

# California Bar-built Estuary Wetland Monitoring Manual

USEPA Three-Tiered Monitoring Strategy for Bar-built Estuaries managed by  
California Department of Parks and Recreation

*Prepared by:* Central Coast Wetlands Group at Moss Landing Marine Labs



*Prepared for:* California Department of Parks and Recreation-Natural Resources  
Division (NRD)

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## Section 1-Introduction

### About this Document

This manual provides a framework to guide the development of a bar-built estuary (BBE) wetland monitoring program for California Department of Parks and Recreation (CDPR) at their coastal State Parks, describing standard data collection protocols. This document is meant to be expanded to include supplemental or modified protocols over time. It is important for CDPR staff to use standardized and repeatable protocols and metrics among systems and district offices to evaluate and report the condition of the 134 bar-built estuary systems owned and/or partially managed by the California Department of Parks and Recreation. These recommended protocols can be replicated temporally and spatially, to prioritize management and restoration activities.

This manual aims to establish a minimum suite of standardized protocols for several indicators and parameters for the implementation of assessments of bar-built estuaries in California. The protocols fit into the EPA's Level 1-2-3 Monitoring Framework.

### Purpose of Document

The principal purpose of this manual is to serve as a tool for CDPR resource managers, scientists, and researchers to support the implementation of local and regional BBE wetland monitoring programs. This manual outlines specific data collection strategies. While monitoring needs often differ between parks, projects, and sites, (e.g. restoration, mitigation, reference sites), adoption of these standardized data collection protocols will aid data comparisons across and within regions. Further, the manual recommends a suite of additional data collection protocols to be added to current monitoring programs and efforts if additional wetland functions and services are of interest.

### Background and Need

Bar-built estuaries, also termed river mouth lagoons, are unique and important coastal wetlands that form at the mouths of coastal watersheds. Connecting marine, freshwater and terrestrial ecosystems, BBEs are complex and dynamic systems that host a great diversity of aquatic habitats and ecosystem services. Typically, high winter streamflows and strong predominant north swell energy keep the stream mouth open; while in the summer, low streamflows and a concomitant shift of swells to the south, a sandbar forms at the mouth of the stream forming a lagoon disconnected from the ocean. As a result, water is impounded behind this bar, increasing aquatic and inundated marsh habitat during the otherwise drier summer months. BBEs can thereby provide important nursery habitat for aquatic species from both the freshwater and marine ecosystems, as well as salmonid species that migrate between the two, including species protected under the Endangered Species Act. Additionally, marsh and wetland habitat adjacent to the BBE channel are important for many resident and migratory species.

BBEs make up 51% of the estimated 539 coastal confluences in California (Heady et al. 2014). The complexity and dynamics of BBEs along the coast, and thus the extent, diversity and dynamics of ecological services have made documenting this diversity difficult. Further, many BBEs have been physically altered, developed or historically mismanaged resulting in dramatic losses in wetland acreage and ecological services (CCWG, 2013).

New threats to BBEs, and the services they provide, include artificial management of bar closure periodicity for flood control and water quality objectives, along with potential future hydrologic alterations due to climate change impacts and increased demand for upstream freshwater resources. Some beach bar alterations are

unavoidable within urbanized systems due to legal water diversions, flood protection, and protection of coastal infrastructure. However, there are a number of BBE characteristics that can be addressed and improved even in the face of inevitable human alterations (Largier et al. 2019).

State regulatory and resource management agencies are routinely tasked with making management decisions, through permitting of development projects and/or artificial breaching activities, without a full understanding of the impact these projects have on BBE resources and species. Further, many management decisions are made with a single species management focus. Thus, there is a critical need for a more detailed understanding of these dynamic ecosystems individually and in terms of their shared characteristics in order to direct management, conservation and restoration actions, and ensure the long-term health and productivity of these coastal ecosystems.

Implementing standardized monitoring protocols in BBEs across the state will enable CDPR and other state agencies to generate the information necessary to devise better strategies to enhance BBE habitats for multiple objectives (including upgrades to visitor services) and species, prioritize limited agency restoration resources, evaluate the effectiveness of management actions and strategies, and properly mitigate secondary impacts of management efforts on species and ecosystem services.

## Setting up a Monitoring and Assessment Program for BBEs

The implementation of tools described in this this monitoring manual will dramatically increase our understanding of the complexities and dynamics of BBEs and how current resource management decisions are influencing condition and functions. The intent is to establish metrics for gauging restoration success, and evaluate the ecosystem services provided by individual wetlands and document how they change through time. By combining the use of standard assessment protocols (California Rapid Assessment Method for Wetlands) with GIS-based watershed stressor analyses, historical habitat change analysis, and species and site specific indicators of condition, this monitoring manual will assist CDPR staff in identifying and prioritizing restoration actions, inform broader watershed management activities and document how actions lead to a change in BBE condition. This approach will promote geographically-defined wetland protection, restoration, and management. By maintaining and updating data in a comprehensive database (EcoAtlas.org), CDPR will be able to evaluate progress towards meeting wetland objectives.

This manual can serve as the basis for an EPA Level 1-2-3 wetland monitoring framework, forming a standardized inter-park and district monitoring strategy for BBE resources. The implementation of this strategy can be supported both by existing staff and programs at the district level and by the Natural Resources Division in Sacramento.

Note: the data generated from the USEPA Region 9 Wetland Program Development grants which funded this project will be available on the CCWG website<sup>1</sup>, through the EcoAtlas<sup>2</sup> portal and the CEMW online portal<sup>3</sup>. A final report describing the outputs of utilizing this manual is available on the CCWG website as well.

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<sup>1</sup> <https://www.mlml.calstate.edu/ccwg/estuary-map/>

<sup>2</sup> <https://www.ecoatlas.org/>

<sup>3</sup> [https://mywaterquality.ca.gov/eco\\_health/estuaries/index.html](https://mywaterquality.ca.gov/eco_health/estuaries/index.html)

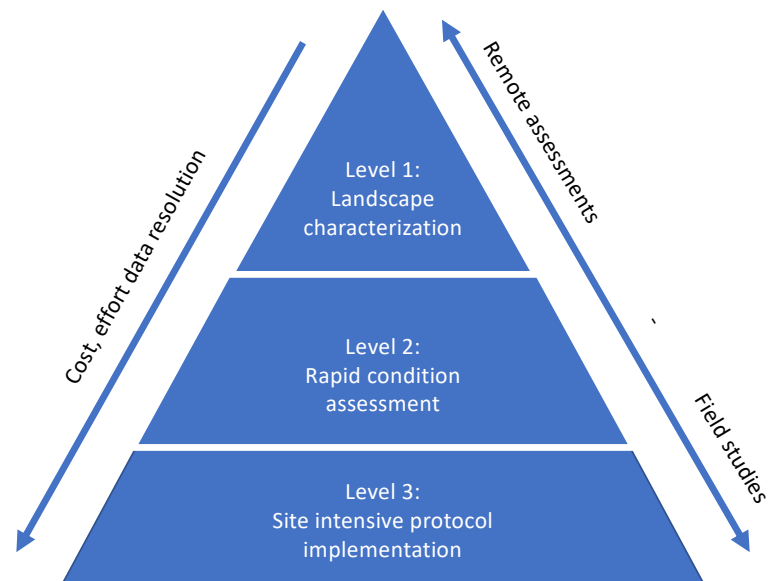
## Introduction to EPA Three-Tiered Monitoring Structure

In 2002, a consortium of scientists and managers from around the state began developing a monitoring and assessment program for wetlands modeled after USEPA’s Level 1-2-3 framework. The fundamental elements of this framework are as follows (modified from WRAMP 2010 and USEPA website, accessed June 2015; **Error! Reference source not found.**):

**Level 1:** A broad landscape-level characterization consisting of wetland and riparian inventories (e.g. National Wetland Inventory) or to answer questions about wetland extent and distribution. Assessment results can also provide a coarse gauge of geology and hydrology of a watershed, broad impacts, or wetland type.

**Level 2:** Rapid assessment of condition, which uses cost-effective field-based diagnostic tools to assess the condition of wetland and riparian areas. Level 2 assessments answer questions about general wetland health along a gradient through qualitative assessments and “stressor checklists”. These assessments can be replicated in the future to document change in habitat condition.

**Level 3:** Intensive site assessments to provide data to validate rapid methods, provide more thorough or rigorous datasets on specific species or habitats, characterize reference conditions, and diagnose causes of wetland condition observed in Levels 1 and 2. Level 3 assessments can be used to test hypotheses and provide insight into functions and processes.



All three Levels of the USEPA’s three-tiered structure should be implemented as needed and funding is available. Level 1 and 2 provide needed preliminary information on wetland area and condition which is needed to develop and implement a site-intensive (Level 3) monitoring program. The strength of site-intensive data collection to document site specific function, species abundance, or detailed restoration trajectories is a vital component of any monitoring program. The adoption of all three “tiers” in the monitoring framework have been found to provide site specific information needed for permitting and local management efforts while also providing the integrated data necessary to track statewide management of the resource.

