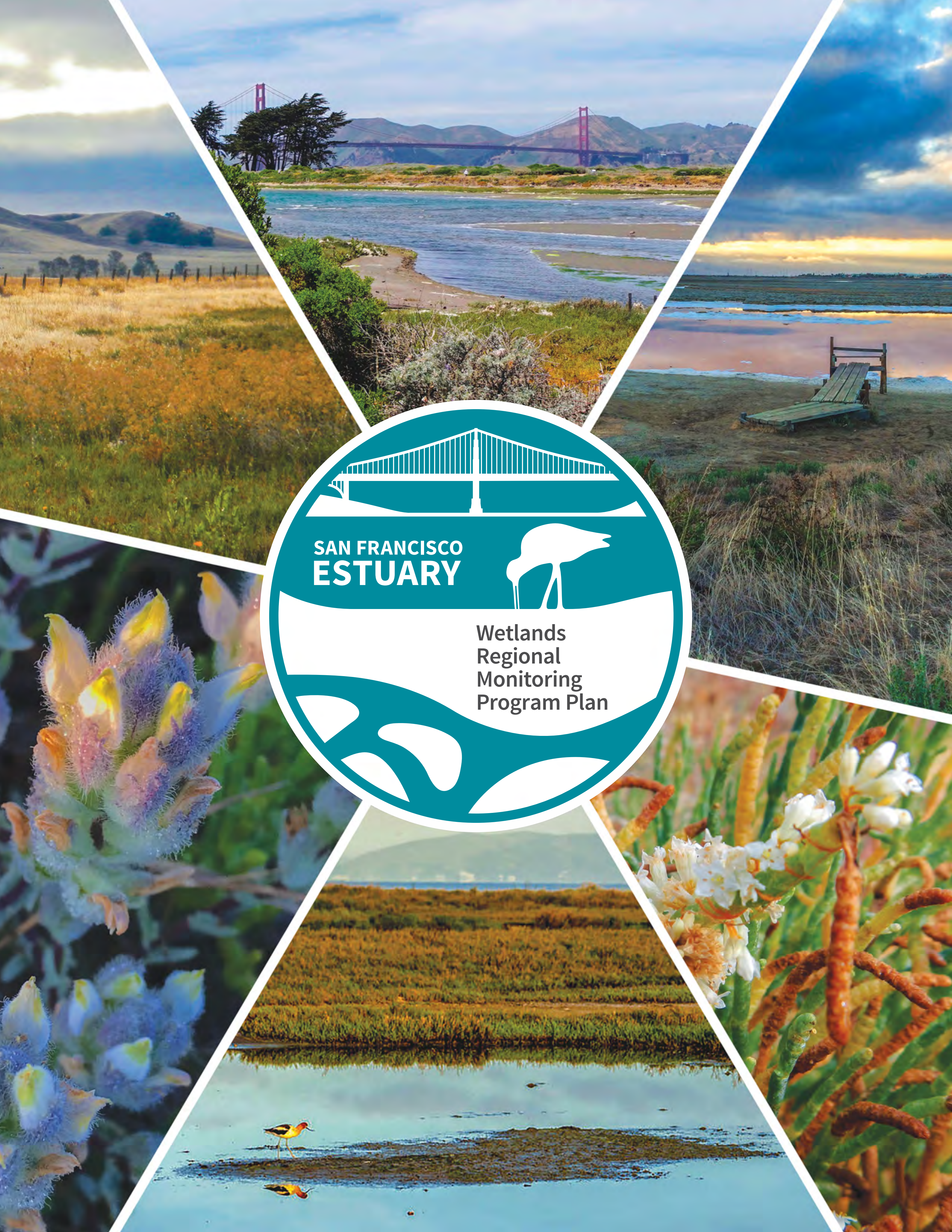

SAN FRANCISCO
ESTUARY

Wetlands Regional Monitoring Program Plan

SF ESTUARY
Wetlands
Regional
Monitoring
Program

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LIST OF ACRONYMS

ASC	Aquatic Science Center
BAARI	Bay Area Aquatic Resources Inventory
Bay RMP	Regional Monitoring Program for Water Quality in San Francisco Bay
BCDC	San Francisco Bay Conservation and Development Commission
BEHGU	Baylands Ecosystem Habitat Goals Update
CCMP	Comprehensive Conservation and Management Plan
CDFW	California Department of Fish and Wildlife
Delta RMP	Delta Regional Monitoring Program
EBRPD	East Bay Regional Parks District
USEPA	U.S. Environmental Protection Agency
GQ	Guiding Question
IEP	Interagency Ecological Program
MAD	Mosquito Abatement District
MQ	Management Question
NERRS	National Estuarine Research Reserve System
NGO	Non-governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OLU	Operational Landscape Unit
QA/QC	Quality Assurance/ Quality Control
SAT	WRMP Science Advisory Team
SC	Steering Committee
SCC	State Coastal Conservancy
SF Bay	Estuary Downstream of the Delta
SF Bay NERR	San Francisco Bay National Estuarine Research Reserve
SFBJV	San Francisco Bay Joint Venture
SFBRA	San Francisco Bay Restoration Authority
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SFEP	San Francisco Estuary Partnership
SLR	Sea Level Rise
SOP	Standard Operating Procedure
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
UAS	Unoccupied Aerial System
USACE	U.S. Army Corp of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WRAMP	Wetland and Riparian Area Monitoring Plan
WRMP	Wetland Regional Monitoring Program

EXECUTIVE SUMMARY

Tidal wetlands in the San Francisco Estuary face an uncertain future due to climate change, continued development pressure, and other regional stressors. Accelerating sea level rise and decreased sediment supplies threaten to drown and erode existing tidal wetlands, undo restoration progress that has been made to date, and increase the risk that new restoration projects will fail to meet intended environmental outcomes. The potential long-term, widespread loss of the Estuary's tidal wetlands not only threatens the health and diversity of its habitats, but places vulnerable shoreline communities at a greater risk of flooding and harm from rising sea levels. A Wetland Regional Monitoring Program (WRMP) can leverage monitoring data to respond and adapt to these challenges and help support a more resilient Estuary. Through a collaborative, consensus-based process, the WRMP is engaging stakeholders to: 1) Understand how the region's tidal wetlands are changing over time and, 2) Support decision-making informed by the best available science.

The Bay Area is host to a diverse array of partners working on wetlands restoration. Environmental advocates, public institutions and agencies, private landowners, and other interests are part of the restoration community working towards a regional and scientifically sound monitoring program to guide tidal wetland restoration design, permitting and adaptive management. This WRMP Plan was developed through a Steering Committee of the public agencies and NGOs responsible for and/or participating in tidal wetland protection and restoration in the Bay Area. The primary goal of the WRMP Plan is to identify the science and technology framework, institutional relations, governance structure, start-up and operational costs, and funding sources for the program. To ensure the high value and relevance of the WRMP, it is being planned to address the following Guiding Questions developed by the Steering Committee:

- Where are the region's tidal wetlands and wetland projects, and what net landscape changes in area and condition are occurring?
- How are external drivers, such as accelerated sea level rise, development pressure, and changes in runoff and sediment supply, impacting tidal wetlands?
- How do policies, programs, and projects to protect and restore tidal marshes affect the distribution, abundance, and health of plants and animals?
- What new information do we need to better understand regional lessons from tidal wetland restoration projects in the future?
- How do policies, programs, and projects to protect and restore tidal wetlands benefit and/or impact public health, safety, and recreation?

The WRMP Plan addresses these guiding questions through a tiered sequence of management and monitoring questions that are in turn answered by a suite of key environmental indicators and metrics. The WRMP developed these questions, indicators, and metrics through a series of targeted technical workshops that engaged hundreds of the region's most knowledgeable

Photo - Aimee Good

experts on the Estuary's varied physical processes, vegetation dynamics, fish and wildlife communities, and mosquito and vector control practices. This work was further supported by the engagement of a WRMP Science Advisory Team that helped develop a coherent vision for turning monitoring data into information for use by decision-makers. The science framework for the WRMP includes the following components:

- A suite of conceptual models meant to inform a shared understanding of the relationships between tidal wetland habitats, processes, and functions in the Estuary.
- A framework for cost-effective monitoring that includes where and when the monitoring will occur in the various subregions of the Estuary's tidal wetlands. See Section 2.4 "Space and Time Framework."
- A "master matrix" of monitoring questions, metrics, and indicators that describes existing sampling approaches that could be utilized by the WRMP, as well as highlighting approaches that need to be developed specifically for the WRMP. See Appendix A.
- A plan to develop a data management strategy that will facilitate the integrated analysis of data from the Estuary's many existing monitoring programs and projects as well as data collected specifically for the WRMP.

The WRMP is a new program that is intended to grow in scope and scale over time, and therefore identifies near-term science priorities that will be the focus of implementation over the next five to ten years. These priorities are:


Photo - Alex Wick

- Conduct regional baseline and subsequent routine surveys and inventories of the distribution, abundance, diversity, and condition of tidal wetlands throughout the region, using existing tools and metrics to the extent practicable and new tools and metrics where necessary.
- Establish the WRMP Monitoring Site Network (dependent on available funding and resources), starting with the Benchmark Site Network (network of relatively undisturbed mature marshes throughout the region that can provide early warning of landscape-scale change).
- Conduct repeated surveys (detect change) of living organisms and their habitats (indicators), and standardize the metrics and reporting for indicators that are common to projects and baseline/subsequent ambient monitoring, across the range of project designs and restoration practices.
- Analyze existing data on the relative roles of estuarine and upland/watershed sources of sediment to counter the threats of marsh drowning, mudflat loss, and shoreline erosion driven by sea level rise.
- Assess the broad range of interactions between people and wetlands that should be monitored for the safety of people and health of the wetlands. This process should better integrate flood control and mosquito and disease vector control into project planning and assessment, and similarly integrate wetland restoration into flood control planning.

Future phases of WRMP planning will refine the program's science framework, data management approach, and funding and governance strategies. These future phases will be guided by the WRMP Steering Committee, with science input from a Technical Advisory Committee similar in nature to the Phase 1 Science Advisory Team. Within this WRMP Plan, several options are considered for funding and organizational options for the eventual program. These ideas will be leveraged in the next phase of the process.

The WRMP Plan is a significant milestone towards establishing a much-needed regional program to support the long-term, region-wide resilience of the Estuary's tidal wetlands, as well as the built and natural communities that depend on them. The WRMP will strengthen the regional community of tidal wetland scientists, engineers, planners, regulators, funders, and managers. It will place robust, peer-reviewed science at the center of collaborative decision-making. It will share responsibility and funding for implementation among community members, based on their missions and capacities, and help build capacity within the community as needed over time. It will produce scientifically sound and timely information to help the community define and achieve its local and regional goals for tidal wetland protection and restoration, and support a healthier Estuary for all.

CHAPTER 1
INTRODUCTION

1.1 Need for the WRMP
1.2 Regulatory Context
1.3 Geographic Scope
1.4 Program Development Process and Phased Approach
1.5 Guiding and Management Questions
1.6 Related Efforts

Photo - John Huseby

INTRODUCTION

1.1 Need for the WRMP

The San Francisco Bay (Bay) needs a Wetlands Regional Monitoring Program (WRMP) for multiple long and short-term data sets that can inform the restoration community and all interested stakeholders on the status and trends of the baylands in the face of climate change stressors. The overall purpose of the WRMP is to improve the protection and restoration of tidal marsh ecosystems in the Bay by turning monitoring data into the information needed by tidal marsh restoration planners, designers, funders, and regulators. The program will implement a science framework based on standardized methods to cost-effectively monitor the response of key tidal marsh indicators to climate change, population growth, and other regional drivers of change. In addition, it will develop a data management platform to share data generated through the program and related efforts.

In this WRMP Plan, the phrase "tidal marsh" refers to the "complete" tidal marsh ecosystem defined by the 2015 Baylands Ecosystem Habitat Goals Update (BEHGU; Goals Project, 2015). This definition includes intertidal habitats such as marsh plains, tidal flats, and channels as well as fringing adjacent subtidal habitats and estuarine-terrestrial transition zones. This emphasis on connected subtidal, intertidal, and supratidal habitats reflects scientific consensus on the importance of landscape connectivity to the long-term resilience of the Bay's tidal marshes in the face of climate change. See full Glossary in Appendix G.

Tidal marsh restoration monitoring in the Bay is currently dominated by project-specific, site-scale monitoring that can obscure the effects of, and interactions between, important landscape-scale drivers such as sea level rise, changes in watershed hydrology and sediment supply, land subsidence, development, flood management activities, invasive species, and more. This creates an information gap that can make it difficult for decision-makers to develop, implement, and adaptively manage tidal marsh restoration projects to respond to these drivers, and support the long-term, landscape-scale resilience of healthy bayland ecosystems. Regional scientific syntheses and planning guidance (see Table A) initiatives to coordinate environmental review and permitting (Delta Independent Science Board, 2017; Bourgeois, 2018), and the establishment of the San Francisco Bay Restoration Authority are all intended to contribute to increasing the pace and scale of tidal marsh restoration throughout the Estuary. These efforts will in turn increase the need for a comprehensive, shared, accessible, and technically rigorous foundation of information that funders, land managers, restoration practitioners, and regulators can rely upon to inform project location/design, permitting, and adaptive management.

The WRMP plan aims to address information needs by folding existing and proposed future tidal marsh monitoring efforts into a new regional framework that focuses on key management questions of interest to decision-makers. This framework is based on regional scientific syntheses such as BEHGU as well as a suite of conceptual models that are generally understood to describe processes, functions, and conditions in the Estuary's tidal marshes (Appendix F). The WRMP Plan has several components. In Section 2, the science framework proposes to collect monitoring data that addresses physical processes, habitats and vegetation communities, fish and wildlife populations, and mosquito and vector control at different scales over space and time. Next, Section 3 includes a robust data QA/QC, management, and reporting structure to turn data into information that can then answer they key management questions. Section 4 proposes options for administration, governance, and funding of the eventual program. Finally, Section 5 provides a roadmap for implementation.

1.2 Regulatory Context

Permitting a tidal marsh restoration project is a time consuming, expensive, complex process that requires significant expertise from the project sponsor, consultants, regulatory staff, and stakeholders. Many laws and regulations apply to tidal marsh restoration projects, including the California Environmental Quality Act, Porter Cologne Water Quality Control Act, California Endangered Species Act, California Native Plant Protection Act, Natural Community Conservation Planning Act, California Fish and Game Code, McAteer-Petris Act, Clean Water Act, National Environmental Policy Act, Federal Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act, Marine Mammal Protection Act, Coastal Zone Management Act, and, depending on the project's location and specific circumstances, other state and municipal laws and regulations. As a result, coordination between the project sponsors and the multiple agencies administering these laws and regulations can be challenging.

The WRMP is designed to support greater efficiencies and enhance the value of monitoring efforts associated with permitting tidal marsh restoration projects. The primary intent of the WRMP is to provide a mechanism to collect regional scientific information to evaluate project performance, improve regional assessment, and reduce data redundancy and monitoring pressure on individual restoration projects. The WRMP will use and standardize methods of data collection, management, and analysis to test broadly accepted conceptual models and assure that project data can be compared over time, relative to ambient conditions. This will provide restoration projects a standardized monitoring framework and allow managers to synthesize monitoring data across multiple temporal and spatial scales, which is necessary to determine the relative influences of project design, management, interactions among projects, and regional factors (such as sea level rise and sediment supply) on the health of tidal marsh ecosystems. The development of the WRMP monitoring site network may provide support to tidal marsh restoration projects by providing long-term data that, with agency approval, could be used to compare individual project performance with regional reference conditions. If data produced from the implementation of the WRMP could be compared with data from individual restoration projects, the time and costs for each project to comply with monitoring requirements could potentially be reduced. By reducing costs, time, effort, and redundancy involved in project monitoring throughout the San Francisco Estuary, robust monitoring results from the WRMP can improve regional efficiency in complying with monitoring requirements. While the WRMP can improve regional understanding of drivers and performance of projects it may not include all regulatory requirements, especially those addressing species facing population and habitat loss. As a result, the monitoring requirements of individual restoration projects might be customized, based on the resources affected by the project, for example, when listed species occupy a project site.

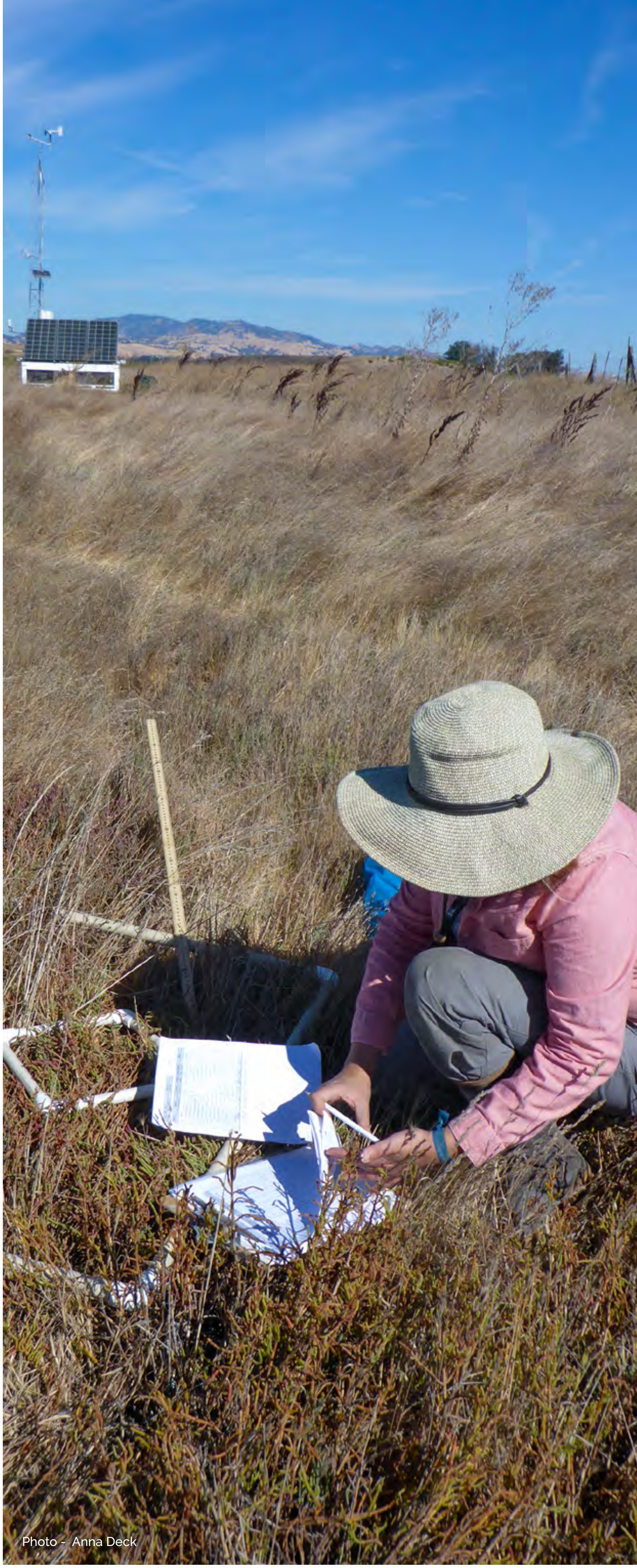


Photo - Anna Deck

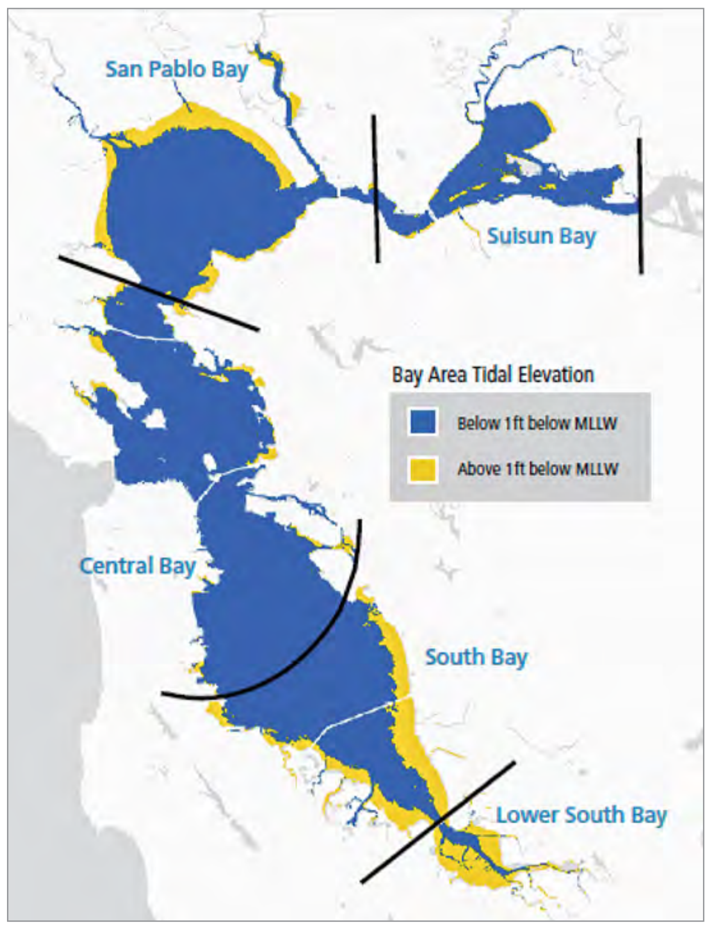
1.3 Geographic Scope

The geographic scope of the WRMP encompasses the "complete" tidal marsh ecosystem, as defined by BEHGU. The complete tidal marsh ecosystem includes subtidal areas to a depth of 12 ft below local Mean Lower Low Water (zero tide height), tidal flats, fully tidal and muted tidal marshes, and adjoining estuarine-terrestrial and estuarine-fluvial transition zones. The scope does not currently include managed marshes, such as duck clubs in Suisun Marsh, or diked non-tidal marshes within the historical limits of the San Francisco baylands (Goals Project, 2015). When these latter systems are restored to tidal action (either by purposeful restoration or by levee failure), they will be incorporated into the scope of the WRMP. The WRMP recognizes that the complete tidal marsh ecosystem includes the entire intertidal zone, the estuarine-terrestrial transition zone, and the subtidal zone to the maximum depth of rooted submergent vegetation and surface wave effects on benthic sediment resuspension. The boundaries of these zones are inexact in nature. Any assessment of distribution, abundance, diversity, or condition of tidal marshes should consider the complete tidal marsh ecosystem. However, unless stated otherwise, the term tidal marsh pertains to the intertidal portion of the ecosystem that supports rooted, vascular vegetation.

The WRMP eventually may expand to include non-tidal, inland wetlands, rivers, streams, and associated riparian areas and transition zones of the watersheds draining to the Estuary downstream of Broad Slough. This expansion can inform and assess the effectiveness of climate change adaptation efforts, especially as they relate to tidal or stream flooding, and management of the connections between watersheds and baylands. Future phases of the WRMP may also expand upstream of Broad Slough into the Sacramento-San Joaquin River Delta (Delta), leveraging the existing and planned future monitoring and data management efforts of the Interagency Ecological Program (IEP), Delta Science Program, Delta Regional Monitoring Program (Delta RMP), and related stakeholders. Fostering collaboration with Delta partners improves the ability to assess the environmental effects of Delta water management and ecosystem restoration actions on estuarine ecology and tidal wetland resilience downstream in the Bay.

To facilitate data analysis, interpretation, and management consistent with other regional monitoring efforts such as the Regional Monitoring Program for Water Quality in San Francisco Bay (Bay RMP), the geographic scope of the WRMP is divided into five subregions including Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay (Figure 1). This is consistent with the Bay RMP. The WRMP may also utilize Operational Landscape Units (OLUs), identified in the San Francisco Bay Shoreline Adaptation Atlas (see Table A). Operational Landscape Units are contiguous areas of baylands and adjoining watersheds distinguished by their unique combination of geology, topography, precipitation, and estuarine conditions that, in general, are likely to respond in similar ways to climate change. OLUs can serve as a natural spatial template at a scale between individual watersheds and subregions or counties for planning and assessing climate change adaptation.

Figure 1. WRMP Subregions



(Source: SFEI)

1.4 Program Development Process and Phased Approach

The WRMP Plan development process began in Fall 2017. A Steering Committee (SC) was formed to guide the decision-making process using a consensus-based approach. The SC is made up of regulators, land managers and scientists. The SC will remain in place during the next phase where they will focus on developing a Charter, Funding Plan, and data management approach for the WRMP.

The SC is supported by a core project team. The core team includes members of the following organizations: San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), San Francisco Bay National Estuarine Research Reserve (SF Bay NERR), U.S. Environmental Protection Agency (USEPA), San Francisco Estuary Partnership (SFEP), San Francisco Estuary Institute - Aquatic Science Center (SFEI - ASC), and the San Francisco Bay Joint Venture (SFBJV) (who will be added in 2020). SFEP is the project lead, and the SFEP Project Manager is also the Chair of the SC.

Science consultation was a critical component of this process. The core team organized a series of workshops to collect input on the science content, led by technical experts. A Science Advisory Team (SAT) was formed and provided input during pivotal phases. In 2020, a Technical Advisory Committee (TAC) will be formed and Chaired by staff of the SFBRWQCB and supported by the core team.

The WRMP Plan is intended to guide program development. The guidance set forth in this document will be implemented in phases. Initial phases will focus on program foundations and baseline science. As WRMP capacity grows, additional elements will be added. During the next planning process phase (2020 - 2021) the project team will utilize the guidance in the WRMP Plan and build from it. A complete description of the project development process can be found in Appendix B.


