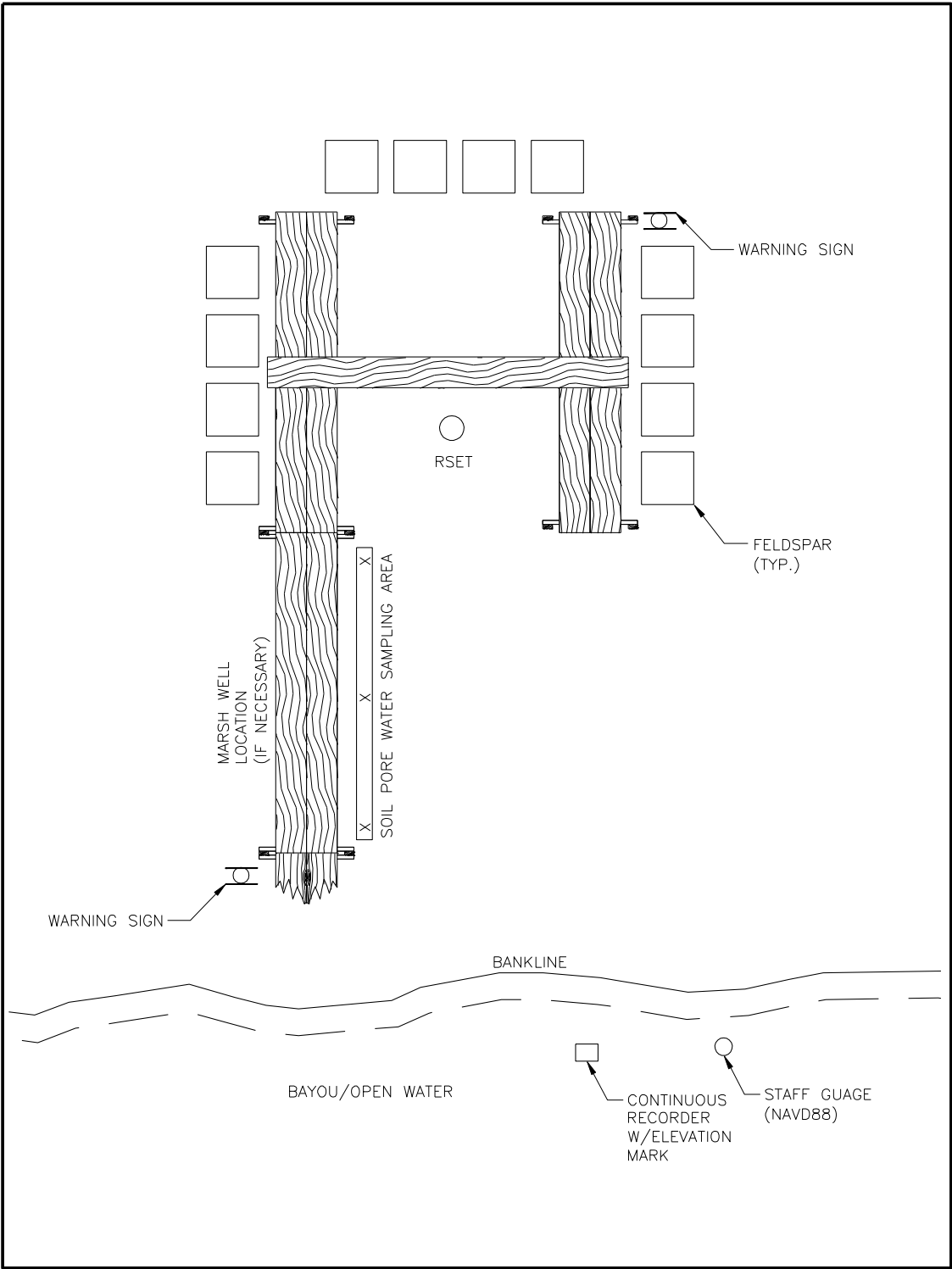
**Figure 2.6.** Photograph of a 2"x12"x12' boardwalk plank with a 2"x4"x8' strong-back bracing underneath.



**Figure 2.7a.** Typical schematic of a base boardwalk in an attached marsh.

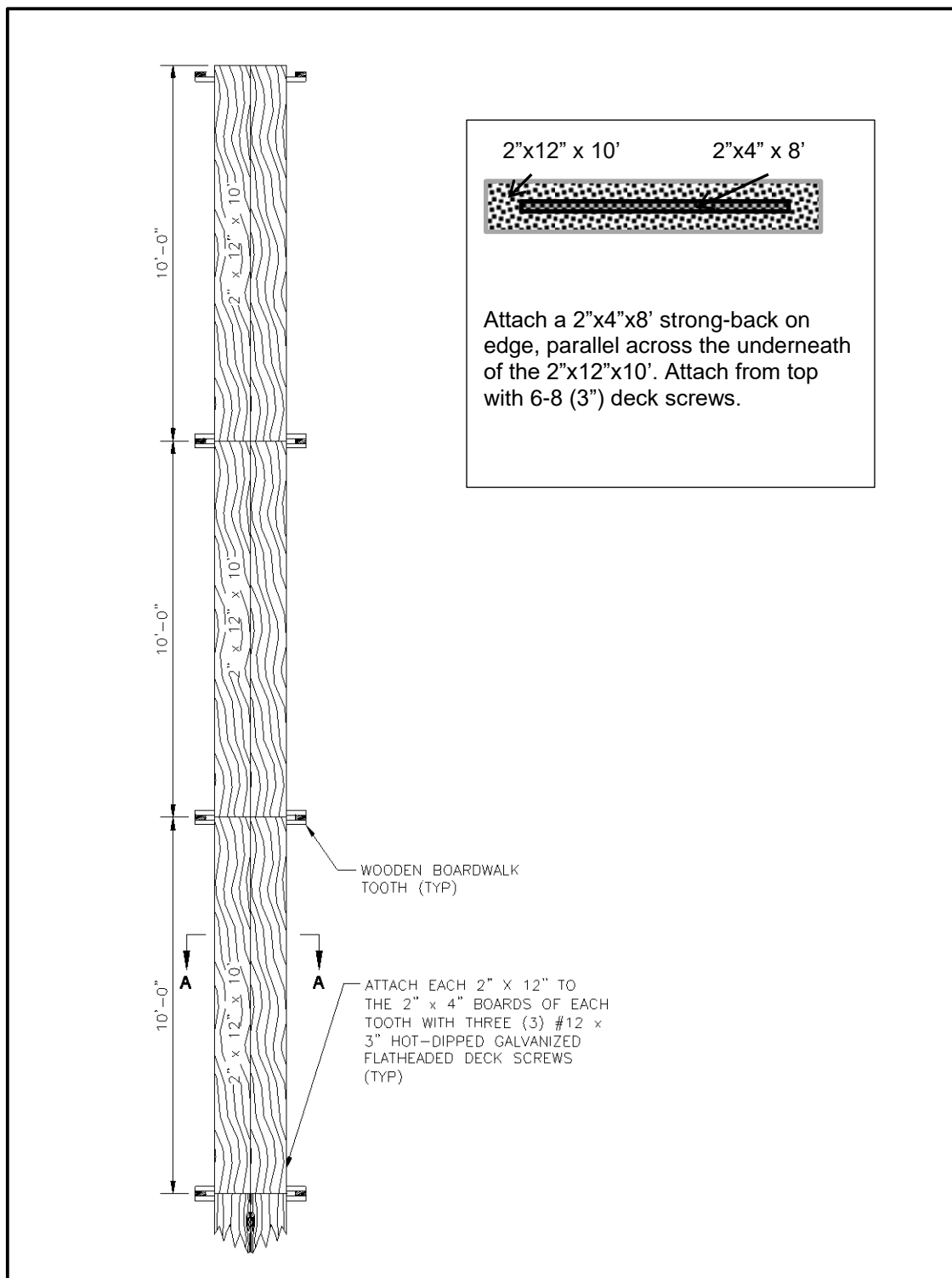


2. Site Establishment and Construction



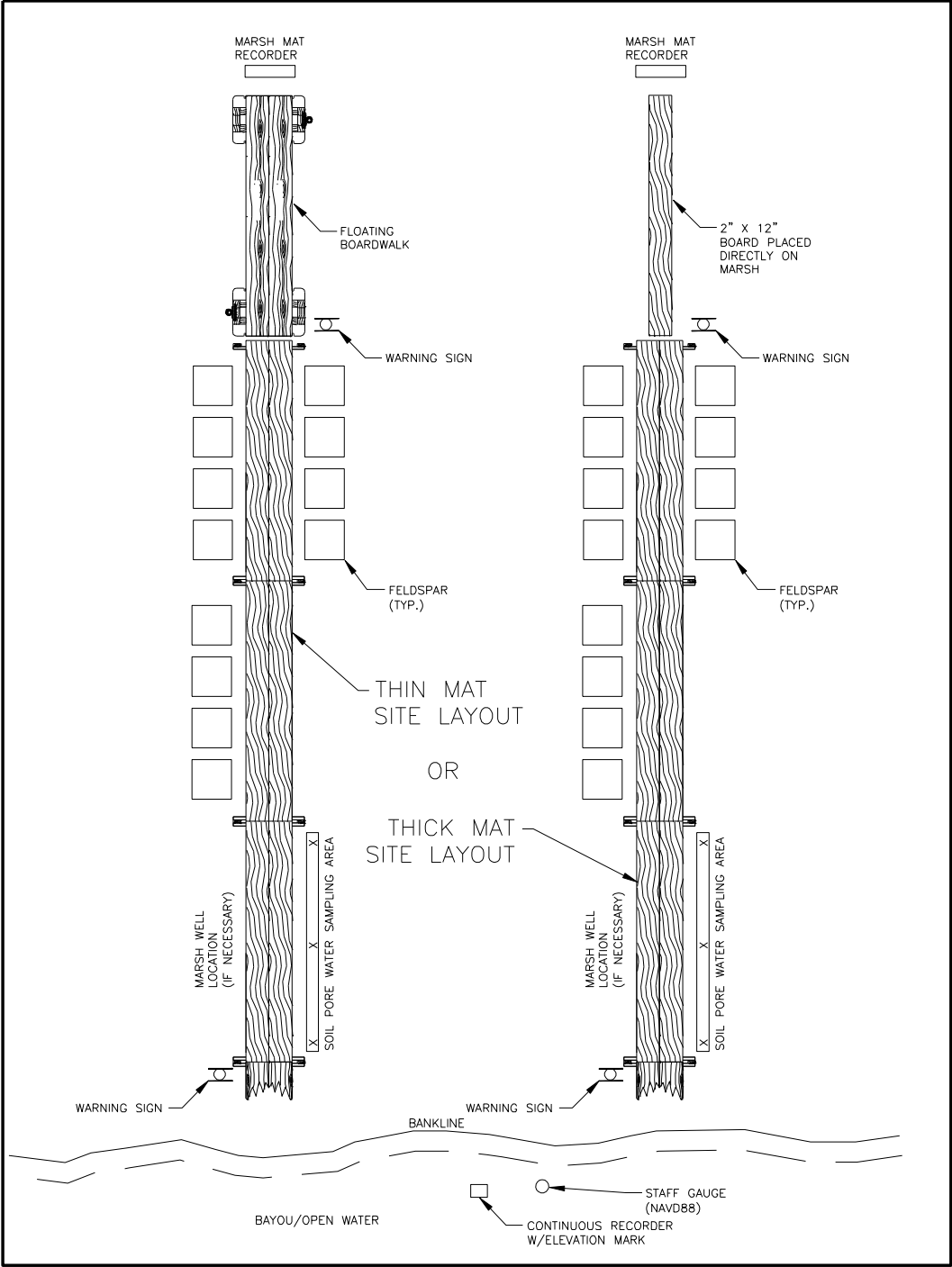
**Figure 2.7b.** Typical layout schematic of the constructed site features at an attached marsh site.

## 2. Site Establishment and Construction

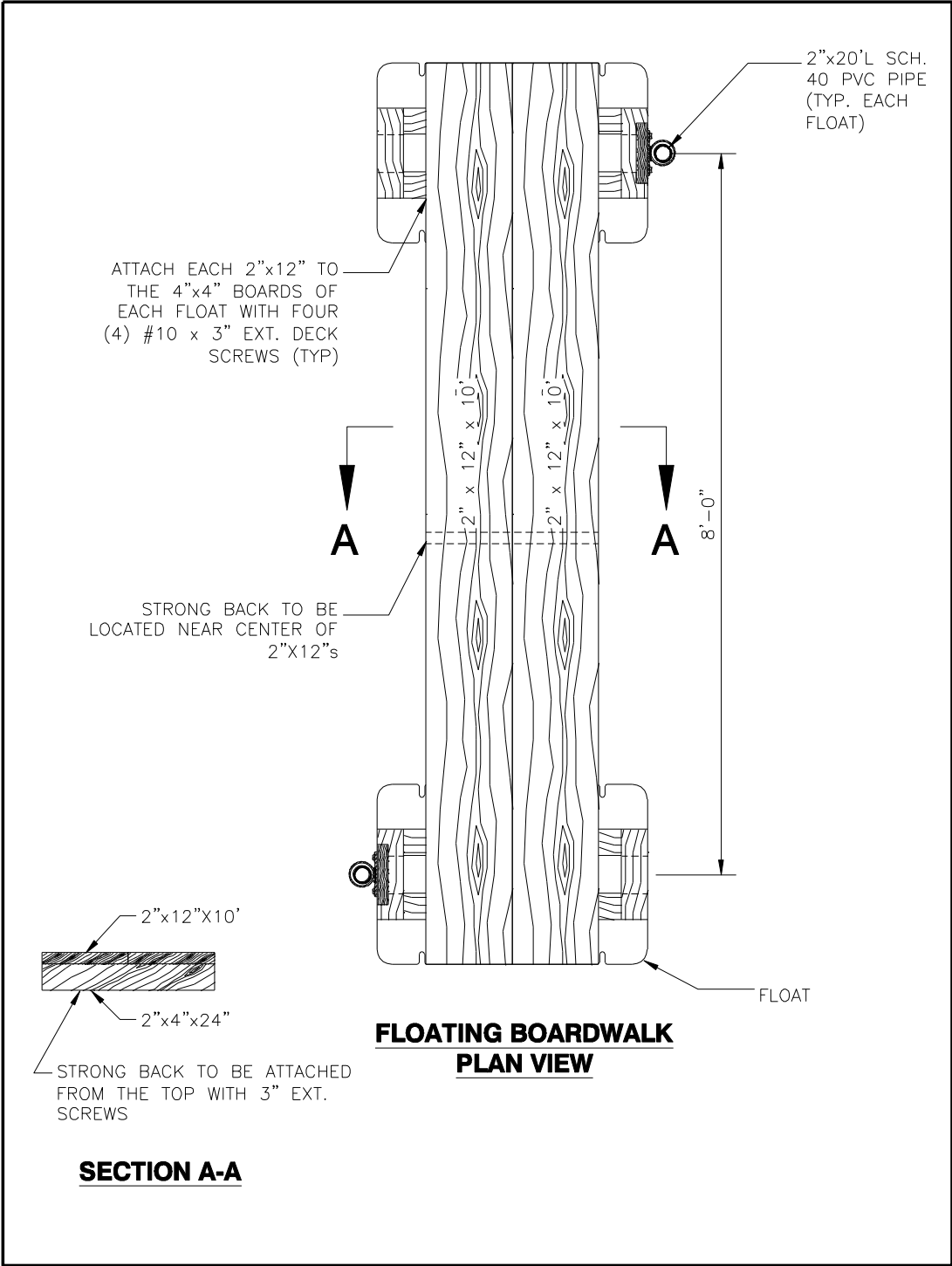


**Figure 2.8a.** Typical schematic of a base boardwalk in a floating marsh

2. Site Establishment and Construction

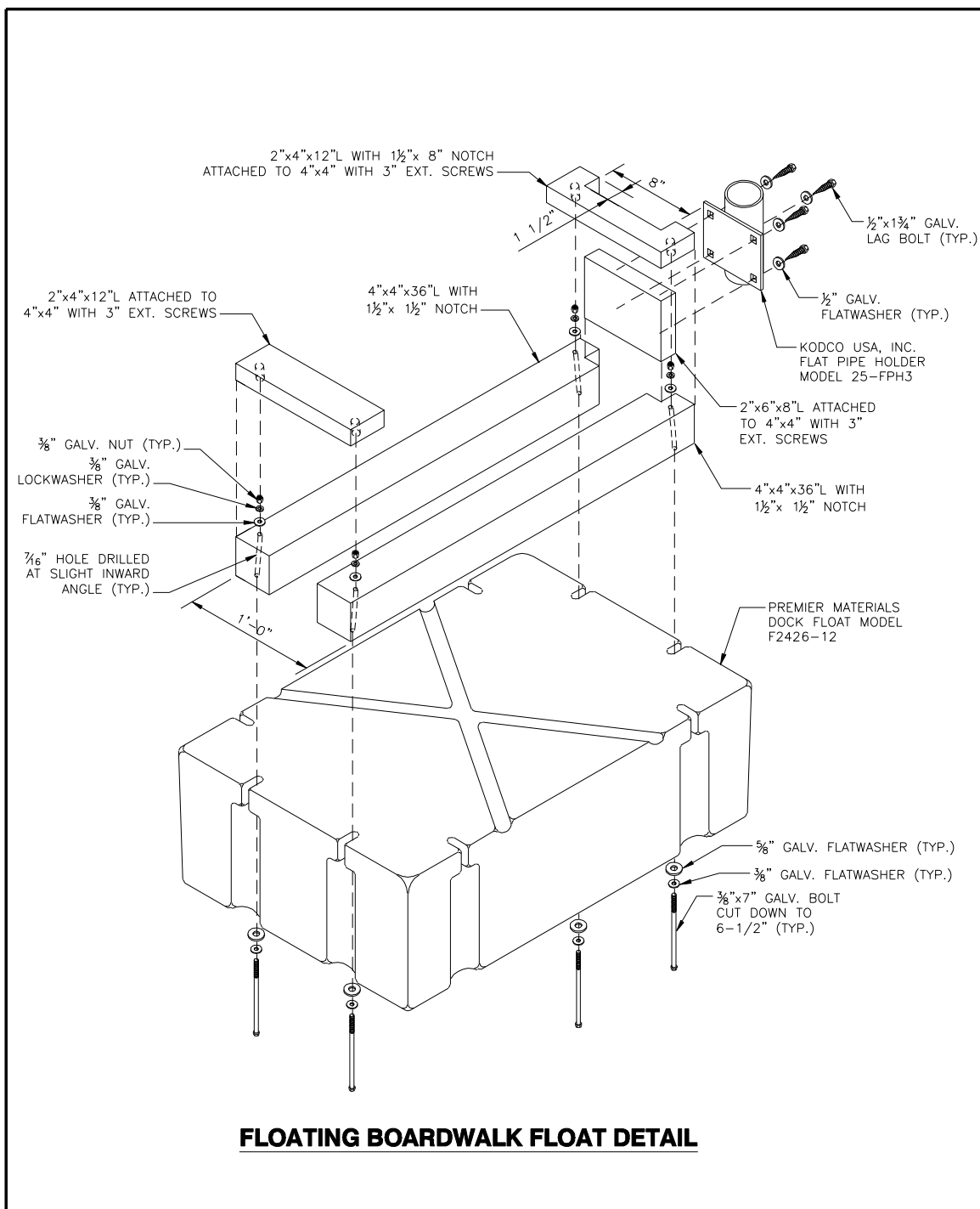


**Figure 2.8b.** Typical layout schematic of the constructed site features at a floating marsh site.



**Figure 2.9a.** Schematic for the construction of a floating boardwalk.

## 2. Site Establishment and Construction



**Figure 2.9b.** Detailed schematic for construction of the float used to support the floating boardwalk.

## 2. Site Establishment and Construction

<b>CRMS Site Construction Sheet (Page 1 of 3)</b>																		
Site: _____		Basin: _____																
Date and Time (CST) of Site Construction: _____		Agency: _____																
Field Personnel: _____		Weather: _____																
<div style="display: flex; justify-content: space-between;"> <div> <p><b>1. Sampling Platform Construction:</b></p> <p>Site Coordinates: Access Point _____</p> <p>Center Point (W) _____</p> <p>(X) _____</p> <p>(Y) _____</p> <p>(Z) _____</p> <p>Length of Access Boardwalk (ft): _____</p> <p>Configuration (floating/attached): _____</p> <p>Photos: _____</p> </div> <div> <p>Easting: _____</p> <p>Northring: _____</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="width: 50%; height: 20px;"></td><td style="width: 50%; height: 20px;"></td></tr> <tr><td style="height: 20px;"></td><td style="height: 20px;"></td></tr> <tr><td style="height: 20px;"></td><td style="height: 20px;"></td></tr> <tr><td style="height: 20px;"></td><td style="height: 20px;"></td></tr> </table> <p>(if floatant, report W and X only)</p> <p>Boardwalk Bearing: Access <span style="border: 1px solid black; padding: 0 10px;"> </span> Base <span style="border: 1px solid black; padding: 0 10px;"> </span></p> <p>Height top of boards above marsh (ft): _____</p> <p>Total Length of teeth (ft): _____</p> <p>Notes: _____</p> </div> <div> <p style="text-align: center;">X   RSET   Y or Y   RSET   X</p> <p style="text-align: center;">W   Z   Z   W</p> </div> </div>																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">Number</th> <th style="width: 15%;">Time Stamp</th> <th style="width: 60%;">Description</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td>Before Construction</td></tr> <tr><td> </td><td> </td><td>After Construction</td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </tbody> </table>				Number	Time Stamp	Description			Before Construction			After Construction						
Number	Time Stamp	Description																
		Before Construction																
		After Construction																
<div style="display: flex; justify-content: space-between;"> <div> <p><b>2. Warning Signs:</b></p> <p>Total Length 3" PVC (ft): _____</p> <p>Height above Substrate (ft): _____</p> <p>Photos: _____</p> </div> <div> <p>Access Rear</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="width: 50%; height: 20px;"></td><td style="width: 50%; height: 20px;"></td></tr> <tr><td style="height: 20px;"></td><td style="height: 20px;"></td></tr> </table> <p>Access Sign (Yellow): _____</p> <p>Rear Sign (Orange): _____</p> </div> <div> <p>Easting: _____</p> <p>Northring: _____</p> </div> </div>																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">Number</th> <th style="width: 15%;">Time Stamp</th> <th style="width: 60%;">Description</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td>Access Before</td></tr> <tr><td> </td><td> </td><td>Access After</td></tr> <tr><td> </td><td> </td><td>Rear Before</td></tr> <tr><td> </td><td> </td><td>Rear After</td></tr> </tbody> </table>				Number	Time Stamp	Description			Access Before			Access After			Rear Before			Rear After
Number	Time Stamp	Description																
		Access Before																
		Access After																
		Rear Before																
		Rear After																
<div style="display: flex; justify-content: space-between;"> <div> <p><b>3. Soil Pore Water Stations</b></p> <p>Coordinates of Location: _____</p> <p>Total Length tooth (ft): _____</p> <p>Height above Substrate (ft): _____</p> <p>Were wells deployed? _____</p> <p>Photos: _____</p> </div> <div> <p>Station Aa _____</p> <p>Station Bb _____</p> <p>Station Cc _____</p> <p>Bentonite used (cups):</p> <p>10 cm A: _____ B: _____ C: _____</p> <p>30 cm a: _____ b: _____ c: _____</p> </div> <div> <p>Easting: _____</p> <p>Northring: _____</p> </div> </div>																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">Number</th> <th style="width: 15%;">Time Stamp</th> <th style="width: 60%;">Description</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td>Before Construction</td></tr> <tr><td> </td><td> </td><td>After Construction</td></tr> </tbody> </table>				Number	Time Stamp	Description			Before Construction			After Construction						
Number	Time Stamp	Description																
		Before Construction																
		After Construction																

**Figure 2.10a.** Site construction report to be completed during the construction of each site. Page 1 of 3.

## 2. Site Establishment and Construction

<b>CRMS Site Construction Sheet (Page 2 of 3)</b>													
Site: _____		Basin: _____											
Date and Time (CST) of Site Construction: _____		Agency: _____											
Field Personnel: _____		Weather: _____											
<b>4. Staff Gauge</b>													
Coordinates of Location: _____		Easting: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	Northing: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>										
Total Length 4x4 (ft): _____		Was gauge attached? _____											
Height above Substrate (ft): _____													
Photos: _____													
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">Number</th> <th style="width: 20%;">Time Stamp</th> <th style="width: 65%;">Description</th> </tr> </thead> <tbody> <tr> <td style="height: 20px;"></td> <td></td> <td>Before Construction</td> </tr> <tr> <td style="height: 20px;"></td> <td></td> <td>After Construction</td> </tr> </tbody> </table>	Number	Time Stamp	Description			Before Construction			After Construction	Notes: _____			
Number	Time Stamp	Description											
		Before Construction											
		After Construction											
<b>5. Continuous Recorder:</b>													
Coordinates of Location: _____		Easting: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	Northing: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>										
Setup: Open water, Well, Mono (circle one)		Was recorder deployed? _____											
Total Length 4x4, 2x4, or pole (ft): _____													
Height above Substrate (ft): _____													
Photos: _____		Notes: _____											
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">Number</th> <th style="width: 20%;">Time Stamp</th> <th style="width: 65%;">Description</th> </tr> </thead> <tbody> <tr> <td style="height: 20px;"></td> <td></td> <td>Before Construction</td> </tr> <tr> <td style="height: 20px;"></td> <td></td> <td>After Construction</td> </tr> </tbody> </table>	Number			Time Stamp	Description			Before Construction			After Construction		
Number	Time Stamp			Description									
		Before Construction											
		After Construction											
<b>6. Marsh Mat Recorder:</b>													
Coordinates of Location: _____		Easting: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>	Northing: <div style="border: 1px solid black; width: 100px; height: 20px;"></div>										
Set-up: Floating or Static (circle one)		Marsh Measurement Information:											
Recorder Length/Distance Information:													
a. Total length of 2" PVC (ft): _____													
b. Length of 2" PVC below the marsh (ft): _____													
c. Total length of aluminum pipe installed (ft): _____													
d. Top of aluminum pipe to elevation mark (1/4" hole) (ft): _____													
e. Firm substrate to top of pipe (ft): _____		a. Mat thickness (ft): _____											
Photos: _____		b. Firm substrate to mat surface (ft): _____											
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">Number</th> <th style="width: 20%;">Time Stamp</th> <th style="width: 65%;">Description</th> </tr> </thead> <tbody> <tr> <td style="height: 20px;"></td> <td></td> <td>Before Construction</td> </tr> <tr> <td style="height: 20px;"></td> <td></td> <td>After Construction</td> </tr> </tbody> </table>	Number	Time Stamp	Description			Before Construction			After Construction	Notes: _____			
Number	Time Stamp	Description											
		Before Construction											
		After Construction											
<b>7. Potential Site Problems:</b> (Is site constructed exactly as described in site visit report? Were future sites damaged?)													
_____													
_____													

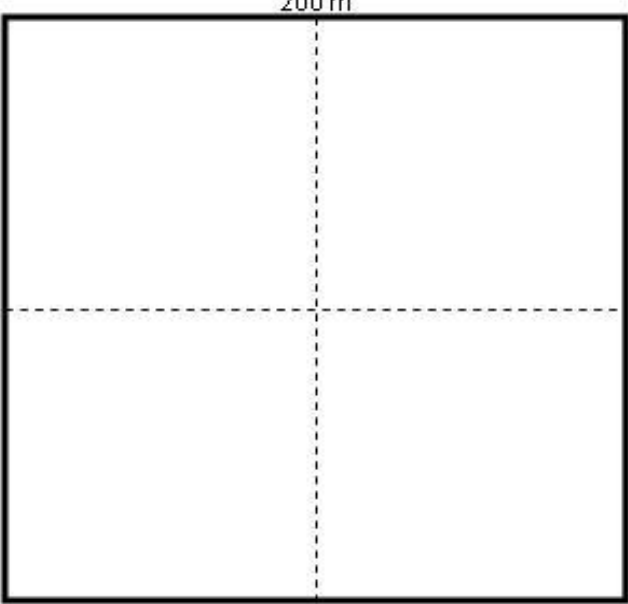
**Figure 2.10b.** Site construction report to be completed during the construction of each site. Page 2 of 3.

## 2. Site Establishment and Construction

**CRMS Site Construction Sheet (Page 3 of 3)**

CRMS Site: \_\_\_\_\_  
 Date & Time: \_\_\_\_\_  
 Personnel: \_\_\_\_\_

Center Coordinates: Easting \_\_\_\_\_  
 Northing \_\_\_\_\_

**N**  


Checklist

- ☐ Compass
- ☐ Camera
- ☐ GPS
- ☐ Survey Rod
- ☐ Permanent Marker

Site Description: (Location and orientation of access route, boardwalk, SET, continuous recorder, and vegetation transect)

Notes: <div style="height: 150px; border: 1px solid black; margin-top: 5px;"></div>	<div style="text-align: center; font-weight: bold; font-size: small;">LEGEND</div> <ul style="list-style-type: none"> <li>△ - Access Point</li> <li>● - Center Point</li> <li>▲ - Marsh Well</li> <li>⊗ - RSET</li> <li>■ - Continuous Recorder</li> <li>— — - Vegetation Transect</li> <li>→ → - Access Route</li> <li>AB - Access Boardwalk</li> <li>BB - Base Boardwalk</li> </ul>
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**Figure 2.10c.** Site construction report to be completed during the construction of each site. Page 3 of 3.



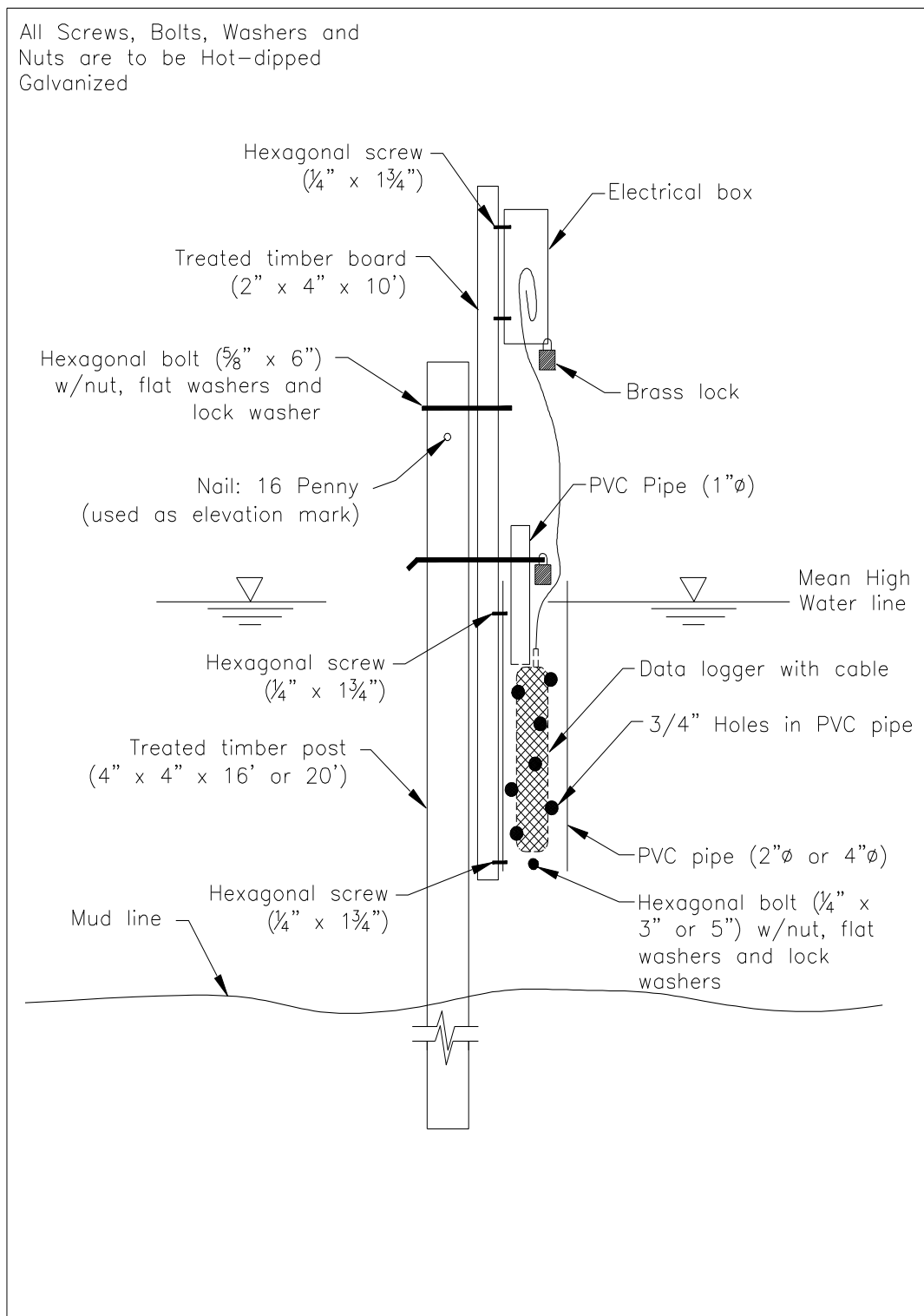
### 3. Hydrologic Data

Highly variable water levels and saltwater intrusion have been shown to cause adverse effects on the health of coastal wetland ecosystems (Gagliano et al. 1981). Consequently, coastal restoration projects have goals to reduce variability in water level, decrease average salinity values, and/or maintaining hydrologic targets for specific habitats. Hydrologic data on a continuous and/or discrete basis is collected at each CRMS site to determine if project goals are being met or to determine baseline conditions. Continuous water level, temperature, specific conductivity, and salinity data are collected hourly from surface waters at permanent monitoring stations with continuous recording instruments (Steyer et al. 1995). Discrete salinity, specific conductance, and temperature data are collected during periodic field trips at multiple locations with a hand-held salinity meter. Discrete measurements are taken in surface water or in soil porewater extracted with a sipper probe from within the root zone in marshes and swamps. More extensive discrete surface-water sampling, including dissolved oxygen, turbidity, chlorophyll a, nutrients, and suspended solids, is conducted for the SWAMP to document changes in key water quality parameters in estuarine water bodies that are sensitive to system drivers and are critical for understanding system dynamics (Hijuelos and Hemmerling 2016).

#### 3.1 Continuous Hydrologic Data Collection

Different sampling stations are used to continuously measure water level and salinity for the following three environments:

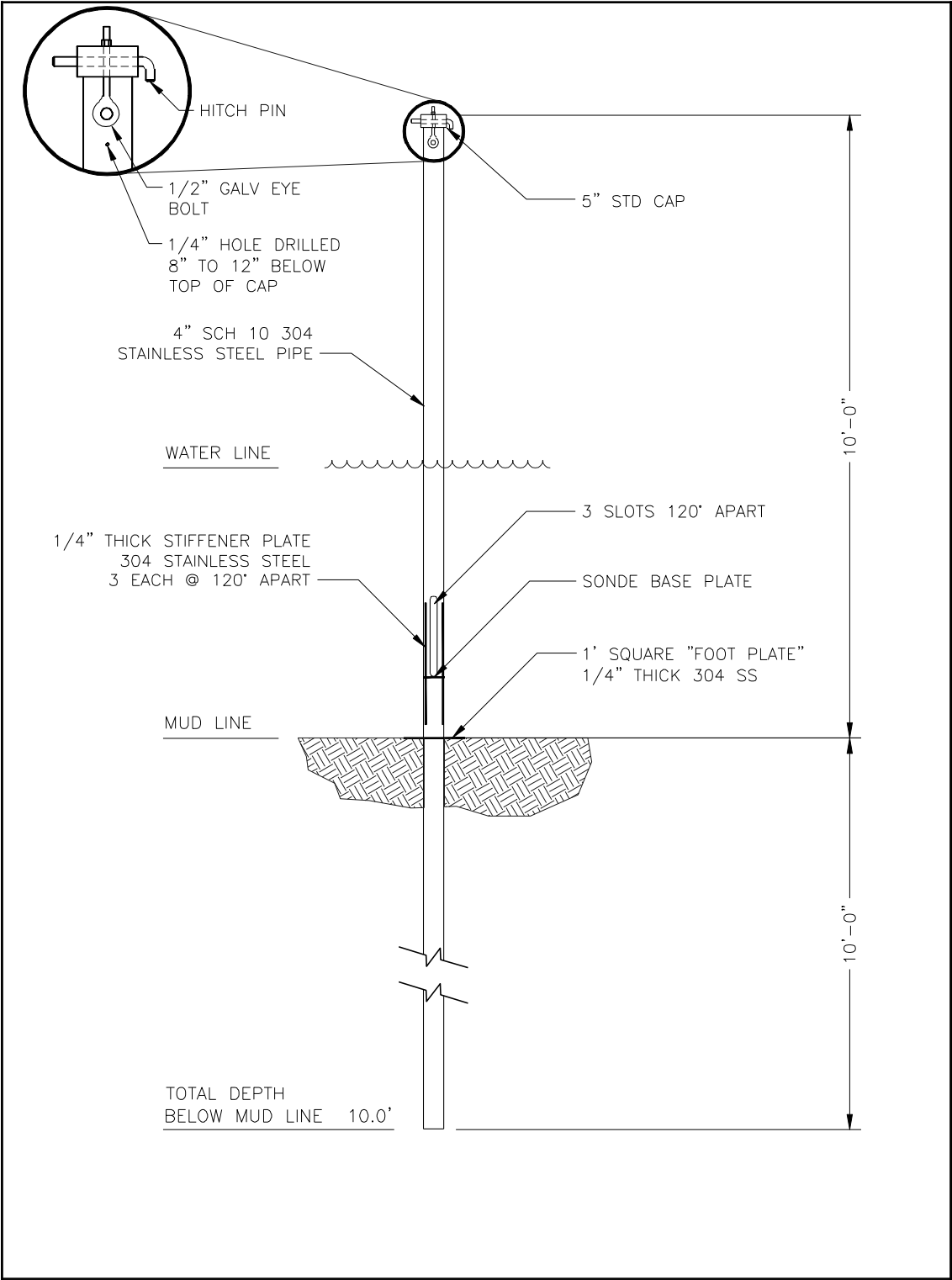
1. *Open water habitats with sufficient yearly water levels to continually submerge the continuous recorder data sensor:*
  - a. The **wooden post system** consists of a 4" x 4" x 20-ft treated wooden post driven into the substrate of an open water body to refusal (Figures 3.1a and 3.1b). [Note: Refusal occurs when the post no longer penetrates the substrate after several attempts to drive it further with a pile driver.] A perforated PVC pipe and electrical box are mounted onto a 2" x 4" x 10-ft board, which is attached onto the wooden post via a bolt and hitch pin. This method works well in meandering bayous, canals, and interior marsh channels where water depth is less than 8 ft, and where wave energy and water velocity are low to moderate.
  - b. The **mono-pole system** is a stainless steel pipe that has a quarter-inch plate welded at a depth such that the plate rests on the bottom for stabilization (Figure 3.2). The pipe has numerous slits in the water column portion of pipe to allow water exchange. While this method can be used for all environments, it is most feasible for use in high-velocity or high-energy areas such as rivers and large navigational waterways.



**Figure 3.1a.** Typical hydrologic recorder station for open-water sampling.



**Figure 3.1b.** Photographs of typical hydrologic recorder stations. The original version is to the left and the newer version is to the right (see Fig. 3.5b for snorkel description).



**Figure 3.2.** Typical stainless steel mono-pole station.

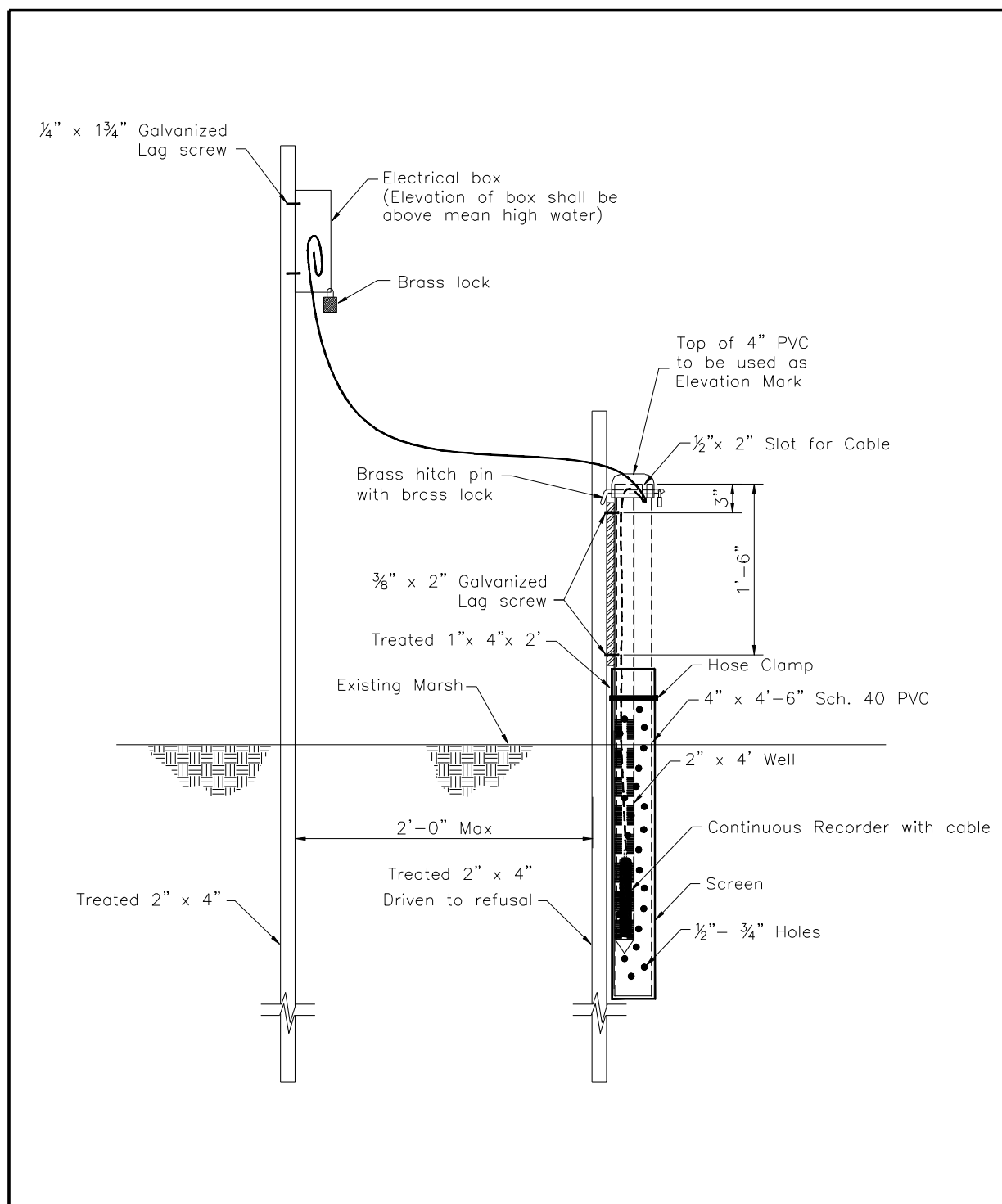
2. *Marsh or swamp habitats where flooding is ephemeral, not deep enough to continually submerge the continuous recorder, or where there is no open water in which to place a continuous recorder:*

The **well system** is a PVC well (Figures 3.3a and 3.3b) with screens that allow surface water to enter and exit the well when the marsh surface is flooded.

When the water table drops below the marsh surface, the well screens allow soil porewater to enter and exit the well. Because the CPRA's interest is mainly surface water properties, how these wells function must be considered when processing (i.e., QA/QC) and interpreting the data. For example, when comparing surface water from wells to surface water at open water stations, salinity recorded during periods when the water level is below the marsh surface will not be comparable.

3. *Floating marshes where the marsh surface is detached and able to float vertically as water level fluctuates:*

The **floating marsh mat system** suspends a water-level recorder below the marsh surface within the marsh mat or below the marsh mat in the fluid ooze layer (Figures 3.4a and 3.4b). Because this system is attached to the floating mat and the distance from the water level sensor to the marsh surface is known, water level in relation to the marsh surface can be calculated.

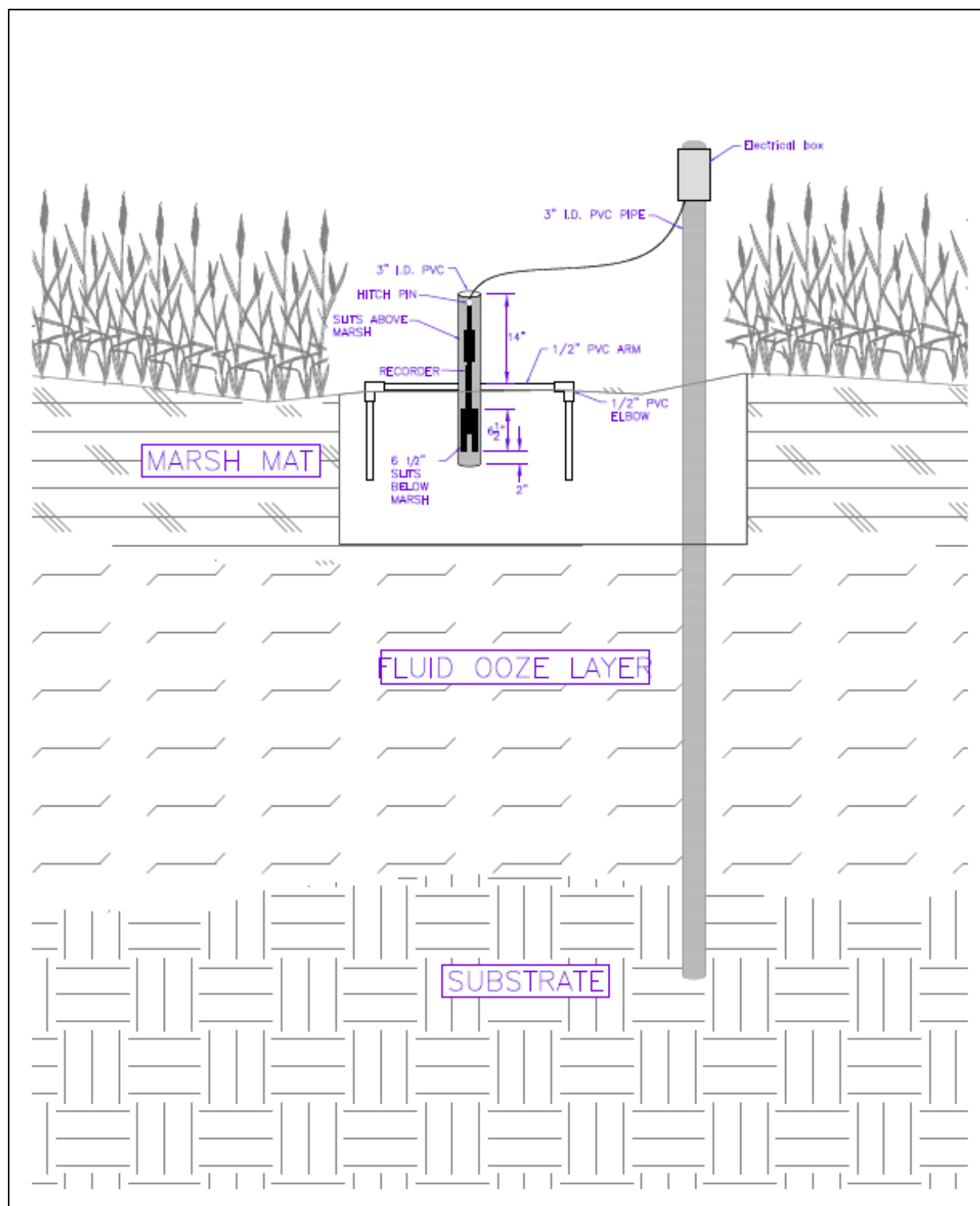


**Figure 3.3a.** Typical marsh well station.



**Figure 3.3b.** Photograph of a marsh well station deployed at a boardwalk.





**Figure 3.4a.** Typical floating marsh mat continuous recorder station.





**Figure 3.4b.** Photographs of a typical floating marsh mat recorder deployed in the field

### 3.1.1 Hydrology Instrumentation

The CPRA currently utilizes the YSI 600LS or equivalent continuous recorder with a vented cable, as the basic model that measures and stores water temperature (°C), specific conductance ( $\mu\text{S}/\text{cm}$ ), salinity (ppt), and water level (m or ft) data at specified time intervals. The water level sensor must be a vented sensor that has a range of 0 to 9.1 m (30 ft), a minimum accuracy of  $\pm 0.003$  m (0.01 ft) in depths to 3.0 m (10 ft), and a minimum accuracy of  $\pm 0.018$  m (0.06 ft) in depths of 3.0 to 9.14 m (10 to 30 ft).

The water temperature and specific conductivity sensor must meet or exceed the following standards. The temperature sensor must be able to function in a range of -5 to 45 °C, have a range of  $\pm 0.15$  °C and a resolution of 0.01 °C, and be able to work in depths of 20 m (66 ft). The conductivity sensor must be able to function in a range of 0 to 100 mS/cm, have an accuracy of  $\pm 0.5\%$  of readings and a resolution of 0.001 mS/cm to 0.1 mS/cm, and be able to function in 20 m (66 ft) of water. The salinity values are calculated from the conductivity and water temperature readings and must have a range of 0 to 70 ppt, an accuracy of  $\pm 1.0\%$  of readings or 0.1 ppt (whichever is greater), and a resolution of 0.01 ppt. In addition to the specifications above, the instrument shall be capable of exporting the raw data through a field display unit or field computer as a .txt file to be processed and imported into the CIMS database.

To verify that the continuous recorder is within calibration at the time of deployment and to calculate the drift of the continuous recorder due to biofouling, a portable, hand-held salinity meter is used to measure water temperature (°C), specific conductance ( $\mu\text{S}/\text{cm}$ ), and salinity (ppt). The hand-held instrument must be capable of taking salinity readings in water depths up to 7.6 m (25 ft) and be capable of undergoing field calibration by using push buttons; also, it must have a backlit display, automatically compensate for temperature, and use a four-electrode conductivity cell. Minimum accuracy requirements for the instrument are found in Table 3.1. Any instrumentation that does not meet these specifications must be approved by the CPRA.

At floating marsh recorder stations, water level is the only parameter collected; therefore, it is not necessary for the instrument used in these environments to collect temperature, specific conductance, or salinity data. The water level sensor must be a vented sensor that has a range of 0 to 9.1 m (30 ft) and a minimum accuracy of  $\pm 0.05\%$  Full Scale.

**Table 3.1.** Minimum standards of range, resolution, and accuracy for the hand-held water quality sensors.

Measurement	Range	Resolution	Accuracy
Specific Conductance	0 to 499.9 $\mu\text{S/cm}$	0.1 $\mu\text{S/cm}$	$\pm 0.1 \mu\text{S/cm}$ or $\pm 0.5\%$
	0 to 4999 $\mu\text{S/cm}$	1 $\mu\text{S/cm}$	$\pm 0.1 \mu\text{S/cm}$ or $\pm 0.5\%$
	0 to 49.99 $\text{mS/cm}$	0.01 $\text{mS/cm}$	$\pm 0.01 \text{mS/cm}$ or $\pm 0.5\%$
	0 to 200.0 $\text{mS/cm}$	0.1 $\text{mS/cm}$	$\pm 0.1 \text{mS/cm}$ or $\pm 0.5\%$
Salinity	0 to 70 ppt	0.01 ppt	$\pm 0.1 \text{ppt}$ or $\pm 1\%$
Temperature	-5 to 70°C	0.1°C	$\pm 0.2^\circ\text{C}$
Dissolved Oxygen	0 to 25 $\text{mg/L}$	0.1 $\text{mg/L}$	$\pm 0.1 \text{mg/L}$ or $\pm 1\%$
Turbidity	0 to 100 FNU	0.1 FNU	$\pm 0.3 \text{FNU}$ $\text{mg/L}$ or 2%

### 3.1.2 Hydrologic Station Construction and Surveying

To ensure proper and consistent data collection, the following construction procedures and specifications have been developed by the CPRA. The construction of all continuous recorder or staff gauge stations associated with CRMS sites requires the use of the “CRMS Site Construction Sheet” (Figures 2.10a, 2.10b, and 2.10c). The appropriate sections of this sheet shall be filled out once station construction is completed. Initial, CRMS station construction followed these protocols and should be referenced for maintenance or replacement of hydrologic stations. Contact CPRA for updates or permission for modifications.

#### 3.1.2.1 Open Water Station Construction

When a station requires establishment in an open water environment, the two set-ups that are recommended are the wooden post for low-energy environments (Figures 3.1 and 3.5) and the mono-pole for high-energy environments (Figure 3.2). However, a hybrid design may be used in high-energy environments with the approval of the CPRA (see note at the end of the Mono-pole section, which follows). Below is a minimum materials list for construction of a single station, as well as the recommended procedures for construction and surveying.

**Snorkel:** A subset of CRMS stations had a ‘snorkel’ mounted to the 4x4 sonde post. The snorkel effectively allows the atmospheric vent hose that connects to the sonde cable to be raised above potential high water levels (storm surge, spring floods). The snorkel consists of a cable housing constructed from PVC pipe mounted to a 2x4 that extends above the sonde setup (Figure 3.5b).

► **Wooden post system:**

*Minimum Materials:*

1. (1) 4" x 4" x 16-ft or 20-ft treated post
2. (1) 2" x 4" x 10-ft treated board
3. (4) Reflectors (one per side of post) with screws for attachment
4. (1)  $\frac{5}{8}$ " x 6" hot-dipped galvanized hexagonal bolt with two flat washers, one locking washer, and one nut
5. (4)  $\frac{1}{4}$ " x 1  $\frac{3}{4}$ " hot-dipped galvanized wood screw
6. (1)  $\frac{1}{4}$ " x 3" or 5" hot-dipped galvanized hexagonal bolt with two flat washers, one locking washer, and one locking nut; bolt length is dependent on PVC diameter, which is determined by instrument type
7. (2) Brass locks provided by the CPRA
8. (1) 2" or 4" schedule 40 PVC perforated pipe with multiple  $\frac{3}{4}$ " holes (28"–36" in length or a minimum of 12" longer than the anticipated instrument); diameter of pipe is dependent on the diameter of the continuous recorder
9. (1) 1" schedule 40 PVC pipe (approximately 24"–36" in length)
10. (1)  $\frac{5}{8}$ " x 9" stainless steel hitch pin
11. (1) 16 or 20 penny galvanized common nail
12. Electrical box (NEMA 3R-Rainproof or similar) that can be secured with a padlock and can house the cable end and desiccant tube from direct exposure to weather

With Snorkel attachment:

13. (1)  $\frac{3}{4}$ " x 10' PVC schedule 40
14. (1)  $\frac{3}{4}$ " PVC Ball Valve
15. (1) 1 $\frac{1}{2}$ " x  $\frac{3}{4}$ " PVC Bushing
16. (1) 1 $\frac{1}{2}$ " PVC Cap
17. (1)  $\frac{3}{4}$ " x  $\frac{1}{2}$ " PVC Tee
18. (2)  $\frac{3}{4}$ " PVC 90 elbow
19. (1) Tubing Fitting  $\frac{1}{4}$ " or 5/16"
20. (3) Vinyl Tubing  $\frac{1}{4}$ " or 5/16" of varying lengths
21. (1) 2x4x8 treated timber
22. (4)  $\frac{1}{4}$ " x 2 $\frac{1}{2}$ "- 3" hot-dipped galvanized wood screw
23. (3)  $\frac{3}{4}$ " metal pipe straps
24. (6) 1" hot-dipped galvanized wood screw

Tools:

1. Pile driver (a.k.a., widow maker) or equivalent used for driving posts into the ground: a cylindrical steel device that is approximately 36" in length, has an inside diameter  $\geq 5 \frac{1}{2}$ " and weighs approximately 60 pounds (or similar device)
2. Wrenches
3. Cordless skill saw and/or reciprocating saw

4. Cordless drill, bits (various sizes), and driver bits
5. Hammer
6. Tie-off rope
7. Socket set with driver
8. Level
9. Duct tape
10. Measuring device (a surveyor's rod capable of measuring in feet, tenths, and hundredths)
11. Personal protective equipment (minimum of gloves and eye protection)
12. Digital camera
13. PVC pipe cutter
14. Knife

#### Construction and Installation:

*Continuous Recorder (CR) support assembly (can be constructed at the office):*

1. Mount the electrical box to one end of the 2" x 4" x 10-ft treated board with 2 - 1/4" x 1 3/4" screws.
2. On the other end of the board, mount the 2" or 4" PVC pipe using 2 - 1/4" x 1 3/4" screws (one at each end of the PVC pipe). Note: A hole may need to be drilled for access.
3. At the bottom end of the PVC, near the end of the board, drill a 1/4" hole 90° from the screw through both sides of the PVC.
4. Thread the 1/4" x 3" or 5" bolt and secure with washers and nut. This serves as the resting place for the instrument. Notes: (1) Only tighten the nut to the PVC pipe; do not overtighten, causing the PVC to bend. (2) The use of PVC caps is not specified for this application due to the increase of biofouling that could occur.

*Support post installation:*

1. Determine the correct location for the station according to the approved PSV packet (Figures 2.4a and 2.4b) or as directed by the CPRA, and shoot a "before construction" picture.
2. Cut a point at one end of the wooden post to facilitate installation (point may be cut prior to going to the site).
3. Place the timber post in the water with the point down. Slowly lower the post into the water to penetrate the subsurface.
4. Using a carpenter's level, make sure the post remains plumb in all directions as the post is being installed.
5. Once the post no longer penetrates the substrate by the post's own weight, then the pile driver or equivalent can be placed on the top of the post.
6. Using the pile driver, drive the post into the substrate until resistance is met. Note: Refusal occurs when the post no longer penetrates the substrate after several

attempts with the pile driver. Approximately 4 ft of the post shall remain above the mean high water level or the marsh surface.