### Connection to WRAMP and EPA

The State of California and the California Wetlands Monitoring Workgroup (CWMW) both call for consistency in wetland monitoring and have integrated the work of the State Wetland and Riparian Monitoring Program<sup>4</sup> into their operations where feasible. The State Wetland and Riparian Monitoring Program (WRAMP) consists of coordinated, comparable regional and statewide efforts that use standardized methods to monitor the effects of

<sup>4</sup> [https://mywaterquality.ca.gov/monitoring\\_council/wetland\\_workgroup/docs/2010/tenetsprogram.pdf](https://mywaterquality.ca.gov/monitoring_council/wetland_workgroup/docs/2010/tenetsprogram.pdf)

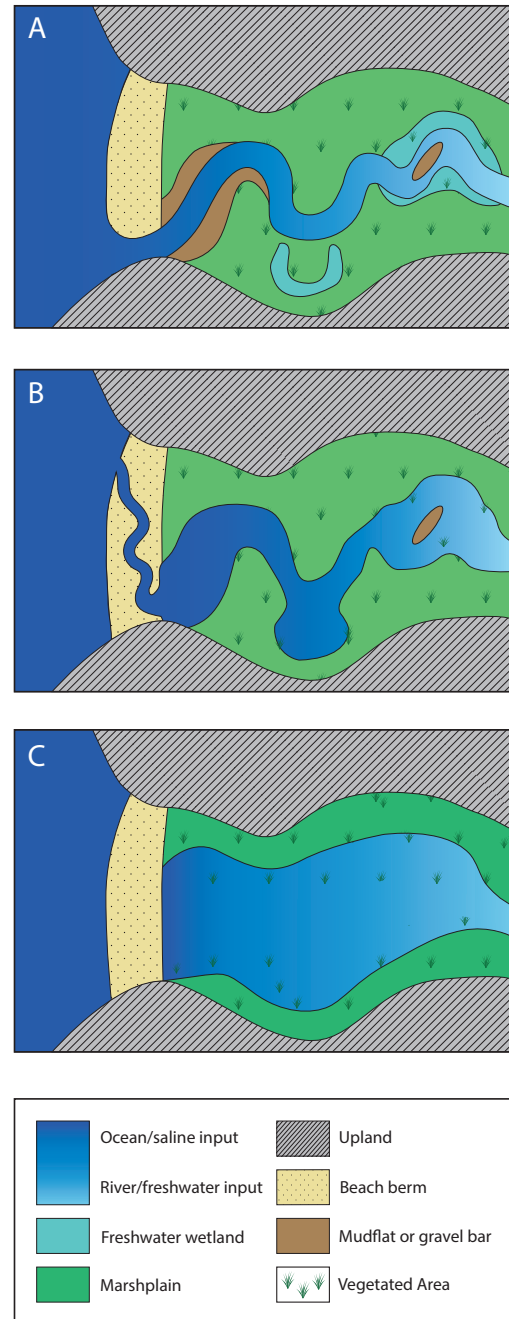
natural processes, climate change, and government policies, programs, and projects on the distribution, abundance, and condition of wetlands and riparian areas<sup>5</sup>. This manual aims to address several challenges and gaps identified in the California Wetland Monitoring Workgroup’s WRAMP, namely the standardization of wetland assessment protocols for bar-built estuaries.

### Bar-built Estuary Definition

Bar-built estuaries are the reaches of coastal rivers and streams that are ecologically influenced by seasonal closures of their tidal inlets through the formation of a sand bar or small barrier beaches. The BBE beach berm formation and resulting marine/freshwater hydrologic interactions are driven by a dynamic set of processes that vary regionally depending on watershed and climatic conditions, the volume of river sediment input, long-shore sediment transport, and wave exposure. The frequency and duration of inlet closure can be natural or managed. Many of these systems frequently exhibit prolonged non-tidal phases, seepage tides, or significant tidal choking, resulting in the tidal regime being muted in comparison to the adjacent marine system when the tidal inlet is open. The salinity regime of a bar-built estuary can be highly variable, ranging from fresh throughout very wet years to hypersaline during extended droughts. This salinity regime trends toward freshwater in more northern systems where rainfall averages are greater. Depending on the local geology, these systems can support a vast set wetland resources or support little more than a channel width lagoon, based on the level of confinement provided by adjacent hills. See Clark and O’Connor (2019) for a systematic survey of BBEs in California.

### Bar-built Estuary Characteristics

Unique processes such as beach bar formation, seasonal flooding, and ocean overtopping create variability in surface water elevations and salinity gradients that are unique to these systems (Figure 1). These variable hydrologic states support a complex set of habitat types and an array of fresh, marine and terrestrial species. The presence and absence of these events will determine the level of services and condition. Decreases in the level of services and condition often correlate with human management and watershed impacts.



**Figure 1. The three primary bar formation phases of a BBE. A) Fully open to tidal input B) Partially open to tidal input C) Closed to all but largest wave overtopping events (figure adapted from Australian Online Coastal Information- [www.ozcoasts.gov.au](http://www.ozcoasts.gov.au)).**

<sup>5</sup> [https://mywaterquality.ca.gov/monitoring\\_council/wetland\\_workgroup/wramp/index.html](https://mywaterquality.ca.gov/monitoring_council/wetland_workgroup/wramp/index.html)

### Characteristic Hydrologic Processes

The sand barrier between the estuary and the sea is continuously altered by the action of waves, tides, winds, and river outflow effecting sediment erosion, transport and deposition. Bar-built estuaries can be separated from the sea at times when deposition due to the action of waves or wind exceeds the scouring action of flows due to river and tides. Mouth closure is common during the dry season and low-inflow conditions can persist for many months during a drought or in systems with weak river inflow. However, if there is a net water inflow, water level rises until inflows are balanced by a combination of evaporation, seepage through the sand barrier, and limited outflow over the sand barrier. During these perched conditions, water levels often rise enough to inundate marshes, creating high-water conditions in the marsh that differ from tidal systems. Breaches can occur naturally when overflow past the sand barrier is strong enough to erode a new channel – this occurs most commonly in winter. A seasonal cycle of opening and closing occurs naturally and is observed in many regions globally – including California, Australia, New Zealand, South Africa, Portugal, Chile and many other countries (e.g., Ranasinghe & Pattiaratchi 2003; Perissonotto 2010).

### Learning through Monitoring

There are a number of cost-effective data collection protocols that can improve bar-built estuary management decisions. These monitoring recommendations assume that ancillary data on external forcing are available, such as river flow, tides, and offshore wave conditions. If these data are not available, then they should be included in a monitoring program.

- *Water Level and Photographic Records:*  
Mouth state and closure duration are key considerations for management of BBEs. Mouth state can be determined from water level and photo documentation. Documenting water elevation in relation to channel depth, marsh plain elevation and off-channel water depth is important for understanding the effect of mouth state on diverse estuarine habitats. Placement of low-cost pressure sensors within BBEs should be a standard practice in all managed systems. In addition, automated cameras can be placed at the mouth of key BBEs to track mouth migration, wave overtopping and breach events. Example key parameters for characterizing the abiotic and biotic state of BBEs are listed in Tables 1 and 2.
- *Morphology Surveys:*  
The height of the sand barrier can be monitored through simple horizon-sighting techniques during a closure episode, so that the natural-breach water level is known. Further, through pre- and post-breach morphological surveys of the sand barrier (and channel depth), scouring efficacy can be related to pre-breach water-level head and post-breach accretion in the mouth channel (and also reveal seasonal changes). While estimates of channel depth and width can be obtained from water-level records and photographs, morphological surveys provide a more complete view of sand barrier modification through breaching. Morphology surveys should include the upper extents of marshes and floodplains that can be inundated by the highest water levels as well as sand dunes adjacent to the estuary mouth, which can play a key role in closures and water level maxima.
- *Stratification and Water Quality Records:*  
Salinity, temperature and dissolved oxygen can be monitored through deployment of time-series sensors at representative sites that capture temporal variability. Periodic water chemistry transects (profiles at a set of stations), and water nutrient and toxicity samples will help document spatial patterns in water chemistry, including identification of refugia for species escaping poor water quality. These data can also be used to track changes in stratification, which is a primary determinant of water quality in the lower layer. Data



during closure events and before/after breach events allow assessment of the spatial extent and temporal duration of water quality effects of breaching.

- Marsh plain and Submerged Aquatic Vegetation (SAV) Condition Surveys:**  
 Marsh and channel SAV species distribution, abundance, diversity and elevation can be surveyed and related to water elevation data within the estuary. Long-term surveys are more important than pre- and post-breach surveys because marsh plant and SAV communities will likely not be affected by a single manual breaching effort. It is also important to note that in the absence of site-specific monitoring data on water depth and water quality, vegetation can tell stories about lagoon hydrology (depth/duration/frequency of inundation, salinity), especially over the long-term. Long-term surveys of plant composition are critical for assessing breaching protocols (e.g., routine breaching that maintains water level below natural peaks) – including the potential for secondary impacts to the marsh communities or subtidal communities (De Decker 1987). Site-specific information on species distribution relative to marsh plain elevation can help minimize impacts to marsh communities by determining the minimum water elevation needed to flood specific plant communities (and the maximum water elevation to avoid flooding of other land uses).
- Fish and other faunal surveys:**  
 Monitoring of fish and other fauna during open/closed states and immediately post-breach is needed to assess impacts of breaching. Surveys can document both immediate effects of breaching on various species as well as longer term effects on resident populations. Population studies should be conducted to assess the additive effects of multiple managed breaches on species like steelhead and tidewater goby as well as species of concern (e.g., frogs, turtles, birds). Emerging monitoring techniques involving the use of sampling for DNA markers (eDNA) in the water column may increase the efficiency of monitoring for fauna in BBEs.
- Soil data collection:**  
 Marsh plain accretion studies using a SET station or feldspar markers can, over the long term, help inform the resiliency of BBE marsh plains to sea level rise. In addition, studies focusing on the carbon content of soil and salinity and reduction horizons within the marsh plain can identify changes in groundwater which may lead to changes in the vegetation community as well as carbon sequestration rates.