Photo - Shira Bezalel

1.5 Guiding and Management Questions

The SC adopted a set of goal statements, guiding questions, and management questions using a consensus-based decision process (see Appendix B). The WRMP will focus on the Guiding Questions in sequence, since the answers build on each other and are somewhat additive.

GUIDING QUESTION 1: Where are the region's tidal marsh ecosystems, including tidal marsh restoration projects, and what net changes in ecosystem area and condition are occurring?

More than 90 percent of the total acreage of historical tidal marshes of the Estuary has been lost since European colonization starting in the 18th century. Many entities are working diligently to achieve a regional goal of 100,000 acres of healthy marsh to secure ecological and social benefits, consistent with the directions set forth in BEHGU. The transition zone and shallow subtidal zone are not included in the tidal marsh acreage goals. It is expected that tidal marsh restoration will consider and include these adjacent areas as appropriate. The restoration work enjoys substantial investments of public monies from bonds, taxes, and the operating budgets of participating public agencies. It is essential to assess progress toward the regional goal, adjust restoration strategies if necessary, and report how the public investments benefit the Estuary's natural and built communities.

MANAGEMENT QUESTION 1A. What is the distribution, abundance, diversity, and condition of tidal marsh ecosystems, and how are they changing over time?

Integrated, regional management of tidal marshes requires an understanding of spatial and temporal trends in the extent, abundance, diversity, and condition of the complete tidal marsh ecosystem. Trends indicate both the direction (i.e., increases or decreases) and rate of change. Baseline regional assessment yields information against which future change can be measured. Tracking changes in the extent of habitats for threatened and endangered species can be especially important. Assessing transition zones (including upland, tidal, and subtidal) can also be especially important, given their broad range of ecological functions, such as protecting wildlife from extreme high tides, serving as safe corridors for wildlife dispersal and migration, processing nutrients, and lessening flood risks for the built environment. In the longer term, transition zones can provide space for the inland migration of tidal ecosystems as sea levels rise.

The remnants of historical, high-elevation, mature tidal marshes of the Estuary deserve special attention. They are rare at this time (Atwater, et al., 1979) and their great ecological value is well documented. The remnants support the greatest diversity of plant and animal species, including most of the rare, threatened, and endangered species (U.S. Fish and Wildlife Service, 2013). They serve as the models for the desired endpoints of tidal marsh restoration and are the source of most of the scientific research about the nature of tidal marsh ecosystems for the Estuary. Several recent studies have demonstrated their vulnerability to the combined effects of rapid sea level rise and diminished regional sediment supply (Stralberg, et al., 2011; Schile, et al., 2014; Takekawa, et al., 2013).

MANAGEMENT QUESTION 1B. Are changes in tidal marsh ecosystems impacting water quality?

Water quality is a complex concern for tidal marsh ecosystems, due in large part to the position of marshes at the boundary between the open embayments of the Estuary, rivers and streams, and agricultural and urban storm drains. Many studies have shown that marshes can help filter water to reduce pollutants and improve quality. This does not pertain to all forms of water pollution, however, and the filtering efficiency of tidal marshes for any pollutant can depend on many factors, including tidal elevation, salinity, vegetation type, marsh size, and pollutant load.

Management practices can have a range of deleterious effects on water quality. For example, the use of flood gates or other water control structures to mute the tidal range at a marsh, or to impound water on the marsh plain, can impair the water quality of the marsh. Grading and excavation of diked areas in preparation for restoration of tidal action can exhume legacy contaminants from onsite land uses that post-date diking, and from off-site uses that pre-date diking. In addition, dredging near a tidal marsh can release contaminants that can be transported into the marsh by the flood tides. Any increased contaminant load within a marsh can be transferred at least in part to other areas of the Estuary via tides and currents.

Methylmercury and dissolved oxygen are two regional, nearly ubiquitous, water quality concerns in the Estuary. Mercury is common in the shallow subtidal and intertidal zones, due to atmospheric deposition and its presence in sediment washed into the Estuary from historical mercury mines and gold mines. Diked areas of former tidelands can have high mercury concentrations due to the tidal deposition of abundant sediment from mines prior to diking and before the mining ceased. Some tidal marshes support methylation of mercury, depending on marsh elevation, salinity regime, vegetation type, and a variety of edaphic factors. The risk of natural or restored marshes generating enough methylmercury to contaminate marsh food webs or other estuarine food webs has resulted in the development of bio-sentinel indicators of intertidal food web exposure to methylmercury.

The WRMP may need to help address a variety of additional water quality issues in the future that are not covered by the current WRMP Plan. These include eutrophication, toxic algal blooms, water temperature, acidification, trash, new biological invasions, microplastics, and other contaminants of emerging concern.

GUIDING QUESTION 2: How are external drivers, such as accelerated sea level rise, development pressure, and changes in runoff and sediment supply, impacting tidal marsh ecosystems?

The WRMP will assess the regional, ambient conditions of tidal marsh ecosystems, and the relative influence of ambient conditions on projects, relative to project design and project management. This will help inform decisions about when and how to adjust project performance criteria, as ambient conditions change. A combination of periodic regional inventories, probabilistic surveys, and monitoring efforts that are scaled across space and time are needed to address this question. This may include intensive monitoring at Benchmark Sites and reference sites as well as project-level monitoring.

MANAGEMENT QUESTION 2A. How are tidal marshes and tidal flats, including restoration projects, changing in elevation and extent relative to local tidal datums?

Monitoring the tidal and geodetic elevation and lateral extent of the three main components of the tidal marsh ecosystem (the intertidal zone, shallow subtidal zone, and transition zone) is vital to assessing the degree to which habitats of these zones are migrating landward, maintaining themselves, or drowning and eroding due to sea level rise, diminished sediment supply, subsidence and settling, tectonic action, or a combination of all of these factors. The WRMP is collaborating with the Sediment Workgroup of the Bay RMP and the Tidal Marsh Remote Sensing Workgroup of the Montezuma Wetlands Project. These collaborations will determine the best ways to combine state-of-the-science remote sensing technologies, tidal datum determination, geodesy, and field-based measures of suspended sediment supply, inorganic sediment deposition, and autochthonous organic matter production to cost-effectively estimate net change in elevation and extent of the zones at regional and project scales. Additional recommendations are expected to cover monitoring the abundance, distribution, and size of tidal marsh pannes and major-dominant plant assemblages. The recommendations are likely to identify public agencies, NGOs, consultancies, and academic institutions that might collaborate on implementation.

MANAGEMENT QUESTION 2B. What are the regional differences in the sources and amounts of sediment available to support accretion in tidal marsh ecosystems?

As sea level rise accelerates, the reliance of tidal marsh ecosystems on fine inorganic sediment to naturally maintain their elevations substantially increases. Maintaining high-elevation mature tidal marshes is especially important. Preliminary estimates of existing supplies relative to anticipated future demands for tidal marsh protection and restoration indicate substantial deficits in supply, although these vary among local watersheds and OLUs. These estimates can initially guide understanding of which mature marshes and restoration projects have the greatest chances of survival and success. This information can in turn guide efforts by the WRMP to generate the monitoring data needed to further develop and calibrate the models used to estimate sediment supply and demand. For example, the WRMP is collaborating with the Sources, Pathways, & Loadings Workgroup of the Bay RMP, and the Sediment Workgroup of the Bay RMP to help determine the locations of the Benchmark Sites of the WRMP, and to identify the best methods to sample suspended sediment and estimate local sediment supplies.

GUIDING QUESTION 3: What new information do we need to better understand regional lessons from tidal marsh restoration projects, advance tidal marsh science, and ensure the continued success of restoration projects?

Management decisions can be enhanced by anticipating what kinds of lessons are important and ensuring that restoration projects are monitored consistently to create information that feeds back into decision-making. The WRMP Plan focuses on indicators that are likely to support projects as learning opportunities. There are many potentially important lessons about the siting, design, and management of tidal marsh restoration projects that can be anticipated. Some questions of high importance to decision-makers include: breach size, whether or not to excavate drainage systems, whether or not to plant vegetation, the use and design of wind-fetch breaks, what amount of topographic relief of constructed marsh plains is optimal, how to control the settling or compaction of dredged sediment used to elevate diked baylands, how to artificially increase sediment bulk density, the ideal thickness of thin lifts of sediment, and how to best nurture suspended sediment concentrations of flood tides. Many new questions will arise about the optimal sites, designs, and management practices for transition zone restoration, since there is relatively little experience in the region.

MANAGEMENT QUESTION 3A. Where and when can interventions, such as placement of dredged sediment, reconnection of restoration projects to watersheds, and construction of living shorelines, help to sustain or increase the quantity and quality of tidal marsh ecosystems?

The WRMP has prioritized the need to learn how project siting can help offset the dual threats of accelerated sea level rise and diminishing sediment supplies, as well as when intentional augmentation of sediment supplies is needed. Project siting is mainly about improving the connection between projects and local watershed yields of terrigenous sediment, as suspended load or bedload.

The WRMP will meet these information needs in four ways. First, the WRMP is working with the Sediment Workgroups of the Bay RMP and the Regional Sediment Management TAC of the Healthy Watersheds and Resilient Baylands Project to select candidate WRMP Benchmark Sites that are directly subjected to large yields of terrigenous sediment, and where validated rating curves to estimate the yields exist or are being developed, and where flow is also being monitored. This will assure that the Benchmark Sites, in aggregate, represent the full range of quantifiable suspended sediment supplies that might be provided by watersheds, in order to explore the correlation between sediment supply and the ability of tidal marshes to maintain their tidal elevations. Second, the WRMP will employ methods to detect annual changes in tidal marsh elevation at the Benchmark Sites to detect any time lags between sediment yield from local watersheds and sediment supplies within local marshes. Potential land subsidence will also be considered through geodetic assessment. Third, the WRMP will monitor annual changes in the distribution and abundance of major-dominant assemblages of vegetation at the Benchmark Sites. This will enable statistical exploration of the vegetation community response to changes in the tidal elevations of the marshes, as affected by local sediment supplies. Finally, as these data accumulate, they will be used to identify thresholds in sediment supply corresponding to measurable decreases in tidal elevation of the marshes that in turn correspond to measurable shift changes in vegetation from high-marsh to low-marsh assemblages, and that could, therefore, prompt intervention to augment sediment supplies.

GUIDING QUESTION 4: How do projects to protect and restore tidal marshes affect the distribution, abundance, and health of plants and animals?

The most common goals of tidal marsh protection and restoration projects are to provide habitat to benefit tidal marsh-dependent wildlife and to increase the resilience of tidal marsh plant and animal communities to sea level rise and increasing storm frequency and intensity. To assess how well projects are providing these benefits and to improve best practices, wildlife response–including responses to public access and recreation in and around tidal marsh habitat–must be assessed and that information must be accessible. Too often, project-related wildlife monitoring is conducted only within the project footprint, if at all, and only for short periods, usually one to three years following implementation. In many cases, wildlife is not expected to respond to the restoration until many years later when there is no longer funding available for monitoring. Without wildlife response data we cannot learn how to improve restoration practices or incorporate design elements that provide benefits for desired species. Furthermore, comparing restoration practices among projects can be difficult to impossible when wildlife assessment methods are not standardized or the data are not accessible, which are often the case. The WRMP seeks to address these issues by: 1) developing or promoting standardized assessment methods; 2) providing a regional context for assessments through a network of sites that are monitored at regular intervals as described in the space-time framework; and 3) relating project-specific changes in wildlife and habitat indicators to the relevant indirect drivers.

MANAGEMENT QUESTION 4A. How are habitats for assemblages of resident species of fish and wildlife in tidal marsh ecosystems changing over time?

This management question involves physical and vegetation mapping and monitoring as it relates to habitat for fish and wildlife. First, monitoring efforts carried out by the WRMP will be informed by and build upon existing guidance and plans (including the Tidal Marsh Recovery Plan; see Table A). Important habitat features for many of the indicator species are already known. For example, gumplant (Grindelia stricta) is important for tidal marsh dependent bird species such as Ridgway's rail (Rallus obsoletus), song sparrow (Melospiza melodia), and common yellowthroat (Geothlypis trichas). Other vegetation metrics related to wildlife include plant richness and abundance, and plant height and vertical density (e.g., stem density at different heights). Measures of habitat connectivity, patch size and shape, elevation within the tidal frame (e.g., low, mid and high marsh), salinity, transition zone characteristics, and distance to urban areas can be important predictors for tidal marsh wildlife and will be considered in the WRMP's assessments of tidal marsh habitat quality. The WRMP will develop or promote standardized habitat assessment methods that incorporate the elements mentioned above at a network of sites as described in the space-time framework (Section 2 and Appendix D). When combined with the mapping efforts the on-the-ground vegetation measurements can be used to produce detailed maps of habitat extent and quality that relate directly to the needs of fish and wildlife. This process will be repeated at regular intervals, or in response to episodic events, to assess change over time and to evaluate how restoration projects are progressing relative to reference sites.

MANAGEMENT QUESTION 4B. How are the distribution and abundance of key resident species of fish and wildlife of tidal marsh ecosystems changing over time?

Some wildlife survey data may be characterized by high annual variation making it a challenge to distinguish a response to restoration actions from "normal" fluctuations. Critical for assessing response to restoration is understanding how fish and wildlife populations are changing over time and the associated drivers of those changes. For example, species abundance at a project site may fluctuate based more on foraging or breeding conditions outside the project area than on the enhancements within the project. In some instances, we may gain a greater understanding of restoration response when that response is evaluated in a regional or broader context. Without the regional context, it may be difficult to determine which restoration practices work best and which may cause more harm than good to the wildlife we aim to benefit.

The WRMP will track changes in fish and wildlife metrics over time at the network of sites to: 1) better understand how species respond to changes in the environment; and 2) facilitate the assessment of project-specific responses. Broader drivers and trends outside the Estuary will also inform these metrics. Tidal restoration in the Estuary has been largely successful in providing benefits to target wildlife but as climate change accelerates, this pattern may change. The "tried and true" restoration techniques we rely on may no longer provide the expected benefits. For this reason, restoration practitioners and funders are increasingly focused on implementing projects that increase fish and wildlife resilience to sea level rise and other climate change-related stressors. Rapidly developing and testing novel restoration and adaptation features are essential for building resilient ecosystems that provide benefits to fish and wildlife into the future.

GUIDING QUESTION 5: How do projects to protect and restore tidal marshes affect public health, safety and recreation?

Public support and investment in tidal marsh restoration require that projects benefit both the Bay's natural and built communities. This question pertains mainly to the regional effects and benefits of tidal wetland restoration and management on flood control, shoreline stability, water quality, public health (including mosquito abatement), public access and recreation, and aesthetics. One or more of these benefits are often cited as part of the justification for tidal marsh restoration. At this time, the WRMP's efforts related to public health and safety and recreation will focus on data and collaborations among agencies that are needed to efficiently control mosquitoes and other disease vectors that are associated with tidal marsh. In the future, the WRMP intends to assess other aspects of the relationship between tidal marsh restoration and human health and safety and recreation, including appropriate access to open space and flood management benefits and risks, with special regard for environmental justice and social equity considerations.

MANAGEMENT QUESTION 5A. What mosquito and vector control strategies need to be considered in restoration design and management to understand the effects that restoration can have on mosquito and vector populations?

Mosquito populations are best controlled in wetland habitats by increasing tidal circulation (primarily through ditches) to enhance drainage between high tide cycles and introduce mosquito larvae predators. Areas of deeper open water are less attractive to mosquitoes because wind action agitates the water surface. Historically diked sites that have been recently breached and restored to tidal action generally result in deep ponds with relatively little mosquito production. However, these sites are expected to change over time, with changes in geomorphology and plant communities. Recently restored sites may have few mosquitoes initially, but abundance may increase over time as marsh elevations evolve. Longer term planning is needed to address the evolution of mosquito habitat and accompanying maintenance needs.

MANAGEMENT QUESTION 5B. What monitoring data are needed to optimize the relationship between tidal marsh restoration, fish and wildlife support, and mosquito and vector control?

Wetland monitoring data should include, but not be limited to, mosquito abundance, arbovirus prevalence, and landscape topography. A key factor for mosquito production is the hydroperiod – the frequency and duration of flooding, as well as the duration of drainage and surface drying. Flood duration is critical because juvenile mosquitoes need time to pass from egg to larvae to pupae while residing in water before emerging as biting adults. Dry surface duration is critical to allow egg conditioning that is needed for some species to hatch successfully. Ineffective management of hydrology and habitat features, such as vegetation and topography, can cause or contribute to increased mosquito abundance. Vegetation protects juvenile mosquitoes from waves, currents, and predators, and the degree of protection depends on plant community composition and density. As marshes accrete and the topography modifies, this can have an impact on the hydrology of the marsh and create low-lying areas where mosquitoes can breed. Wetland projects should be designed, monitored, and adapted in ways that reduce mosquito abundance so that risk to humans and wildlife is minimized.


Photo - Aimee Good

1.6 Related Efforts

Several related planning efforts informed and guided the program development process. Those processes are summarized below in Table A.

Table A. Related Planning Efforts

RELATED PLANNING EFFORTS	
Estuary Blueprint	The 2016 CCMP or Estuary Blueprint is the third in a series, updating 1992 and 2007 plans undertaken by the San Francisco Estuary Partnership. This landmark update addresses current concerns and future uncertainties—ranging from rising sea levels to drought, habitat loss, and failing fish and wildlife—and provides priority actions under the following topic areas: Habitats and Living Resources, Climate Resilience, Water Quality and Quantity, and Stewardship.
SF Bay Joint Venture Implementation Plan	In 2001 the San Francisco Bay Joint Venture (SFBJV) published a 20-year collaborative plan for the restoration of wetlands and wildlife in the Bay region called Restoring the Estuary: An Implementation Strategy for the SFBJV. This strategy establishes specific acreage goals for wetlands of three distinct types—Bay habitats, seasonal wetlands, and creeks and lakes—and lays out programmatic and cooperative strategies for accomplishing them. A revision to this plan is in progress.
Baylands Ecosystem Habitat Goals Science Update	The Baylands Ecosystem Habitat Goals Science Update (2015) is an update to the 1999 Baylands Ecosystem Habitat Goals that for the first time set comprehensive restoration goals for the San Francisco Bay. It synthesizes the latest science—particularly advances in the understanding of climate change and sediment supply—and incorporates projected changes through 2100 to generate new recommendations for achieving healthy baylands ecosystems.
Interagency Ecological Program (IEP): Tidal Wetland Monitoring Framework for the Upper San Francisco Estuary	The Tidal Wetland Monitoring Framework for the Upper San Francisco Estuary is a resource to facilitate the development of scientifically sound project-specific plans for monitoring the effectiveness of tidal wetland restoration in providing benefits to at-risk fish species.
National Estuary Research Reserve System System-wide Monitoring Program	The National Estuarine Research Reserve System (NERRS) provides a valuable model for the WRMP. As part of its System-wide Monitoring Program (SWMP), the NERRS has been developing the Sentinel Site Program (SSP) for long-term, high-precision monitoring of mature tidal marsh ecosystems. With input from the SSP, SFEP included Action 2-4 to the CCMP/Estuary Blueprint to: "Establish a regional network of sentinel tidal marsh monitoring stations within the Delta and the Bay to support ecological forecasting and planning, incorporating and building on the San Francisco Bay National Estuarine Research Reserve program." To address this Action, the WRMP will establish additional monitoring sites, comparable to the two existing SSP sites, that together will represent the full range of natural condition of mature tidal marsh ecosystems in the Bay Area, as well as their range in vulnerability to climate change. To avoid confusion with the SSP, the WRMP sites are termed Benchmark Sites (see Section 2.5.1 below).
Tidal Marsh Recovery Plan (U.S. Fish and Wildlife Service)	The Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (Tidal Marsh Recovery Plan) features five endangered species: two endangered animals, California clapper rail (Rallus longirostris obsoletus) and salt marsh harvest mouse (Reithrodontomys raviventris) and three endangered plants, Cirsium hydrophilum var. hydrophilum (Suisun thistle), Chloropyron molle ssp. molle (soft bird's-beak), and Suaeda californica (California sea-blite). The biology of these species is at the core of the recovery plan, but the goal of this effort is the comprehensive restoration and management of tidal marsh ecosystems.
Regional Monitoring Program for Water Quality in San Francisco Bay	The Regional Monitoring Program for Water Quality in San Francisco Bay (Bay RMP) provides water quality information that regulators and decision-makers need to manage the Bay effectively. The Bay RMP is an innovative collaborative effort between the San Francisco Estuary Institute (SFEI), the SFBRWQCB, and the regulated discharger community.

RELATED PLANNING EFFORTS	
Delta Science Plan	The Delta Science Plan (2019) is an update from the 2013 Delta Science Plan initially developed to improve the use of science to inform the development and implementation of all Delta policies. This update outlines six objectives to achieve the One Delta, One Estuary vision including: strengthen science-management interactions; coordinate and integrate Delta science in a transparent manner; enable and promote science synthesis; manage and reduce scientific conflict; support effective adaptive management; and maintain, communicate, and advance understanding of the Delta.
Fill for Habitat Amendment to the San Francisco Bay Plan	The Fill for Habitat Amendment (2019) to the San Francisco Bay Plan will allow for more fill for habitat restoration projects in the Bay to restore and enhance natural habitat to adapt to sea level rise. On July 20, 2017, BCDC unanimously initiated a process to amend the San Francisco Bay Plan. The amendment includes additional changes that will overall improve how BCDC evaluates habitat projects moving forward. The Commission unanimously adopted Bay Plan Amendment 1-17 on October 3, 2019. On December 27, 2019 the Office of Administrative Law approved the policy amendment. As a result, BCDC will apply these revised policies to all non-federal projects. The Office of Coastal Management is now reviewing the policies for use with federal projects.
San Francisco Bay Subtidal Habitat Goals Report	The San Francisco Bay Subtidal Habitat Goals Report (2010) was a collaboration among BCDC, California Ocean Protection Council/California State Coastal Conservancy (SCC), National Oceanic and Atmospheric Administration (NOAA) Habitat Conservation, NOAA Restoration Center, and SFEP. The report outlines science, protection, and restoration goals for six subtidal habitats including soft substrate, rock, artificial structures, shellfish beds, submerged aquatic vegetation, and macroalgal beds. Where possible these goals include connections with intertidal, bayland, and upland habitats.
SFBRWQCB Wetland Policy Climate Change Update Project	The SFBRWQCB is proposing to develop an amendment to the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) to include guidance for planning and permitting decisions to address the threat of climate change and sea level rise. The Wetland Policy Climate Change Update Project Report provides the scientific background for these wetland fill challenges and future regulatory options in relation to climate change needed for the amendment.
San Francisco Bay Shoreline Adaptation Atlas	Developed by SFEI and San Francisco Planning and Urban Research, the San Francisco Bay Shoreline Adaptation Atlas (2019) proposes the use of Operational Landscape Units (OLUs), a science-based framework to manage the complex San Francisco Bay shoreline in the face of climate change. The Adaptation Atlas divides the shoreline in 30 OLUs and identifies where nature-based and hybrid measures in addition to engineering approaches can be implemented successfully to adapt to sea level rise.
Adapting to Rising Tides	Adapting to Rising Tides, a collaboration of local, state, and federal entities led by BCDC and NOAA Office for Coastal Management, was established in 2010 initially to plan for current and future flooding issues along the Alameda County shoreline. Since then, the program has been expanded to other regions along the Bay shoreline to lead and support multi-sector, cross-jurisdictional projects that build local and regional capacity.

CHAPTER 2
SCIENCE FRAMEWORK

2.1 WRAMP Framework

2.2 Priority Recommended Actions

2.3 Science Content

2.4 Space and Time Framework

2.5 Indicator Recommendations

Photo - Michael Vasey

SCIENCE FRAMEWORK

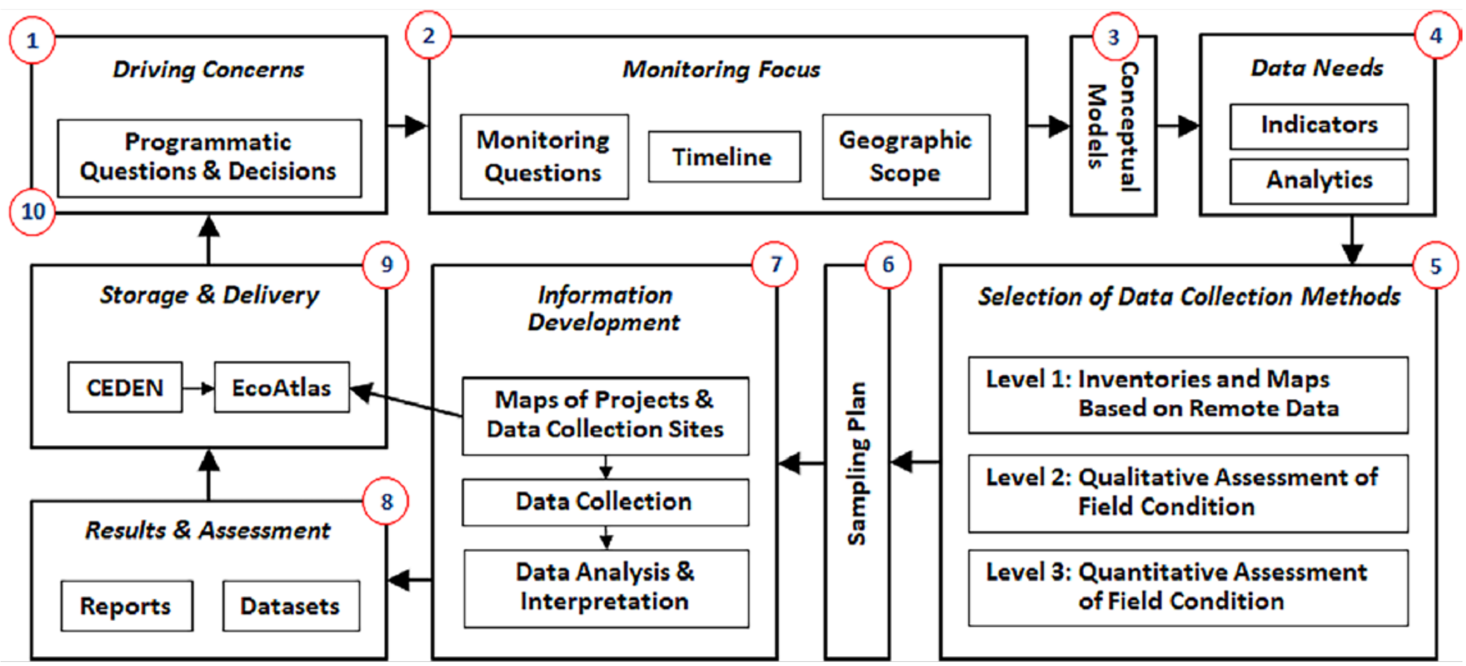
The science framework is the technical heart of the WRMP around which strategies for governance, funding, and data management are or will be structured. This section describes the WRMP's science content, key management and monitoring questions, and plans for phased implementation. The appendices provide additional details about monitoring elements, foundational conceptual models, and the collaborative process through which the WRMP science content evolved.