7. Make sure that the post is plumb in all directions and does not exhibit considerable horizontal movement.
8. If the top of the post was damaged, cut the damaged section off. Make sure to cut the post square.

*Mounting the CR support assembly to the wooden post:*

1. With the CR support assembly in hand, determine a vertical position in the water column so that 1) the continuous recorder sensor is submerged during low water events, 2) the electrical box is above mean high water, and 3) the end of the continuous recorder is a minimum of 4" above the mud line. In shallow water this is easy to achieve, but in deeper water, all three criteria cannot be met. In this case, position the CR support assembly so that criteria 1 and 2 are met, and disregard the criterion that the continuous recorder be 4" above the mud line (i.e., criterion 3).
2. Secure the 2" x 4" CR support assembly to the wooden post in two or three places with duct tape.
3. Drill a  $\frac{3}{4}$ " hole a minimum of 6" from the top of the post through the post and the 2" x 4" board.
4. Secure with the 6" bolt, washers, and nut.
5. Drill a  $\frac{3}{4}$ " hole a minimum of 16" from the hole in step 2 such that the hitch pin is above normal water levels but close to the PVC used to house the instruments.
6. Place the continuous recorder inside the PVC housing pipe in order to measure the length of the 1" PVC used to secure the instrument (stop-pipe) and prevent vertical movement.
7. Measure from the top of the instrument to the top of the bottom  $\frac{3}{4}$ " hole, and then add a minimum of 4".
8. Cut the 1" PVC to the measurement in step 7.
9. Place 1" PVC on top of the instrument to determine where to drill the hole that will allow the hitch pin to go through the post, board, and 1" PVC pipe.
10. Drill a hole in the 1" PVC for the  $\frac{5}{8}$ " hitch pin.
11. Drive a 16 penny nail two-thirds of the way into the side of the post. This nail must be driven perpendicular to the post in order to serve as a reference mark for measuring water level while servicing. Notes: (1) No post shall have more than one nail. (2) The nail should be positioned on either side of the 2" x 4" board and on the side least likely to be damaged by the boat during servicing.
12. Secure three reflectors near the top of the wooden post and the remaining reflector to the 2"x4" board.
13. Once completed, the station shall resemble Figures 3.1a and 3.1b.
14. Document the measurements on the "Continuous Recorder Water Level Sensor Data Sheet" (Figure 3.7) by referencing Figure 3.5a and 3.5b.
15. Shoot an "after construction" photo.

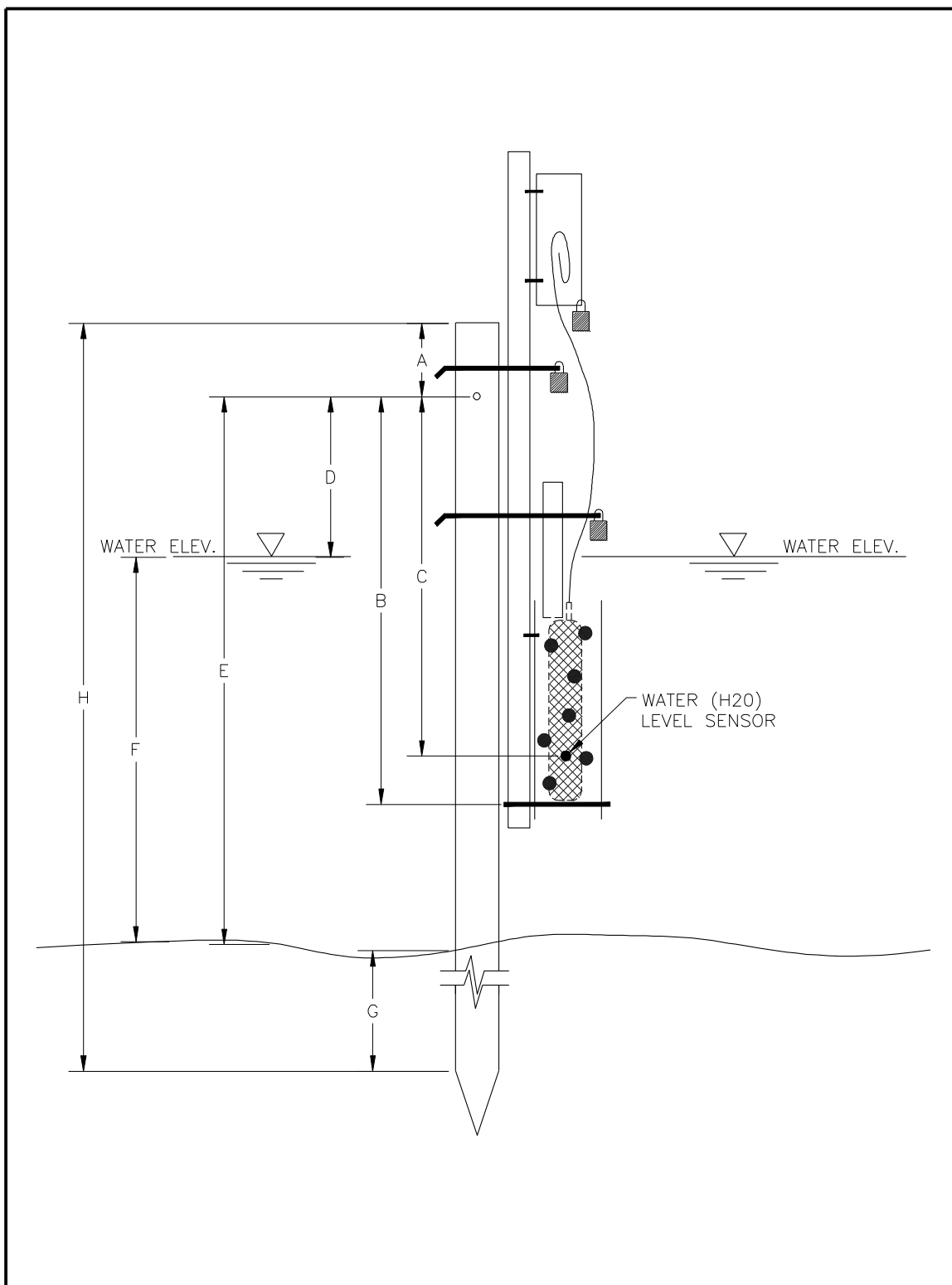
16. Complete the *Continuous Recorder* section (#5) on the “CRMS Site Construction Sheet” (Figures 2.10a, 2.10b, and 2.10c), including the station coordinates, the total length of the support post (ft), the height of the station above the substrate (ft), and number/time stamp of photos. Document whether a continuous recorder was deployed and provide notes regarding station construction, if necessary.

*Snorkel Design and Assembly (Figure 3.5b):*

1. Cut the 10 ft Sch 40 PVC into 3 separate pieces; 2 pieces 6” in length and the remaining piece equaling 9 ft in length
2. Glue the ball valve onto the bottom end of the 6” PVC pipe and on the other end glue the  $\frac{3}{4}$ ” x  $\frac{1}{2}$ ” PVC Tee.
3. Secure a  $\frac{1}{2}$ ” tubing fitting into the  $\frac{1}{2}$ ” side of the PVC Tee to allow for tubing to be connected.
4. Glue the 9 ft section of PVC pipe into the top of the  $\frac{3}{4}$ ” x  $\frac{1}{2}$ ” PVC Tee
5. Glue a PVC 90 elbow onto each end of the other 6” PVC Pipe
6. Glue the  $\frac{3}{4}$ ” x 1.5” bushing into one side of the PVC 90 elbow.
7. Glue a 1.5” PVC Cap onto the 1.5” bushing completed in step.6
8. Drill multiple  $\frac{1}{16}$ ” holes into the bottom of the PVC cap to allow air to flow freely
9. Glue another 90 elbow onto the other end of the 6” PVC and then glue the 90 onto the 9 ft PVC pipe completed in step 4.

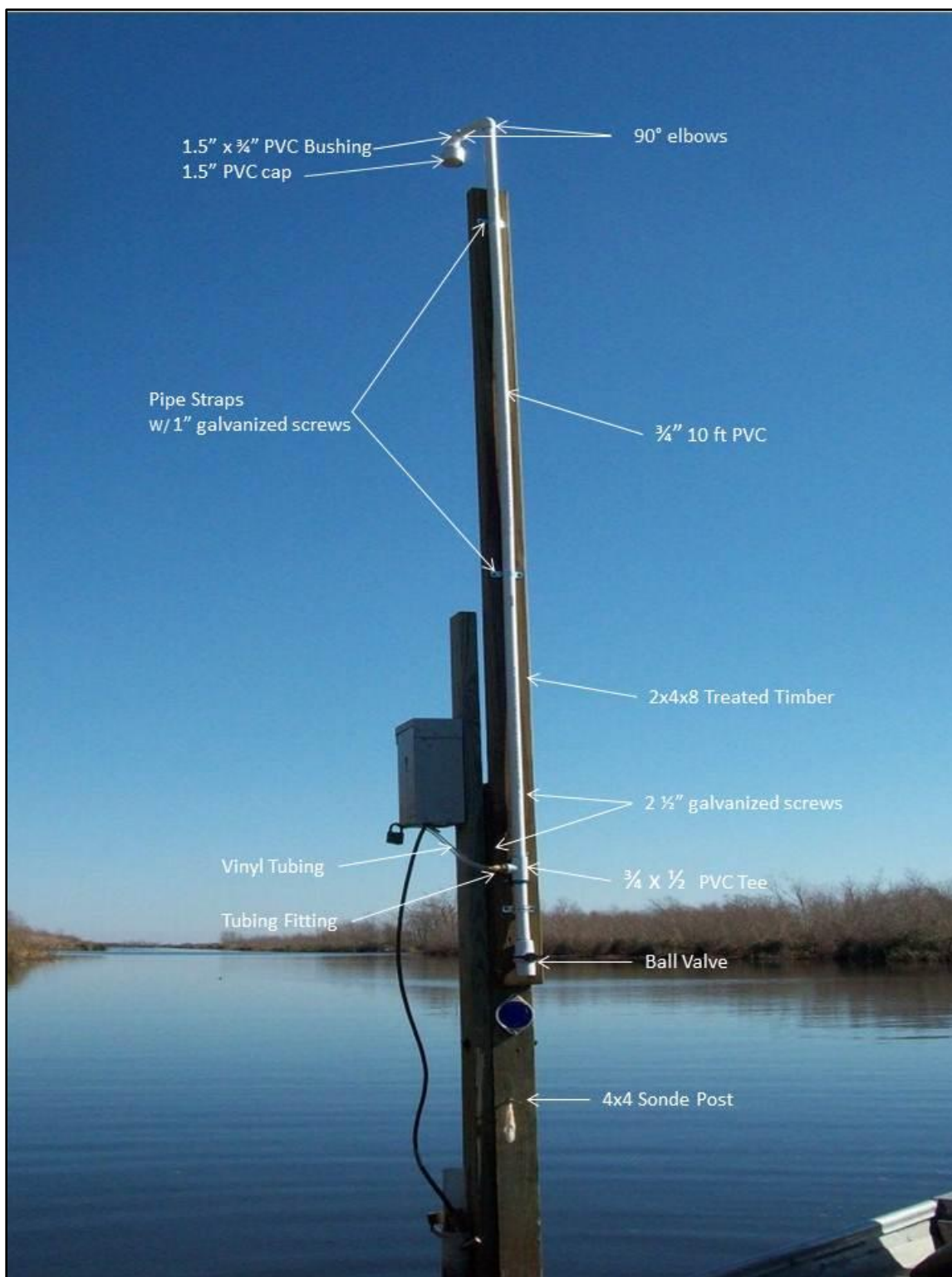
*Mounting the snorkel assembly to the wooden post:*

10. Mount the snorkel to the 2”x4”x8’ using the (3)  $\frac{3}{4}$ ” metal pipe straps and secure using the 1” hot-dipped galvanized wood screws.
11. Place the 2”x4”x8’ to the existing 4x4 sonde post in a vertical position and fasten to the post using the (4)  $\frac{1}{4}$ ” x 2  $\frac{1}{2}$ ”- 3” hot-dipped galvanized wood screws.
12. The 2”x4”x8’ should extend 5 to 6 ft vertically after it is fastened to the 4x4 sonde post.
13. Measure and cut the ( $\frac{1}{4}$ ” or  $\frac{5}{16}$ ”) vinyl tubing and make the connections from the snorkel to the desiccant pack located inside the electrical box.

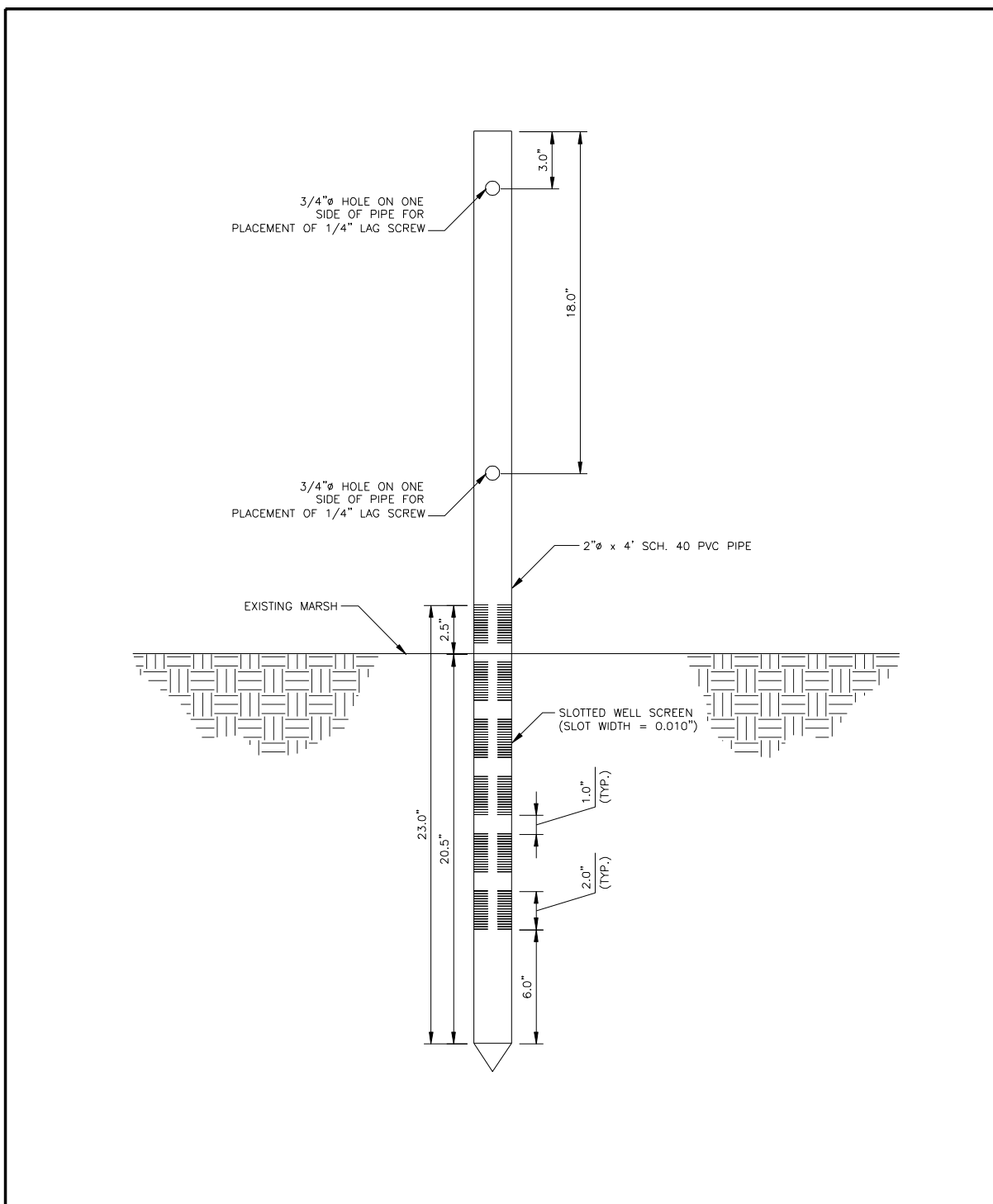


**Figure 3.5a.** Schematic of distances measured for elevation calculations for the wooden post continuous recorder set-up.





**Figure 3.5b.** Photograph of a wooden post setup with sonde snorkel construction details.



**Figure 3.6.** Detailed drawing of the inner 2" PVC well where the continuous recorder is placed in the marsh well set-up.

### 3. Hydrologic Data

CONTINUOUS RECORDER WATER LEVEL SENSOR DATA SHEET			
Station: _____			
Date of Measure: _____		Time (CST): _____ Agency: _____	
Reason for Measure:      Post / Pole Installed                      Periodic Check                      Change of Instrumentation			
Field Personnel: _____			
Continuous Recorder: _____ (Manufacturer)      _____ (Model)      _____ (Serial Number)			
(Deployed)      _____ (Overall length)      _____ (Top to water level sensor)			
Date of Post / Pole Installation: _____			
<input type="checkbox"/> <u>Wooden Post</u>		<input type="checkbox"/> <u>Mono-Pole</u>	
_____ (ft) A. Nail to top of post		_____ (ft) A. Top of 1/4" hole to top of pipe	
_____ (ft) B. Nail to bottom of continuous recorder		_____ (ft) B. Top of 1/4" hole to bottom of continuous recorder	
_____ (ft) C. Nail to water level sensor		_____ (ft) C. Top of 1/4" hole to water level sensor	
_____ (ft) D. Nail to water line		_____ (ft) D. Top of 1/4" hole to water line	
_____ (ft) E. Nail to subsurface		_____ (ft) E. Top of 1/4" hole to subsurface	
_____ (ft) F. Water depth		_____ (ft) F. Water depth	
_____ (ft) G. Penetration depth		_____ (ft) G. Penetration depth	
_____ (ft) H. Total pole length		_____ (ft) H. Total pole length	
		_____ (ft) I. Mud line to load plate (if not resting on subsurface)	
		_____ (ft) J. Amount of casing removed (if damage was done during installation)	

**Figure 3.7.** Continuous-recorder water-level sensor data sheet.

► ***Mono-pole system:***

The mono-pole is fabricated from a metal pole and thus is more durable than the wooden post design. Figure 3.2 illustrates the design specifications. Installation of the mono-pole is best accomplished with a vibra-core. A pile driver badly damages the end of the mono-pole and should not be used. Note: A hybrid design with features of the wooden post and mono-pole design can be used if needed at relatively deep and high-energy sites. This alternate design has a 3" x 20-ft schedule 40 aluminum post as the support post, and the CR support assembly is attached to the aluminum post in a similar manner as in the wooden post design.

### **3.1.2.2 Marsh Well Station Construction**

The marsh well method will be utilized at sites where there are no adequate water bodies to constantly submerge a continuous recorder during low-water periods, or where the site may be entirely marsh or swamp (see CRMS-*Wetlands* Site Decision Tree, Figure 2.3). The marsh well station will be established adjacent to the boardwalk in a predetermined location (Figures 2.7 and 2.8).

*Minimum Materials:*

1. 2 - 2" x 4" x 8-ft or 10-ft treated boards
2. 4 - 1/4" x 1 3/4" hot-dipped galvanized lag screws
3. 1 - Electrical box
4. 1 - 2" x 4-ft schedule 40 PVC slotted well (slot width = 0.01") (Figure 3.6)
5. 1 - 1" schedule 40 PVC with a 6" brass hitch pin
6. 1 - 16 penny hot-dipped galvanized nail
7. 2 - CPRA-issued brass locks
8. 1 - 4" (4–6-ft) schedule 40 PVC with cap
9. 1 - mesh screen (PVC, aluminum, or copper); resistant to saltwater
10. 2 - hose clamps (large enough to secure screen to 4" PVC)
11. 1 - 1" x 4" x 2-ft treated board for spacer
12. 1 - 4" schedule 40 PVC cap
13. 2 - 1 1/2" galvanized screws

Tools:

1. Pile driver: a cylindrical steel device that is approximately 36" in length, has an inside diameter  $\geq 5 \frac{1}{2}$ " and weighs approximately 60 pounds; used for driving post or equivalent device used to drive the post to resistance.
2. Wrenches
3. Cordless skill saw and/or reciprocating saw
4. Cordless drill and bits (various sizes)
5. Hammer
6. Socket set with driver

7. Measuring device (a surveyor's rod capable of measuring in feet, tenths, and hundredths)
8. 4" diameter soil core extractor (~3 ft long)
9. Personal protective equipment (e.g., gloves and eye protection)
10. Digital camera

#### Construction and Installation:

1. From the boardwalk, determine the correct location for the marsh well according to the approved PSV packet (Figures 2.4a and 2.4b) or as directed by the CPRA, and shoot a "before construction" picture.
2. Drive a 2" x 4" x 8-ft or longer board to resistance using a pile driver, making sure the board remains plumb. This post will serve as the well support post and as a benchmark for the well (i.e., it will be surveyed to a known datum). Therefore, an adequate length of board must remain above the marsh surface to allow full attachment of the well, but the post should not extend too high, as to allow lateral movement.
3. Extract a 24"-deep pilot hole adjacent to the well support post using a 4"-diameter soil core to minimize clogging of the marsh well's screens during installation.
4. Remove the soil and place in bucket.
5. Drill  $\frac{1}{2}$ " to  $\frac{3}{4}$ " holes along the length of the 4" PVC that will be below the marsh and extending to 2" above the marsh (Figure 3.3a). Cover the sides and bottom of the vented portion of the 4" well with the mesh screen and secure with hose clamps. Place the 4" PVC marsh well with screen into the pilot hole. The top 2" section of screen shall remain above the marsh surface as illustrated in Figure 3.6.
6. Secure the 4" PVC well to the board using two (2),  $\frac{1}{4}$ " x  $1\frac{3}{4}$ " lag screws approximately 3" and 18" from the top. Note: A  $\frac{3}{4}$ " hole will have to be drilled on one side to facilitate access for securing the screw. See Figures 3.3a, 3.3b, and 3.6.
7. Place the 2" PVC well inside the 4" pipe and secure with 2,  $1\frac{1}{2}$ " screws.
8. Place the instrument into the 2" PVC well. Then place the 1" PVC pipe in the well to secure the instrument.
9. Drill a hole through the board and the 4" PVC pipe above the 2" PVC well to receive the hitch pin.
10. Cut the 1" PVC pipe approximately 4" above the hole (beneath the top of the 4" PVC well) to remove any excess pipe.
11. Secure the cap onto the 4" PVC well.
12. Drive a nail into the side of the support post leaving ~ 2" to serve as the survey mark.
13. From the boardwalk, drive a second 2" x 4" board into the soil a maximum of 2 ft from the well station. This board does not have to be driven to resistance. It only has to be stable enough to house the electrical box and cable, but it must be high enough to not allow water to enter the box during high-water events.
14. Mount the electrical box to the board using the  $\frac{1}{4}$ " x  $1\frac{3}{4}$ " lag screws. The box should be a minimum of 4 ft above the surface.
15. Upon completion of construction the station shall resemble Figures 3.3a and 3.3b.

16. Document the measurements on the “Continuous Recorder Water Level Sensor Data Sheet” (Figure 3.7). Note: Because the data sheet is not specifically designed for a well system, use the wooden post column, noting that it is a well station.
17. To document proper installation, shoot an “after construction” photograph.
18. Complete the *Continuous Recorder* section (#5) on the “CRMS Site Construction Sheet” (Figures 2.10a, 2.10b, and 2.10c), including the station coordinates, the total length of the support post (ft), the height of the station above the substrate (ft), and number/time stamp of photos. Document whether a continuous recorder was deployed and provide notes regarding station construction, if necessary.

#### **3.1.2.3 Floating Marsh Mat Recorder Station Construction**

Previously, floating marsh sites employed two measuring systems to measure marsh mat vertical movement (Folse et. al 2018). In areas with thicker mats, a piece of plywood with a series of PVC pipes was anchored to the surface of the marsh and housed a continuous recorder that measured water level. The data from this recorder was paired with a nearby open water station in an attempt to calculate mat elevation to a known datum, and thus mat movement through time. A static system utilizing a counterweight pulley attached to the marsh mat and a recorder instrument was used in areas where the mat was too thin to support the weight of the heavier thick mat system. Again, the focus of the static system was to calculate mat elevation.

The current floating system (updated in 2020) utilizes a lightweight marsh mat well, constructed of PVC pipe that is designed to remain stable under various water level conditions and marsh mat thicknesses. A water level recorder is deployed to record water level on an hourly basis, unless otherwise specified by the CPRA. The focus of the current design is to obtain a direct measurement of water level in relation to the marsh surface to calculate depth and duration of flooding of the marsh mat. Calculation of mat elevation has been suspended at the floating marsh sites.

#### *Minimum Materials:*

1. Schedule 40, 3” PVC pipe
2. Schedule 40, 3” perforated snap-in PVC end cap
3. Schedule 40, ½” PVC pipe, threaded on one end
4. Schedule 40 ½” PVC pipe, unthreaded
5. Schedule 40, ½” PVC 90-degree elbow
6. Stainless steel screws ½” #7
7. Brass hitch pins, 9” long
8. Brass locks (provided by the CPRA)
9. 1” stainless steel split ring
10. Electrical box

#### *Tools:*

1. Drill
2. Drill bits: 23/32", 3/4"
3. Pipe tap, 1/2" NPT Carbon Steel
4. Miter saw with 1/8" blade
5. PVC glue
6. Tape measure
7. Digital camera

#### *Construction:*

##### Marsh Mat Recorder Setup (Figure 3.8):

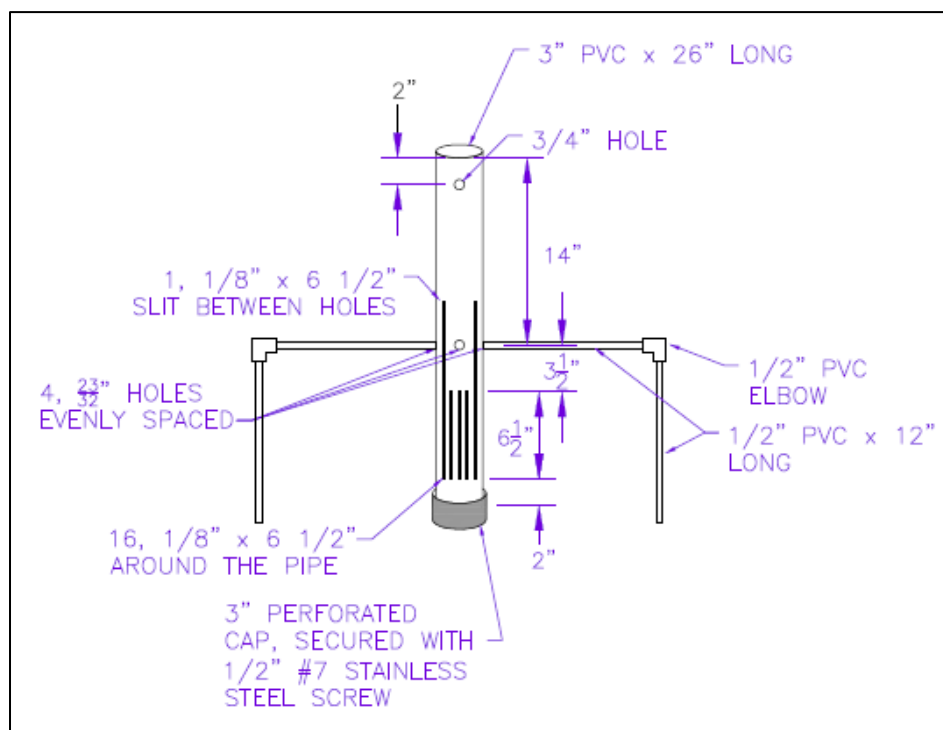
1. Cut the 3" schedule 40 PVC pipe to a length of 26".
2. Cut 16 1/8" wide X 6 1/2" long slits vertically into the bottom half of the 3" schedule 40 PVC pipe with a miter saw to allow for water exchange below the marsh mat surface. Slits should start at approximately 2" inches from the bottom of the pipe and be one inch apart.
3. Insert the 3" perforated end cap into the bottom end of the 3" schedule 40 PVC pipe and secure with three 1/2" #7 stainless steel screws.
4. Drill four 23/32" mounting holes at equal distances around the 3" PVC pipe 14" from the top of the pipe.
5. Thread the 23/32" mounting holes with a 1/2" NPT CS pipe tap.
6. Cut four additional 1/8" wide X 6 1/2" slits vertically between the mounting holes to allow for water exchange near the marsh mat surface.
7. Cut four sections of threaded 1/2" diameter PVC pipe to a length of 12 inches.
8. Thread the 1/2" diameter PVC pipe into the 3" schedule 40 PVC pipe. These will act as stabilizer arms, laying horizontally on the marsh surface.
9. Glue 1/2" PVC 90° elbows to the outer ends of the stabilizer arms, facing downward.
10. Cut four sections of 1/2" diameter PVC pipe to a length of 12 inches.
11. Glue the four sections of 1/2" diameter PVC pipe into the 90° elbows. These will serve as anchors to secure the setup to the marsh.
12. Drill a 3/4" hole through the top of the 3" PVC pipe approximately 2" from the top of the pipe. Note: This hole will hold the hitch pin to be used to secure and suspend the instrument using the 1" stainless steel split ring.
13. Mount the electrical box to a 10 ft section of 3" schedule 40 PVC pipe. This will serve to house the excess cable and desiccant from the recorder.

#### Installation:

1. The station will be located a minimum of 10 ft away from the boardwalk either in the designated area shown in Figure 2.8 or where requested by the CPRA. Once the proper location for the station has been determined, shoot a "before construction" photo.

2. Place a board(s) on the marsh surface to displace the weight of the person (people) installing the equipment.
3. With the soil corer or auger, cut a hole through the marsh mat, and remove the resulting soil materials from the site.
4. Measure the thickness of the marsh mat and record the measurement in a field notebook with the site name, number, and date.
5. Place the set-up in the hole such that the 3" pipe goes through the marsh mat with the perforated end cap side inserted first.
6. Secure the set-up to the marsh surface using the four PVC anchor arms.
7. Drive the 10' section of 3" schedule 40 PVC pipe approximately 2 ft from the well with the electrical box on top. This pipe does not have to be driven to resistance. It only has to be stable enough to support the electrical box and cable, but it must be high enough to not allow water to enter the box during high-water events.
8. If the instrument is not being deployed at this time, lock the well using the brass hitch pin and lock.
9. To document proper installation, shoot an "after construction" photograph.
10. Complete all necessary information in the *Marsh Mat Recorder* section (#6) on the "CRMS Site Construction Sheet" (Figures 2.10a, 2.10b, and 2.10c).

With this installation method, the water level sensor on the continuous recorder will be located within the marsh mat. The measurement from the marsh surface to the water-level sensor is a crucial measurement, because it will be used to determine depth and duration of the flooding of the floating mat.



**Figure 3.8.** Construction diagram for components of the floating marsh mat recorder.



#### **3.1.2.4 Staff Gauge Installation**

The CPRA utilizes staff gauges with the following specifications: ceramic-coated gauge 2.5" wide ranging from -2 to +3 ft, graduated to hundredths, marked at every foot and every tenth, and five grommet holes for fastening with ¼" x 1 ½" stainless steel hexagonal screws with a slotted head. The gauge is mounted to a 2" x 4"x 6-ft treated board, which is then attached to a 4" x 4" treated wooden post or a 2" galvanized pipe driven to resistance (Figure 3.9). The staff gauge will be set to the vertical datum NAVD88 (North American Vertical Datum, 1988) in feet during the surveying procedure.

When placed in proximity to a continuous recorder set-up, the staff gauge set-up should not be placed in a location where it may hinder the 2" x 4" board on the continuous recorder set-up from being swiveled fully for periodic servicing or inspections. In addition, the ceramic-coated gauge should be oriented so that it can be viewed easily from the continuous recorder station during servicing.

##### *Minimum Materials:*

1. 4" x 4" treated wooden post either 16 ft or 20 ft in length
2. Or 5-ft-long, 2" galvanized pipe threaded on both ends
3. 2" galvanized couplings
4. 2" galvanized caps

##### *Tools:*

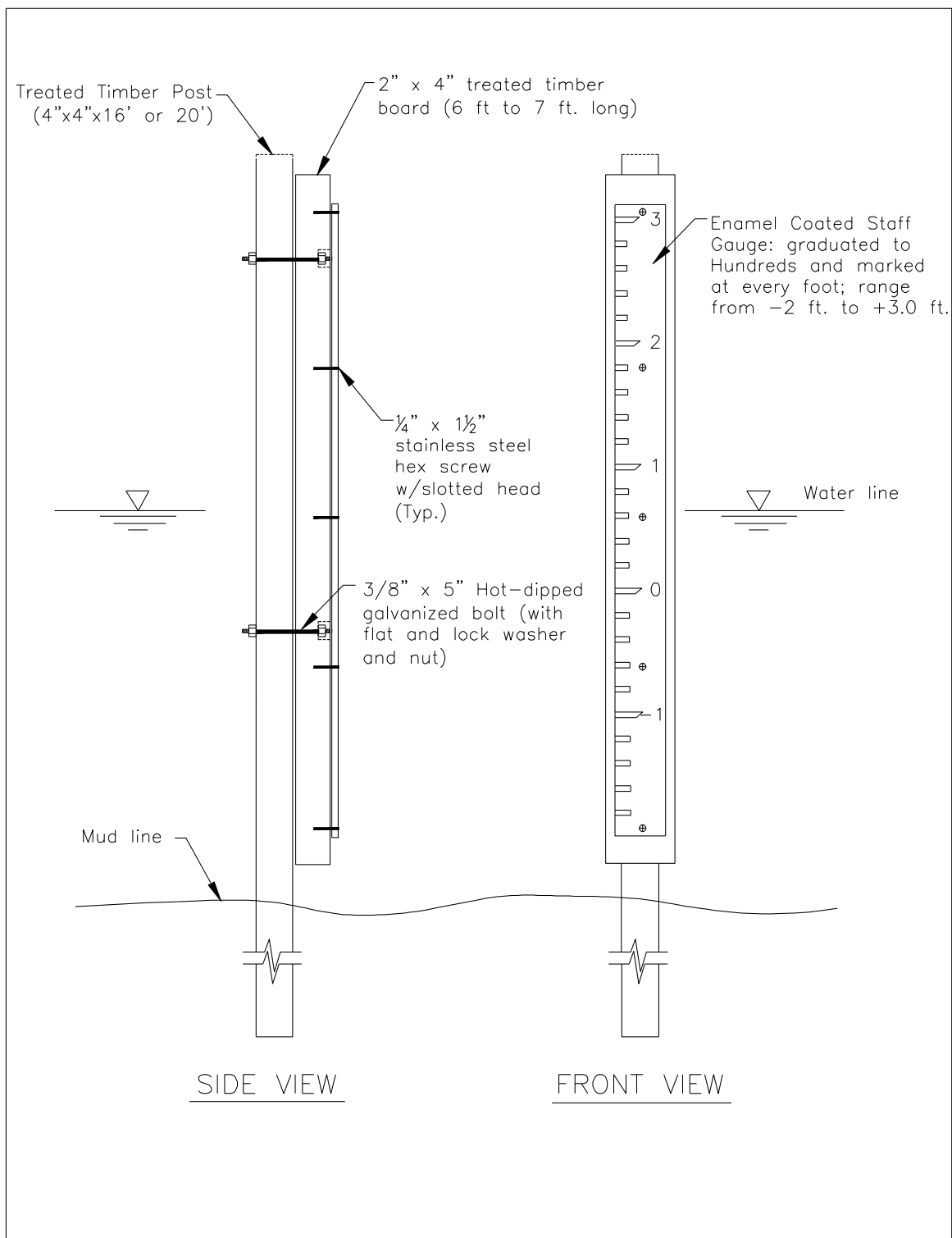
1. 2 Pipe wrenches
2. Pile driver
3. Digital camera

##### *Installation:*

The procedures for installing the wooden post are the same as in section 3.1.2.1. The procedures for installing the pipe to resistance are as follows:

1. Determine the correct location for the staff gauge according to the approved PSV packet (Figures 2.4a and 2.4b) or as directed by the CPRA, and shoot a "before construction" picture.
2. Connect two or more pieces of the pipe using the couplings and tighten with the wrenches.
3. Place the pipe in the water at the desired location and push the pipe into the substrate by hand, making sure the pipe remains plumb.
4. Continue to add sections of pipe as needed and tightening with the wrenches.
5. Once resistance has been achieved, loosely thread the 2" galvanized cap on the top pipe. The cap is used to prevent damage to the pipe threads while using the pile driver. The cap should be removed after each section of pipe is driven.

6. Continue to add sections of pipe and drive them in the same manner.
7. The process is complete when the pipe has met refusal and a minimum of 4 ft remains above the marsh surface.
8. Tighten the cap onto the end of the pipe.
9. To document proper installation, shoot an “after construction” photograph.
10. Complete all necessary information in the *Staff Gauge* section (#4) on the “CRMS Site Construction Sheet” (Figures 2.10a, 2.10b, and 2.10c).



**Figure 3.9.** Typical staff gauge installation.

### **3.1.2.5 Surveying Procedures**

CRMS has had two comprehensive professional survey efforts conducted by licensed professional land surveyors (PLS); the initial effort during construction where sites were surveyed individually as they were constructed and the 2014 survey effort where all of the sites were re-surveyed within a short timeframe. Most of the initial effort took place between 2006 and 2008. Published secondary monument elevations were used and new monuments were installed if there was not a monument within 3.5 km of the CRMS site (approximately 80 new monuments). RTK was utilized to establish elevations of the RSET, the sonde post and staff gauge, and the marsh. For the 2014 re-survey, CRMS elevations were updated in one coast-wide survey effort using a network solution where CRMS sites were surveyed relative to a constrained network of secondary monuments. RTK was utilized to get elevations of the RSET and level loops were utilized to get elevations of the sonde post and staff gauge. Marsh elevation was measured separately at each of the vegetation stations instead of along a transect across the 200-m<sup>2</sup> data collection area as they were in the initial survey. The initial survey was in Geoid 99 with some updates in Geoid 03 and 09 that were converted to Geoid 99. The 2014 survey was in Geoid 12A. All sites were surveyed to CPRA LCZ GPS Network utilizing NAVD88 utilizing the latest Geoid model and completed in accordance to CPRA's "A Contractors Guide to Minimum Standards 2013". For each professionally surveyed CRMS station, a report has been generated for the continuous recorder, well, staff gauge, and RSET rod along with its corresponding benchmark (Figure 3.10, 3.11, 3.12). All survey reports and their established elevation marks (NAVD 88) are available for viewing and downloading at <http://www.lacoast.gov/crms2/Home.aspx>.

The procedures outlined in this section are general surveying practices. Maintenance surveying may be required on a site-to-site basis based on field or data observations prior to the next comprehensive survey. All professional surveying shall be done in accordance with CPRA's "A Contractor's Guide to the Standards of Practice: For CPRA Contractors Performing GPS Surveys and Determining GPS Derived Orthometric Heights within the Louisiana Coastal Zone" (CPRA 2019).

#### **► Survey Check:**

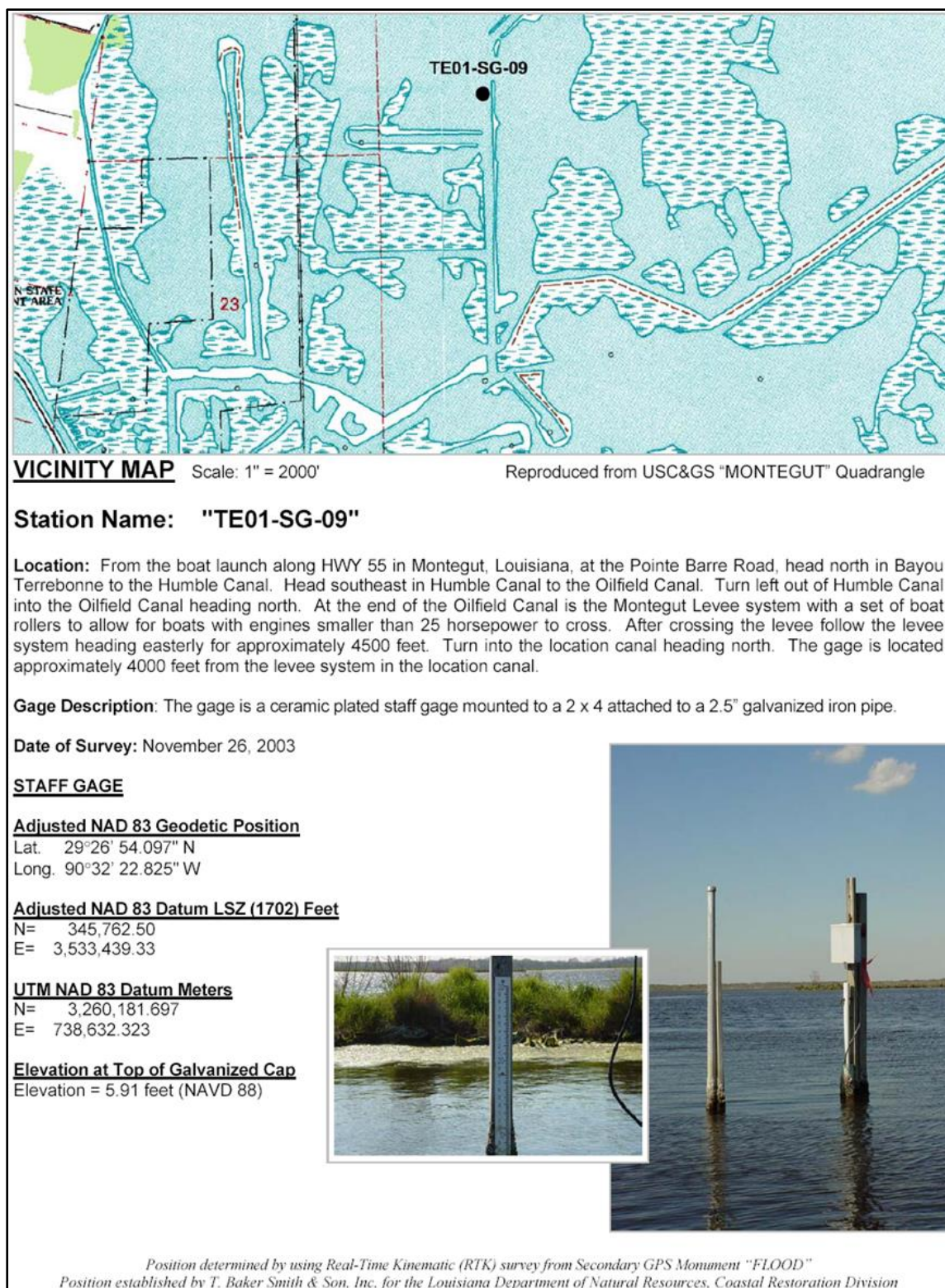
Because elevations are continuously used throughout the CRMS network a check shall be performed as needed to adjust elevations at the continuous recorder and the staff gauge to the elevation of the RSET rod. Note: Floating sites do not have an SET rod and would not be covered by this procedure.

The following survey procedures shall be used:

1. Properly mount and level the auto-level / laser level according to the manufacture's operator manual away from the boardwalk and any data collection stations (i.e. accretion or vegetation stations).

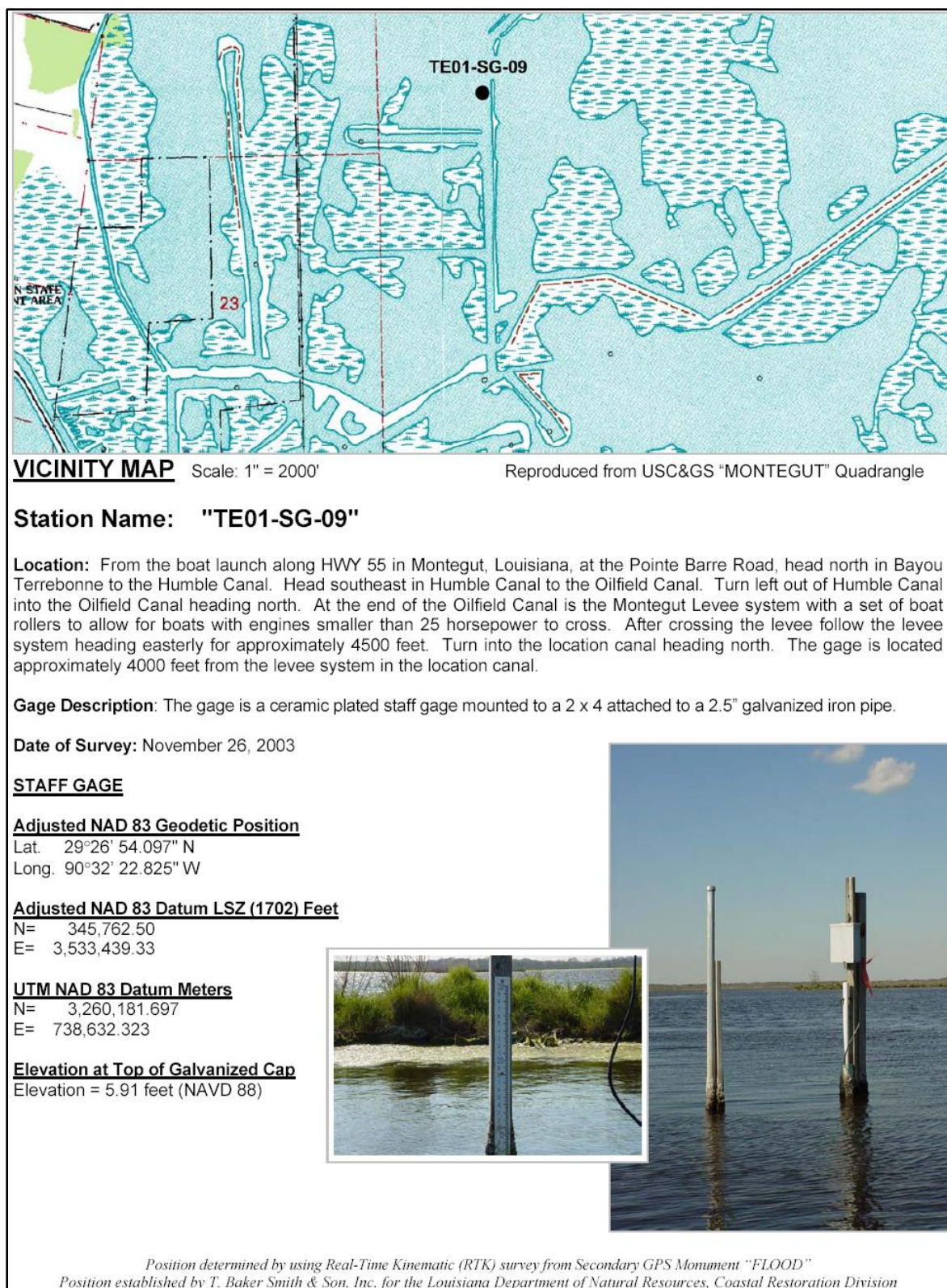
Note: The line of sight or laser beam should be established such that it is above the highest point being surveyed (i.e. the nail on the continuous recorder or staff gauge post). This makes it easier to calculate the elevations.

2. From a board that spans the base boardwalk, place the surveyor's rod on top of the RSET.
3. Using the procedures described in the operator manual, obtain the Rod Reading on Top of RSET.
4. Calculate the Instrument Height using the RSET elevation from the most recent survey report and the following formula:  
$$\text{Instrument Height} = \text{RSET elevation} + \text{Rod Reading on Top of RSET}$$
5. Obtain readings at the top of the continuous recorder and staff gauge posts.
6. Calculate the Top of Recorder Support Pole and Top of Staff Gauge Support Pole elevations using the following formula:  
$$\text{Top of Support Pole Elevation} = \text{Instrument Height} - \text{Rod Reading on Top of support Pole}$$
7. Using a tape measure displaying feet, tenths, and hundredths, obtain and record the following distances:
  - a. Top of recorder post to top of nail shank or top of 1/4" hole.
  - b. Top of recorder and staff gauge posts to top of water.
8. Calculate the elevation of the nail shank or hole and the water. Document elevations and calculations in the Continuous Recorder and Staff Gauge Data Sheet (Figure 3.13).
9. Lastly, go back to the RSET and obtain another reading from the top of the RSET to compare back to the initial Rod Reading on Top of RSET.
10. This reading in surveying terms "closes the loop" which means it verifies that the instrument has not moved during the survey and verifies that the readings obtained should be correct.
11. If the "before" and "after" Top of RSET readings are more than 0.07 feet different, then repeat the survey.

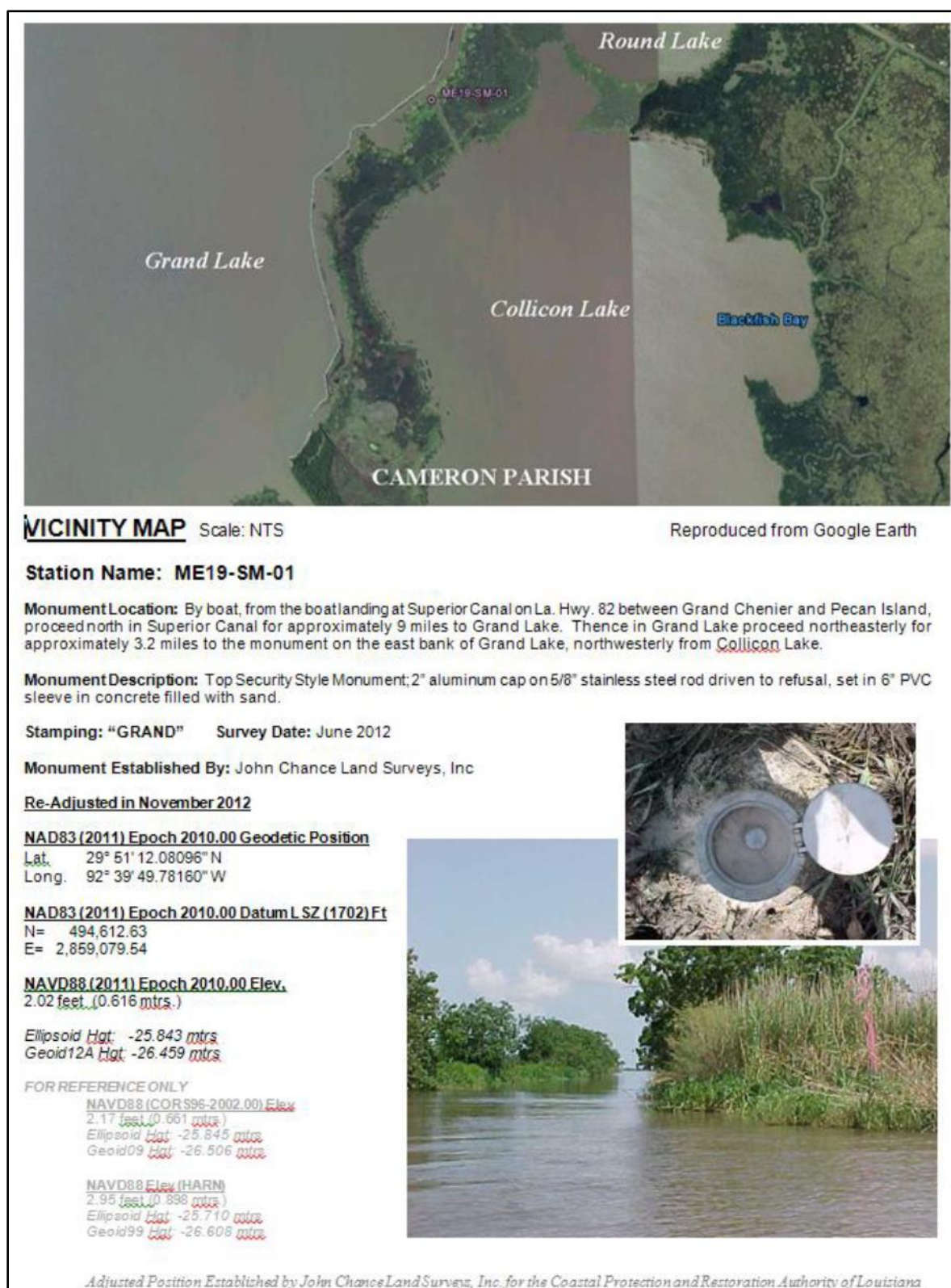


**Figure 3.10.** Example of continuous recorder data sheet from CRMS TE-01 survey report.





**Figure 3.11** Example of staff gauge data sheet from CRMS TE-01 survey report.



**Figure 3.12** Example of benchmark monument data sheet from CRMS TE-01 survey report.



Continuous Recorder and Staff Gauge Survey Data Sheet

Station	Date	Continuous Recorder Gauge				
		Top of Recorder Support Pole (4x4 Post, Cap of Pipe, etc.)	Top of Support Pole to Nail or Top of 1/4" Hole	Nail or Hole Elevation	Top of Recorder Support Pole to Top of Water Distance	Water Elevation
		(NAVD 88, Ft.)	(Ft.)	(NAVD 88, Ft.)	(Ft.)	(NAVD 88, Ft.)

**How to Obtain Readings for Each Continuous Recorder Gauge Column**

**Top of Recorder Support Pole:** Obtained by using department approved surveying methods.

**Top of Support Pole to Nail or 1/4" Hole:** Obtained by physically measuring the distance between the two points.

**Nail or Hole Elevation:** Obtained by using the formula subtracting the two previous columns.

**Top of Recorder Support Pole to Top of Water Distance:** Obtained by measuring the distance between the two points.

**Water Elevation:** Obtained by using the formula: Top of Recorder Support Pole - Top of Recorder Support Pole to Top of Water Distance.

Station	Date	Staff Gauge						
		Existing Staff Gauge Reading (Upon Arrival)	Top of Staff Gauge Support Pole	Top of Staff Gauge Support Pole to Top of Water Distance	Water Elevation	Staff Gauge Reading (After Establishment or Adjustment)	Computed Difference (Water Elevation vs. Staff Gauge)	Correction Factor
			(NAVD 88, Ft.)	(Ft.)	(NAVD 88, Ft.)	(NAVD 88, Ft.)		

**How to Obtain Readings for Each Staff Gauge Column**

**Existing Staff Gauge Reading:** If a staff gauge is present at this location, obtain a reading before any adjustments are made.

**Top of Staff Gauge Support Pole:** Obtained by using department approved surveying methods.

**Top of Staff Gauge Pole to Top of Water Distance:** Obtained by physically measuring the distance between the two points.

**Water Elevation:** Obtained by subtracting the two previous readings (Top of Staff Gauge Support Pole and Top of Staff Gauge Support Pole to Top of Water Distance).

**Staff Gauge Reading:** Obtained by reading the staff gauge after it has been set to the datum.

**Computed Difference:** Obtained by subtracting the two previous readings (water elevation and Staff Gauge Reading).

**Correction Factor:** Obtained by subtracting the Existing Staff Gauge Reading and the Staff Gauge Reading. The correction factor is used to correct all previously data collected.

**Figure 3.13.** Example of a surveying spreadsheet used to calculate correction factors for historical monitoring hydrologic data.

#### ► **Continuous recorder sites:**

The purpose of the survey is to obtain the elevation of the top of the support post of the continuous recorder stations. This elevation, once obtained, will allow for the calculation of the “mark” (nail or hole) elevation located on the side of the support post. The “mark” elevation will allow for the depth data collected at each station to be converted to the same vertical datum (NAVD88 in feet).

Document elevations and calculations in the Continuous Recorder and Staff Gauge Data Sheet (Figure 3.13).

1. Utilize the leveling procedures from the section titled “Survey Check” or survey report to establish the elevation of the top of the 4x4 continuous recorder post.
2. Using a tape measure displaying feet, tenths, and hundredths, obtain and record the following distances:
  - a. Top of post to top of nail shank or top of ¼” hole.
  - b. Top of post to top of water.
3. Calculate the elevation of the nail shank or hole and the water. Document these calculations (Figure 3.13).
4. Shoot photo for survey data sheet.

#### *Swamp Sites:*

The CPRA recognizes the difficulty of surveying in a swamp environment. If propagation errors occur due to the dense forest canopy, conventional elevation surveys may be performed as long as temporary benchmarks (TBMs) have been established using professional surveying methods. The TBM must be within the 3.5-mile radius of a Louisiana Coastal Zone (LCZ) GPS network secondary monument (SM) or another TBM that has been surveyed into this network. In addition, a level loop (single-run leveling) must be performed to minimize the effects of elevation misclosure when using optical instruments.

#### ► **Staff gauge Installation:**

Staff gauges are surveyed to directly measure water elevation within a vertical datum. In addition, staff gauges are used for verification (quality control) of continuous recorder water elevation data. Gauges are mounted to a 2” x 4” x 6-ft board that will then be attached to a support post.

The following survey procedures shall be used:

1. Utilize leveling procedures from the section titled “Survey Check” or survey report to establish the elevation of the top of the 4x4 staff gauge post.
2. Calculate the 3-ft mark using the elevation of the top of post. Top of post elevation – 3.00 = Distance from top of post.