**Table 1. Example Key parameters for characterizing the abiotic state of BBEs**

<b>State of BBE</b>	
Mouth state	The elevation of the sand barrier determines if the mouth is considered fully open, partially open (muted tides), closed, or perched.
Stratification state	Whether the water body is vertically mixed, weakly stratified, or exhibits intense 2-layer stratification.
Water balance	Positive (filling): more freshwater enters from runoff than leaves by evaporation and seepage through barrier. Negative (draining): less freshwater enters from runoff than leaves by evaporation and seepage through barrier.
<b>Abiotic Conditions in BBE</b>	
Water level	Measure of the daily average and daily range of water level in the estuary.



Stratification	Strength and depth of interface (pycnocline) in the water column.
Light depth	Penetration depth of photosynthetically active radiation (PAR) in water column, often measured as secchi depth.
Temperature	Depth-averaged or upper & lower layer temperatures (daily average; daily range).
Salinity	Depth-averaged or upper & lower layer salinity (daily average; daily range).
Oxygen	Depth-averaged or upper & lower layer dissolved oxygen (daily average; daily range).
Redox state of sediments	Index of oxygen demand at sediment interface
Turbidity	Depth-averaged or upper & lower layer turbidity.
Volume of water	Total volume or layer volumes when stratified.
Area of photic bed	Area of benthic habitat exposed to PAR
Area of inundation	Area of marsh plain inundated by water

**Table 1. Example Key parameters characterizing the biotic state of BBEs.**

<b>Biotic Conditions in BBE</b>	
Special Status Species	Surveys of species including fish, turtles, frogs, snakes, birds, etc.
Habitat Condition Score	California Rapid Assessment Method for Wetlands (CRAM)
Marsh plain inundation	Interpretation of extent and duration of wetted marsh based on water level in channel and marsh plain elevation
Soil condition	Salinity and moisture content
Vegetation community	Composition and richness (Environmental Protection Agency's Environmental Mapping and Assessment Program)
Phytoplankton community	Daily average and daily range of primary production and chlorophyll a; species composition and richness
Submerged aquatic vegetation community	Composition, richness, density, distribution, etc.
Invertebrate community	Benthic community composition and richness Water column community composition and richness
Fish Community	Surveys of species including salmonids, goby, flatfish
Marine subsidy	Role and magnitude of marine subsidies (e.g. kelp over wash) in estuary productivity

## Section 2-Specific Data Collection Protocols and Strategies

### Level 1: Landscape Level Protocols

#### California's Coastal Confluences Inventory

A comprehensive inventory of California's coastal confluences (Heady et al. 2014) was completed through a state partnership that built off of previous efforts to include additional estuaries identified through National Wetlands Inventory (NWI) and aerial imagery (California Coastal Records Project). Within this inventory and associated geodatabase, we included georeferenced location, other locational information, size, available data, and estuarine classifications previously applied to each estuary. The inventory thus serves as a crosswalk between the CCWG classification, federally accepted marine and coastal habitat classification system, and estuarine classifications previously applied to various West Coast estuaries.

#### Regional Footprint of State Park BBE Management

Bar-built estuaries make up 51% (276) of the estimated 539 coastal confluences in California (Figure 2). Of those 276 BBEs, 134 of them are located partially or entirely within a California State Park. The complete inventory and classification of coastal confluences in California is available on the CCWG<sup>6</sup> and PMEP websites<sup>7</sup>.

The size distribution of BBEs in State Park Management is representative of the overall population size distribution in California (Figure 3).

While it is not necessary for the inventory of estuaries owned /managed by CDPR to be completed again, it should be updated as new properties are acquired, boundaries change, or estuary mouth management leads to an estuary type change.

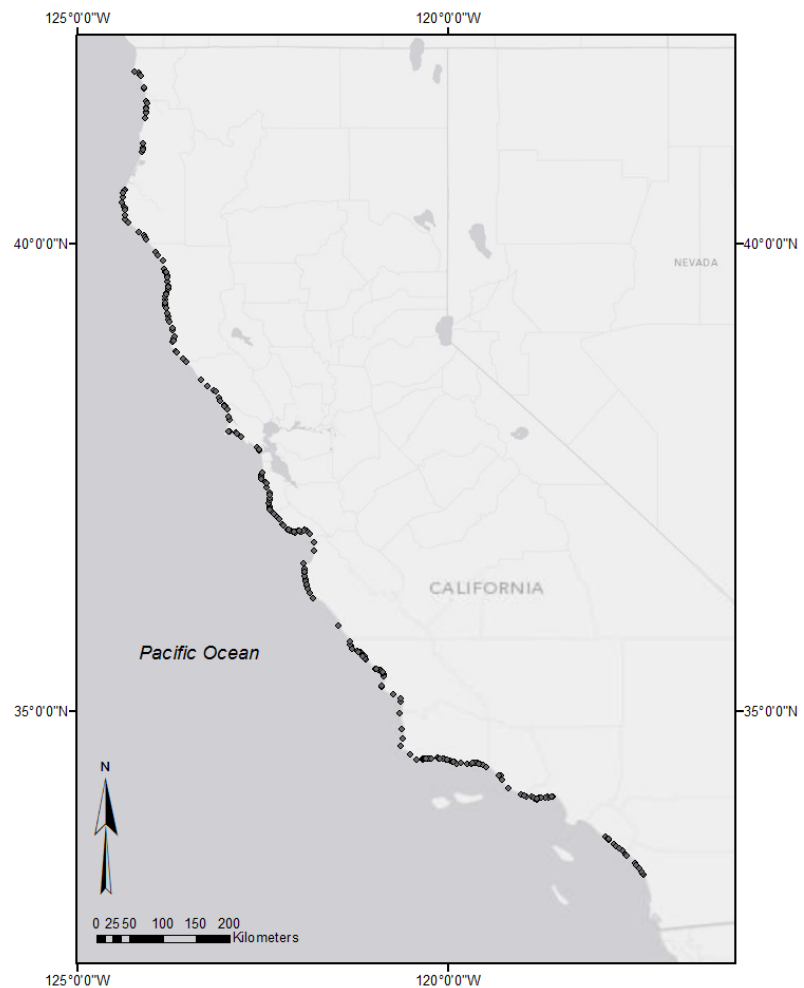


Figure 2. Inventory of all BBEs in California (N=276)

<sup>6</sup> <https://www.mlml.calstate.edu/ccwg/wetland-research/>

<sup>7</sup> <http://www.pacificfishhabitat.org>

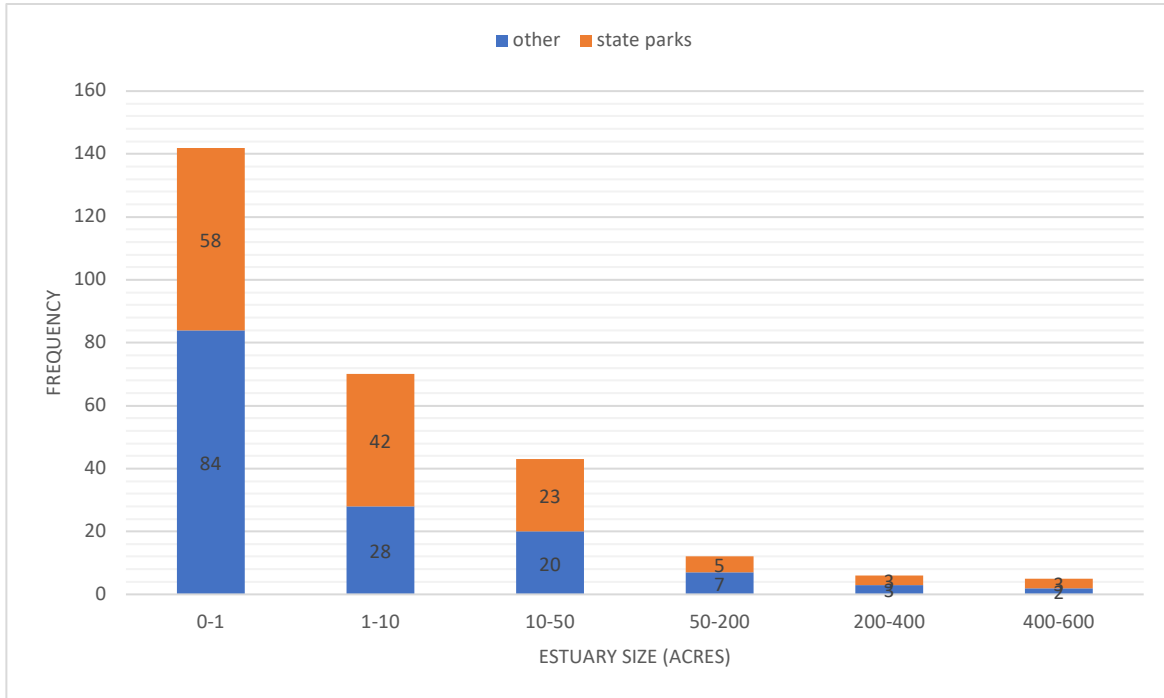


Figure3. Size distribution of BBEs in State Park Management (red) and all others (blue).