2.1 WRAMP Framework

Recommendations for monitoring indicators, metrics, and methods have been guided by the Wetland and Riparian Area Monitoring Plan (WRAMP). WRAMP is a living product of the Wetland Monitoring Workgroup of the California Water Quality Monitoring Council. WRAMP is a framework to integrate cost-effective project monitoring with ambient (external to project) monitoring in the watershed and regional contexts, based on prioritized management questions. According to the 10-step WRAMP framework presented below in Figure 2, the recommended WRMP science content will cover the details of indicators, metrics, data collection, sampling design, data management and interpretation, reporting, and operating costs. The WRMP science content will be consistent with the three spatial levels of data collection methods reference in Box 5 including: Level 1, or regional inventories that collect data across a broad region at the same time; Level 2, or regional probabilistic surveys that collect certain types of data at representative subsets of sites across a region or sub-region usually via remote sensing; and Level 3, or site-specific monitoring.

Many of the needed methods and tools of data collection and management already exist and are readily available. For example, research organizations such as the U.S. Geological Survey and the San Francisco Estuary Institute have developed standard operating procedures (SOPs) to collect, analyze, and manage data related to shoreline morphological change, suspended sediment concentrations, and accretion in marshes and mudflats. As much as possible, the WRMP will utilize and build off existing SOPs utilized by the Estuary's tidal wetland research community.

Figure 2. WRAMP Framework



SOURCE: California Wetland Monitoring Workgroup

2.2 Priority Recommended Actions

The sequence of guiding questions is intended to drive monitoring over a long period of time in order to provide answers in the form of regional trends. For an overview of the guiding and management questions, see Section 1.5. The guiding questions are tiered such that the answer to any one question depends in part on the answer(s) to the preceding question(s). A set of discrete monitoring questions that bridge the management questions and science are also proposed within the WRMP Plan. The monitoring questions are listed in the WRMP Master Matrix in Appendix A.

With input from the technical workshops, the Phase 1 SAT, and the Core Team, the SC has recommended five priority actions to be completed by the WRMP during its first 3-10 years of implementation. The exact timeframe to complete these actions cannot be foreseen due to uncertainties about program funding, staff resources, program governance, and other elements that will be addressed in Phase 2 of WRMP planning. These priority actions are summarized in Table B below. Further details describing data collection, QA/QC, and analysis are presented in Section 2 and Appendix A. As the WRMP is implemented, other actions or additional actions may be adopted, based on changing opportunities and constraints identified by the WRMP SC with the assistance of the TAC.

Table B. Summary of Priority Recommended Actions

GUIDING QUESTION	PRIORITY RECOMMENDED ACTION
1. Where are the region's tidal wetlands and wetland projects, and what net landscape changes in area and condition are occurring?	Conduct regional baseline and subsequent routine surveys and inventories of the distribution, abundance, diversity, and condition of tidal wetlands throughout the region, using existing tools and metrics to the extent practicable and developing new tools and metrics where necessary.
2. How are external drivers, such as accelerated sea level rise, development pressure, and changes in runoff and sediment supply, impacting tidal wetlands?	Establish Benchmark Sites (see Section 2.5.1 below) and other components of the WRMP monitoring site network (dependent on available funding and resources), and analyze WRMP data collected to answer Guiding Question 1 together with non-WRMP data on external drivers to track external drivers as potential causes or correlates of tidal marsh change.
3. How do policies, programs, and projects to protect and restore tidal marshes affect the distribution, abundance, and health of plants and animals?	Repeat surveys (detect change) of living organisms and their habitats (indicators), and standardize the metrics and reporting for indicators that are common to projects and baseline/subsequent ambient monitoring across the range of project designs and restoration practices.
4. What new information do we need to better understand regional lessons from tidal wetland restoration projects in the future?	Analyze WRMP data collected to answer Guiding Questions 1-3 with new data on the relative roles of estuarine and upland/watershed sources of sediment to counter the threat of sea level rise (see "Regional Sediment Science" in Section 2). Other drivers will be addressed in later WRMP phases.
5. How do policies, programs, and projects to protect and restore tidal wetlands benefit and/or impact public health, safety, and recreation?	The broad range of interactions between people and wetlands should be monitored for the safety of people and health of the marshes. This process should better integrate flood control and mosquito and disease vector control into project planning and assessment and similarly integrate wetland restoration into flood control planning. Continue to grow the WRMP to assess the effects of climate adaptation on relationships between people and nature in the watershed or landscape context.

A recommended priority action is to determine the relative roles of estuarine and upland/watershed sources of inorganic sediment to tidal marshes. This may be the most important early action of the WRMP. The emphasis on this action reflects the strong scientific consensus that the survival of existing and future restored marshes will depend on increasing supplies of sediment as sea level rise accelerates, through natural delivery processes or by adaptive management and strategic sediment placement, as sea level rise accelerates. The emphasis is further supported by the following logic:

- Under conditions of accelerating relative sea level rise, tidal marsh resilience depends on adequate supplies of suitable inorganic sediment to maintain marsh habitats for native marsh vegetation.

Photo - Michael Vasey

- The siting and design of marsh restoration projects, decisions to intervene (i.e. sediment management actions) in marsh evolution, and the definition of restoration targets/ performance criteria conditions would be informed by an understanding of the variation in sediment supplies throughout the region.
- There are three main immediate sources of suitable inorganic sediment subject to natural delivery mechanisms: the bays and straits of the estuary (estuarine currents), tidal flats (wind-wave resuspension and deposition), and local rivers and streams (fluvial flooding).
- The relative importance of each of these sediment sources is unknown at this time, may be affected by climate and land use change, and is generally expected to vary with marsh location and position, relative to tidal currents, tidal flats, and fluvial discharge.
- Monitoring is needed to develop the empirical data necessary to understand, and hence model, the effect of marsh position and sediment source on marsh resilience, and the response of tidal marshes to changes in sediment sources and delivery mechanisms over time.

2.3 Science Content

The WRMP science content is designed to efficiently answer the management questions. Over time, the answers can support decisions about tidal marsh project funding, siting, design, permitting, and management via established adaptive management processes. The monitoring results will raise new questions that may require modifications of the Program. Advances in science and technology will also affect the Program. Addressing new questions and incorporating new science into the WRMP may involve focused studies and new partnerships. The Estuary's tidal wetland protection and restoration community will need an adaptive program of empirical observation and modeling of tidal marsh ecosystems to meet the ever-evolving challenges of local and regional tidal marsh conservation. The roles of marsh migration and carefully planned adaptive management to augment marsh evolutionary processes will inevitably become larger.

The science content has three main components that are summarized in this section with additional information included in appendices (data management, analysis and interpretation, and reporting are essential aspects of a complete, adaptively managed, regional monitoring program that are discussed Section 4):

- A Master Matrix of monitoring questions and related indicators, metrics, and a basic monitoring or reporting schedule (See Appendix A)
- A Space and Time Framework that describes how the monitoring effort should be organized to assess tidal marsh response to climate change and management actions at different spatial and temporal scales, with a suggested scope of baseline monitoring (See Appendix D)
- A Compendium of Conceptual Models that represent the common state of understanding of factors and processes affecting the distribution, abundance, diversity, and condition of tidal marshes in the Bay (See Appendix F)

The Master Matrix is intended as a living document that will continue to evolve through engagement of the SC and eventually the TAC. It includes the following information:

- Monitoring questions that translate management questions into actionable science, which develop information necessary to answer the key management questions
- Indicators that translate the monitoring questions into factors or processes to monitor, which answer the monitoring questions
- Metrics that stipulate how the indicators will be quantified, which are the data necessary to develop the indicators
- Data types that describe the units of measurements generated by the metric
- Sampling plans that state the locations and frequencies of data collection, measuring the indicators which provide the data that form the metrics. The sampling plans include descriptions of where, when, and how frequently the WRMP proposes to collect data (see the Space and Time Framework in Section 2.4 below). Collectively, sampling plans and their corresponding monitoring locations/ frequencies/intervals are called "monitoring elements."
- Ranges of cost estimates to implement each indicator

Developing initial aspects of the funding program should happen first and is a high priority for development. Multiple funding sources may be used to fund various aspects of the WRMP. The WRMP Charter, which will be developed in 2020, will provide guidelines on the purpose, function and goals of the WRMP that will inform development of the funding plan. Allocations of funds across program elements (special studies, communications, governance, program management) will change over time.

The funding options listed below are currently being explored as funding streams for the WRMP and will be further developed in the next phase of program planning. Some aspects were informed by the Russian River Regional Monitoring Program Funding Models Document dated March 7, 2019.

2.4 Space and Time Framework

The Space and Time Framework is designed to assure that the monitoring efforts in aggregate adequately assess the responses of the tidal marsh ecosystem to climate change and management actions that are evident at different scales. The Framework is summarized here, with a more complete discussion included in Appendix D. The geomorphological setting is further described in Appendix D, Section D3. The Framework is based on the following logic:

- Wetlands subject to different sources of fresh and marine water and sediment, and at different stages of evolution, respond differently to changing sea level and sediment supply, and to adaptive management designed to counteract undesired responses.
- Different responses occur at different space and time scales.
- Tracking responses at different scales is necessary to identify thresholds that trigger management actions.

Inherent in this logic is the assumption that the WRMP should support long term data collection of leading indicators that have a numerical threshold at which a management or regulatory action could be triggered to prevent tidal marsh loss or otherwise enhance its conservation. This is a practical translation of adaptive management following the classic pressure-state-response model. These relationships are based on the science in the Compendium of Conceptual Models (Appendix F):

- Cause-and-effect relationships can be illustrated in a hierarchy of three levels of interacting indicators: (1) external drivers (external to the marsh ecosystem) that can affect the; (2) distribution, abundance and condition of tidal marsh habitats, which in turn can affect; (3) the distribution and abundance of plants and animals. Some external drivers, such as weather, can directly affect the distribution of plants and animals through mechanisms other than impacts to habitat.
- Tidal marshes evolve through four eco-physiographic stages: unvegetated tidal flats (mudflats); new marsh (i.e., tidal flats recently colonized by vascular vegetation); centennial marsh (tidal marsh exhibiting conditions along the middle of the trajectory from new to mature marsh); and mature or millennial marsh (tidal marsh exhibiting mature conditions).
- The recommended indicators in aggregate should describe seasonal, annual, and long-term (i.e., multi-year) responses to external drivers. The effects of extreme events, such as major flooding, are captured in the annual timeframe. The effects of episodic conditions such as drought are captured in the multi-year timeframe. Both are defined in hindsight using seasonal and annual data.
- The indicators and three monitoring timeframes call for three different spatial scales of monitoring: site-specific monitoring (Level 3 monitoring); regional probabilistic surveys (Level 2 monitoring: collecting certain types of data at representative subsets of sites across a region or sub-region); and regional inventories (Level 1 monitoring: collection of data across a broad region at the same time, usually via remote sensing).
- The indicators and monitoring timeframes also suggest three periods or intervals of reporting: short-term (e.g., seasonal or annual), mid-term (e.g., every 5 years), and long-term, (e.g., every decade).

Based on the consensus understanding of complex marsh evolution and the recommended indicators, the Framework spreads tidal marsh monitoring across three types of sites:

- **Benchmark** (mature marshes)
- **Reference** (marshes at mid- to late stages of evolution), and
- **Project** (restoration projects implemented over roughly the past 20 years).

This structure provides the minimum organization necessary to define non-linear relationships and changes in tidal marsh distribution, abundance, diversity, and condition at different scales of time. Each kind of site can be represented throughout the region, to account for variations in driving factors, such as freshwater and sediment supplies, as well as project design and management. The WRMP site network will be further refined in Phase 2 of WRMP planning. Due to anticipated resource constraints, it is likely that the WRMP site network will initially focus on developing Benchmark Sites, as well as integrating existing project monitoring into the WRMP framework. Phase 2 will address how the WRMP site network will expand as additional resources become available and as additional projects come online.

BENCHMARK SITES

Benchmark Sites are mature (millennial) marshes that represent the target or endpoint conditions of tidal marsh restoration projects. Changes in their condition can trigger changes in project objectives and designs. As some of the oldest and most mature high-elevation marshes in the region, they are especially sensitive to changes in the frequency, duration, and depth of tidal flooding. They therefore serve as “canaries in the coal mine” to detect early stages of marsh drowning. Benchmark Sites are located to help assess the relative importance of different sediment sources and delivery processes. As pointed out previously, Benchmark Sites are similar to “Sentinel Sites,” a term used by the National Estuarine Research Reserve/

NOAA program that has similar goals as Benchmark Sites for the WRMP. For purposes of this document, the terms will be considered synonymous.

Benchmark Sites are selected to collectively represent the regional tidal range, salinity, and inorganic suspended sediment concentration. This means that sites should be in the commonly recognized sub-regions: Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay. Each of these sub-regions represents a reasonably distinctive position along the main estuarine salinity gradient, a different tidal range, different sediment supply dynamics, different degrees of urbanization, and different plant and wildlife communities. Within each subregion, the sources of sediment for benchmark sites occur along gradients between estuarine and riverine environments. The following additional criteria pertain to Benchmark Sites.

- The site represents intact, relatively undisturbed, generally equilibrial conditions.
- The site is necessary to assess the influences of (a) estuarine currents in the major embayments, (b) wind-wave erosion of tidal flats, and (c) runoff from local watersheds on the availability of suspended sediment. Correlation analyses will be used to assess the relationships among marsh resilience (accretion and vegetation homeostasis), sediment availability, and marsh position relative to different sediment delivery processes.
- Benchmark Sites should be associated with the complementary network of stations proposed by the Bay RMP to monitor salinity, tides, and suspended sediment in the major embayments in order to adequately assess the effects of climate change and large-scale tidal marsh restoration or shoreline modification on tidal marsh conditions. They should also be associated with careful geodetic control to isolate the effects of shallow and deep subsidence on marsh elevations.

REFERENCE SITES

These are marshes in intermediate stages of evolution, including relatively mature centennial marshes, that represent mid-term target conditions for restoration and mitigation projects. They are more geomorphically evolved than Project Sites. Reference Sites must be carefully selected to represent the desired developmental trajectory of Project Sites, based on relationships described by the Compendium of Conceptual Models (Appendix F). Multiple Reference Sites may be used to determine a "reference envelope" of acceptable future conditions for restoration projects (i.e., a range of acceptable conditions). The following criteria pertain to Reference Sites. Since Reference Sites can represent a relatively broad range of conditions, every criterion may not apply to each Reference Site.

- The site has pre-existing data sets for one or more WRMP indicators.
- The site is linked to one or more Benchmark Sites and/or Project Sites based on empirical observation, conceptual models (Appendix E), simulation models, or consensus best professional judgment.
- The site is known to support or to have the potential to support the morphology and functions of the "complete tidal marsh ecosystem" as defined by BEHGU (Goals Project, 2015).
- The site provides target ecosystem functions and services that are commonly prioritized for protection or restoration by resource agencies, regulatory agencies, and project funders.
- Collectively, Reference Sites should reflect a similar range of physical and ecological drivers as Benchmark Sites (e.g., tidal range, salinity, sediment supply, urbanization, plant and wildlife communities).

PROJECT SITES

These are existing and planned restoration and compensatory mitigation projects intended to recover lost wetland functions, whether from historical (i.e., preceding federal or state regulations protecting wetlands) or permitted land uses. To the extent that projects use the same indicators, metrics, and data management system recommended by the WRMP for ambient monitoring, they can be compared to each other over time, and their effect on ambient condition can be assessed.

The following criteria pertain to Project Sites:

- The site is a project with ongoing and/or recent monitoring consistent with the WRMP.
- The site is necessary to represent a restoration approach and/or range of design features.
- The site is linked to one or more Benchmark Sites and/or Reference Sites based on location, empirical observation, conceptual models (Appendix E), simulation models, and/or consensus best professional judgment.
- Project Sites should collectively reflect a similar range of physical and ecological drivers as Benchmark Sites (e.g., tidal range, salinity, sediment supply, urbanization, plant and wildlife communities).
- The goal of restoration projects is to directly and positively affect the distribution, abundance, diversity, or condition of tidal marsh ecosystems and wildlife. Projects are monitored as a condition of their permits. Projects are commonly required to monitor a variety of factors and processes at the project site and at its reference sites(s). Example projects include the South Bay and Napa-Sonoma Salt Ponds, Hamilton Wetlands, Sonoma Baylands, Cullinan Ranch, Sears Point, Tule Red, and the Montezuma Wetlands Project, among others. Older project sites with monitoring approaches and data sets that are consistent with the WRMP framework may also be included.

Projects in the region represent a variety of design approaches that reflect the continuing evolution of restoration science and management, as well as ongoing physical changes in the Estuary. Examples of design features that differ among projects include the reuse of dredged sediments to elevate subsided baylands, excavation of pilot channels to accelerate channel development, construction of marsh mounds to provide high tide refugia, construction of berms to manage wind fetch, grading of levees to broaden their inboard or outboard slopes, invasive plant species control, and transition zone planting and irrigation. There is a significant need for the WRMP to provide field data and related information that help assess how effective these and other features are at achieving their respective design objectives.

While it is acknowledged that some tidal marsh project and programmatic monitoring by management and regulatory agencies will remain project- and program-specific, to the degree appropriate, project monitoring should use the same indicators, metrics, and methods as ambient monitoring.

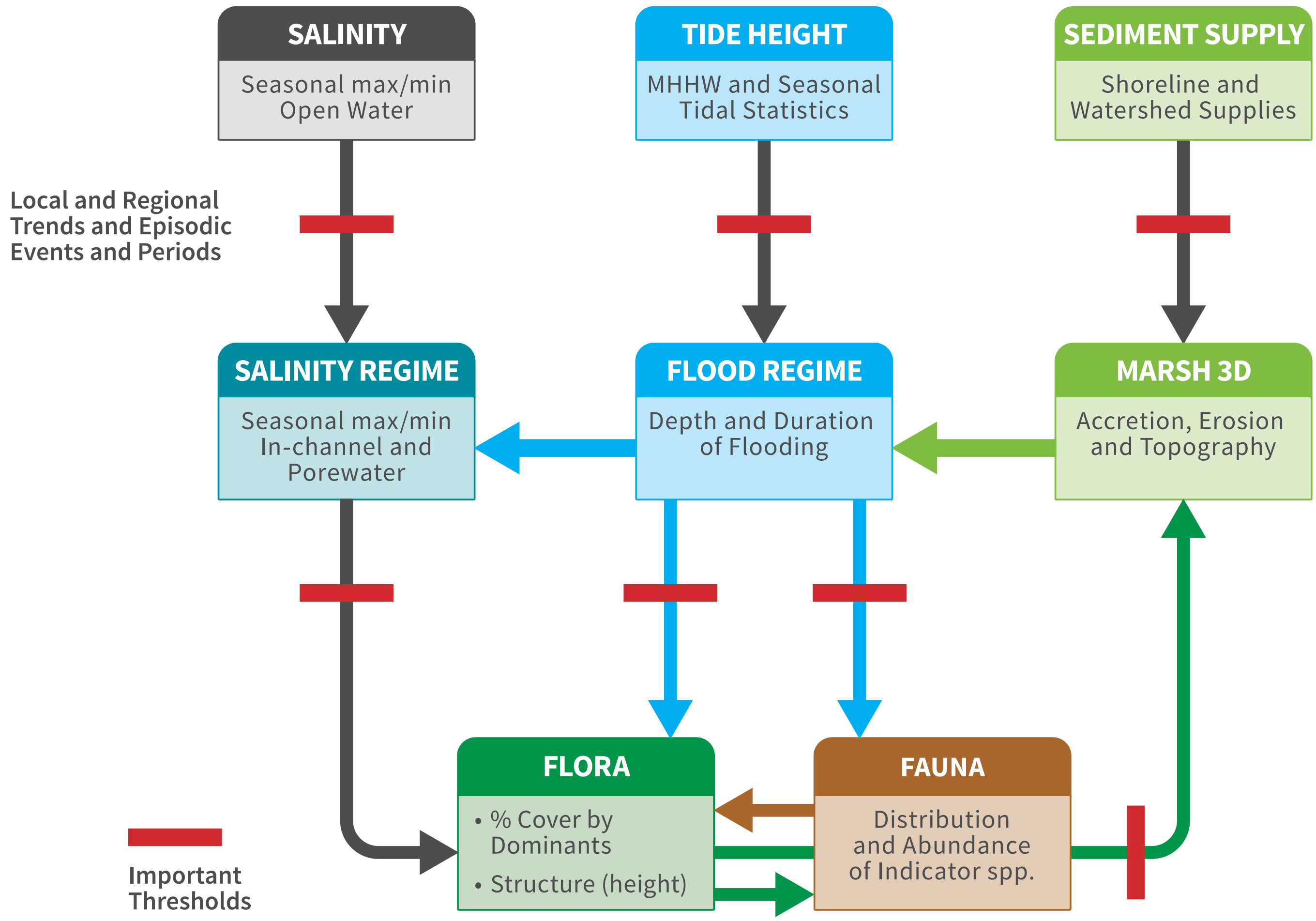
2.5 Indicator Recommendations

The technical workshops, subsequent meetings among the workshop leaders, and the SAT generated the minimum array of indicators and metrics needed to address the management questions through the priority actions in the Master Matrix. Multiple indicators are needed to answer most of the monitoring questions, others only one. For example, answering the question: "Where are rates of wetland accretion keeping pace with rising sea levels" requires monitoring both accretion and sea level rise. Most of the indicators (or the data used to evaluate them) will be used multiple times to help answer different monitoring and management questions.

As stated earlier, a primary objective of the WRMP is to identify thresholds in indicator values that should trigger regulatory or adaptive management actions (Figure 3). This requires understanding the functional relationships among the indicators and identifying strong statistical correlations. In monitoring parlance, the evaluations of leading indicators (indicators that predict directions and/or rates of change) are used to forecast the conditions of tightly linked trailing indicators (indicators that demonstrate directions and/or rates of change). A threshold identifies the numerical value of a leading indicator that corresponds to a significant change in the trailing indicator. In the context of tidal marsh conservation, the change in the trailing indicator is significant if it triggers a change in marsh management. For example, it is expected that augmentation of sediment supplies might be triggered by a threshold value in either existing supplies or tidal flooding (leading indicator) that corresponds to declining vegetation health or the initiation of vertical erosion (trailing indicator). The functional and operational relationships among leading and trailing indicators are illustrated in the diagram below.

Photo - Shira Bezalel

Figure 3. Indicator Thresholds



WRMP indicators represent factors and processes driving tidal marsh habitat conditions (upper row of diagram), the response of habitat to the drivers (middle row), and the response of resident flora and fauna to habitat change (lower row of diagram). The arrows between rows, and between boxes within the rows, represent causal and correlative relationships. The system of indicators and the network of monitoring sites is designed to elucidate thresholds in these relationships (red bars) that trigger significant changes in marsh condition, which in turn may trigger management responses. There may also be thresholds in the relationship between external factors and processes, such as climate change and land use, and the more proximal drivers of marsh condition, but these thresholds can be very difficult to manage. The external factors and processes are not shown in this diagram. The indicators noted in the diagram are a subset of the recommended indicators. The interrelationships among all the indicators is much more complex than suggested in this simplified schematic explanation of thresholds and triggers.