3. Using a tape measure, measure from the top of post where the elevation was measured and place a mark at the distance calculated in step 2. This should be the 3.00-ft NAVD88 elevation.
4. From this mark, extend a level line on the side of the post.
5. Attach the staff gauge using two or three screws to the 2" x 4" board. The staff gauge should be positioned such that the bottom of the staff gauge is near the bottom of the board and that the board extends a few inches above the staff gauge.
6. Extend the 3-ft mark from the staff gauge to the same side of the 2" x 4" board that will align with the line drawn in step 4.
7. Clamp to the post the 2" x 4" with the attached staff gauge such that the two 3-ft lines match.
8. Measure the distance from the top of the post to the water.
9. Calculate the water elevation using the formula: Water elevation = Top of post elevation (obtained in step 1) – Distance (obtained in step 8).
10. The value calculated in step 9 should be the same value on the staff gauge. If not, then an error has occurred and must be corrected.
11. At the continuous recorder post, use the top of the post elevation from the continuous recorder, re-measure the distance to the water, and calculate the water's elevation.
12. The water elevation from the continuous recorder and the staff gauge reading should be within the error of the survey instrument.
13. If all values are within tolerance, proceed with securing the staff gauge to the post by drilling a 1/2" hole through the top of the 2" x 4" above the staff gauge and through the 4" x 4" post.
14. Unclamp and remove the board and staff gauge from the post.
15. Unscrew the two or three screws from the staff gauge and remove.
16. Place just the 2" x 4" board back on the post and secure with the 3/8" x 6" bolt with washers and nut.
17. Drill another hole through the 2" x 4" and post as close to the water line as possible.
18. Remove the 2" x 4" and drill a hole to counter sink the bolt head. Note: The bolt head must be counter sunk completely to allow the staff gauge to be mounted flush to the board to prevent biofouling between the two from occurring.
19. Place the bolt in the hole that was drilled in step 17.
20. Attach the staff gauge to the 2" x 4" board using all five screws. Note: Do not overtighten the screws. Placing too much pressure on the staff gauge will chip the enamel coating and cause rusting.
21. Attach the board with staff gauge to the 4"x 4" post using the bolt, washers, and nut.
22. Check measurements again.
23. Shoot photos for documentation and survey data sheet.

Upon completion of the installation, obtain all the measurements that will complete the spreadsheet *Continuous recorders and staff gauge format for surveyor.xls* (Figure 3.13). These measurements verify that the staff gauge and the nail elevation are within the accuracy of the instrument. The difference between the water elevation reading with respect to the nail elevation and the staff gauge shall be within 0.05 ft of each other. If these readings are not within this range, elevations must be obtained and adjustments must be made until it is within the acceptable range. Also, a staff gauge data sheet shall be produced (Figure 3.13).

#### ► **Surface elevation:**

##### *Marsh Surface Elevation:*

Marsh elevation will be determined along the transect line but just outside the one meter square area of the 10 vegetation monitoring stations at a minimum of 20 points in attached marshes and swamps. Those areas that are classified as floating marshes will not be surveyed. The top of the RSET rod will function as an elevation reference point at each site with elevations established in feet NAVD88. A laser level will be used to carry this elevation to rod at each of the vegetation stations. In general, marsh surface with respect to elevation surveys is defined as “when the survey rod is resting among living stems or is supported by soil containing living roots.” In order to get a consistent reading, it will often be necessary to move stems in some marsh vegetation where stem density is extremely high. The 20 elevations are averaged to obtain marsh elevation. All 20 readings and the average will be recorded in an Excel spreadsheet identical to the format presented in this document.

When the dominant species is *Spartina patens* (saltmeadow cordgrass), a minimum of forty (40) elevations will be recorded. Twenty elevations will be recorded on the marsh surface (as described above), and 20 elevations will be recorded on the crown/individual tuft (a small cluster of elongated flexible outgrowths attached or close together at the base and free at the opposite ends) of the *Spartina patens* that is adjacent to the marsh surface reading. These readings shall be recorded and labeled in the Excel spreadsheet as “marsh surface” or “*Spartina patens*.”

For sites that are dominated with *Phragmites australis*, elevations shall be taken in close proximity to the boardwalk or the nearest area that provides surveying visibility. This area must be within the 200-m sq. extent established from the center point of the boardwalk and represent the marsh surface of the CRMS site.

Once the survey at each station is completed, the surveyor shall record the type of terrain encountered during the survey. This should include whether the marsh was firm and easy to traverse, spongy with minimal difficulty, or very soft with extreme difficulty and holes in the marsh surface.

CRMS Marsh Elevation Surveys Conducted to Date: Marsh elevations have been surveyed twice, once during initial surveys conducted when sites were constructed mostly between 2006 and 2008 and another as part of an update effort in 2014. For the initial survey, elevation was collected along a transect across the 200-m sq at representative sites selected by the surveyor. For the 2014 survey, elevations were collected from each of the existing vegetation stations instead of the original locations.

#### *Swamp Surface Elevation:*

The CPRA recognizes that swamp environments vary between regions, and that these differences must be considered when determining the actual surface of the swamp. In some areas where the swamp is seasonally flooded, the swamp surface may be easily determined, especially when there is no water above the surface of the swamp floor. For this type of environment, the swamp floor is determined “when the survey rod is resting among living stems or is supported by soil containing living roots.”

In an environment where the swamp is permanently flooded, some areas may or may not have aquatic vegetation that has rooted together to form floating marsh mats. Some areas may not have these floating marsh mats, but may have an environment where determining the swamp surface may be difficult due to a layer of unconsolidated materials and a spongy surface. Prior to surveying, the surveyor shall discuss with the CPRA a proposed method that shall be used at similar sites to consistently determine the swamp surface elevation at these sites.

### 3.1.3 Initial Deployment of Continuous Recorders

Prior to the initial deployment, the continuous recorder shall be programmed to record the date (mm/dd/yyyy), time (hh:mm:ss), water temperature (°C), specific conductance (µS/cm), salinity (ppt), water level (ft), and battery volts (v). The recorder must be programmed to record the time in Central Standard Time using the 24-hour system and must remain in that time configuration during Daylight Savings Time. Any data previously recorded on the instrument shall be deleted before initial deployment.

All procedures regarding the deployment of continuous recorder instruments in Open Water (Section 3.1.3.1) and Marsh Wells (Section 3.1.3.2) require the use of the electronic data sheet in Excel format titled “Continuous Recorder Calibration Sheet” (Figure 3.14), which is provided by the CPRA.

#### **3.1.3.1 Open Water Deployment**

The following steps should be taken when deploying a continuous recorder in the open water environment:

1. Complete the *Station*, *Collected By*, *Agency*, *Calibration Instrument*, and *Serial Number* fields at the top of the calibration sheet. The *Collected By* and *Agency* names must be entered exactly as specified by the CPRA to be recognized by the CPRA’s database.
2. Complete the *Station Information* box on the calibration sheet. Three static measurements to be noted in this section include:
  - A. The *Mark to Sensor Distance (FT)*, which is the distance between the nail located on the wooden post or the top of the ¼” hole on the stainless steel pole to the water level sensor on the continuous recorder. This measurement will allow the water level readings to be converted to a vertical datum when the nail or top of ¼” hole has been surveyed by a professional, licensed surveyor.
    - i. the *Mark Elevation (NAVD88, FT)*, provided by a professional surveyor
    - ii. the *Marsh Elevation (NAVD88, FT)*, provided by a professional surveyor

If any of these measurements are unavailable, “N/A” should be entered.
3. Calibrate the instrument’s water level sensor to zero (0) when it is out of the water prior to deployment. Follow the procedures in the owner’s manual for the specific instrument being used.
4. Calibrate the continuous recorder and hand-held instrument’s salinity probe to a known conductivity standard that is similar to the ambient water salinity concentration at the time of deployment. Document the calibration and calibration standard in the *Notes* section of the calibration sheet.
5. Verify that the continuous recorder has accepted the calibration by using the calibrated hand-held salinity meter:

- A. Place the two salinity probes next to each other and lower them into the water to the deployment depth.
- B. Record the water temperature, specific conductance, and salinity reading from both instruments in the *Post-Calibration Readings* section of the calibration sheet.
- C. The specific conductance difference will automatically be calculated using the formulas:

Specific Conductance Difference = Calibration Instrument – Continuous Recorder

% Difference = (Specific Conductance Difference / Specific Conductance of Calibration Instrument) \* 100

If the percent difference is below 5%, then the instrument is successfully calibrated. If the percent difference is above 5%, then the instrument needs to be recalibrated or is malfunctioning. If the percent difference is still above 5% after two calibration attempts, then the instrument should be replaced. Steps 3 through 5 should then be repeated to calibrate the replacement instrument. All issues related to the calibration of the instrument should be noted in the *Calibration Information* section of the calibration sheet.

6. Once the continuous recorder is calibrated, place the instrument into position for deployment.
7. Once the continuous recorder has stabilized, record the depth of the water from the instrument onto the calibration sheet in the *Post-Calibration Readings* section.

Verify that the water depth reading is correct using the following method:

- A. Place a surveyor's measuring rod (ft) at the *Mark to Sensor Distance* value at the nail on the timber post or the top of the 1/4" hole on the "mono-pole." This places the bottom of the rod (zero reading) at the same depth as the water level sensor on the continuous recorder.
- B. Read the water level on the rod and record the value in the *Post-Calibration Readings* section in the *Calibration Instrument* column in the *Depth* field.
- C. The difference between the water level on the rod and the depth reading from the instrument will automatically be calculated using the formulas:

Water Level Difference = Water Level on Rod - Continuous Recorder Reading

% Difference = (Water Level Difference / Water Level on Rod) \* 100

- D. If the percent difference is below 5%, then the instrument is calibrated. If the percent difference is above 5%, then the instrument needs to be recalibrated or is malfunctioning.

<b>Continuous Recorder Calibration Sheet</b>				
(Revised 06/07/2011 by CES)				
Station	Collected By	Agency	Date & CS Time	
<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	
Calibration Instrument	Serial Number	Sonde Date & Time		
<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>		
Continuous Recorder	Serial Number	Battery Volts / %	Download Filename	Deployed Date and Time
<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
<b>Station Information</b>				
		Mark Elevation (NAVD88, FT)	<input style="width: 95%;" type="text"/>	
Marsh Elevation (NAVD88, FT)		Mark to Sensor Distance (FT)	<input style="width: 95%;" type="text"/>	
<input style="width: 95%;" type="text"/>		If floating: Mat to Sensor Distance (FT)	<input style="width: 95%;" type="text"/>	
<b>Dirty Readings</b>				
		Sensor Elevation (NAVD88, FT)	<input style="width: 95%;" type="text"/>	
	Continuous Recorder	Calibration Instrument	Difference	% Difference
Temp. (°C)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
SpCond (µS/cm)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
Salinity (ppt)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
Depth (ft)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
<b>Post-Calibration Readings</b>				
	Continuous Recorder	Calibration Instrument	Difference	% Difference
Temp. (°C)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
SpCond (µS/cm)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
Salinity (ppt)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
Depth (ft)	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>
<b>Deployment</b>				
Continuous Recorder	Serial Number	Battery Volts / %	Desiccant Changed	
<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	
Deploy Filename	Sonde Date & CS Time	Batteries Changed		
<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>	<input style="width: 95%;" type="text"/>		
<b>Notes:</b> (Note any communication problems, equipment damage, changes in Mark to Sensor distance, changes to 4X4 sonde setup, etc.)				
<div style="border: 1px solid black; height: 100px; width: 100%;"></div>		Biofouling: <input style="width: 95%;" type="text"/>		
		Staff Gauge (NAVD88, FT) <input style="width: 95%;" type="text"/>		
		Marsh Flooded: <input style="width: 95%;" type="text"/>		
		Vegetation Condition: <input style="width: 95%;" type="text"/>		
		SAV: <input style="width: 95%;" type="text"/>		
<b>Calibration Information:</b> (Note any problems/issues encountered during sonde calibration)				
		Water Level Relative to Marsh (FT) <input style="width: 95%;" type="text"/>		
		Water Elev to Datum(NAVD88, FT) <input style="width: 95%;" type="text"/>		
		Staff Gauge - Water Elev <input style="width: 95%;" type="text"/>		
<b>Infrastructure Damage Assessment:</b> (Note any damage to sonde setup and/or other CRMS features)				

Figure 3.14. Continuous recorder calibration sheet.



8. Follow the owner's manual for setting the continuous recorder in an unattended mode. Complete all fields in the *Deployment* section of the calibration sheet, including:
  - A. *Continuous Recorder*: The manufacturer and model number of the continuous recorder must be entered as in the following examples: YSI 600LS, YSI 6920, Hydrolab MS5, etc.
  - B. *Serial Number*: Enter the serial # of the continuous recorder. In the case of a Hydrolab, only the last five digits of the serial number are required.
  - C. *Deploy Filename*: The filename must be deployed and documented as in the following example: 061201H1, where 0612 represents the site number, 01 designates the month in which the file was established, H designates the station as hydrologic open water (W = marsh well, M = floating mat), and 1 represents the station number.
  - D. *Date & CS Time*: The actual date and time the instrument is deployed must be documented. All times must be in Central Standard Time (CST) and written in 24-hour time convention (e.g., 3:00 p.m. = 15:00) even during Daylight Savings Time (DST). This is 'watch time'.
  - E. *Battery Volts*: Enter the battery voltage at the time of deployment.
  - F. *Batteries Changed* and *Desiccant Changed*: Fresh batteries and desiccant should always be used during the initial deployment of the instrument. Therefore, a YES should be selected for both fields. Note: When securing the desiccant tube in the electrical box, make sure that the plastic tubing is free of sharp bends or kinks that could result in the collection of non-vented data.
9. Complete all necessary information in the *Notes* section of the calibration sheet, including the staff gauge reading (if applicable). If this is the first time a sonde is being deployed at a particular station, then "Initial Deployment" should be typed into the *Notes* box. If a sonde is being deployed after a station has been rebuilt, then "Station Rebuilt" should be typed into the *Notes* box.

After the initial deployment has taken place, the instrument needs to be serviced no earlier than 30 days after deployment and no more than 60 days after deployment unless otherwise stated or agreed upon by the CPRA. Sites experiencing high levels of biofouling may need to be serviced every 30 days or as needed. Some sites may be subject to special landowner restrictions, which may prohibit servicing trips during certain times of the year (i.e., duck season). Trips should be planned to closely bracket these restricted periods to minimize the length of time between servicing.

### **3.1.3.2 Marsh Well Deployment**

The procedures for deployment of continuous recorders at marsh well sites shall remain the same as the procedures for deployment in the open water body except for the following:

1. Servicing and deployment of the recorder will not take place from a water vessel. The marsh well set-up will be serviced from the CRMS boardwalk. Enter and exit the site without stepping on the marsh surface. Note: The exposed continuous recorder cable may be enclosed in a wire mesh sleeve to prevent damage by animals.
2. Calibration readings from the continuous recorder and the hand-held salinity meter must be taken separately since both instruments will not fit in the well simultaneously (see Section 3.1.3.1, #5).
  - a) Place the handheld calibration probe inside the well and record the *Post-Calibration Readings* in the *Calibration Instrument* column. Remove probe.
  - b) Place the calibrated recorder inside the well. Connect to unit and record the water temperature, specific conductance, salinity and depth under Post-Calibration Readings in the Continuous Recorder column.
3. Place a surveyor's rod on the Nail (mark elevation) on outside of sonde post and record water on marsh in NAVD elevation (ft).
4. Record the salinity and depth of the surface water on the marsh adjacent to the well.

### **3.1.3.3 Floating Marsh Mat Deployment**

The procedures for deployment of continuous recorders at marsh mat sites are slightly different than the procedures for deployment in the open water body. The marsh mat sites require the use of a different electronic data sheet in excel format titled "Floating Marsh Mat Recorder Calibration Sheet"(Figure 3.15), which is provided by the CPRA.

1. Servicing and deployment of the recorder will not take place from a water vessel. The floating mat set-up will be serviced from a 2" x 12" x 10-ft board placed on the marsh surface. These stations are located away from the boardwalk since the boardwalk may inhibit vertical movement of the marsh mat. There is no surveyed nail ('Mark') elevation since the set-up moves vertically with the floating mat. Note: The exposed continuous recorder cable may be enclosed in a wire mesh sleeve to prevent damage by animals.
2. Complete the *Station*, *Date & CSTime*, *Field Personnel*, and *Agency/Company* fields at the top of the calibration sheet. For first time deployment, the remaining fields at the top of the sheet will remain blank.
3. Complete the *Station Information* box on the calibration sheet. Three static measurements to be noted in this section include:

- a. The *Top of Pipe to Sensor Distance (ft)* is the distance from the top of the PVC well pipe to the water level sensor on the recorder.
  - b. The *Sensor to Marsh Surface (ft)* is the distance from the marsh mat surface to the water level sensor.
  - c. The *Top of Pipe to Marsh Surface (ft)* is the distance from the top of the PVC well pipe to the marsh mat surface.
4. Calibrate the instrument's water level sensor to zero (0) feet when it is out of the water prior to deployment. Follow the calibration procedures in the owner's manual for the specific instrument being used.
  5. Place the recorder inside the well and record the depth in the *Continuous Recorder: Clean Water Depth* box under the *Readings* section on the Calibration Sheet

Verify that the water depth reading is correct using the following method:

- A. Measure from the top of the well pipe to the water surface. If the marsh is flooded, measure on the outside of the well using a survey rod by placing the survey rod on the horizontal stabilizer arm near the main body. If water is below the marsh, insert a stainless steel rod coated with water-indicating paste into the well to obtain a measurement and record in the *Top of Pipe to Water Surface (ft)* box.
- B. Subtract that measurement from the *Top of Pipe to Sensor Distance*.
- C. Record the value in the *Calculated Water Depth* box on the calibration sheet.
- D. The % difference between the *Calculated Water Depth* and the *Continuous Recorder: Clean Water Depth* will automatically be calculated using the formulas:

Water Level Difference = Calculated Water Depth - Continuous Recorder:  
Clean Water Depth

% Difference = (Water Level Difference / Calculated Water Depth) \* 100

- E. If the percent difference is below 5%, then the instrument is calibrated. If the percent difference is above 5%, then the instrument needs to be re-calibrated or is malfunctioning.
6. Follow the owner's manual for setting the continuous recorder in an unattended mode. Complete all fields in the *Deployment* section of the calibration sheet, including:
    - G. *Continuous Recorder*. The manufacturer and model number of the continuous recorder must be entered as in the following examples: YSI 600LS, YSI 6920, Hydrolab MS5, etc.
    - H. *Serial Number*. Enter the serial # of the continuous recorder. In the case of a Hydrolab, only the last five digits of the serial number are required.
    - I. *Deploy Filename*. The filename must be deployed and documented as in the following example: 061201M1, where 0612 represents the site number,

01 designates the month in which the file was established, M designates the station as floating mat and 1 represents the station number.

- J. *Date & CS Time*: The actual date and time the instrument is deployed must be documented. All times must be in Central Standard Time (CST) and written in 24-hour time convention (e.g., 3:00 p.m. = 15:00) even during Daylight Savings Time (DST). This is 'watch time'.
  - K. *Battery Volts*: Enter the battery voltage at the time of deployment.
  - L. *Batteries Changed* and *Desiccant Changed*: Fresh batteries and desiccant should always be used during the initial deployment of the instrument. Therefore, a YES should be selected for both fields. Note: When securing the desiccant tube in the electrical box, make sure that the plastic tubing is free of sharp bends or kinks that could result in the collection of non-vented data.
6. Complete all necessary information in the *Notes* section of the calibration sheet, including the staff gauge reading (if applicable). If this is the first time a sonde is being deployed at a particular station, then "Initial Deployment" should be typed into the *Notes* box. If a sonde is being deployed after a station has been rebuilt, then "Station Rebuilt" should be typed into the *Notes* box.

<b>Floating Marsh Mat Recorder Calibration Sheet</b>			
Station <input style="width: 90%;" type="text"/>	Date & CStime <input style="width: 90%;" type="text"/>	Sonde Date & Time <input style="width: 90%;" type="text"/>	Deployed Date & Time <input style="width: 90%;" type="text"/>
Field Personnel <input style="width: 90%;" type="text"/>		Agency / Company <input style="width: 90%;" type="text"/>	
Continuous Recorder <input style="width: 90%;" type="text"/>	Serial Number <input style="width: 90%;" type="text"/>	Battery Volts <input style="width: 90%;" type="text"/>	Download Filename <input style="width: 90%;" type="text"/>
<b>Station Information</b>			
Top of Pipe to Sensor (ft) <input style="width: 90%;" type="text"/>	Sensor to Marsh Surface (ft) <input style="width: 90%;" type="text"/>	Top of Pipe to Marsh Surface (ft) <input style="width: 90%;" type="text"/>	
<b>Readings</b>			
Continuous Recorder: Dirty Water Depth (ft) <input style="width: 90%;" type="text"/>	Top of Pipe to Water Surface (ft) <input style="width: 90%;" type="text"/>		
Calculated Water Depth (ft) <input style="width: 90%;" type="text"/>	Continuous Recorder: Clean Water Depth (ft) <input style="width: 90%;" type="text"/>	% Difference <input style="width: 90%;" type="text"/>	
<b>Deployment</b>			
Continuous Recorder <input style="width: 90%;" type="text"/>	Serial Number <input style="width: 90%;" type="text"/>	Battery Volts <input style="width: 90%;" type="text"/>	Battery Changed <input style="width: 90%;" type="text"/>
Deploy Filename <input style="width: 90%;" type="text"/>	Date & CS Time <input style="width: 90%;" type="text"/>	Dessicant Change <input style="width: 90%;" type="text"/>	
<b>Notes:</b>			
Vegetation condition: <input style="width: 90%;" type="text"/>		Setup Cleaned/Flushed <input style="width: 90%;" type="text"/>	
Water Above or Below Marsh Surface: <input style="width: 90%;" type="text"/>		Water Level on Marsh (ft) <input style="width: 90%;" type="text"/>	
Staff Gauge (NAVD88, ft) <input style="width: 90%;" type="text"/>			

**Figure 3.15.** Floating marsh mat recorder calibration sheet.

### 3.1.4 Continuous Recorder Servicing

#### 3.1.4.1 Open Water Servicing

The following steps should be taken when servicing and redeploying a continuous recorder in the open water environment, using the Continuous Recorder Calibration Sheet (Figure 3.16):

1. Calibrate the hand-held instrument before use and document the calibration solution used in the *Notes* section. Note: After calibration, discard the used calibration solution.
2. Upon arrival at the station, complete the *Station, Collected By, Agency, Calibration Instrument and Serial Number, Download Filename, and Deployed Date and Time* fields at the top of the calibration sheet.
3. Complete the *Station Information* box on the calibration sheet with the following:
  - A. The *Mark to Sensor Distance (FT)*, which is the distance between the nail located on the wooden post or the top of the 1/4" hole on the stainless steel pole to the water level sensor on the continuous recorder. This measurement will allow the water level readings to be converted to a vertical datum (NAVD88) when the nail or top of the 1/4" hole has been surveyed by a professional and licensed individual or company.
  - B. The *Mark Elevation (NAVD88, FT)*, provided by a professional surveyor.
  - C. The *Marsh Elevation (NAVD88, FT)*, provided by a professional surveyor.
 If any of these measurements are unavailable, "N/A" should be entered.
 

Note: If there is no surveyed nail elevation for whatever reason, then record a nail to water measurement for the constant recorder setup in the notes section of the field calibration sheet. This is essential for back correcting data to the proper datum once the nail (mark) is surveyed in.
4. Without disturbing the instrument, connect to the instrument using a laptop computer or a field instrument capable of interfacing with the recorder.
5. Record the date and time as Central Standard Time (CST) (24-hour convention) from the technician's watch in the *Date & CS Time* field and from the instrument in the *Sonde Date & Time* field. Note: If the difference between the two timepieces is greater than 10 minutes, then the instrument time needs to be reset to Central Standard Time (CST) (24 hr system).
6. Record the battery voltage reading from the continuous recorder in the *Battery Volts* field.
7. Stop the instrument from logging and download the data file as a .txt file.
8. If the instrument is out of the water upon arrival, field readings can be obtained by using surface water in a bucket to obtain the Dirty/Post Calibrations Readings. Depth readings can also be obtained within the bucket to record the Dirty and Post Calibration readings. Note: (Dirty/Post calibration depth readings in the air can also be recorded in the notes section and used to compare with the readings collected using the bucket).

9. Lower the hand-held salinity meter probe to a depth near the sensor of the continuous recorder.
10. In the *Dirty Readings* section, record an in situ “dirty” water temperature, specific conductivity, salinity, and depth from the display unit attached to the continuous recorder.
11. In the *Dirty Readings* section, record the readings from the hand-held salinity meter. This includes the water temperature, specific conductance, and salinity. The specific conductance *Difference* and *% Difference* will automatically be calculated in the calibration sheet using the formulas:

Specific Conductance Difference = Calibration Instrument – Continuous Recorder

% Difference = (Specific Conductance Difference / Specific Conductance of Calibration Instrument) \* 100

Note: If the percent difference is 5% or greater, then the data will be shifted during processing to account for biofouling.

12. Remove the continuous recorder from its secured position and place it in the water vessel.
13. In the top section of the calibration sheet, enter the manufacturer and model number of the instrument in the *Continuous Recorder* field, and the serial number in the *Serial Number* field.
14. Following the recommended cleaning procedures in the owner’s manual, clean all sensors and the exterior of the instrument such that it is free of all biofouling agents.
15. Clean the inside and outside of the PVC tube or mono-pole to prevent the buildup of biofouling agents over time. Any barnacles, oysters, or other agents must be removed during each servicing trip. Note: For more thorough cleaning and inspection purposes, the PVC tube must be pivoted out of the water at least quarterly or as needed in higher biofouling areas. All biofouling agents should be removed and the holding bolt at the bottom of the PVC tube should be inspected for signs of deterioration.
16. Determine whether the battery power remaining in the instrument is sufficient to power the instrument until the next servicing. The batteries must be changed if there is one-third less than the full battery power remaining or if the same batteries have been in use for three months or longer. Please be aware that some instruments also contain an internal lithium battery, which must be changed annually to accurately power the internal clock. Failure to do so may affect data quality.
17. Calibrate the salinity probe of the continuous recorder following the procedures in the owner’s manual for the instrument. Use a standard that is closest to the specific conductance reading on the salinity meter.
18. Set the water sensor to zero (0.00) while the instrument is out of the water, following the procedures described in the owner’s manual.
19. Lower the instrument back into its unattended position.
20. Lower the calibration instrument to the deployment depth of the continuous recorder.

21. Once the readings have stabilized, record the water temperature, specific conductance, and salinity of both instruments, as well as the depth of the continuous recorder, in the appropriate boxes under the *Post-Calibration Readings* section.
22. As in step 11, the specific conductance *Difference* and *% Difference* will be calculated for the post-calibration readings. If the percent difference is < 5%, then the instrument does not need recalibration (proceed to step 23). If the percent difference is above 5%, then attempt to recalibrate the instrument. If the instrument does not calibrate, then replace the instrument with a spare unit. Steps 17 through 22 should be repeated to calibrate the replacement instrument.
23. Determine whether the water level data will require a biofouling shift and whether the calibrated water depth reading is reading correctly using the following method:
  - A. Place a surveyor's measuring rod (ft) at the *Mark to Sensor Distance* value at the nail on the timber post or the top of the ¼" hole on the "mono-pole." This places the bottom of the rod (zero reading) at the same depth as the water level sensor on the continuous recorder.
  - B. Read the water level on the rod and record the value in the *Calibration Instrument* column in the *Depth* field of both the *Dirty Readings* section and the *Post-Calibration Readings* section.
  - C. The difference between the water level on the rod and the depth reading from the instrument will automatically be calculated using the formulas:

$$\text{Water Level Difference} = \text{Water Level on Rod} - \text{Continuous Recorder}$$

$$\% \text{ Difference} = (\text{Water Level Difference} / \text{Water Level on Rod}) * 100$$

Note: If the percent difference in the *Dirty Readings* section is 5% or greater, then the depth data will be shifted for biofouling during processing.

- If the percent difference in the *Post-Calibration Readings* section is below 5%, then the instrument is calibrated. If the percent difference is above 5%, then the instrument needs to be re-calibrated or is malfunctioning.
24. Follow the owner's manual for setting the continuous recorder in an unattended mode and complete the *Deployment* section of the calibration sheet. Instructions are presented in the previous section (3.1.3.1. Open Water Deployment, # 9). In cases where an instrument is deployed twice in the same month, the file name for the second deployment shall end with a "B" rather than a "1" (e.g., 061201HB). Note: It is not necessary to delete the recently collected data from the sonde before monthly redeployment. On a yearly basis, however, the data must be deleted since the file names will repeat themselves.
  25. Check the desiccant pack to see if it needs to be changed. It should be changed a minimum of every 60 days or according to manufacturer's instructions. Note: When replacing and securing the desiccant tube in the electrical box, make sure that the plastic tubing is free of sharp bends or kinks, which could result in the collection of non-vented data.
  26. Secure the instrument and cable using the brass locks on the brass hitch pin and the electrical box on the wooden post. For the mono-pole set-up, secure the cap to the top of the pipe using the brass hitch pin and brass lock.



27. Notes shall be taken and documented in the *Notes* section of the calibration sheet.

These notes shall include:

- A. Communication and/or equipment issues including probe failures, failure to connect to the continuous recorder, dead batteries, condition of the cable, water in the battery compartment, etc.
- B. Calibration information including the initial calibration of the hand-held salinity meter as well as problems with calibrating or recalibrating the continuous recorder.
- C. Severity of biofouling on the instrument: Select LIGHT or HEAVY.
- D. The staff gauge reading (NAVD88, ft), if available.
- E. Biological conditions in the area surrounding the site, including a measurement of water level relative to marsh surface elevation, details concerning the overall condition of the surrounding vegetation, and the presence or absence of SAV. Notes regarding the condition of the vegetation should include whether the vegetation was healthy, stressed, burned, senesced, etc. Evidence of herbivory should also be noted.
- F. *Infrastructure Damage Assessment* section: If the station is associated with a CRMS site, document if there has been any vandalism, deterioration, or other damage to the recorder set-up, boardwalk, accretion stations, vegetation stations, or anything associated with the data collection efforts at the site.
- G. Any significant changes in the marsh with respect to erosion, subsidence, movement, etc.
- H. If the instrument is near a water control structure, document the flow direction of the water and approximate the speed of the water flow.

**TROUBLESHOOTING:** The continuous recorder will be removed from the field when the instrument malfunctions. Examples of such malfunctions may include, but are not limited to, inability to establish communication with the instrument, erroneous readings due to a malfunctioning sensor, or failure of the instrument to accept or hold calibration. Before removing the instrument from the field, several troubleshooting techniques shall be performed: 1) inspect the old batteries and compartment while changing the batteries and look for exploded batteries, acid, and/or corrosion; 2) carefully clean all the sensors and attempt to calibrate; 3) check the cable connections between the continuous recorder and field display instrument; and, 4) change the cable. If the continuous recorder is still malfunctioning, remove the existing instrument and replace it with a new instrument. Document this replacement in the *Deployment* section and follow the deployment procedures listed above. If a malfunctioning instrument belongs to the CPRA, the instrument shall be returned to the CPRA field office responsible for the station accompanied by a written description of the malfunction.

**CHANGES IN MARK TO SENSOR DISTANCE:** The *Mark to Sensor Distance* may have to be remeasured for various reasons, including physical changes to the station or a change in sonde type (Table 3.2). For example, if it is determined that any sensor is resting in the sediment and causing erroneous readings, then the instrument needs to be raised. This

will cause the *Mark to Sensor Distance* to change, which will affect the conversion of the depth data to the vertical datum (NAVD88, ft). The following procedures should be used in cases where the *Mark to Sensor Distance* changes during a servicing trip:

The original measurement should remain in the *Station Information* box on the calibration sheet. The new *Mark to Sensor Distance* should be noted in the *Notes* box and entered into the *Station Information* box during the next servicing trip.

The “water level on rod” reading used to determine the water level shift must be taken using the original *Mark to Sensor Distance* (see Section 3.1.4.1, #23). Therefore, the reading can be compared to the ‘dirty’ sonde depth reading.

The “water level on rod” reading used to confirm calibration must be taken using the new *Mark to Sensor Distance* in order for the depth to be compared at the new sensor location.

Any additional notes regarding changes to the *Mark to Sensor Distance* should be made in the *Notes* box of the calibration sheet.

**Note:** On the data sheet, the time to be used is the time from the sonde servicing personnel’s watch (CST) in all time boxes except the “Sonde Date/Time” box at the top of the data sheet.

**Table 3.2.** Total instrument length (ft) and distance from bottom to depth sensor (ft) for the most commonly used continuous recorder models.

Instrument Type	Total Instrument Length (ft)	Distance from Bottom to Depth Sensor (ft)
YSI 600LS	1.46	0.33
YSI 600LSC	1.20	0.33
YSI 600XLM	1.81	0.57
<i>In Situ</i>	1.40	0.06

#### **3.1.4.2 Marsh Well Servicing**

The changes noted in Section 3.1.3.2 regarding the initial deployment of continuous recorders at marsh well sites also apply to the servicing and redeployment of marsh well sites.

Before collecting calibration readings, do not disturb the unit inside the well. Connect the handheld unit to sonde and record the water temperature, specific conductance, salinity and depth in the appropriate boxes under *Dirty Readings* on the Continuous Recorder Calibration Sheet. Dirty readings should not be taken with the hand-held salinity meter to determine the biofouling shift because only raw specific conductivity and salinity data are required at marsh well sites. However, procedures for determining the depth data shift will still be followed.

All other procedures regarding the servicing of continuous recorders at marsh well sites will remain the same as the procedures for open water stations.

#### **3.1.4.3 Floating Marsh Mat Servicing**

The differences noted in Section 3.1.3.3 regarding the initial deployment of continuous recorders at floating marsh sites also apply to the servicing and redeployment of floating marsh sites:

- a. Before disturbing the recorder, record the depth reading from the recorder in the *Continuous Recorder: Dirty Water Depth* box on the calibration sheet.
- b. Measure from the top of the well pipe to the water surface to obtain the *Top of Pipe to Water Surface* reading. If the marsh is flooded, measure on the outside of the well using a survey rod. If water is below the marsh, insert a stainless steel rod coated with water-indicating paste into the well to obtain a measurement.
2. Subtract that measurement from the *Top of Pipe to Sensor* distance.
3. Record the value in the *Calculated Water Depth* box on the calibration sheet.
4. The difference between the *Calculated Water Depth* and the *Continuous Recorder: Clean Water Depth* reading from the instrument will automatically be calculated using the formulas:

$$\text{Water Level \% Difference} = \frac{\text{Calculated Water Depth} - \text{Continuous Recorder: Clean Water Depth}}{\text{Calculated Water Depth}} \times 100$$

$$\% \text{ Difference} = (\text{Water Level Difference} / \text{Calculated Water Depth}) * 100$$

If the percent difference is below 5%, then the instrument is calibrated. If the percent difference is above 5%, then the instrument needs to be re-calibrated or is malfunctioning.

Additional comments should be made in the general *Notes* section associated with the condition of the floating mat site. Briefly describe the condition of the area with respect to any noticeable changes that may have occurred since the last trip. Document the water level in relation to the marsh surface by measuring how many inches above or estimating how many inches below the marsh surface the water level is at the time of servicing.

During servicing, examine the inside of the well for organic material accumulation and if present, clean out the inside of the well. The well should be checked monthly to ensure that it is not sinking into or through the marsh mat layer. The station should also be checked to ensure that vegetation is not growing on top of the stabilizer arms. Stations experiencing these problems may need to be relocated to ensure data accuracy. Also, check the marsh mat thickness annually to ensure that it is not attached to the subsurface.

### 3.1.5 Hydrologic Data Processing

#### 3.1.5.1 Processing of Open Water Data

The CPRA has implemented a two-phase protocol for data processing. These two phases are referred to as data entry (Phase I) and quality assurance/quality control (QA/QC) (Phase II). These two phases are conducted by separate individuals to assure that the final product is correct.

**DATA ENTRY (PHASE I):** Phase I is conducted by the individual responsible for the field data collection and requires three main tasks: 1. calibration sheet review, 2. data processing, and 3. data verification. These tasks require specific procedures as described below:

#### 1. Calibration Sheet Review

The Continuous Recorder Calibration Sheet (Figure 3.16) is filled out in the field during sonde calibration. Values from the calibration sheet must be transferred to a digital file provided by CPRA in order to generate the data file that is loaded into CPRA's CIMS database.

- a. Review the calibration sheet for completeness and accuracy.
- b. If the calibration sheet needs to be edited, describe and document changes made in the *Notes* section.
- c. Data from the calibration sheet is transferred to a specified digital .xls file for entry into CPRA's CIMS database. A template will be provided.

#### 2. Data Processing

- a. The data processing phase involves the use of the CPRA remote data load protocol. To properly process the data from its field format to its final QA/QC format, three files are needed:
  - i. The raw data file downloaded from the continuous recorder in .txt format. The filename should remain in the same format as the downloaded filename (example: 061201H1.txt).
  - ii. The electronic calibration sheet developed in step 1.c. above (.xls) (example file name: 061201H1 Calibration Sheet.xls). This template will be provided by CPRA.
  - iii. A "data processing" workbook file (.xls), also developed and provided by the CPRA, or an equivalent file. Transfer the raw data from the .txt file (2.a.i. above) into the workbook along with information from the calibration sheet (.xls) file (2.a.ii. above).
- b. The "data processing" workbook file contains three worksheets:
  - i. "Data": You will populate this worksheet with information from the calibration sheet and with the raw data from the continuous recorder. The Data sheet is programmed with formulas that will apply shifts to water level and salinity if there is more than 5% difference between clean and dirty values collected during calibration. The top rows of

the sheet contain fields for information from the field Calibration Sheet. Below that, there is space for the raw data to be inserted. Once you've populated the "Raw" data columns, the "Adjusted" data columns will auto populate with salinity and water level data adjusted (shifted) as necessary based on calibration measurements. Descriptive statistics are generated automatically and appear to the far right side of the worksheet.

- ii. "CIMS": This .xls worksheet transforms the data from the "Data" worksheet into the appropriate format for the CIMS database (Figure 3.16).
- iii. "Graphs": This worksheet will display two graphs; One that depicts shifted salinity and water elevation data to a vertical datum (ft NAVD88) and another that depicts the depth and duration of flooding relative to marsh elevation (ft NAVD 88).
- c. Transfer the raw data from the .txt file and the necessary information from the calibration sheet file into the appropriate fields of the "Data" worksheet of the "data processing" workbook file. Verify that all data and calibration sheet information were entered correctly. Also verify that the shifts, if needed, were applied correctly. If the percent difference was greater than 5% between the dirty continuous recorder readings and the calibration instrument for the salinity or water level data, then a shift should have been applied in the "Adjusted" data columns.
- d. Make a visual check of the raw and adjusted (shifted) data by inspecting the "Data" worksheet and the graphs. If any data are identified as being incorrect and need to be deleted, always delete the data from the ADJUSTED (shifted) columns—never delete data from the RAW columns. In the "CIMS" worksheet, use the "Comments" column to provide a brief explanation of data deletions. Reasons to delete data include, but are not limited to:
  - i. **NEGATIVE ADJUSTED SALINITY VALUES:** In very low salinity or low water conditions, data shifts may cause some ADJUSTED (shifted) salinity values to be negative (which is impossible). In this case, the negative ADJUSTED (shifted) values should be deleted. Describe date range of data deleted in the Comments column.
  - ii. **NEGATIVE RAW WATER LEVEL:** Raw water level cannot be negative (the instrument cannot read levels below the sensor). If negative raw water level values are collected, there was either an instrument malfunction or the water level was below the depth sensor. Since the instruments themselves are inaccurate when they are barely flooded, if the raw water level reading is  $\leq 0.03$  ft, the corresponding ADJUSTED (shifted) data must be deleted.
- e. Insert date/time spacers for any missed readings. There should be a row for each hour that the equipment was logging. Missed readings may occur due to instrument servicing, instrument malfunction, or battery failure. If this occurred, insert the missing rows into both the "Data"

worksheet and the “CIMS” worksheet. Enter the missing date, time, and organization name into the appropriate columns, as well as a brief explanation for the missing data in the “Comments” column. All other columns for these “missing data” rows should remain blank.

- f. Use the “Graphs” worksheet to inspect the transition between the data in the previous month’s file and the data in the current file. Compare the last two weeks of data from the previous file (if one exists) to the data in the beginning of the current file to verify that the transition is smooth, the pattern is similar, and there are no missing data. If the transition between the two files is not smooth, then the technician must attempt to resolve the problem by examining the data and the calibration sheet associated with the files. In some cases, a bad transition between datasets will reveal problems with the biofouling shift in the previous data set.

### 3. Data Verification

- a. Upon completion of steps 1 and 2, double-check the data processing workbook file for accuracy. In addition to examining the transition between the datasets, compare the first data line to the previous calibration sheet to verify that the data are similar to the data collected by the instrument during the post-calibration readings. Examine the last data line to verify that the data are similar to the data collected on the current calibration sheet. If a shift was applied to the salinity and water level readings, it must be determined if this shift is accurate with respect to what was collected in the field.
- b. Upon completion of the review of the data, provide all associated electronic files to another individual for further examination and verification. This individual is referred to as the QA/QC officer. These files should include the raw data file (.txt), the calibration sheet files (digital CIMS upload version and the hardcopy/digital xls from field), and the newly processed data processing workbook file (.xls).

### 3. Hydrologic Data

Station ID	Date (mm/dd/yyyy)	Time (hh:mm:ss)	Time Zone	Sensor Environment	Raw Water Temperature (°C)	Adjusted Water Temperature (°C)	Raw Specific Conductan ce (uS/cm)	Adjusted Specific Conductan ce (uS/cm)	Raw Salinity (ppt)
CRMS0527-H02	04/30/2017	6:00:08	CST	Surface Water	25.20	25.20	583.50	562.63	0.28
CRMS####-M10#	###/##/20##	##:##:##	CST	Flotant Marsh					

(continued...)

Adjusted Salinity (ppt)	Raw Water Level (ft)	Adjusted Water Level (ft)	Raw Water Elevation to Marsh (ft)	Adjusted Water Elevation to Marsh (ft)	Raw Water Elevation to Datum (ft)	Adjusted Water Elevation to Datum (ft)	Raw Marsh Mat Elevation (ft)	Adjusted Marsh Mat Elevation to Datum	Geoid
0.26	2.53	2.53		3.09		4.37			GEOID12A
	###.##	###.##		###.##					

(continued...)

Raw Battery (V)	Adjusted Battery (V)	Raw Wind Speed (mph)	Adjusted Wind Speed (mph)	Raw Wind Direction (degrees)	Adjusted Wind Direction (degrees)	Raw Velocity (ft/sec)	Adjusted Velocity (ft/sec)	Raw Precipitation (tips/hour)	Adjusted Precipitation (inches)
6.10	6.10								
#.##	#.##								

(continued...)

Raw Air Pressure (mm of Hg)	Adjusted Air Pressure (mm of Hg)	Raw Total Chlorophyll (micrograms/L)	Adjusted Total Chlorophyll (micrograms/L)	Raw Dissolved Oxygen (milligrams/L)	Adjusted Dissolved Oxygen (milligrams/L)	Raw pH (pH units)	Adjusted pH (pH units)	Raw Turbidity (FNU)

(continued...)

Adjusted Turbidity (FNU)	Raw Discharge (cubic ft/sec)	Adjusted Discharge (cubic ft/sec)	Organization Name	Comments
			CONTRACTOR	
			CONTRACTOR	

**Figure 3.16.** Post-processing format of continuous hydrographic data in .xlsx file and CIMS.



**QUALITY ASSURANCE/QUALITY CONTROL (PHASE II):** Phase II begins when the QA/QC officer is provided the completed electronic files. The QA/QC officer should follow the steps below to ensure the data has been processed properly.

1. Examine the calibration sheet for completeness and accuracy.
2. Check the data from the calibration sheet to ensure it was correctly transferred into the “Data” worksheet of the Excel file.
3. Check that the starting/ending dates and times of the data within the Excel file correspond with the dates and times on the calibration sheets.
4. Ensure that there is no suspect data in the “Data” worksheet of the data processing workbook file, that all data have been shifted correctly, and that depth data were correctly converted to NAVD88, ft. Any missing data must be explained in the “Comments” column of the “CIMS” worksheet.
5. Check that the transition between the previous and current month’s data is smooth and that no sample point is missing between the two sample periods due to instrument servicing.
6. If mistakes are found, notify the data collector so any mistakes can be corrected or explained.
7. Continue this process until no mistakes are found.

Once Phases I and II have been completed, the data processing workbook and the electronic calibration sheet .xls files are loaded as a matched file-pair onto the CIMS database buffer using the naming conventions established during the deployment of the field file. The filenames must include the addition of the month that they were placed on the CIMS database buffer as the first two characters (example – **07**061205H1, where 07 is added as the month the file was placed on the CIMS database buffer the first time). The files are to be zipped and uploaded to the CIMS Data Entry Remote Load where the data is loaded into a QA/QC buffer for CPRA review. Once the files are loaded, if the CIMS database detects any errors in the files, the files will not load with a reason given for the rejection. If any files are corrected and reloaded, the corrected files must be named exactly the same as when they were first placed on the CIMS database buffer. Check the CIMS Data Entry Remote Load for updated information.

### **3.1.5.2 Processing of Marsh Well Data**

Procedures for the processing and QA/QC of data from marsh well sites are very similar to the procedures for open water stations. The main difference is that adjusted temperature, adjusted salinity, and adjusted specific conductivity data are not generated for these sites. All data in these columns should be deleted from the “data processing workbook” .xls file during processing. It is not necessary to provide an explanation for this voided data in the “Comments” column of the “CIMS” worksheet. Raw data should never be deleted from the file. The data processing .xls file and the calibration .xls file should be loaded as a matched file-pair onto the CPRA CIMS database buffer using the naming conventions and protocols described for Open Water data. Once the files are loaded, if the CPRA CIMS database detects any errors in the files the files will not load and with a reason given for the rejection. If any files are corrected and reloaded, the corrected files must be named exactly the same as when they were first placed on the CIMS database buffer.

### **3.1.5.3 Processing of Floating Marsh Mat Data**

The processing of data collected at floating marsh mat stations is similar to the process used for open water stations, except a slightly modified “data processing workbook” .xls file is used during processing. Only water level data are recorded in the file and marsh flooding is calculated by subtracting the *Sensor to Marsh Surface* distance from the adjusted water level readings. The temperature, conductivity, salinity and adjusted water elevation to datum columns should remain blank. The measurement of mat thickness should be noted in the “Comments” column of the .xls file. The data processing .xls file and the calibration .xls file should be loaded as a matched file-pair into the CPRA CIMS database buffer using the naming conventions and protocols described for Open Water data. If the CPRA CIMS database detects any errors in the loaded files, the files will automatically be rejected with a reason given for the rejection. When files are corrected and reloaded, the corrected files must be named exactly the same as when they were first placed on the CIMS database buffer.

### **3.1.6 Continuous Data Deliverables**

#### **3.1.6.1 Surveying Data Deliverables**

All data collected under section 3.1.2.5, Surveying Procedures, shall be provided to the CPRA in the form of a survey report saved as a PDF, and Microsoft Word and Excel files. Survey reports include, but are not limited to:

1. a title page
2. a methodology report section including a description of the survey, location of the site, planning and layout of the GPS survey, data collection and processing summary, and quality assurance procedures
3. the marsh survey data sheet (.xls)
4. the completed Continuous Recorder and Staff Gauge Survey Data Sheet (.xls)
5. the RSET survey data sheet (if applicable)
6. a copy of the field notebook
7. the secondary benchmark data sheet
8. raw survey data if requested by CPRA

Prior to the composition of the survey report, it is recommended that a brief discussion occur for clarity.

#### **3.1.6.2 Open Water, Marsh Well, and Floating Marsh Mat Data Deliverables**

All files associated with the open water, marsh well, or floating mat datasets (see Sections 3.1.5.1, 3.1.5.2, and 3.1.5.3) will be provided to the CPRA through the FTP site once the QA/QC process is complete and data is entered into the CIMS buffer. This includes:

1. the raw data file (.txt)
2. the processed “data processing workbook” file (.xls)
3. the calibration sheet (.xls)

### 3.2. Discrete Hydrologic Data Collection

Discrete samples include surface water and/or soil porewater readings that are collected at the same location over time to indicate a spatial and temporal variation in salinity. Standard discrete readings, as collected for CRMS are taken with a portable, hand-held instrument that provides the user with water temperature (°C), specific conductance (µS/cm), and salinity (ppt) readings; additionally, an expanded suite of data, including dissolved oxygen (mg/L and % Saturation) and turbidity (FNU) are collected for SWAMP and project-specific sampling. A certified instrument with parameter specific or multiple functions is appropriate. When sampling the water column, sampling depth may also be determined by adding a weight near the sensor and graduating the cord. Depth is then measured by gently lowering the cord to the subsurface, assuring that the cord is perpendicular. Water quality samples for SWAMP are also collected for laboratory analyses of suspended solids, nutrients, and chlorophyll *a*.

Field personnel will measure soil porewater at each CRMS site at 10 cm (3.94 in) and 30 cm (11.81 in) depths (Sprecher 2000, Bohn 2001) when the continuous recorder is deployed or serviced, during RSET/Accretion measurement, and in at least five vegetation stations during emergent vegetation sampling. Soil porewater constituents are relatively uniform above 20–25 cm (Feijtel et al. 1988), and the sampling depths represent the approximate mean and maximum depth of the root zone (Mitsch and Gosselink 1993).

#### 3.2.1 Hand-Held Water-Quality Meter Calibration

In order to achieve quality data, the CPRA has developed extensive protocols with respect to instrument calibration, field sampling methods, and instrument quality assurance. Before readings are taken in the field with a hand-held water-quality meter, the meter must be calibrated for quality assurance. Because the meter is capable of measuring in a wide range of salinity concentrations, the instrument shall be calibrated with a solution that is relatively close to the conditions in the field. The instrument must also be calibrated whenever field conditions have dramatically changed during the sampling trip.

Use the following procedures to calibrate the instrument before taking discrete readings in the field:

1. Make sure that the conductivity probe is clean and free from any organic or mineral sediment.
2. Rinse the probe with conductivity-free water, preferably deionized water, between changes of calibration solutions. Conductivity standards must be purchased from an approved manufacturer. Once the standard is removed from its original container, it shall be discarded after its use since the standard is then considered contaminated.

3. Calibrate the instrument using a conductivity standard most similar to the range of the field samples. The concentration of the standard used for the calibration should be based on the testing needs for the field activity. A single point check standard in the range of the sample concentration to be measured shall be used for field screening and shall be within  $\pm 5\%$  range of accuracy of true value for the calibration to be acceptable.

Note: It is important that the calibration process established by the instrument manufacturer be examined in order to determine suggested concentrations of the conductivity standards for the operating environment encountered at the time of field sampling.

4. Using the manufacturer's recommended container for calibration, transfer the appropriate amount of solution to the container.
5. Suspend the probe in the solution so that the electrode does not rest against the container. Make sure the electrode's vent hole is submerged. If necessary, move the probe vigorously from side to side to free the vent hole of air bubbles.
6. Calibrate the instrument by following the manufacturer's manual for calibration.
7. Document the concentration of the standard used on the *Discrete Hydrographic/Soil Porewater Data Sheet*, if applicable (Figure 3.17).

Test and calibrate every hand-held meter monthly using the following protocol and record on the *Monthly Hand-held Meter Calibration Data Sheet* (Figure 3.18).

1. Obtain a thermometer that manufactured to the standards set by the American Society for Testing and Materials. This thermometer should have the following minimum capabilities: range of 0 °C to 100 °C and divisions of 0.1 °C.
2. Pour an amount of a known calibration solution into a container rinsed with the calibration solution to sufficiently cover sampling ports. Note: Do not pour this solution back into the bottle.
3. Place the thermometer into the solution and set it aside for a few minutes. This allows the solution to reach room temperature and allows the thermometer to become acclimated to the solution.
4. Take this time to examine the meter. Check for cuts on the wire and for sufficient battery life. Determine whether the instrument is clean, the keypad is working properly, and the LED screen is readable.
5. Place the probe into the solution and record the temperature from the thermometer and probe once the readings have stabilized.
6. If the specific conductance/dissolved oxygen/turbidity reading is off, calibrate the instrument to ensure it is working correctly and maintaining the calibration.
7. Complete the data sheet with the required information.
8. If the temperature difference between the thermometer and the meter is greater than 1 °C, then send the instrument in for inspection unless the instrument has the capability of adjusting the temperature.

### 3. Hydrologic Data

[illegible]

**Figure 3.17.** Discrete hydrographic/soil porewater data sheet.

[illegible]

\*If the instrument is dirty, indicate and clean to prevent any damages.

**\*\* If cuts are found on the cable, then replace cable or send instrument in for repairs unless the cuts do not penetrate the exterior coating.**

**Figure 3.18.** Monthly hand-held salinity meter calibration data sheet.

### 3.2.2 Methods for Discrete Data Collection

#### 3.2.2.1 Discrete Surface Water Data Collection

The following methods should be used to collect discrete readings in the surface water environment generally used for CRMS discrete surface water data collection. A weight may be fastened to the cable near the probe to ensure the probe remains at the proper depth during sampling. If data is being digitally entered, bring hard copies for back-up.

1. Before using the instrument in the field, use a calibrated measuring device and place a piece of waterproof tape at 1-ft increments along the cable. Make sure to begin from the probe and continue the length of the cable.
2. Either record surface water data on the Discrete Hydrographic/Soil Porewater Data Sheet (Figure 3.17) or directly enter electronically into the Sample Discrete Hydrographic.xls file (Figure 3.24) located on the CIMS Sample Upload Files.
3. Upon arrival at the station, complete the top section of the field data sheet, if using, then document the station number, date (MM/DD/YYYY), and time in Central Standard Time (CST) using the 24-hour military code for this reading. Record the staff gauge reading, if available.
4. Measure the water depth with a stadia rod, fathometer/depth finder, or the instrument probe and record the water depth (ft).

Note: If the instrument does not have a water depth sensor, then measure the water depth with the aid of the calibrated tape marks along the cable and record the depth to approximately 0.5 ft accuracy. Pull the probe completely out of the water and rinse it free of organic matter before continuing with data collection.

5. Gently drop the probe until it is suspended within the top 20% of the water column. Record the top readings for temperature (°C), specific conductance (µS/cm), and salinity (ppt) in the *Surface Water* column of the field data sheet or Excel file. Note: If the water depth is ≤ 1.5 ft, only one reading will be taken and recorded as both surface and bottom readings.
6. If deeper than 1.5 ft, gently drop the probe until suspended in the bottom 20% of the water column. Do not allow the probe to rest on the bottom. Record the bottom readings for temperature (°C), specific conductance (µS/cm), and salinity (ppt) in the *Surface Water* column of the field data sheet or Excel file.

#### ADDITIONAL QUALITY CONTROL READINGS:

1. The discrete reading instrument(s) shall remain powered if data are being collected all day with the instrument.
2. For each instrument, a minimum of three post-calibration readings (multiple readings) shall be collected from the surface and recorded on the field data sheet or Excel file at the beginning and end of each sampling day, and if the meters need to be recalibrated for different salinity settings.

### **3.2.2.2 Soil Porewater Data Collection**

The sipper probe method will be utilized to measure soil porewater salinity at all CRMS sites. Collect soil porewater at the boardwalk when the boardwalk is accessed for any reason, during vegetation sampling, and while servicing continuous hydrologic recorders. The boardwalk is accessed during RSET and accretion sampling in the late winter/early spring, marsh well and floating mat station servicing, annual vegetation sampling, and boardwalk maintenance. During vegetation data collection, collect porewater at each vegetation station and at the boardwalk. While servicing continuous hydrologic recorders, collect soil porewater from the wetland soil approximately 10 m from the water's edge. Collect soil porewater samples with a sipper probe (Figures 3.19 and 3.20) to extract interstitial water from 10-cm and 30-cm depths and measure with a hand-held salinity meter (McKee et al. 1988).