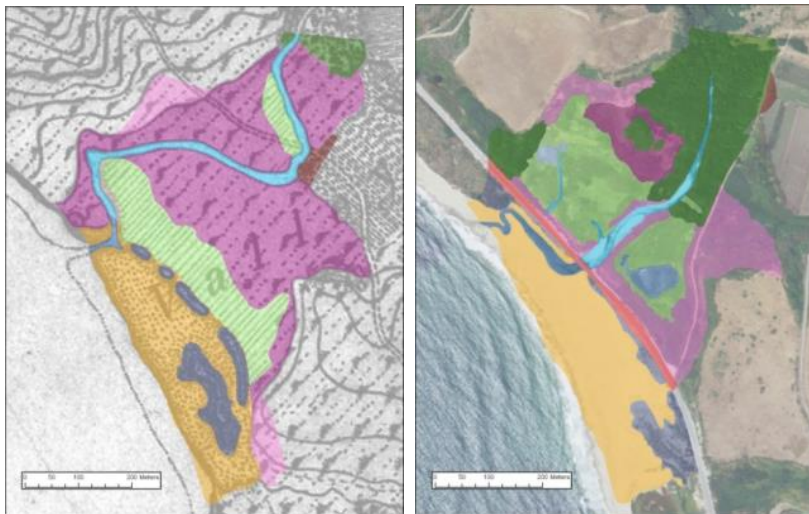
### Habitat Change Analysis

According to the often cited US Fish and Wildlife Study (Dahl 1990), 91% of California’s wetlands were lost between the 1780’s and 1980’s. Wetlands continue to be lost, and a recent report on the status and trends of wetlands showed a reduction in net wetland acreage on the Pacific Coast of 5,220 acres between 2004 and 2009 (Dahl and Steadman 2013). While this bleak assessment is valuable on the whole, it does not specify whether this loss is evenly distributed among all wetland types, or if some types have seen greater loss than others. Part of what is special about bar-built estuaries is that within a BBE there are diverse set of aquatic habitat types with unique beneficial services to many rare species. The intent of this evaluation was to document the total loss of wetland acreage as well as the conversion habitat classifications within the wetland system. This methodology can be expanded to other BBE systems other wetland types by CDPH to assess the loss and alterations of various wetland types throughout the State Parks network. The goal of this standard inventory effort is to answer the following questions:

- What acreage loss or gain (entire wetland and specific habitat classes) has been documented within each region of the state?
- What are key causes of loss (filling, diking, urbanization etc.)?
- What are key watershed impacts on lagoons by region?
- What, if anything, does this tell us about how systems should be managed on an individual or regional level?

The habitat change analysis used 19<sup>th</sup> century T-sheets<sup>8</sup> (ArcGIS rectified) to compare with current imagery and wetland inventories including the National Agriculture Imagery Program (NAIP)<sup>9</sup> maps and the National Wetland Inventory. At each site, a polygon shapefile was drawn to encompass what we determined was the maximum extent of the specific BBE for both the current and historical condition. Inland extent was determined using multiple lines of evidence including the 10 foot elevation contour, a narrowing of channel width, a change in vegetation type, and in some cases, the inland extent of our inventory was determined by the inland coverage of the 19<sup>th</sup> century T-sheet maps (especially larger systems). Lateral extent was determined by looking at topographic indicators and the presence of surface waters that are physically/hydrologically connected to the channel. The digital habitat extent polygons were generated by hand saved as “current” and “historical” files.

Using the “cut polygon features” tool, the polygons were cut by tracing habitat boundaries for both the current and historical maps until each specific habitat zone had been delineated (Figure 4). One of the biggest challenges was to craft the habitat type naming convention that would best characterize these systems and document all the habitats, without becoming too specific which made comparison among sites and between centuries difficult and inaccurate. The selected naming convention helped to ensure confident and consistent habitat identification, and accounted for variability among historic T-sheets, made by different people with different expertise. Each individual habitat type was classified and the area for each was calculated in ArcGIS. The four tiers of habitat classification are defined in Table 3. Once the classification of each of the sites was complete for both the current and historical condition, we copied the attribute tables into one large Excel spreadsheet and then uploaded it to R for analysis. We calculated absolute and percent change of habitat for Tier 1 and Tier 2 for each site individually, for each region of the State, and for the State as a whole. Results can be found in the accompanying complete final report on the CCWG website<sup>10</sup>.



**Figure 4. Historical (left) and current (right) map of habitat types at Scott Creek Lagoon**

<sup>8</sup> Available from: <https://shoreline.noaa.gov/data/datasheets/t-sheets.html>

<sup>9</sup> Available from: <https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/>

<sup>10</sup> Available from: <https://www.mlml.calstate.edu/ccwg/estuary-map/>



**Table 3. CCWG BBE habitat classification system**

TIER 1	TIER 2	TIER 3	TIER 4		
<p><b>Wetland (W):</b>                      Regularly or occasionally wet, or with a high water table that supports wetland vegetation. Depending on the salinity gradient these systems would be classified by NWI as Riverine, Estuarine or Palustrine.</p>	<p><b>Beach/Berm/Inlet (B):</b> Sandy shoreline between the lagoon mouth and the ocean. At times, the lagoon can pond on this shoreline creating a distinct habitat type. <b>NWI:</b> Unconsolidated Shore (US), typically Sand (2).</p>	<p><b>Beach (Be):</b> Non-vegetated, exposed sand.</p> <p><b>Beach Channel/Inlet (I):</b> Area of the beach that contains open water communication between ocean and lagoon. <b>NWI:</b> Marine (M) Intertidal (2)</p>	<p><b>Hydrologically Connected (HC):</b> or <b>Hydrologically Isolated (HI):</b> Project specific descriptor for whether existing wetlands are still hydrologically connected to the lagoon, or whether they have been isolated by management actions.</p>		
	<p><b>Wetable Lowland:</b> Low lying land that is potentially inundated by lagoon dynamics.  <b>NWI:</b> see our Level 3</p>	<p><b>Periodically Inundated (PI):</b> Surface water only present during situations with especially high freshwater flows, high tides, or unusually high inundation. Vegetation likely to be a mix of hydrophilic and upland vegetation. <b>NWI:</b> Scrub Shrub (SS) or occasionally Emergent (EM) with modifier Intermittently Flooded (J). *Note: Historical T-sheet sites that do not define the habitat type but are topographically low lying are put in this category by default.</p> <p><b>Marsh Plain (M):</b> ground that is regularly, seasonally, or intermittently wetted with either surface water or saturated soils. Supports wetland species of plants. <b>NWI:</b> Emergent (EM) with possible modifiers Temporarily Flooded (A), Saturated (B), Seasonally Flooded/Saturated (C/E), Regularly Flooded (N)</p>			
	<p><b>Open Water (O):</b> Areas experiencing standing or flowing water that are not vegetated. The extent and elevation of actual water may vary within or among days (tidally), seasonally (seasonal tides and stormflows), and interannually.  <b>NWI:</b> see our Level 3</p>	<p><b>Flats (F):</b> Non-vegetated sand or gravel flats, not including the beach or channel area that are maintained in this state by episodic flows. <b>NWI:</b> Unconsolidated Shore (US) which could be Cobble-Gravel (1), Sand (2),</p>		<p><b>Channel (C):</b> unvegetated areas of water conveyance. <b>NWI:</b> Riverine or Estuarine (R or E) Tidal (1)</p>	
		<p><b>Pond (P):</b> Off-channel areas of still water. <b>NWI:</b> Lacustrine (L), Estuarine (E) Intertidal (2) Unconsolidated Shore (US), or Palustrine (P) Unconsolidated Bottom (UB)</p>		<p><b>Bars (Ba):</b> Non-vegetated sand or gravel flats, not including the beach, within the greater channel area, that are maintained in this state by episodic flows. <b>NWI:</b> Unconsolidated Shore (US) which could be Cobble-Gravel (1), Sand (2),</p>	
		<p><b>Altered, Developed or Disturbed (D):</b> Areas that show signs of human disturbance, but inundation is at least partially maintained. <b>NWI:</b> depending upon the level of disturbance <b>NWI</b> may not classify these as wetland.</p>		<p><b>Vegetated Woody (VWo):</b> Vegetated land covered by trees and shrubs that are typically hydrophilic such as willows. <b>NWI:</b> Forested (FO)</p>	
	<p><b>Non-Wetland (NW):</b>                      generally upland or developed land with either impervious or well drained soils, is thereby only wet from storm events, and dries relatively quickly. <b>NWI</b> does not subcategorize these; they are typically defined as "Upland."</p>	<p><b>Developed (D):</b> Highly impacted by people, often with hardened or compressed surfaces, and thus the area does not fit the Level 1 definition of "Wetland." It may or may not have been Wetland prior to disturbance.</p> <p><b>Undeveloped (UD):</b> Non-wetland that is allowed to remain in a natural or semi-natural state.</p>		<p><b>Transportation Corridor (TC):</b> Paved and dirt roads, railroad tracks and heavily trafficked paths.</p>	<p><b>Not-Applicable (NA):</b>                      The issue of hydrologic connectivity is not applicable in non-wetland settings</p>
				<p><b>Agriculture (A):</b> farmed agricultural land including grapes, row crops, grains and orchards</p>	
<p><b>Grazing (G):</b> Land used for grazing, including cows, sheep and horses.</p>					
<p><b>Urban (Ur):</b> developed land with a high percentage of impervious surface including residential, commercial and industrial uses.</p>					
<p><b>Parking Lot (PL):</b> Land adjacent to the site that is used solely for parking.</p>					
<p><b>Other (Ot):</b> Non-wetland land that doesn't fit into other categories. NOTE: this could include fallow ag land that is disced, undeveloped bare ground.</p>					
<p><b>Vegetated Upland (VUp):</b> Upland land that is typically vegetated with non-wetland species</p> <p><b>Dune (Du):</b> Sand dunes, could be vegetated or bare.</p>					

## Landscape and Watershed Stressors

Landscape level investigations of potential stressors can be conducted for each estuary. The watersheds of each estuary can be demarcated using Watershed Delineation Tools in ArcGIS. The predominance of different landform modifications and land cover types that can affect the condition of downstream wetland habitat are calculated for each bar-built estuary. The effects of watershed stressors on downstream BBE resources was studied at four different scales: 1) the entire watershed; 2) a 2 kilometer area surrounding the bar-built estuary; 3) within a 250 meter buffers of all watershed streams; and 4) within a 250 meter buffers of all streams within the 2 kilometer area surrounding the bar-built estuary. These four geographic scales test the significance of various landscape scale stresses on bar-built estuary habitat. Our previous research throughout California has shown these four landscape scales to be useful in highlighting the influence of different stressors on condition and in prioritizing management actions. Specific methods are outlined below.