CHAPTER 3
DATA MANAGEMENT

3.1 Guiding Principles
3.2 Data Management Approach
3.3 Data Documentation
3.4 Data Synthesis, Distribution, and Visualization

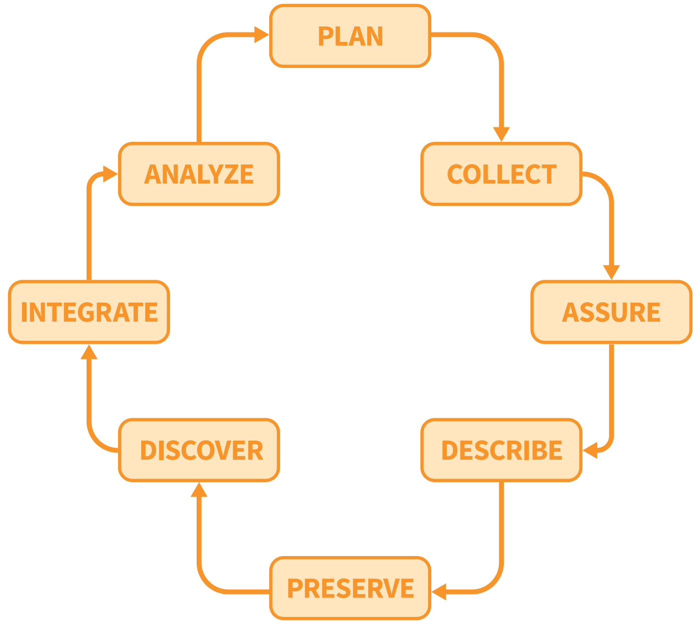
Photo - Michael Vasey

DATA MANAGEMENT

The WRMP Plan described above outlines a broad set of management questions that cover topics spanning across time, space, and scientific domains. Acquisition and management of high-quality data is also paramount. With understanding of restoration success informed by the answers emerging from the program, it will be all the more important to provide reliable assurances of data quality and clarity of interpretation. Such data, in the context of the WRMP, demand consistent documentation that can transparently describe the high-quality datasets—how the data were collected, processed, analyzed and interpreted (metadata). Typically, the degree to which science and technology are integrated into a collaborative decision-making framework marks a monitoring program's level of excellence and effectiveness.

As part of the WRMP implementation planning effort, data management systems will be further explored, and a cost estimate developed that outlines the various costs of supporting the proposed data management effort. When developing a data management strategy, the data life cycle developed by DataONE (Figure 4) is helpful to explain the core components involved in the successful management and preservation of data for use and reuse, and to highlight how technology practices must actively adapt to align with the Program's adaptive management needs.

Figure 4. Data Life Cycle from DataONE




Corte Madera marsh, UAS image by SFEI

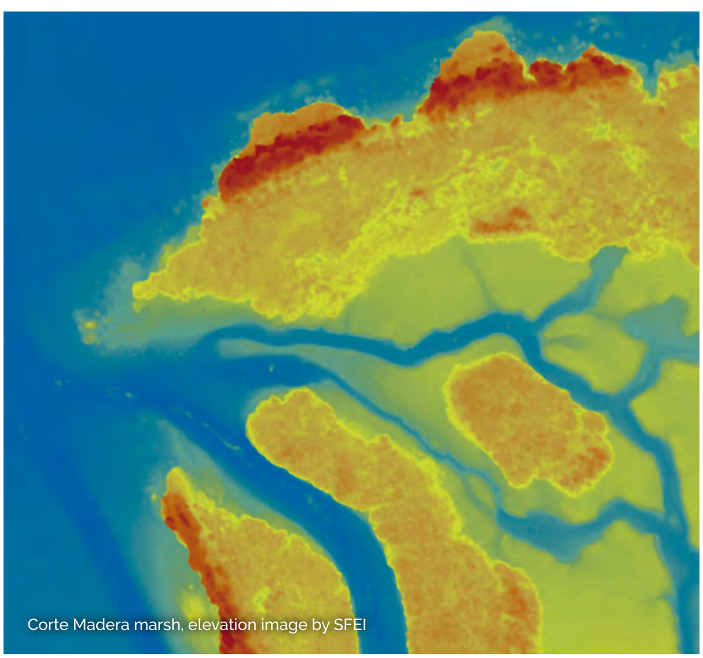
3.1 Guiding Principles

| PLAN |

The Program Governance Elements, Section 4.1, articulates the key program principles to guide how the program will conduct its work and address its goals. From these elements we derive guidance that influences how the data management team might execute its tasks. This guidance can be translated into specific practices, policies, and decisions to ensure that the collection, processing, analysis, and distribution of the data remain in alignment with the program's broad goals. The following represents principles with the greatest relevance to data management:

- **Collaboration among institutions:** The WRMP will work across institutions and organizations to achieve program goals.
- **Legitimacy through transparency:** The WRMP will function through a fair, deliberative and transparent process.
- **Long-term ownership and sustainability:** We intend that the WRMP, once established, will be long lasting and sustainable.
- **Adaptative management:** The WRMP is rooted in an adaptive management model. As new science emerges, the program can adapt [its methods and technology] through adjustment of management questions.

By extension, the principles enumerated above are closely related to additional concepts with relevance to data management, such as consistency, integrity, and credibility. Taken as a whole, these guiding principles—in encouraging collaboration, process transparency, technical and financial sustainability, and life-cycle adaptation—influence the approach that the Data Management Team will adopt in helping to address the program's management questions.



Corte Madera marsh, elevation image by SFEI

3.2 Data Management Approach

| PLAN | DISCOVER | COLLECT |

DATA STEWARDS

The WRMP anticipates collecting data from various sources, ranging from in-situ tide gauges to aerial imagery. While the data contributors might be pulled from a broad pool of organizations, the data stewards—those charged with shepherding the data, performing quality assurance procedures, and harmonizing various datasets—might hail from an altogether different set of entities. Data stewards occupy a key role within the program and must uphold the WRMP principles with consistency and care. Accordingly, to promote transparency and legitimacy as defined above, the WRMP will partner with data stewards that serve the public trust with a track record in alignment with transparent, deliberative decision-making. When handling the Program's data, transparency and legitimacy will be closely linked. Furthermore, due to the need for a tight integration between the science and technical teams, the data stewards should be prepared to demonstrate a track record of excellent technical work in service of natural science programs.

DATA SOURCES

Data sources will be selected based on relevance to the development of threshold values for the indicators that represent a major change over time in marsh status (abundance, distribution, diversity, and condition). These data sources themselves might change over time, but the Program will ensure the integrity of longitudinal analysis through careful documentation, substitutions, and analytical translations. The data stewards will facilitate exploration of those data for purposes of decision-making and information sharing. Data sources with restrictive licensing that prohibits redistribution should be avoided in all but the narrowest of cases to ensure that the basis of analysis can be publicly distributed, in alignment with the guiding principles.

SELECTION OF DATA COLLECTION AND DISTRIBUTION TOOLS

The Data Management Team will work collaboratively with the Synthesis Team to determine the proper suite of tools to facilitate data collection, analysis, visualization, and distribution that facilitate long-term stewardship and sustainability. Licensing costs should be taken into account and factored into adoption decisions to ensure that the Program's fiduciary responsibilities are met. In many cases, there will be tools already available for free or low cost. If existing tools are scientifically valid, reasonably priced, and suited to the task, then they should be carefully considered. If they are adaptable to future demands by the Program, then this would also elevate the tool for consideration.

3.3 Data Documentation

| ASSURE | DESCRIBE | PRESERVE | DISCOVER |

To facilitate consistency and comparability of data over time, the procedures for data collection, quality assurance, transformation, integration, updating, and distribution must be well-documented, maintained and accessible to end users. By requiring all partners to adhere to established practices, the Program will advance its data integrity and, in turn, scientific credibility. Furthermore, accurate and timely information will be available for the adaptive management of the Program.

There are several different types of documentation needed to guide the Program's data life cycle of collection, compilation, distribution and reporting:

The Quality Assurance Program Plan (QAPP) will ensure data are collected and processed in a manner that is reflective of the programmatic objectives and management questions. The Minimum Quality Objectives for each indicator and the indicator calculations used to address the management questions will be outlined in the QAPP.

Standard Operating Procedures (SOP) describe the data chain of custody (provenance) and the integration and distribution processes to fulfill Program objectives. The SOPs will be revised regularly to meet the changing protocols and needs of the Program. For example, the existing Bay Area Aquatic Resources Inventory (BAARI) SOP needs to be revised to include headwater streams and isolated wetlands such as vernal pools.

Data processing guidance is needed to provide a shared understanding of the data management and QA/QC procedures while promoting consistency in data formatting and compilation over time and across different data contributors. As a companion to this document, **data publication rules** will be developed and shared internally. These rules will address the durable process by which a given processed dataset finds its way to the distribution platform through a series of automated and manual checks and ensure that data are delivered in a timely and consistent fashion.

Metadata standards, such as Ecological Markup Language (EML) and Federal Geographic Data Committee (FGDC), will be specified for each data type and included with the data so users will have the information needed to properly use and aggregate the Program's data. Standard metadata formats will be used.

Training curricula and videos are needed to ensure an adequate understanding of the data management procedures, and increase usability and accessibility of the data and tools. These documents and videos will provide standardized key messages and resources for engaging with stakeholders and the public in a coordinated approach. The development and maintenance of the QAPP, SOPs, data processing guidance, metadata standards, and training curricula and videos should be aligned with the Synthesis Team and TAC by way of regular consultations.

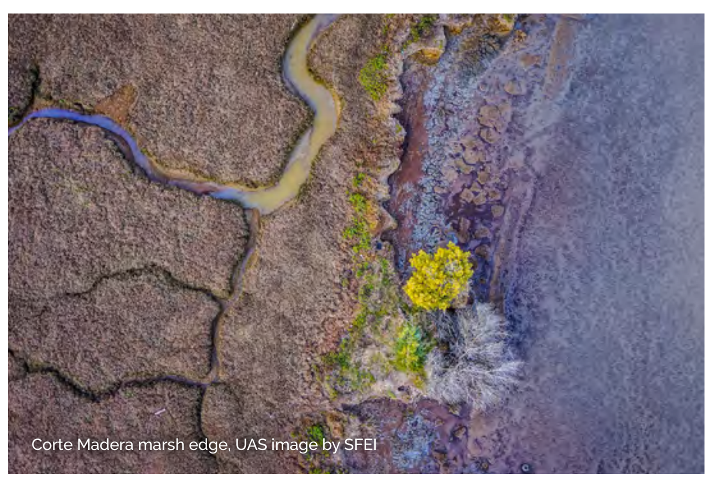
3.4 Analysis, Interpretation, and Informatics

| ANALYZE | INTEGRATE |

Collaboration between intended users (such as land managers and regulators), scientists, and technologists is key to the success of the Program. The Synthesis Team and TAC will be consulted to ensure that the data management system is designed to accommodate scientific and technological adaptation. The coordinated system must reflect and support the identified indicators and provide the best available science for the calculation of the indicators.

Data will be shared in a readily accessible format, available for visualization and distribution to researchers, agency staffers, and the general public. Data will be re-formatted as necessary to harmonize differences in the constituent datasets. Following the SOPs, the Program will compile and integrate scientifically validated data, transform the data by performing indicator calculations, and prepare derived information or processed data from analyses. This analytical process, in aggregating heterogenous data into a framework determined by the indicator calculations, enhances the value of each individual dataset. How data must be analyzed, summarized, and prepared for publication will be directly informed by the Synthesis Team.

Related to a parallel outreach effort, the Data Management Team will survey their nearline stakeholder audience to guide priorities for data distribution which will, in turn, influence the portfolio of suitable data formats. In so doing, the Team will identify the highest priority topics and forms for new data visualization modules useful to the greatest number. Visualization of the data, after all, is important to ensure that the significance of the information is clearly communicated and relevant to the concerns of the target audience. Furthermore, summarized findings, processed data, and raw data results will be hosted and shared on an online platform for redistribution to all interested stakeholders. Past investments in technology, data, and reporting will be leveraged whenever possible to promote financial sustainability. The Data Management Team will pursue alignment with emerging open data standards so that the data can be dynamically exchanged with available open-data repositories, further enhancing accessibility.



Corte Madera marsh edge, UAS image by SFEI

CHAPTER 4

ADMINISTRATION AND GOVERNANCE

4.1 Program Governance Elements
4.2 Primary Program Elements
4.3 Funding Needs and Options
4.4 Analysis, Interpretation, and Informatics

Photo - Michael Vasey

ADMINISTRATION AND GOVERNANCE

The Administration and Governance section of the WRMP Plan provides a summary of decisions and guidance to date from the WRMP Steering Committee (see Appendix B). This section includes a summary of the key Program governance elements, primary Program elements, and funding needs and options related to establishment of the WRMP.

4.1 Program Governance Elements

During the WRMP development process, the Steering Committee considered several models for Program governance, administration and management. Discussion centered on best practices, approaches and development of criteria. The Steering Committee looked at existing models and discussed the benefits and challenges associated with those models. Based upon this discussion, the Steering Committee identified several key principles to guide Program development (Table C). These principles inform Program management considerations, Program and science administration as well as governance principles.

Table C. Key Program Principles

KEY PROGRAM PRINCIPLES	
Technical Excellence	The WRMP will strive to maintain the highest standards of technical and scientific excellence, relying on the most appropriate methodologies for all aspects of scientific inquiry.
Scientific Objectivity	The WRMP will conduct science guided by consensus expert opinion subject to peer review, based on established facts, what can be reasonably inferred from facts, and best professional judgment, while documenting dissenting opinion.
Independence	The WRMP will not be influenced by any pecuniary or political interests in its work or its findings, and will strive to be fairly trusted by all interests in any scientific or technical issue addressed by the WRMP.
Collaboration Among Institutions	The WRMP will work across institutions and organizations to achieve program goals. Leadership from regulatory agencies will set the pace for incorporation of findings into permit-driven monitoring. Leadership from the science community will ensure WRMP guidance and science content are technically sound and interdisciplinary. Leadership from land managers and resource agencies will ensure that restoration goals are represented.
Coordinated Regionally	The WRMP will incorporate stakeholder input to develop guiding and management questions and ensure regional representation in decision-making processes.
Implement Regulatory Requirements	The WRMP will ensure that recommendations and Program actions are in close alignment with regulatory requirements and, to the extent possible, increase efficiency in those requirements.
Legitimacy	The WRMP will function through a fair, deliberative and transparent process. Legitimacy and credibility is ensured through a process using sound science, adaptive measures, and collaborative principles.
Long-term Ownership	The success of the WRMP requires long-term ownership and investment. This includes stability and clarity in implementation of the scientific framework as well as program administration. The Program, once established, will be long lasting and sustainable.
Stable Source of Funding	The WRMP will involve many facets of science, communication, administration and reporting. While the funding sources will likely vary for these tasks, the core Program elements will require a stable source of funding for the Program to be maintained over the long term.
Adaptive Management	The WRMP is rooted in an adaptive management model. As new science emerges, the Program will adapt through adjustment of Guiding Questions and Management Questions.

4.2 Primary Program Elements

The WRMP will have core capacities that span governance, program management and data management (Table D). The WRMP Steering Committee was formed to shape the Program development process.

Current thinking regarding the decision-making body recognizes that key participants should include regulators, funders, and land managers, but be kept relatively small in number. The Program charter, which will be developed in 2020, will include developing a clearly defined structure for making decisions, multi-year plans, staffing, administration, and guidance for interfacing with data management and science teams or technical advisory committee/s.

Table D. Primary Program Elements

PRIMARY PROGRAM ELEMENTS	
Governance	The WRMP is governed by a Steering Committee. Its future primary tasks may include: • Develop the Guiding Questions and management questions that drive the Program and adapt the questions over time • Establish the TAC and oversee its formation of workgroups (TAC will be formed in 2020 and will require ongoing coordination) • Consider approval and implementation of TAC recommendations • Approve an annual workplan and budget • Allocate funds for key Program areas and special studies • Track overall Program progress and effectiveness • Review Program operations and peer review processes to ensure optimal performance, scientific excellence, objectivity, and independence • Address other administrative, strategic planning and "big picture" issues as needed
Program Management	One or more organizations administers the Program, including: • Serving as the fiduciary agent • Contract management • Coordinating the Steering Committee, TAC, and Workgroups • Managing data and information • Managing outreach and communication • Science and administrative presentation and reporting • Stakeholder engagement • Grant writing and other fundraising • Data collection, data management, data analysis and interpretation • Implementation of the benchmark site network • Reporting of findings for monitoring and special studies • Coordinated regional ambient and project-based data collection, analysis, and interpretation • Place-based or methods-based pilot or case study projects that support broader WRMP goals and are "sponsored" by the program (special studies include priority monitoring areas that are implemented during a given performance period--this could include SF Bay Restoration Authority-funded projects)
Data Management	• Data acquisition including uploads and web services • QA/QC • Data assembly and organization • Analysis, visualization, and delivery

In addition to these core program elements, pilot projects may be included as a program activity. The Program and/or Science Administrator or one of its partners might be contracted by an agency or private consultancy to manage monitoring data, carry out pilot projects, and/or develop special projects. Pilot projects and special projects for monitoring efforts can test methods proposed within the WRMP. Conducting pilot projects and special projects can improve cost estimates and understanding of how to implement WRMP monitoring approaches on a broader scale.

4.3 Funding Needs and Options

Initial phases of the WRMP will be supported through seed funding over the next 2-5 years. This may be provided by grants or small contracts to support program development and implementation. The existing funding that supported this Program development process is considered seed funding. While grants and contracts can support phased Program implementation, it won't be enough to support the long-term success of the Program.

Long-term funding sources will need to be flexible to support the many ways that entities within the San Francisco Bay achieve compliance monitoring. For example, while some organizations pay consulting firms to carry out monitoring, others utilize existing staff funded by local, state or federal entities; non-profits that engage volunteers; or academic partnerships that engage graduate students, and may not be able to pay a fee as a replacement. In addition, the science priorities within the WRMP will be implemented in phases, and different science content elements will require different funding sources.

The WRMP Charter, which will be developed in 2020, will provide guidelines on the purpose, function and goals of the WRMP that will inform development of the funding plan. Developing initial aspects of the funding program should happen first and is a high priority for development. Multiple funding sources may be used to fund various aspects of the WRMP. Allocations of funds across Program elements (special studies, communications, governance, program management) will change over time.

Current WRMP participants, including the Core Team and SC, are exploring the funding options listed below and plan to further develop sustainable funding models in the next year of the phased Program planning. Some of these options were informed by the Russian River Regional Monitoring Program Funding Models Document dated March 7, 2019. Before any specific funding options are selected, a more robust analysis will be conducted that weighs these various options. Like all aspects of the WRMP, this will also include extensive consultation from stakeholders. In addition, a cost analysis which will be completed in early 2020 will help to ground these options in the real startup costs that are expected to be associated with the WRMP.


Photo - Aimee Good

NEAR-TERM FUNDING OPTIONS

Optional monitoring payments – For projects that require compliance monitoring associated with permit conditions, permittees may pay into the WRMP to carry out monitoring of their project site. Project proponents could also seek funding from grant sources such as the SF Bay Restoration Authority to include optional monitoring payments within grant-funded budgets. Optional monitoring payments will be discussed and considered by some of the regulatory agencies involved in the WRMP during the next phase of the development process. Each agency would need to determine if this method is consistent with existing laws and aligns with long-term objectives allowable under their respective authorities. Optional monitoring fees alone are unlikely to fund the Program due to the small number of restoration project sponsors that might participate.

Grants and Contracts – Grants and contracts may support some aspects of the WRMP. Awards may be given for pilot projects or monitoring efforts at a specific project location. These funds might be managed directly by the WRMP Program Administrator, or one of the core project partners and would be coordinated through the Steering Committee and Core Team. Grants may also support other aspects of the WRMP. For example, the WRMP might propose additional seed funding during start-up years for implementation of management questions, Program administration support, baseline mapping, establishment of the Benchmark Site Network or data management. While many of these activities are intended to be funded by a more stable source over the long-term, individual grants may provide short-term funding for specific elements of the WRMP.

Participant dues – Individuals, organizations or programs could pay a fee to be included in the Program, or for use or maintenance of the data management tool or other aspects of the Program. Participant dues could also include participant sponsorships at higher levels. Methods for implementing a participant dues model could include annual fees, one-time fees for participation, or a free service that provides optional added fees for specific services such as database management, visualization and summation tools, or data synthesis and queries by broader audiences such as educators.

POSSIBLE LONG-TERM FUNDING OPTIONS

Advertising – The WRMP may consider selling advertising space on project web pages or on the data management platform. The legality of this option would be investigated further.

In-kind services and cost sharing – As the Program grows, there may be an opportunity to combine and leverage other efforts and to identify support through in-kind services that are funded through other efforts or programs, or cost-sharing through similar means.

Philanthropy – Philanthropic donations, endowments or grants from foundations have been done in the past for larger, mature regional monitoring programs.

Supplement environmental projects and enforcement funding – Supplemental environmental projects (SEPs) are environmentally beneficial projects undertaken to offset a civil penalty as a result of a violation of the Clean Water Act. SEPs may be a funding source for certain WRMP activities that fall within the SEP policy, but would need a clear nexus to the violation. Additional funds such as fines for enforcement actions by other agencies may also be a source of funding.

Legislative approach – A legislative approach could be considered for funding certain aspects of the WRMP. This effort would include developing and supporting state legislation to fund wetland restoration or monitoring, financial appropriations or other financial support and/or direction on wetland monitoring.

CHAPTER 5
IMPLEMENTATION ROADMAP

5.1 WRMP Charter

5.2 Governance and Program Options

5.3 Cost Estimates

Photo - Aimee Good

IMPLEMENTATION ROADMAP

The development process is designed to start small and grow as the program has funding and capacity to do so. Implementation of the WRMP will be phased, meaning that the functional capacity of the WRMP and the number of indicators tracked by it will increase over time. This implementation roadmap covers critical next phases in the process and initial concepts for how we might get there.

5.1 WRMP Charter

During the next phase of the WRMP development process, the SC and Core Team will develop a charter that builds off the guidance included within this Plan. Development of a charter will be intrinsically linked to a funding model that can secure adequate and sustainable financing. Cost estimates are currently in development for the science content, and this information will provide guidance on funding needs and support prioritization. The SC and Core Team will consider a range of funding models that may be appropriate for different operational aspects of the WRMP, such as governance, program management, monitoring, special studies, QA/QC and data services, and communications.

The charter will also include a governance plan to be developed during the next phase of the development process, informed by models such as the Bay RMP and Russian River RMP. Development of institutional relations will likely focus on the functional relationship of the WRMP to wetland regulatory and nonregulatory programs and initiatives[1]. The next phase of the WRMP development process will focus on finding linkages between the diverse wetland interests in the San Francisco Bay, and how they can operationally support the WRMP. Review of the draft charter will involve outreach to selected permittees and other stakeholders, including but not limited to, state agencies, counties, municipalities, non-profit organizations, and special districts, to help assess the efficacy of the planned WRMP.

It is expected that the charter will cover the details of Key Definitions; Purpose, Goals, and Functions; Guiding Principles; Governance Structure (including institutional relations, roles, and responsibilities); Decision-Making; Record Keeping; and Charter Revisions. Answering the guiding and management questions and achieving key goals of the WRMP will overlap in many cases with project monitoring required by permit conditions and present opportunities to make data collection more efficient.

Photo - Aimee Good

1. Notable management program and initiatives that will inform this work include 404 Program of the SF District of the USACE; the SF Bay NERR and Sentinel Site Program of NOAA; NWI of USFWS; NHD of USGS and DWR; the IEP and Delta Science Program; the 401 Certification Program, WDR Program, Basin Plan, and Mercury TMDL of the San Francisco Bay Regional Water Board; the Bay Plan of BCDC; the SF Bay Joint Venture Implementation Plan; the Bay and Delta RMPs; the SFBRA guidelines and procedures; and the Bay Restoration Regulatory Integration Team

5.2 Governance and Program Options

Governance and funding options will also be further developed in the next phase. This work will focus on determining WRMP funding, governance and program administration as well as how the WRMP will serve federal, state, and regional regulatory programs. Several organizational arrangements were discussed during the development process (Table E). While no specific arrangement is recommended within this document, the summary below looks at the two most likely scenarios that were considered and some benefits and challenges associated with those approaches. The final decision on organizational arrangements will be made during development of a Program Charter in 2020 – 2022, through the guidance and decision of the Steering Committee. This will include interim sponsors for various components of the Program as well as a permanent home/s for it. Specific organizations that may meet the criteria below have not yet been considered.

Table E. Organizational Program Options

ORGANIZATIONAL ARRANGEMENT OPTIONS			
OPTIONS	**HOW WOULD THIS WORK?**	**BENEFITS**	**CHALLENGES**
Option 1: Program and Science Administration are managed jointly — existing organization will act at host entity	Single organization would house all components of the WRMP. Program could be housed within a bridge organization, regulatory agency or science institution.	• Administrative efficiency • Ease of coordination • Easily identifiable "home" for the Program	Would require an organization with broad-ranging capacity in order to manage
Option 2: Program and Science Administration are separated and managed jointly by two (or more) separate organizations	Two (or more) organizations would work in coordination to manage all aspects of the WRMP. Each would be responsible for Program and Science Administration roles.	Greater cost efficiency through leveraging core capacities of different institutions	Would need high level of coordination and alignment

In addition to the two arrangements discussed above, two organizational arrangements were discussed but are considered unlikely to move forward. The first organizational arrangement that was removed from consideration was creation of a new organization to manage the WRMP. This model includes the formation of a new non-profit or other entity to administer and house all components of the WRMP. It would add another organization to an already complex restoration landscape and would likely be much more expensive and time consuming than utilizing an existing host entity. The second organizational arrangement considered was merging the WRMP with the Bay RMP. While initially this idea has merit, there are several inherent challenges to merging the programs. First, the Bay RMP is well established with a scope of work that does not generally overlap with the program area of the WRMP and an existing decision-making body that includes the funders of the program. Regardless of the eventual home for the WRMP, certain topic areas (such as sediment) will be addressed by both the WRMP and the Bay RMP. For this reason, close alignment with the Bay RMP is critical to the success of the WRMP.

Photo - Michael Vasey

5.3 Cost Estimates

A range of cost estimates for implementing the WRMP science content are in development to assist in understanding the scope of funding needed for the program. The estimates will be based on routine, expert use of recommended Level 1-3 indicators, as described in the Master Matrix, which is a living document that will continue to be updated over time. A range of estimated costs associated with each indicator will be included in the Master Matrix. The estimated implementation costs are one of the criteria that will be used by the SC to prioritize indicators. Cost estimates were developed through phone interviews conducted with recommended experts in the fields associated with each indicator. Table F includes a broad itemization of the types of costs that may be associated with the indicators in three phases of program implementation. A standalone costings analysis will be completed in early 2020.