#### **POREWATER SIPPER ASSEMBLY PROCEDURE:**

##### *Porewater Sipper Materials:*

1. Rigid sipper probes:
  - a. Rigid plastic or stainless steel tubing with a diameter up to 3.2 mm (1/8 in.)
  - b. Water proof epoxy or sealant
  - c. Drill and bit (up to 1/8")
2. 60-ml syringe
3. 50-ml plastic centrifuge tube (or similar tube) with an inside diameter of at least 2.54 cm (1.0 in.) or large enough for the salinity meter probe
4. Hand-held discrete salinity meter
5. Tygon® tubing: 30–90 cm (1.0–3.0 ft) length of Tygon® tubing attached to the open end of the rigid sipper probe
6. Two-way valve (if necessary)
7. Cheesecloth or panty hose material (if necessary)

##### *Construction of Porewater Sipper:*

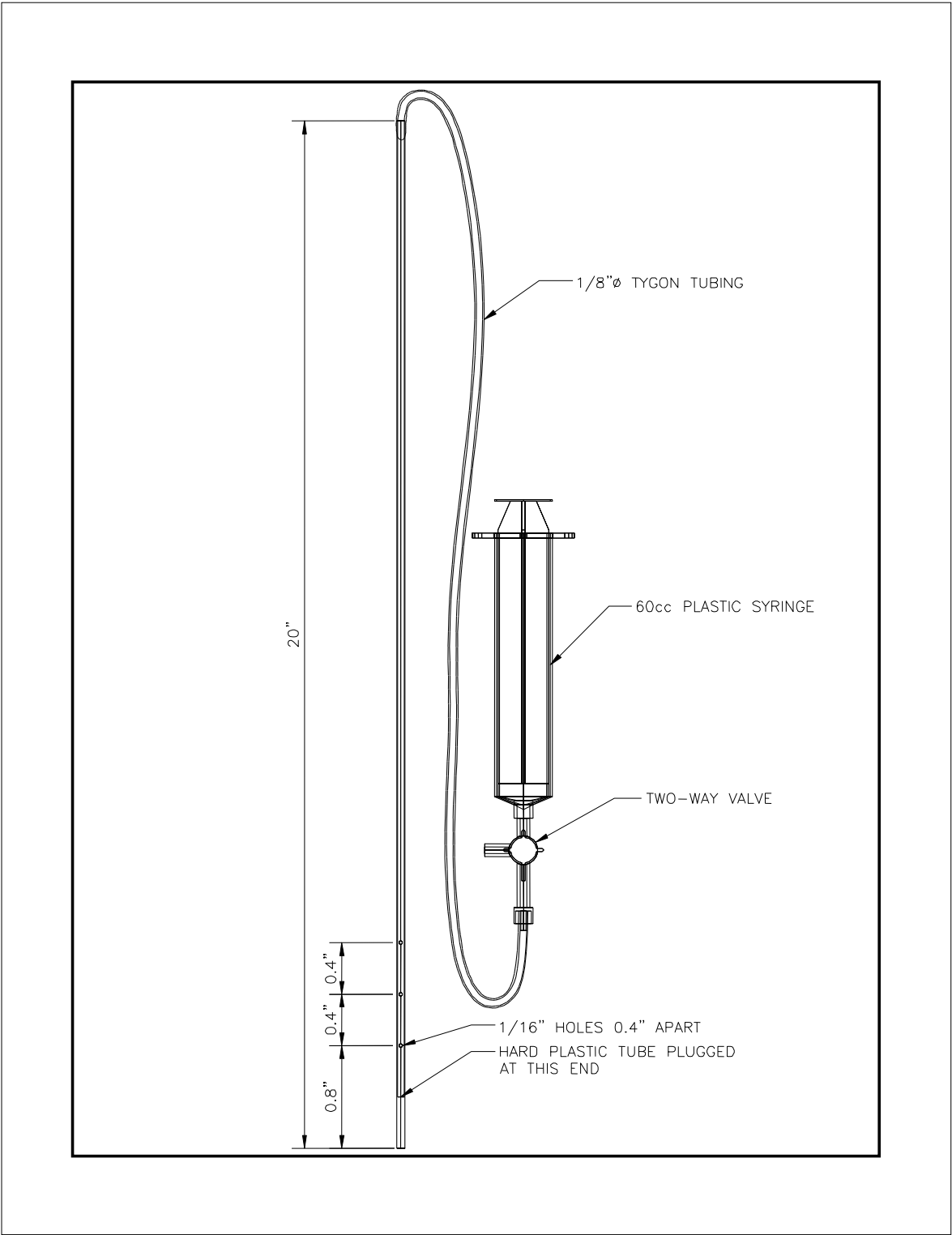
1. Cut the rigid plastic or stainless steel tubing to length (~50 cm or longer if necessary).
2. Seal one end of the tubing with an epoxy or sealant to prevent the passage of any liquid material.
3. Drill three (3) 1/16 in. holes, at ninety-degree (90°) angles to each other around the probe, 2, 3, and 4 cm from the sealed end. Larger holes can be drilled if needed (Figure 3.23C).
4. Mark 10 cm and 30 cm on the rigid plastic tube measured from the center of the drilled holes. Mark using tape or score the tube so that the correct depth can be felt upon insertion. Washers can be used for flooded conditions (Figure 3.20).
5. Securely attach a piece of the Tygon® tubing to the other end of the probe.
6. Attach a two-way valve to the syringe and to the other end of the Tygon® tubing. Figure 3.19 shows the completed porewater extractor and syringe schematic.



During each data collection effort, porewater data will be collected at two depths (10 cm and 30 cm). For data collection at the boardwalk, collect porewater from beginning with the sample closest to the access point. At vegetation stations, porewater data will be collected at each station using the -V## station name being careful not to step into the vegetation station. While servicing continuous recorders, collect porewater from three stations 10 m from the water's edge; station names should be CRMS####-P04,-P05,-P06, and the approximate locations should be repeated over subsequent visits.

The following procedure shall be utilized to properly collect soil porewater salinity at 10 cm and 30 cm below the surface:

1. Complete the top section *Discrete Hydrographic/Soil Porewater Data Sheet* (Figure 3.17) or enter directly into the Sample Discrete Hydrographic.xls file (Figure 3.24) located on the CIMS Sample Upload Files.
2. Prior to each sample, inspect the sipper holes for blockage and unclog.
3. From the boardwalk in the designated area, or from the outside of the vegetation plot reaching toward the center, insert the porewater sipper into the soil to the 10-cm mark.
4. Before measuring porewater salinity, rinse the tubing, syringe, and centrifuge tube with porewater from each sampling depth at least once. Slowly fill about one-third to one-half the volume (~20–30 ml) of the syringe with porewater and rinse the interior of the syringe thoroughly. Discard the water. Extract another 30 ml of porewater and use it to rinse the centrifuge tube (the use of a two-way valve to dispense water from the syringe into the centrifuge tube is helpful to prevent losing suction on the sipper or the sipper hose).
  - a. Use deionized water when there is not enough water in the marsh soil for rinsing.
5. Dispose of the rinse and pull a third aliquot of porewater—enough to cover the probe when it is in the centrifuge tube (~30–45 ml). In highly organic soils, porewater extraction may be blocked or severely inhibited by organic or small clay particles. If this condition occurs, securely fasten a piece of cheesecloth or panty hose material around the intake holes of the porewater sipper(s) to filter obstructing particles and extract another sample.
6. Dispense the sample into the centrifuge tube and insert the salinity probe. Try to keep the probe from touching the side of the centrifuge tube. Record the station ID, date (MM/DD/YYYY), time (CST), temperature (°C), specific conductance ( $\mu\text{S}/\text{cm}$ ), and salinity (ppt) in the *Soil Porewater* column of the field data sheet (Figure 3.17) or Excel file for each porewater sample.
7. Carefully push the sipper to the 30-cm graduation mark. Repeat steps 3–6.
8. Remove the sipper probe and move to the next station. Repeat steps 1–6 for each station.
9. If a porewater sample cannot be collected, make notes explaining why in the notes/comments on the datasheet or Excel file.



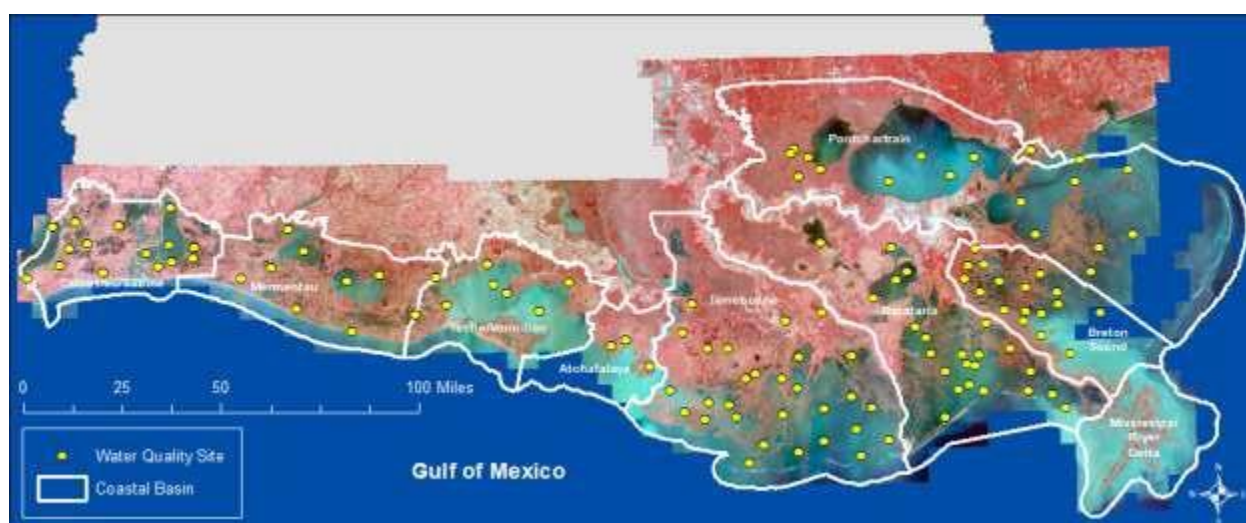
**Figure 3.19.** Typical soil porewater sipper.



**Figure 3.20.** Stainless steel sipper tube alternatives for soil porewater collection. (A) Green and red tape mark 10 cm and 30 cm soil depths, respectively, for non-flooded conditions. (B) Metal washers fixed with a marine grade, metal adhesive (epoxy or weld compound) stop the tube at 10 cm and 30 cm soil depths in flooded conditions. (C) Larger diameter holes (1/8 in. diameter) are drilled to reduce clogging at the extraction depth.

### 3.2.3 Methods for Water Quality Data Collection

More extensive discrete surface water sampling is conducted at 120 stations for the System-Wide Assessment Monitoring Program (SWAMP) to document changes in key water quality parameters in estuarine open water bodies that are sensitive to system drivers and are critical for understanding system dynamics (Figure 3.21). The water quality methodologies are generally in accordance with the guidelines from “Standard Operating Procedures (SOP) for Water Sample Collection, Preservation, Documentation and Shipping, Sonde Deployment, and Continuous Monitoring” developed by the Louisiana Department of Environmental Quality Office of Environmental Compliance Surveillance Division, Revision 10, dated September 7, 2021.



**Figure 3.21.** SWAMP water quality stations across coastal Louisiana.

#### 3.2.3.1 Discrete Water Quality Measurements

Discrete water quality measurements are recorded for water temperature ( $^{\circ}\text{C}$ ), specific conductance ( $\mu\text{S}/\text{cm}$ ), salinity (ppt), dissolved oxygen (DO, mg/L) and turbidity (FNU) at SWAMP stations (Table 3.3). Measurements are taken throughout the water column over the entire depth profile. Prior to collection of discrete water quality measurements, sensors are calibrated per the sonde manufacturer’s specifications and recorded (Figure 3.22 a).

**Table 3.3** Discrete Water Quality Measurement Parameters

Parameter	Units
Dissolved Oxygen	mg/L
Water temperature	°C
Specific conductance	µS/cm
Salinity	ppt
Turbidity	FNU

1. Once collectors arrive at a station, anchor the vessel, and verify the GPS coordinates.
2. Measure water depth with fathometer or stadia rod to determine sampling increments and record along with environmental conditions on data sheet. If the water depth is less than 20 feet, collect water quality readings in 1-foot increments. If water depth is greater than or equal to 20 feet, collect water quality readings in 2-foot increments; record additional measurements in the NOTES section (Figure 3.22 b or c depending on station depth).
3. Fill out the header of the discrete water quality sampling data sheet (Figure 3.22 b or 3.22 c) depending on station depth) to record station information and environmental conditions. Either hard copies or digital data sheets may be used. The Station ID naming convention is SWMP####.
4. Lower the probe(s) to targeted depths until readings stabilize and record for each parameter on data sheet (Figures 3.22 b or c). If readings are stored digitally, confirm data are collected for all required depth intervals.
5. After collecting the measurements at each depth interval, prepare the meter and sensors for transport to the next station per the manufacturer's guidance.
6. At the end of each sampling day, perform a post-sampling calibration check of the sensors and note these readings on the calibration sheet (Figure 3.22a).
7. Store the meters and sensors per manufacturer's specifications until the next sampling event.

### **3.2.3.2 Grab-Water Samples for Laboratory Analysis**

Discrete water samples are collected at a designated depth using a water-column sampling device such as a Van Dorn type water sampler. The collected water samples will be sent to a laboratory approved by CPRA for water quality analyses. The sampler should have the capacity to collect at least three times the amount of water needed for water samples and QC triplicates to account for spillage during transfer. Prior to initiating sampling activities, clean the sampler with phosphate free detergent and triple rinse with distilled, deionized, or ultrapure water. The sampler is to be stored in a sealed container for transport between sampling events and between each station. For each sample:

1. Triple rinse the sampler with ambient water from the station.
2. Lower the sampler down a graduated rope to the target depth, defined as halfway through the water column, unless otherwise specified and noted. Record the sample depth in the "Sample Depth (ft)" box on the SWAMP – Water Quality Sampling sheet (Figure 3.22 b or 3.22 c).

3. Trigger the sampler and retrieve the grab sample from the target depth and bring it back up to the vessel.
4. Prior to filling the sample bottles, purge the sampler spigot by opening the valve and allowing water to run approximately 5 seconds to clear any potential contamination.
5. Transfer the water sample into pre-cleaned, labeled bottles or jars for each parameter type below such that the container is completely full and free of air bubbles; required volumes are based on laboratory analysis specifications and methods. Labels should include Station ID (SWMP####), Parameter Type (see below), Collection Date and Time, and Collected by personnel. Currently, three 500 ml bottles are being used for the grab water sample.
  - a. Chlorophyll *a* – clean amber bottle or jar to prevent light from affecting the sample. This bottle shall not be acid washed. If a non-amber bottle is used, it is wrapped in aluminum foil to prevent light penetration.
  - b. Nutrients – acid-washed and rinsed or certified-clean bottle or jar. Acid washing should be done with HCl solution. Nitric acid should not be used to avoid contamination with nitrogen analyses.
  - c. Suspended Solids – clean bottle or jar.
6. Place properly labeled containers immediately on ice in a cooler with lid for storage and transport.
7. When sampling is completed at a station, secure and store the water sampler for transport to the next station.

<b>Instrument Calibration Sheet</b>				
<b>SWAMP Program - Water Quality Sampling</b>				
Personnel:				
Sampling Run:				
Organization:				
Instrument:		Serial Number:		
<b>Pre-Sampling Calibration Readings</b>				
		DATE:		TIME:
	<b>Instrument Reading</b>	<b>Calibration Standard</b>	<b>Difference</b>	<b>% Difference</b>
Sp. Conductance (uS/cm)				
Turbidity (FNU)				
Optical D.O. (%)				
Depth (ft)				
<b>Post-Sampling Calibration Readings</b>				
		DATE:		TIME:
	<b>Instrument Reading</b>	<b>Calibration Standard</b>	<b>Difference</b>	<b>% Difference</b>
Sp. Conductance (uS/cm)				
Turbidity (FNU)				
Optical D.O. (%)				
Depth (ft)				
<b>NOTES:</b>		<b>Calibration Standard Information:</b>		
			<b>Conductivity</b>	<b>Turbidity</b>
		<b>Lot Number</b>		
		<b>Expiration Date</b>		

**Figure 3.22 a.** Pre and Post Calibration field sheet

SWAMP Program - Water Quality Sampling					
Personnel:				Organization:	
Instrument:		Serial Number:			
Station ID	Station Depth (ft)	Sample Depth (ft)	Date	Time (CST)	
SWMP####					
Skies: sunny / partly cloudy / cloudy / rainy / foggy					
Water clarity: clear / murky / turbid / tannic / algae bloom			Seas: <1 ft / 1-3 ft / >3 ft		
Wind: <5 kts / 5-10 kts / 10-15 kts / >15 kts			Wind: NW / N / NE / E / SE / S / SW / W / Variable		
Depth (ft)	Temperature (C)	Sp. Cond (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Turbidity (FNU)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
NOTES:					

**Figure 3.22 b.** Discrete Water Quality Sampling field data sheet for 1-foot increments (water depth <20ft.).



<b>SWAMP Program - Water Quality Sampling</b>					
Personnel: <input style="width: 100px;" type="text"/>		<input style="width: 100px;" type="text"/>		<input style="width: 100px;" type="text"/>	
Instrument: <input style="width: 100px;" type="text"/>		Serial Number: <input style="width: 100px;" type="text"/>		Organization: <input style="width: 100px;" type="text"/>	
Station ID	Station Depth (ft)	Sample Depth (ft)	Date	Time (CST)	
SWMP####	<input style="width: 100px;" type="text"/>	<input style="width: 100px;" type="text"/>	<input style="width: 100px;" type="text"/>	<input style="width: 100px;" type="text"/>	
Skies: sunny / partly cloudy / cloudy / rainy / foggy					
Water clarity: clear / murky / turbid / tannic / algae bloom      Seas: <1 ft / 1-3 ft / >3 ft					
Wind: <5 kts / 5-10 kts / 10-15 kts / >15 kts      Wind: NW / N / NE / E / SE / S / SW / W / Variable					
Depth (ft)	Temperature (C)	Sp. Cond (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Turbidity (FNU)
2					
4					
6					
8					
10					
12					
14					
16					
18					
20					
22					
24					
26					
28					
30					
32					
34					
36					
38					
40					
NOTES:					

**Figure 3.22 c.** Discrete Water Quality Sampling field data sheet for 2-foot increments (water depth  $\geq 20$ ft.).

### **3.2.3.3 Quality Control Samples**

#### **Equipment Blanks**

Collect equipment blanks (rinsate) used to monitor possible contamination from the sample collection equipment, to monitor the effectiveness of sample decontamination protocols, and, thus, to estimate the potential for cross-contamination between samples. The rinsate should be collected after cleaning the sampler and prior to collecting any field samples to show that a non-contaminated sampler was used. One 500 ml rinsate blank is collected for every 20 grab water quality samples collected. The rinsate is to be collected by pouring analyte free [distilled or deionized (DI)] water into and over the sampling equipment and collecting the water into sample containers referenced in section 3.2.3.2. Analyze the collected rinsate for the same compounds and constituents as the water quality samples. Record rinsate location in the NOTES section of SWAMP – Water Quality Sampling sheet (Figure 3.22 b or 3.22 c) of the nearest station.

#### **Field Triplicate Samples**

Collect field triplicate samples used to qualitatively assess the variability of the sampling and laboratory methods and the variability of natural water samples. Field triplicates should be collected every 20 stations sampled per monthly sampling event by distributing equal amounts of collected ambient water volume from the sampling device into a triplicate set of sampling containers. Collect triplicate samples, following procedures in section 3.2.3.2, from a different station within a hydrologic basin on a randomized basis and record the location in the NOTES section of SWAMP – Water Quality Sampling sheet (Figure 3.22 b or 3.22 c). Field duplicate samples were utilized rather than triplicates from November 2015 – May 2019.

#### **Quality Control Random Sample Selection**

As noted above, both equipment blanks (rinsate) and triplicate samples are collected approximately every 20 stations. With 120 total stations in the SWAMP WQ Program design, QC samples should be collected at 6 stations per monthly sampling event. To obtain a more representative sample design, the QC stations are randomly selected within each hydrologic basin since most basins have approximately 20 sampling stations. For those basins with a smaller number of stations, several basins are aggregated to accommodate this process (Table 3.4).

**Table 3.4** Number of stations per hydrologic basin and quality control sample selection. Basins designated with an \* are aggregated for QC sample selection.

<u>Basin</u>	<u>Number of Stations</u>
Atchafalaya*	3
Barataria	23
Breton Sound	18
Calcasieu-Sabine	15
Mermentau*	7
Pontchartrain	18
Terrebonne	29
Teche-Vermilion*	7

### **3.2.3.4 Sample Transport**

Properly label, package, preserve in ice chests, and transport the water samples to a water quality analysis laboratory for analyses specified in Table 3.5. Ensure samples are prepared, processed, and analyzed within appropriate hold times, as dictated by EPA and/or standard method protocols. If no sample preparation for laboratory analyses, such as filtering or adding sample stabilizers, is conducted by the sample collector, then deliver the samples within 24 hours to maintain preservation and holding times. A runner may be employed to meet the field crew at the dock and transport the samples to the laboratory. If the sample collector is preparing and processing the samples for analysis prior to delivery to the analysis's laboratory, then samples should be prepared within 48 hours and properly stored for sample integrity. Once in a stable condition, samples should be analyzed within the appropriate 28-day hold time.

### **3.2.3.5 Sample Chain-of-Custody Documentation**

EPA chain-of-custody (COC) protocols are to be followed. Relinquishment of custody should be recorded on the COC form for each sample collected (Figure 3.23). The COC form will provide a written record that can be used to trace the possession and holding of samples from collection to data analysis and reporting. COC forms are to be signed by the sample custodian. All completed forms should be placed in zip lock bags and placed in the ice chest or hand delivered to the laboratory. Digital COC forms can be used, provided that proper signatures, dates, and times are recorded appropriately.

Chain of Custody Record														
Project/Sample/Contact Information										Page 1				
Project Name:										Note: Shaded area to be completed by Collection Team Samples Delivered To:				
Report Copy to:										Analysis Requested Check all that apply				
Sample Information										Chlorophyll a				
Station ID (SWMPXXXX)										TSS, TVS				
Sample Date										SiO2				
Sample Time										N+N, NH3, PO4				
Matrix code - Water										TN, TP				
Sample Type - Grab										Salinity				
Temp. Inside Cooler (C)										Basin				
Temp. Inside Cooler (C)										# of containers				
Temp. Inside Cooler (C)										Custody Sealed?				
Temp. Inside Cooler (C)										Samples Intact?				
Temp. Inside Cooler (C)										Samples Arrived within Hold Time?				
Received on Ice?										Relinquished By:				
Sampler Name (printed):										Affiliation:				
Sampler Name (signed):										Relinquished Date / Time:				
Sample Date:										Received By:				
Additional Notes:										Affiliation:				
										Received Date / Time:				
										Received Location:				

Figure 3.23. Sample Chain of Custody form for water quality samples.

### 3.2.3.6 Sample Processing and Water Sample Analyses

The ultimate goal of SWAMP is to obtain repeated long-term (e.g., years to decades) measurements that can be analyzed to detect changes from a variety of sources. Therefore, research laboratory methodologies with low laboratory analytical detection limits have been adopted to measure background levels obtained for parameters (see Table 3.5). Deviations from these methodologies must be approved by CPRA. Acceptable data ranges were determined from relevant studies and datasets in Louisiana waters. The minimums of the data ranges were set by the lab reporting limit.

**Table 3.5.** Current parameters of grab-water samples (Chlorophyll *a* in green, Nutrients in blue, and Suspended Solids in brown) for laboratory analysis, analysis methods, acceptable ranges, and reporting limits.

Parameter	Analysis Method	Acceptable Data Range	Reporting Limit
Chlorophyll <i>a</i>	EPA 445	0.05 – 756 (mg/L)	0.500 µg/l
Total Nitrogen (TN) (mg/L)	SM 4500 P-J	0.028 – 23	0.006
Total Kjeldahl Nitrogen (TKN) (mg/L)	Calculated by the formula: $TKN = TN - (NO_3 + NO_2)$		
Nitrate + Nitrite (NO <sub>3</sub> +NO <sub>2</sub> ), filtered (mg/L)	EPA 353.4	0.006 – 10	0.006
Nitrate (NO <sub>3</sub> ) as N, filtered (mg/L)	EPA 353.4	0.006 – 10 (≤ NO <sub>3</sub> +NO <sub>2</sub> )	--
Nitrite (NO <sub>2</sub> ) as N, filtered (mg/L)	EPA 353.4	0.006 – 10 (≤ NO <sub>3</sub> +NO <sub>2</sub> )	--
Ammonium (NH <sub>4</sub> ) as N, filtered (mg/L)	EPA 350.1	0.007 – 7	0.007
Total Phosphorous (TP) (mg/L)	SM 4500 P-J	0.012 – 31	0.008
Orthophosphate (PO <sub>4</sub> ), filtered (mg/L)	EPA 365.5	0.007 – 13	0.007
Silica (SiO <sub>2</sub> ), filtered (mg/L)	EPA 366.0	0.026 – 13	0.026
Total Suspended Solids (TSS) (mg/L)	SM 2540D	4.00 – 20,000	4.00
Volatile Suspended Solids (VSS) (mg/L)	SM 2540 E	4.00 - 20,000 (≤ TSS)	4.00

### Water Quality Analysis Methods and Reporting Limits

Water quality methodologies and reporting limits were modified with the change in analytical labs from Industry to Research on March 19, 2019, for the Coastal Transect Study and in November 2019 for the SWAMP Water Quality program. Reporting limits were modified at Industry Lab on October 23, 2018, before the transfer to Research Lab, to report results at lowered detection limits.

The analysis of silica, orthophosphate, nitrate + nitrite, and ammonium was “unfiltered” November 2015 through October 2019 and “filtered” from November 2019 to present. Samples are filtered using nylon filters with a 0.45 µm pore size to remove particulates. The analytical methodologies and reporting limits from Industry Lab and Research Lab are documented in Table 3.6.

**Table 3.6** Industrial and Research Reporting limits

Parameter	Industrial Lab Method	Industrial Lab Reporting Limit Before 10/23/2018 (mg/L)	Industrial Lab Reporting Limit After 10/23/2018 (mg/L)	Research Lab Method Started Nov 2019	Research Lab Reporting Limit (mg/L)
Total Kjeldahl Nitrogen (TKN)	EPA-351.2	0.1*	0.10*	EPA 351.2	0.006**
Total Nitrogen (TN)	40 CFR part 432.2	1.0***	0.15***	SM 4500 P-J	0.006
Nitrate+Nitrite (NO <sub>3</sub> + NO <sub>2</sub> ; unfiltered)	SM-4500-NO <sub>3</sub> F	0.05	0.05	--	--
Nitrate+Nitrite (NO <sub>3</sub> + NO <sub>2</sub> ; filtered)	--	--	--	EPA 353.4	0.006
Ammonium (NH <sub>3</sub> ; unfiltered)	SM-4500-NH <sub>3</sub> G	0.10	0.10	--	--
Ammonium (NH <sub>3</sub> ; filtered)	--	--	--	EPA 350.1	0.007
Total Phosphorus (TP)	EPA 356.4	0.05	0.10	SM 4500 P-J	0.008
Orthophosphate (PO <sub>4</sub> ; unfiltered)	SM 4500 P-E	0.01	0.05	--	--
Orthophosphate (PO <sub>4</sub> ; filtered)	--	--	--	EPA 365.5	0.007
Silica (SiO <sub>2</sub> ; unfiltered)	SM 4500 SiO <sub>2</sub> C	1.00	1.00	--	--

Parameter	Industrial Lab Method	Industrial Lab Reporting Limit Before 10/23/2018 (mg/L)	Industrial Lab Reporting Limit After 10/23/2018 (mg/L)	Research Lab Method Started Nov 2019	Research Lab Reporting Limit (mg/L)
Silica (SiO <sub>2</sub> ; filtered)	--	--	--	EPA 366.0	0.026
Total Suspended Solids (TSS)	SM 2540 D	4.00	4.00	SM 2540 D	4.00
Volatile Suspended Solids	SM 2540 E	10.00	4.00	SM 2540 E	4.00
Chlorophyll <i>a</i>	SM 10200	5.0-25.0****	1.0 – 5.0****	EPA 445.0	0.500 µg/l
* 2015-2016 SWAMP data does not have calculated TKN ** TKN is not analyzed by Research Lab. This value is calculated. *** TN was not analyzed by Industrial Lab. This value was calculated. **** dependent upon volume of water sampled filtered					

### 3.2.4 Discrete Data Processing and QA/QC

CPRA has implemented a two-phase protocol for data processing of discrete hydrologic data. These two phases are referred to as data entry (Phase I) and data quality assurance/quality control (Phase II). These two phases are conducted by separate individuals to assure that the final product is correct. The sample collection party is responsible for entry and QA/QC of data from contracted laboratory analyses.

#### Data Entry (Phase I)

Phase I is conducted by the individual responsible for the field data collection and requires three main tasks: 1. field data sheet review, 2. data transcription, and 3. data verification. These tasks require specific procedures necessary to satisfy the deliverable requirements. Below are the procedures for each task.

1. Field Data Sheet Review
  - a. Review the data sheet, if applicable, for legibility, completeness, and accuracy. If electronic data sheets are used, steps b and c are not necessary.
  - b. Make corrections using a different color pen without erasing original data. To correct an error, strike a single line through the error and write the changes close to the error.
  - c. Accompany changes with the responsible person's initials and date.
2. Data Transcription
  - a. This task requires the photocopied field data sheet and the "Sample\_Discrete\_Hydrographic.xls" file located on the CIMS Sample

Upload Files (Figure 3.24), unless the data file (.xlsx) and/or field data sheet was completed digitally in the field during data collection.

- b. Once the Excel file has been located and saved to a local computer, save the file using the following naming convention:

Soil porewater: "CRMSXXXX\_PW\_YYYY-MM.xls," Water Quality: "SWMPXXX\_WQ\_YYYY-MM.xls"

- c. If a data sheet was used in the field, enter the discrete data verbatim into the .xlsx file. If discrete data was saved digitally in the field, copy the data verbatim into the .xlsx file. There should be a separate soil porewater data file for each CRMS site and a separate water quality data file for each SWAMP site. Data files from contracted laboratories may be copied and pasted.

### 3. Data Verification

- a. Upon completion of steps 1 and 2, double-check the file for accuracy.
- b. Upon completion of the review of data, provide the field data sheet, if applicable, along with the electronic files to the QA/QC officer. This should be part of the packet for the continuous recorder data if discrete data were collected during continuous hydrologic data download for CRMS.

### Quality Assurance/Quality Control (Phase II)

Phase II begins when the Quality Assurance/Quality Control (QA/QC) officer is provided with the field data sheet and/or the completed Excel file. The QA/QC officer should follow the steps below to ensure the data has been processed properly:

1. Examine the field data sheets (digital or scanned hard copy) and Excel files for completeness and errors (e.g., data entered into incorrect columns, incorrect station names).
2. Check the data from the field data sheet or digitally saved data, as available, to ensure it was correctly entered into the Excel file.
3. Check the discrete profile and lab analyses data for outliers (i.e., readings that seem improbable compared to other readings at the site(s)).
4. If mistakes are found, return to the data collector so any mistakes can be corrected or explained. If lab analyses data are deemed questionable then request confirmation from the lab.
5. Continue this process until no mistakes are found.

Once Phases I and II have been completed, the .xlsx file CRMS####\_PW\_YYYY-MM.xlsx" or "SWAMP\_WQ\_XX (2-character basin identifier) YYYY\_MMDD (sampling run name).xlsx" can be uploaded to CPRA's CIMS database buffer.



### **3.2.5 Discrete Data Deliverables**

The following deliverables will be provided to CPRA for discrete data collection:

1. The data sheets (.pdf), if applicable, digitally saved discrete data file (if applicable), processed data file (.xlsx), data files from contracted laboratories, and Chain-of-Custody forms will be provided through the CPRA SharePoint site.
2. The processed data file (.xlsx) will be uploaded into the CIMS database buffer following the Figure 3.24 format.

### 3. Hydrologic Data

CPRA Station ID	Original Collector Station ID	Date (mm/dd/yyyy)	Time (hh:mm)	Time Zone	Staff Gauge (ft)	Geoid	Station Depth (ft)	Measurement Depth (ft)	Water Temperature (°C)
CS27-04R		03/07/2012	9:10	CST	1.5	GEOID12A		0.5	18.4
CRMS0543-P03		08/25/2016	9:15	CST	0.93	GEOID12A		0.984	
SWMP0018		3/14/2016	7:50	CST			4	2	21.26

(continued...)

Specific Conductance (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	pH (pH units)	Velocity (ft/sec)	Soil Porewater Temperature (°C)	Soil Porewater Specific Conductance (uS/cm)	Soil Porewater Salinity (ppt)	Turbidity (FNU)	Chlorophyll a (ug/L)
7350	4.1								
					30.5	1676	0.8		
5562	3.01	5.19						19.1	35.8

(continued...)

Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate as N (mg/L)	Nitrite as N (mg/L)	Nitrate+Nitrite as N (unfiltered; mg/L)	Nitrate+Nitrite as N (filtered; mg/L)	Ammonium as N (unfiltered; mg/L)	Ammonium as N (filtered; mg/L)	Total Phosphorus (mg/L)	Orthophosphate as P (unfiltered; mg/L)	Orthophosphate as P (filtered; mg/L)
1.9	1.6	0.24	0.05	0.3		0.23		0.11	0.06	

(continued...)

Silica (unfiltered; mg/L)	Silica (filtered; mg/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi (ft)	Fecal Coliform (MPN/100ml)	Organization Name	Comments
						Agency Name	
						Contractor Name	Dry
4.9		25	11			Contractor Name	Skies: sunny. Wind: Northeast at 5-10 kts. Seas: <1 ft. Water clarity: clear. b.d. = below detection

**Figure 3.24.** Post-processing format of discrete hydrographic data in .xlsx file and CIMS

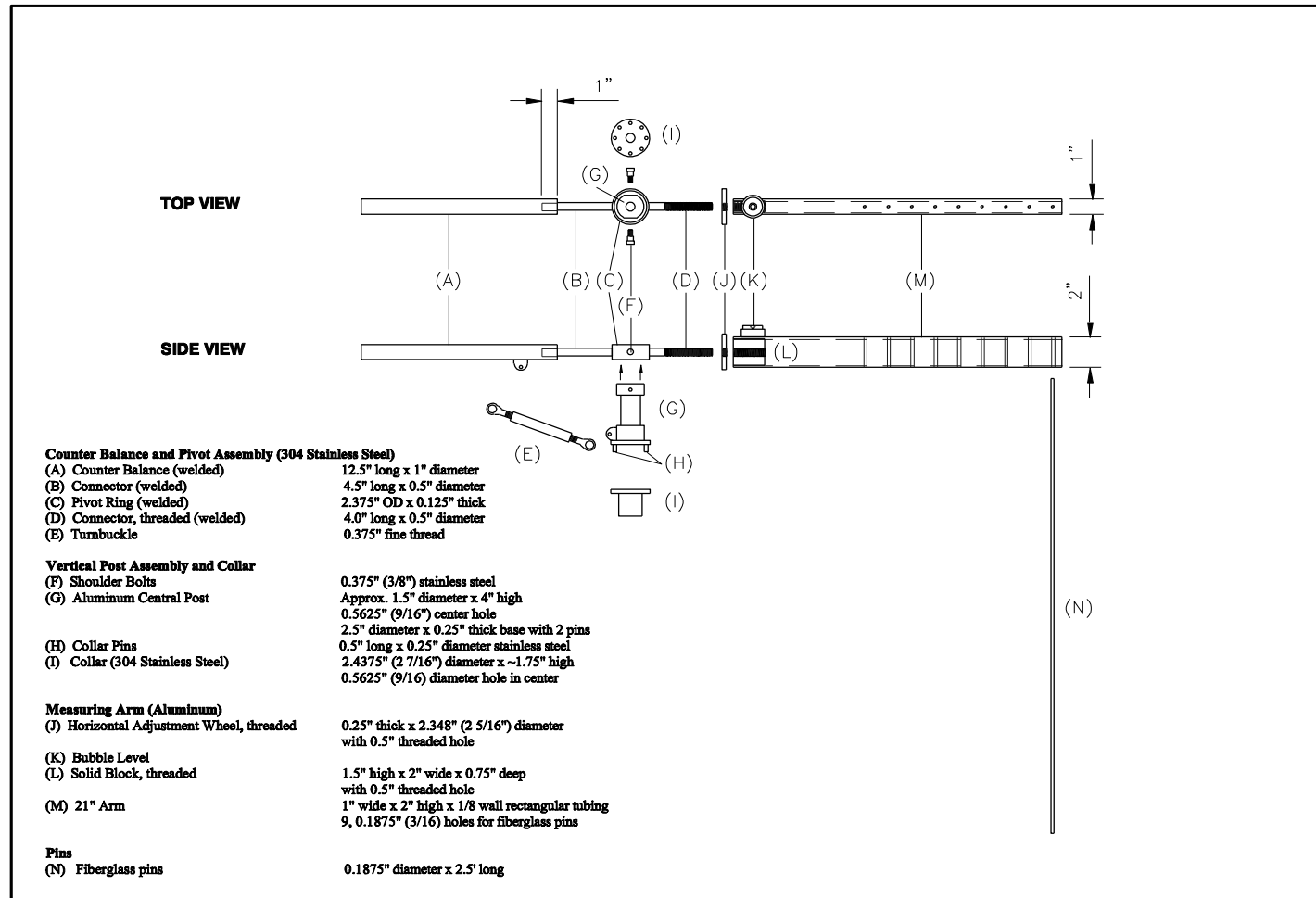
## 4. Rod-Surface Elevation Table

The CPRA has implemented the use of the rod-surface elevation table (RSET) technique that has been developed by Cahoon et al. (2002a) and Cahoon et al. (2002b). The RSET is the preferred version of the surface elevation table (SET) that has been established at specified locations in attached, herbaceous marsh and swamp/bottomland hardwood forest ecosystems. The RSET method provides a non-destructive process that precisely measures changes in surface elevation over time relative to a fixed subsurface datum. Briefly, a series of 4-ft stainless steel benchmark rods are driven through the root zone, the organic matter, and any soft underlying materials until refusal is encountered by a driving force on the rod. The rod remains approximately 2 ft above the marsh surface and is stabilized by a 6-in diameter pipe that is cemented at the surface. A custom-made stainless steel collar (Figure 4.1, part “I”) is permanently attached to the rod to provide a constant horizontal reference plane for long-term repeatability as the table remains fixed for each sampling period. The RSET table is custom made and constructed of aluminum and stainless steel. The CPRA will supply surface elevation tables and components necessary to acquire repeatable, precise, and accurate measurements.

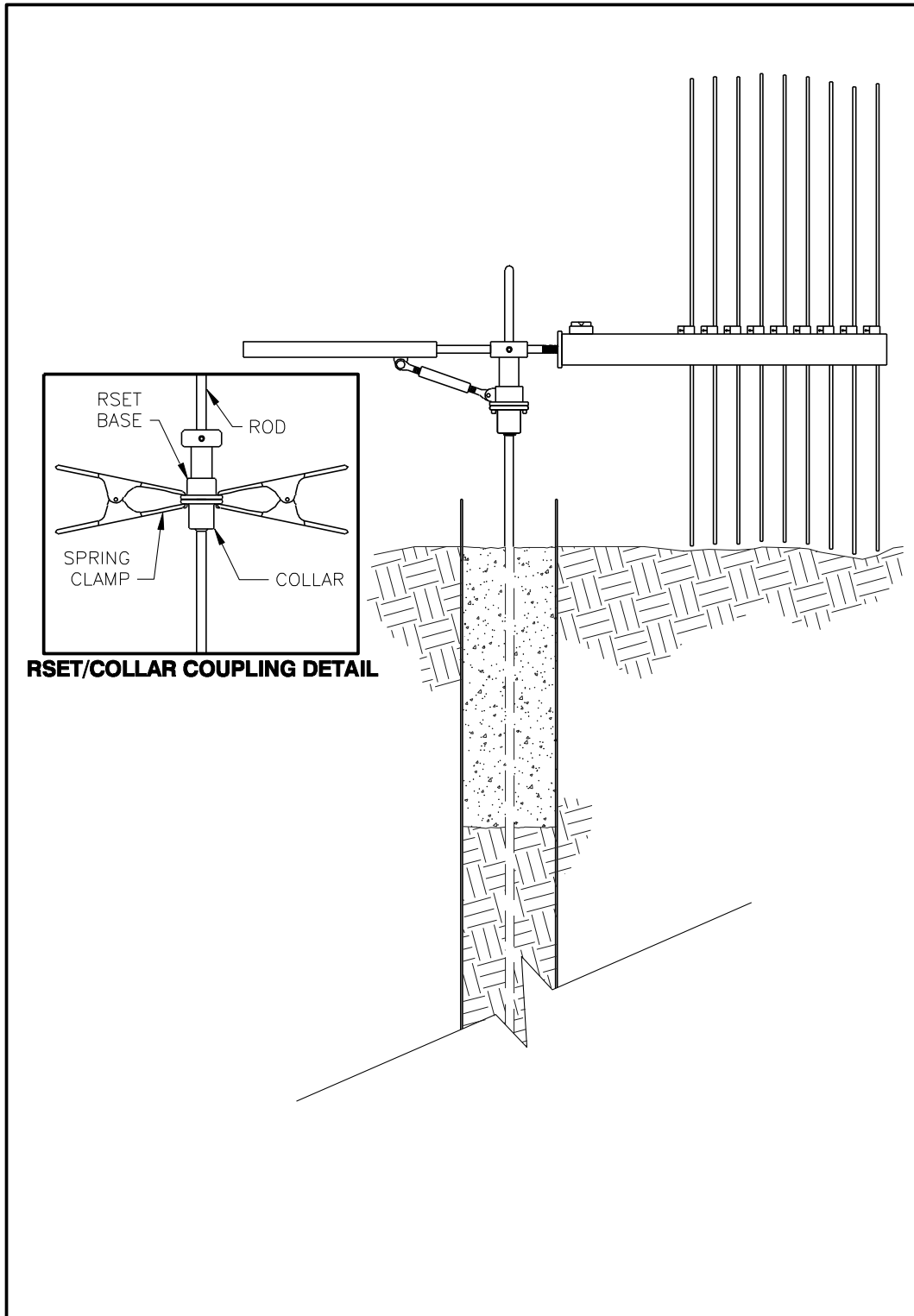
Data collection occurs by attaching a custom-made RSET table (Figure 4.1) to the collar and lowering nine fiberglass pins through the table to the soil surface (Figures 4.2a and 4.2b). The height (mm) that each pin extends above the table is recorded to calculate vertical changes of the soil surface over time. The table is repositioned to measure the soil surface at four 90° angles, providing 36 measurements per station. Using previously collected data, the rate of vertical change can be calculated with respect to changes occurring between the surface and the bottom of the stainless steel rod.

Surface elevation change measured with the RSET is influenced by both subsurface processes occurring in the soil profile and surface accretion, whereas the feldspar marker horizon (Section 5, Vertical Accretion) measures only surface accretion. When these two techniques are used in conjunction, they can provide information on below ground processes that influence surface elevation change. Differences between the rates of vertical accretion and surface change can be attributed to processes occurring below the feldspar layer and above the bottom of the RSET benchmark pipe. Consequently, it is imperative that the first RSET measurement occurs on the same day as the establishment of the accretion stations, and subsequent RSET measurements occur on the same day accretion data is collected. The accretion stations are established using the feldspar marker horizon method described in Section 5. The information derived from these two methods does not account for any process that occurs beneath the depth of the rod.

From 2006 through 2020, RSETs and feldspar marker horizons were measured twice per year (late winter/early spring and late summer/early fall). Starting in 2021, RSETs and feldspar marker horizons are measured at the beginning of the year (January through April) during periods of low water.



**Figure 4.1.** Construction drawing of a surface elevation table used on a 9/16" benchmark rod (Source: Cahoon et al. 2002b).



**Figure 4.2a.** A typical RSET data collection schematic showing nine pins used to measure marsh surface elevation.



**Figure 4.2b.** Photograph of a RSET instrument with pins setup on the rod and collar prior to lowering the pins down on to the marsh surface.

### 4.1 Rod-Surface Elevation Table Station Establishment

The deep rod needed for the RSET is installed from the boardwalks at new CRMS sites. When installing new sites, it is imperative that the installation of the rod for the RSET be performed without disturbing the area. The rod for the RSET shall be driven to refusal according to guidelines set forth in Cahoon et al. (2002) which describes the design of the RSET that will be supplied by the CPRA and the benchmark rods that can be used with the RSET.

The CPRA will provide the collar to permanently attach to the rod during the installation phase. CPRA will also provide the RSET and the necessary components needed to collect the measurements. Figures 4.3a and 4.3b show a schematic and photograph of the benchmark with the collar.

The RSET will be established at sites approved by the CPRA. In areas where the marsh is classified as floating, a rod for the RSET will not be established. Over time, sites and boardwalk areas may convert to from one coastal habitat type to another. When sites convert from floating to attached marshes, RSET and accretion stations shall be installed after consulting CPRA. When sites convert from attached marsh to floating marsh, RSET and accretion stations shall not be removed.

The establishment of this secondary monument will follow “A Contractor’s Guide to the Standards of Practice” (CPRA 2019).

*Deep Rod Benchmark Materials:*

1. Multiple 9/16” diameter by 4-ft stainless steel rods with threads (Berntsen SS91604 or equivalent)
2. 9/16” diameter stainless steel drive point (Berntsen SS12 or equivalent)
3. Locking connector thread (Berntsen M13 or equivalent)
4. Steel drive pin for a 9/16” diameter rod (Berntsen M1DPA or equivalent)
5. Power driving adapter (Berntsen PDA or equivalent)
6. Loctite® cement for stainless steel
7. PVC, Schedule 40, 6” diameter by 3–4 ft
8. Cement mix
9. Collar and screws (Figures 4.3a and 4.3b, in RSET; provided by CPRA)

*Minimum Installation Materials:*

1. Power driving device (Pionjar 120, Cobra 148, or equivalent)
2. Pipe wrenches (two 6” wrenches)
3. Post-hole digger (maximum 6” diameter)
4. Hacksaw
5. File
6. 2” x 12” x 10-ft treated board (2)
7. Cement mixing equipment: bucket, shovel, water, etc.
8. protective equipment (minimum eye protection, gloves, and ear plugs)

9. Hammer or small sledgehammer
10. Bucket to remove the soil

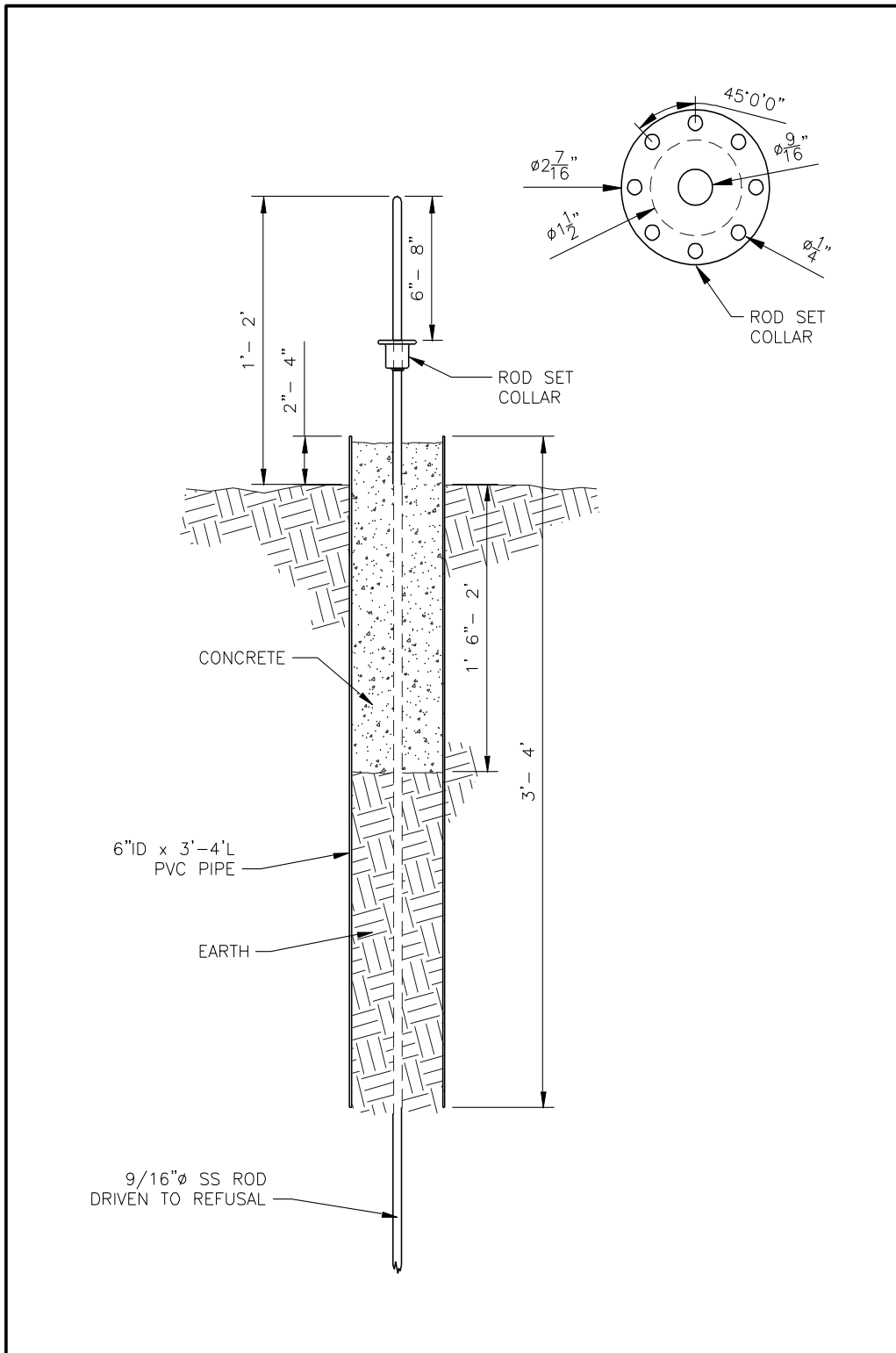
*Deep Rod Benchmark Installation Procedure:*

1. Place the board(s) across the two existing boardwalks where the rod for the RSET will be installed. If more than one person will be installing the rod for the RSET, a second board shall be used for safety.
2. Using a post-hole digger, dig a hole 1½–2 ft deep with a maximum diameter of 6 in. in the center between the two boardwalks and the center of the 10-ft boardwalk. Note: All soil or surface material extracted from the hole shall be placed in a bucket and not on the marsh/swamp surface. Upon completion, the extracted material must be discarded outside of the 200 x 200-m site. No soil or extracted material shall remain on the surface within the boardwalk area.
3. Drive the 9/16" stainless steel rods in the center of the hole to refusal using the manufacture's recommended procedures for the rods. These procedures shall include the use of all the materials listed in the benchmark materials list. Note: Refusal is defined as "No more than 1 foot of penetration of the rod in one minute of impacting with a gasoline powered reciprocating driver (i.e., Pionjar 120, Cobra 148, or equivalent)." The rod must also be plumb at the end of the installation.
4. The rod shall remain 2 ft above the marsh surface after the rod is driven to refusal. Any excess shall be cut level with a hacksaw.
5. Position the 6" PVC such that the 9/16" stainless steel rod is at the center. Push the PVC pipe into the soil until 2–4" remain above the surface. A small hammer may be used, depending on the soil characteristics.
6. Mix enough cement to fill the PVC. Note: When mixing the cement and or filling the PVC, no cement shall remain on the sediment surface outside the PVC.
7. Fill the PVC with the cement. Be sure not to overflow the PVC.
8. Slide the collar 8" below the top of the stainless steel rod.
9. Position four of the eight holes on the collar to point toward the four corners of the surrounding boardwalk such that Collar Direction #1 points towards the back-left corner.
10. Attach the collar in position so that the Collar IDs stamped on the collar are oriented toward the corner of the RSET plot using the four screws and Loctite® cement. Be sure not to move the rod when fastening the collar to the rod if the cement is still wet.
11. The final product shall resemble Figures 4.3a and 4.3b.

Documentation shall be made of the depth of refusal and the distance from the top of the rod to the top of the collar at each site and shall include the number of rods used during the installation as well as a length in feet. Pictures shall contain the RSET, the area approximately four feet around the RSET, and a date stamp. These pictures will ensure the CPRA that the surface adjacent to the monument was not disturbed.



#### 4. Rod-Surface Elevation Table



**Figure 4.3a.** Detailed construction drawing of a typical RSET station with collar. Inset: Collar detail.



**Figure 4.3b.** Photograph of an RSET rod and collar installed in the marsh.

When establishing the elevation of the rod for the RSET using RTK surveying or any CPRA approved method, no equipment shall touch the surface between or within a 10-m (32.8-ft) buffer zone around the boardwalk. Because this area is being used for the collection of scientific data, any instrumentation or equipment that is placed on the marsh/swamp surface may compromise the data collection efforts. Consequently, all the equipment that is used to determine the elevation of the benchmark must be raised using a technique that meets the requirements of the surveyor and meets approval from the CPRA.

If the RSET station is damaged over time, contact CPRA to discuss the appropriate actions. Thus far, we have seen bent rods from airboat incidents, leaning stations from surrounding soil failure, and burial of rods by sedimentation that requires rod extensions.

### 4.2 Rod-Surface Elevation Table Data Collection

The CPRA shall provide all the necessary components needed for the RSET data collection. To ensure that the highest degree of precision is achieved, it is imperative that all the components of an individual unit remain together. Since the CPRA will provide multiple units, each one will possess a unique serial number. Therefore, when a piece breaks or problems arise with the equipment, the CPRA must be informed immediately because this equipment is manufactured through the specifications developed by this agency.

Each RSET unit shall contain the following components (minimum):

1. The surface elevation table
2. Minimum of nine (9) fiberglass pins (numbered to correspond with numbered holes on table)
3. Minimum of nine (9) badge clips
4. Minimum of two (2) spring clamps
5. Aluminum metric ruler, capable of measuring in millimeters with the end being zero millimeters

Because of variability between crucial pieces, it is imperative that the RSET unit being used to take the initial reading at a station be used for all subsequent measurements. Therefore, the unit used for the initial reading shall be documented on the “Surface Elevation Table (RSET) Data Sheet” (Figure 4.4) to verify that the same unit was used at all subsequent data collections.

The following protocol has been adopted from the sampling method developed by Cahoon et al. (2002a, b). The sampling protocol is also thoroughly explained on Cahoon’s USGS web site <http://www.pwrc.usgs.gov/resshow/cahoon/>. These references give an excellent overview of how the sampling occurs, but note that the following protocol is written for the collection of data according to the CPRA standards.



#### 4. Rod-Surface Elevation Table

Surface Elevation Table (RSET) Data Sheet					
Distance from top of rod to collar (mm): _____			RSET ID: _____		
Project: CRMS-Wetlands		Sample Date: _____		Time: _____	
Station: _____		Establishment Date: _____		Time: _____	
Organization: CONTRACTOR or AGENCY					
Measured by: _____		Field personnel: _____			

Pin	Direction		Observed Pin Height (mm)	Omit (X)	Observation Comments (specific notes on pin placement)
	(Degrees)	(Collar #)			
1					
2					
3					
4					
5					
6					
7					
8					
9					
1					
2					
3					
4					
5					
6					
7					
8					
9					
1					
2					
3					
4					
5					
6					
7					
8					
9					
1					
2					
3					
4					
5					
6					
7					
8					
9					

**Site Conditions:** Water depth: \_\_\_\_\_ cm / not flooded (wet / dry)

**Soil Type:** organic / mineral (sandy / silty / clayey)

**Thatch thickness** (if any): \_\_\_\_\_ cm; **Pins placed:** on top of / beneath

**Dominant spp.** \_\_\_\_\_

**Other:** \_\_\_\_\_

**Vegetation:** healthy / senesced / stressed / dead

**Consistency:** very firm / firm / soft / very soft / unconsolidated

**Disturbance** (if any):

☐ Human  
☐ Grazed  
☐ Burned  
☐ Animal tracks/nest

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**Figure 4.4.** Surface elevation table (RSET) data sheet.

*Minimum Field Materials:*

1. RSET unit (contains the RSET and components listed previously)
2. Data sheet(s) (Figure 4.4)
3. Field notebook Pencils
4. One or two 2" x 12" x 10-ft boards
5. Compass
6. Digital camera
7. Cleaning supplies (brushes, towels, WD40®, etc.)

*Procedures:*

Note: Accretion stations will be established on the same day as the first RSET reading and are to be sampled when subsequent RSET measurements are taken.

Note: Data from the previous RSET sampling should be downloaded from the database in order to review notes about the surface on which pins were previously placed in order to replicate that sampling effort as much as possible.

Note: No walking on the soil surface is permitted; all work is performed from the boardwalk.

Swamp Site Note: If the site is flooded and the soils are flocculent and/or have floating marsh at the surface, no data collection for RSET or accretion cores shall take place on that trip. In that case, RSET and accretion data collection shall be postponed until water levels are low enough to do so (with no flocculent soils and mat not floating) to ensure that the surface on which the accretion measurement is made (from the feldspar to the top of the soil frozen in the core) is the same surface on which RSET pins are placed. In highly flocculent soils with multiple potential RSET surfaces, making measurements on the same surface is impossible or would only reflect water level, not soil level in floating marsh systems. CPRA maintains a list of stations where elevation change measurements have been suspended or eliminated.

*Data Collection:*

1. Place one or two boards between the boardwalks.
2. Move any material that has grown or accumulated on the stainless steel rod and collar. The table must sit flush on the collar.
3. Verify that the collar has not moved vertically or around the rod.
  - a. Using a metric ruler, measure the distance between the collar at Direction 1 and the top of the stainless steel rod in millimeters. Record the distance in the appropriate place on the data sheet.
  - b. Slide the RSET onto the rod, and align the collar pins (Figure 4.1, part "H") with the holes in the collar such that the table points in the number 1 direction on the collar. Secure the RSET using the clamps.

- c. Check the bearing of the table direction 1 to determine whether or not the collar has rotated around the rod.
- d. If the collar has moved, continue to step 4. If the collar has not moved, proceed to step 5.
4. Document that the collar has moved and note any other obvious damage that would prevent a direction from being used. Report the damage to CPRA, document with pictures and detailed comments, and re-tighten the collar.
  - a. Re-tighten the collar as close as possible to the original height and position (bearing). Apply Loctite® to the threads of the four screws and make sure the collar is secure.
  - b. The RSET instrument should be leveled after the collar is re-tightened and the Loctite® is dry. The data from the first reading after adjusting the collar will be considered a new baseline. The station establishment date and time should be the date of collar maintenance from that point forward.
5. Fill out the top of the data sheet including: the collar to top of rod measurement obtained in step 3 or 4, RSET ID number stamped on the instrument, project name (CRMS), group (if one is provided by CPRA), station ID, sampling date and time, data collection organization's name, establishment date and time, the name of the person reading the measurements, and the names of other field personnel on the trip.  
Note: Establishment date refers to the date the first reading was taken from the RSET. If the collar is reset such that the horizontal position is changed, then a new establishment date shall be used.
6. Slide the RSET (Figure 4.1) onto the rod, aligning the collar pins (Figure 4.1, part "H") with the holes in the collar such that the table points in the direction of one of the four corners of the boardwalk. Note: Sampling will typically occur at four (4) 90° angles at Directions 1, 3, 5, and 7. Alternate collar directions can be established only during the first reading when a primary direction is damaged or obstructed.
7. Clamp the RSET to the collar using two spring clamps.
8. Level the RSET vertically and horizontally using the level bubble and lock it into place with the turnbuckle. The RSET should perfectly level in order to get precise measurements. If the table is bumped during data acquisition, then re-level it.
9. Record the compass bearing next to the corresponding collar ID direction on the "Surface Elevation Table (RSET) Data Sheet" (Figure 4.4).
10. Place the nine (9) fiberglass pins (3/16") in their corresponding numbered holes on the arm of the RSET and secure them with badge clips so that the pins are just below the bottom of the RSET arm.
11. Gently lower each of the pins onto the soil surface and secure with the badge clips.  
Note 1: It is easiest to lower pins in order of farthest from the reader to closest to the reader. Unclip badge clips before lowering pins instead of

pulling against the clip so as not to make indentions in the surface with already-placed pins.