### *Watershed Delineation*

The delineation of California coastal watersheds was accomplished using ArcGIS in tandem with the ESRI geoprocessing toolbox entitled “Watershed Delineation Tools.” The toolbox contains three tools: i) Watershed Delineation, ii) iRainDrop, and iii) and iWatershed. Only the Watershed Delineation tool was used during this study to create stream networks and delineate watersheds for all stream links. The Watershed Delineation tool required the use of digital elevation models (DEM’s, 10 m resolution) which were downloaded and clipped according to approximate boundaries of watershed zones. The tool assigns stream networks within a watershed based on a set threshold value; the threshold value defines the minimum number of upland cells from a DEM that are required to empty into the network for the stream to be identified. For this project, the threshold value was set to the default minimum of 10,000 cells. Once the watershed and stream networks were delineated, resulting datasets were run through a series of analysis and overlay tools, organized into a custom ESRI toolset model (Figure 5), to create the following five shapefiles for each of the watershed sites:

- 1) watershed\_WS: polygon of entire watershed.
- 2) watershed\_2k: polygon of watershed buffered 2 km from coastal mouth.
- 3) 250RWS\_clip: 250 m buffer zone of entire watershed stream network, clipped to remain within the boundary of the watershed.
- 4) 250RWS\_2k: 250 m buffer zone of 2km watershed stream network
- 5) watershed\_RWS: polylines of all streams within watershed



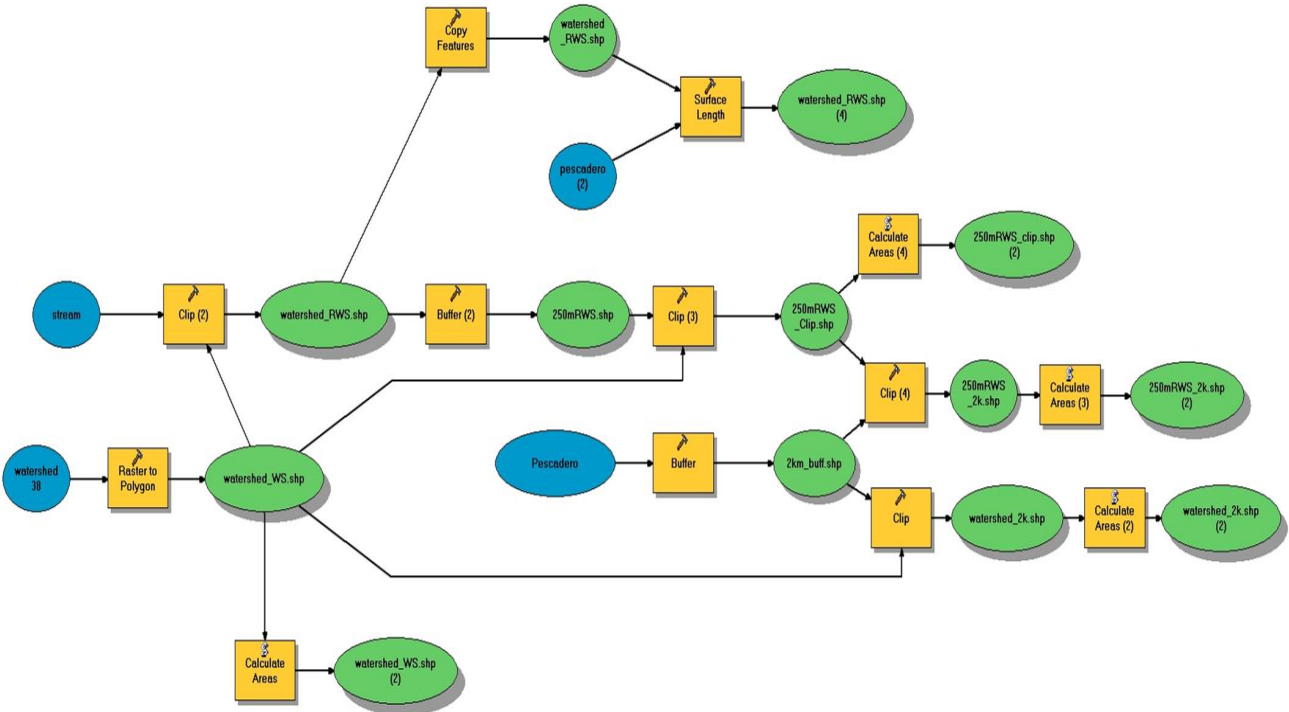


Figure 5. Customized ESRI toolset model for delineating watershed zones.

Polygon shapefiles 1-4 listed above were each assigned their corresponding watershed name and alphabetical ID number and merged together to create 4 individual shapefiles, each with the selected watersheds as features. Utilizing overlay and extraction tools in ArcGIS, the above products were used to summarize data from approximately 50 land-based metric datasets. Extracted information was reported numerically in a spreadsheet. Maps of specific watersheds were also presented to show the geospatial extent of each watershed, buffer zone, and stream network (Figure 6).

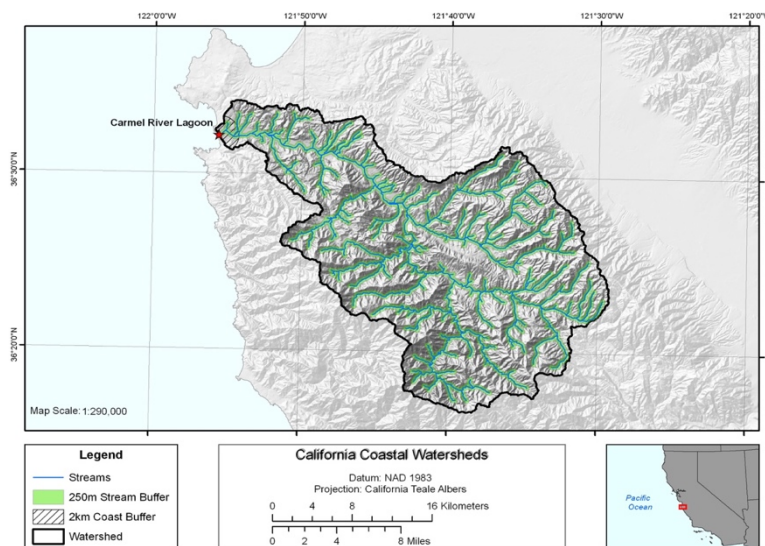


Figure 6. Example of watershed map showing the geospatial extent of each watershed, buffer zone, and stream network.



### *Data Extraction*

#### *Raster Datasets:*

Five raster datasets were included for data extraction: 30 yr. average monthly precipitation (1971-2000); 30 year average monthly temperature (1971-2000); National Land Cover Database 2011 (NLCD) percent impervious surface; and NLCD land use 2011.

Data from the precipitation and temperature datasets was extracted using Zonal Statistics in tandem with the WS and 2k watershed zones. Data from the NLCD percent impervious surface was first reclassified into categories of 0% imperviousness and 1-100% imperviousness. Zonal Statistics were then applied for extraction from all watershed zones. Data from NLCD land use was reclassified into the following classes: Developed (classes 21-24), Forest (classes 41-43), Shrub/Grassland (classes 52-71), Agriculture (classes 81-82), Wetlands (classes 90 and 95), and Open Water (class 11). The analysis excludes Perennial Ice/Snow (class 12) and Barren Land (class 31). The Tabulate Area tool was then used to cross-tabulate areas between the reclassified land use zones and the watershed zones.

#### *Feature Datasets:*

The following polygon, polyline, and point feature datasets were used for data extraction: geologic units (for calculating naturally occurring soil nitrogen, phosphorous, and sulfur), invasive invertebrates and plants, stream types and length, burn areas (2000 to present), grazing allotments, dams (including drainage areas and storage), mines, EPA 303(d) Listed Impaired Waters, CQWIS discharge sites, and roads. With the exception of the geologic units dataset, all polygon and polyline datasets were processed using the Intersect tool in tandem with the watershed zone files. Segmented polygon and polylines were then recalculated to get accurate areas and lengths and summarized using Summary Statistics. The geologic units dataset required the use of Hawth's Analysis "polygon in polygon" tool to calculate the weighted average of the soil elements within the specified zone. Point datasets of invasive species were buffered and intersected with the stream dataset, and dam and discharge sites were intersected with watershed zones and summarized using Summary Statistics.

#### *Future Inventory Efforts*

Conducting a comprehensive inventory of BBEs managed by CDPR on a recurring interval (~10 years) would inform potential changes in estuary type or size through time (due to management actions or climate change). Additionally, habitat change and watershed stressor analyses can be performed on BBEs managed by CDPR that were not analyzed by CCWG for this project.

## Level 2: Rapid Assessment Protocols and Strategies:

### Introduction to the California Rapid Assessment Method

The California Rapid Assessment Method for Wetlands (CRAM) is a rapid habitat condition assessment. CRAM is a standardized tool for wetland monitoring, developed with support from EPA. CRAM provides a cost-effective assessment tool for wetlands that can be used to assess the condition on a variety of scales, ranging from portions of individual wetlands to assessments of wetland condition throughout watersheds and climatic regions.

It is based on the concept that the structure and complexity of a wetland is indicative of its capacity to provide a range of functions and services. It is designed for assessing ambient conditions within watersheds, regions, and throughout the State. It can also be used to assess the performance of restoration projects. CRAM requires a team of 2-3 trained practitioners less than 3 hours to assess a representative wetland area.