Table F. Cost Types

PHASE	COST TYPE
Baseline	Existing data
	Baseline map
	Data analysis and reporting
Start-up	Equipment
	Fieldwork
	Special studies
	Data analysis and reporting
Ongoing	Field work
	Lab work
	Special studies
	Baseline map update
	Data analysis and reporting

Photo - Aimee Good

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APPENDIX A: INDICATOR PRIORITIZATION AND MASTER MATRIX

A1. Procedure to Prioritize WRMP Candidate Indicators

The WRMP is being designed to answer a set of management questions developed and adopted by the WRMP Steering Committee. Indicators are what are measured to answer the Management Questions. The metrics are the measurement methods. The WRMP technical workshops delivered an abundance of candidate indicators. During the same period, the Core Team worked with the SAT to develop a list of criteria that could be used to prioritize the indicators (Table G). The criteria are intended to account for the following aspects of indicator soundness or strength.

Some criteria are more important than others, regardless of their soundness. The following criteria were determined as having the highest weight for indicator prioritization. Additional criteria are listed in Table G below.

1. Indicator is necessary to assess near-term, lasting, regional baseline change
2. Indicator meets high priority regulatory needs such as protection of threatened and endangered species, implementation of a Total Maximum Daily Load (TMDL); early warning of marsh drowning; early warning of increasing need for mosquito or vector control, etc.
3. Indicator directly answers entirely or in part more than one Management Question

Table G. Indicator Prioritization

INDICATOR PRIORITIZATION	
CRITERIA	DESCRIPTION
Relevance	There is a clear relationship between the indicator and a Management Question.
Accuracy	The indicator measures what it purports to measure.
Importance	The measurement is necessary to answer a WRMP Management Question.
Usefulness	The results guide successful tidal marsh ecosystem restoration and protection.
Feasibility	Data can be obtained with reasonable and affordable effort.
Credibility	The indicator has been recommended by leading experts.
Validity	To the extent possible, the indicator has been field-tested.
Distinctiveness	The indicator lacks redundancy and does not measure something already captured by other indicators.

A2. Master Matrix

The WRMP Master Matrix of Indicators was developed by the Core Team in close coordination with the Phase 1 Science Advisory Team, science synthesis teams and the Steering Committee. It incorporates input from attendees of the technical workshops.

The Master Matrix is intended as a living document that can continue to be updated over time. As such, it is provided here as a link to a live document. A next step for the Master Matrix will be refinement of the methods in coordination with the costings analysis to determine the most cost-effective methods. The TAC will play a significant role in guiding this discussion.

Link to the Master Matrix: ClickHere

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Photo - Aimee Good

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Relevance	There is a clear relationship between the indicator and a Management Question.
Accuracy	The indicator measures what it purports to measure.
Importance	The measurement is necessary to answer a WRMP Management Question.
Usefulness	The results guide successful tidal marsh ecosystem restoration and protection.
Feasibility	Data can be obtained with reasonable and affordable effort.
Credibility	The indicator has been recommended by leading experts.
Validity	To the extent possible, the indicator has been field-tested.
Distinctiveness	The indicator lacks redundancy and does not measure something already captured by other indicators.

A2. Master Matrix

The WRMP Master Matrix of Indicators was developed by the Core Team in close coordination with the Phase 1 Science Advisory Team, science synthesis teams and the Steering Committee. It incorporates input from attendees of the technical workshops.

The Master Matrix is intended as a living document that can continue to be updated over time. As such, it is provided here as a link to a live document. A next step for the Master Matrix will be refinement of the methods in coordination with the costings analysis to determine the most cost-effective methods. The TAC will play a significant role in guiding this discussion.

Link to the Master Matrix: ClickHere

APPENDIX B: PROGRAM AND SCIENCE DEVELOPMENT PROCESS

B1. Program Development Process

The WRMP planning process was kicked off in Fall 2017. The process included establishment of a Steering Committee and Core Team with decision-making procedures, four technical workshops, guidance from a Science Advisory Team and consultation with technical experts. The Steering Committee represents the primary decision-making body for the WRMP development process. The charge of the Steering Committee for this phase of the WRMP was to ensure that the WRMP Plan identifies the science and technology, institutional relations and governance structure, and budget necessary to address key questions shared by the environmental regulatory and management community about tidal marsh protection and restoration.

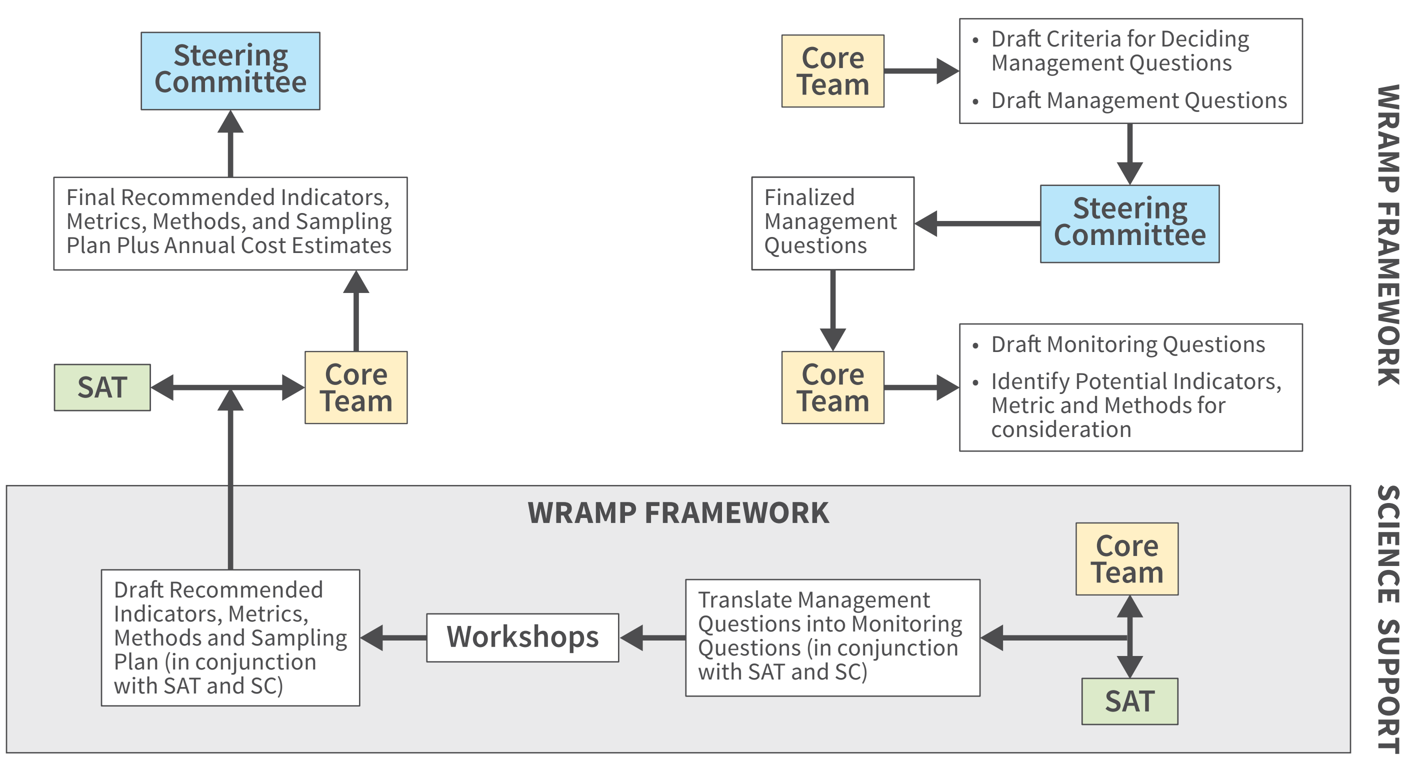
Steering Committee Goal Statements (approved by Steering Committee on 5/22/18):

1. The Steering Committee is a collaborative body tasked with guiding the development of a pilot Program Plan including the foundational management questions and science needs for the WRMP.
2. The emphasis of the pilot Program Plan is to focus monitoring efforts on evaluating tidal wetland habitat as defined by the BEHGU, and projects on a regional basis.
3. The Steering Committee will strive for transparency; we will seek input from and share progress with stakeholders.
4. The Steering Committee will seek agreement on an efficient pilot Program Plan that will meet regulatory needs and the needs of the restoration community by including recommendations for program implementation.

The Steering Committee developed a decision-making structure document (outlined in Figure 5).

Consensus will be reached initially by taking a straw poll with SC members using "thumbs up" or "thumbs down" on a particular topic. If there is broad disagreement, the concerns will be discussed, and the proposal will be adapted accordingly.

Figure 5. WRMP Decision-Making Process Flow Chart



As the Steering Committee and future decision-making bodies are and will be composed of people representing diverse organizations, trust in the decision-making process is especially important. The Steering Committee strove for a participatory process in discussing issues and arriving at a decision using a consensus-based approach. In consensus decision-making, consensus does not always mean agreeing to a first choice. It can mean accepting a proposal that a participant can “live with” for the good of the group.

Members of the WRMP Steering Committee were selected by the Core Team, including the funder, USEPA. Steering Committee members were selected based on representation within four categories: 1) science; 2) regulatory and permitting; 3) restoration and land management; and 4) community engagement, participatory research and environmental justice. Individuals who serve multiple purposes/criteria were considered. All members of the Steering Committee were required to:

- Have a regional perspective on tidal wetland restoration, monitoring, and adaptive management
- Have experience collaborating with colleagues from diverse backgrounds
- Be strong advocates on the need for a WRMP and can be alliance builders

The Steering Committee met 10 times during 2018 - 2019. The project team intends to largely maintain the structure of the Steering Committee as it moves into the next phase of the grant.

B2. Steering Committee

The WRMP Steering Committee is made up of partners that represent land management, regulatory, science and community outreach institutions working on restoration and enhancement of tidal wetlands in the San Francisco Bay. The Steering Committee is chaired by Heidi Nutters, the project manager for the grant. The Steering Committee roster is made up of the following members, with additional members stepping off/being added over time:

- Kaylee Allen, Field Supervisor, US Fish and Wildlife Service
- Donna Ball, Restoration Director, Save the Bay
- John Bourgeois, Environmental Science Associates (Later moved to Science Advisory Team)
- Kathy Boyer, Professor, Estuary and Ocean Science Center
- John Callaway, Lead Scientist, Delta Science Council
- Erika Castillo, Regulatory and Public Affairs Director, Alameda County Mosquito Abatement District
- Sahrye Cohen, Ecologist, US Army Corps of Engineers
- Dr. Josh Collins, Lead Scientist, San Francisco Estuary Institute
- Gregg Erickson, Program Manager, CA Department of Fish and Wildlife
- Xavier Fernandez, Manager, SF Bay Regional Water Quality Control Board
- Matt Gerhart, San Francisco Bay Area Regional Manager, State Coastal Conservancy (2017-2019)
- Brenda Goeden, Sediment Program Manager, Bay Conservation and Development Commission
- Matt Graul, Chief of Stewardship, East Bay Regional Parks District
- Dave Halsing, Executive Project Manager, South Bay Salt Pond Restoration Project
- Beth Huning, Coordination, San Francisco Bay Joint Venture (2017 – 2019)
- Tom Kimball, Research Manager, US Geological Survey
- Moira McEnespy, San Francisco Bay Area Regional Manager, State Coastal Conservancy
- Sandra Scoggin, Coordinator, San Francisco Bay Joint Venture
- Phil Smith, District Manager, Marin/Sonoma Mosquito Abatement District (2017-2019)
- Renee Spenst, Regional Biologist, Ducks Unlimited
- Dr. Michael Vasey, Manager, San Francisco Bay National Estuarine Research Reserve
- Carl Wilcox, Policy Advisor, CA Department of Fish and Wildlife
- Julian Wood, San Francisco Bay Program Leader, Point Blue Conservation Science

B3. Core Project Team

The Core Team scope included setting agendas for meetings, identifying project priorities and strategies, and working with stakeholders throughout the process.

CORE PROJECT TEAM MEMBERS

- Jillian Burns, San Francisco Estuary Partnership
- Dr. Joshua Collins, San Francisco Estuary Institute (2018-2019)
- Naomi Feger, SF Bay Regional Water Quality Control Board (2017-2018)
- Xavier Fernandez, SF Bay Regional Water Quality Control Board
- Matt Gerhart, State Coastal Conservancy (2017-2018)
- Aimee Good, SF Bay National Estuarine Research Reserve
- Ian Kelmartin, San Francisco Estuary Partnership (2018-2019)
- Heidi Nutters, San Francisco Estuary Partnership (Core Team lead)
- Jennifer Siu, Environmental Protection Agency
- Christina Toms, SF Bay Regional Water Quality Control Board
- Luisa Valiela, Environmental Protection Agency
- Dr. Michael Vasey, SF Bay National Estuarine Research Reserve (2018-2019)

Extensive partner coordination was essential to this process. The Core Team met on a regular basis with members of the Steering Committee, Science Advisory Team as well as other interested parties. In addition, Core Team members frequently attended partner meetings to present information about the WRMP development process. Project partners played a crucial role in fostering trust and collaboration during this process.

B4. Science Advisory Team

The SAT was formed to advise the Steering Committee on science and technical foundation of program development. The SAT consisted of regional leaders in the scientific disciplines and technologies central to WRMP content. The SAT worked with the Core Team to translate the management questions into monitoring questions, and to identify the most appropriate monitoring indicators, metrics, and methods, based on criteria developed collaboratively by the Core Team and the SAT. Some Steering Committee members served on the SAT to assure the science content was aligned with the management questions. The SAT reviewed plans for technical workshops necessary to vet the science content with the broader regional community of tidal marsh science and management.

The SAT met eight times during the development process. Members of the SAT also participated in workshops, science synthesis groups and on workgroups that were formed to refine science content.

SCIENCE ADVISORY TEAM MEMBERS

- Joy Albertson, US Fish and Wildlife Service
- John Bourgeois, ESA
- Dr. Kristin Byrd, US Geological Survey
- Dr. Joshua Collins, San Francisco Estuary Institute
- Dr. Steve Culberson, Delta Science Program
- Dr. Jay Davis, San Francisco Estuary Institute
- Ron Duke, HT Harvey
- Dr. Letitia Grenier, San Francisco Estuary Institute
- Michelle Orr, ESA
- Dr. Karen Thorne, US Geological Survey
- Dr. Michael Vasey, San Francisco Bay National Estuarine Research Reserve

B5. Science Synthesis Process

This process included input from over 175 experts who participated in four day-long workshops on physical processes, vegetation, fish and wildlife, and mosquito control, as well as multiple subsequent meetings focused on integrating and synthesizing across indicators. The SAT advised on workshop planning and reviewed outputs. Workshop leaders met together to derive key indicators and metrics. The workshop leaders, selected SAT members, and Core Team members met as a synthesis team to review the draft recommendations of science content.

After the completion of the technical workshops, synthesis workgroups were formed to spearhead a coordinated progress on science content. The output from the workgroups will be organized into a Master Matrix that relates the output to the Management Questions. The synthesis workgroups identified indicators, metrics, data sources and related costs to answer a set of monitoring questions derived from the workshops and translated from the Management Questions. The workgroups included the Suspended Sediment Availability Workgroup, the Marsh Elevation Change and Vegetation Response Workgroup, the Wildlife and Vector Control Workgroup, and Geospatial Analysis and Data Management.

WORKGROUPS

Suspended Sediment Availability Workgroup: Measurements of suspended sediment availability to marshes help explain marsh elevation change. This workgroup ensured consistent standard operating procedures (SOPs) for these measurements are used to ensure marsh and bay modelers can answer relevant management questions. The intent was to develop one recommended sampling plan that serves the needs of the Bay RMP, WRMP, Long Term Management Strategy for the Placement of Dredged Material in the Bay Region, SediMatch, regional sediment management plan, and other local and regional efforts to manage sediment demand and availability for tidal marshes, with clearly delineated focus for the WRMP.

Marsh Elevation Change and Vegetation Response Workgroup: This workgroup recommended how to use on-the-ground and remote sensing measures of marsh surface topography and lateral marsh extent to assess net vertical and lateral marsh erosion and accretion relative to sea level rise and land motion. This same workgroup recommended how to best integrate on-the-ground and remotely measured vegetation parameters into site-specific and regional assessments of change in tidal marsh vegetation over time.

Wildlife and Vector Control Workgroup: This workgroup worked closely with the Marsh Elevation Change and Vegetation Response workgroup to develop a sampling plan that integrates on-the-ground and remotely measured parameters of wildlife and vector distribution, abundance, and habitat into site-specific and regional assessments of change in tidal marsh support for wildlife and disease vectors.

Geospatial Analysis and Data Management: This group consisted of the leaders of the technical workshops and the science workgroups, plus additional data management experts from the existing Regional Geospatial Workgroup, to ensure that data collected at different spatial and temporal scales can be adequately inter-calibrated and validated. This workgroup outlined the system of data and information management and visualization and will continue to assist the Core Team to develop an approach to public reporting.

WORKGROUPS SYNTHESIS

Synthesis across the workgroups was achieved through the prioritization of indicators; the plan to coordinate monitoring among regional synoptic surveys, benchmark sites, and projects; and the plan of data and information management for the first phase of WRMP implementation. The Core Team worked closely with the workgroups to achieve this synthesis, with SAT advice and review. A final science synthesis meeting took place on July 31, 2019 at SFEI to review the proposed indicators in the Master Matrix and science recommendations to be presented to the Steering Committee.

INDICATOR PRIORITIZATION CRITERIA

The Core Team worked with the SAT to develop a list of criteria that could be used to prioritize the indicators. See Appendix A1 for a detailed description of the indicator prioritization criteria and process.

APPENDIX C: TECHNICAL WORKSHOPS

A series of technical workshops with the broader regional community of scientists refined and vetted the WRMP science content.

The primary purpose of the technical workshops was to solicit input from the diverse regional community of tidal marsh interests on the technical direction and content of the WRMP. The workshops focused on four main subjects: (1) physical processes that control the form, structure, and functions of tidal landscapes including sediment and tidal regimes; (2) tidal marsh vegetation, (3) tidal marsh wildlife, and (4) mosquito and disease vector control in relation to tidal marsh protection and restoration. The workshops took place between August 2018 and March 2019.

Table H. Technical Workshop List

TECHNICAL WORKSHOP LIST				
WORKSHOP TITLE	TECHNICAL LEADS	LEAD ORGANIZER	DATE	NUMBER OF ATTENDEES[2]
Physical Processes Workshop	Christina Toms (SFBRWQCB) and Scott Dusterhoff (SFEI)	Aimee Good (SF Bay NERR)	August 23, 2018	45
Vegetation Workshop	Mike Vasey (SF Bay NERR) and Iryna Dronova (UC Berkeley)	Aimee Good (SF Bay NERR)	October 30, 2018	53
Mosquito and Vector Control Workshop	Josh Collins (SFEI), Karl Malamud-Roam (Vector Control Consultants), and Wes Maffei (Napa County Mosquito Abatement District)	Josh Collins (SFEI) and Ian Kelmartin (SFEP)	March 21, 2019	35
Wildlife Response Workshop	Julian Wood (Point Blue Conservation Science) and Steve Culberson (IEP)	Aimee Good (SF Bay NERR)	March 26, 2019	63

Following completion of each workshop, a summary report was developed by the technical leads. The technical leads presented their initial workshop plan as well as their key findings to the SAT. Workshop summaries will be available on the wrmp.org website in early 2020.

2. Number is based on RSVPs and notes from each workshop and may not be exactly accurate.

APPENDIX D: SPATIAL AND TEMPORAL MONITORING FRAMEWORK

D1. Summary

The WRMP will generate information that is necessary to identify, guide, and assess regulatory and management actions intended to mitigate for the potentially negative effects of climate change, especially accelerated sea level rise, and land use change, such as tidal marsh restoration and shoreline hardening, on the health of the tidal wetland ecosystems of the San Francisco Estuary. The WRMP Steering Committee identified five Guiding Questions (GQs):

- Where are the region's tidal wetlands and wetland projects, and what net landscape changes in area and condition are occurring?
- How are external drivers, such as accelerated sea level rise, development pressure, and changes in runoff and sediment supply, impacting tidal wetlands?
- How do policies, programs, and projects to protect and restore tidal wetlands affect the distribution, abundance, and health of plants and animals?
- What new information do we need to better understand regional lessons from tidal wetland restoration and enhancement projects in the future?
- How do policies, programs, and projects to protect and restore tidal wetlands benefit and/or impact public health, safety, and recreation?

Each Guiding Question is associated with a tiered set of Management Questions that address more specific information needs for the tidal wetland restoration community. Answering the GQs will be largely sequential, but collecting data necessary to answer each may begin out of sequence; the answer to GQ2 depends at least in major part on the answer to GQ1; the answer to GQ3 depends on the answer to GQ2, and so forth. The answers to the GQs sequentially build in political, economic, and scientific scope. GQ1 simply addresses the baseline, ambient condition of the regional tidal wetland ecosystem. GQ2 addresses trends in condition and is answered by repeated measures of regional ambient condition. GQ3 addresses lessons learned from assessing the effects of tidal wetland restoration and protection on habitats and ambient conditions. GQ4 gets at the heart of one of the WRMP's near-term considerations--where should restoration be focused to maximize its chances of success, in the context of climate change and land use change? GQ5 is the most complicated and addresses the relationship of the tidal wetland ecosystem to human wellbeing. Answering GQ5 will require forging local and regional adaptation strategies that coordinate tidal wetland conservation with public health and safety.

Addressing GQ4 will require multi-year records of empirical monitoring data to develop and calibrate predictive models of future marsh response to climate change and land use change at various spatial scales. The predictions will need to be anchored with an empirical measure of baseline conditions. Therefore, the WRMP will initially focus on addressing GQ1, to establish the baseline, and on establishing the Benchmark Sites to begin addressing GQ4. Furthermore, the scope of the effort to address MQ5 will be influenced strongly by the answers to GQ1 and GQ4.

D2. Monitoring Context

The WRMP held Technical Workshops on physical processes, vegetation, fish and wildlife, and vector control, and formed cross-disciplinary Synthesis Workgroups to integrate across the workshops to recommend indicators of tidal wetland ecosystem response to climate change, land use change, and large-scale restoration of intertidal habitats. The workshops provided four fundamental insights on physical processes and wetland evolution:

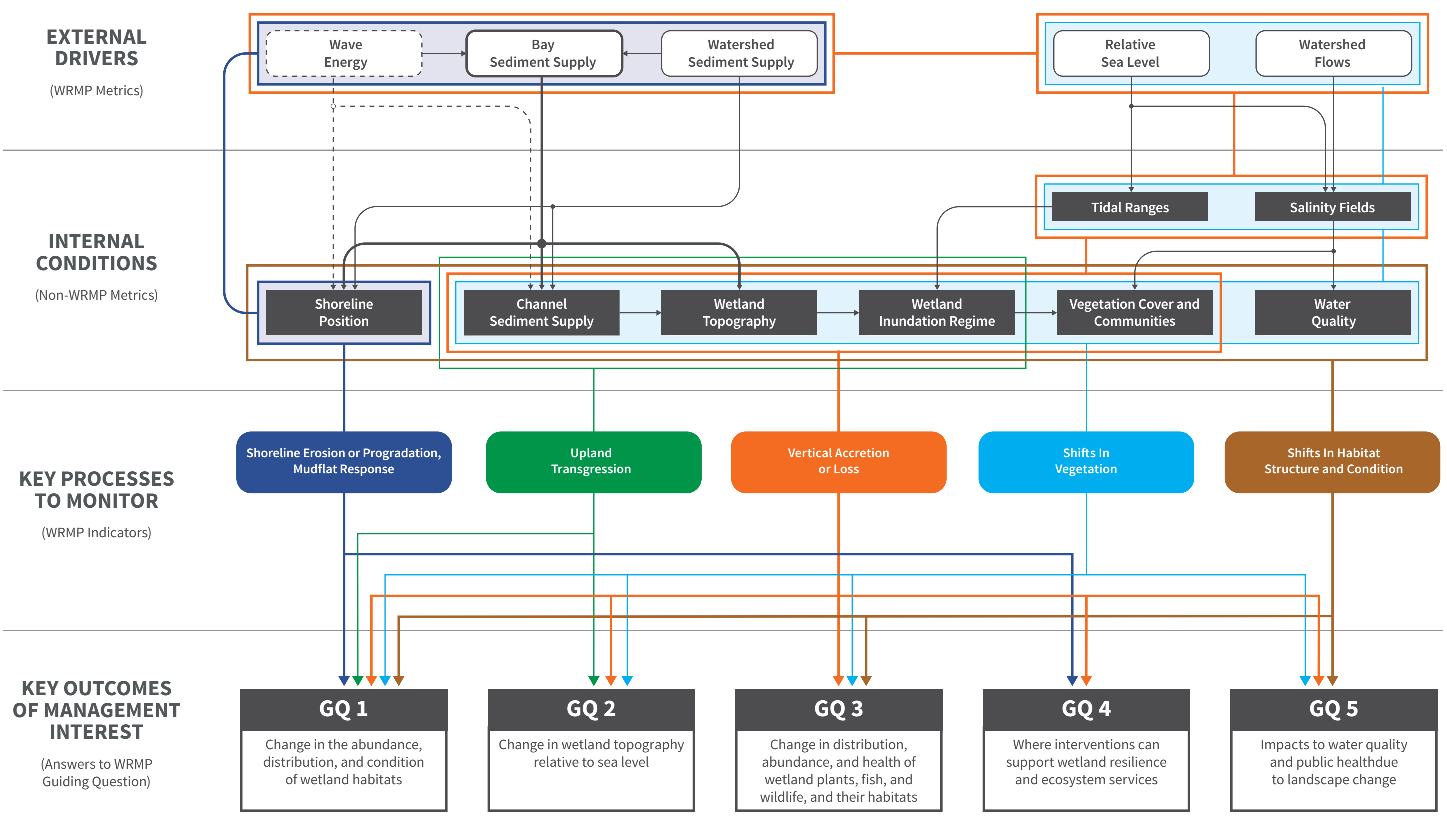
- The evolution of highly functional tidal wetland ecosystems could be slowed, or even reversed, by rates of sea level rise that outpace rates of sedimentation.
- Wetland ecosystems at different locations relative to sources of freshwater and sediment, potential for subsidence, and at different stages of evolution, may respond differently to changes in water level and sediment supply, and to actions and interventions intended to counteract these changes.
- Different kinds of responses will occur at different spatial and temporal scales.
- Establishment of a geodetic framework for the region is important for long-term monitoring, particularly in the event of sudden or gradual subsidence at monitoring sites.
- Tracking responses at different scales is necessary to identify thresholds and triggers that will guide management actions.