Note 2: There are multiple potential soil surfaces. Each RSET reader tends to interpret the surface differently from other readers, so it is best that the same person read the RSET at a given site. If this is not possible, the fact that there are different readers should be noted under “Site Conditions.” An effort should be made each time RSET data is collected to interpret the surface the same way it was previously interpreted. These notes can be placed in the “Site Conditions” section at the bottom of the data sheet.

Note 3: Accretion and RSET measurements should be taken at the same time and the two persons collecting the data should communicate while deciding how to define the surface. After the first cryo-core is taken and while pins are being placed in the first RSET direction, the RSET and accretion measurers should make sure both persons understand and can identify the surface being measured to. For example, if the person reading the RSET would define the surface as a more consolidated layer just beneath a watery slurry, the accretion measurer should make sure he/ she could distinguish that surface in the cryo-core. The muddy slurry may look the same as the consolidated surface when frozen. In that case, the RSET reader would need to level pins to the muddy slurry. Or, as a second example, if the person reading the RSET would prefer to work pins through a thick layer of unconsolidated thatch down to a more consolidated organic surface, the accretion reader should make sure he/she can distinguish the thatch from the more consolidated organic layer. If the thatch looks the same as the organic surface in the cryo-core, the RSET reader would need to level to the top of the thatch.

12. Measure from the top of the RSET arm (Figure 4.1, part “M”) to the top of the pin and record the distance in millimeters on the data sheet in the “Observed Pin Height (mm)” field. The measurer should make sure his/her eyes are level with the top of the pin to avoid parallax. Note: The person recording the measurements should verbally repeat the measurement back to the measurer to assure that the correct number was understood and recorded.
13. As the RSET pins are being placed on the surface and measurements are being taken, the measurer should make specific comments about the surface that individual pins are resting on if it differs from the other pins in that direction (e.g., “in a crab hole” or “in a culm of *Spartina patens*”). These pin-specific comments go in the “Observation Comments” field on the data sheet.
14. If it is not possible to place pins on the surface or it is the professional opinion of the RSET reader that the pin is on an unrepresentative surface for that site or in a hole, record the “Observed Pin Height (mm)” and mark an “X” in the “Omit (X)” field on the data sheet for that pin. All omissions should be accompanied by an Observation Comment. Common reasons for omitting pins include:

- a. A pin is blocked from reaching the surface by a thick stem or shrub.
- b. A pin lands in a hole not representative of the marsh type, like a crab burrow or pig track.

Note: Natural depressions and higher elevation areas caused by subsurface roots should be noted but not omitted. In some cases, especially in fresher marsh types, the surface is a net of roots with spaces between them. In those cases, note the surface that the pins fall on but do not omit them if they are truly representative of the surface. Some surfaces are highly variable, and the variation is to be expected. At particularly problematic, confusing, or odd sites, photograph the plant-soil interaction. Use as descriptive botanical terms as possible when describing the reason for omitting pins due to interaction with the base of a plant (e.g., aerial roots, rhizome, stem base).

15. After recording measurements, pull each pin about two-thirds of its length up and clip each with a badge clip so that the bottoms of the pins do not interfere with rotating the RSET.
16. Unclamp, lift, and rotate the RSET towards another RSET direction.
17. Repeat steps 11 through 16 until all four sets of measurements have been obtained.
18. Describe the condition of the RSET plot in the "Site Conditions" box at the bottom of the data sheet. There are prompts in "Site Conditions" for the following data:
  - a. Water depth in the RSET plot (measure in three or more locations and estimate average depth) or note whether it is wet or dry if not flooded. Provide additional notes if it is very dry and cracked.
  - b. Vegetative health (healthy, senesced, stressed, dead) and dominant vegetation species.
  - c. Description of the soil surface composition (organic or mineral) and if mineral, what kind of mineral (sand, silt, clay), if known. More than one mineral soil type can be selected or type of mineral soil does not have to be selected.
  - d. Disturbance to the RSET plot and the cause of the disturbance, if known (fire, grazing, other animal activity [trails, nests], human, other).
19. Take a digital picture providing an overall view of the RSET plot (above). The picture should be taken from the access boardwalk, facing the RSET plot and short boardwalk. Another picture shall be taken providing a close-up view of the marsh surface (flash on) somewhere within the RSET plot that is representative of the site surface (below). The below picture should include the base of dominant vegetation if present. Other digital pictures should be taken of the marsh surface for all unusual or difficult pins.
20. If a disturbance occurs that would alter all of the readings in a particular direction, discontinue collecting data from that direction but do not change directions. If the disturbance is not human-induced and it affects all possible directions, continue to measure the RSET if possible.



21. Data shall still be recorded if the RSET is not measured during the sampling season. Enter the last attempted date or final date of sampling season as the Sample Date, describe reason for not sampling in the Site Condition notes along with any other observations, and copy data to be repeated from previous data collection (RSET ID, Measured by, and Direction Degrees and Collar #).

#### CONVERSION OF STATIONS TO OPEN WATER:

The intent of the CRMS monitoring program is to maintain the original monitoring stations for as long as possible. RSET stations will not be moved to new locations if the original location erodes away. Therefore, every attempt will be made to collect elevation change data during each sampling interval. If longer pins are needed to reach the surface in an eroding environment, the contractor should be prepared with longer pins or should return to a site to re-sample if pins were inadequate. RSET rods are not expected to stand up to wave action in open water for extended periods of time. If the rods become bent and the station is in open water, install a staff gauge at the site and continue to measure bottom surface elevation in the four directions around the original RSET rod location. Database modifications will have to be made to accommodate these staff gauge data. CPRA will advise as needed when these issues arise.

#### **HURRICANE DAMAGED STATIONS:**

Tips for straightening RSET rods:

1. Determine where rod is bent relative to the concrete.
2. If rod is bent above concrete, then:
  - a. Mark collar position at Direction 1 and measure Top of Rod to Top of Collar (TRTC).
  - b. Remove collar
  - c. Place cheater pipe around rod down to the concrete (important, otherwise the rod will bend further or another bend will occur)
  - d. Straighten rod with cheater pipe
  - e. Check the rod for straightness
  - f. Repeat C and readjust rod with cheater pipe if necessary.
  - g. If the collar does not need to be repositioned: Replace collar to marked position and re-measure TRTC to verify if it changed (see h. iv. if TRTC has changed).
  - h. If the collar needs to be repositioned:
    - i. Replace collar to new height.
    - ii. Maintain the same compass bearings for the collar directions of the previous position.
    - iii. Measure new TRTC distance.
    - iv. Adjust previous Pin Height data by subtracting the difference of TRTC distances:  

$$\text{Adj Pin Heights} = \text{Prev Pin Heights} - (\text{TRTC}_0 - \text{TRTC}_i)$$
3. If rod leaning but is not bent above the concrete, then:
  - a. Try to hold the rod and concrete/PVC upright and straight

- b. Drive 4, 12' 2x4s snug around the PVC and equally spaced to splint PVC/Concrete base in position
- c. Drive or cut tops of 2x4s to below the collar to be able to move the RSET and make measurements.
- d. Bind 2x4s with ring clamp(s), ideally at or below top of the PVC.

OR

- e. Another option could be using a larger diameter PVC:
  - i. slide a larger diameter PVC pipe (8" ID) around the concrete/PVC (6.625" OD),
  - ii. drive larger diameter PVC to a secure depth,
  - iii. cut the top off even with the previously existing concrete/PVC if possible
  - iv. shim gap between PVC pipes if needed to prevent movement of PVC pipes.

In areas that were converted from marsh to open water and the RSET is too exposed to rough wave conditions for continued use, then get one final measurement if possible.

- 1. If RSET rod is bent or leaning (or wobbly), then straighten and stabilize using protocols above; something less rigorous such as holding the rod in place may be employed to temporarily stabilize the rod for RSET measurement.
- 2. Bring long RSET pins if available to account for scour.
- 3. If the distance from the top of RSET arm to the water bottom is too long for pins, then use a stadia rod for a few measurements along the arm in each direction using pin positions 1, 4, and 9. Measurements should be taken to the top of the RSET arm and converted to mm.
- 4. Convert the new measurement to the original pin height ( $PH_o$ ) by subtracting the current pin height ( $PH_i$ ) from the original pin length ( $PL_o$ ):

$$P_{ho} = P_{lo} - P_{hi} \quad \text{Ex. } P_{ho} = 900 \text{ mm} - 1400 \text{ mm} = -500 \text{ mm}$$

For RSETs that can be stabilized and measured into the future:

- 1. If Long Pins will reach the sediment surface, then replace shorter pins.
  - a. Take pin height measurements with long pins and record in typical fashion.
  - b. Convert previous pin height data in database to longer pins by adding the difference in pin lengths to the original pin heights and including a note in each Verified Pin Height Comment for each pin stating the adjustment amount. CPRA can assist in this process.
  - c. Send the adjusted RSET data set to CPRA who will replace the previous data in the CIMS database.
- 2. If distance is too long or other conditions make using the long pins infeasible (e.g. too much wave energy or no boardwalk to measure from), then use the Stadia Rod as described above.

The variability caused by the scour event will overwhelm any loss of precision caused by switching measurement techniques.

### 4.3 Rod-Surface Elevation Table Data Processing

The CPRA has implemented a two-phase protocol for data processing. These two phases are referred to as data entry (Phase I) and data quality assurance/quality control (Phase II). These two phases are conducted by separate individuals to assure that the final product is correct.

**DATA ENTRY (PHASE I):** Phase I is conducted by the individual responsible for the field data collection (e.g., the measurer) and requires three main tasks: 1. field data sheet review, 2. data transcription, and 3. data verification. These tasks require specific procedures as described below.

1. Field Data Sheet Review
  - a. Review the original data sheet for legibility, completeness, and accuracy.
  - b. If the data sheet needs to be corrected, make corrections using a different color pen without erasing original data. Strike a single line through the error and write the changes close to the error. Note: The original data should still be legible after corrections are made.
  - c. Accompany changes with the person's initials and date.
  - d. Changes made to Verified Pin Height (mm) data during data processing shall have an accompanying Verification Comment describing the action taken.
2. Data Transcription
  - a. CPRA will provide a data upload tool that allows the user to enter data into a Microsoft Excel spreadsheet that looks like the field data sheet. The Excel file transfers the data from the digital data sheet into a spreadsheet that is formatted for upload to the CIMS database. The file, "RSET\_data\_tool.xlsx" is available on the CRMS Data Depot site. Alternately, the contractor may elect to develop their own data transcription tool.
  - b. Enter recently collected data into the Data Sheet worksheet which is formatted to look like the field data sheet.
  - c. When entering pin comments into the Observation Comments cell, enter specific observations about individual pins first and any general comments on the entire direction last.
  - d. The prompted drop-down boxes in the Site Conditions section of the Data Sheet worksheet are the minimum site notes required. Additional comments are entered in the Other notes section
  - e. Data entered into the Data Sheet worksheet will automatically populate the CIMS worksheet formatted for upload to CIMS (Figure 4.5) through the CPRA remote-upload site.
  - f. Save a copy of the RSET data tool to the CRMS Data Depot site using the following naming convention: "*Station\_RSET\_data\_tool\_seasonYEAR.xls*", e.g., "*CRMS0398\_RSET\_data\_tool\_Spring2011.xlsx*"

- g. Save the digital photos as .jpg files using the following naming convention: “Station\_E01\_Above or below \_seasonYEAR.jpg,” e.g., “CRMS0398\_E01\_Above\_Spring2011.jpg.” “Above” refers to the photo taken of the RSET area from above. “Below” refers to the photo taken of the marsh surface down in the vegetation, if present.

3. Data Verification

- a. Ensure no transcription errors occurred from the field data sheet to the digital data sheet.
- b. Check that the data was automatically populated to the CIMS worksheet correctly and in a clear fashion. Check that the Site Conditions section merged clearly and that the RSET measurer name on the Data Sheet is the first person listed under Personnel.
- c. In order to assure highest-quality data collection, make the following checks relative to previously collected RSET data:

Note: The data from the previous data collection should have been downloaded from CIMS before sampling occurred to refresh the RSET reader’s memory about decisions made previously concerning the definition of the soil surface at that site.

The following should be checked against the previous data collection:

- i. RSET reader is the same person if possible (first name in Personnel). If the RSET reader must change, the discrepancy should be noted in the Site Conditions section of the comments.
- ii. RSET Direction (Collar #) and Direction (Deg) are consistent over time. The bearing (deg) for Collar #s should not change.
- iii. The same RSET instrument (RSET ID) is consistently being used at a CRMS site. If the RSET instrument must change, the discrepancy should be noted in the Site Conditions section of the comments.
- d. Upon completion of the review, provide the data along with the field data sheet to the QA/QC officer.

**QUALITY ASSURANCE/QUALITY CONTROL (PHASE II):** Phase II begins when the QA/QC officer is provided the field data sheet and is notified that the digital data sheet is ready. The QA/QC officer should follow the steps below to ensure the data has been processed properly.

The QA/QC officer should complete the following procedures:

- 1. Examine the field data sheet for completeness and errors.
- 2. Check the data from the Data Sheet worksheet against the field data sheet (Figure 4.4) to ensure it was correctly entered into the Excel file.
- 3. Check that the data was automatically populated to the CIMS worksheet correctly and in a clear fashion.
- 4. If mistakes are found, return the field data sheet and Excel file to the data collector so any mistakes can be corrected or explained.
- 5. Continue this process iteratively until no mistakes are found.

6. Scan a copy of the corrected data sheet into a .pdf file for upload to the CRMS Data Depot site.

Once Phases I and II have been completed, upload the data files to the CIMS buffer. The RSET Data Tool.xlsx files are to be zipped and uploaded to the CIMS Data Entry Bulk Load where data from the CIMS worksheet is loaded into QA/QC buffer for CPRA review. Check the CIMS Data Entry Remote Load for updated information.

#### **4.4 Rod-Surface Elevation Table Deliverables**

Electronic files in the appropriate deliverable format shall be delivered to the CRMS Data Depot site once the QA/QC process is complete and data is entered into the CIMS buffer.

Deliverables should include the following:

1. RSET data tool file (.xlsx)
2. RSET original/digital field data sheet (.pdf)
3. Photographs (.jpg)

The Rod Surface Elevation Tables will occasionally be inspected by CPRA staff to insure that the instrument is being well maintained. Pins should be straight and labeled, clips should be in good condition, the pin holes on the RSET arm should be clean and lubricated with WD-40, and the RSET should be in good condition overall.

#### 4. Rod-Surface Elevation Table

Station ID	Group	Sample Date (mm/dd/yyyy)	Sample Time (hh:mm)	Establishment Date (mm/dd/yyyy)	Establishment Time (hh:mm)
CRMS0545-E01		10/9/2014	10:44	6/7/2008	11:46
CRMS0545-E01		10/9/2014	10:44	6/7/2008	11:46
CRMS0545-E01		10/9/2014	10:44	6/7/2008	11:46
CRMS0545-E01		10/9/2014	10:44	6/7/2008	11:46
CRMS0545-E01		10/9/2014	10:44	6/7/2008	11:46
CRMS0545-E01		10/9/2014	10:44	6/7/2008	11:46

(continued...)

Time Zone	Direction (Collar Number)	Direction (Compass Degrees)	Pin Number	Observed Pin Height (mm)	Verified Pin Height (mm)	SET ID
CST	1	14	1	460		2005-1
CST	1	14	2	406	406	2005-1
CST	1	14	3	425	425	2005-1
CST	1	14	4	406	406	2005-1
CST	1	14	5	620		2005-1
CST	1	14	6	407	407	2005-1

(continued...)

Organization	Personnel	Observation Comments	Verification Comments
Coastal Protection and Restoration Authority	M. Luent;B. Wood;M. Miller;M. Mouledous	On stem	
Coastal Protection and Restoration Authority	M. Luent;B. Wood;M. Miller;M. Mouledous		
Coastal Protection and Restoration Authority	M. Luent;B. Wood;M. Miller;M. Mouledous		
Coastal Protection and Restoration Authority	M. Luent;B. Wood;M. Miller;M. Mouledous		
Coastal Protection and Restoration Authority	M. Luent;B. Wood;M. Miller;M. Mouledous		Observed Pin Height recording error
Coastal Protection and Restoration Authority	M. Luent;B. Wood;M. Miller;M. Mouledous		

(continued...)

Site Conditions
Site is not flooded (wet); Vegetation is healthy; Dominant spp. are Vigna luteola; Firm organic soil; Thatch 9 cm thick. Pins placed beneath thatch; No Disturbance; Rod to collar = 196 mm
Site is not flooded (wet); Vegetation is healthy; Dominant spp. are Vigna luteola; Firm organic soil; Thatch 9 cm thick. Pins placed beneath thatch; No Disturbance; Rod to collar = 196 mm
Site is not flooded (wet); Vegetation is healthy; Dominant spp. are Vigna luteola; Firm organic soil; Thatch 9 cm thick. Pins placed beneath thatch; No Disturbance; Rod to collar = 196 mm
Site is not flooded (wet); Vegetation is healthy; Dominant spp. are Vigna luteola; Firm organic soil; Thatch 9 cm thick. Pins placed beneath thatch; No Disturbance; Rod to collar = 196 mm
Site is not flooded (wet); Vegetation is healthy; Dominant spp. are Vigna luteola; Firm organic soil; Thatch 9 cm thick. Pins placed beneath thatch; No Disturbance; Rod to collar = 196 mm
Roseu cane in rSET area; Site is not flooded (wet); Vegetation is healthy; Dominant spp. are Vigna luteola; Firm organic soil; Thatch 9 cm thick. Pins placed beneath thatch; No Disturbance; Rod to collar = 196 mm

**Figure 4.5.** RSET post-process data format in .xlsx file and CIMS

## 5. Vertical Accretion

Vertical accretion/loss will be measured from marker horizon stations placed outside the RSET boardwalk. The marker horizon, white feldspar clay that is easily distinguishable from the natural substrate, is evenly sprinkled on the surface of the wetland in sets of stations every two years. Stations will be sampled repeatedly over time to determine the rate of soil accumulation/removal over the marker horizon using cryogenic coring (Cahoon et al. 1996). From 2006 through 2020, RSETs and feldspar marker horizons were measured twice per year (late winter/early spring and late summer/early fall). Starting in 2021, RSETs and feldspar marker horizons are measured at the beginning of the year (January through April) during periods of low water. This SOP describes vertical accretion station establishment and sampling schedules starting in 2021; the previous schedules can be found in previous SOPs (see Folse et al. 2018).

### 5.1 Vertical Accretion Station Establishment

Vertical accretion (VA) stations are established and initial RSET readings are recorded on the same day to synchronize both baselines for data analysis. Within a predetermined layout around the base boardwalk, a set of three, 0.5 m x 0.5 m stations are systematically established starting with the lowest available number along each side of the boardwalk; the numbering of the stations depends on the access boardwalk location when initially constructed (Figures 5.1a, 5.1b, and 5.1c). To standardize the age of accretion measurements, a new set of stations will be established coast-wide every four measurement periods while continuing to sample previously established sets of stations periodically (Figure 5.2).

Each set of three stations established on the same date is referred to as plot set (PS). The sampling schedule for PSs is designed to enable comparison of recently accreted material at all sites coast-wide and to measure the accretion process over longer time scales at sites that maintain feldspar. Stations are sampled annually during the initial, short-term sampling period and less frequently in the long-term sampling period. A process for deciding when to abandon accretion sampling in a PS due to lack of available data has been established in an effort to balance sampling effort and data quality. If all stations of a PS fail to produce accretion data after multiple attempts on repeated visits, the PS is abandoned; and, then, if consecutive PSs are abandoned in the short-term period at a site, the vertical accretion technique is abandoned at the site altogether. CPRA will provide a list of stations to be sampled each season based on stations assigned to each PS and those that have been abandoned.

The vertical accretion method is not suitable for all coastal Louisiana habitats. The method is not used at floating marsh sites and some swamp sites. Some frequently inundated swamp sites or deltaic marshes should be measured when water levels are

low enough for quality sampling, typically after cold front passage. Discuss problematic sites with CPRA.

Establish stations using the lowest station number available along each of the boardwalk sides (Figures 5.1a, 5.1b, and 5.1c). If a newly selected station is obstructed (e.g., disturbance, tree, hole, cypress knee), then select the next lowest number within that side. Because multiple PSs will be active simultaneously, station numbers (A01, A05, etc.) should be marked and maintained on the station marker stake closest to the boardwalk with a permanent marker for identification.

Note: All station establishment and data collection procedures must be conducted from the boardwalk or portable boardwalks extending from the permanent boardwalk to avoid the disturbance of the marsh and future sampling areas.

In order to prevent temporal gaps in data collection and collection of short-term data, a set of stations may be re-established during the second sampling trip after establishment if no viable data was collected (Figure 5.2). If stations are destroyed and cannot be located within the first year since establishment, they can also be re-established. There are no other times when stations should be re-established. From that point on, PSs are abandoned altogether if they fail to produce data from all of the stations in two consecutive sampling periods or if they are damaged.

Over time, sites and boardwalk areas may convert to from one coastal habitat type to another. When sites convert from floating to attached marshes, RSET and accretion stations shall be installed after consulting CPRA. When sites convert from attached marsh to floating marsh, RSET and accretion stations shall not be removed.

### *Minimum Materials:*

1. Safety equipment: respirator, gloves, and eye protection
2. Feldspar for marker horizon: G-200 white feldspar clay from the Feldspar Corporation, Minspar 200 or equivalent (5–6 stations per 50-lb bag)
3. 50-cm x 50-cm PVC square with detachable corners
4. 5-ft stakes to mark opposite corners of the station (minimum of two per station): PVC pipes or other material except for metal rebar
5. Permanent marker for labeling stakes
6. Spreader/sieve: small cup-like device used to evenly spread the feldspar within the station
7. Container as large or larger than the square: Used when the marsh is flooded to prevent the feldspar from settling outside the station area
8. Watering can or garden sprayer: Used to moisten the feldspar on a dry marsh; must be able to moisten feldspar without disrupting an even feldspar layer



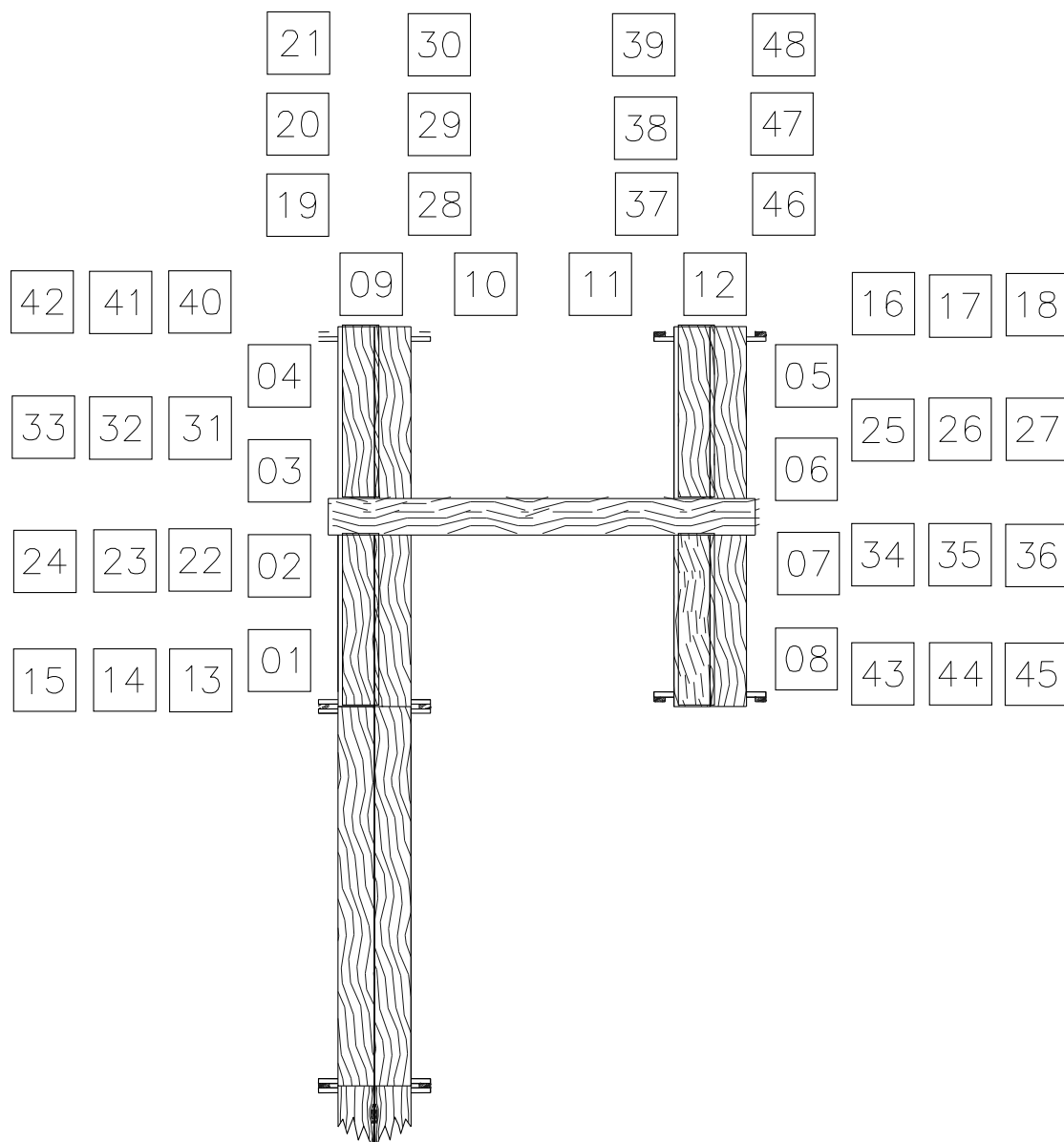
9. Digital camera: Capable of displaying a date stamp to document the establishment of the stations
10. Ruler: To measure depth of marsh surface flooding.
11. Global Positioning System (GPS) with sub-meter accuracy (Trimble GeoXT or equivalent).
12. Field data sheet (Figure 5.3)

*Procedures:*

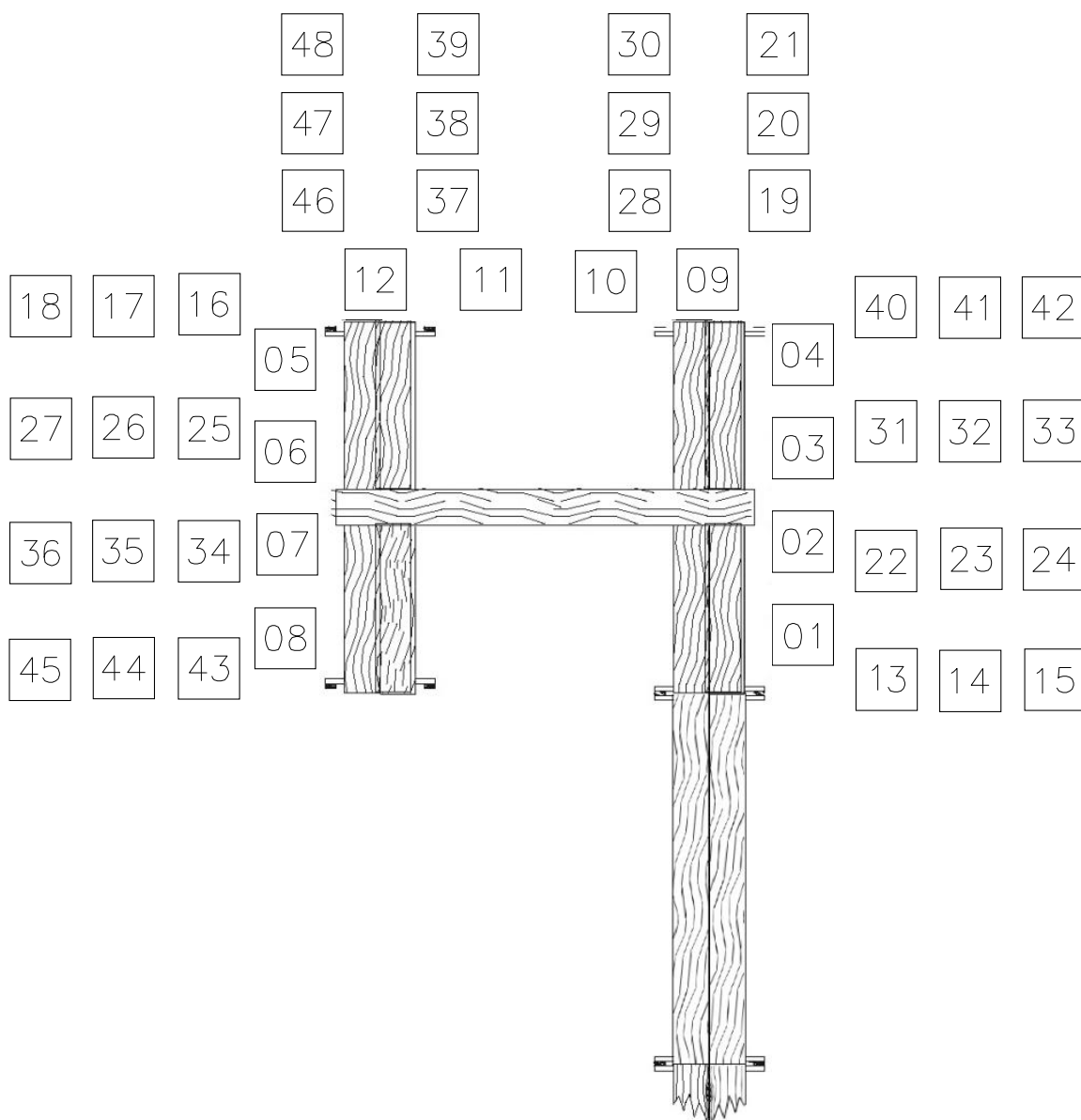
Note for establishing stations beyond the first row: Do not disturb the surface of future stations, which extend approximately 10 ft from the sampling platform. The stations not directly adjacent to the boardwalk will be reached from a temporary boardwalk that extends perpendicularly from the boardwalk between rows of stations (Figures 5.1a, 5.1b, and 5.1c). The type of temporary boardwalk will vary based on the type and/or condition of the marsh.

1. Complete the top portion of the data sheet (Figure 5.3): *Site, Group (PS#), Establishment Date and Time, Sample Date and Time, Organization, Measured by, and Other Personnel*. *Note: Establishment Date and Time and Sample Date and Time will be the same.*
2. When applying the feldspar, all necessary health precautions should be taken because the material is a fine powder that can be easily inhaled and irritate the eyes. Note: An appropriate respirator, sealed eye protection, and gloves are required.
3. Carefully place the 0.5 m × 0.5 m square over the soil surface representing the station illustrated in Figure 5.1 while not damaging the vegetation or disturbing the soil. Note: If vegetation is too thick and/or high, then the square can be disassembled, positioned around the vegetation, and reassembled.
4. Secure the square and mark the station for future measurements by lodging no less than two stakes into the soil just inside opposite corners of the square, leaving at least 2.5 ft above the surface. Record the station number on the stake closest to the boardwalk on the bottom left corner with a permanent marker for future identification. Also, mark the approximate location on the boardwalk in case the stakes are lost. Note: Longer stakes may be required to leave 2.5 ft above the surface.
5. Using a small cup or sieve, evenly sprinkle the feldspar on the soil surface, making sure not to leave any on the standing vegetation or loose litter/thatch (vegetation can be gently shaken to remove any feldspar from the vegetation to the soil surface). Cover the soil surface with a minimum thickness of 5 mm or no less than 80 ounces (2.27 kg) of feldspar. Tip: Position yourself upwind from the station to avoid the clay dust, and pour the feldspar close to the soil surface to minimize the clay dust. Ensure that the feldspar adheres to the soil surface:

- a. If dry during station establishment, carefully sprinkle water to moisten the feldspar, being careful not to wash it away from the surface.
  - b. If flooded during station establishment, use a container to allow the feldspar to settle to the surface without drifting away from the station. Prior to applying the feldspar, place the container around the square and markers so there is no space between the soil surface and container. When the feldspar is applied, it has a tendency to float until it becomes completely saturated, which may take 15 minutes or longer. When the feldspar is no longer suspended in the water and has settled onto the soil surface (settlement time varies depending on water depth and movement and the soil surface), carefully remove the container to not disturb the feldspar and to check that the feldspar is adhering to the soil surface. Note: It has been observed that containers that sit just below the water surface allow for faster settling than those that cross the water surface. If feldspar leaches out of the station, then replace the container to allow the feldspar more time to adhere to the surface. Repeat checking until no appreciable feldspar leaches; the purpose of this is to avoid the confusion of multiple feldspar layers in future stations. Tips: Having three containers will save time during feldspar deployment. Also, long settlement times at some sites may require multiple trips.
6. Photo document the establishment from directly above each station (pre/post establishment) and the location of the set of stations within the site (picture of the entire sampling platform showing the station markers). Note: Label the digital pictures (jpeg format) with the appropriate station number and establishment date. Name the files with the following convention: Site-station\_YYYY-MM-DD\_Pre or Post PS#.jpg (e.g., CRMS0395-A01\_2005-03-24\_Pre\_PS1.jpg).
  7. In the station sections of the datasheet (Figure 5.3), record the station number and observable Add'l Notes (*Water Level, Vegetation, Dominant Spp., Soil desc*).
  8. Record the coordinates of each station from the bottom right corner closest to the boardwalk using a sub-meter GPS in the *Other Notes* section of the datasheet. The station coordinates (northing and easting) will also be provided to the CPRA in UTM, NAD83 Meters using the "Station Coordinates" Excel file.
  9. Record the *Core Coords* as 0;0, all four *Accretion Measurements* as 0 mm, and *Feldspar Quality* as Established on the data sheet.



**Figure 5.1a.** Schematic of the accretion stations around an attached marsh site when access is on left side of boardwalk. Portable boardwalks are to be placed between rows of stations when establishing or sampling stations that are not adjacent to the permanent boardwalk.



**Figure 5.1b.** Schematic of the accretion stations around an attached marsh site when access is on the right side of the boardwalk. Portable boardwalks are to be placed between rows of stations when establishing or sampling stations that are not adjacent to the permanent boardwalk.



**Figure 5.1c.** Photographs of boardwalks with access on the left side (top) and right side (bottom).

## 5. Vertical Accretion

Sampling Season	Set of Stations (Plot Set, PS)											N stations scheduled
	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	
Pre Fa 09	E											3
	x											3
	x											3
Fa 09	x											3
Sp 10	x	E										6
Fa 10		x										3
Sp 11	x	x RE										6
Fa 11		x										3
Sp 12		x	E									6
Fa 12	x		x									6
Sp 13		x	x RE									6
Fa 13			x									3
Sp 14	x		x	E								9
Fa 14		x		x								6
Sp 15			x	x RE								6
Fa 15	x			x								6
Sp 16		x		x	E							6
Fa 16			x		E							6
Sp 17	x			x	x							9
Fa 17		x			x							6
Sp 18			x		x	E						9
Fa 18	x			x		x						9
Sp 19		x			x	x RE						9
Fa 19			x			x						6
Sp 20	x			x		x	E					12
Fa 20		x			x		x					9
W/S 2021			x			x	x RE					9
W/S 2022	x			x			x					9
W/S 2023		x			x		x	E				12
W/S 2024			x			x		x				9
W/S 2025	x			x			x	x RE				12
W/S 2026		x			x			x				9
W/S 2027			x			x		x	E			12
W/S 2028	x			x			x		x			12
W/S 2029		x			x			x	x RE			12
W/S 2030			x			x			x			9
W/S 2031	x			x			x		x	E		15
W/S 2032		x			x			x		x		9
W/S 2033			x			x			x	x RE		12
W/S 2034	x			x			x			x		12
W/S 2035		x			x			x		x	E	12
W/S 2036			x			x			x		x	9

**Figure 5.2.** Typical establishment and sampling (short-term and long-term) schedule for accretion stations. The shaded area is past establishment and sampling. The schedule changed from twice per year sampling to once per year sampling in 2021.

## 5. Vertical Accretion

Vertical Accretion Measurement Data Sheet										
Site: _____ Establishment Date: _____ Time: _____								Plot Set		
Organization: _____ Sample Date: _____ Time: _____										
Measured by: _____ Other Personnel: _____										
Station: _____					Core Conditions					
Core Coords (X;Y)	Accretion Measurements (mm)				Feldspar Quality (Solid/Broken/None)	Notes (incl. prominent layers and features)				
	1	2	3	4						
Add'l Notes: Water level: _____ cm; if not flooded: (wet / dry)						Vegetation: healthy / senesced / stressed / dead				
Roots: Abundance (none / high / med / low)						Dominant spp.				
Soil type: organic / mineral (sandy / silty / clayey)						Consistency: veryfirm / firm / soft / verysoft / unconsolidated				
Thatch thickness (if any): _____ cm; Measured to: top of / beneath						Other: _____				
Disturbance (if any):										
<input type="checkbox"/> Human _____ <input type="checkbox"/> Burned _____										
<input type="checkbox"/> Grazed _____ <input type="checkbox"/> Animal tracks/nest _____										
Station: _____						Core Conditions				
Core Coords (X;Y)	Accretion Measurements (mm)				Feldspar Quality (Solid/Broken/None)	Notes (incl. prominent layers and features)				
	1	2	3	4						
Add'l Notes: Water level: _____ cm; if not flooded: (wet / dry)						Vegetation: healthy / senesced / stressed / dead				
Roots: Abundance (none / high / med / low)						Dominant spp.				
Soil type: organic / mineral (sandy / silty / clayey)						Consistency: veryfirm / firm / soft / verysoft / unconsolidated				
Thatch thickness (if any): _____ cm; Measured to: top of / beneath						Other: _____				
Disturbance (if any):										
<input type="checkbox"/> Human _____ <input type="checkbox"/> Burned _____										
<input type="checkbox"/> Grazed _____ <input type="checkbox"/> Animal tracks/nest _____										
Station: _____						Core Conditions				
Core Coords (X;Y)	Accretion Measurements (mm)				Feldspar Quality (Solid/Broken/None)	Notes (incl. prominent layers and features)				
	1	2	3	4						
Add'l Notes: Water level: _____ cm; if not flooded: (wet / dry)						Vegetation: healthy / senesced / stressed / dead				
Roots: Abundance (none / high / med / low)						Dominant spp.				
Soil type: organic / mineral (sandy / silty / clayey)						Consistency: veryfirm / firm / soft / verysoft / unconsolidated				
Thatch thickness (if any): _____ cm; Measured to: top of / beneath						Other: _____				
Disturbance (if any):										
<input type="checkbox"/> Human _____ <input type="checkbox"/> Burned _____										
<input type="checkbox"/> Grazed _____ <input type="checkbox"/> Animal tracks/nest _____										

**Figure 5.3.** Example of a vertical accretion (VA) field data sheet.

## 5.2 Vertical Accretion Data Collection

Feldspar horizon marker sampling occurs once per year, (January - March) concurrent with RSET. The preferred method of sampling is a cryogenic technique (Cahoon et al. 1996) that utilizes a 15–20 liter, self-pressurized, liquid-nitrogen dewar attached to a copper tube fitted with a tapered end (usually a .30 caliber/.308" diameter bullet) for easy insertion into the marsh (Figures 5.4a and b). The bullet is inserted into the marsh to a depth deeper than the feldspar, and liquid nitrogen is injected into the tube to freeze the wetland soil to the bullet. Once frozen, a soil sample is extracted from the marsh and up to four evenly spaced measurements are made from the feldspar layer to the surface (Figure 5.5). Note: For high water level/highly inundated sites (e.g., swamps), sampling trips should be timed to ensure that water levels are the lowest (i.e., the end of cold fronts).

Data are collected from a set of stations beginning with a short-term period of four years, with sampling every year (Figure 5.2). If a set of stations is abandoned and a new set re-established during the short-term period (see 5.2 Station Establishment), then retain the short-term schedule of the original set but be sure to update the "Establishment Date" of the new set in the database. After the short-term period, transition the PS into the long-term period of sampling every 3 years with an interim 2-year sample (Figure 5.2). At any one time, there will be one set of short-term stations and multiple sets of long-term stations to be sampled as new stations are established (Figure 5.2).

### Plot Set Abandonment:

- Abandon a PS when all stations are deemed nonviable for two consecutive trips. Nonviable cores are defined as cores where no more than one measurement can be taken (i.e. no feldspar or only a speck of feldspar can be found). Up to three coring attempts are to be made from a station during a sampling trip. If all three attempts yield nonviable cores, then the station is nonviable. All stations within a plot set shall be sampled until all stations are nonviable. Individual stations shall not be abandoned without CPRA review and agreement.
- Continue sampling from individual stations until all 25 coordinates have been sampled; discontinue sampling from an individual station within a PS when all 25 coordinates have been sampled. Contact CPRA when all 25 coordinates per station have been sampled at all stations within a PS.

Defining the exact soil surface can be subjective, especially in organic soils and/or areas with a lot of plant litter or fallen thatch. It is critically important that a common surface be defined for both the RSET and VA. The person measuring VA should coordinate with the person measuring the RSET to define the surface in order to maintain consistency between the two measurements that are later combined to describe elevation change processes. For example, a thin or thick layer of new organic deposition (thatch/litter) that has not been integrated into the soil often covers the surface. The person reading the



RSET may be inclined to place pins beneath the thatch/litter. The person measuring VA should make sure they can differentiate the thatch/litter in the frozen core. When the marsh is flooded, it can be difficult to differentiate thatch/litter in a frozen core. If that is the case, the person reading the RSET should place pins on top of the thatch/litter layer. Also, when possible, the same combination of people should always measure a specific site to maintain consistency and familiarity over time.

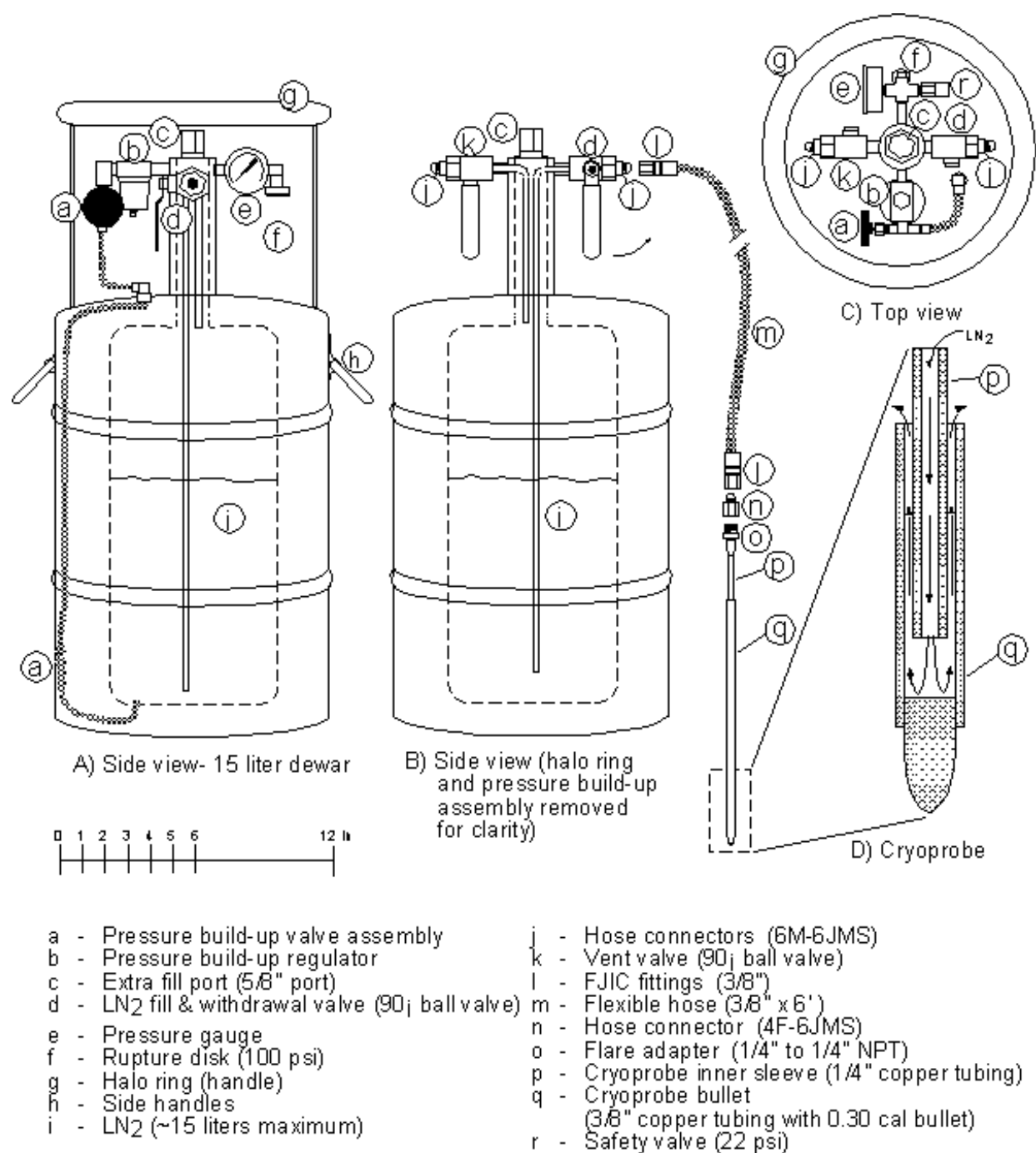
Data are collected and recorded on a data sheet developed by the CPRA (Figure 5.3). In addition to the accretion measurements, describe the core conditions (quality of feldspar layer and unique notes about the core including prominent layers and features) for each core collected. Other notes to be collected about the station (if applicable) include: flooding or soil saturation if not flooded, soil composition and consistency, vegetation health, dominant species, root abundance, disturbance to the station, thatch thickness, whether accretion was measured above or below thatch layer, and any other observations.

Make reasonable and safe attempts to measure VA and the RSET on the same day. Maintain your equipment in good condition and bring replacement equipment and tools in case of equipment failure or loss. Prevent running out of liquid nitrogen by bringing two full dewars. If completion of a task (RSET or VA) is not possible, then collect data from both tasks on the return trip even if repeating one of the tasks and check that the correct dates are entered into the spreadsheets.

The following materials list contains the minimum equipment necessary to collect quality data and the procedures that shall be followed for the cryogenic technique for sampling (see also [http:// www.pwrc.usgs.gov/set/](http://www.pwrc.usgs.gov/set/)).

### *Minimum Materials:*

1. Personal protective equipment (gloves and eye protection)
2. Self-pressurized, liquid-nitrogen dewar and assembly (Figure 5.4 a and b)
3. Stainless steel flexible hose, fittings, and appropriate wrenches
4. Copper bullets (12" and 18")
5. 50-cm × 50-cm square (also used during station establishment)
6. List of randomly selected and previously sampled coordinates
7. Data sheets (Figure 5.3)
8. Knife for scraping cryo-core and potentially cutting core out of roots
9. Calipers: High quality stainless steel that measure up to 150 millimeters (mm) in increments no greater than 0.02 mm
10. Digital camera
11. Metric ruler (meter stick)



**Figure 5.4a.** Schematic for the cryogenic coring device developed by Cahoon et al. 1996. A) A side view of a 15-L low pressure nitrogen tank (dewar); B) The side view rotated 90° with a halo ring removed for clarity; C) A top view; D) An enlarged view of the cryoprobe used to collect the sample.



**Figure 5.4b.** Photograph of cryogenic coring equipment including the liquid nitrogen cylinder (cryo-cyl), flexible hose, and copper bullet (cryo-probe).





**Figure 5.5.** Photographs depict accretion being measured above feldspar on a cryogenic core (top) and detail of a white feldspar ring on a frozen core (bottom).

*Procedures:*Sample Collection:

Before the sampling season begins, plan to collect the VA cores in a controlled manner in order to not sample a previously cored location. Each station (0.5 m × 0.5 m) is intended to be visually subdivided into an evenly spaced, X;Y-coordinate grid with each coordinate being a sample location (25 locations: 1;1 to 5;5). To aide in creating a visual grid, mark the square to create five equal sections on each side. Make a list of all 25 randomly selected coordinates for each station, being careful to exclude or note previously sampled coordinates. Use this list to dictate which coordinate to sample on the next sampling trip, and update the list to exclude newly sampled coordinates.

Prior to the sampling field trip, review notes and data sheets from the previous sampling trip to be prepared for local conditions and to establish new stations if needed. Normally, two lengths of sleeves and bullets are made (12" and 18"); however, a longer sleeve and bullet will be required based on the amount of sediment that has accumulated on top of the feldspar and the depth of water on the soil surface. Do not collect VA or RSET data if the surface layer of soil cannot be identified because (1) it is separated from the substrate if you are not in a known floating marsh or (2) there is a slurry of mud between the soil surface and water surface. Return to the site to measure when water levels are low enough for the surface to be identified. Decisions to change the timing or to discontinue sampling of a CRMS site will be made in consultation with CPRA on a case-by-case basis.

Upon arrival to the site, follow these steps for sample collection at each site:

1. Complete the top portion of the data sheet: *Site, Group (PS#), Establishment Date and Time, Sample Date and Time, Organization, Measured by, and Other Personnel.*
2. List the appropriate station being sampled.
3. If feldspar is observable on the surface of more than half of the station, then do not collect a core. Record the *Core Coords* as blank, all four *Accretion Measurements* as 0 mm, *Feldspar Quality* as "No Core. Feldspar visible of surface", and any other *Add'l Notes* observations on the data sheet.
4. Connect the appropriate hose and fittings to the dewar and insert the inner core sleeve completely into the bullet to protect the sleeve and prevent any disturbance once the bullet penetrates the marsh surface.
5. Don the personal protective equipment to prevent any injuries. Gloves and eye glasses are required when handling extremely cold items (bullet and hose from liquid nitrogen) and knives. **CAUTION:** The liquid nitrogen and frozen metal equipment can cause serious burn injuries when in contact with bare skin. Tip: Wrap the liquid nitrogen hose with foam insulation to prevent contact with skin.

6. Place the 0.5 m x 0.5 m square over the stakes that mark the station location, taking care to not damage the vegetation.
7. From the list of coordinates, find the core location within the station using the evenly marked sections on the square (position 1;1 is the bottom, left corner of the square as you face the station from the boardwalk). On the data sheet, record the station number and core coordinate. If the position is obstructed, record this on the data sheet and try the next coordinate on the list. Note: Make sure these coordinates have not been cored previously.
8. Push the bullet with the inner core straight into the soil as close to the middle of the section as possible (avoid standing vegetation or other obstructions). The bullet should be deep enough to freeze the feldspar and sediment to the bullet; this depth varies but can be estimated by reviewing previous feldspar depths. Do not rock or move the bullet once it penetrates the surface. The soil surface must remain in contact with the bullet for this process to be effective. Note: This is difficult to achieve when leaning over the station. If the surface of the marsh is not frozen to the bullet, then the surface will appear to “dip” where the underlying soil was frozen to the bullet. Avoid measuring this portion of the core.
9. Open the valve on the dewar and start the flow of the liquid nitrogen into the bullet.
10. Allow the marsh to freeze around the bullet. Normally the core is frozen when steam streams from the top of the bullet. Note: It may be best to let the liquid nitrogen run a bit longer until the person using it has experience with this procedure.
11. Turn the dewar off when the core is frozen.
12. Remove the inner sleeve from the bullet and place it into another bullet or some other protective sheath. Be very careful with the hose, as it becomes very brittle once it is frozen and may break if kinked.
13. With gloved hands, grab the top of the bullet and pull the core straight up and out of the marsh, being cautious to not disturb adjacent marsh. Note: Roots around the core may need to be cut before extruding the core from the soil.

*Alternative method:* If equipment failure prevents frozen core collection or the soil is too dry, then, under the right conditions (non-flooded, firm/consolidated soil), a soil plug can be cut out with a knife. Cut a large enough area within the position to allow for prying out the plug. After removing the plug, proceed as normal with data collection, note that the soil plug technique was used, and return the soil plug to its hole.

### Data Collection:

After collection of the frozen core (also known as “cryo-core” or “marshsicle”), follow these steps for data collection, being sure to record all data on the data sheet (Figure 5.5). Note: Multiple data sheets may be needed depending on the number of PSs being sampled. Note: See 5.1 Procedure #9 for station Establishment data collection.

1. Find the feldspar layer. It may be necessary to carefully scrape the core starting from the bottom and working towards the soil surface to avoid disturbing the soil above the feldspar layer. Do not scrape the core over the VA or RSET stations because the soil addition may affect future measurements.
2. Document the quality of the feldspar layer (ability to measure from the feldspar layer to the surface) in the *Feldspar Quality* column based on completeness of the visible ring (solid, broken, or no feldspar).

Note: If a minimum of two different measurements can be made, then continue to step 4. If insufficient feldspar (only one measurement location or no feldspar) is found to reliably estimate accretion, then attempt another core from the list of remaining coordinates.

Note: A minimum of three attempts (cores) to find acceptable feldspar per station is required; after three unsuccessful attempts the station is deemed nonviable for this sampling trip.

3. Space the measurements around the core as evenly as possible (four measurements at 90° spacing are optimal). Measure the distance (mm) from the top of the feldspar layer to the soil surface using the calipers, and record data in numbered columns under *Accretion Measurements (mm)*. Notes: (1) Record a zero if the feldspar layer is visible on the soil surface; draw a line through the data cell if a measurement is not taken. Zeroes mean no measurable sediment is on the feldspar. (2) Refreeze the core if it begins to thaw before data collection is complete.
4. Record any other unique notes about the core (e.g., odor, color, prominent layers including storm deposits and their thickness) under the *Notes* column.
5. Record other information about the core and station conditions (flooding, roots, soil, vegetation, disturbance, thatch thickness) as prompted by the data sheet or otherwise observed by the field personnel. Notes: (1) If stations are losing feldspar, then suggest why in the “Other” section. (2) Take pictures of unique observations.
  - a. If it appears that all of the surface water was frozen onto the bullet when extracting the core, flooding can be measured from the core. Otherwise measure flooding with a ruler from the surface of the station.
  - b. If there are no pertinent root health or abundance notes, those fields on the data sheet can be left blank.
  - c. Thatch refers to dead stems that are on top of the soil surface. The RSET and accretion should both be measured to the same surface relative to thatch. Measurements to beneath the thatch are preferred if possible. Collection of other notes beyond the prompted notes is encouraged.
6. When possible, return the frozen core back to its hole. If this process is done properly, a hole will not be left in the soil where the sample was taken. Note: Do not place the core on the soil surface in the vicinity of the VA or RSET stations.

7. The station has been sampled when one of the following conditions is met: a core is extracted and a minimum of two measurements are collected, or a minimum of three sampling attempts have been made.
8. Data shall still be recorded if the station (or site) is not measured during the sampling season. Enter the last attempted date or final date of sampling season as the *Sample Date and Time*, leave *Core Coords* and *Accretion Measurements* blank, place "No Core" in *Feldspar Quality*, describe reason for not sampling in the *Core Condition-Notes*, and record any other observations in *Add'l Notes* and expanded explanation for not sampling in *Other* if needed.
9. Before leaving each site, field data sheets are to be examined for clarity and completion. Any information that was not completed on the boardwalk should be completed prior to leaving the site.

### CONVERSION OF STATIONS TO OPEN WATER:

The intent of the CRMS monitoring program is to maintain the original monitoring stations for as long as possible. Accretion stations will not be moved to new locations if the original location erodes away. The rules for station establishment and re-establishment provide a condition for when to abandon the feldspar method at a site. If stations wash away rapidly, CPRA may provide guidance to abandon the method sooner.

### HURRICANE DAMAGED STATIONS:

At Vertical Accretion stations at scoured sites where stations are still identifiable and the boardwalk has been reconstructed, determine if finding feldspar is still a viable option. Vertical accretion measurements may not be an option if the marsh was scoured to beneath the feldspar. Cryo-coring in these conditions is very time consuming and requires a lot of liquid nitrogen. The RSET measurement and water depth can be used to estimate whether feldspar is present.

1. The RSET elevation change from the last measurement gives an estimate of how deep the marsh was scoured.
2. Use water depth difference from RSET to near accretion station to adjust the scour depth. NOTE: This should first be done at the oldest PS; if scour is deeper than feldspar, then assume the same for the other stations unless some elevation differences among stations is obvious.
3. Check VA measurement of feldspar depth from the latest measurement at the station.
4. If the scour depth is 1/3 greater than the previous feldspar depth (that would be 4 inches on 1 foot), then a core doesn't need to be attempted:

$$\text{Scour Depth} > \text{Previous Feldspar Depth} * 1.33$$

NOTE: A proportional approach rather than a set distance accounts for accretion rate at the station.

If vertical accretion is continued in open water, then consider insulating the part of the bullet that will be in the water column.