CRAM provides an Index score of the condition of a wetland relative to other wetlands of that type throughout the state. This Index score is calculated as an average of four Attribute scores. The Attribute scores are the result of a combination of metrics scores based upon visual and easily measured indicators of ecological condition in the field. The metrics assessed in CRAM are similar across various wetland classes but are adapted as necessary to fit the characteristics unique to each wetland type.

CRAM is composed of four main Attributes of condition:

1. **Buffer and Landscape Context** - measured by assessing the quantity and condition of adjacent aquatic areas as well as extent and quality of the buffering environment adjacent to the Assessment Area.
2. **Hydrology** - assesses the sources of water, the hydroperiod of the estuary from evidence of alterations to the mouth of the lagoon, and the hydrologic connectivity of rising flood waters in the estuary
3. **Physical Structure** - measured by counting the number of patch types<sup>11</sup> found within the AA and the topographic complexity of the marsh plain.
4. **Biotic Structure** - measures the site on several factors including the number of plant vertical layers, the number of different species that are commonly found in the marsh, the percent of the common species that are invasive, and the horizontal and vertical heterogeneity of the plant communities.

These four attributes are consistent for all wetland modules of CRAM. Each of the four attribute categories is comprised of a number of metrics and sub metrics that are evaluated in the field and scored on a scale of (A)12 to (D)3. The metrics that are measured may vary between wetland types. Each of the four attribute categories are then converted to a scale of 25 through 100, and the average of these four scores is the final CRAM index score, also ranging on a scale from 25 (lowest possible) to a maximum of 100.

The scale of condition categories presented in Table 4 is appropriate for the purposes of evenly distributing CRAM results into quartiles.

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<sup>11</sup> A patch is a spatially distinct structural element of a wetland system large enough to serve as a habitat for wildlife, or to serve as an indicator of spatial variations in hydrological or edaphic (soil) conditions within a wetland.

**Table 4. CRAM condition categories and associated index scoring ranges**

Condition Category	Total CRAM Index Score Range
Good	76-100
Fair	51-75
Poor	25-50

#### Implementation of CRAM

CRAM implementation requires application of the most appropriate wetland type-specific module. There are both field and office components, and one assessment area takes approximately 2-4 hours to complete. Additionally, accurate CRAM assessments require multiple certified scientists who have undergone calibration and training.

Assessments should be conducted prior to management actions (restoration, enhancement, changes in breaching dynamics, etc.) taking place that may affect wetland habitat condition, and then repeated following implementation of the action on a regularly occurring interval to monitor change through time (every other year or so). To track ambient condition through time (unrelated to a specific management action), assessments may be needed on a 3 to 5 year occurrence interval.

For more information on implementation of CRAM for various purposes, please see the document titled “USING THE CALIFORNIA RAPID ASSESSMENT METHOD (CRAM) FOR PROJECT ASSESSMENT AS AN ELEMENT OF REGULATORY, GRANT, AND OTHER MANAGEMENT PROGRAMS, TECHNICAL Bulletin – Version 2.0”, prepared by the California Wetlands Monitoring Workgroup, available from [www.cramwetlands.org](http://www.cramwetlands.org)<sup>12</sup>.

#### General steps of a CRAM Assessment:

1. Assemble the background information;
2. Classify the wetland;
3. Verify the appropriate season;
4. Sketch the CRAM Assessment Area (AA) (e.g. Figure 7);
5. Conduct the office assessment portion of the AA;
6. Conduct the field assessment portion of the AA (including completing the stressor checklist);
7. Complete the quality control check of the data; and
8. Submit results online.

<sup>12</sup> [https://www.cramwetlands.org/sites/default/files/2019CRAM\\_TechnicalBulletin.pdf](https://www.cramwetlands.org/sites/default/files/2019CRAM_TechnicalBulletin.pdf)



**Figure 7. Example CRAM assessment areas in the Salinas River Lagoon**

#### Special Considerations for Selecting CRAM Assessment Areas within Bar-built Estuarine Wetlands

Bar-built Estuarine wetlands often support extensive wetland resources along the flood plain that are often classified separately from the main BBE channel. The National Wetland Inventory classifies wetland resources within the BBE flood plain differently. Deep Channel resources are classified as estuarine or riverine and flood plain resources are often classified as palustrine. All of these wetland features function together to form the BBE complex.

CRAM was created to evaluate the condition of single classes of wetlands within an Assessment Area (AA) and failed to fully qualify the importance of the secondary wetland areas within the BBE flood plain. The BBE CRAM module was modified in several ways to better reflect the importance of these secondary wetland resources and the functions and services they provide (Heady et al 2015). In addition, land use changes and urban development have impacted or eliminated these floodplain resources and those impacts must be fully characterized. Therefore, some CRAM metrics include characterization of resources (similar to buffer within all classes) outside of the AA. It is a fundamental assumption of the BBE CRAM module that BBEs that function in concert with these secondary floodplain resources provide many additional services and are of better condition than those that have lost those resources.

AA boundaries for the BBE wetland class have been established as the main channel of the system and secondary channels that are hydrologically connected during low water conditions (Figure 8). The condition of floodplain marsh resources that exceed the size limits of the AA are integrated into several metrics and can be assessed separately if necessary. Often it is difficult to establish the upstream limit of the BBE wetland sub-type and as a result, the upstream extent will be determined by the 10-foot contour combined with visual indicators, including a change in wetland type or a significant hydrologic break, such as the presence of tide gates.

Frequently BBE wetlands are small and the AA may encompass the entire wetland. In either case, the AA should include the vegetation near the mouth of the BBE (where cover exceeds 10%) and extend inland

to the limits describe above. The main channel and any side channels will be included, and the AA will extend to the top of the banks of these features where a break in slope is observed and include the immediate “riparian” area. The AA can extend across the marsh plain between these features as well. If a distinct break in slope is not observed, the lateral extent of the AA will be determined by the potential for allochthonous input of plant material to the channel.

The AA should not extend above the backshore, as indicated by wrack lines, and transitions from tidal to upland vegetation. The AA should not extend into any hydrologically isolated wetlands on the marsh plain (i.e. perched fresh water ponds). Additionally, the AA should not cross across any channel that is wider than 50 m or that cannot be safely crossed at low tide. The boundary of the AA can extend along the midline of such channels but not across them.



**Figure 8. Example Assessment Area in a Bar-built Estuary.**

[CRAMWETLANDS.ORG](http://CRAMWETLANDS.ORG) and [EcoAtlas/Project Tracker](http://EcoAtlas/Project Tracker)

The [CRAMWETLANDS.ORG](http://CRAMWETLANDS.ORG) website is the main portal for information on CRAM, data entry, and data reporting. The website offers an easy-to-use data entry interface which ensures that all of the appropriate information associated with CRAM assessments can be captured and utilized to inform decision-makers. It gives practitioners the ability to delineate CRAM assessment areas by drawing on a map, access to a practitioner dashboard where assessments can be created and edited, and an up to date list of all trained practitioners in the state. Users can also generate PDF reports of assessment locations, filter assessments, and download assessment data for analysis. All CRAM data reference in this report is available online at the CRAM website.

All data entered into the CRAM website that are marked as “public” are displayed on [EcoAtlas.org](http://EcoAtlas.org). EcoAtlas is a science-based data management and mapping toolset designed to aggregate data from many different sources. Developed in collaboration with a statewide network of Federal, State, Regional, and local public agencies and NGOs, EcoAtlas coordinates natural resource restoration and protection efforts in the context of population growth and climate change. EcoAtlas dynamically displays data made available in public databases, and provides sophisticated analytics to share and visualize information for addressing critical resource management questions. The use of EcoAtlas is expanding as it uniquely enables users to aggregate the best available data for strategic decision support in the landscape, watershed, or regional context.



Project Tracker<sup>13</sup> provides online data entry forms to enable public agencies, restoration managers, and NGOs to map and share information about their on-the-ground landscape, restoration, mitigation and adaptation projects in EcoAtlas and other web-based visualization tools.

### Level 3: Intensive Site Assessment Protocols and Strategies

Unique processes such as beach bar formation, seasonal flooding, and ocean overtopping create variability in surface water elevations and salinity gradients that are unique to these systems. The presence and absence of these events will determine the level of services and condition. Decreases in the level of services and condition often correlate with human management and watershed impacts. Marine or watershed dominance (and the interaction of both) can lead to varying salinity and water levels. These variable hydrologic states support a complex set of habitat types and an array of fresh, marine and terrestrial species.

Several Level 3 data collection protocols are described below which were utilized by CCWG to characterize the unique process present in these systems.

#### Beach Sediment Characterization

##### *Sample Collection*

Beach sediment samples were collected in a small plastic sandwich just under the surface of the sand. Collections took place along 4 transects running perpendicular to the ocean, distributed on each side of the channel between the estuary and the ocean. Each transect included three samples; one at the shore face (A), one at the top of the beach berm (B), and one from the runnel at the back edge of the beach (C) (Figure 9). A Trimble Juno differential GPS was used to collect location and elevation data for each sediment sample.