To address GQ4 as soon as possible, the workshops also identified four fundamental insights on sediment-water relations:

- Under conditions of accelerating relative sea level rise, tidal marsh resilience depends on adequate supplies of suitable inorganic sediment to maintain marsh habitats for native marsh vegetation.
- Siting and design of marsh restoration projects, and the definition of restoration target conditions, should be informed by an understanding of the variation in sediment supplies throughout the region.
- There are three main immediate sources of suitable inorganic sediment subject to natural delivery mechanisms: the bays and straits of the Estuary (estuarine currents), tidal flats (wind-wave resuspension), and local rivers and streams (terrestrial and fluvial erosion, and fluvial flooding).
- The relative importance of each of these sediment sources is unknown at this time, may be affected by climate and land use change, but is generally expected to vary with marsh position, relative to tidal currents, tidal flats, and fluvial discharge.
- Based on well-established conceptual models of tidal wetland evolution and function, the spatial and temporal scales of wetland responses to climate change and interventions can be determined and used to organize the indicators of response into an efficient monitoring plan.

Figure 6 below is a conceptual model that attempts to explain the likely correlative or causal relationships among physical processes and vegetation and wildlife responses. Indicators have been identified for each box in this model.

Figure 6. The WRMP Conceptual Model links indicators of external physical drivers and internal wetland conditions (top two rows) with key processes of change and outcomes of management interest (WRMP guiding and management questions)



Types of Monitoring

The WRMP recognizes the need to assess long-term responses of the tidal wetland ecosystem to climate change and management or regulatory actions, such as restoration and mitigation projects, across the full regional range of aqueous salinity, tidal range, sediment supply, and wetland evolutionary stage. There are a few standard approaches to such assessments.

Stratified probabilistic surveys account for major factors affecting wetland condition, while quantifying the proportions of the overall wetland ecosystem within condition categories, as defined by the WRMP. This is a likely approach to monitoring the overall, ambient condition of all the tidal wetlands in the region. Stratification can increase the power of this approach by accounting for major, systematic differences in tidal wetland response among different categories of wetlands, such low or high elevation, or young or old marsh, and among spatial strata, such as subregions or Operational Landscape Units.

Inventories or censuses are detailed counts or measures rather than samples. For example, measures of habitat abundance and diversity might be provided by standardized, exhaustive mapping and re-mapping of all intertidal habitats in the region.

Targeted monitoring is directed to selected tidal wetlands, such as Benchmark Sites, Reference Sites, and projects that are monitored intensively to assess fine-scale changes over time and space, as needed to assess the early developmental trajectory of projects, effects of extreme events, and to elucidate leading indicators and thresholds of significant change.

D3. Temporal Framework

The temporal framework identifies the time scales of tidal wetland ecosystem responses to climate change and land use change, as well as to management and regulatory actions that should be monitored to improve the efficacy of the actions over time.

Physical and Biological Characteristics of Different Stages of Wetland Evolution

The WRMP recognizes that tidal wetlands in the region generally can be classified into three evolutionary stages or age classes based upon a variety of important physical and biological attributes. These age classes are: millennial, centennial, and new. It is not the age of these tidal wetlands per se that is of greatest importance but, rather, the difference in physical and biological attributes they generally represent.

Coordinated, standardized monitoring of selected indicators across new, centennial, and millennial tidal wetlands will enable the WRMP to compare one project to another, assess the evolutionary trajectory of projects relative to their objectives and ambient conditions, adjust their objectives if necessary, and initiate adaptive management interventions when and where appropriate, as necessary to address GQs 2-5.

Millennial Tidal Wetland

These mature wetlands are remnants of the Holocene tidal wetland ecosystem that formed roughly between 2,000 and 5,000 years ago. Approximately 98% of these mature wetlands have been lost since European colonization in the region, starting in the late 18th century. Millennial marshes tend to be the most physically complex tidal wetlands, with broad, stable, dendritic channel networks draining high marsh plains, abundant high tide refugia along tidal channels and the bayward (wave overwash) edges of marshes, ponds/pannes, and (in some locations) beaches. As a result of this physical complexity, millennial tidal wetlands also tend to be the most biologically diverse, and support varied native and rare plant communities as well as the most special-status fish and wildlife species. For these reasons, millennial tidal wetlands are commonly used to define desired endpoints for tidal wetland restoration projects. Examples of millennial wetlands include Rush Ranch in Suisun Marsh, Petaluma Marsh, the southern portion of Coon Island in Napa, and the western portion of Greco Island in the South Bay. Recent studies that model the fate of SF Bay tidal wetlands in the face of different rates of sea-level rise and levels of sediment supply suggest that some millennial wetlands (which are mostly high marsh) might convert (drown or downshift) to low marsh or mudflats by 2100 (Schile, et al., 2014). In order to help protect these highly valued tidal wetlands, and to evaluate whether they should continue to represent the desired and achievable endpoint conditions of restoration projects, efforts by the WRMP to assess the effects of climate change on wetland ecosystems will initially focus on tracking and forecasting changes in their condition. This focus is consistent with the emphasis on addressing GQ4 as soon as possible.

Centennial Tidal Wetlands

This is a large, varied category of tidal wetlands that have become established during the post-colonial era through a variety of natural processes and land use practices. Most of these wetlands are between 50 and 150 years old, based on historical mapping and local studies of wetland evolution. The functions and services provided by centennial wetlands vary according to their age, morphology, and position along the salinity gradients of the Estuary. For purposes of the WRMP, centennial wetlands may be categorized into three groups:

sform along the shorelines of the major embayments due to the deposition of inorganic sediment and organic debris by estuarine currents and wind-waves. These wetlands vary in width but tend to exist high in the intertidal zone. They can be supratidal at some locations where abundant sediment and debris is entrained by especially high waves, and deposited in a splash zone above the tides. They generally lack extensive tidal channel networks, and tend to retain tidal and wave-driven flood waters on their plains. Examples of fringing overwash wetlands include the “strip marsh” south of Highway 37 and at the mouths of Novato Creek, Sonoma Creek, and the Petaluma River along San Pablo Bay, as well as the wetlands along the eastern side of Grizzly Bay (e.g. Tule Red and Grizzly King duck clubs).

FRINGING INFILL WETLANDS are generally narrow, linear wetlands that formed along tidal channels between reclamation levees as the channels shoaled and narrowed in response to the decreases in their tidal prism. Many of these channels have equilibrated to the historical changes in tidal prism, and their fringing infill wetlands have matured, as indicated by their high intertidal plains served by dense channel networks. A special characteristic of these marshes is the parallel arrangement of the networks, owing to the uniform slope of the marsh plains toward the larger channels they fringe. Examples of fringing infill wetlands include the wetlands along Mowry Slough and Coyote Creek in the South Bay, and along Novato and Sonoma Creeks in the North Bay.

REVERTED WETLANDS exist where tidal action has been restored to formerly reclaimed millennial wetlands due to unplanned levee failures. The accidental or passive breaching of their levees distinguishes reverted wetlands from restoration projects, where the breaches are intentional and carefully planned. Reverted wetlands tend to pre-date the laws and regulations governing levee work, and therefore include many older, more mature centennial wetlands. These older reverted centennial marshes can resemble millennial wetlands in some obvious ways. For example, many of the oldest reverted wetlands have dense dendritic channel networks that serve broad, high-elevation marsh plains, and they can support similar assemblages of plants and animals (including special-status species). Examples include Ryer Island in Suisun Marsh, Bull Island along the Napa River, Wildcat Creek Marsh in Richmond, Faber Marsh in Palo Alto, and the Whale's Tail Marsh at the mouth of Old Alameda Creek.

These categories of centennial wetlands have measurably different mechanisms of response to accelerating sea level rise, and some may serve as early indicators of thresholds of wetland drowning/downshifting. The WRMP must take care to properly contextualize data gathered from these different categories of centennial wetlands. Therefore, they may serve as sampling strata for periodic, regional, probabilistic surveys of tidal wetland condition.

New Tidal Wetlands

These wetlands have the characteristics of very immature, low-elevation marshes, at the early stages of evolution from tidal flats or newly inundated uplands. They generally fall into three categories: (1) recent restoration and mitigation projects aimed at recovering tidal wetland acreage; (2) areas along shorelines where sediments have naturally accumulated at high enough elevations to support colonization by wetland vegetation; and (3) areas along the upland-estuarine transition zone where tidal wetland habitats prograde over adjacent terrestrial habitats due to sea level rise. With the exception of newly prograded (high) marsh, characteristics of new tidal wetlands include extensive subtidal and/or intertidal mudflats, an immature or absent tidal channel network, a general lack of high tide refugia, and vegetation communities dominated by low marsh species (e.g. Spartina foliosa). By far, the largest areas of new tidal wetlands are found in restoration projects such as the South Bay and Napa-Sonoma Salt Pond Restoration Projects. The WRMP recommends indicators that can be applied in standard ways at new projects, such that the projects can serve to assess early responses to restoration designs, techniques, and climate change. The same indicators can be used to develop "lessons learned" that might inform future project designs and adaptive management.

Timeframes of Tidal Wetland Response

The Technical Workshops and Synthesis Workgroups have identified measurable physical and ecological processes or parameters that are likely to be sensitive to climate change, large-scale intertidal restoration, and shoreline hardening. There are six intervals of time over which tidal wetland response can be meaningfully assessed, depending on the process or parameter being measured. They are: continuous, short-term, semi-annual, annual, long-term, and episodic/extreme events. Seasons are included in the category of semi-annual, and king tides are included as extreme events. Note that for any indicator, the interval of data collection may be shorter that the interval or scale of change assessment. For example, annual measures of rainfall are needed to define the beginning and ending of a multi-year wet period. Continuous measures of tide height may be needed to define an extreme flood event. Furthermore, the indicators measured daily or continuously (such as tide height) provide a basis to explore the effects of natural, short-term cycles (such the semi-monthly neap-spring tide cycle) on marsh condition.

D4. Spatial Framework

The Technical Workshops and Synthesis Workgroups have identified three spatial scales at which tidal wetland response to climate change and regulatory or management action should be monitored: region, sub-region, and individual wetland. The region is the complete tidal wetland ecosystem of the San Francisco Estuary between the Golden Gate and the western boundary of the legally defined Delta at Broad Slough. However, we note that, to the greatest extent feasible, the WRMP will be coordinated with monitoring work in the Delta. The sub-regions are the conventional major embayments of the region, namely Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay. The eastern half of Carquinez Straight is included in Suisun Bay, and the western half is included in San Pablo Bay.

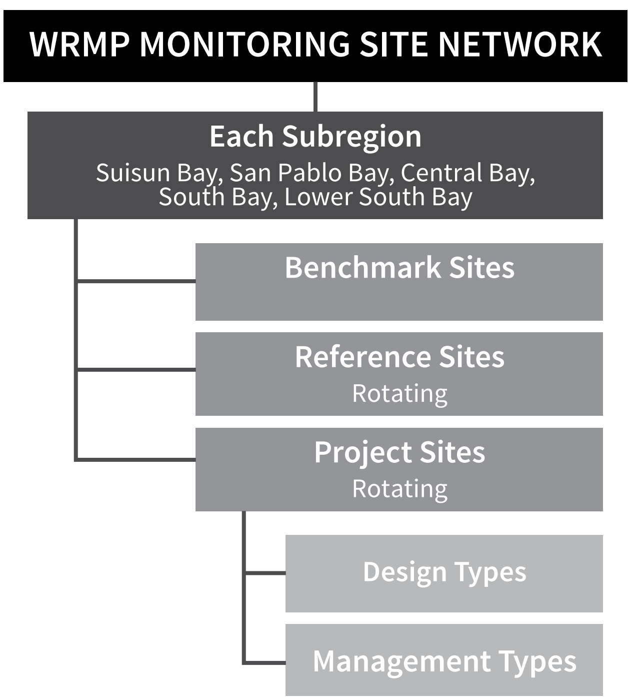
Individual tidal wetlands include restoration projects and areas of natural tidal wetland separated from each other by areas of uplands, open water embayments, diked wetland, or tidal flats that are broad enough to inhibit immigration or emigration of resident species of wildlife, especially special-status species. Most of the millennial tidal wetlands that fit this characterization have traditional place names. The WRMP will consider using Operational Landscape Units (OLUs) to assess ambient conditions at an intermediate spatial scale, between sub-regions and individual wetlands, and especially where they represent major "subordinate estuaries" within the Bay (e.g. Napa-Sonoma). Figure 7 begins to organize the WRMP based on the temporal and spatial scales of monitored wetland responses.

Monitoring Site Network

The WRMP monitoring network will include three types of monitoring sites: Benchmark Sites, Reference Sites, and Project Sites (see Figure 7 for an illustration of the general WRMP monitoring site hierarchy). A primary purpose of the WRMP is to track and improve the effects of permitted projects on the condition of the regional tidal wetland ecosystem, as expressed by GQ3. This can only be accomplished by comparing projects to reference and ambient conditions based on standardized indicators and metrics, as guided by the relationships described in the Compendium of Conceptual Models (see Appendix F). The monitoring site network plus regional inventories and surveys facilitate this comparison.

This section describes the three types of sites and proposed criteria for their selection. All the sites will share some common characteristics, however. All WRMP sites must be accessible and safe to access. In these regards, factors to consider include, but are not limited to: ease of access (access permission requirements, road access versus dependence on boats), personnel safety, and the likely security of any in-situ instrumentation.

Figure 7. The general hierarchy of monitoring sites within the WRMP network



BENCHMARK SITES

Benchmark Sites serve the WRMP in three main ways. Monitoring at these sites serves to develop and calibrate indicators used to address GQ1 through 3, and GQ5. For example, remote sensing indicators of vegetation condition must be calibrated against field measurements. Monitoring at Benchmark Sites will also serve to detect thresholds of wetland response to external factors driving wetland condition, while revealing how these effects differ between multi-year dry and wet periods. These are important aspects of the answers to GQs 2, 3 and 5. This monitoring will also elucidate the relative importance of estuarine currents, wave-wind erosion of tidal flats, and runoff from local watersheds as sources and mechanisms of sediment delivery to tidal wetlands. This information is essential to address GQ4.

Selection Criteria for Benchmark Sites

The WRMP is especially concerned about addressing GQ4 as soon as possible, by assessing the effects of climate change on mature wetlands, and the likelihood that restoration projects will fail to meet environmental outcomes due to inadequate rates of sedimentation to offset accelerating sea level rise. The initial Benchmark Network will therefore focus on assessing two priority risks:

- **Risk of Mature Marshes Drowning and/or Downshifting.** Some Benchmark Sites will be used to empirically estimate the maximum longevity of highly valued, mature, high-elevation marshlands. Existing numerical models of sediment distribution by tidal currents, resuspension by wind-waves, and sediment yield from local watersheds will be used to help identify mature marshes associated with modeled large suspended sediment supplies. Benchmark Sites used to asses this risk will be chosen along reaches of shoreline that are expected to receive large amounts of sediment delivered by bay currents or wind-waves (i.e., “shoreline sites”), as well as along the upstream tidal reaches of rivers or streams draining watersheds with large sediment yields (i.e., “watershed sites”).

- **Risk of Failure to Meet Environmental Outcomes.** Some Benchmark Sites will be selected in areas where future large-scale tidal restoration is likely to happen, in order to inform the design and adaptive management of these projects and empirically estimate the adequacy of their suspended sediment supplies. Examples of these areas include Suisun Marsh (Department of Water Resources EcoRestore), the Marin-Sonoma-Napa baylands, publicly owned lands in the South Bay, and proposed SF Bay Restoration Authority project locations. If suitable Benchmark Sites are not established in some areas of major planned restoration, then select Reference Sites (see below) may be used to assess this risk. Benchmark Sites used to asses this risk should be on the mainstem of the tidal drainage system that will convey sediment to the restoration area. Ideally, such sites will be upstream of a Bay RMP suspended sediment monitoring station, located at or near the mouth of the same drainage system.

Based on the need to assess the two risks described immediately above, the following Benchmark Site selection criteria have been developed. No candidate Benchmark Site is expected to meet all of these selection criteria, though selected sites should meet most of them. These criteria are not weighted for their relative importance.

A. The site is necessary for the Benchmark Network to represent: (a) the main estuarine gradients of salinity and tidal range between the Lower South Bay and the San Pablo Bay, and between the San Pablo Bay and the Delta at Broad Slough; and (b) gradients of sediment supply, transport, and redistribution mechanisms within and between sub-regions of the Estuary. This means that sites should be located in each of the five commonly recognized sub-regions: Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay. Each of these sub-regions represents a reasonably distinctive position along the main estuarine salinity gradient, a different tidal range, different sediment supply dynamics, and different plant and wildlife communities.

B. The site represents intact, relatively undisturbed, mature, equilibrium conditions. Benchmark Sites should strongly signal their responses to climate change and nearby regulatory or management actions. This means that the sites should be in approximate equilibrium with existing sediment supplies, salinity regimes, and tidal regimes, such that changes in these parameters can be detected at the sites using WRMP indicators. The response signal will be weak or noisy at sites that are rapidly adjusting to past local changes in these parameters. Equilibrium conditions are indicative of mature wetlands. This suggests that the candidate Benchmark Sites are millennial wetlands, mature reverted wetlands, or mature fringing infill wetlands. Wetland age class is not necessarily the best indicator of maturity, however. Dependable geomorphic indicators include marsh plains high in the tidal frame, the presence of ponds/pannes in the high marsh plain, adequate channel density to effectively drain the marsh plain at low tide, and no significant change in channel density or channel cross-section area at the mouth of the drainage network during the last decade. In this region, millennial and reverted wetlands that meet this criterion have an area of 100-300 acres. Fringing infill wetlands that meet this criterion are smaller.

C. The site will help assess the influences of: (a) estuarine currents in the major embayments, (b) wind-wave erosion of tidal flats, (c) runoff from local watersheds, and (d) sediment redistribution processes on the availability of suspended sediment to increase and maintain the tidal elevations of mature wetland plains. To adequately assess the effects of climate change and large-scale tidal marsh restoration or shoreline modification on tidal marsh conditions, Benchmark Sites should be associated with the complimentary network of stations proposed by the Bay RMP to monitor salinity, tides, and suspended sediment in the Bay's five major embayments.

REFERENCE SITES

These are wetlands used to assess the performance of wetland restoration and mitigation projects. They can include both millennial and centennial wetlands, but they are always more geomorphically evolved than project sites. Data from these sites will likely have a relatively lower "signal to noise" ratio (i.e., will be more variable in condition over time) than data from Benchmark Sites. To increase the "signal to noise" ratio, Reference Sites must be carefully correlated spatially and temporally with Benchmark Sites and Project Sites, based on relationships described by the WRMP's Compendium of Conceptual Models. Benchmark Sites and mature Reference Sites may be used to identify a "reference envelope" of desired and achievable conditions for restoration projects (i.e., a range of acceptable conditions), which may change over time.

Selection Criteria for Reference Sites

The selection criteria for Reference Sites include:

A. The site has pre-existing data sets for one or more WRMP indicators. Though relatively few wetlands in the Bay have existing, long-term records for multiple indicators (these are almost exclusively candidate Benchmark Sites), some wetlands in the region have been the subject of past multi-disciplinary research and/or monitoring efforts initiated by the US Geological Survey, US Fish and Wildlife Service, universities and colleges, and other scientific organizations. Example wetlands include Muzzi Marsh, Faber Tract, Bair Island, Petaluma Marsh, China Camp, Rush Ranch, and the study sites of the Integrated Regional Wetland Monitoring Pilot Project (i.e., Carl's Marsh, Coon Island, Bull Island, Napa Pond 2A, Brown's Island).

B. The site is strongly linked by physical processes to Benchmark Sites and/or other WRMP Sites based on empirical observation, simulation models, or consensus best professional judgement. For example, numerical models and general professional agreement indicate that Rush Ranch and the fringing marshes along the western reaches of Montezuma all receive their suspended sediment from Grizzly Bay.

C. The site supports, or has the potential to support, the morphology and functions of the "complete tidal wetland ecosystem" as defined by the Baylands Ecosystem Habitat Goals Update (Goals Project 2015). Management interventions to accelerate wetland evolution or maintain intertidal elevations may be especially valuable at wetlands with landscape connectivity to functioning estuarine-terrestrial transition zones and subtidal habitats (e.g., channels, mudflats, and shallow open water), or have the potential to support connectivity through structural (e.g., levee breaches) or non-structural (e.g., land acquisition) means.

D. The site is not a Benchmark Site but provides target ecosystem functions and services that are commonly prioritized for protection or restoration by resource agencies, regulatory agencies, and project funders. At least some Reference Sites should support the ecosystem functions and services that serve as performance targets for restoration projects. These include but are not limited to: (a) providing habitat for special status species; (b) supporting especially diverse plant, fish, and wildlife communities; (c) buffering areas landward of a wetland from flooding and wave action; and (d) supporting water quality consistent with regulatory standards. These wetlands are most likely to be older restored wetlands and, in limited cases, larger fringing infill wetlands (e.g., wetlands outboard of salt pond levees along Mowry Slough).

SELECTED PROJECT SITES

These are existing and planned restoration and compensatory mitigation projects intended to recover wetland functions that have been lost due to historical (i.e., preceding federal or state regulations protecting wetlands) or permitted land uses. Modern projects require a suite of permits from regulatory and resource agencies that require project-specific monitoring. The monitoring requirements are usually more specific for mitigation projects, the purpose of which is to compensate for permitted losses of specific wetland functions. To the extent that projects use the same indicators, metrics, and data management system recommended by the WRMP, they can be compared to each other over time, and their effect on ambient condition can be assessed. This information is necessary to answer GQs 2, 3 and 5. Data from Project Sites will likely have low "signal to noise" ratios due to being in early stages of tidal wetland evolution. Project Sites should ideally be carefully correlated spatially and temporally with Benchmark and/or Reference Sites, based on relationships described by the WRMP's Compendium of Conceptual Models.

Selection Criteria for Project Sites

The selection criteria for Project Sites include criteria for Reference Sites above, as well as the following:

A. The site is a project with ongoing and/or recent monitoring consistent with the WRMP. The goal of restoration projects is to directly affect the distribution, abundance, diversity or condition of tidal wetlands. Projects are monitored as a condition of their permits. Projects are commonly required to monitor a variety of on-site factors and processes that are also likely to be monitored by the WRMP at Benchmark Sites and through regional surveys and inventories. If projects and the WRMP use the same indicators, metrics, and data management systems to measure the same factors and processes, then the projects can be compared to each other, over time, and to regional ambient conditions. The WRMP might thereby provide a regional context for project design and evaluation. Examples of these projects include the South Bay and Napa-Sonoma Salt Ponds, Hamilton Wetlands, Sonoma Baylands, Cullinan Ranch, Blacklock, Sears Point, Montezuma Wetlands Project, and Sonoma Creek.