If the vertical accretion stations and poles are buried by storm deposited marsh balls, mats, or wrack:

1. Find outside edge and start/end points of boardwalks for orientation.
2. Estimate station location along boardwalk from Overall station pictures collected in Spring 2020 during PS7 deployment.
3. Look for station poles along the edge of the boardwalk and reference the Overall picture for pole orientation. As per the SOP, the pole adjacent to the board walk should be the bottom left corner near 1;1, but that is not always the case.
4. If pole is found, then use sampling quad to estimate the opposite pole location.
5. Replace poles with longer poles. Marking the poles by PSes is helpful for verifying stations.

### 5.3 Vertical Accretion Data Processing

The CPRA has a two-phase protocol for data processing: data entry (Phase I) and data quality assurance/quality control (Phase II). Separate individuals conduct these two phases to assure that the final product is correct.

**DATA ENTRY (PHASE I):** Phase I is conducted by the individual responsible for the field data collection and requires following three main tasks: 1. field data sheet review, 2. data transcription, and 3. data verification. Below are the procedures for each task:

1. Field Data Sheet Review
  - a. Review the field/digital data sheet for legibility, completeness, and accuracy.
  - b. Make corrections using a different color pen without erasing original data. If an error needs to be corrected, then strike a single line through the error and write the changes close to the error. Note: The original data should still be legible after corrections are made.
  - c. Initials and date changes.
2. Data Transcription
  - a. CPRA will provide a data upload tool that allows the user to enter data into a Microsoft Excel spreadsheet that looks like the field data sheet. The Excel file transfers the data from the digital data sheet into a spreadsheet that is formatted for upload to the CIMS database (Figure 5.6).
  - b. Enter recently collected data into the “Data Sheet” worksheet which is formatted to look like the field data sheet.
    - i. The prompted drop-down boxes in the *Core Conditions* and *Add'l Notes* section are the minimum station notes required.

- c. Data entered into “Data Sheet” worksheet will automatically populate the “CIMS” worksheet for upload to the CIMS Data Entry Remote Load.
- d. Save a copy of the Acc data tool using the following naming convention: “*Station\_Acc\_data\_tool\_seasonYEAR\_PS#.xlsx*”, e.g., “CRMS0398\_Acc\_data\_tool\_Spring2017\_PS5.xlsx”.

3. Data Verification

- a. Double-check “Data Sheet” for accurate transcription.
- b. Check that the data was automatically populated to “CIMS” correctly and in a clear fashion. Especially check that the “Notes” section merged clearly and that the “Measured by” name on the data sheet is the first person listed under “Personnel.”
- c. Upon completion of Data Entry (Phase I), the field data sheet along with the electronic file shall be provided to the QA/QC officer.

**QUALITY ASSURANCE/QUALITY CONTROL (PHASE II):** Phase II begins when the QA/QC officer is provided with the field data sheet and is notified that the Excel file has been completed. The QA/QC officer should follow the steps below to ensure the data has been processed properly.

The QA/QC officer should complete the following procedures:

1. Examine the field data sheet for completeness and errors.
2. Check the data from the “Data Sheet” worksheet against the field data sheet to ensure it was correctly entered into the Excel file.
3. Check that the data was automatically populated to “CIMS” correctly and in a clear fashion.
4. If mistakes are found, return the field data sheet and Excel file to the data collector so any mistakes can be corrected or explained.
5. Check that Core Coordinates have not previously been used. If a Core Coordinate had already been used, then delete the *Core Coords*, place “Invalid Core” in *Feldspar Quality*, place an explanation in the *Core Condition Notes* (e.g. Core Coordinate previously used), and move the measurements to the *Core Condition Notes*.
6. Continue this process until no mistakes are found.
7. Scan a copy of the corrected data sheet into a .pdf file for upload to the CPRA FTP site.

Once Phases I and II have been completed, upload the final version of the “Acc\_data\_tool.xlsx” file using the naming convention: “*Station\_Acc\_seasonYEAR\_PS#.xlsx*”, e.g., “CRMS0398\_Acc\_Spring2012\_PS1.xlsx” for data upload to CIMS Data Entry Remote Load where data from the CIMS worksheet is loaded into QA/QC buffer for CPRA review. CIMS currently accepts Excel files (.xls,

.xlsx, or .xlsm) zipped into a ZIP format. CIMS searches for the “CIMS” worksheet with in the Excel file for data download. Check the CIMS Data Entry for updated information.

## 5.4 Vertical Accretion Deliverables

Electronic files containing the data shall be in the appropriate deliverable format and delivered to CRMS Data Depot once the data has completed the QA/QC process.

Deliverables should include the following:

Accretion original/digital field data sheet (*Station\_Acc\_seasonYEAR\_PS#.pdf*)

Accretion data tool (*Station\_Acc\_data\_tool\_seasonYEAR\_PS#.xlsx*)

Photographs when PS is established (*Station\_Acc\_seasonYEAR\_PS description.jpg*)

Station ID	Group	Sample Date (mm/dd/yy)	Sample Time (hh:mm)	Establishment Date (mm/dd/yy)	Establishment Time (hh:mm)	Time Zone
CRMS####-A###	PS#	###/###/####	##:##	###/###/####	##:##	CST
CRMS####-A###	PS#	###/###/####	##:##	###/###/####	##:##	CST
CRMS####-A###	PS#	###/###/####	##:##	###/###/####	##:##	CST
CRMS####-A###	PS#	###/###/####	##:##	###/###/####	##:##	CST
CRMS####-A###	PS#	###/###/####	##:##	###/###/####	##:##	CST

(continued...)

Core X:Y	Accretion Measurement 1 (mm)	Accretion Measurement 2 (mm)	Accretion Measurement 3 (mm)	Accretion Measurement 4 (mm)	Core Conditions
##	0	0	0	0	Feldspar Established (n=4)
##	##	##	##	##	Excellent (Solid Feldspar; n=4); silt layer over feldspar
##	###	###	###		Fair (Broken Feldspar; n=3)
##					No Feldspar
##					No Core; plot disturbed by airboat

(continued...)

Organization	Personnel	Notes
Contractor/Agency Name	F. Measurer; I. Recorder	Coordinates: 444332 3299475; Site is flooded...
Contractor/Agency Name	F. Measurer; I. Recorder	Site is flooded 3 cm; Vegetation is dead; Dominant spp. are Schoenoplectus americanus; Root Abundance is medium. ; Firm organic soil; No Thatch; No Disturbance;
Contractor/Agency Name	F. Measurer; I. Recorder	Site is not flooded (dry); Vegetation is healthy;...
Contractor/Agency Name	F. Measurer; I. Recorder	Site is flooded 3 cm; Vegetation is stressed; ....
Contractor/Agency Name	F. Measurer; I. Recorder	Site is flooded 30 cm; Vegetation is dead; ....

**Figure 5.6.** Accretion data format in .xlsx file and CIMS

## 6. Maintenance

Once a site has been constructed and construction has been approved, the site must be maintained for safety and for accurate data collection. Proper procedures shall be followed as outlined below:

1. The field crew shall document all items that need to be repaired or replaced in the field, including photos of the damage.
2. The contractor shall identify the damaged sites in the weekly activity report submitted by email to the CPRA contract manager and the CPRA field office supervisor.
3. A follow up email submitted to the CPRA contract manager and the field office supervisor shall identify:
  - a. Station/site to be repaired
  - b. Description of damage
  - c. Description of work needed
  - d. Materials list for repairs
4. The CPRA regional supervisor will review the proposed work and send an email to the contractor's O&M manager, the contractor's field manager, and the CPRA contract manager approving the work.
5. The work will be conducted within two months of identification of the damage to the site. Photos will be taken to document the work and will be submitted to the CPRA regional office supervisor and the contract manager as verification of the work in order to receive payment.

## 7. Vegetation

The objective of CRMS vegetation sampling is to spatially and temporally describe the vegetative community of Louisiana's coast. Vegetation sampling is conducted annually at each herbaceous station in the marsh and swamp, and every three years for forest stations in the swamp. Canopy cover is measured annually at each forest station.

### 7.1 Emergent Vegetation Sampling

#### 7.1.1 Herbaceous Vegetation Methods

There are 10 herbaceous vegetation monitoring stations at each CRMS marsh site (Figure 2.1) and 9 herbaceous vegetation monitoring stations at each CRMS swamp site. The delineation of swamp herbaceous stations is described in section 7.2.1. Vegetation transects are oriented diagonally across the 200 m square data collection area, either NW to SE or NE to SW. Transects are established away from spoil banks or any type of human-induced surface alterations whenever possible to avoid biased data. CPRA will provide a randomized vegetation station list with coordinates of all established and potential vegetation sampling stations. At each CRMS marsh site, there are 85 potential vegetation stations, one every 3 m on a 283 m transect and excluding those within 10 m of the boardwalk or near the edge of the 200 m square. These stations have been named according to their spatial order, where CRMS0000-V01 is farthest north and -V85 is farthest south. When naming these stations, the initial, spatially-related order number is always used, not the random order number. The ten stations initially established are maintained throughout the life of the CRMS program, unless specifically moved via CPRA's instructions.

#### STATION ESTABLISHMENT:

##### *Minimum Materials:*

This list of equipment and supplies is needed to establish and to sample vegetation stations in herbaceous wetlands. Other equipment and/or supplies may be necessary depending on the site.

1. PVC pipes: ½" diameter or larger 10-ft long pipes used as station locators
2. 2 m x 2 m PVC square
3. 4-m telescopic leveling rod and meter stick
4. Compass: 0° to 360° azimuth dial with 2° gradations
5. Sub meter GPS (Trimble GeoXT or equivalent)
6. Materials for creating a sign to be included in the site photos (ex. dry erase board and markers)
7. Vegetation and porewater data sheets
8. Copy of the previous year's vegetation data sheet

9. Plant reference books
10. Zip lock bags for unknown plants
11. Ice chest for plant samples
12. Digital camera capable of capturing 8 MP or better photographs for recording station number and vegetation in plot
13. Porewater sipper, syringe, and centrifuge tubes
14. YSI 30 or equivalent to measure soil porewater
15. Conductivity standard
16. Permanent markers

Field personnel should reference the randomized vegetation station list to determine the location of the first vegetation plot. The first station located is the initial order number associated with random order number “1.” The field crew should stay on the east side of the transect when it runs from NE to SW. Crews can access transects that run from NW to SE from either side but should provide a buffer between the access route and the station. A 10 m or greater buffer should be maintained between the boat and the vegetation station if possible. Once the station is located, a PVC pole should be installed at the station coordinate, marking the southeast corner of the vegetation plot. The 2 m x 2 m PVC quadrat should then be placed around the plot so that the pole is the southeast corner of the quadrat and one side is facing due north and the other due west. During the initial station setup, if a plot is  $\geq 55\%$  land, the plot is selected and sampled. If the plot is  $< 55\%$  land, the plot is not used and the field crew should replace it with the next random order station number.

**DATA COLLECTION:** Annual vegetation sampling shall occur between June 1 and August 31. Less variable emergent vegetation marsh types (brackish and saline) should be prioritized and occur during the early part of the sampling period beginning June 1. Fresh and intermediate habitat types will be sampled during the peak growing season and will begin July 1. Extensions to this monitoring period may be permitted if necessary and first approved by the CPRA.

Data sheets will be utilized for recording herbaceous wetland community and porewater data at each vegetation station. At least two field personnel must estimate cover percentages and assess species composition at each station.

Note: The method for collecting herbaceous vegetation data is slightly different in swamps than in marshes. In swamps, the tree layer is quantified separately in larger 20 m x 20 m plots every three years. The herbaceous plots do not include overstory species data collection.

Note: The list of species used in the CPRA vegetation database comes from the USDA PLANTS list for Louisiana (USDA, NRCS 2020). If new species are identified during vegetation data collection, the data collector must follow the procedures required to update the PLANTS database as described on the USDA website (<http://plants.usda.gov/du/DistributionUpdate.html>)

## Data Collection Procedure:

1. Using the “Herbaceous Marsh Vegetation Sampling Data Sheet” or the “Herbaceous Swamp Vegetation Sampling Data Sheet” (Figures 7.1 and 7.2), completely fill out all the station information (sample type, vegetation type, project, station, group, personnel, plot size, date, station coordinates, organization, and plant community type) before beginning the collection of data at the station.
2. Place the 2 m x 2 m PVC quadrat such that the pole is the southeast corner of the quadrat (Figure 7.3). One side will be facing due north with the other facing due west. When collecting data using this method, project four geometrical vertical planes (square) from the soil surface to the sky and document the percent cover for any species within the 2 m x 2 m square. This cover includes plants rooted outside but hanging over the quadrat. For shrub and tree species that are not rooted in the plot, only overhang, add a note in the species description column that says “overhang only.”
3. Take a high quality photo of the plot from the SE corner. The photo should be at least 8 megapixels to allow for zooming in on specific plants for identification verification. The picture should contain the sign with the site name, station number, and date. It should also contain the 2 m x 2 m quadrat and pole in the SE corner. The objective is to obtain a full-plot photo. Do not block the view of the vegetation with the sign, a person, or other obstruction. If a plot feature needs to be documented that is not obvious in the photograph, take an additional photograph of that feature and note the feature in the comments.
4. Estimate to the nearest whole number the total % cover of live vegetation in the plot. Total percent cover in marshes includes tree, herbaceous, shrub, and carpet layers. In swamps, the tree layer is excluded from total cover. Total % cover must be between 0 and 100% and must meet the following parameters:
  - a. Cannot be > 100%.
  - b. Cannot be > the sum of the % covers of the individual species.
  - c. Cannot be < the % cover of any one plant species present.
  - d. When only one species is present, the % cover of that species should = the total % cover.
  - e. Vegetation rooted outside of, but hanging over the plot is included in the estimate of total % cover.

## 7. Vegetation

[illegible]

**Figure 7.1.** Herbaceous marsh vegetation sampling data sheet.

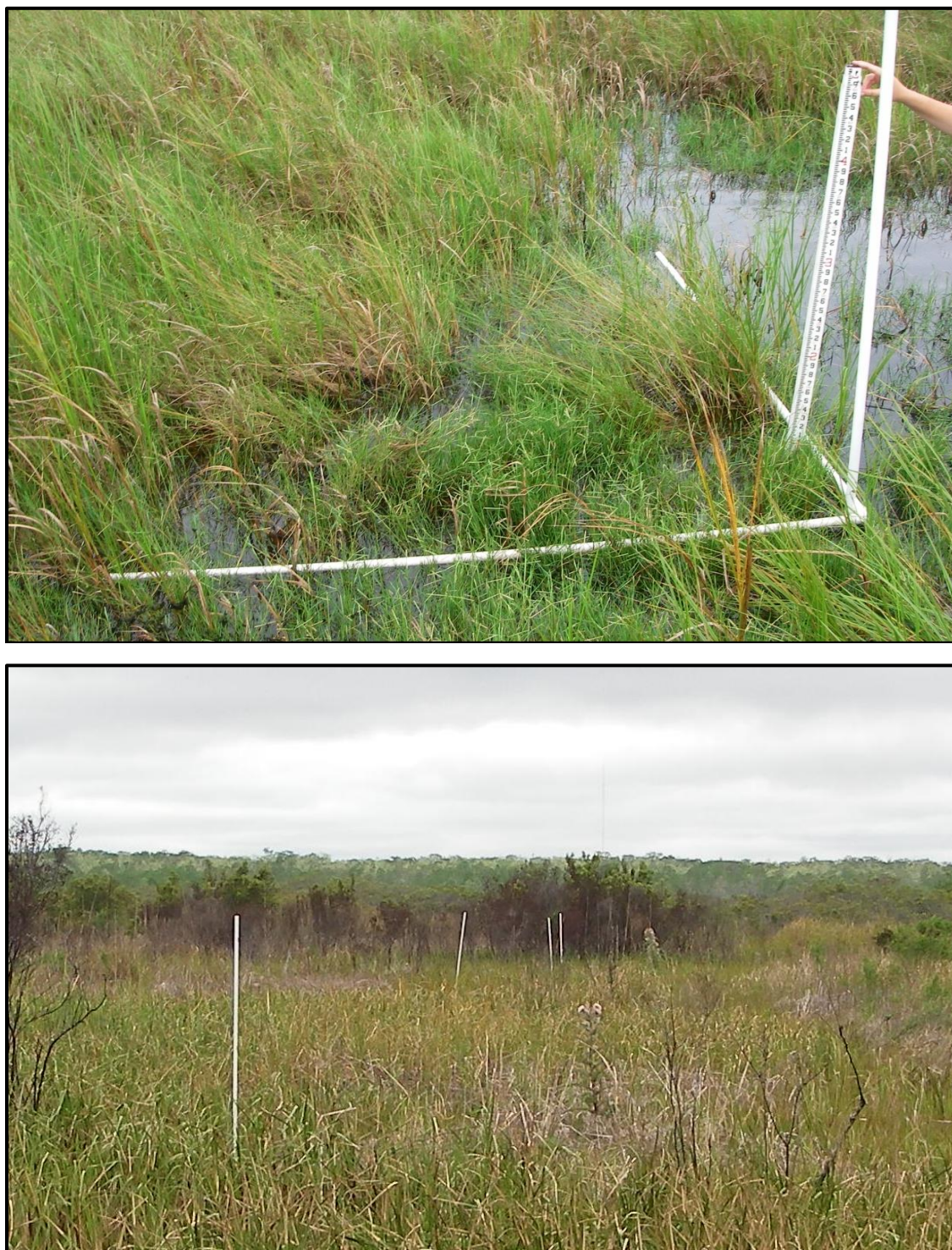


## 7. Vegetation

[illegible]

\*Total cover at herbaceous swamp stations does not include trees > 5 cm dbh.

**Figure 7.2.** Herbaceous swamp vegetation sampling data sheet.



**Figure 7.3.** Photographs of a herbaceous marsh vegetation station depicting the 2 m x 2 m station and a leveling rod for measuring height of vegetation and water level above marsh (top) and vegetation stations along a transect (bottom) as seen from the marsh.

5. Use the “Unvegetated Surface” portion of the data sheet (Figures 7.1 and 7.2) to describe in detail the plot area not covered by the vegetative layers. Enter these data (description and % cover) in the Comments field on the data entry screen (ex. bare ground: 20%). The following descriptors should be used to define the unvegetated area.
  - a. **Open water:** an area with insufficient elevation to support emergent vegetation. For example, a station that is located completely or partially in deep open water, like on the edge of an expanding waterway, bay, marsh channel, marsh pond, or lake. The substrate could be eroded and/or subsided and likely would not re-vegetate without intervention.
  - b. **Bare ground:** an area devoid of emergent vegetation but may be of sufficient elevation to support emergent vegetation. Indicators of bare ground include rooted vegetation at a similar elevation near the plot and burned or grazed surfaces. If the surface cannot be seen (water too turbid) and it is impossible to tell the nature of the surface, “Flooded/Undetermined” may be a more appropriate designation.
  - c. **Dead vegetation:** an area devoid of live vegetation. The wetland surface is covered with standing, rooted dead vegetation. Dormant or senescent vegetation is not considered dead.
  - d. **Flooded/Undetermined:** used when it is not possible to determine whether the station is bare ground or open water as described above.
6. At swamp herbaceous stations, record as Tree Trunk Cover the percentage of the plot that is covered in living tree trunks and cypress knees (Figure 7.2). Dead tree trunks are considered Dead Vegetation. Please indicate in the Notes if cypress knees are contributing to Tree Trunk Cover.
7. Estimate to the nearest whole number the % cover of live vegetation in the herbaceous marsh plot for individual layers (tree, herbaceous, shrub, carpet), using these guidelines:
  - a. Percent cover of each layer must be between 0 and 100% (not > 100%).
  - b. Cannot be < the % cover of any one plant species present within that layer.
  - c. If only one layer is present, then % total cover should = % cover of the layer.
  - d. Sum of layer % covers (tree, shrub, herbaceous, carpet) are frequently > 100% because of species overlap.
  - e. Vegetation rooted outside of, but hanging over the plot is included in the estimate of % cover for each layer estimated.
  - f. For herbaceous swamp vegetation stations, data for the tree layer is recorded only under Ancillary Data as % Canopy Cover and % Tree Trunk cover (Figure 7.2)

Note: The sum of the Total % Cover, the Unvegetated Surface % covers and the Tree Trunk % Cover should equal 100%. If the sum of covers is greater than 100%, provide an explanation for the overlapping covers in the Notes.

8. A combination of professional judgment and the following *general* guidelines will be used to delineate tree, shrub, herbaceous, and carpet layers:
  - a. Tree: DBH (diameter at breast height)  $\geq 5$  cm; however, if a tree species is close to 5 cm DBH and is  $> 4$  m tall, then best professional judgment would likely classify the species as a tree. Diameter at breast height is measured at 137 cm (4.5 ft) above ground.
  - b. Shrub: plant is woody,  $< 5$  cm DBH, and is between 0.5 m – 4 m tall. Certain exceptions apply—for example, *Sabal minor* is categorized in the shrub layer even if it is outside of the DBH range for this category.
  - c. Herbaceous: plant is woody,  $< 5$  cm DBH, and  $\geq 10$  cm but  $< 50$  cm tall.
  - d. Herbaceous emergent marsh vegetation: plant is  $\geq 10$  cm but  $< 50$  cm tall. Certain exceptions apply; for example, *Typha* spp. and *Phragmites australis* are categorized in the herbaceous layer even if their height is taller than the height category for herbaceous vegetation.
  - e. Carpet:  $< 10$  cm height.
  
9. Identify and record all species that fall **IN** the plot.
  - a. Project the boundaries of the 2 m x 2 m square plot up through all of the vegetative layers. All plants contained by and overhanging the plot boundaries are considered IN.
  - b. Submerged aquatic vegetation (SAV) and floating aquatic vegetation (FAV) are not recorded in the species list, but species are included in the Notes (7.1.1.12).
  - c. Species should not be identified to the variety level.
  - d. Trees:
    - i. A tree is defined as having a diameter at breast height (DBH)  $\geq 5$  cm.
    - ii. In herbaceous marsh plots, trees are included in the species list; the cover of each species is estimated along with the cover of the overall tree layer. Trees are included in total cover.
    - iii. In Herbaceous Swamp plots, trees are not included in the species list and the percent cover for the tree layer is not estimated. Data on specific trees are collected in the larger overstory data sets in the forests. The herbaceous plots are meant to quantify the forest floor. Trees occurring inside the plot and their tag numbers are recorded in the Notes.

## e. Unknowns:

- i. For species that cannot be identified in the field, collect a full plant (with roots/fruits/flowers/seeds, if possible) to send to the plant taxonomist. Place unknown species in a labeled zip lock bag.
  - ii. Prior to plant collection, take a photo of the unknown plant as it stands in the field and take a photo of the plant before it is bagged. Maintain photos until the plant identity has been resolved. If unknown data are delivered to the database, provide a photo of each unknown labeled by vegetation station (Ex: CRMS0000\_8-15-14\_Unknown\_1) in the deliverables.
  - iii. For all unknown species, notes about the plant characteristics are required in the Additional Species Description field.
  - iv. Mark on the outside of the bag the station name, the date collected, and the unknown ID (example: CRMS0660-V56, 09/09/2011, Unknown #1). Place an ID tag (piece of duct tape) inside the bag and record on it the station ID, date collected, and unknown ID. The same unknown species does not need to be recollected along the transect, as long as it can be positively identified as the same unknown species.
  - v. Comments received from the plant taxonomist regarding unknown species must be entered into the Additional Species Description field. It must be noted if a species cannot be identified or can only be identified to the genus level. If there is some uncertainty about the identification, a note should be made that "Dr. XYZ thinks it is "x" species with "y" degree of certainty."
10. Identify all species within 15 ft (4.5 m) of the plot (**OUT**). Only record species that are not already included in the list. For swamp herbaceous plots, tree species that are categorized in the tree layer and are OUT of the plot are not recorded. Younger trees (seedlings/saplings) that fall into the shrub, herbaceous or carpet layers are recorded in the list. For herbaceous marsh sites, OUT species should be designated as herb, shrub or tree within the Additional Species Description field.
  11. Assign IN/OUT/BOTH categories to all species in the list. If a species occurs both IN and OUT of a plot, it is recorded as BOTH. If a species is rooted OUT of the plot, but is hanging over the plot, it is also recorded as BOTH.
  12. Estimate to the nearest whole number the % cover of each live vegetation species IN the plot. Note that the database converts cover data to the Braun-Blanquet cover scale (Mueller-Dombois and Ellenburg 1974) (Table 7.1).
    - a. Estimates should be made with the plants "as is" (i.e., if the plants are lying over, that is how the % cover estimate needs to be evaluated).

- b. Include species both rooted and hanging in the plot.
- c. Do not estimate % cover for species outside (OUT) of the plot.
- d. Estimates should reflect the opinions of at least two people.
- e. The sum of the % covers for individual species are frequently > 100% since the cover of species can overlap within the plot.
- f. The total % cover cannot be > 100% and cannot be > the sum of the % covers of the individual species.

**Table 7.1.** Vegetative cover values associated with the Braun-Blanquet method.

Cover Range	Braun–Blanquet Rank Value
Solitary (1)	r
< 1% (2)	+
1–5%	1
6–25%	2
26–50%	3
51–75%	4
76–100%	5

13. SAV and FAV are not included in the species list; however, if present inside or outside of the plot, identify it to species and record in the Notes section. If SAV or FAV are located IN the plot, also record each species' % cover in the Notes. DO NOT include either in the total or layer % cover estimates.
14. Measure 5 stem heights for the dominant species present (i.e. the species with the greatest % cover in the plot); the dominant species can be from any layer, with the exception of the tree layer in the swamp. Record the unit of measurement, centimeters (cm) is encouraged. If less than 5 specimens are in a plot, then measure those individuals and note how many were measured. The plants should be elongated vertically for height measurement. Vine heights should not be measured. If a vine is dominant, measure the next dominant non-vine species as the dominant species and note it in the Additional Species Description. If there are 2 or 3 co-dominant species with equal % cover, record in the Additional Species Description which species was measured for stem height. Average the stem heights and record under Average Height: Dominant Height.
15. Measure the average height of each vegetation layer present (tree in a marsh, shrub, herbaceous, carpet). The plants should be left "as is" for this measurement (i.e., if the plants are laid over that is how they should be measured).
16. Collect one porewater sample at 10 cm and 30 cm depths at every vegetation station (10 in marsh / 9 in swamp), and one additional porewater sample within 10 m of the CRMS boardwalk at both 10 cm and 30 cm depths (identified as



station CRMS0000-P01). Refer to Section 3.2.2.2. Soil Porewater Data Collection for a complete description of collection methods. Porewater data should be entered on a *Discrete Hydrographic/Soil Porewater Data Sheet* (Figure 3.21). Only one sheet is necessary for each CRMS site. Each porewater sample should be named using the number for the vegetation station where the sample was collected (e.g., porewater collected at CRMS0135-V46 is named CRMS0135-V46). The samples collected at the boardwalk for the monthly servicing events do not change (CRMS0135-P01, P02, P03). If vegetation sampling coincides with monthly hydrologic servicing, collect three porewater samples for each depth at the boardwalk.

17. Measure water level relative to the wetland surface at each vegetation plot and record under Ancillary Data. Record the unit of measurement.
18. Record whether or not the marsh is floating.

#### **REESTABLISHMENT:**

1. If the PVC pole is missing, the station should be reestablished as close to the original GPS coordinates as possible and a new PVC pole should be installed.
2. If a significant, unnatural anthropomorphic change to the study site has occurred (e.g., digging or dumping of soil at the site), the station should be reestablished using the next available random order number.
3. If a formerly emergent marsh vegetates with sufficient, persistent >5 cm DBH woody vegetation, that site may shift to a forested wetland and thus be subject to the swamp forest vegetation sampling methodology (Section 7.2). If CPRA determines that the swamp forest vegetation sampling methodology applies, forested stations will be established following CRMS protocol to incorporate as many of the existing herbaceous stations as possible.

CPRA should be consulted prior to the establishment of new stations, the relocation of existing stations, and a change between sampling methodologies.

#### **CONVERSION OF STATIONS TO OPEN WATER:**

The intent of the CRMS monitoring program is to maintain the original monitoring stations for as long as possible. If the vegetation stations convert to open water, they will be maintained and data from the originally established stations will continue to be collected for the CRMS project life. Total cover will be recorded as 0% and water depth in the plot will be measured according to the sampling protocol. Stations may have to be re-established if they are disturbed by unnatural processes (are buried under a levee, etc...). CPRA will advise on how to proceed when stations are lost.

### 7.1.2 Herbaceous Vegetation and Porewater Data Processing

The CPRA has implemented a two-phase protocol for data processing: data entry (Phase I) and quality assurance/quality control (Phase II). The two phases are conducted by separate individuals to ensure that the final product is correct.

**DATA ENTRY (PHASE I):** Phase I is conducted by the individual responsible for the field data collection. This individual is termed the “data collector.”

The data collector should complete the following procedures:

1. **Verification of Field Samples:** The samples collected in the field that were not positively identified must be examined by a qualified individual, such as a botanist or plant taxonomist. The plants shall be provided to the person as soon as possible before the integrity of the samples diminishes.
2. **Review of Herbaceous Marsh or Herbaceous Swamp Vegetation Sampling Data Sheet**
  - a. Review the data sheet for completeness, accuracy, and legibility.
  - b. For corrections, strike a single line through the error and write the changes adjacent to the error along with the data collector’s initials and date.
  - c. Examine the data sheet for the proper selection of each plant species. It is acceptable to use abbreviations for species in the field, but they should be defined in the office prior to delivery to the appropriate CPRA regional office. Use the standard botanical names listed in the USDA Plants Database (<http://plants.usda.gov/>). Genus and species are sufficient. Changes must be accompanied by the data collector’s initials and date.
3. **Review of Station Photographs**
  - a. Confirm that the station name and date are correct on the photograph.
  - b. If a correction needs to be made to the station name and/or date, draw a single red line through the incorrect information and rewrite either on the placard if space allows, or somewhere else in the photograph where the text will not cover anything of importance.
4. **Review of Porewater Data Sheet**
  - a. Review the data sheet for completeness, accuracy and legibility.
  - b. If a correction needs to be made, strike a single line through the error and write the changes adjacent to the error.
  - c. Accompany changes with the data collector’s initials and date.
5. **Data Transcription**
  - a. Enter the vegetation herbaceous data into an Excel spreadsheet in the appropriate format for the CIMS database and save as an .xlsx file using the naming convention: “*Station\_V\_YYYY-MM.xlsx*”. See Figure 7.4 for



proper data format. Note: Enter all stations into the spreadsheet, regardless of whether they are vegetated.

- b. Enter species' names into the data file using the complete name from the USDA Plants Database list utilized by the CIMS database, including the author's name (e.g., *Spartina patens* (Ait.) Muhl.).
- c. Enter the porewater data into an Excel spreadsheet in the appropriate format for the CIMS database and save as an .xlsx file using the naming convention: "*Station\_PW\_YYYY-MM.xlsx*." See Figure 7.5 for proper data format.
- d. Save the photographs of the herbaceous marsh stations using the naming convention: "*Station-VNN.jpg*," where NN is the station. Save the photographs of the herbaceous swamp stations using the naming convention "*Station-F00VXX.jpg*." See section 7.2.1 for an explanation of the naming convention for herbaceous swamp stations.

#### 6. Data Verification

- a. After data transcription is completed, double-check the files for accuracy.
- b. Upon completion of the review of data, provide the electronic files to the QA/QC officer.

Once the data sheets have been corrected with respect to the unidentified and renamed plants, the data collector can begin the two-phase process established by the CPRA to ensure the accuracy of the data.

**QUALITY ASSURANCE / QUALITY CONTROL (PHASE II):** Phase II begins when the QA/QC officer is provided the field data sheet and is notified that the .xlsx file has been completed. The QA/QC officer should follow the steps below to ensure the data have been processed properly.

The QA/QC officer should complete the following procedures:

1. Compare the .xlsx file to the field data sheet, checking for completeness and consistency. Note: CPRA has developed a SAS program that checks for logical inconsistencies in the vegetation data. Logical inconsistencies include those described in Section 7.1.1 "Methods." The SAS program is available on the CRMS Data Depot site or by request.
2. Compare the photographs of each station against the species list on the data sheet for accuracy and identification errors.
3. If mistakes are found, notify the data collector so they can be corrected.
4. Continue this process until no mistakes are found.

Once Phases I and II have been completed, upload the vegetation and porewater .xlsx files to CPRA's CIMS buffer.

### 7.1.3 Herbaceous Vegetation and Porewater Deliverables

Electronic data files shall be in the appropriate deliverable format and delivered to CPRA once the data collector and QA/QC officer have completed the QA/QC process. Review the scanned .pdf files prior to submittal to ensure the text is legible.

Deliverables should include the following:

1. Herbaceous Marsh or Swamp Vegetation Sampling scanned Data Sheet (.pdf) or digital equivalent (Figures 7.1 and 7.2)
2. Excel spreadsheet (.xlsx) of the herbaceous vegetation data (Figure 7.4)
3. Discrete Hydrographic/Soil Porewater Data Sheet (.pdf) (Figure 3.21)
4. Excel spreadsheet (.xlsx) of the porewater data (Figure 7.5)
5. Eight megapixel or greater photographs of all herbaceous plots (.jpg)
6. Photographs of unknown plants.

## 7. Vegetation

Station ID	Group	Plot Size (m2)	Collection Date (mm/dd/yyyy)	Community	Sample Type	Vegetation Type	% Cover Total	% Cover Tree	% Cover Shrub	% Cover Herb
CRMS0489-V49		4	8/31/2016	Freshwater	Transect	Natural	95		55	50
CRMS0489-V49		4	8/31/2016	Freshwater	Transect	Natural	95		55	50

(continued...)

% Cover Carpet	Average Height Dominant (cm)	Average Height Tree (cm)	Average Height Shrub (cm)	Average Height Herb (cm)	Average Height Carpet (cm)	Scientific Name As Originally Observed	Common Name As Originally Observed
	145.69		182.88	152.4		Cicuta maculata L.	spotted water hemlock
	145.69		182.88	152.4		Typha domingensis Pers.	southern cattail

(continued...)

Scientific Name As Currently Recognized	Common Name As Currently Recognized	% Cover	Braun-Blanquet Rank	In/Out	Number Planted	Number Alive	Additional Species Description
Cicuta maculata L.	spotted water hemlock	25	2	Both			
Typha domingensis Pers.	southern cattail			Out			In Flower

(continued...)

Organization	Personnel	Comments
COASTAL PROTECTION AND RESTORATION AUTHORITY	W.B. Wood; M. Mouledous	Water Level is 0 ft above marsh. Open water is 0%. Bare ground is 0%. Dead vegetation is 5%. Flooded-Undetermined is 0%.
COASTAL PROTECTION AND RESTORATION AUTHORITY	W.B. Wood; M. Mouledous	Water Level is 0 ft above marsh. Open water is 0%. Bare ground is 0%. Dead vegetation is 5%. Flooded-Undetermined is 0%.

**Figure 7.4.** Herbaceous vegetation data format in .xlsx file and CIMS.

## 7. Vegetation

CPRA Station ID	Original Collector Station ID	Date (mm/dd/yyyy)	Time (hh:mm)	Time Zone	Staff Gauge (ft)	Geoid	Station Depth (ft)	Measurement Depth (ft)	Water Temperature (°C)
CRMS0543-V19		08/25/2016	9:00	CST		GEOID12A		0.328	
CRMS0543-V19		08/25/2016	9:10	CST		GEOID12A		0.984	

(continued...)

Specific Conductance (uS/cm)	Salinity (ppt)	Dissolved Oxygen (mg/L)	pH (pH units)	Velocity (ft/sec)	Soil Porewater Temperature (°C)	Soil Porewater Specific Conductance (uS/cm)	Soil Porewater Salinity (ppt)	Turbidity (FNU)	Chlorophyll a (ug/L)	Total Nitrogen (mg/L)
					28.1	2066	1.0			
					30.1	638	0.3			

(continued...)

Total Kjeldahl Nitrogen (mg/L)	Nitrate as N (mg/L)	Nitrite as N (mg/L)	Nitrate+Nitrite as N (unfiltered; mg/L)	Nitrate+Nitrite as N (filtered; mg/L)	Ammonium as N (unfiltered; mg/L)	Ammonium as N (filtered; mg/L)	Total Phosphorous (unfiltered; mg/L)	Total Phosphorous (filtered; mg/L)	Orthophosphate as P (unfiltered; mg/L)

(continued...)

Orthophosphate as P (filtered; mg/L)	Silica (unfiltered; mg/L)	Silica (filtered; mg/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi (ft)	Fecal Coliform (MPN/100ml)	Organization Name	Comments
							CONTRACTOR/AGENCY	Dry
							CONTRACTOR/AGENCY	Dry

**Figure 7.5.** Soil porewater data format in .xlsx file and CIMS at emergent vegetation stations. Measurement Depth 0.328 ft is 10 cm, and Measurement Depth 0.984 ft is 30 cm.

## 7.2 Swamp Forest Vegetation Sampling

### 7.2.1 Swamp Vegetation Site Design

The forest sampling design currently includes vegetation stations for surveying the canopy and herbaceous layers of forested CRMS sites; the herbaceous stations are within the currently inactive understory stations. All sampling takes place within three replicate 20 m x 20 m forest stations located within a 200 m x 200 m data collection area (DCA). Nested within each of the three 20 m x 20 m forest stations are three inactive 6 m x 6 m understory stations, each containing one 2 m x 2 m herbaceous station (Figure 7.6). Each CRMS swamp site includes a total of three forest stations, nine herbaceous stations, and nine, currently inactive, understory stations.

#### Forest Stations (3 per CRMS site)

The three forest stations are randomly selected from nine potential forest stations that are located every 30 m along the 283 m diagonal transect of the DCA (Figure 7.6). The southeast corner of the forest station is located on the DCA transect. Transects are oriented across the DCA, either NW to SE or NE to SW and are established away from spoil banks or any type of human-induced surface alterations to avoid biased data. Forest stations are named according to their spatial order, where CRMS0000-F01 is farthest north and CRMS0000-F09 is farthest south. The three forest stations chosen for sampling are based on their randomized order. CPRA will generate and provide the randomized station list, which includes the coordinates for each station, the station numbers in their initial spatial order, and the randomly generated number for each station.

#### Understory Stations (3 per forest station, 9 per CRMS site)

The three inactive 6 m x 6 m understory stations are located in the center and two corners of each forest station along its diagonal transect. The forest station transect should have the same orientation as the larger DCA station transect when possible (Figure 7.6).

#### Herbaceous Stations (3 per forest station, 9 per CRMS site)

One 2 m x 2 m herbaceous station is located in each of the inactive understory stations and is oriented along the same transect as the understory station. For the corner understory stations, the herbaceous station is aligned with the corner of the forest station. For the center understory station, the herbaceous station is located north of the center point, as depicted in Figure 7.6.

The naming convention for the swamp stations is as follows (Figures 7.7a and 7.7b):

Forest (F) Station (20 m x 20 m) = CRMS0000-F00, which is the CRMS site number followed by a hyphen (-), and ending with the forest station number. For example, CRMS0100-F03 would indicate CRMS site 0100 and forest station 03.

Understory (U) Station (6 m x 6 m) = CRMS0000-F00UXX, which is the CRMS site number, followed by a hyphen (-), the forest station number, U for understory, and the orientation of the understory station within the forest station. Orientation choices include

“C” for the center station and the appropriate compass direction (NE, NW, SE or SW) for the corner stations. For example, CRMS0100-F03UNW would indicate forest station CRMS0100-F03 and the understory station located in the northwest corner of the forest plot.

Herbaceous (V) Station (2 m x 2 m) = CRMS0000-F00VXX, which follows the same naming convention that applies to the understory stations, except a “V” is used instead of a “U”.

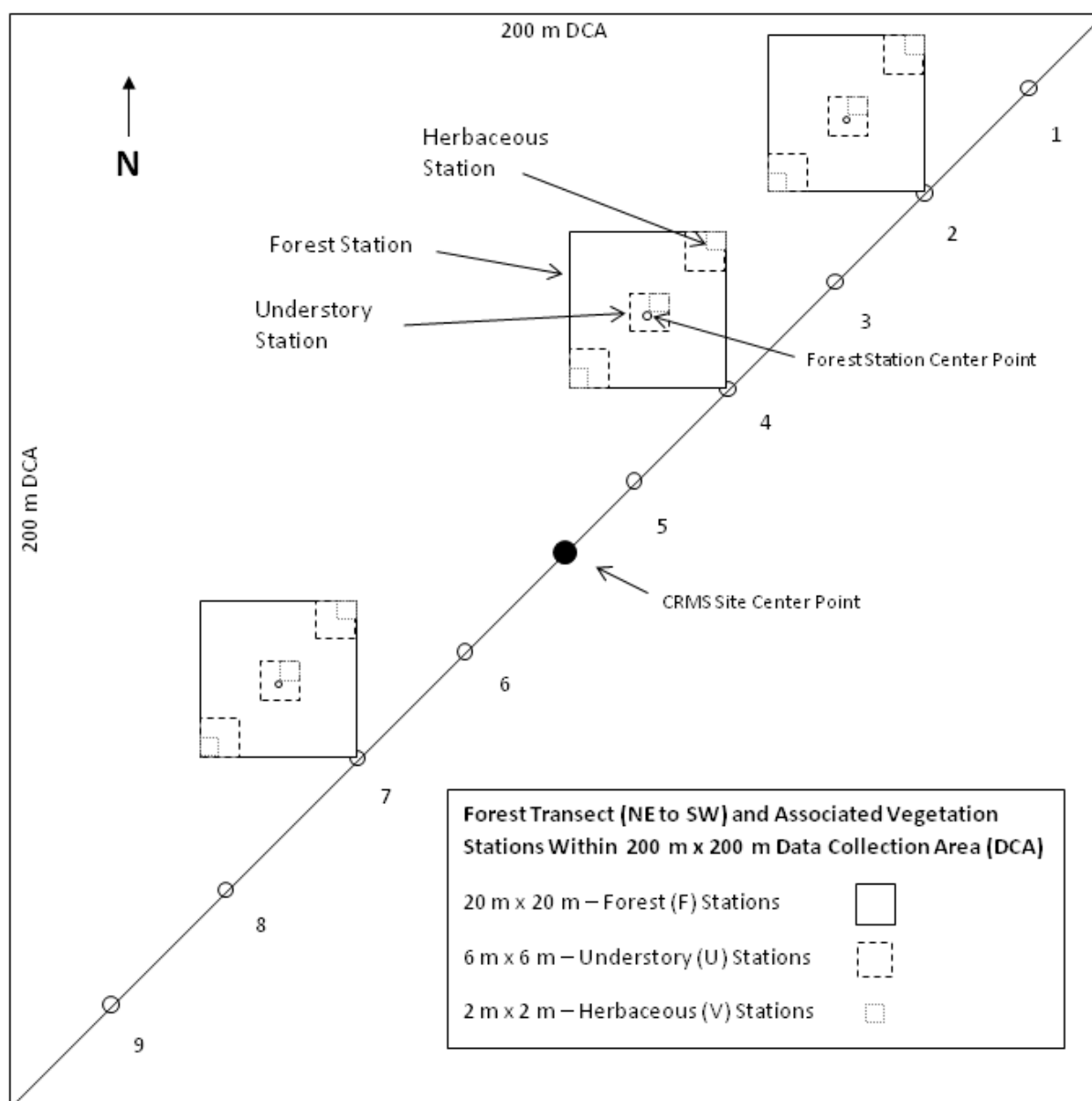
### 7.2.2 Swamp Vegetation Station Establishment

#### *Materials:*

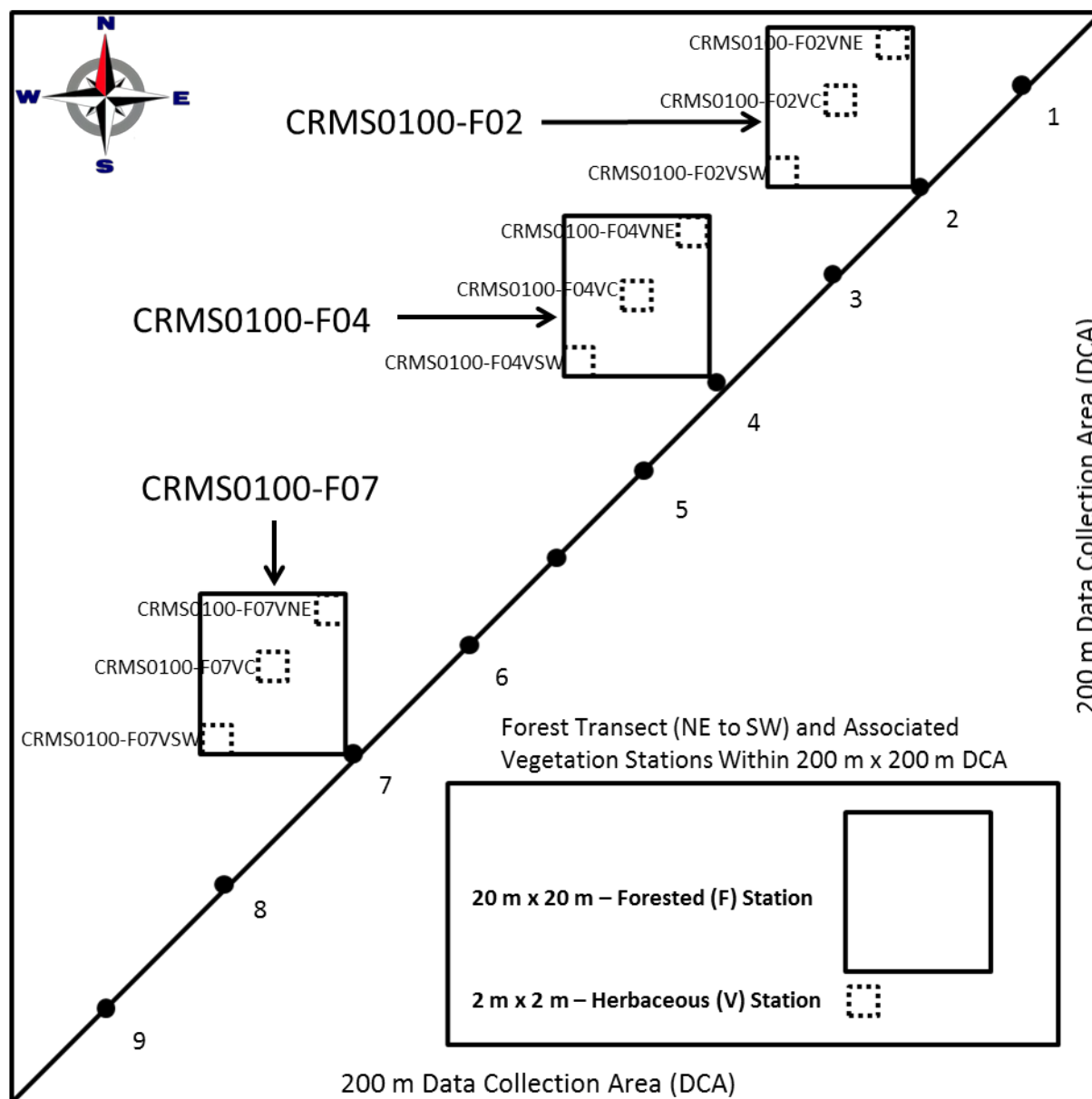
In addition to the materials listed in Section 7.1.1, the following list of materials is needed to establish and sample vegetation stations at forested CRMS sites. Some of these materials may not be needed in a given year, depending on the type of sampling that is being conducted. Other equipment and/or supplies may be needed depending on the site.

1. 10-ft long PVC pipe (typically 2" diameter) to mark the 4 corners and center point of each forest station
2. 2" diameter PVC marker caps
3. 10-ft long PVC pipe (typically ¾" diameter) to mark the southeast corner of each understory and herbaceous station
4. Measuring tape/device: ½" fiberglass measuring tape capable of measuring 100 m
5. Canopy, understory, herbaceous, and porewater data sheets
6. Diameter tape: fabric tape used to measure the diameter of trees in centimeters
7. Calipers for measuring the diameter of trees and shrubs
8. Tree marking chalk or flagging: used to mark trees that have been measured
9. Hammer, aluminum nails, and numbered tree tags: used to identify individual trees and to mark where the diameter at breast height (DBH) should be taken
10. Aluminum ladder: used to reach the height for shifted DBH measurements
11. Densiometer
12. Densiometer stand
13. Loppers/cutters
14. Protective clothing and gloves in case toxic species are encountered

Locate the forest station with random order number “1.” Stay on the east side of the transect when it runs from NE to SW. Transects that run from NW to SE can be accessed from either side, but crews should maintain a minimum buffer of 10 m between the access route and the station. Install a 10-ft long, 2" diameter PVC pole at the coordinate that marks the SE corner of the forest station. Measure the outline of the 20 m x 20 m quadrant and mark the NE, NW and SW corners and the center point with 2" diameter PVC poles. Place PVC marker caps on the SE and center pole to aid in orientation. Upon initial setup, the stations must contain ≥ 55% land. If the station contains < 55% land, the field crew shall replace it with the next random order number. This process is repeated until all three stations are established. After the three forest stations are established, the nested understory and herbaceous stations shall be delineated and marked with PVC poles.



**Figure 7.6.** Illustration of CRMS swamp-site design for vegetation stations (not to scale) including active forested stations and herbaceous stations as well as **inactive** understory stations.



**Figure 7.7a.** Illustration of the naming convention for swamp stations and their nested herbaceous stations. This does not show the inactive understory plots; their naming convention is similar to the herbaceous plots but uses a “U” instead of a “V”.





**Figure 7.7b.** Photograph of a forested herbaceous vegetation station with the station name displayed in the photo.

### 7.2.3 Swamp Vegetation Data Collection

Forest vegetation sampling shall occur during the 12-week period between August 1 and October 31; extensions to the monitoring period may be permitted if necessary and first approved by CPRA. Some landowners limit access to sites in October due to deer hunting activities; therefore, sites with this restriction must be sampled in August and September. Soil cores are collected from CRMS sites every six years and may need to be collected in conjunction with swamp sampling. Soil sampling methods are described in Section 8.

#### 7.2.3.1 Canopy Layer

##### ***Species composition and tree diameters:***

Sampling methods described in this section are performed every three years, with the next three samplings occurring in 2021, 2024, and 2027. Within each of the three 20 m x 20 m stations at each CRMS site, trees  $\geq 5$  cm DBH are identified to the species level, tagged (if not already tagged), and measured at the appropriate height for DBH. These data are recorded on the data sheet titled *Forest Community Data Sheet - Canopy Layer* (Figure 7.8). Diameter at breast height (DBH) is defined as tree diameter at 4.5 ft (137.2 cm) above ground as measured from the uphill side of the tree. Because DBH measurements will be replicated every three years, numbered identification tags are nailed on trees at the height where DBH was measured. This height may be shifted for trees with irregular or fluted stems.

The following procedures are used to measure DBH of trees with irregular stems [reference pages 144–149 in Avery and Burkhart (1994)]. In all cases, the tree is tagged in the shifted location only if DBH  $\geq 5$  cm.

1. If a tree stem is forked immediately above breast height, measure DBH below the swell resulting from the double stem. Record the height above ground that the shifted DBH was measured and explain the reason for the shifted DBH in the Additional Species Description (Figure 7.8).
2. If the tree stem is forked below breast height, each stem is considered to be a separate tree. The diameter of each stem is measured at 3.5 ft (106.7 cm) above the fork and marked at this location with a numbered tag. Note this change on the data sheet as described in step 1.
3. If the tree has a buttress or fluted bole (e.g., tupelo or cypress) and the buttress is greater than 3.0 ft (91.4 cm) high, DBH is measured and the tree is tagged at 1.5 ft (45.7 cm) above the point where the buttress swell stops noticeably tapering. Note this change on the data sheet as described in step 1.
4. If a tree is newly tagged due to recruitment into the tree layer, record in the Additional Species Description that it is a new tree.

5. If a tree has died since the last sampling event, record the DBH measurement and record that the tree is dead in the Additional Species Description.

During sampling, trees may be temporarily marked with chalk or flagging to ensure that each tree has been measured. If a species cannot be identified in the field, collect any structures that may aid in identification (leaves, stems, fruits, flowers, seeds) and follow procedures outlined in Section 7.1.1.8.e.

***Canopy cover (densiometer):***

Canopy cover is measured annually. A convex spherical densiometer is used to measure % canopy cover in each of the four cardinal directions (N, E, S and W) from the center of each of the three 20 m x 20 m forest stations at a CRMS site.

***Materials:***

1. One 2" diameter schedule 40 PVC pipe, 4' long
2. 4" x 4" square plate
3. Convex spherical densitometer
4. Calculator
5. Rubber bands, blue tac, double sided tape, etc.

A densiometer stand is used to standardize the height at which densiometer readings are taken and to aid in stabilizing the instrument. To construct the stand, cut a 4' PVC pipe so that both ends are square. Center and permanently affix the 4" x 4" plate to one end of the pipe. This stand design allows the densiometer to be placed on the plate and secured by two rubber bands or a similar securing device.

Densiometer measurements are taken at the center of the 20 m x 20 m forest station. If it is not feasible to stand in the exact center, the closest possible location should be used as long as it is within the 20 m x 20 m station and not within a 2 m x 2 m herbaceous station. Place the base of the densiometer stand firmly on the ground so that the 4" x 4" square plate is on top and level. Center and secure the densiometer to the top of the plate. The bubble level in the densiometer should be on the side closest to the data collector. Stand approximately half an arm's reach away from the pole so that no reflection is cast in the mirror. If any unnatural item is casting a reflection, move the item prior to data collection. Center the bubble level before taking any readings on the densiometer.

The convex mirrored surface of the densitometer is etched with 24 squares in a grid pattern. Each square should be viewed as if subdivided into four smaller squares, resulting in a total of 96 subsquares. Starting with the first square at the top left of the grid, count how many of its four subsquares are dominated by canopy cover. If a subsquare is dominated by canopy, it is given a value of "1." If it is not dominated by canopy, it is given a value of "0" (Figure 7.9). A value of 0–4 should be determined for each of the 24 squares. Continue moving in a systematic fashion until all 24 squares (96 subsquares) have been counted to provide a number from 0 to 96. Collect and record densiometer values for each cardinal direction following the same procedure.

Note: To ensure consistency and reduce the inherent variability in reading canopy cover, a minimum of two field personnel should calculate percent canopy cover for each station. The readings should be taken within a few minutes of each other to eliminate lighting variation. If the difference between any two of the percent canopy cover measurements is greater than 25%, field personnel should retake their readings and/or discuss differences of interpretation until a consensus is reached. The percent canopy cover readings from the data collectors are averaged to calculate the final percent canopy cover value. Canopy cover data are recorded on the data sheet titled *Forest Community Data Sheet-Canopy Layer* (Figure 7.8).

Percent canopy cover can be determined by counting squares with no canopy cover (open canopy) or squares with canopy cover (closed canopy), as long as the correct equation is used. Indicate on the data sheet whether open or closed canopy counting was used to assess canopy cover.

Open canopy (%):  $100 - (\text{average densiometer} \times 1.04)$

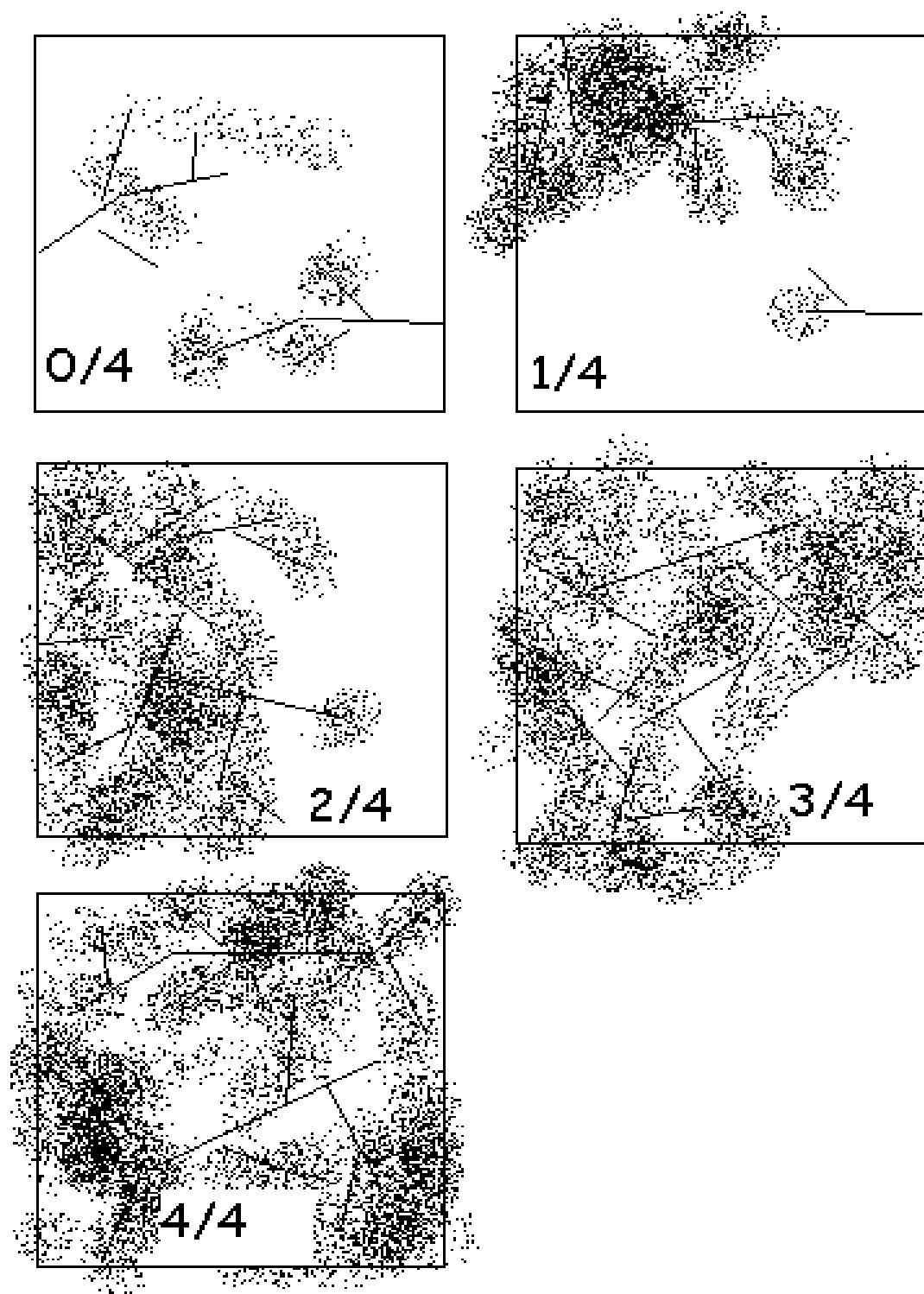
Closed canopy (%):  $100 - ((96 - \text{average densiometer}) \times 1.04)$

Average the densiometer readings from each direction to determine the densiometer value for the site. Record these values for each data collector.