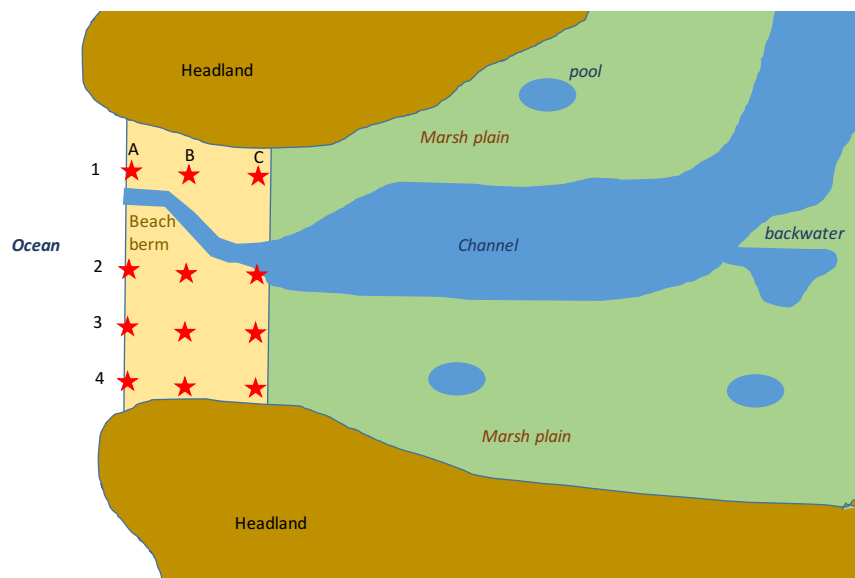


Figure 9. Example BBE with beach sediment collection locations (red).

<sup>13</sup> <https://ptrack.ecoatlas.org/>

### *Grain Size Analysis*

The procedures used for the particle size analysis of the sediment samples includes preliminary processing and subsampling, running standards before and after the sediment analysis, repeated grain size analyses for each sample and data export.

Particle size analyses are carried out with a Beckman-Coulter LS 13 320 laser particle size analyzer (LPSA) attached to an aqueous module equipped with a pump and a built-in ultrasound unit. The measured size distributions analyzed is from 0.04  $\mu\text{m}$  to 2 mm. Measurements of such a wide particle size range are possible because the particle sizer is composed of two units: a laser beam for conventional (Fraunhofer) diffraction (from 0.4  $\mu\text{m}$  to 2 mm) and a polarized intensity differential scatter (PIDS) unit, which measures particles based on the Mie theory of light scattering (0.04  $\mu\text{m}$ ; Beckman Coulter Inc., 2003).

The sediment samples are subsampled and dispersed in de-ionized water. Subsampling of the solutions for the laser particle analysis is done with a pipette (diameter = >2 mm) while vibrating the flask to resuspend the sediment and ensure random sampling. Increasing amounts of the sediment solution are then added to the aqueous module of the particle sizer until obscuration values of 10%–15% and PIDS obscuration values of 48%–52% are obtained. Obscuration is the percentage or fraction of light that is attenuated because of extinction (scattering and/or absorption) by the particles and is also known as optical concentration.

Instrument settings during operations are as follows:

- Pump speed = 100%.
- Obscuration = 10%–15%
- Duration of each analysis (during which the grain size is averaged) = 90 s.

De-ionized water is used to supply the liquid module. The optical model chosen for grain size determination is the default Fraunhofer model, based on the Fraunhofer theory of light scattering. Data interpolation and statistical analyses are calculated with the laser particle sizer proprietary software (Beckman Coulter Inc., 2003). Because all samples analyzed tend to log-normal grain size distributions in the 0.04  $\mu\text{m}$  to 2 mm spectrum, geometric rather than arithmetic statistics were applied to the values obtained by the logarithmically spaced size channels of the particle sizer.

### **Procedure**

1. Each sample bag/vial is first inspected to assess whether enough material for particle size analysis was present and for the presence of large (>2mm) pebbles, rock fragments, shells and shell fragments and any other component that could not be measured with the LPSA.
2. The second critical step is to resample each sample bag using an objective repeatable method to obtain a representative sub-sample for further processing and LPSA. This can be done either using a micro splitter or by homogenizing thoroughly the sample in the zip-lock bag and then isolating a portion of the bag which where the sub-sample is finally collected.
3. Very wet samples are partially dried in an oven at 60°C between 2 and 48 hours depending on the water content. Drying is interrupted once the sample is semi consolidated, e.g. having a tooth paste-like consistency. The reason for this drying procedure is because during drying the coarser material settles at the bottom; by creating a paste-like substance it is



possible to obtain subsamples or ‘pie-slices’ which include all grain sizes in their ‘natural’ proportions.

4. Test samples are run before carrying out the samples analyses with LPSA. 3 standards were used: 03 μm (Fluka standard), 15μm (LG control 15), and 35μm garnet standard (Control G35D). The
5. Each dry subsample is analyzed for particle sizes using the LPSA. For the majority of the samples this is done several times and always at least twice: replicates of each respective sample were run until three runs containing mean grain size statistic within 3 um of one another were obtained or until ten replicates of the respective sample are run, whichever came first.
6. The main statistical results are reported for each run as well as average of the multiple runs carried out for each sample. Grain size statistical data include:

Parameter	Description
Mean grain size (μm)	Mean grain size in micrometers (μm)
Median grain size (μm)	Median grain size in micrometers (μm)
S.D.:	Standard deviation in micrometers (μm)
Variance	Variance
Skewness	Skewness
Kurtosis	Kurtosis
d10	10th percentile of particle size
d50	50th percentile of particle size
d90	90th percentile of particle size
Specific Surf. Area	Specific surface area in micrometers squared (μm <sup>2</sup> )
Clay (<4μm)	Percent Clay, particles less than 4 micrometers in size (<4μm)
Silt(4μm<<63μm)	Percent Silt, particles from 4 to less than 63 micrometers in size (4μm<<63μm)
Sand(63μm<<2000μm)	Percent Sand, particles from 63 to less than 2000 micrometers in size (63μm<<2000μm)

7. Test samples are run after carrying out the sample analyses with LPSA. 3 standards are used: 03 μm (Fluka standard), 15μm (LG control 15), and 35μm garnet standard (Control G35D).

#### Marsh Plain Inundation and Mouth Breaching Dynamics

In-Situ Rugged Troll 100 data loggers<sup>14</sup> (Temperature/depth loggers), recording data every 15 minutes, were utilized to collect the temperature and depth data. They were suspended on a stainless steel cable and deployed in a perforated PVC tube attached to a 6 to 9 foot long metal stake which was pounded into the estuary substrate (Figure 10). The location for each logger was selected carefully. A site was chosen which would most likely be inundated when the water in the main channel was low (either due to the mouth being open or due to low flow from the watershed). In addition, the site was usually off the main channel to prevent the logger from being washed out to sea in a strong flow.

<sup>14</sup> <https://in-situ.com/products/water-level-monitoring/rugged-troll-100/>

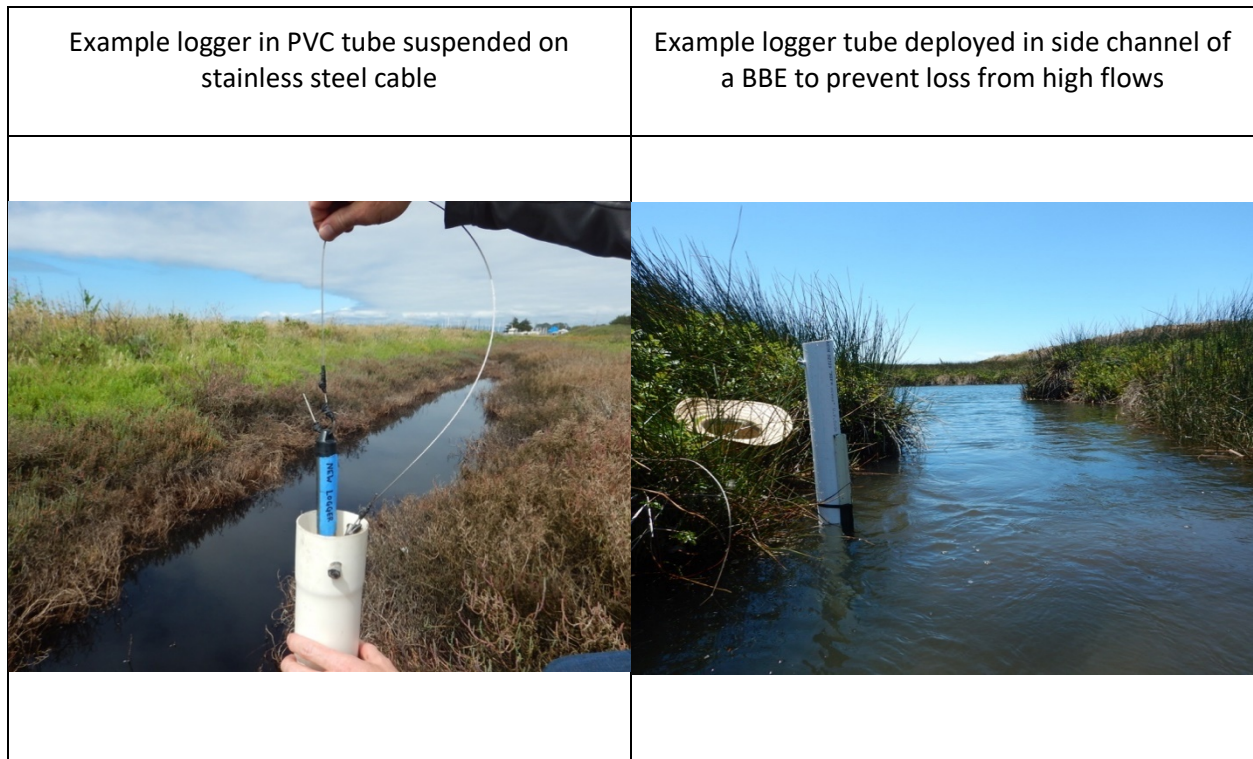


Figure 10. In-Situ logger deployment example.

CCWG worked with State Park District staff along the coast to exchange the loggers each summer. This resulted in a 1 to 3 year data set for many of the original 26 sites (Table 5). Most of the estuaries still have loggers deployed and actively collecting data. CCWG will continue to house the logger data and to work with State Park District staff to annually exchange the data loggers.