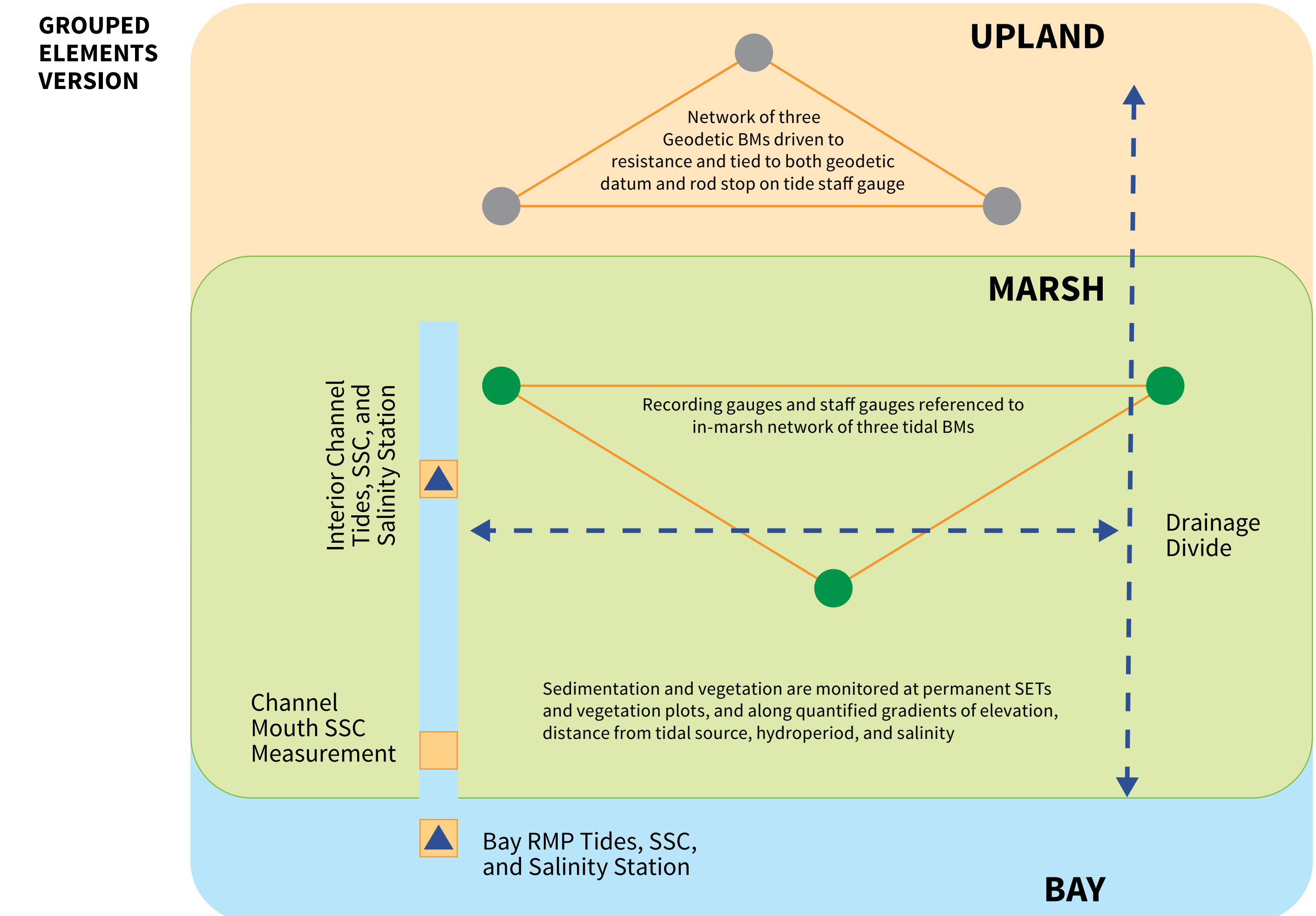
B. The site is necessary to represent a particular restoration approach. Projects in the region represent a variety of design approaches that reflect the continuing evolution of restoration science and regulation, as well as ongoing physical changes in the estuary. Examples of design factors that differ among projects include the beneficial reuse of dredged sediments, excavation of pilot channels, construction of wetland mounds and wind-wave berms, grading of outboard levees, invasive plant species, transition zone planting and irrigation, and many more. There is a significant need for the WRMP to provide information to help identify which approaches are most effective.

Arrangement of Monitoring Efforts at Benchmark Sites

Monitoring at Benchmark Sites should help elucidate the effects of external driving factors, such a sea level rise, sediment supply, and water salinity on marsh condition. Indicators of marsh condition must be monitored along on-site gradients of these driving factors. If these gradients are ignored, the variability in the monitoring data may obscure the relationship between condition and the driving factors. Based on these considerations, a schematic diagram of the possible arrangement of different monitoring efforts within a Benchmark Site has been drafted (see Figure 8 below). This is a stylized ideal from which actual sites may differ. It is assumed that a detailed elevation model (DEM) and plant cover map will be developed for each Site based on remote sensing with field-based calibration and validation.

Each Benchmark Site will be provided with permanent benchmarks to account for the effects of tidal wetland sedimentation, subsidence, and surrounding land motion on annual changes in wetland plain and tidal flat elevation and extent.

Figure 8. Schematic diagram of possible arrangement of monitoring efforts within a Benchmark Site



D5. Temporal Framework

The WRMP Master Matrix (Appendix A2) begins to organize the WRMP based on the temporal and spatial scales of monitoring and reporting of wetland responses and indicators. Though sampling at Reference and Selected Project Sites will likely be less intense and frequent than at Benchmark Sites, the larger number of potential Reference and Project Sites will likely necessitate a phased approach (where increasing numbers of sites are monitored as additional funds become available) and/or a rotating approach (where a select subset of sites are monitored at the appropriate interval). Site rotation may work better for some physical indicators than wildlife indicators. Other approaches are also possible based on the direction of related monitoring efforts such as the Bay Sediment RMP and the pace of SFBRA project implementation. It is highly likely that the spatial and temporal scales of WRMP monitoring will change over time, particularly once enough data are collected to identify leading indicators and thresholds of change (e.g., triggers for management/intervention).

We propose that the WRMP engage a TAC to guide the schedules and locations of monitoring efforts over time, based on the following principles:

- The WRMP should periodically yield a summary report of tidal marsh conditions throughout the region, while helping to coordinate project-based monitoring, and be able to identify major episodic events.
- Indicators designed or selected to work together as correlates across spatial scales, or to test cause-and-effect relationships should be carefully aligned in space and time.
- The frequency and location of monitoring for one or more indicators may be decided based on the identification of new data gaps and information needs, budgetary changes, and other considerations.
- The TAC will help maintain WRMP technical excellence and cost-effectiveness by identifying monitoring locations and frequencies, interpreting results, identifying new questions and recommending special studies, and advising project conceptual designs and monitoring plans. The roles and responsibilities of the TAC will be decided during Phase 2 of WRMP planning.

APPENDIX E: RELATED MONITORING EFFORTS

The WRMP is designed to leverage and coordinate with multiple parallel and related monitoring and research efforts and projects throughout the Estuary to avoid duplicating monitoring efforts, maximize the temporal and spatial coverage of monitoring activities, and more efficiently develop information needed by stakeholders. This section summarizes these efforts and how they relate to the WRMP.

Tidal marsh restoration includes the full range of restoration, creation, rehabilitation, and enhancement of tidal marsh as either a voluntary action or as compensatory mitigation for permitted impacts. Standardization of monitoring allows projects to be compared to each other and to ambient conditions over time, and thus can help integrate project monitoring results into regional assessments of tidal marsh condition.

The WRMP may work in conjunction or coordination with related projects around the region. Larger projects that represent larger portions of the regional ecosystem generally provide significant opportunity for mutual learning and exchange as well as collaboration. The largest projects, such as the South Bay Salt Pond Restoration Project, Hamilton/Bel Marin Keys Unit V Wetlands Restoration Project, Napa-Sonoma Marsh Restoration Project, SF Estuary Invasive Spartina Project, SF Bay Living Shorelines Project, and Montezuma Wetlands Restoration Project have their own dedicated similar science and/or technical working groups that can help coordinate project monitoring with the WRMP. Additional projects are being developed, and it is expected that the WRMP may serve projects by conducting their monitoring, managing their data, and providing independent review of monitoring results and findings. This may not preclude the need for project specific monitoring on projects affecting species listed under the ESA.

Regional Monitoring Program for Water Quality in San Francisco Bay

The Bay RMP is a collaborative effort between the SFBRWQCB, the regulated discharger community, and SFEI to monitor water quality and the effectiveness of water quality regulations throughout the Bay. The geographic scope of the Bay RMP and WRMP is the same, although wetlands have generally been considered beyond the scope of the Bay RMP. Since the Bay RMP's inception in 1993, the discharger community has provided a consistent stream of funding to support both long-term monitoring of priority estuarine contaminants such as metals, PCBs, and dioxins, as well as special studies focused on emerging contaminants (e.g., pharmaceuticals, pesticides, and microplastics), sediment, stormwater, selenium, and other topics. The Bay RMP monitoring and reporting activities are guided by an evolving set of management questions adopted by the steering committee, based on recommendations from the technical review committee and multiple workgroups. This structure allows the Bay RMP to adapt to changing conditions and priorities and helps to ensure the program provides the information necessary to inform a range of decision-makers, including but not limited to regulatory agencies and dischargers. This management-oriented framework makes the Bay RMP a helpful model for the WRMP. Large-scale efforts to restore tidal marsh around the Bay will undoubtedly affect Bay water quality. The Bay RMP and WRMP will therefore need to be coordinated.

Sediment Science

Two sedimentary processes account for most of the gains in elevation of tidal marshes. One process is the accumulation of organic matter, mostly roots and stems, produced in-situ by tidal marsh vascular vegetation. The other process is the retention and accumulation of inorganic matter, mostly sands, clays and silts, delivered directly to the marshes from the Estuary (via estuarine currents, wakes and waves, and flood tides), or delivered from local watersheds (via river and stream floods). An imbalance between water and sediment supplies can convert marshes into terrestrial habitats (too much sediment) or cause marshes to drown and erode (too much water relative to the sediment supply). Understanding the effects of climate change on Bay level and the availability of sediment is essential to guide restoration efforts.

The concern that sea level rise might outpace rates of sediment accretion in the Bay's tidal wetlands due to decreasing supplies of inorganic sediment from the Delta and local watersheds has led to multiple regional scientific studies to assess the sources and amounts of inorganic sediment available to marshes now and into the future. The USEPA-funded Healthy Watersheds Resilient Baylands study involves an assessment of the sources, availability, and demand for inorganic sediment to restore various tidal marshes within the region, before 2100. The Bay RMP sediment workgroup is funding studies to monitor and model sediment flux at various locations around the bay, assess recent bathymetric changes throughout the entire Bay and develop an integrated sediment monitoring and modeling plan. The SFBRWQCB is supporting a separate study of the sediment yield from urbanized watersheds in the region, in conjunction with the study of sediment sources and demand mentioned above. The WRMP is actively coordinating with these and other current studies of sedimentary processes in the Estuary to maximize their value to the marsh restoration enterprise. All these studies build on a rich history of empirical studies and predictive modeling of how the sedimentary processes of the Bay's tidal marshes vary through space and over time. These new studies and the WRMP are needed to fill information gaps and translate the science into effective restoration guidance. Knowing where restoration is likely to be successful with minimum intervention and how much of what kinds of intervention are needed elsewhere is especially important.

Nutrients Science Program

The San Francisco Bay Nutrient Management Strategy (NMS), led by the San Francisco Bay Regional Water Quality Control Board with support from SFEI and the Southern California Coastal Water Research Program (SCCWRP), is a regional initiative aimed generating the scientific understanding needed to inform major nutrient management decisions in the Bay. The NMS involves federal and state agencies, local governments, non-profit organizations, and academic institutions.

San Francisco Bay has long been recognized as a nutrient-enriched estuary. The NMS will help determine the relative importance of various factors maintaining high levels of dissolved oxygen and low levels of phytoplankton biomass in the open bay environments, despite their nutrient enrichment. Regional decreases in turbidity due to decreased suspended sediment supplies are expected to lessen the Bay's resistance to nutrient loading. Since the Bay is the State's largest estuary, and one for which there is currently a relative wealth of data, it is also an important focus of a state-wide effort to develop Nutrient Numeric Endpoints (NNEs) for estuaries. As part of the state-wide effort, the NMS links to the effort that is developing an NNE framework specific to the Bay.

The NMS recently entered its second five-year planning cycle, and is revisited annually to identify each year's priority activities. This approach allows the NMS to remain flexible and adapt to new information. Large-scale efforts to restore tidal marsh around the Bay have the potential to substantially influence its response to nutrients, for example, by attenuating nutrient sources, or increasing organic matter inputs to the Bay. The WRMP will therefore need to coordinate with the NMS.

San Francisco Bay National Estuarine Research Reserve

The SF Bay NERR operates long-term estuarine research, monitoring, education, coastal training, and stewardship programs at two tidal marsh components in China Camp State Park (Marin County, along San Pablo Bay) and Rush Ranch Open Space Preserve (Solano County, in Suisun Marsh). These landscapes are two of the largest remaining millennial marshes subject to mostly natural physical and ecological processes in the Bay and both also maintain relatively intact physical and ecological connections to uplands that have largely been eliminated elsewhere in the region. Because of their unique vegetation, rare populations of marsh dependent species, and diverse landscapes, both of these sites have been used historically as reference sites for tidal wetland restoration design and monitoring projects throughout much of the Estuary. Since 2008, both marshes have participated in the NERR's System Wide Monitoring Program that includes continuous measurements of water quality and local meteorological conditions. The SF Bay NERR also conducts long-term monitoring of emergent tidal vegetation at China Camp and Rush Ranch, monthly oyster recruitment along the Marin County shoreline, and annual bay-wide oyster population surveys. Further, it is currently building out its Sentinel Site Framework and gathering water level, accretion, vegetation, and other related data. Due to the physical and ecological integrity of the tidal marshes at China Camp and Rush Ranch, as well as the history of monitoring data at these sites, the WRMP framework will likely propose that both marshes be designated as "Benchmark Sites" to support continued monitoring of multiple metrics (see Section 2 and Appendix D for more details).

Further, as noted above, the SF Bay NERR has specifically been called upon to champion a sentinel marsh program for Action 2 (regional monitoring) in the CCMP. As part of the NERRS program, the SF Bay NERR has access to a rapidly evolving national program that is perfecting its methods of data acquisition, data analysis, and visualization to assist local resource managers in decision making. The SF Bay NERR will draw upon these and other national resources (e.g., the Center for Operational Oceanographic Products and Services (COOPS) and the National Geodetic Survey (NGS)) to help build the regional wetland monitoring network.

Delta Science Program and Interagency Ecological Program

The Delta Science Program is a component of the Delta Stewardship Council and was established by the Delta Reform Act of 2009 to provide scientific information and synthesis for the state on issues critical for managing the Bay-Delta system, with an emphasis on informing water and environmental decision-making in the Delta. This knowledge must be unbiased, relevant, authoritative, integrated across agencies, and communicated to stakeholders. The Delta Science Program assists with development and periodic updates of the Delta Plan and supports the Delta Plan by promoting adaptive management and best available science.

The Interagency Ecological Program (IEP) is a consortium of state and federal agencies that has been collecting data since the 1970s. IEP provides and integrates relevant and timely ecological information for management of the Bay-Delta ecosystem and the freshwater that flows through it, with a focus on the Delta and Suisun. IEP also holds an annual workshop, publishes a quarterly newsletter and science highlights, and conducts technical and programmatic reviews of the program and its elements. The IEP Lead Scientist regularly works with the Delta Science Program to identify, track, and explain the status and needs of Bay-Delta science.

In general, monitoring and research efforts led by the Delta Science Program and IEP are limited to the geographic boundaries of the legal Delta (the Delta and Suisun Marsh), and do not extend into downstream wetlands and waters in San Francisco Bay. This limits the ability of Delta science initiatives to integrate physical and ecosystem dynamics outside the legal Delta into their analyses, and it impedes the study and management of the Bay-Delta as a single, connected estuary. For example, recent work on the population dynamics of state-listed longfin smelt (Spirinchus thaleichthys) has demonstrated that in wet years, this species is abundant in marshes, tributaries, and open water of San Pablo Bay, the South Bay, and the Lower South Bay (Grimaldo et al., 2017; Lewis et al., 2019). However, recovery planning for this species is primarily focused on the Delta, which limits the integration of non-Delta population dynamics into efforts to recover the species across the region. The WRMP aims to bring a more unified lens to monitoring activities in the Estuary by coordinating with the Delta Science Program and IEP to support regional data collection, analysis, and reporting to support decision-making.

Wildlife Monitoring

Various entities currently monitor wildlife throughout the Estuary. The Estuary's tidal wetland habitat hosts many wildlife taxa relevant to the WRMP including marsh birds, mammals, and fish. The partial list of monitoring programs described below were each initiated for a specific purpose, though the WRMP may be able to leverage these existing efforts to address proposed indicators.

Marsh Birds – Annual surveys targeting Ridgway's rails and other secretive marsh birds are conducted throughout the Estuary annually through a coordinated multi-agency effort that is largely the result of required monitoring under a USFWS ESA Section 7 formal endangered species consultation on the Invasive Spartina Program (ISP) (USFWS File No: 08ESMF00-2012-F-0584-xx) and includes USFWS, CDFW, the State Coastal Conservancy's ISP, Point Blue Conservation Science, USGS, EBRPD, and Avocet Research Associates. The surveys have been conducted using a number of protocols and are now mostly conducted following the USFWS Site-Specific Protocol for Monitoring Marsh Birds and the data are stored with each data collecting agency and organization and are also being consolidated in the Avian Knowledge Network along with marsh bird data from Refuges across the nation. Point Blue Conservation Science monitors tidal marsh birds including WRMP proposed indicator species, song sparrow, common yellowthroat, and California black rail throughout the Estuary, collecting data on spatial population trends. Monitoring began in 1996 and is conducted annually during the breeding season (April-May). Data are available upon request with some summaries posted online.

Other bird species that rely on tidal marsh habitat but are not obligates, include herons, egrets, waterfowl, and shorebirds. Audubon Canyon Ranch and the San Francisco Bay Bird Observatory monitor heron and egret nesting colonies, including the species great egret (Ardea alba), great blue heron (Ardea herodias), snowy egret (Egretta thula), black-crowned night heron (Nycticorax nycticorax), and double-crested cormorant (Phalacrocorax auritus). The survey is conducted annually, beginning in 1996, and spans marshes and upland habitat, from the Bay's edge, inland, and out to the Pacific coast. Data are available online through reports and publications. The USGS also monitors a variety of marsh bird species, their habitats, and stressors such as mercury and selenium in the bay including decades long research regarding waterfowl, shorebirds, snowy egret, and night heron, with a variety of peer reviewed publications available publicly.

Marsh Mammals – Salt Marsh Harvest Mouse (Reithrodontomys raviventris) is listed as endangered under the Federal Endangered Species Act and California Endangered Species Act. Long-term monitoring has been conducted in Suisun Marsh since 2000, San Pablo Bay since 1998, and the South Bay since 1976. Monitoring is conducted, sometimes intermittently, by scientists from CDFW, USGS, USFWS, UC Davis, and the East Bay Regional Parks District to keep track of populations, inform conservation actions, and comply with regulatory requirements (i.e. the Suisun Marsh Habitat Management, Preservation, and Restoration Plan Biological Opinion). The monitoring documents trends in capture success. Data are stored with each data collecting agency and are publicized through various reports and scientific publications.

Fish – As described above, the IEP is a consortium of state and federal agencies that administer multiple long-term hydrodynamic, water quality, and biological monitoring surveys throughout the Estuary. The Department of Water Resources (DWR), USFWS, and CDFW conduct multiple fish surveys targeting various life stages, species, and habitats. Many surveys are conducted in open water and deep channel areas; additional surveys track littoral areas or water adjacent to restoration wetlands projects. More relevant to the WRMP, UC Davis conducts a long-term IEP monitoring fish survey in tidal marsh habitat. The Suisun Marsh Fish Study was initiated in 1979 to monitor native and alien fishes, impacts of restoration and other anthropogenic activity, and train students. Fish and invertebrates are sampled through net trawls and beach seines. With almost 40 years of data, researchers can detect trends in species populations, including listed species like Delta smelt (Hypomesus transpacificus) and longfin smelt, in relation to external stressors. Other UC Davis researchers have been conducting fish and invertebrate monitoring in the South Bay since 2010 to monitor species response to the South Bay Salt Ponds Restoration Project. The survey deploys otter trawls and 20-millimeter net tows to measure use of restored salt ponds and other habitats by fish including listed species (e.g., longfin smelt) and macroinvertebrates (e.g., various shrimp and other zooplankton species). This survey currently only has short-term funding for otter trawling. Data are available online and through scientific publications.

Mosquito and Vector Control Surveillance

Mosquitoes and other disease vectors, as defined by the State, are effectively monitored and controlled for the protection of public health and reduction of public nuisance by local, special-purpose government agencies which include Mosquito Abatement Districts, Vector Control Districts, and combined programs, collectively referred to as MADs. The nine Bay Area MADs employ nearly 200 full-time staff and cover a service area larger than 7,300 square-miles. Many of the staff are dedicated to collecting and analyzing data regarding the distribution of mosquitoes and mosquito habitat and related environmental factors. The MADs continue to sustain the largest, longest-lasting, wetlands monitoring enterprise in the region.

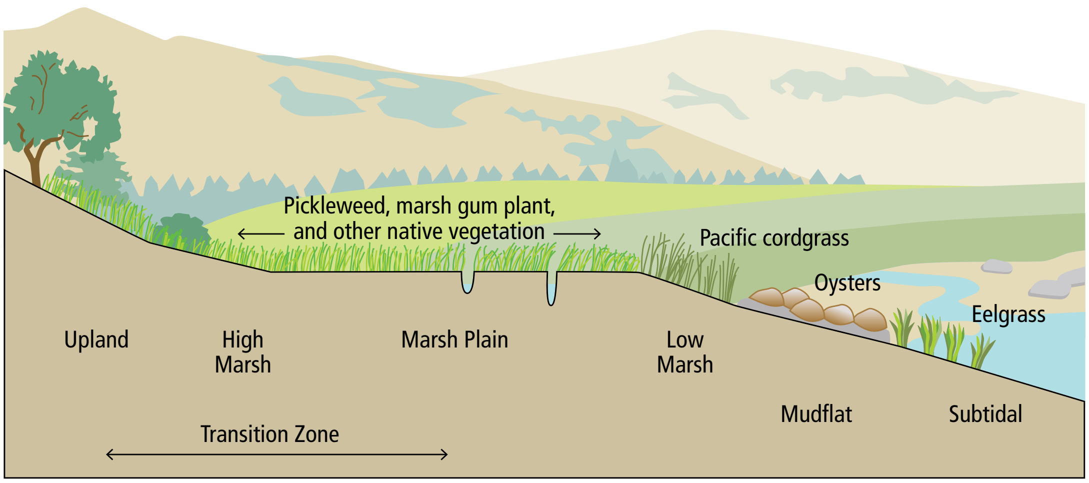
Activities of the MADs are guided and coordinated by the California Department of Public Health, but they are locally funded and are directed either by County Supervisors (Santa Clara) or by independent local Boards of Directors. They have a high degree of institutional independence although they voluntarily share information, coordinate their activities with each other, and collectively represent themselves with regulatory agencies and landowners. The MADs have substantial governmental powers, including access to sites, use of mosquito control methods, legal abatement of public nuisances, billing for cost recovery, etc. The extent of these powers on private and state lands is codified in the California Health and Safety Code but has not been fully defined or tested on federal lands.

Relations between MADs and wetland managers, regulators, and tidal marsh restoration proponents are generally productive, but the MADs have expressed desires for improved interactions regarding tidal marsh restoration planning, design, permitting, and monitoring. It is expected that the WRMP will improve the collaboration between the MADs and other interests in wetlands condition.

APPENDIX F: CONCEPTUAL MODELS

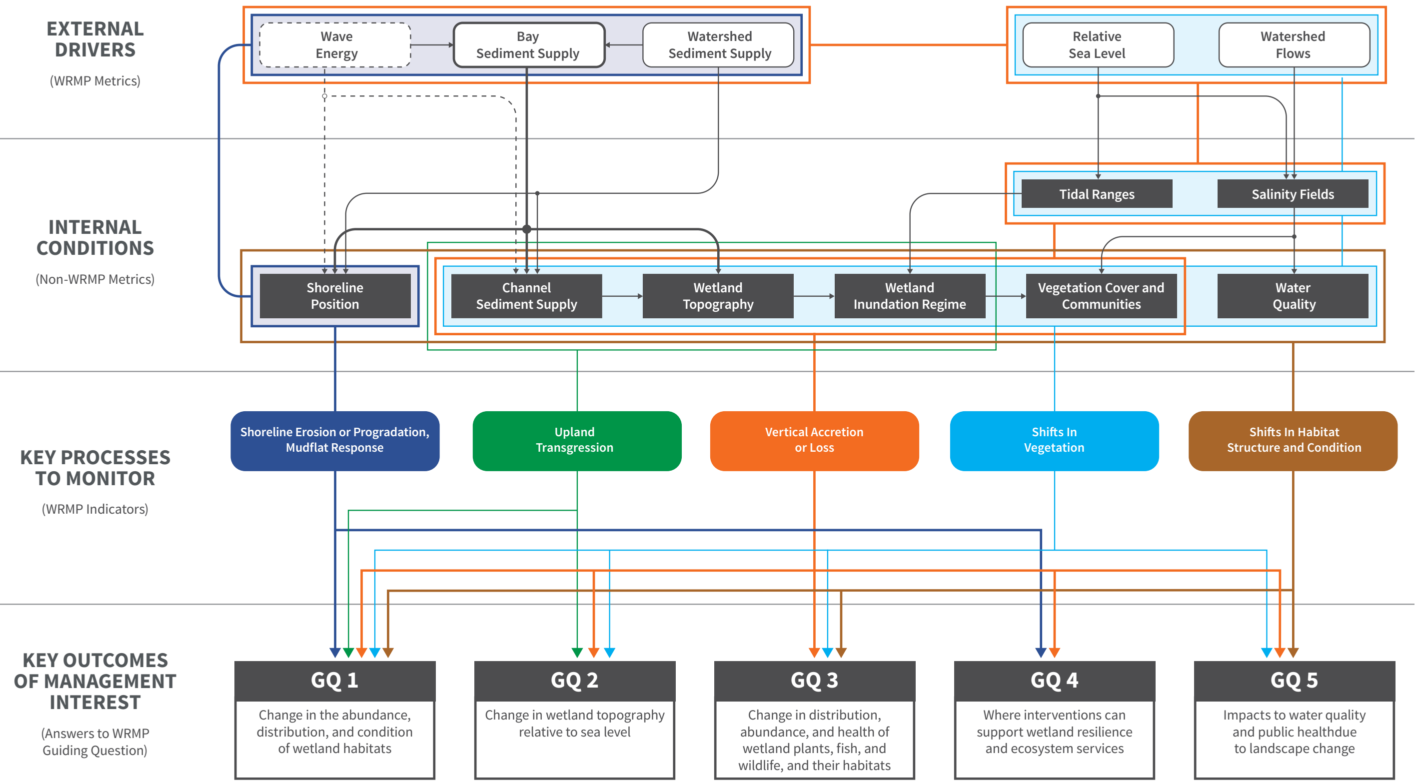
This is the Compendium of Conceptual Models used in the development of the WRMP science content.