## 7. Vegetation

[illegible]

**Figure 7.8.** Field data sheet for canopy layer data collection, which includes tree tag numbers, species composition, DBH measurements, and densiometer readings.



**Figure 7.9.** Examples of acceptable values for canopy cover in one square of the densiometer. Each square is assessed as if it is divided into four subsquares. If a subsquare is dominated by canopy cover (closed) it is given a value of 1; therefore, each square can have a maximum value of 4.

### **7.2.3.2 Understory Layer**

The Understory Layer is no longer regularly sampled (**INACTIVE**) in CRMS. Sampling of the understory layer was conducted every three years in conjunction with the canopy layer sampling described in Section 7.2.3.1. Three 6 m x 6 m understory stations nested within each of the three 20 m x 20 m forest stations were sampled, for a total of nine understory stations per CRMS site (Figure 7.6).

#### *Materials:*

1. DBH tape or calipers
2. 4-m telescopic leveling rod and meter stick

#### Understory Protocol, (not currently collected):

Shrubs were NOT tagged for the understory sampling, only woody plants  $\geq 5$  cm DBH are tagged.

1. If a tree or shrub was  $\leq 5$  cm DBH, and is  $\geq 137$  cm tall, then:
  - a. Identify the species
  - b. If a species cannot be identified in the field, collect any potential identifying structures (leaves, stems, fruits, flowers, seeds) and follow procedures outlined in section 7.1.1.8.e.
  - c. Categorize the tree or shrub as single or multi-stem. **Single stem** describes a growth form with one main stem at the base of the plant. **Multi-stem** describes shrubs or trees with multiple stems at or just above the base of the plant. Use the Additional Species Description field on the Understory data sheet to describe unusual growth forms.
  - d. Count the number of stems **at breast height (137 cm)**
  - e. Measure DBH for up to 3 stems. A tree/shrub with a single stem growth form can still have multiple stems measured for DBH, since a tree/shrub with a single main stem/trunk can be forked into multiple stems at 137 cm height.
  - f. The following procedures are used to measure DBH of trees with irregular stems [adapted from pages 144–149 in Avery and Burkhart (1994)]. *Avery and Burkhart measurements are followed for trees, but not shrubs.*
    - i. If a tree stem is forked immediately above breast height, measure DBH below the swell resulting from the double stem. Record the height above ground that the shifted DBH was measured and explain the reason for the shift in the Additional Species Description (Figure 7.10).
    - ii. If the tree stem is forked below breast height, measure up to 3 stems at 3.5 ft (106.7 cm) above the fork. Record the height above ground that the shifted DBH was measured and explain the reason for the shift in the Additional Species Description (Figure 7.10).
    - iii. If the tree is not tall enough for this measurement, measure DBH at the standard height of 137 cm and note in the Addition Species Description.

- g. Measure the height of the plant. Height is measured from the ground to the uppermost point of the tree or shrub.
  - h. Certain exceptions apply—a  $\geq 5$  cm DBH *Sabal minor* is included in the understory layer even if it is outside of the DBH range for this category.
2. If a tree or shrub was  $\leq 5$  cm DBH, and is  $\geq 50$  cm and  $< 137$  cm tall:
- a. Identify the species
  - b. If a species cannot be identified in the field, collect any potential identifying structures (leaves, stems, fruits, flowers, seeds) and follow procedures outlined in section 7.1.1.8.e.
  - c. Categorize as single or multi-stem
  - d. Do not record number of stems (stems are counted at 137 cm height)
  - e. Do not measure the DBH
  - f. Measure the height of the plant

Shrubs or trees species less than 50 cm tall were not surveyed in the understory stations.

All data was recorded on the data sheet titled *Forest Community Data Sheet - Understory Layer* (Figure 7.10).

### **7.2.3.3 Herbaceous Layer**

Sampling for the swamp herbaceous layer and for porewater at the herbaceous stations is conducted annually. Nine 2 m x 2 m herbaceous stations (1 within each inactive understory station) are sampled at each CRMS swamp site (Figure 7.6). Sampling methods, data sheets, QA/QC, and deliverables for swamp herbaceous and porewater sampling are described in Section 7.1.

#### **REESTABLISHMENT:**

- 1. If the PVC pole is missing, the station should be reestablished as close to the original GPS coordinates as possible and a new PVC pole should be installed.
- 2. If a significant, unnatural anthropomorphic change to the study site has occurred (e.g., digging or dumping of soil at the site), the station should be reestablished using the next available random order number.
- 3. If a formerly forested wetland site losses all  $>5$  cm DBH woody vegetation in perpetuity and shifts to an emergent wetland, it may become subject to the emergent vegetation sampling protocol (Section 7.1). If CPRA determines that the emergent vegetation sampling methodology applies, then as many of the original herbaceous vegetation stations (9) as possible shall be conserved, and one additional herbaceous station shall be added randomly along the existing transect. The original forested stations will remain active in the database in perpetuity and continue to record zeros in the database for



Diameter at Breast Height, plant height, and canopy cover, reflecting the loss of coastal forested habitat.

CPRA should be consulted prior to the establishment of new stations, the relocation of existing stations, and a change of vegetation sampling methodologies.

### **CONVERSION OF STATIONS TO OPEN WATER:**

The intent of the CRMS monitoring program is to maintain the original monitoring stations for as long as possible. If the vegetation stations convert to open water, they will be maintained and data from the originally established stations will continue to be collected for the CRMS project life. Total cover will be recorded as 0% and water depth in the plot will be measured according to the sampling protocol. Stations may have to be re-established if they are disturbed by unnatural processes (are buried under a levee, etc...). CPRA will advise on how to proceed when stations are lost.

### **7.2.4 Swamp Vegetation Data Processing**

The CPRA has implemented a two-phase protocol for data processing: data entry (Phase I) and quality assurance/quality control (Phase II). The two phases are conducted by separate individuals to ensure that the final product is in 100% agreement with the data collected during the field sampling procedure. Herbaceous and porewater data processing is covered in section 7.1.2.

**DATA ENTRY (PHASE I):** Phase I is conducted by the individual responsible for the field data collection. This individual is termed the “data collector.”

The data collector should complete the following procedures:

1. Verification of Field Samples: The samples collected in the field that were not positively identified must be examined by a qualified individual, such as a botanist or plant taxonomist. The plants shall be identified as soon as possible before the integrity of the samples diminishes.
2. Review of Canopy and Understory (inactive) Data Sheets
  - a. Review the canopy and understory layer data sheets for completeness, accuracy, and legibility.
  - b. For corrections, strike a single line through the error and write the changes adjacent to the error along with the data collector’s initials and date.
  - c. Examine the data sheets for the proper selection of each plant species. It is acceptable to use abbreviations for species in the field, but they should be defined in the office prior to delivery to the appropriate CPRA office. Use the standard botanical names listed in the USDA Plants Database (<http://plants.usda.gov/>). Genus and species are sufficient.

### 3. Data Transcription

- a. Enter the data from each of the vegetation layers into Excel spreadsheets in the appropriate format for CIMS. Follow the column order and formatting given in Figure 7.11. Canopy and the **inactive** understory data are recorded on separate data sheets but are uploaded and stored together in the database. Save the spreadsheets as .xlsx files using the following naming convention: “*Station\_forest\_YYYY-MM.xlsx*” (ex. CRMS0008\_forest\_2011-10). These files will contain the entire set of stations for each data type for each site (e.g., three “F” stations and nine “U” stations). Note: Enter all stations into the spreadsheet, regardless of whether they are vegetated or not.
- b. Enter species’ names into the data file using the complete name from the USDA Plants Database list, including the author’s name [e.g., *Taxodium distichum* (L.) Rich.].

### 4. Data Verification

- a. After data transcription is completed, double-check the files for accuracy.
- b. Upon completion of the review of data, provide the electronic files to the QA/QC officer.

**QUALITY ASSURANCE/QUALITY CONTROL (PHASE II):** Phase II begins when the QA/QC officer is provided the field data sheets and is notified that the .xlsx files have been completed. The QA/QC officer should follow the steps below to ensure the data have been processed properly.

The QA/QC officer should complete the following procedures:

1. Compare the .xlsx file to the field data sheet, checking for completeness and consistency.
2. If errors are found, have the data collector make all necessary corrections.
3. Continue this process until no mistakes are found.

Once Phases I and II have been completed, upload the vegetation files to CPRA’s CIMS buffer.

## 7. Vegetation

[illegible]

**Figure 7.10.** Field data sheet for the inactive understory layer, which includes woody shrubs and sapling trees < 5 cm diameter at breast height. S = single stem, M = multi-stem.

### 7.2.5 Swamp Vegetation Deliverables

Electronic data files shall be in the appropriate deliverable format and delivered to CPRA once the data collector and QA/QC officer have completed the QA/QC process. Review the scanned .pdf files prior to submittal to ensure the text is legible.

Deliverables should include the following:

Canopy Layer:

1. Forest Community Data Sheet-Canopy Layer (.pdf) (Figure 7.8)
2. Excel spreadsheet (.xlsx) of the canopy layer data (Figure 7.11)

Understory Layer (**Inactive**):

1. Forest Community Data Sheet-Understory Layer (.pdf) (Figure 7.10)
2. Excel spreadsheet (.xlsx) of the understory layer data (Figure 7.11)

## 7. Vegetation

Station ID	Forest Layer	Group	Plot Size (m2)	Collection Date (mm/dd/yyyy)	Community	Sample Type	Densiometer Reading - North	Densiometer Reading - South
CRMS0008-F01	OVERSTORY		400	8/5/2015	Swamp	Transect	4	7
CRMS0008-F01UC	UNDERSTORY		36	8/5/2015	Swamp	Transect		

(continued...)

Densiometer Reading - East	Densiometer Reading - West	Average Densiometer Reading	Canopy Cover (%)	Tree Number	Scientific Name As Originally Observed	Common Name As Originally Observed	Scientific Name As Currently Recognized
4	3	4.5	95.32	553	Nyssa aquatica L.	water tupelo	Nyssa aquatica L.
					Fraxinus caroliniana Mill.	Carolina ash	Fraxinus caroliniana Mill.

(continued...)

Common Name As Currently Recognized	Understory Layer Growth Form	Overstory Layer Tree Diameter (cm)	Overstory Tree DBH Distance Aboveground (cm)	Total Number of Stems	Understory Plant Diameter (cm) At Breast Height 1	Understory Plant Diameter (cm) At Breast Height 2	Understory Plant Diameter (cm) At Breast Height 3
water tupelo		48.2	137				
Carolina ash	Multi Stem			2	2.5	3.1	

(continued...)

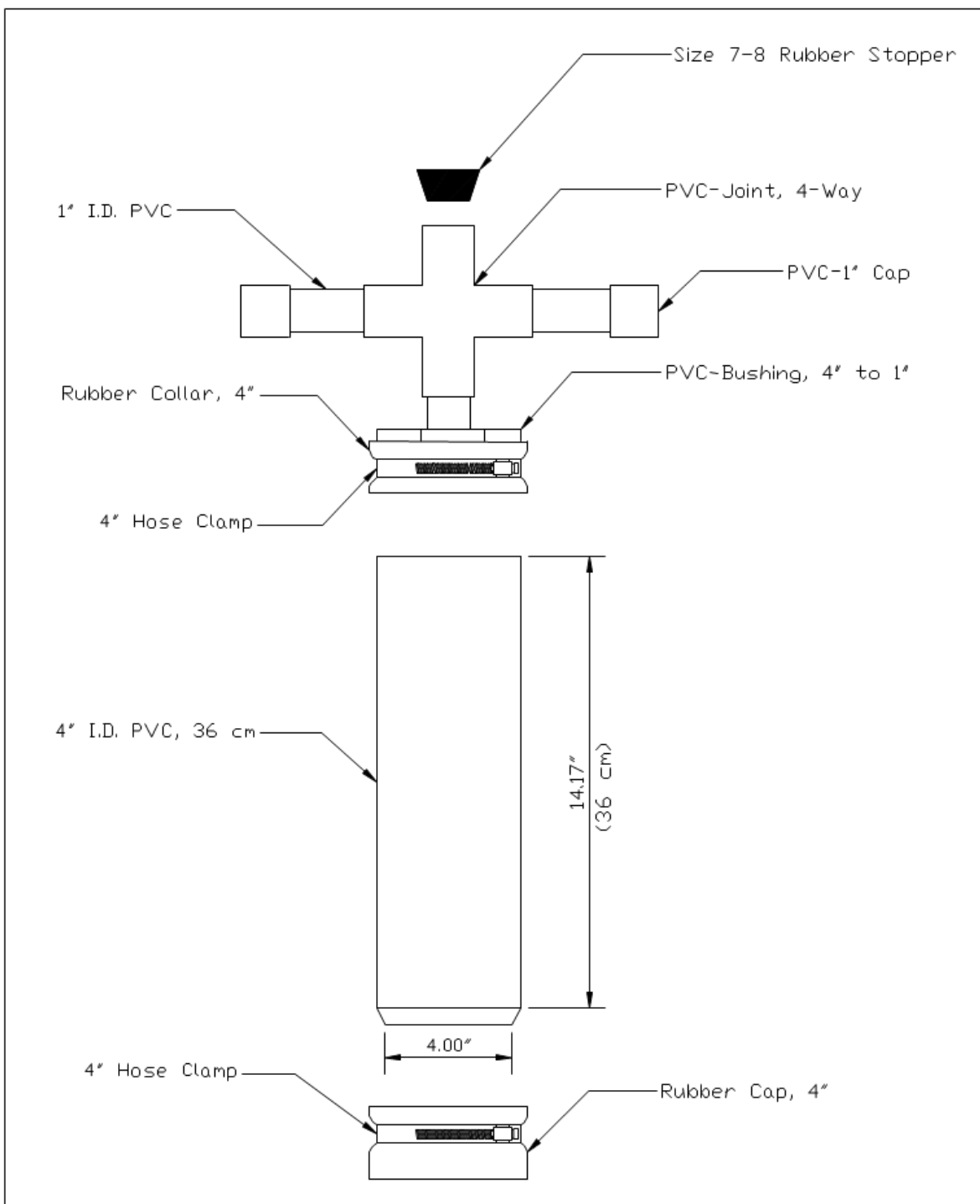
Understory Plant Height (cm)	Additional Species Description	Organization	Personnel	Comments
		CPRA	W.B. Wood; C.M. Miller	Water Level is below marsh, FAV present.
304.8		CPRA	W.B. Wood; C.M. Miller	Water Level is below marsh, FAV present.

**Figure 7.11.** Forest canopy (-F01) and **inactive** understory layer (-F01UC) data format in .xlsx file and CIMS.

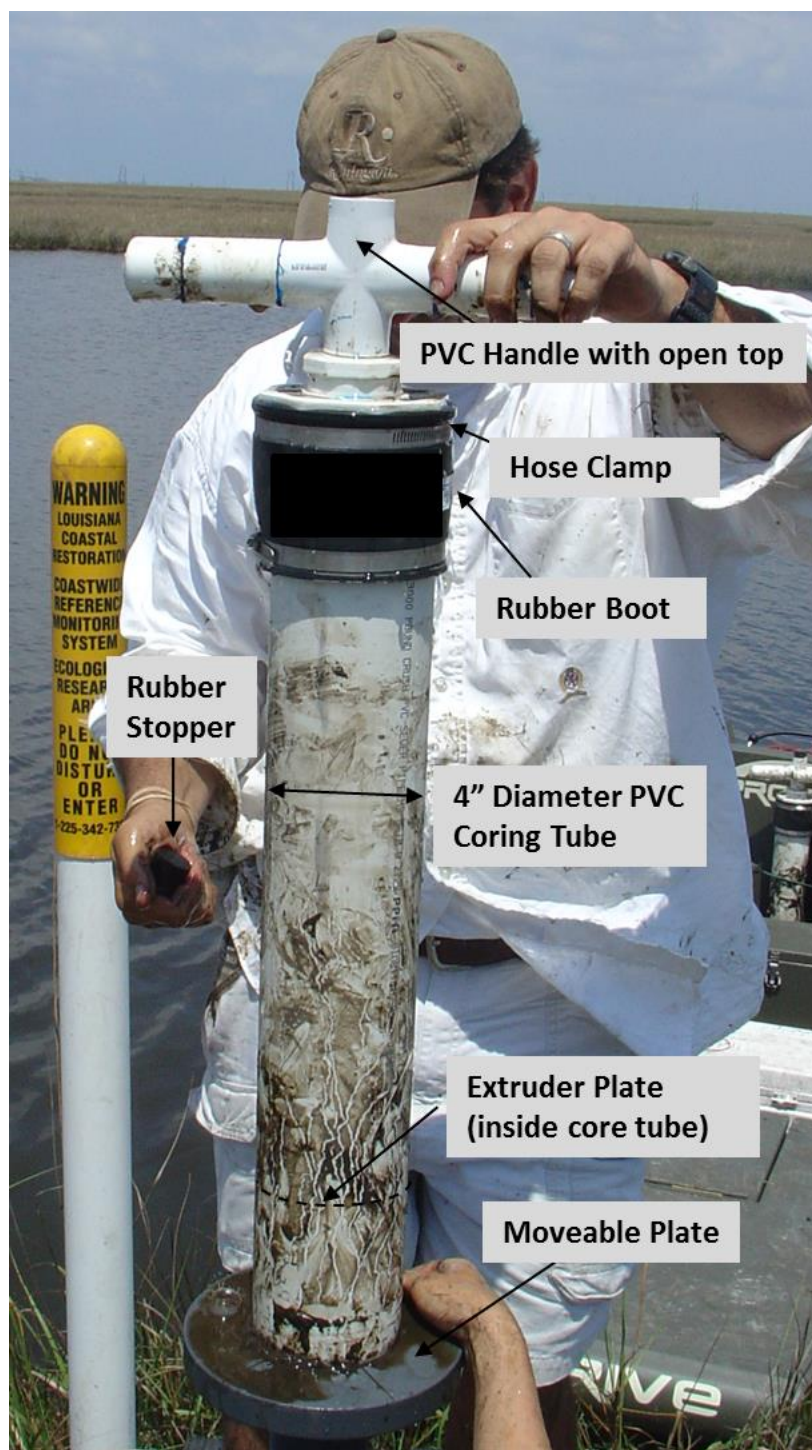
## 8. Soil Properties

The soil properties of concern to the CPRA include but are not limited to soil pH, soil salinity (EC), bulk density, soil moisture, percent organic matter (loss-on-ignition or LOI), and wet/dry volume. Soil pH and EC are no longer analyzed for CRMS; however, the protocols remain because of previous data collection. Soil pH is determined through a standardized procedure on both wet and dry soils. The average of replicate samples for both saturated and dry pH measurements, which is reported for each sample as the ratio of wet saturated and dry soil pH, indicates the potential for pyrite formation. Soil salinity is determined by laboratory measurements of a saturated sample's electrical conductivity (Brady and Weil 2002). The average of replicate samples for electrical conductivity is reported in both mS/cm and ppt. Bulk density is defined as the total weight of dry material—both organic and inorganic fractions—in a known volume of sample ( $\text{g}/\text{cm}^3$ ). Bulk density of organic wetland soils can be as low as  $0.01 \text{ g}/\text{cm}^3$  but it is commonly around  $0.2$  to  $0.3 \text{ g}/\text{cm}^3$ . In mineral wetland soils, bulk density can be as low as  $0.5 \text{ g}/\text{cm}^3$ , but it is usually between  $1$  and  $2 \text{ g}/\text{cm}^3$ . Soil density in wetland soils is controlled by the amount of mineral material that infiltrates the organic material framework in highly organic marsh soils. Soil moisture will be determined through the drying process for bulk density and is calculated as a percentage from the wet and dry sample weight. Percent organic matter is determined by the amount of weight loss upon ignition at  $550^\circ\text{C}$  (Andrejko et al. 1983). Soils composed completely of organic matter will lose most of the sample matter upon ignition. Both wet and dry volume of each sample will be determined and the ratio of wet to dry volume will be calculated. The wet/dry volume ratio provides the potential for linear compaction for each sample and can be used to determine soil porosity.

Several core extraction devices have been designed for use in wetlands. The ideal core tube is sharpened on the bottom so that the root mat can be cut as the core tube is slowly inserted. A clear core tube may also be beneficial as any compaction can be identified before the core is fully extracted and adjustments can be made. Many corers have been designed to facilitate the process of extracting cores with the least amount of marsh disturbance and compaction (e.g., Swenson 1982, Hargis and Twilley 1994, Meriwether et al. 1996). Any combination of core tube materials and caps may be used to obtain cores as situations require, as long as the inside diameter of the tube is 4" and cores can be sliced into 1.57" (4-cm) increments in the field. As minimizing the compaction of soil inside the core tube and reducing damage to the wetland are paramount, the CPRA suggests the use of a Meriwether corer (Meriwether et al. 1996) to collect 30-cm-deep cores (Figures 8.1a and 8.1b). This corer has been documented to work well in saturated and semi-saturated salt and brackish marsh soils. Field personnel shall determine the best core extraction method to use in each situation.



**Figure 8.1a.** Typical specifications of a core extracting device (modified from Meriwether et al. 1996 and Phillips 2002).



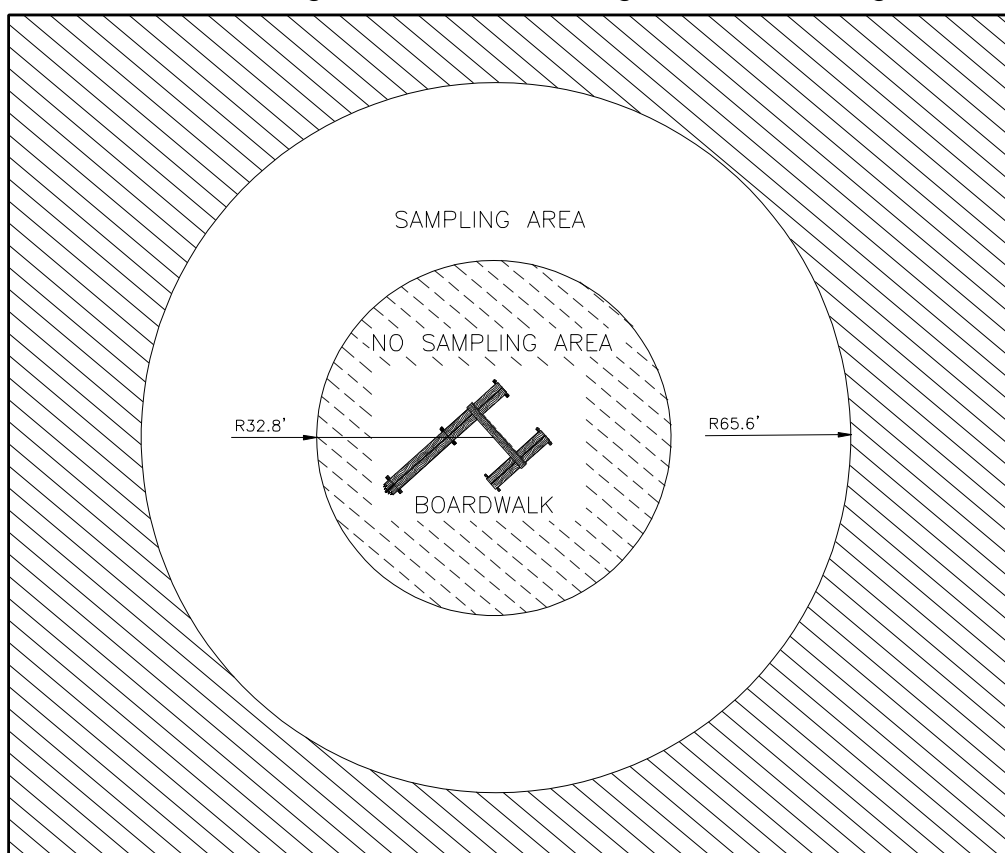
**Figure 8.1b.** Photograph of a core being extruded in the field depicting parts of the Meriwether corer and the core extruder.



## 8.1 Soil Station Establishment

Baseline soil samples shall be collected from all sites within one year of CRMS site establishment. Soil cores were collected at swamp sites in 2014 and shall be collected from marsh sites in 2018. Cores will be taken 10–20 m (33–66 ft) away from the CRMS boardwalk and at least 10 m (33 ft) from other CRMS sampling stations (Figure 8.2). Cores will be taken in the same marsh type as is represented by the CRMS DCA. Cores will be taken on a surface that is representative of the area (i.e., not on obvious high or low points, on clumps, or in trenasses).

Every attempt shall be made to take cores on a similar surface in each marsh type (e.g., between culms of grass in *Spartina patens* dominated marsh). Cores will be taken at least 5 m (16.4 ft) from each other. A detailed guide to determining where soil cores should be taken can be found below in Section 8.2 (Data Collection, Procedures). Care should be taken not to 1) damage the wetland when extracting/extruding cores and 2) interfere with future monitoring activities such as vegetation monitoring.



**Figure 8.2.** Diagram of CRMS site boardwalk area and the area available for sediment sample collection. Field personnel shall not collect soil cores or step within the 10-m (33-ft) buffer around the boardwalk. Soil samples shall be collected within 20 m (66 ft) of the boardwalk. Note: The vegetation station transect should be avoided.

## 8.2 Soil Data Collection

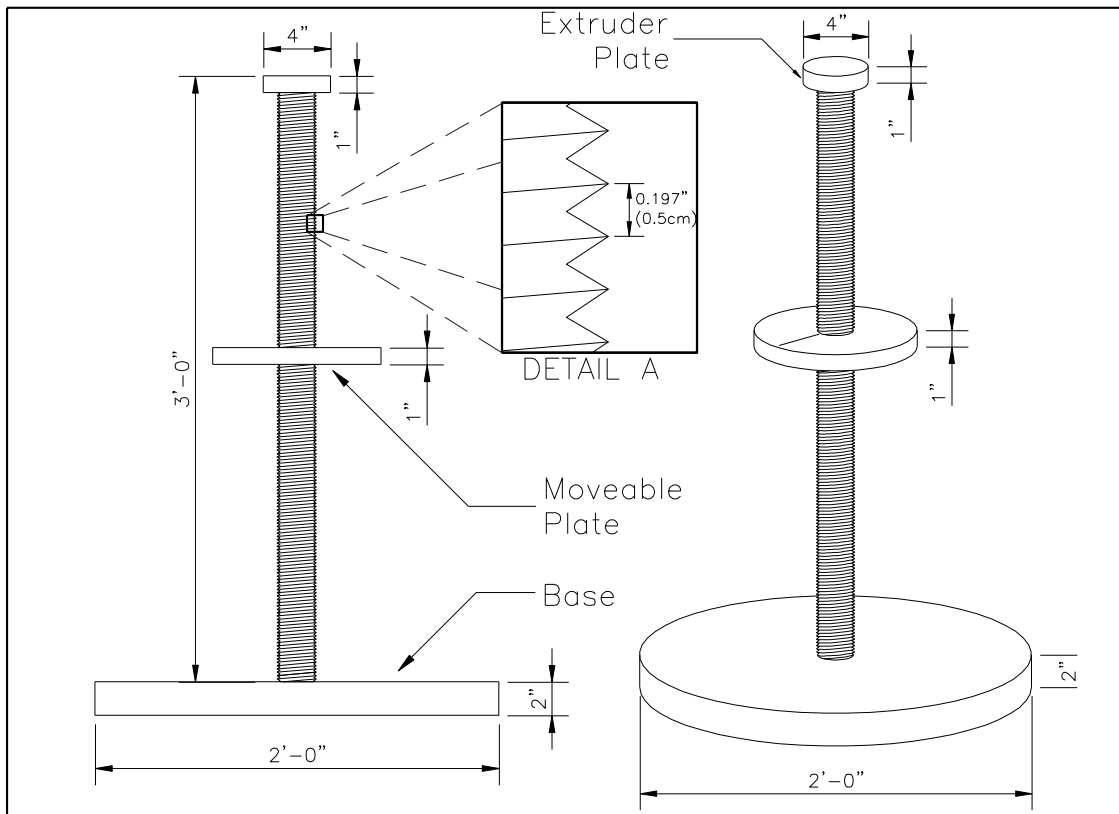
Soil cores shall be collected carefully to obtain a known volume of soil with little to no compaction of the soil matrix. Field personnel will collect three (3) soil cores with an inside diameter of 4" (10.2 cm) to a depth of 30.0 cm (11.8") from each CRMS-*Wetlands* site. Cores will be extruded in the field using a precise core-extruding device (Figures 8.3a and b) and sliced in the field into 4 cm (1.57") increments to a depth of 24 cm (9.45"). Each core slice shall be placed in a plastic bag. The remainder of the core is returned to the core hole after the total depth of the core is determined by extrusion and recorded in the appropriate space on the soil cores data sheet (Figure 8.4). Core samples will be placed on ice immediately after collection and delivered to the contracted soils lab in labeled storage bags (or containers) along with the chain of custody form within 48 hours of collection (Figure 8.5). The closable plastic bags shall be large enough to contain the core slice, minimum of quart size bag for 4 cm core slices and gallon size bag for 16 cm slices, and strong enough to resist puncturing.

The Meriwether corer includes a coring handle constructed of PVC with rubber stopper attached to the top of the core tube. The handle is attached to the core tube and the tube is slowly inserted into the soil to a depth of 30 cm, slowly cutting through the root zone by turning the core tube as it is inserted. Measurements of the depth of insertion from the top of the core tube to the soil surface both inside and outside of the core tube are then made with a ruler graduated in centimeters and recorded in the correct spaces on the soil cores data sheet (Figure 8.4). Note that the Meriwether coring handle must be removed to make these measurements. The head space in the top of the core and handle is filled with water from the nearest source and is stoppered to create a seal. The core is then slowly pulled from the marsh surface and a rubber cap is placed on the bottom of the core as it emerges. The Meriwether corer facilitates core extraction without digging out the core or losing core material from the bottom of the core. It may be necessary to cut the root zone as the core tube is inserted and to use clear core tubes to help reduce compaction.

Some sites may have soils that are too fluid or unconsolidated to extrude and slice with any precision. Two (2) attempts will be made to obtain cores that can be sliced. If cores cannot be sliced, three (3) cores shall be collected from those sites to a depth of 16 cm (5.9") using a 4" (10.2-cm) diameter core tube sharpened on the end. For the 16-cm (5.9") deep, unsliced samples, a large stopper or cap should be placed over the top of a 16-cm (5.9") core tube. A sharpened aluminum tube may be best for this application. The handle is not necessary for the shallow sediments. The top of the core should then be stoppered or capped and the core should be extracted by hand and quickly capped on the bottom. The entire 5.9" (16-cm) core sample (including interstitial water) should be placed on ice in a

labeled gallon-sized, closable plastic storage bag (or other container) and delivered to the contracted soils lab.

Problems will be encountered from site to site. There may be better core sampling conditions on some days than others. At each CRMS site, the best coring method should be determined and utilized. Refer to the detailed procedures provided below. Detailed notes should be recorded in the given blanks on the soil cores data sheet (Figure 8.4).



**Figure 8.3a.** Typical construction diagram for the soil core extruder (redrawn from Phillips 2002). The 4" extruder plate fits tightly inside the core tube. A moveable plate (diameter typically ~6-8") moves up or down the lead screw with a precise pitch of 0.197" (0.5 cm) per one revolution. The extruder is constructed of PVC and custom machined.



**Figure 8.3b.** Photographs of a core extruder (left) and a 4-cm core section being extruded and sliced in the field (right).

Soil Cores Data Sheet									
Project: _____		Date: _____							
Site: _____		Organization: _____							
Personnel: _____									
Station	Coordinates		Core Tube top to soil surface (cm)		Core Extraction (sampling)		Core Length Sampled (cm)	Core Length Remaining (cm)	Core Extrusion (Slicing)
(SO#)	Nothing	Easting	INSIDE	OUTSIDE	Tube length (cm)	% Compaction			Depth Extruded (cm)      % Compaction
					54				
					54				
					54				
<b>Field Conditions:</b> Was Marsh Flooded?      YES / NO      Flood Depth (cm): _____ Was it possible to get a consolidated core?      YES / NO If No, How many attempts were made? _____ Were the cores sliced?      YES / NO Core Tube:    Aluminum/Steel      PVC      Acrylic      Core Tube Inside Diameter:    10.14 cm Core Method:    Sliced Meriwether \ Single 16-cm Sample Was external water used to fill core tube head space?    YES / NO If yes, where was the water collected? _____ Dominant Species: _____									
<b>Additional Comments:</b>  <div style="text-align: right;">           [Depth Inserted = Tube Length - OUTSIDE]    [Depth Extracted = Tube Length - INSIDE]    [Depth Extruded (cm) = Core length sampled + Core length remaining (cm)]            [Extraction Compaction (%) = ((INSIDE-OUTSIDE)/(Depth inserted))*100]    [Extrusion Compaction (%) = ((Depth extracted - Depth extruded) / Depth extracted) * 100]         </div>									

Figure 8.4. Soil cores data sheet.

**Figure 8.5.** Chain-of-custody form.

### *Minimum Field Materials:*

1. Three (3) sharpened 4" (10.2-cm) inside-diameter core tubes at least 11.8" (30 cm) long. Core tubes can be acrylic, aluminum, or PVC. Tubes 14.2" (36 cm) long are recommended as the rubber boot on the Meriwether corer covers 2.4" (6 cm) of the core tube
2. Sharpened 4" (10.2-cm) inside-diameter core tube exactly 5.9" (16 cm) long or with 5.9" (16 cm) from bottom clearly marked/etched on the core tube
3. PVC Meriwether corer with rubber boot
4. Carboy, or other container, for transporting water from nearest source to coring site, for use with Meriwether corer
5. Rubber stopper to fit top PVC opening of Meriwether corer (size 7–8)
6. Six (6) 4" (10.2-cm) rubber core end caps with tightening bands
7. Nut driver that fits tightening bands (0.5")
8. Large rubber stopper or cap (large enough to fit in 4" (10.2-cm) core tube)
9. Soil core extruder with 4" (10.2-cm) extruder plate attached; machined to 0.5 cm per revolution
10. Serrated knife (at least 6" long) for core slicing and root zone slicing
11. Sheet of plywood (~4 ft x 4 ft)
12. Eighteen (18) labeled, closable, plastic storage bags. Label should include CRMS-*Wetlands* site number, core number, and sample depth (i.e., 0–4 cm, 4–8 cm, etc.). An additional three (3) large, labeled storage bags to be used for 16-cm cores if soils are too fluid to extrude and slice.
13. Additional storage bags large enough to hold all samples from each core
14. Ice chest and ice for sample storage and transportation
15. Soil cores data sheet (Figure 8.4)
16. Chain of custody form (Figure 8.5)

### *Procedures:*

The following section describes the procedure for identifying the location for soil core collection at each CRMS site and for collecting the core samples.

### Soil Core Decision Tree and Extraction Protocol:

1. Core samples shall be collected outside of a 32.8-ft (10-m) radius but within a 65.6-ft (20-m) radius of the sampling platform and at least 32.8 ft (10 m) from any other sampling plot. Are you within this zone? If yes, go to the next step. If no, relocate core sampling area.
2. Are you in an area/vegetation type representative of the 200 m x 200-m plot? If yes, go to the next step. If no, relocate and go to step 1.

3. Are you away from any obvious high or low spots? If yes, go to the next step. If no, relocate and go to step 1.
4. If this is the second or third core, are you at least 16.4 ft (5 m) from the previous core location? If yes, go to the next step. If no, relocate and go to step 1.
5. Take 11.8" (30-cm) core.
6. To collect the core sample, use a 4" (10.2-cm) inside-diameter sharpened core tube (Figures 8.1a and 8.1b). Sharpened clear acrylic, thin-walled aluminum, or PVC core tubes may be utilized.
7. Slowly depress the core tube into the sediment using a rotating/twisting motion to assist in cutting root and peat material in order to minimize compaction. Unless the core tube is sharp enough to easily penetrate the soil and root/peat material, it may be necessary to cut around the base of the core tube straight up and down with a serrated knife through the root zone before inserting the core tube into the soil.
8. Depress the core tube to 30 cm depth or greater while continuing to rotate/twist the tube. Take care not to compact/compress the soil inside the tube.
9. To document compaction, measure the distance to the sediment surface on the outside and inside of the core tube. Measurements should be made with a ruler graduated in centimeters at the same place on the outside and inside of the core tube to avoid differences in ground height caused by uneven surfaces or vegetation density. If using the Meriwether corer, the cap should be removed or measurements should be taken through the cap before the cork is inserted, as best as possible given the soil consistency.
10. Record both measurements on the soil cores data sheet (Figure 8.4).
11. Core compaction should be 10% or less (i.e., < 3 cm for a 30-cm core) in most soil types. Highly organic soils (e.g., floating marsh, flooded swamp sites) may have a compaction rate of up to 20%. All caution should be taken to obtain cores with a minimal amount of compaction.
12. Plug or cap the top of the core tube to assure suction, filling the head space with water from the immediate area if using the Meriwether corer. If the soils are not saturated, no water should be added to the head space.
13. Remove the core from the marsh and quickly cap the bottom of the core tube to avoid loss of material.
14. Remove the bottom cap from the core tube and place the core tube on the core extruder.
15. Remove the stopper from the Meriwether corer to break the seal and remove the coring handle.
16. Position the core extruder plate so the surface of the soil core is at the top of the core tube.
17. Is the soil core solid enough to extrude and slice? If yes, go to the next step. If no, discard the soil core material away from all sampling areas and



- go back to step 5 above and take a second core. If the second core attempt results in a core too fluid to be sliced, go to step 22 below.
18. Extrude the top 4 cm of the soil core (0–4 cm), carefully slice, and place in a pre-labeled plastic bag or other airtight container. Any sample remaining on the knife should be included with the sample.
  19. Repeat for remaining intervals (4–8, 8–12, 12–16, 16–20, 20–24 cm).
  20. Repeat until three (3) viable cores have been taken and processed.
  21. Place all soil samples on ice and transport back to the lab.
  22. If the soil core is too fluid to be sliced (determined in step 17, above), take a 16-cm core using the following protocol (steps 23–33).
  23. Use a 4" inside-diameter sharpened clear acrylic, thin-walled aluminum, or PVC core tube. The Meriwether corer should not be used for this application.
  24. Slowly depress the core tube into the sediment using a rotating/twisting motion to assist in cutting root and peat material in order to minimize compaction. Unless the core tube is sharp enough to easily penetrate the soil and root/peat material, cut around the base of the core tube straight up and down with a serrated knife through the root zone before inserting the core tube into the soil.
  25. Depress the core tube to 16 cm depth while continuing to rotate/twist the tube. Take care to minimize compaction/compression of the soil inside the tube.
  26. To document compaction, measure the distance to the sediment surface on the outside and inside of the core tube with a ruler graduated in centimeters. Measurements should be made at the same place on the outside and inside of the core tube to avoid differences in ground height caused by uneven surfaces or vegetation density.
  27. Record both measurements on the soil core field data sheet.
  28. Core compaction should be 10% or less ( $< 1.6$  cm for a 16-cm core) in most soil types. Highly organic soils (e.g., floating marsh, flooded swamp sites) may have a compaction rate of up to 20%. All caution should be taken to obtain cores with a minimal amount of compaction.
  29. Plug or cap the top of the core tube to assure suction. Any head space should not be filled with external water for this application.
  30. Dig a narrow trench around one side of the core tube and place a flat, rigid object under the core tube to avoid loss of material upon removal.
  31. Extrude the entire 16-cm core, including all indigenous water in the core tube, into a pre-labeled larger plastic bag or other airtight container as a composite sample.
  32. Repeat until three (3) viable cores have been taken and processed.
  33. Place all soil samples on ice and transport to the lab within 48 hours.

The soil cores data sheet (Figure 8.4) shall be filled out completely. The Station field shall be S01, S02, and S03 for the first set of cores and should continue with S04, S05, and S06 for the second set of cores collected in 2014 at swamp sites and 2018 at marsh sites. After the core has been inserted into the soil matrix, measurements of the distance (cm) from the top of the core tube to the soil surface on both the inside and outside of the core tube should be recorded in the appropriate blanks on the data sheet. Additional measurements that are to be noted on the data sheet about each core include the exact length of the core tube being utilized (cm) and the depth of material that was extruded (Depth Extruded) from the core when it was sliced (cm). The latter measurement can be obtained by continuing to extrude the core down to the bottom after it has been sliced, noting the number of 0.5-cm revolutions required to reach the bottom of the core. These measurements will be used to calculate two types of compaction: compaction due to extraction or core sampling, and compaction due to extrusion and core slicing. These numbers will be used to assess core quality. Compaction due to extraction is calculated as:

$$\% \text{ Compaction} = ((\text{INSIDE-OUTSIDE})/(\text{Depth Inserted}))*100$$

and compaction due to extrusion is calculated as:

$$\% \text{ Compaction} = ((\text{Depth Extracted} - \text{Depth Extruded})/\text{Depth Extracted})*100.$$

Compaction due to extraction should be minimized as much as possible by inserting the core tube slowly, using a cutting blade, and using clear acrylic tubing to see inside the core as the core tube is depressed. Other descriptive information about each core should be included on the core data sheet, including site characteristics, soil characteristics, and core method.

### 8.3. Soil Data Processing

#### 8.3.1 Soil Laboratory Analysis

The following procedures will be used by a contracted laboratory to analyze soil pH, soil salinity (EC), dry bulk density, percent soil moisture, percent organic matter (loss-on-ignition), and wet/dry volume of the collected soil samples. These procedures, which were developed by the Coastal Wetlands Soils Characterization Lab, Department of Agronomy & Environmental Management, Louisiana State University, will provide a standardized procedure for all soil analyses associated with the CRMS project. Different soil laboratories may have slightly different protocols.

##### *Sample Delivery and Storage:*

All soil samples will be delivered to the contracted laboratory on ice in labeled, sealed containers. The chain of custody form (Figure 8.5) will be completed, documenting receipt of samples. All samples will be cold-stored (4°C) from the time of receipt until the samples are processed and analyzed.

##### *Analysis Protocols:*

#### **8.3.1.1 Soil pH**

Soil reaction (pH) is affected by the ratio of soil:water, the salt content, time of reaction, and the CO<sub>2</sub> content. It is therefore necessary to standardize conditions to obtain reproducible results.

##### **Soil pH Laboratory Materials:**

1. Deionized water
2. Glassware
3. pH meter (ORION 710A or equivalent)
4. Balance (OHAUS TS400 or equivalent)

##### **Soil pH Laboratory Procedures:**

1. Record soil sample ID number into laboratory log book.
2. Weigh vessel + sample (Vessel + Sample<sub>wet</sub>) to nearest 0.01 g to obtain Wet Sample Weight and record for Bulk Density processing
3. Take two, ~20-g subsamples of the soil sample from the container.

4. Weigh duplicate 20-g samples of fresh soil samples into beakers and record.
5. Add 20 ml of deionized water to each 20-g subsample.
6. Stir for one minute at 30-minute intervals for one hour (three times over one hour).
7. Calibrate pH meter before measuring the samples, using pH buffers 4.0 and 7.0. Recheck the meter with pH buffer 7.0 between every ten samples. If the meter does not read 7.0, recalibrate the meter, re-read any suspect previous samples, and proceed with the remaining samples.
8. Record the pH value after the meter is stable (approximately 1 minute after immersing the electrode).

No soil sample should be destroyed or compromised, as it will be added back to the soil analyzed for bulk density and subsequent percent organic analysis.

### **Soil pH Laboratory Calculations:**

Correct the readings for dilution with 20 ml of deionized water.

The results of soil pH will be reported based on the average of two replicated subsamples.

### **Soil pH Laboratory QA/QC:**

1. Handled all samples consistently. Use a stopwatch for stirring the samples.
2. Make sure the labels are correct and the data are recorded in the right position.
3. Make sure the samples are mixed thoroughly.
4. Run the two replications of the sample.
5. If the difference between the pH values of the two replicates (rep1 and rep2) of a sample is greater than 0.5, then repeat the analysis for that particular sample.

### **8.3.1.2 Soil Salinity (EC)**

Conductivity is measured in mS/cm (milliSiemens per centimeter) and gives an indication of soil salinity measured in ppt (parts per thousand). One mS/cm is equivalent to one mmhos/cm (millimhos per centimeter). Various EC meters measure in different ranges. Some meters even read low enough levels to measure in  $\mu\text{S/cm}$  (microSiemens per centimeter). It takes 1,000  $\mu\text{S/cm}$  to equal one mS/cm or one mmhos/cm.

Laboratories commonly make measurements on a 1:1 by weight of soil-to-water slurry, which is the method to be used in the EC analysis. EC analysis will use the same solution which was prepared for pH analysis.

### **Soil Salinity (EC) Laboratory Materials:**

1. Conductivity meter (Thermo Orion 150A+ or equivalent)
2. Calibration solutions (12.9 mS/cm and 1413 $\mu$ S/cm)
3. Deionized water

### **Soil Salinity (EC) Laboratory Procedures:**

Soil subsampling and dilution (1-5) were conducted for Soil.pH if performed:

1. Record soil sample ID number into laboratory log book.
2. Weigh wet sample including sample bag (Sample<sub>wet</sub> + Bag) to nearest 0.01 g and record for Bulk Density and Percent Moisture processing.
3. Take two, ~20-g subsamples of the soil sample from the container.
4. Weigh duplicate 20-g samples of fresh soil samples into beakers and record.
5. Add 20 ml of deionized water to each 20-g subsample.
6. Stir for one minute at 30-minute intervals for one hour (three times over one hour).
7. Record the EC value after the meter is stable (approximately 1 minute after immersing the electrode).

No soil sample should be destroyed or compromised, as it will be added back to the soil analyzed for bulk density and subsequent percent organic analysis.

### **Soil Salinity (EC) Laboratory Calculations:**

Correct the readings for dilution with 20 ml of deionized water.

The results of soil EC will be reported based on the average of two replicates.

### **Soil Salinity (EC) Laboratory QA/QC:**

1. Follow the procedure described in pH measurement.
2. Calibrate the EC meter between every measurement and check the reading in standard solutions (12.9 mS/cm or 1413 $\mu$ S/cm) every 10 samples.
3. If the difference between the EC values of the duplicate samples is greater than 5%, then repeat the analysis for that particular sample.
4. The sequence of reading and time between samples must be consistent.

### 1.3.1.3 Bulk Density, Soil Moisture, and Wet/Dry Volume Ratio

Bulk density, which is a measure of both the organic and inorganic fractions, may be expressed as either wet bulk density (includes the water in the sample) or as dry bulk density (the sample is allowed to dry). However, since the convention is normally to use dry bulk density, this discussion is confined to that variable. It has been shown that soil density is controlled by the amount of mineral material that infiltrates the organic material framework of the highly organic marsh soils (Gosselink and Hatton 1984). This organic material framework appears to have a fairly constant ratio of mass to volume. Dry bulk density values generally range from 0.05 g/cm<sup>3</sup> to 1.25 g/cm<sup>3</sup>. In highly organic soils, such as those found in coastal marshes, it is more meaningful to express soil nutrients in terms of volume instead of mass (Clarke and Hannon 1967; Mehlich 1972; Delaune et al. 1979; Rainey 1979). Since vegetation roots penetrate a given volume of soil as opposed to a given mass of soil, plant biomass shows a better relationship to soil nutrients expressed on a per volume basis as opposed to a per mass basis (Delaune et al. 1979).

All soil samples are refrigerated and maintained at a constant temperature of 4° C until analyzed. At this temperature the density of water is equal to 1 g/cm<sup>3</sup>, which means that 1 g of water will have a volume of 1 cm<sup>3</sup>.

#### **Bulk Density, Soil Moisture, and Wet/Dry Volume Materials:**

1. Soil sample of known volume
  - a. Cylinder of radius  $r$  (cm), height  $h$  (cm): Volume ( $V$ , cm<sup>3</sup>) =  $\pi r^2 h$
2. Drying oven
3. Balance sensitive to 0.01 g
4. Desiccator

#### **Bulk Density, Soil Moisture, and Wet/Dry Volume Procedures:**

1. Record soil sample number.
2. Weigh wet sample including sample bag ( $\text{Sample}_{\text{wet}} + \text{Bag}$ ) to nearest 0.01 g and record. This step would have been done if Soil pH or Salinity analyses were conducted.
3. Obtain Bag Weight ( $\text{Bag}_{\text{ave}}$ ) by averaging weight of 10 clean and dry bags from the same container of bags used as sample container. This step can be done prior to sample collection.
4. Weigh and record weight of labeled, dry, and clean drying vessel (Vessel).
5. Empty sample from bag and rinse contents sticking to bag into a labeled drying vessel and record vessel label with sample number. Note: The

(Sample<sub>wet</sub> + Bag) has already been recorded so a little water rinse will not change the calculations

6. Place drying vessel with sample in forced-air drying oven set at 60 °C for 48 hours.
7. Remove all drying vessels with samples from the oven, allow to cool in a desiccator, weigh, and record (Sample<sub>dry</sub> + Vessel).
8. Return all samples to the oven (60 °C) for 6 hours, cool in desiccator, and re-weigh. If weights are within  $\pm 5\%$  of the original dried weight, proceed to calculations. If weights are  $> \pm 5\%$ , place these samples back into the 60 °C oven for 24 hours, cool, and weigh. Repeat this process until a constant weight is obtained.
9. Record weight to nearest 0.01 g (Sample<sub>dry</sub> + Vessel).

### **Bulk Density, Soil Moisture, and Wet/Dry Volume Calculations:**

1. Wet Sample Weight (g) = (Sample<sub>wet</sub> + Bag) – Bag<sub>ave</sub>
2. Dry Sample Weight (g) = (Sample<sub>dry</sub> + Vessel) – Vessel
3. Oven Dry Bulk Density (g/cm<sup>3</sup>) = Dry Sample Weight (g) / Volume of Soil Sample (cm<sup>3</sup>)
4. Soil Moisture Content (%) = [(Wet Sample Weight – Dry Sample Weight) / (Wet Sample Weight)] \* 100
5. Wet Soil Volume (cm<sup>3</sup>) = Volume of Soil Sample  
 Where: Volume of Soil Sample (V, cm<sup>3</sup>) =  $\pi r^2 h$   
 $r$  = radius of core (5.08 cm for 4" ID core tube)  
 $H$  = height of samples (either 4 cm or 16 cm)
6. Dry Soil Volume (cm<sup>3</sup>) = Volume of Soil Sample – Volume of Water  
Note: Volume of Water (cm<sup>3</sup>) is a 1:1 conversion of the Weight of Water (g); therefore, the Volume of Water (cm<sup>3</sup>) = Wet Sample Weight (g) – Dry Sample Weight (g) found in in Soil Moisture Content.
7. Wet/Dry Volume Ratio = Wet Soil Volume / Dry Soil Volume

### **Bulk Density, Soil Moisture, and Wet/Dry Volume QA/QC:**

1. Check labels from sample bags and drying vessels match.
2. Average bag weights should be determined from the same package of bags.
3. Check that all samples are dried to a constant weight.

#### **8.3.1.4 Percent Organic Content (Loss-on-Ignition, LOI)**

Organic matter in soils and sediments is widely distributed in almost all terrestrial and aquatic environments (Schnitzer 1978). Soils and sediments contain a large variety of organic materials. The determination of organic carbon is an essential part of any site characterization since its presence or absence can markedly

influence how chemicals react in the soil or sediment. Organic carbon contents may be used qualitatively to assess the nature of the sampling location or to normalize portions of the analytical chemistry dataset. Loss-on-ignition (LOI) is a common and widely used method to estimate the organic matter content (Henri et al. 2001) and involves the heated destruction of all organic matter in the soil or sediment.

#### **Percent Organic Content Materials:**

1. 2-mm sieve (No. 10)
2. Ashing crucibles, numbered
3. Muffle furnace
4. Analytical balance (at least 0.001-g sensitivity)
5. Safety gloves (thermal and plastic)
6. Desiccator

#### **Percent Organic Content Procedures:**

1. With a gloved hand, break the dried soil sample from bulk density analysis into small pieces and homogenize.
2. Collect approximately half of the homogenized soil sample for further processing.
3. Grind the dried soil sample enough to pass through a 2-mm (No. 10) sieve screen. Note: Different grinding techniques (e.g. mortar and pestle, grinders) may be required for the soil (soil grinder) and plant material (plant grinder); if so, then mix ground soil and plant material before analysis. The mixed samples will also be used for the dry soil pH analysis. Note: If nutrient analyses are being conducted, transfer the sample to a ball mill or wiley mill for finer grinding.
4. Randomly select 10% of the samples to be analyzed for QA/QC and run replicate analyses.
5. Record the soil sample ID number, the crucible ID number, and the crucible tare weight into a laboratory log book.
6. Thoroughly homogenize the ground soil sample.
7. Weigh approximately 2–3 g of dried and ground soil that has passed through a 2-mm sieve into a clean crucible.
8. Record the crucible + soil sample weight (Crucible + Soil Wt. B<sub>60</sub>) into a laboratory log book. Note: The value “60” represents the temperature at which the sample was previously dried.
9. Place crucible + soil into a cool muffle furnace and bring temperature to 550 °C. Once the target temperature has been reached, leave samples in the furnace to ignite for 2 hours.
10. Remove crucible + soil sample (Crucible + Soil Wt. A<sub>550</sub>) from the furnace using safety gloves and tongs. Allow to air-cool slightly, then place in a



desiccator to prevent moisture accumulation. Note: The value “550” represents the temperature at which the sample was ignited.

11. Once cool, weigh to the nearest 0.001 g and record data in laboratory log book. Note: The remaining ash is the mineral component and the organic matter was lost during ignition of the soil sample.

12. Calculate the percent organic matter of the soil sample following the formula below.

### Percent Organic Content Calculations:

Percent Organic Matter (% O.M.):

$$\% \text{ O.M.} = \frac{[(\text{Soil Wt. } B_{60}) - (\text{Soil Wt. } A_{550})]}{(\text{Soil Wt. } B_{60})} \times 100$$

Where: Soil Wt.  $B_{60}$  = Weight of soil samples before ashing (previously dried at 60°C)

$$= [(\text{Crucible} + \text{Soil Wt. } B_{60}) - (\text{Crucible})]$$

Soil Wt.  $A_{550}$  = Weight of soil samples after ashing (at 550°C)

$$= [(\text{Crucible} + \text{Soil Wt. } A_{550}) - (\text{Crucible})]$$

### Percent Organic Content QA/QC

1. Replicates of 10% of samples will be run as a QA/QC check.
2. Calculate the percent difference between the replicate samples selected for QA/QC. If the sample organic content of the replicates is within  $\pm 5\%$  of each other, record the primary reading as the final reading.
3. If the QA/QC samples are not within  $\pm 5\%$  of each other, repeat the ashing process until the organic content is within  $\pm 5\%$ .

Data validation for these methods consists of checking to be sure that all sample containers are properly labeled and that sample numbers and crucible numbers are double-checked by laboratory personnel during analysis procedures. In addition, the laboratory personnel must be sure to check the labels on the standards before use.

### 8.3.2 Soil Data Reporting and Transferal from Lab to Contractor

Data reporting will be done by the laboratory as soon as the samples are analyzed. A report will be sent to the original contractor that collected the samples which will contain the following:

1. Chain of custody form
2. Values of standards
3. Results of QC checks
4. Analysis results in digital format provided by the CPRA (Figure 8.6).
5. Discussions of any problems along with steps taken to address them.

### 8.3.3 Soil Data Entry and QA/QC

**DATA ENTRY (PHASE I):** The contractor will obtain the sample analysis data in the appropriate format from the contracted laboratory. Data will be checked for completeness and consistency. Ensure that the data are within a logical range for each parameter measured (Table 8.1). If any data are deemed illogical, contact the contracted laboratory and resolve the discrepancy. Verify that the soil cores data sheet is complete.

**Table 8.1.** Soil parameters to be measured by the lab and their associated units with acceptable ranges.

Parameter	Acceptable Range
Soil pH	0 to 14
Soil salinity (EC)	0 to 90 mS/cm
Soil salinity (EC)	0 to 60 ppt
Bulk density	0.01 to 2.0 g/cm <sup>3</sup>
Soil moisture	0 to 100%
Percent organic matter (LOI)	0 to 100%
Wet volume	324.29 cm <sup>3</sup> (4 cm slice) or 1297.17 cm <sup>3</sup> (16 cm core)
Dry volume	less than wet volume (cm <sup>3</sup> )

**QUALITY ASSURANCE / QUALITY CONTROL (PHASE II):** Once the data from the laboratory has been checked and accepted by the contractor, wet pH, dry pH, soil salinity (ppt), bulk density (g/cm<sup>3</sup>), soil moisture (%), percent organic matter (%), and the calculated wet/dry volume ratio should be graphed as a soil profile with depth on the y-axis and the mean value  $\pm$  standard error of the three cores from each site on the x-axis. The variability within the three cores for a site at a depth should be low (less than 5%). If not, re-check data from the laboratory for correctness. Verify that the contracted soils laboratory followed the appropriate QA/QC protocols.