Table 5. BBE name and status of temperature/depth logger data collection.

Site Name	Logger deployed in 2015 for EPA grant?	Years of data collected	Current status (as of January 2020)
10-Mile River	yes	3	in place collecting data
Aptos Creek	yes	0-logger stolen	no logger
Arroyo de la Cruz	yes	4	in place collecting data
Arroyo Grande Creek	yes	3	in place collecting data
Arroyo Sequit	yes	3	no logger
Big Sycamore Creek	yes	2	in place collecting data
Brush Creek	yes	2	in place collecting data
Carpinteria Creek	yes	2	no logger
Canada del Capitan	yes	3	in place collecting data
Fern Canyon (Home Creek)	yes	4	in place collecting data
Fort Ross Creek	yes	4	in place collecting data
Laguna Creek	yes	4	in place collecting data
Lake Davis (Manchester Creek)	yes	3	in place collecting data

Los Penasquitos Lagoon	Not needed-logger already in place, maintained by CDPR and TRNERR <sup>15</sup>	continuous and ongoing	in place collecting data
Malibu Creek	Not needed -logger already in place, maintained by CDPR <sup>16</sup>	continuous and ongoing	in place collecting data
Navarro River	yes	3	in place collecting data
Ossagon Creek	yes	4	in place collecting data
Pescadero Lagoon	yes	2	no logger
Canada del Refugio	yes	4	in place collecting data
Russian Gulch	yes	0-logger stolen	no logger
Salinas River	yes	4	in place collecting data
Salmon Creek	yes	2	no logger
San Jose Creek	yes	3	no logger
San Mateo Creek	yes	1	no logger
San Simeon Creek	yes	3	in place collecting data
Stump Beach Creek	No	0	no logger
Tijuana River	Not needed-logger already in place, maintained by TRNERR <sup>17</sup>	continuous and ongoing	in place collecting data
Villa Creek	yes	3	in place collecting data
Waddell Creek	yes	3	in place collecting data
Wilder Creek	yes	3	in place collecting data

These temperature and water depth measurements were supplemented by vegetation surveys linked to topographic data collected using a Trimble Juno differential GPS. Initial vegetation and marsh plain topographic surveys were targeted for specific features. The location and elevation of different plant communities, along with different marsh plain elevations and physical features (backwater habitats) were recorded (Figure 11).

<sup>15</sup> Visit: <http://torreypines.trnerr.org/index.cfm>

<sup>16</sup> Contact State Park staff at Malibu Creek State Park for data (818-880-0367)

<sup>17</sup> Visit: <http://trnerr.org/system-wide-monitoring-program/>

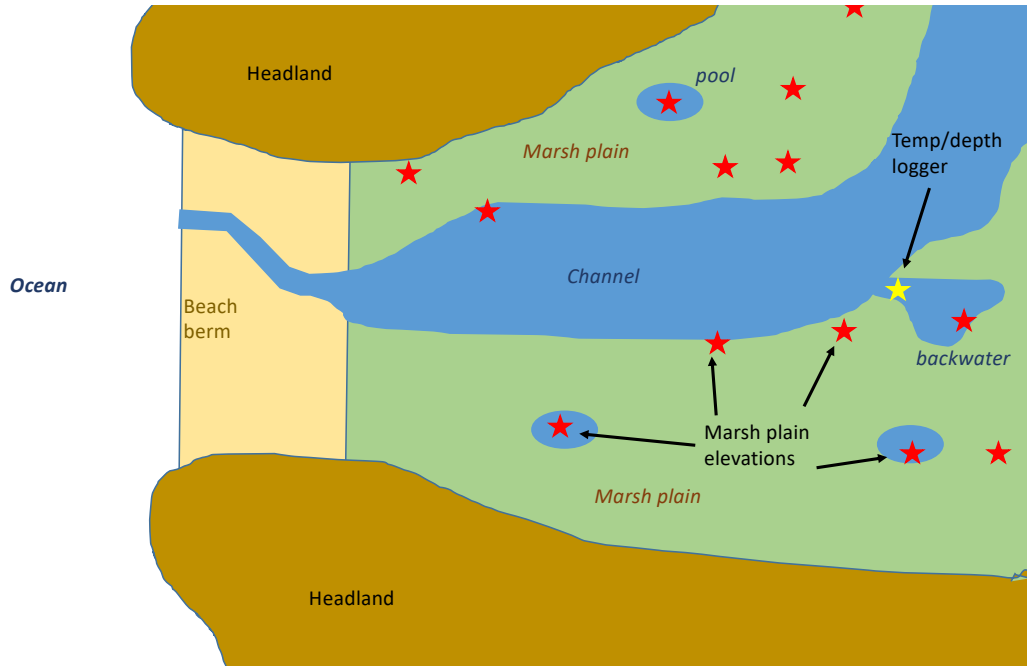


Figure 11. Example BBE with logger deployment location (yellow), and GPS/topographic monitoring locations (red).

A return visit to each BBE allowed for a more systematic survey of the vegetation community on each marsh plain. At each estuary two to four transects were completed. Each transect was at most 100m long and ran perpendicular to the main channel, starting at the water's edge and extending towards the upland habitat transition zone. A 1-m<sup>2</sup> quadrat was laid down every 5 meters along the transect and the elevation was taken at the center of the quadrat using a Trimble Juno differential GPS. Within each quadrat, each plant species was recorded at each of the 9 intercept points. If there were two layers of plants rooted in the substrate, both species were recorded (Figure 12). This combination of data allowed for the assessment of estuary water levels, breaching events, inundation of the marsh at multiple elevations, and characterization of the plant community with different lengths of inundation.

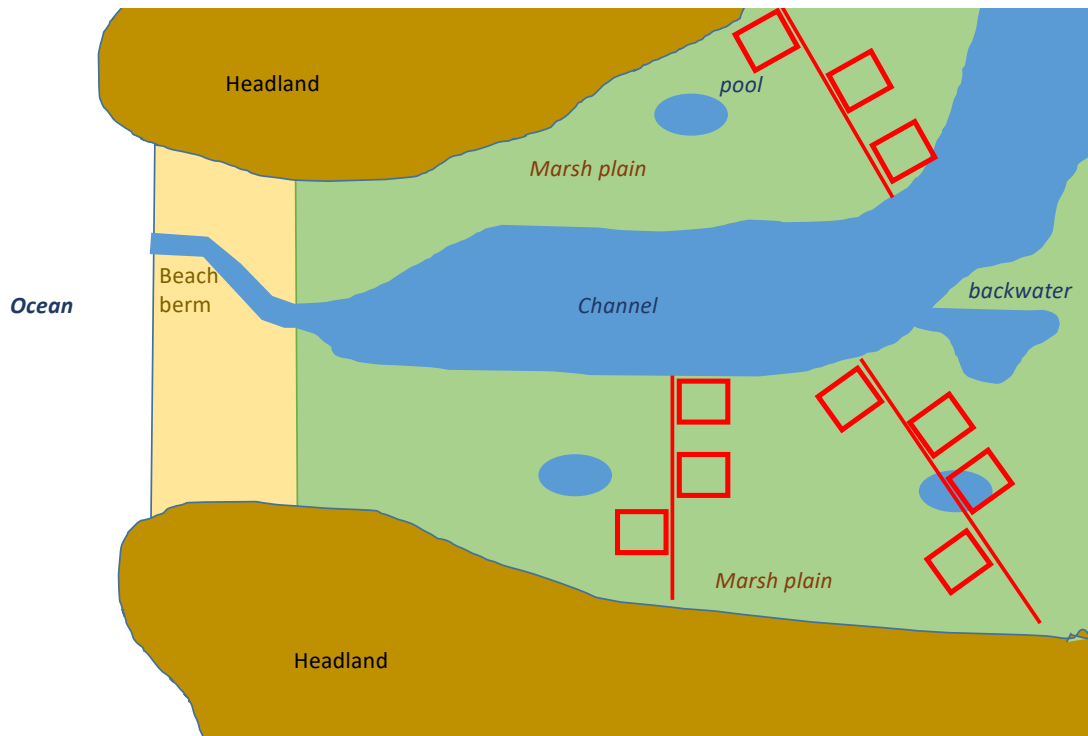


Figure 12. Example BBE with topographic and vegetation community data collection using quadrates (red squares) along set transects (red lines), from channel edge out to upland transition.

#### *Data Analysis and Reporting*

After a year of deployment, and annually for 2 additional years for some sites, the data was downloaded from the temperature/depth loggers and subsequently re-deployed. Water level over the course of the year was determined by combining the recorded depths with the elevation of the logger. The nature of water level fluctuations allows for the determination of breaching events. Data from the vegetation surveys was used to define minimum, maximum, and average elevations of the marsh—if the water level is above a given elevation then everything below that elevation is assumed to be inundated. Inundation percent of marsh elevations was calculated by combining water levels and topographic data.

The advantages of this monitoring approach of bar-built estuaries is that once a methodology is in place it eases the difficulty of long-term monitoring. Much of the processing, analysis, and figure generation has been automated, meaning that once certain files are updated with new data the analysis can be completed or the figure generated with little hassle.

Once the data was processed and analyzed it was used to create three types of figures: composite graphs of multiple variables for each BBE, marsh plain inundation maps, and vegetation inundation boxplots.

Please refer to the document titled “Final Report: Development of a Bar-built estuary monitoring system and resource management prioritization framework for California State Parks” for a complete description of the tools mentioned in this manual and their utility. Please visit [www.centralcoastwetlands.org](http://www.centralcoastwetlands.org) for a copy of the report.

## References

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