Once the data have been fully QA/QC'd, the .xls file containing the analysis results (Figure 8.6) shall be saved (.xls) with one file for each CRMS site.

### 8.4 Soil Deliverables

The following deliverables shall be placed on the CRMS Data Depot site in the "Soil Properties" folder:

1. The analysis results in .xls format from soils laboratory.
2. The soil cores data sheet in .pdf format (Figure 8.4).
3. The chain of custody form in .pdf format (Figure 8.5).
4. The data upload file in .xls format (Figure 8.6)

The original sediment cores data sheet and chain of custody form shall be delivered to the CPRA within one week of electronic data delivery.

## 8. Soil Properties

Station ID	Group	Sample Date (mm/dd/yyyy)	Sample Depth (cm)	Wet Soil pH (pH units)	Dry Soil pH (pH units)	Soil Specific Conductance (uS/cm)	Soil Salinity (ppt)
CRMS####-S##		##/##/20##	0 to 4	###	###	#####	###.##
CRMS####-S##		##/##/20##	4 to 8	###	###	#####	###.##
CRMS####-S##		##/##/20##	8 to 12	###	###	#####	###.##
CRMS####-S##		##/##/20##	12 to 16	###	###	#####	###.##
CRMS####-S##		##/##/20##	16 to 20	###	###	#####	###.##
CRMS####-S##		##/##/20##	20 to 24	###	###	#####	###.##

(continued...)

Soil Moisture Content (%)	Bulk Density (g/cm3)	Organic Matter (%)	Wet Volume (cm3)	Dry Volume (cm3)	Biomass Target Flora Species	Belowground Live Biomass (g/m2)	Belowground Dead Biomass (g/m2)
###.##	###.##	###.##	#####.##	#####.##			
###.##	###.##	###.##	#####.##	#####.##			
###.##	###.##	###.##	#####.##	#####.##			
###.##	###.##	###.##	#####.##	#####.##			
###.##	###.##	###.##	#####.##	#####.##			
###.##	###.##	###.##	#####.##	#####.##			

(continued)

Belowground Dead Biomass (g/m2)	Organic Density (g/cm3)	Total Carbon (g/kg)	Carbon Density (mg/cm3)	Total Nitrogen (g/kg)	Total Phosphorus (mg/kg)	Sand (%)	Silt (%)	Clay (%)	Particl e Size Mean (phi)
	###.##								
	###.##								
	###.##								
	###.##								
	###.##								
	###.##								

(continued)

Particle Size Median (phi)	Particle Size Standard Deviation (phi)	Organization	Personnel	Comments
		Collecting Contractor/Agency	F. Last	
		Collecting Contractor/Agency	F. Last	
		Collecting Contractor/Agency	F. Last	
		Collecting Contractor/Agency	F. Last	
		Collecting Contractor/Agency	F. Last	
###.##	###.##	Collecting Contractor/Agency	F. Last	

**Figure 8.6.** Soil core data format in .xlsx and CIMS. Soil pH, Specific Conductance, and Soil Salinity is no longer analyzed for soil properties. Organic Density and Carbon Density are calculated in CIMS.

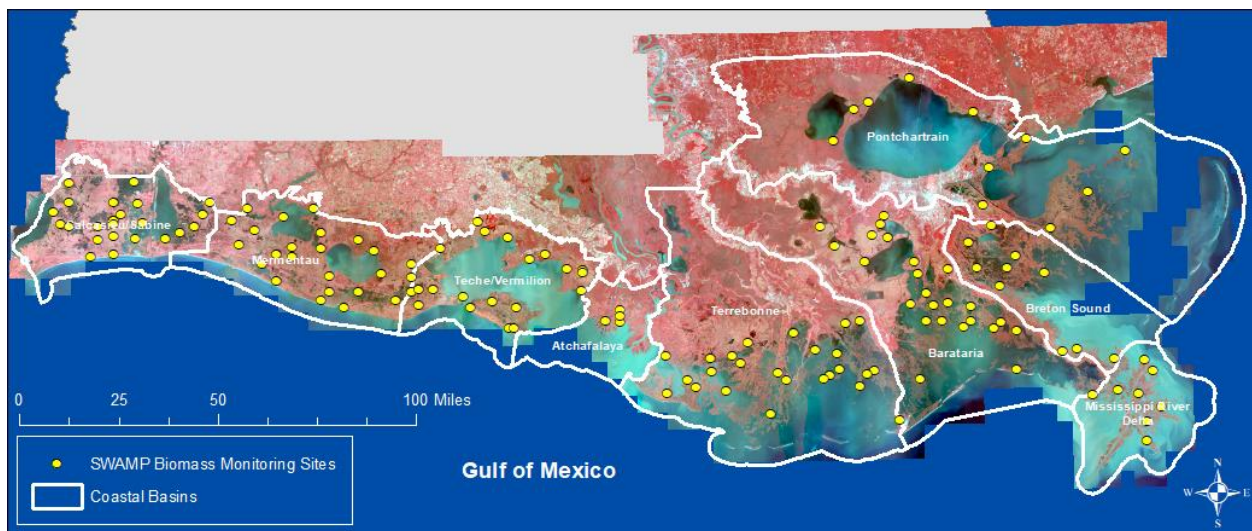
## 9 Aboveground and Belowground Vegetation Biomass and Nutrients

Wetland biomass production, decomposition, and storage of organic matter govern estuarine energy transfer, in addition to determining the physical sustainability of marshes exposed to sea-level rise and subsidence. Peak standing biomass represents an indicator of wetland production or productivity but does not account for turnover (production and decomposition) of different pools of biomass with time. Understanding the nutrient status of plant biomass can be particularly helpful in diagnosing what constituents may be limiting wetland production. The biomass and nutrient measures described in the following field/laboratory data collection procedures are designed to provide the raw data to support predictive ecosystem models, as well as answer basic wetland process questions that will help inform restoration decisions.

The following procedures outline the field and laboratory methods to collect vegetation biomass and other plant or soil characteristics as needed for the SWAMP. The sampling design incorporates expanded collection from predefined target plant species that typically occur within selected CRMS stations. CPRA will provide instructions regarding any data collection adjustments that may deviate from the general steps provided herein.

### 9.1 Station Establishment

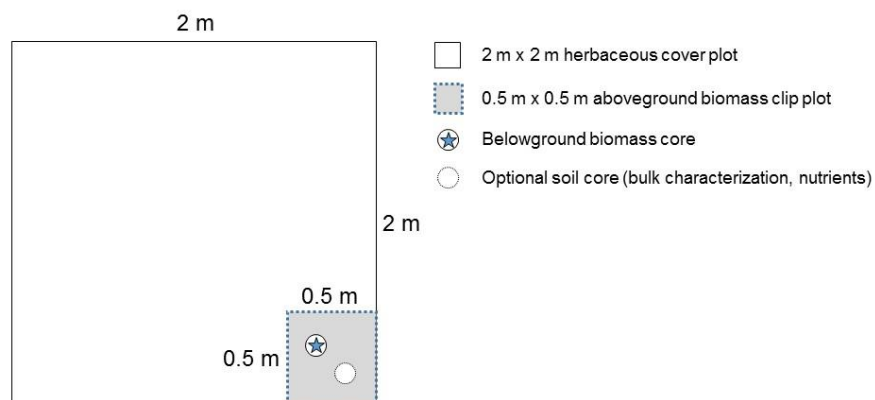
Aboveground and belowground biomass and nutrient samples will be collected for the SWAMP program at selected CRMS sites in each hydrologic basin (162 total sites, Figure 9.1). After baseline samples are collected, vegetation parameters will be sampled every 5 years. Sampling should occur between June 1 and September 30 with flexibility allowed for unforeseen events. Scheduling consideration should be given to sites with access controlled by private land owners.



**Figure 9.1.** Vegetation biomass sites for SWAMP at CRMS sites.

The primary intent of biomass sampling is to inform CPRA master plan models, which are primarily concerned with seven taxa (hereafter referred to as “target species”): *Spartina alterniflora*, *Spartina patens*, *Sagittaria latifolia*, *Sagittaria lancifolia*, *Zizaniopsis miliacea*, *Typha* spp., and *Phragmites* spp. Sites for biomass and nutrient monitoring have been selected because they contain at least one of the seven target species. Because vegetation composition can be highly variable within a site, vegetation station locations should be carefully selected in areas with taxa that are representative of the site as a whole. Prior to sampling field trips, CRMS vegetation data will be examined to identify areas along the vegetation transect that are likely to have the target species. In the case where species composition at a selected site has changed since the previous CRMS vegetation transect data collection, and the selected site does not contain any of the seven target species, three random plots will be established that represent the dominant species. Prior to field access, CPRA will provide the locations where destructive sampling is permitted and will also provide the target species for the random vegetation stations that will be sampled. Field personnel will secure landowner permission for site access.

The vegetation biomass and nutrients sampling design includes stations for collecting herbaceous marsh species percent cover (see Chapter 7.1.1. Vegetation - Herbaceous Vegetation Sampling), aboveground biomass and nutrients, belowground biomass, and soil characterization and nutrients. All data will be collected from within three (3) replicate 2 m x 2 m vegetation stations. Nested within each vegetation station is one 0.5 m x 0.5 m aboveground biomass clip-plot. Nested within the clip-plot are 2 soil core locations, one for belowground biomass sampling, and one for soil characterization and nutrient analysis (Figure 9.2). Vegetation stations should be located at least 10 m from CRMS boardwalks or vegetation transects to avoid impeding upon other CRMS data collection efforts. The stations should be replicates of one another and contain the same target vegetation taxa. Each station will be identified with GPS coordinates. Different data types should share the same station numbers when possible. Filling out a SWAMP Biomass Controls datasheet as station establishment, sampling, and sample/data progress is helpful with keeping track (Figure 9.3).



**Figure 9.2.** Diagram of the nested biomass and soil core stations.

SWAMP BIOMASS VEGETATION CONTROLS DATASHEET	
Site ID: _____	Date: _____
Field Crew: _____	Weather: _____
Dominant Species: _____	
Site Latitude _____	Longitude _____
<b>SAMPLING: SUMMARY, from Each Plot:</b>	
<b>Cover Estimate</b>	<b>1 Biomass Core</b>
<b>1 Aboveground Harvest</b>	<b>1 Soil Nutrient Core</b>
<b>1 Leaf Tissue Nutrient Sample</b>	
1. Establish 3 Vegetation Stations to represent target taxa (3 replicate plots): YES NO	
2. Record GPS location for each Biomass Station: YES NO	
Station 1: _____ Station 2: _____ Station 3: _____	
3. Cover Estimate (Use attached CRMS Veg Sheet, 3 plots) : YES NO	
4. Photo of plot taken: YES NO	
Plot# _____ Camera #: _____ Picture Numbers: _____	
Plot# _____ Camera #: _____ Picture Numbers: _____	
Plot# _____ Camera #: _____ Picture Numbers: _____	
If no photos obtained, explain:	
****COMPLETE COVER ESTIMATE BEFORE HARVESTING PLOT****	
5. Aboveground Biomass Harvested ( 3, 0.25m <sup>2</sup> clip plots nested within the 2 x 2m veg plots): YES NO If not all 3 harvested, explain:	
6. Leaf Tissue Nutrient sample collected for each target species and/or dominant species near each of three veg plots: YES NO If not all 3 plots collected, explain:	
7. Belowground Biomass Taken (1, 30-cm core from each 0.25m <sup>2</sup> plot): YES NO	
8. Biomass Cores cut at 8, 16 and 24 cm depth: YES NO If not, explain:	
9. Soil Properties/Nutrient Cores collected (1, 30-cm core from each 0.25m <sup>2</sup> plot): YES NO	
10. Soil Properties/Nutrient Cores cut at 4, 8, 12, 16, 20, and 24 cm depth: YES NO If not, explain:	

**Figure 9.3a.** SWAMP Biomass Controls datasheet for station establishment and sampling

<p><b>SWAMP Vegetation Biomass Samples Controls Sheet (cont.)</b></p> <p>Site: _____ Date: _____</p> <p>Field Crew: _____</p> <p><b>SAMPLE STORAGE/DATA STORAGE:</b></p> <p>11. Chain of custody form completed? YES    NO</p> <p>12. Aboveground Biomass Samples ( 3 bags/site) transported to processing lab, labeled with water-proof tag and placed in cooler: YES            NO</p> <p>If not, explain:</p> <p>13. Aboveground Tissue Nutrient Samples (at least 3 bags/site) transported to processing lab, labeled with water-proof tag and placed in cooler: YES            NO</p> <p>If not, explain:</p> <p>14. Belowground Biomass Core Samples (9 bags/site) transported to processing lab, labeled with water-proof tag and placed in cooler: YES            NO</p> <p>If no, explain:</p> <p>15. Soil Properties and Nutrient Core Samples (18 bags/site) transported to processing lab, labeled with water-proof tag and placed in cooler: YES            NO</p> <p>If no, explain:</p> <p>16. Datasheets scanned and saved to YES    NO</p> <p>If not, explain:</p> <p>17. Photos uploaded and saved YES    NO</p> <p>***Create a new folder for each site***</p> <p>If not, explain:</p> <p>Other notes or comments.</p>	
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**Figure 9.3b.** SWAMP Biomass Controls datasheet for sample and data storage



## 9.2 Field Data and Sample Collection

### 9.2.1 Herbaceous Marsh Vegetation Data Collection

In an effort to correlate destructively harvested biomass data with non-destructive historical and future CRMS herbaceous vegetation assessments, the CRMS emergent vegetation Braun-Blanquet sampling method (Mueller-Dombois and Ellenburg, 1974; see Chapter 7.1.1. Vegetation - Herbaceous Vegetation Sampling) will be used at each biomass station. Field station locations will be located within the area inhabited by target species. The vegetation data will be given the naming convention CRMS####-VB## to indicate vegetation at biomass plots and recorded on the Herbaceous Marsh Vegetation Sampling Data Sheet (Figure 7.1). Data will be uploaded to Coastal Information Management System (CIMS) as described in Chapter 7.1.2 Vegetation - Herbaceous Vegetation and Porewater Data Processing.

The 2 m x 2 m herbaceous vegetation assessment will be conducted first and care shall be taken to avoid damage to the vegetation and marsh surface inside the plot as additional sampling will be performed (Figure 9.2). Progress will be recorded on Biomass Control data sheet (Figure 9.3a).

### 9.2.2 Aboveground Biomass Collection

Aboveground biomass samples will be collected using a clip-plot method in which vegetation is destructively cut and harvested from a 0.5 m x 0.5 m area within the 2 m x 2 m vegetation station (Figure 9.2).

*Field Safety:* Collecting biomass and soil cores requires adequately sharpened equipment to accomplish the job effectively; poorly sharpened instruments carry even higher risks of human injury due to physical ‘over-forcing’ of the task. While gloves and eyeglasses are standard PPE to execute these activities, the use of bypass or anvil pruners or other clipping tools to sever vegetation requires extra *awareness of the location of both hands as they move*—the one hand that is clipping and the other hand that is securing the bundles of vegetation as they are cut. Care should be taken to keep the retrieving/holding hand safely away from the cutting shears.

1. Station ID: There will be three (3) aboveground biomass clip-plots (replicates) harvested at each selected CRMS site. Station ID naming convention will use “BAG” to distinguish the Biomass Aboveground parameter (CRMS####-BAG##) and will share the same station number as the larger vegetation plot.
2. Plot size: Aboveground biomass will be collected from 0.5 m x 0.5 m quadrats in the SE corner of the larger 2 m x 2 m vegetation station (Figure 9.2).
3. Biomass harvesting:
  - a. A quadrat 0.5 m x 0.5 m will be placed around the vegetation at the sampling location. The quadrat should have one open end, which will facilitate sliding the quadrat around the bottom of the vegetation. Care should be taken to

avoid damaging the vegetation and while placing all rooted plants inside the quadrat. Extra care should be taken when the surface is under flooded conditions and visibility is not optimal.

- b. With the quadrat in place, the live and dead stems of vegetation will be clipped as close as possible to the soil surface.
- c. All aboveground live and dead biomass components from the sample plot will be collected intact into one large, plastic garbage bag (unless more than one is needed) and labelled appropriately with both an internal and external waterproof identification tag.

*Note:* Stems of the target species should not be broken in order to fit a plastic bag size; instead, larger bags should be used to accommodate the length of the species. This will ensure that target species are kept intact—from base to tip—for consistent length and diameter data to be measured in the laboratory. *Phragmites spp.* may carefully be folded to fit into a large bag; but, first randomly select five stems and measure stem lengths and base diameters to transfer with the sample to the sample processors (see 7.3.3.1).

- d. After collection of the standing live and dead fractions, there may still be residual dead culms and litter laying above the soil surface. These residual culms and fresh litter will be collected with a light passage of the hand over the plot, without excessive scraping and removal of particulate surface detritus.
- e. Target species and dominant species for each aboveground biomass clip plot will be recorded on chain of custody sheet to accompany aboveground biomass clip samples to the processing laboratory.
- f. All samples should be accounted for before leaving the vegetation station (Figure 7.14a).

### 4. Sample Treatment from Field to Lab:

- a. The team will strive to protect the physical integrity and timeliness of the samples from field to cold storage.
- b. The samples will be stored in a cooler with ice during transport from the field to the lab. A cooler with extra ice may be kept at the launch to cool the plants from the field to the lab. The above ground sample does not have to be kept on ice while in the field unless the trip will extend for more than one field day.
- c. All aboveground samples will be delivered to cold storage within the evening of the day that they are harvested, or no more than 18 hours after harvesting.
- d. All samples should be accounted for before leaving the lab (Figure 7.14b).
- e. The lab shall maintain the samples at 4 °C temperature.

### 9.2.3 Aboveground Tissue Nutrient Collection

Leaf or aboveground green/live tissue will be collected separately from the aboveground biomass samples in a manner to not affect the aboveground biomass measurement and to reduce contamination for the nutrient analyses that are to be conducted. At each station, one sample per target taxa, or the dominant species if not a target taxa, will be collected near each vegetation station. The live leaf material should be collected from outside of the 2 m x 2 m vegetation station. Three sets of aboveground tissue samples will be collected at each site (i.e. 1 set per vegetation station).

#### Collection and Types of Tissue:

- a. Mature green (live) leaves will be collected, with care to exclude stems. Avoid the youngest new tissue or leaves that are undergoing senescence.
- b. With clean hands, approximately 10 g of fresh leaf tissue will be collected (approximately a full quart-sized closeable plastic bag).
- c. The tissue samples will be placed in separate, sealable, and labelled plastic bags. Sharing the same station number as the larger vegetation plot, the naming convention will use “TN-GeSp” to distinguish the Tissue Nutrient parameter and species collected (CRMS####-TN##-GeSp).
- d. Tissue samples will be placed in an iced cooler during transport from the field to the lab.

### 9.2.4 Belowground Biomass Collection

The collection of belowground biomass will occur in the plots where aboveground biomass was collected (Figure 9.2). Core tubes will be sharpened to cut through roots and minimize soil compaction. The methods used for field collection of cores will follow the Chapter 8.2 Soil Properties – Soil Data Collection.

1. Core number: There will be three (3) belowground biomass cores collected from each site. Sharing the same station number as the larger vegetation plot, station ID naming convention will use “BBG” to distinguish the Biomass Belowground parameter (CRMS####-BBG##).
2. Core diameter: The inner diameter of the core tube should be 10.16 cm (4 in).
3. Core location: Cores will be taken on a surface that is representative of the Vegetation Biomass Station (i.e., not on obvious high or low points, on clumps, or in trenasses/animal trails). If in a *Spartina patens* dominated marsh, cores should be taken on top of culms of vegetation.
4. Core depth and sectioning:
  - a. The core tube will be inserted to approximately 30-cm depth to minimize loss of soil from the bottom of the core when extracted.

- b. Following procedures set out in Chapter 8.2 Soil Properties – Soil Data Collection, core compaction will be measured, calculated and recorded (Figure 8.4). If compaction thresholds are exceeded, the core will be re-sampled per SOP guidelines.
  - c. The core should be extruded in a fashion that minimizes compaction and allows for controlled sectioning at 8-cm intervals.
  - d. Three (3) 8-cm sections will be collected from each core and placed into pre-labeled, gallon-sized, closeable, plastic bags (1 bag per section). The remainder of the core beyond 24 cm will be returned to the core hole after the total depth of the core is determined and recorded.
  - e. If soil cores do not meet the full 24 cm depth criteria, clear notes should be recorded on the data sheet indicating the revised core section depth so that correct core volumes can be used in calculations. Any deviation should be clearly communicated to the processing lab.
  - f. In unconsolidated soils, the top 16 cm section of the core will be collected, the rest of the sample discarded, the soil conditions and core length notated.
5. All samples should be accounted for before leaving the station (Figure 9.3a).
  6. Sample Treatment from Field to Lab: The samples will be stored in a cooler with ice during transport from the field to the lab.

### 9.2.5 Soil Properties and Nutrient Collection

A second core will be extracted from each Vegetation Biomass plot for quantification of soil properties and nutrients (Figure 9.2). The core should be taken from a similar surface as was used for the biomass core, following core collection procedures described in Chapter 8.2 Soil Properties – Soil Data Collection (Figure 8.4).

1. Core number: There will be three (3) soil properties cores collected from each site. Sharing the same station number as the Vegetation Biomass plot, station ID naming convention will use “BS” (CRMS####-SB##) to be consistent with other Vegetation Biomass parameters and distinguish from the CRMS soil properties cores.
2. Core diameter: The inner diameter of the core tube should be 10.16 cm (4 in).
3. Core location: Cores will be taken on a surface that is representative of the Vegetation Biomass Station (i.e., not on obvious high or low points, on clumps, or in trenasses/animal trails). If failed core attempts in the biomass plot demand that the core be collected from another location, clip the surface of the nearby marsh and take a representative core. If in a *Spartina patens* dominated marsh, cores should be taken on top of culms of vegetation.
4. Core depth and sectioning:

- a. The core tube will be inserted to approximately 30-cm depth to minimize loss of soil from the bottom of the core when extracted.
  - b. Following procedures set out in Chapter 8.2 Soil Properties – Soil Data Collection, core compaction will be measured, calculated, and recorded (Figure 8.4). If compaction thresholds are exceeded, the core will be re-sampled per SOP guidelines.
  - c. The core should be extruded in a fashion that minimizes compaction and allows for controlled sectioning at 8-cm intervals.
  - d. Six (6) 4-cm sections will be collected from each core and placed into pre-labeled, gallon-sized, closeable, plastic bags (1 bag per section). The remainder of the core beyond 24 cm will be returned to the core hole after the total depth of the core is determined and recorded.
  - e. If soil cores do not meet the full 24-cm depth criteria, clear notes should be recorded on the data sheet indicating the revised core section depth so that correct core volumes can be used in calculations. Any deviation should be clearly communicated to the processing lab.
  - f. In unconsolidated soils, the top 16-cm section of the core will be collected, the rest of the sample discarded, the soil conditions and core length notated.
5. All samples should be accounted for before leaving the station (Figure 9.3a).
  6. Sample Treatment from Field to Lab: The samples will be stored in a cooler with ice during transport from the field to the lab.

### 9.2.6 Laboratory Transport and Storage

**Sample Delivery and Storage:** All vegetation and soil samples will be delivered on ice to the contract laboratory in labeled, sealed containers. To verify transfer of samples, chain of custody (COC) forms will be completed for each receiving laboratory: Aboveground and Belowground Biomass and Belowground Soil Properties and Nutrients (Figure 7.4). All samples will be cold stored at 4° C from the time of receipt until the samples are processed and analyzed.

## 9. Vegetation Biomass

CHAIN-OF-CUSTODY for Above- and Belowground Biomass and Nutrients				
<b>Collector Information</b> Facility City, ST ZipCode Contact Email Phone			<b>Project Information</b> Project Name: SWAMP Biomass Report To: Project Lead	
			<b>Samples Shipped To:</b> Facility City, ST ZipCode Contact Email Phone	
SAMPLE INFORMATION			REQUESTED ANALYSIS	Species of Interest
Item #	Sample ID	Collection Date	Biomass Above Ground (BAG), Leaf Tissue Nutrients (TN), Biomass Belowground (BBG)	For Aboveground Biomass and Tissue samples: Provide Target and/or Dominant Species (Genus species)
1	CRMS####-BAG01	mm/dd/yyyy	BAG	<i>Sagittaria lancifolia</i> , <i>Spartina patens</i>
2	CRMS####-BAG01-TN-1	mm/dd/yyyy	TN	<i>Spartina patens</i>
3	CRMS####-BAG01-TN-2	mm/dd/yyyy	TN	<i>Sagittaria lancifolia</i>
4	CRMS####-BBG01	mm/dd/yyyy	BBG	NA
5	CRMS####-BAG02	mm/dd/yyyy	BAG	<i>Sagittaria lancifolia</i>
6	CRMS####-BAG02-TN-1	mm/dd/yyyy	TN	<i>Sagittaria lancifolia</i>
7	CRMS####-BBG02	mm/dd/yyyy	BBG	NA
8	CRMS####-BAG03	mm/dd/yyyy	BAG	<i>Sagittaria lancifolia</i> , <i>Spartina patens</i>
9	CRMS####-BAG03-TN-1	mm/dd/yyyy	TN	<i>Spartina patens</i>
10	CRMS####-BAG03-TN-2	mm/dd/yyyy	TN	<i>Sagittaria lancifolia</i>
11	CRMS####-BBG03	mm/dd/yyyy	BBG	NA
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
Sampled by: _____ Relinquished by: _____ Date/Time: _____				
Accepted by: _____ Date/Time: _____				
<b>Sample Condition</b> Received on Ice?                      Sample Intact?                      Species of Interest Confirmed? YES / NO                                      YES / NO                                      YES / NO				

**Figure 9.4.** Chain of Custody form for SWAMP Biomass samples

### 9.3 Aboveground and Belowground Sample Processing

#### 9.3.1 Aboveground Biomass Processing

Live and dead biomass components will be separated to obtain dry masses of each. Further separation to species will be determined by the dominant species and by target species as prescribed by individual task order. Stem length and diameter will be measured for the target and dominant (non-target) species.

1. Bags will be oven-dried at 60°C for 48 hours. Record weight on bag.
2. All plant material will be carefully rinsed with deionized water and allowed to air dry while processing.
3. Live biomass will be separated from dead biomass. Live biomass will be defined by the presence of green, yellow, red, or purple pigments in leaf material and stems. The presence of any detectable pigment will qualify any plant as live. Complete absence of pigment will be considered dead.
4. The target and dominant (non-target) species will be separated from all other live biomass. Thus, the total sample will be reduced to three main pools:
  - a. Live biomass for each targeted and dominant (non-target) species
  - b. Live biomass of all other species present (not including the above species of interest)
  - c. Dead biomass of all species
5. For each targeted species and dominant (not target), the following information will be obtained and recorded (Figure 9.5):
  - a. Total stem count (number of stems) per each species
  - b. Stem length to the nearest 0.1 cm for five (5) randomly selected stems. If less than 5 stems, then measure all stems.
  - c. Of the 5 stems selected for length, obtain the basal stem diameter to the nearest 0.1 mm. To measure basal stem diameter, use calipers to measure diameter at base of shoot.
6. Each component will be placed in a separate, labeled paper bag(s). Biomass may be cut to fit in bags after stem length and diameter measurements have been made. Each bag will be labeled as follows:

CRMS SWAMP

STATION ID (ex: CRMS3641-BAG01)

COMPONENT (ex. Target/Dominant species or "Other Live" or "Dead")

Collection date

Process date

Name (first initial, last name)

## 9. Vegetation Biomass

7. Larger components may require more than one bag. Multiple bags from a single STATION ID will be labeled as Bag # of Total # of Bags (ex. Bag 1 of 5). There will be a minimum of three bags per sample.
8. After 72 hours, 2-3 bags will be removed and the weight of the bag and plant together recorded. The bags will be returned to the oven for 24 hrs, and then re-weighed in the same manner. Dry samples will have less than a 1% reduction in weight over this 24 hr period, determined as:

$$((1 - (\text{weight at time 2} / \text{weight at time 1})) * 100$$

9. After the biomass is dry, the Biomass + Bag Mass and corresponding Bag Mass will be recorded to the nearest 0.1 g (Figure 9.5).
10. Data from Sample Processing data sheet will be entered into spreadsheet to transform raw data into data formatted for entry into CIMS:
  - Subtract out Bag Mass for Aboveground Biomass columns.
  - Convert Aboveground Biomass from the 0.25 m<sup>2</sup> plots to g/m<sup>2</sup>.
  - For Live Stem Height and Diameters, calculate the averages and standard errors.

Sample Processing - CRMS SWAMP Aboveground Biomass											
Sample ID (CRMS####-BAG##)	Bag (#)	Component (Target sp/ Dominant Sp/ Remaining Live/ Dead)	Initial Storage (MM-DD-YYYY)	Sorted (MM-DD-YYYY)	Stem Count (N)	Stem Length (cm.)	Stem Diameter (mm.)	Biomass + Bag Mass (g.)	Bag Mass (g.)	Initial	Comments
	1	Genus species - Dominant			###	###.#	##.#	####.##	####.##		
	2					###.#	##.#	####.##	####.##		
	3					###.#	##.#	####.##	####.##		
						###.#	##.#				
						###.#	##.#				
	4	Genus species - Target 1			###	###.#	##.#	####.##	####.##		
						###.#	##.#				
						###.#	##.#				
						###.#	##.#				
						###.#	##.#				
						###.#	##.#				
	5	Remaining Live						####.##	####.##		
	6	Remaining Live						####.##	####.##		
	7	Dead						####.##	####.##		
	8	Dead						####.##	####.##		

Each bag of biomass gets a separate line with a minimum of 3 bags per sample. Some Components require more than 1 bag.

Each Target Sp and non-target Dominant has a stem count and 5 stems measured (length and diameter) if available.

Dominant species can be a Target species or a non-Target species

**Figure 9.5.** Example datasheet for Aboveground Biomass Processing



### 9.3.2 Aboveground Tissue Nutrient Processing

#### Preparation:

1. Laboratory personnel will wear gloves at all times when handling samples for nutrient analysis.
2. Paper bag will be labeled as follows and bag mass recorded (Figure 9.6):  
CRMS SWAMP  
SWAMP ID (ex: CRMS3641-BAG01-TN1)  
SPECIES ID (ex: *Sagittaria lancifolia*)  
Collection Date (from chain of custody form)  
Process Date  
Name (first initial, last name)
3. Any dead material from the Tissue Nutrient Sample will be removed and discarded.
4. Leaves will be rinsed carefully with DI water.
5. Rinsed leaves will be placed in labeled paper bag (Figure 9.6).
6. All equipment will be cleaned with DI water between samples.
7. Labeled paper bag containing plant tissue will be placed in forced-air drying oven at 60 °C.
8. The aboveground tissue nutrient samples will be dried to a constant weight at 60°C in the drying oven (see 9.3.1 Aboveground Biomass Processing – Step 8) and mass recorded at each time interval (Figure 9.6).
9. The dried samples will be stored in the original labeled paper bag placed inside an airtight plastic bin until further processing.

#### Tissue Sample Grinding:

10. If samples are too large to place directly in the Wiley Mill, plant samples will be cut into 10-cm lengths using clean clippers. The clipped tissue will be thoroughly mixed to create a homogeneous mixture. Small samples (e.g., leaf tissue) will be ground directly in the Wiley Mill.
11. The sample will be passed through the Wiley Mill with a 20 mesh (850µm) sieve. The ground sample will be placed in a small, Whirlpak-like bag labeled with the same information from the associated paper bag(s).
12. The ground sample will be thoroughly mixed in the Whirlpak-like bag to create a homogenous sample.
13. Individual scintillation vials will be labeled with information from Whirlpak-like bags:  
CRMS SWAMP CHN  
SWAMP ID (ex: CRMS3641-BAG01-TN1)  
SPECIES ID (ex: *Sagittaria lancifolia*)  
COLLECTION DATE
14. A clean plastic scoop will be used to transfer a subsample of the homogenous mixture to a sterile glass scintillation vial; the mass of subsample and volume of scintillation vial will be dictated by the analyses laboratory. Remaining material will be stored in the labeled, Whirlpak-like bag for future analyses. The bags will be stored in plastic airtight bin.

15. The ground subsample in the scintillation vial (with a loose cap) will be dried at 60°C for 72 hours, then placed (with a tightened cap) in desiccator until analyzed for nutrients.
16. The Wiley Mill should be cleaned between each sample. The glass cover will be removed and a brush used to clean tissue particles from the blades. The chamber should be vacuumed and the blade area and funnel should be cleaned with a canned-air duster.

Sample ID (CRMS###-BAG##-TN#)	Genus species (Target sp/ Dominant Sp)	Initial Storage (Date)	Rinse (Date)	Oven Dried (Date)	Bag Mass (g.##)	Dry Tissue Mass			Intermed Storage (Date)	Wiley Mill (Date)	Scint. Vial Oven (Date)	Ground Subsample Mass (g.##)
						72 hr (g.##)	24 hr (g.##)	Extra Time (g.##)				
CRMS###-BAG01-TN1	Genus species - Dominant				##.##	##.##	##.##	##.##				##.##
CRMS###-BAG01-TN2	Genus species - Target 1				##.##	##.##	##.##	##.##				##.##
CRMS###-BAG02-TN1	Genus species - Dominant/Target 1				##.##	##.##	##.##	##.##				##.##
CRMS###-BAG02-TN2	Genus species - Target 2				##.##	##.##	##.##	##.##				##.##
CRMS###-BAG02-TN3	Genus species - Target 3				##.##	##.##	##.##	##.##				##.##
CRMS###-BAG02-TN2	Genus species - Dominant/Target 1				##.##	##.##	##.##	##.##				##.##
CRMS###-BAG02-TN1	Genus species - Target 2				##.##	##.##	##.##	##.##				##.##

Each Target (up to 7) and non-target Dominant (1) species gets a separate line.  
Dominant species can be a Target species or a non-Target species.

**Figure 9.6.** Example datasheet for Aboveground Tissue Nutrient sample processing.

#### Plant Tissue Nutrient Analyses:

Analyses of total carbon, total nitrogen, and total phosphorous of pre-weighed ground sample using a dry combustion technique will be performed in-house or by a subcontracted laboratory following specification in place by the laboratory (e.g. Tiessen and Moir, 1993; McGill and Figueiredo, 1993). Proper QA/QC should be conducted during analysis, including the use of standard curves developed from certified materials recommended by manufacturer. Additional QA/QC checks should be performed with certified standards after every tenth sample.

### 9.3.3 Belowground Biomass Processing

The separation of belowground biomass requires distinguishing between live and dead fractions. Using a sieve (1-mm mesh size), the mineral soil and very fine organic particles will wash out with water, leaving macro organic matter. The macro organic matter will then be sorted into live and dead fractions. The live fraction will include live roots and rhizomes. The dead fraction will include dead roots and rhizomes as well as unidentifiable organic matter (Schubauer and Hopkinson 1984; Neill, 1992).

Live fractions will be separated using several criteria including color, turgidity, buoyancy, and plasticity/brittleness to physical resistance. In most cases wetland plants and their organs will have a 'whiteness' factor (white, blonde, beige), and this is often accompanied by turgidity (hydrated cells), as opposed to a stained, necrotic, or flaccid condition of dead or dying tissue. Extensive small roots hairs arising from large roots and rhizomes may help provide clues to freshness. Whereas most species have live roots that are 'white', some species, such as *Juncus roemerianus* (black needle rush), may have very dark

color on the exterior of the rhizomes, but by breaking these open there may be white tissue that indicates live condition.

The live and dead fractions will be sorted out into tins. Because of varying amounts of each fraction, different sized tins will be used.

1. Tins 1, 2, 3, ...n will be pre-labeled and several tins from each size category will be included. Each tin should have a unique identifier.
2. Labeled tins will be oven-dried at 60°C for 24 hours.
3. Weight of labeled and dried tins will be recorded to the nearest 0.1 g on the “tin spreadsheet”.
4. Individual core sections will be placed in the 1-mm sieve, and the soil material will be rinsed, allowing fine organic matter and mineral matter to pass through. With continued rinsing and hand separation the sample will become cleaner with respect to any further particles passing through the sieve. Large pieces of mineral material should be removed.
5. Appropriately sized tins will be selected based on the estimated biomass in each fraction. For example, if it appears that the dead biomass fraction will be small, then a small or medium-sized tin should be used. The unique tin ID# and tin mass for each sample fraction will be recorded on the “biomass spreadsheet”. The tin ID will be used to identify the sample after the fraction has been oven-dried.
6. Portions of the sample will be placed into a tray of water. The obvious live and dead roots and rhizomes will be separated and placed in labelled tins. Densely entwined small roots should be separated. Roots that float typically indicate live condition.

NOTE: If sorting is interrupted, sorted biomass should be kept in tins and placed in refrigerator until sorting can resume. Unsorted (but rinsed) biomass should be kept in a closeable plastic bag and placed in a refrigerator until sorting can resume.

7. After sorting, the biomass fractions will be dried to a constant weight in a forced-air drying oven set at 60° C (see 9.3.1 Aboveground Biomass Processing – Step 8).
8. After the biomass is dried, with the sample still in the tin, the ‘*total mass*’ (biomass +tin) will be recorded to the nearest 0.1 g.
9. Data from Sample Processing datasheet will be entered into spreadsheet to transform raw data into data formatted for entry into CIMS:
  - Subtract out Tin Mass for Aboveground Biomass columns.
  - Convert Aboveground Biomass from the 81.07 cm<sup>2</sup> core to g/m<sup>2</sup>.

Sample Processing - CRMS SWAMP Belowground Biomass									
Sample ID (CRMS####-BBG##)	Sample Depth (cm)	Initial Storage (Date)	Boimass Fraction (Live/Dead)	Sorted (Date)	Tin (#)	Roots + tin mass			Tin Mass (g.##)
						72 hr (g.##)	24 hr (g.##)	Extra Time (g.##)	
CRMS####-BBG01	0 to 8		Live			###.##	###.##	###.##	###.##
CRMS####-BBG01	0 to 8		Live			###.##	###.##	###.##	###.##
CRMS####-BBG01	8 to 16		Live			###.##	###.##	###.##	###.##
CRMS####-BBG01	16 to 24		Live			###.##	###.##	###.##	###.##
CRMS####-BBG02	0 to 8		Dead			###.##	###.##	###.##	###.##
CRMS####-BBG02	8 to 16		Dead			###.##	###.##	###.##	###.##
CRMS####-BBG02	16 to 24		Dead			###.##	###.##	###.##	###.##
CRMS####-BBG03	0 to 8		Dead			###.##	###.##	###.##	###.##
CRMS####-BBG03	8 to 16		Dead			###.##	###.##	###.##	###.##
CRMS####-BBG03	16 to 21		Dead			###.##	###.##	###.##	###.##

Each tin of biomass gets a separate line, some fractions may require more than 1 tin.

Extra Time only needed if 72 hr mass is 1% > 24 hr mass.

Depth Sections are 8 cm to maximum depth of core. Ex, The deepest section could be 16 to 21 cm.

**Figure 9.7.** Example datasheet for Belowground Biomass Processing

### 9.3.4 Soil Properties and Nutrients Processing

In addition to the standard soil properties for CRMS, expanded analyses for SWAMP will include nutrients (Total Carbon, Nitrogen, and Phosphorous), sediment fractions (Percent Sand, Silt, Clay), and Particle Size (Mean, Median, and Standard Deviation). Analyses will be conducted on the soil core extracted from the biomass plot that was cut into 4 cm increments. The core is to be delivered to the contracted soils lab for processing (see Chapter 8.3.1 Soil Properties - Soil Laboratory Analysis) being sure to include proper data sheets and chain-of-custody forms.

## 9.4 Vegetation Biomass and Nutrient Data Processing

### 9.4.1 Data Reporting and Transferal to CPRA

All data delivery and reporting to CPRA is the responsibility of the prime contractor (or agency) rather than sub-contracted laboratories. Sub-contracted data such as aboveground biomass, aboveground tissue nutrients, belowground biomass, and soil properties and nutrients should be reported within two weeks after the samples are analyzed. The report sent to CPRA will contain the following:

1. Chain-of-Custody forms
2. Results of QC checks
3. Analysis results in digital format from processing laboratories.
4. Discussions of any problems along with steps taken to address them.

All data entry into CPRA's CIMS database buffer is the responsibility of the prime contractor, not the subcontracted processing and analyses laboratories.

### 9.4.2 Vegetation Cover Data Entry and QA/QC

#### **DATA ENTRY (PHASE I):**

1. Herbaceous vegetation cover data: each 2 m x 2 m stations will be processed following guidelines in Chapter 7.1.2 Vegetation – Herbaceous Vegetation and Porewater Data Processing.
2. Herbaceous vegetation cover data will be entered and checked by contractor.

#### **QUALITY ASSURANCE / QUALITY CONTROL (PHASE II):**

1. Herbaceous vegetation cover data: Follow QA/QC protocols in Chapter 7.1.2 Vegetation – Herbaceous Vegetation and Porewater Data Processing.
2. Once Phases I and II have been completed, the vegetation cover files will be uploaded to CPRA's CIMS buffer.

### 9.4.3 Vegetation Biomass and Nutrients Data Entry and QA/QC

**DATA ENTRY (PHASE I):** The contractor will obtain the sample analysis data in the appropriate format from the contracted laboratory.

1. Datasheets will be checked for accuracy and completeness.
2. Data sheets will be scanned and saved as pdf file(s) by CRMS site and data type:
  - a. SWAMP\_CRMS####\_BAG\_MM-DD-YYYY.pdf
  - b. SWAMP\_CRMS####\_BTN\_MM-DD-YYYY.pdf
  - c. SWAMP\_CRMS####\_BBG\_MM-DD-YYYY.pdf
  - d. SWAMP\_CRMS####\_SB\_MM-DD-YYYY.pdf

NOTE: Data sheets may be imbedded in .xlsx files for digital entry as worksheets.

3. Data will be checked to ensure that the data are within a logical range for each parameter measured. If data are deemed illogical, the contracted laboratory will be contacted to resolve the discrepancy.
4. The Vegetation Biomass and Nutrient data will be entered into an Excel spreadsheet (.xlsx file) in the appropriate format for the CIMS database in a CIMS worksheet for aboveground (see Figure 9.8) and belowground (see Figure 9.9) data parameters.
5. Upon completion of the review of data, the electronic files will be provided to the QA/QC officer for Phase II.

**QUALITY ASSURANCE / QUALITY CONTROL (PHASE II):**

1. The data will be checked for completeness and consistency between field data sheets and data files (CIMS worksheet in .xlsx file).
2. If any errors are found, the data collector or laboratory will make all necessary corrections.
3. This process will continue until no errors are identified.

Once Phases I and II have been completed, the files will be uploaded to CPRA's CIMS buffer.

## **9.5 Vegetation Biomass and Nutrients Deliverables**

Electronic files shall be in the appropriate deliverable format and delivered to CPRA once the data collector and QA/QC officer have completed the QA/QC process. The scanned .pdf files will be reviewed prior to submittal to ensure the text is legible.

Deliverables should include the following:

1. The herbaceous vegetation cover field data sheets (.pdf or within .xlsx)
2. The herbaceous vegetation cover data (.xlsx)
3. The Aboveground Biomass field and laboratory data sheets (.pdf or within .xlsx)
4. The Aboveground Biomass analysis data (.xlsx)
5. The Belowground Biomass field and laboratory data sheets (.pdf or within .xlsx)
6. The Belowground Biomass analysis data (.xlsx)
7. The Soil Properties collection data sheets (.pdf or within .xlsx)
8. The Soil Properties analysis data (.xlsx)
9. The chain-of-custody forms (.pdf)
10. Vegetation Biomass Station pictures (.jpg)

## 9. Vegetation Biomass

Station ID	Sample Date (mm/dd/yyyy)	Plot Size (m2)	Total Plot Aboveground Live Biomass (g/m2)	Total Plot Aboveground Dead Biomass (g/m2)	Scientific Name As Originally Observed
CRMS0033-BAG02	10/26/2017	0.25	1094.88	496.12	<i>Panicum repens</i> L.
CRMS0033-BAG02	10/26/2017	0.25	1094.88	496.12	<i>Sagittaria lancifolia</i> L.
CRMS0033-BAG02	10/26/2017	0.25	1094.88	496.12	<i>Typha latifolia</i> L.
CRMS0033-BAG02	10/26/2017	0.25	1094.88	496.12	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.

(continued)

Common Name As Originally Observed	Scientific Name as Currently Recognized	Common Name as Currently Recognized	Live stems (N)	Average Live Stem Height (cm)
torpedo grass	<i>Panicum repens</i> L.	torpedo grass	123	84.3
bulltongue arrowhead	<i>Sagittaria lancifolia</i> L.	bulltongue arrowhead	24	83.8
broadleaf cattail	<i>Typha latifolia</i> L.	broadleaf cattail	3	195
common reed	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	common reed	3	180.5

(continued)

Standard Error Live Stem Height (cm)	Average Live Stem Diameter (mm)	Standard Error Live Stem Diameter (mm)	Aboveground Live Biomass (g/m2)	Total Carbon (mg/g)
4.1	2.8	0.2	311.44	457.7
4.2	19.2	0.9	108.72	450.16
7.1	25.6	2	243.36	439.71
29.9	7.7	1.2	195.2	447.51

(continued)

Total Nitrogen (mg/g)	Total Phosphorus (mg/kg)	Organization	Personnel	Comments
16.45	1167	Collecting Contractor/Agency	F. Last, F. Last	
15.39	1480	Collecting Contractor/Agency	F. Last, F. Last	
30.75	2115	Collecting Contractor/Agency	F. Last, F. Last	
19.37	1042	Collecting Contractor/Agency	F. Last, F. Last	

**Figure 9.8.** Example data format of aboveground biomass and plant tissue nutrient in .xlsx file and CIMS. Species include dominant if not a target (ex. *Panicum repens*) and other target species.

## 9. Vegetation Biomass

Station ID	Group	Sample Date (mm/dd/yyyy)	Sample Depth (cm)	Wet Soil pH (pH units)	Dry Soil pH (pH units)	Soil Specific Conductance (uS/cm)	Soil Salinity (ppt)
CRMS0225-BBG01		8/29/2016	0 to 8				
CRMS0225-BBG01		8/29/2016	8 to 16				
CRMS0225-BBG01		8/29/2016	16 to 21				
CRMS####-SB0#		##/##/####	0 to 4			#####	##.##

(continued)

Soil Moisture Content (%)	Bulk Density (g/cm3)	Organic Matter (%)	Wet Volume (cm3)	Dry Volume (cm3)	Biomass Target Flora Species	Belowground Live Biomass (g/m2)
					Spartina patens (Aiton) Muhl.	####.##
					Spartina patens (Aiton) Muhl.	####.##
					Spartina patens (Aiton) Muhl.	####.##
###.##	#.##	###.##	###.##	###.##	Genus species (credits)	

(continued)

Belowground Dead Biomass (g/m2)	Organic Density (g/cm3)	Total Carbon (g/kg)	Carbon Density (mg/cm3)	Total Nitrogen (g/kg)	Total Phosphorus (mg/kg)	Sand (%)	Silt (%)	Clay (%)	Particl e Size Mean (phi)
####.##									
####.##									
####.##									
		##.###	###.###	###.###	####.###	###.##	###.##	###.##	##.###

(continued)

Particle Size Median (phi)	Particle Size Standard Deviation (phi)	Organization	Personnel	Comments
		Collecting Contractor/Agency	F. Last	
		Collecting Contractor/Agency	F. Last	
		Collecting Contractor/Agency	F. Last	
##.###	##.###	Collecting Contractor/Agency	F. Last	

(continued)

**Figure 9.9.** Example of belowground biomass and soil properties/nutrient data format in .xlsx file and CIMS. Fields to be entered are filled in with example data or symbols. Note belowground biomass (BBG) Sample Depths are in 8-cm increments to maximum depth, and Soil cores for nutrients and physical properties (SB) are 4-cm in increments. For Biomass Target Flora Species, list all target and non-target dominant species present.



## 10. Imagery

### 10.1. Aerial Photography

As part of CRMS, Digital Orthophoto Quarter Quadrangles (DOQQs) for the coastal region of Louisiana are created for years when coastwide land-water classifications are required. A DOQQ is a raster image in which displacement in the image caused by sensor orientation and terrain relief has been corrected. These images combine the image characteristics of a photo with the geometric qualities of a map. The DOQQs generated for this project consist of four components or spectral bands of information: blue, green, red and very-near infrared (VNIR). These images are referred to as Color Infrared (CIR) digital imagery.

CRMS site-level assessments of land-water coverage will be based off of color-infrared photography acquired for coastal Louisiana and clipped to each 1-km<sup>2</sup> CRMS-*Wetlands* site. Unless otherwise noted as a specific preliminary condition, all vegetation such as scrub-shrub, emergent vegetation, and forested areas will fall under the land classification, while open water, non-vegetated, regularly flooded mud flats, and aquatic vegetation beds will be characterized as water.

CRMS imagery contracts are managed and issued by the United States Geological Survey (USGS) Wetland and Aquatic Research Center.

#### 10.1.1 Steps to Classify Land-Water

Since 2012, classification of land-water for the CRMS-*Wetlands* program has included a three phase process. The first phase, Automated Processing, includes several steps enabling an initial, computer-based classification of land-water. The second phase, Data Improvement, involves several steps including verification of the computer-based classification and accuracy assessments completed by experienced image analysts. The final phase, Deliverable Production, creates map products depicting the land-water classifications, the comparison matrices, and finalizes deliverables through an internal USGS publication review and approval process.

##### 10.1.1.1 Automated Processing Phase

*Preprocess-Imagery Clips:* All of the aerial images are clipped to the 1-km<sup>2</sup> CRMS site boundaries to remove areas which are outside the area of interest for spatial analyses. This is done to remove areas which are not part of the classification analysis and to remove accompanying sources of potential classification noise or complexity contained within the extraneous areas. Clipping non-interest areas lessens the chance of the computer-based classifier incorporating confusing patterns introduced by areas outside of the areas of interest of the image.

*Preprocessing – Index Calculation:* The automated classification techniques rely heavily upon the use of the near infrared (NIR) band of CIR imagery, as well as several indices

which produce information regarding the composition of a pixel, particularly land-water composition.

*Preprocessing-mNDWI Calculation:* An altered version of the modified Normalized Difference Water Index (mNDWI) is calculated for each pixel of the imagery. This index was originally described by Xu et al. (2005, 2006) and in this case, due to the lack of a SWIR band, is slightly altered and described by the equation below:

$$\text{mNDWI} = (\text{Vis (green)} - \text{NIR}) / (\text{Vis (green)} + \text{NIR})$$

This index has been found to be particularly adept at separating land-water features. The mNDWI has been shown to be capable of revealing subtle features of water more efficiently than other spectral bands and indices.

*Preprocessing- NDVI Calculation:* A Normalized Difference Vegetation Index (NDVI), originally proposed by Kreiger et al. (1969) is also calculated to provide information regarding the vegetation present in each image. In general, this index is described by the following equation:

$$\text{NDVI} = (\text{Vis(red)} - \text{VNIR}) / (\text{Vis (red)} + \text{VNIR})$$

One particularly difficult aspect of creating land-water classifications in coastal Louisiana results from the common occurrence of floating aquatic vegetation in the area. Spectrally, these areas can appear to be very similar to land, but certain indices can provide information to enable floating aquatic vegetation to be distinguished from land. The NDVI and the mNDWI are used to provide the computer-based classifier useful information regarding floating aquatic vegetation.

*Initial Image Thresholds:* Indices are examined by image interpreters for threshold values which represent a division between land and water categories in most cases. These thresholds are used to create a preliminary land-water classification layer which accurately represents the land-water composition of each CRMS site in a majority of pixels. This preliminary layer is later used as an ancillary data layer for the automated classification.

*Training Data:* The automated classification uses randomly selected points in multiple sources of previous land-water datasets as training data. For example, in past spatial analyses training datasets have included the 2005, 2008, 2012, and 2015/16 CRMS land-water datasets. Change vector analysis is used to eliminate areas in which a change has been observed between the training data and the date of the current classification, i.e. 2018 vs. 2021. Change vector analysis ensures that areas of change will not be utilized as training data for later dates of classification.

*Classification Tree Generation:* Decision-trees are automatically generated from training layers and independent variables. This methodology uses an artificial neural network to recognize patterns that differentiate classes in the independent variables (i.e., original

aerial imagery, mNDWI and NDVI) as discerned via the training data. These patterns are then exploited to build rule-sets for classifying the remainder of the image. Following construction of the decision-tree, the classification proceeds by subjecting each independent variable (i.e., spectral bands and indices) to the rule-sets developed for categorizing each pixel into a land-water type. This methodology uses a Classification and Regression Tree (CART) classifier (Breiman et al., 1983).

#### **10.1.1.2 Data Improvement Phase**

*Image Analyst Review:* Experienced image analysts use manual interpretation to verify, review, and edit computer-based classification as needed. The image analyst edits the initial results of the automated process to ensure accuracy. Due to the inherent nature of high resolution imagery, spectral variance may be minimal between different types of vegetation and therefore hard to distinguish through automated classification. Data improvements involve editing the automated classification to ensure shadows, floating aquatics, burns, saturated land, tidally influenced area (low-tide vs. high-tide) and mudflats are properly classified. Sometimes the contrast of the imagery may make automated classification difficult and manual optical editing is required to ensure accuracy. When editing, the classified dataset is overlaid onto the imagery and manually hand edited for accuracy. Ancillary image datasets are used to assist in the verification process. Ancillary datasets may be from a different season which assists in proper classification of landscape features. Imagery from different time periods of the same location, show vegetation in a different stage of the growing season and informs classification decisions. For example, in one image versus another, areas appearing saturated may be drier, floating vegetation may not be present reducing confusion of emergent vegetation vs. floating vegetation, sun angle may be different reducing shadows and water levels may be conducive to better identify shorelines. The editing phase gathers as much landscape information as possible to make accurate classification decisions.

*Overall Accuracy Assessment:* An accuracy assessment of remotely sensed data products relies on comparing classification results to a random sample of points at which the land cover category is known. Generally, a sample size sufficient to appropriately represent the population is needed. In this case, the population is the total number of pixels classified. Each CRMS site is 1km x 1km, so at 1-m resolution, each site is 1000 pixels x 1000 pixels (or a total of one million pixels) in each site. As there are 390 CRMS sites, this means a total of 390 million pixels are classified. So, to assess a sufficient sample, (for example, a 1% sample) would require 3.9 million points of known land cover. The immensity of assessing this sample size was the driving force behind stratifying point selection with greater emphasis in areas of change as determined by a multi-year matrix because areas of change are more likely to contain error. Conversely, those that have persisted as one category for most or all analyses are less likely to contain error as the likelihood of the image interpreter erroneously classifying the area is decreased with each additional analysis. Focusing accuracy assessment in areas of change results in smaller sample sizes (~15,000 accuracy assessment locations) that have valuable information regarding the accuracy of the dataset.

At each of the random but stratified sites, two image analysts examine the assessment location at multiple scales and determine the land cover category (land or water) for each point. When there is disagreement among image analysts at a particular point, three additional image analysts are asked to “vote and the majority vote is taken as truth. The overall, producer’s and user’s accuracy are then determined and that information is documented in the metadata of the spatial datasets.

The accuracy of the horizontal positions is based on the accuracy of the georeferenced data source (which can be USGS DOQQs, Digital Elevation Models (DEM flight line center points, and/or calibration reports). All USGS mapping products adhere to the National Mapping Accuracy Standard.

### **10.1.1.3 Deliverable Production Phase**

*Land-Water Maps and Spatial Datasets:* After review by CWPPRA team members and associated revisions completed by USGS, maps (11 inch x 17 inch) depicting the analysis with acreage per classification category will be finalized and sent to CPRA. In addition, land-water maps, image data and land-water classification data for each individual CRMS site will be uploaded to the CRMS website, and USGS Science Base (an online data archiving repository, <https://www.sciencebase.gov/catalog/>), and made available for download. Each land-water dataset will contain a metadata record which will describe dates of image acquisition, process dates, classification methods and procedures, and any data restrictions if applicable.

*Matrix Datasets:* To facilitate the comparison of land-water datasets among years (2005, 2008, 2012, 2015, 2018, etc...) matrix datasets and maps (11 inch x 17 inch) are created depicting the change in land and water categories through time. These datasets and maps for each individual CRMS site will also be uploaded to the CRMS website, USGS Science Base, and made available for download. Each spatial dataset will contain a metadata record which will describe dates of image acquisition, process dates, classification methods and procedures, and any data restrictions if applicable.

## **10.2 Satellite Imagery**

Satellite imagery will be acquired for every cloud-free acquisition of freely available satellite imagery at a spatial resolution suitable for regional assessment of land and water trends. Landsat data, both historical including Landsat MSS, TM, ETM, and future acquisitions of Landsat (OLI) imagery and other Earth Observing Satellites (EOS) will be used for the initial assessments, although other imagery may be incorporated as newer satellites are deployed and/or the data become accessible. All imagery will be radiometrically corrected to normalize for between-image differences due to atmospheric and other sources of variability. Landsat imagery will be processed using a series of indices and algorithms which differentiate between land and water classes. Land-water datasets will be utilized in conjunction with historical datasets to identify wetland change and quantify the rates of that change. Tables and figures summarizing land and water area changes for areas of interest, matrix change datasets, and maps will be provided. Improvements in satellite

technologies will be continually assessed over time for potential application in land and water trend analysis. Reductions in cost and improvements in accuracy may allow one high-resolution satellite image to meet the site-specific and regional assessment requirements of the CRMS-*Wetlands* program.

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