F1. Tidal Marsh Ecosystem Definition



The tidal marsh ecosystem incorporates the shallow sub-tidal zone (to depth 12 ft below local MLLW), the entire intertidal zone including tidal flats, and the transition zone that includes the bayward and landward (upstream) extents of measurable interactions among abiotic and biotic riverine, terrestrial, and estuarine processes and events (Goals Project, 2015).

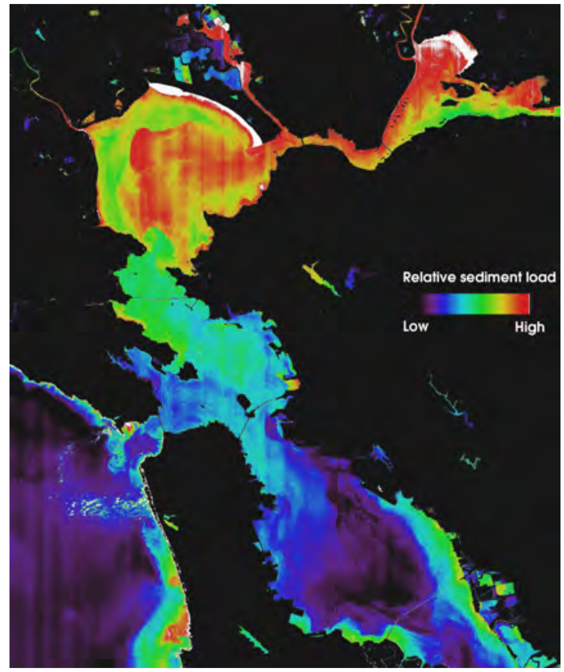
F2. WRMP Conceptual Model v1.1



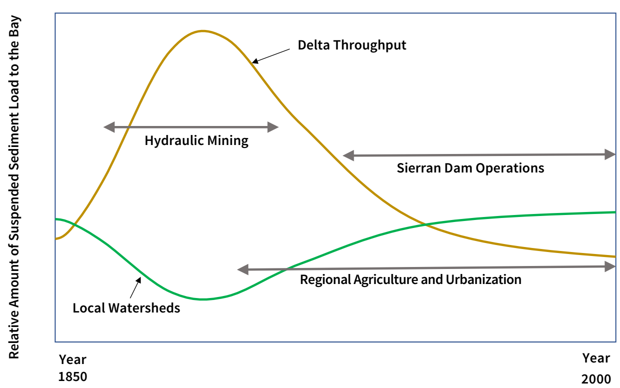
V1.1 of the WRMP conceptual model attempts to link key metrics (External Drivers and Internal Conditions) that address monitoring questions (Key Processes to Monitor) which in turn address WRMP management guiding questions (Key Outcomes of Management Interest). The colored lines group metrics that are relevant to key processes, and indicate which processes influence which key outcomes. Metrics are color-coded according to whether they are addressed through Level 1, 2, or 3 monitoring. Some metrics can be addressed through multiple types of monitoring, with corresponding differences in levels of data precision and accuracy. Note that this conceptual model is primarily focused on physical processes and vegetation; future revisions will also address fish and wildlife, and vector control.

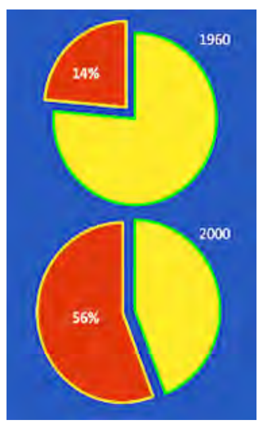
Distribution of Suspended Sediment among the Sub-regions of SF Bay

Sediment entering the Bay through the Delta is largely confined to Suisun Bay, San Pablo Bay and Central Bay, with supplies in South Bay especially dependent on yields from local South Bay watersheds (McKee, et al., 2002).



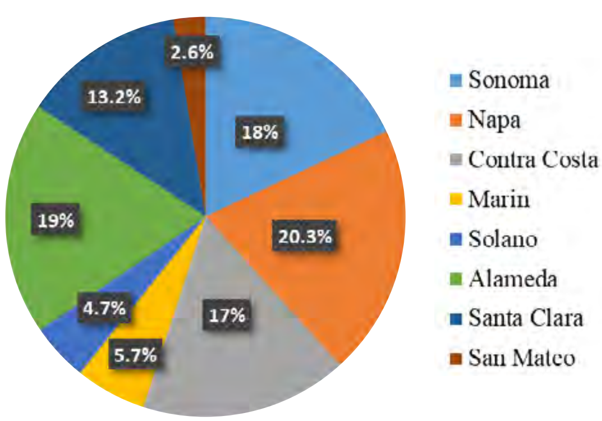
Relative Contributions of Delta Throughput and Local Watersheds to Suspended Sediment in SF Bay





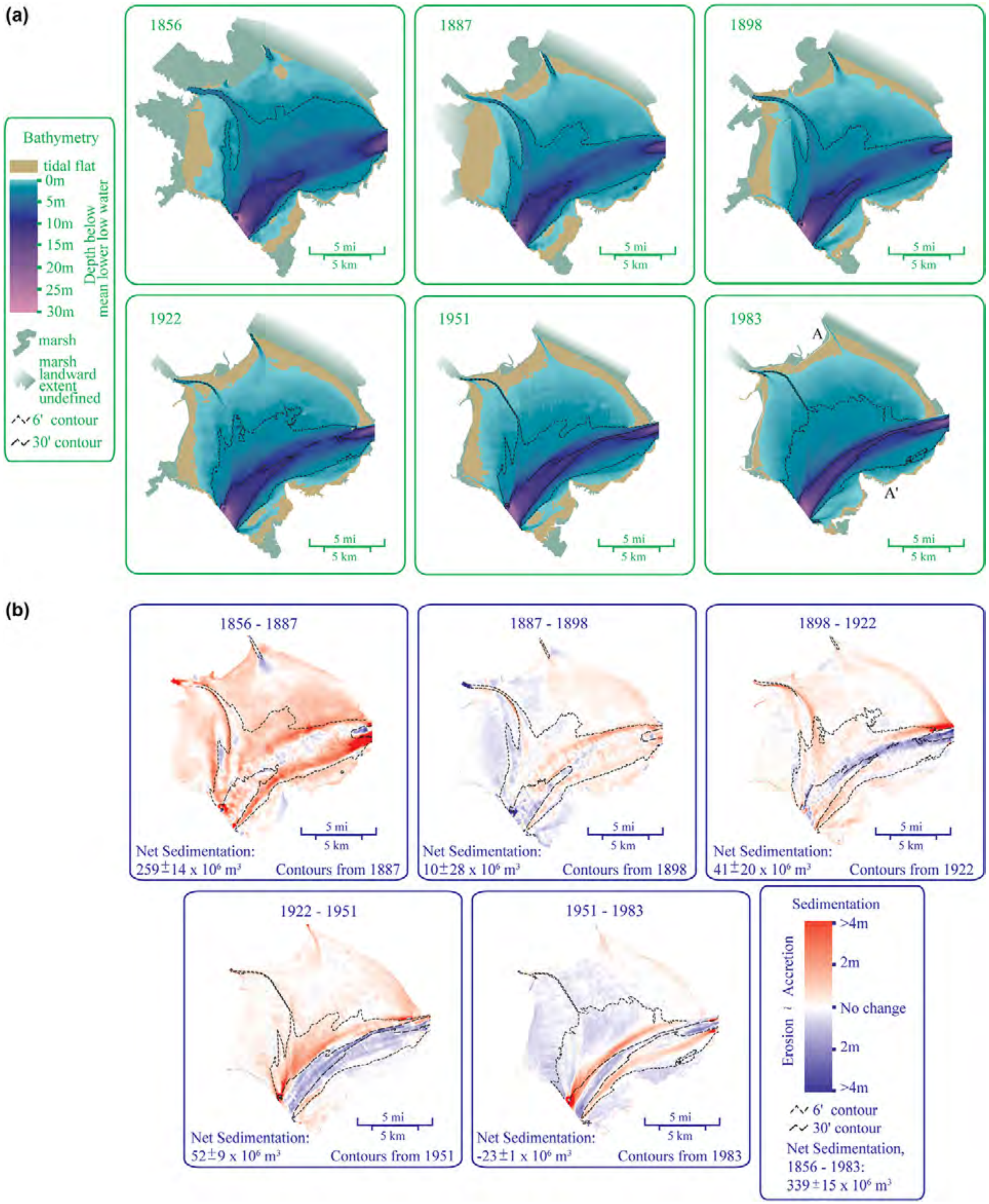
Shift is relative abundance of sediment inputs from the Delta (yellow) vs Bay Area watersheds (orangered) between 1960

The implication is that sediment load from small tributaries has a larger impact on siltation in near-shore marinas, shipping facilities, and wetlands than sediment derived from the Sacramento–San Joaquin watershed (McKee, et al., 2002; Mckee, et al., 2013; Barnard, et al., 2013).



From 1995-2016, the majority of the Bay's sediment supply (63%) was from local tributaries. Together, the Napa River and Sonoma Creek accounted for roughly 22% of the small tributary load, and 14% of the total load (Schoellhamer, et al., 2018). The vast majority of this sediment is suspended; net bedload is a small fraction of the total sediment supply.

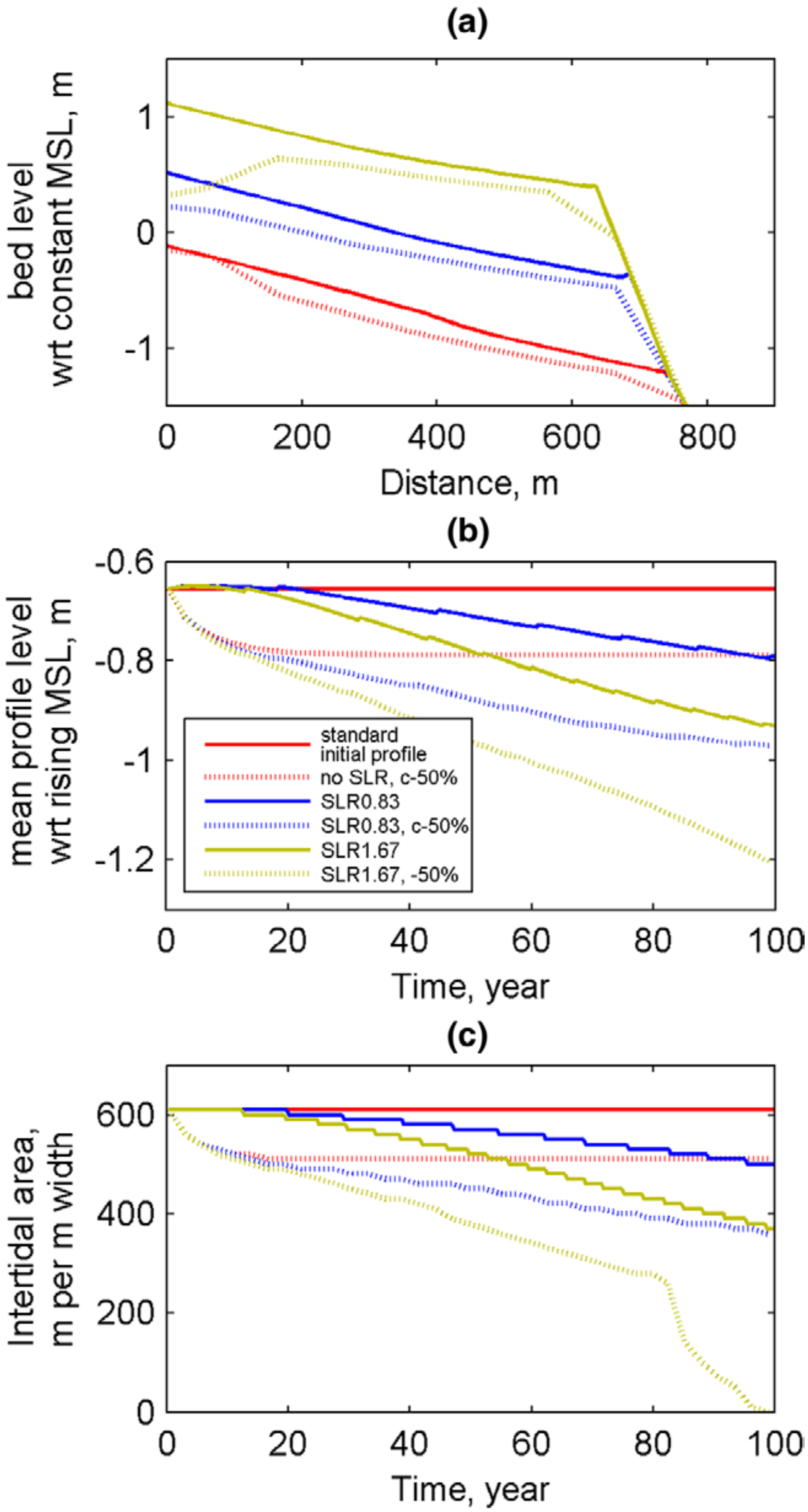
Historical Change in San Pablo Bay Bathymetry Due to Decreasing Sediment Supply.



Subtidal and lower intertidal sedimentation regimes (a) are sensitive to sediment supply. In San Pablo Bay, net aggradation during the latter 19th century resulted from large pulses of Sierran hydraulic mining debris and local grazing practices. The cessation of mining plus subsequent damming of Sierran rivers and local agricultural erosion control has reduced the sediment supply, causing a shift to net degradation/erosion (b) (Jaffe, Smith, & Foxgrover, 2007).

F5. Mudflat Response to SLR and Changing SSC

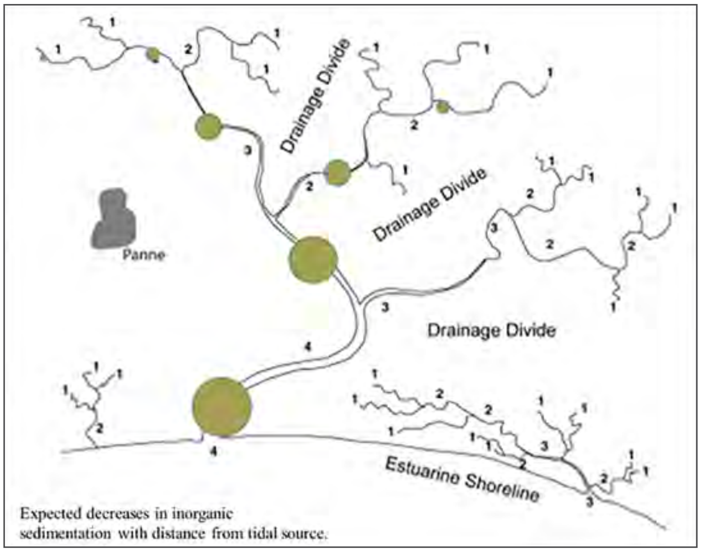
Effects of SLR and SCC on Mudflat Profiles in South Bay (van der Wegen, Jaffe, Foxgrover, & Roelvink, 2017).



SLR leads to a proportionally higher mudflat profile with a slightly gentler slope (solid lines in Fig. a). The mudflat becomes narrower as the mudflat edge develops along the imposed bed level slope. Doubling SLR (from 0.83 to 1.67 m/century) roughly leads to a doubling of mudflat accretion (0.6 m to about 1.2 m/century). An abrupt 50 % reduction in SSC leads to an almost uniformly lower mudflat profile of about 0.15 m (Fig. b). Combination of lower SSC and SLR leads to lower profiles. Exceptionally, a combination of high SLR (1.67 m/century) and a drop in SSC level leads to a mudflat that does not accrete anymore at the landward end.

An abrupt 50 % decay of SSC has a relatively fast effect on the mean mudflat level, which stabilizes afterward (dotted red line in Fig b). SLR drowns the mudflat more slowly, albeit at a continuous rate. Although the mudflat accretes under SLR scenarios, it also drowns because of the larger increase in MSL. Figure c shows that intertidal area decreases as well. A higher SLR leads to faster loss of intertidal area.

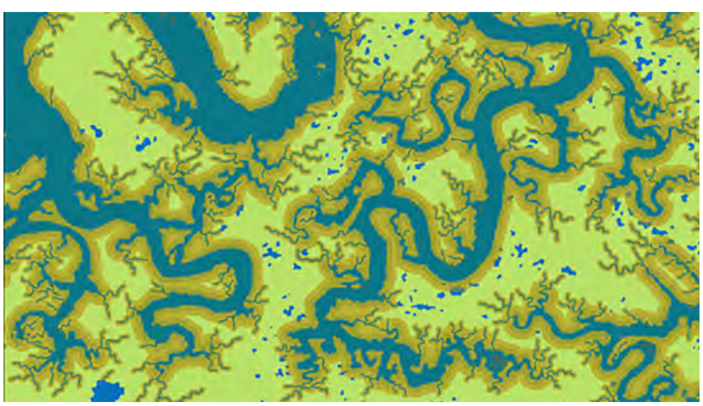
Distribution of Suspended Sediment among the Sub-regions of SF Bay



Expected decreases in inorganic sedimentation with distance from tidal source.

Suspended sediment entering a network on flood tide tends to be contained within the networks due to combination of settling through the water column and waters higher in the water column above the sediment-laden water moving upstream faster. 1st-order channels farthest from the tidal source convey the least amount of sediment. During tides that do not inundate the marsh plain, within networks in equilibrium with their tidal prism and sediment supplies, the sediment entering the network on flood tide exits the network during ebb tide (Collins, Collins, & Leopold, 1987). After Collins et al. 1987.

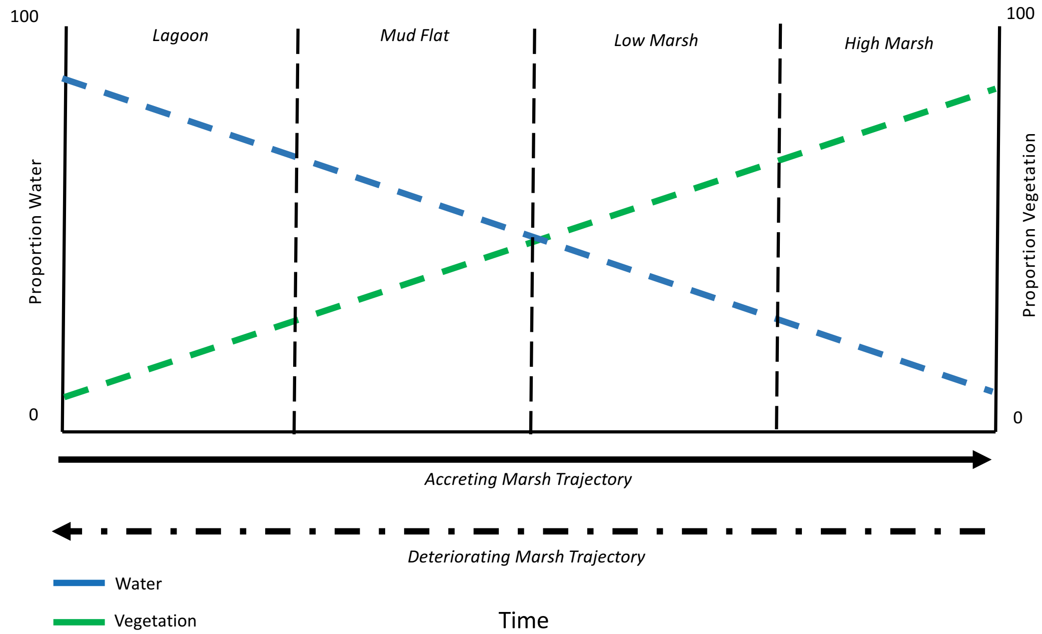
Distribution of Suspended Sediment along a Drainage Network with Distance from Channel Banks



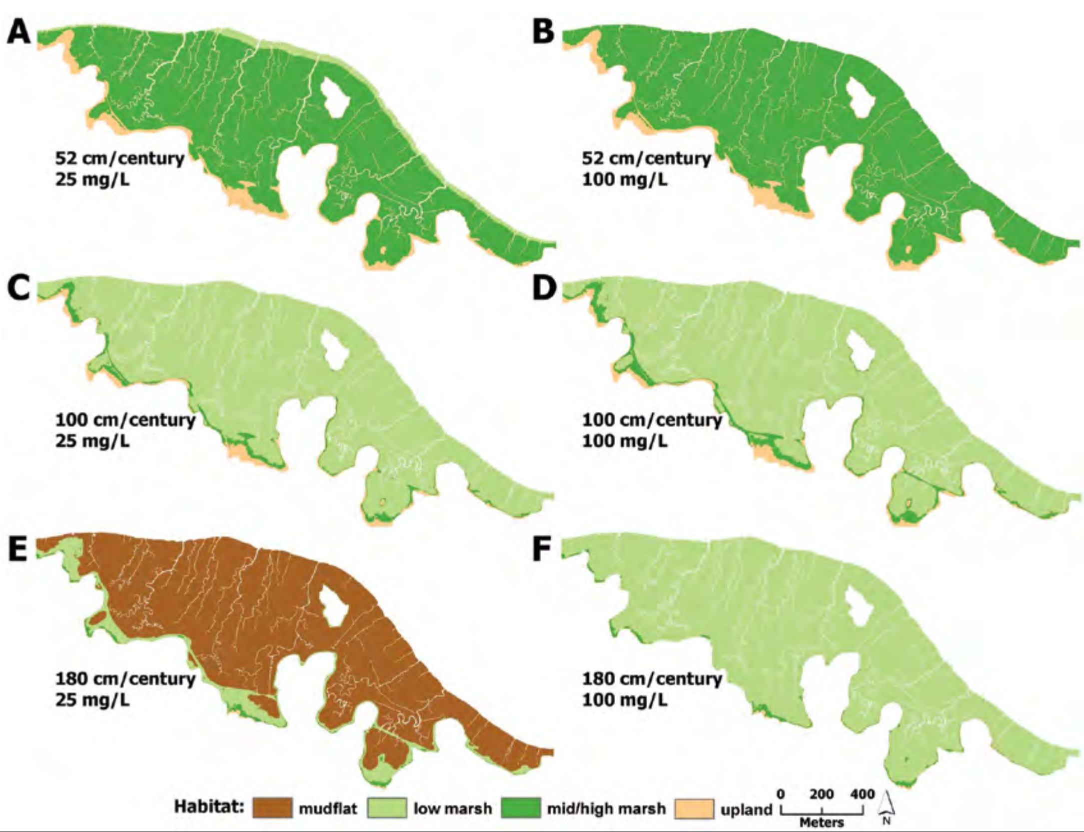
Suspended sediment conveyed to the marsh plain by flood tides tends to settle rapidly and be filtered by marsh vegetation, such that the sediment is largely confined to the immediate margins of the channels. The concentration of suspended sediment in the waters that inundate the marsh, and the duration of inundation decrease upstream and with distance across the marsh plain away from the channel banks.

Therefore, the width of the depositional zones along the channels also decreases with distance upstream. The depositional zone tends to be higher in elevation than adjoining areas of the marsh plain, and tends to be to colonized first during early stages of marsh formation. In a mature, high-elevation marsh, the contribution of allochthonous suspended sediment deposition to marsh elevation, relative to autochthonous organic sediment production decreases with distance from channel banks (Collins, Collins, & Leopold, 1987). Note that elevation is an imperfect proxy for inundation frequency/depth/duration due to the effects of channel hydraulics and planform morphology (distance from channel, etc.)

F7. Marsh Geomorphology 1: Marsh Evolution and De-evolution

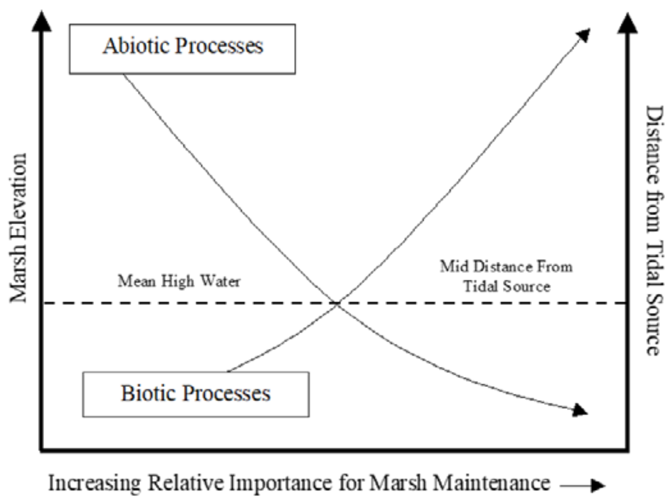


In a very general sense, marshes become increasingly vegetated as they gain tidal elevation through sediment accretion. Inversely, surface erosion due to excessive flooding (e.g., from sea level rise) in the absence of adequate sediment supplies can cause a marsh to lose elevation, driving the downshifting of vegetation communities (e.g., high marsh communities to low marsh communities) and even the potential conversion of vegetation marsh to unvegetated mudflat (Schile et al. 2014). The WRMP should adopt indicators sensitive to vegetation community shifts, net accretion (elevation gain), and net erosion (elevation loss) (WRMP Core Team; Ganju, et al. 2017).



F8. Marsh Geomorphology 2: Distribution of Biotic and Abiotic Processes

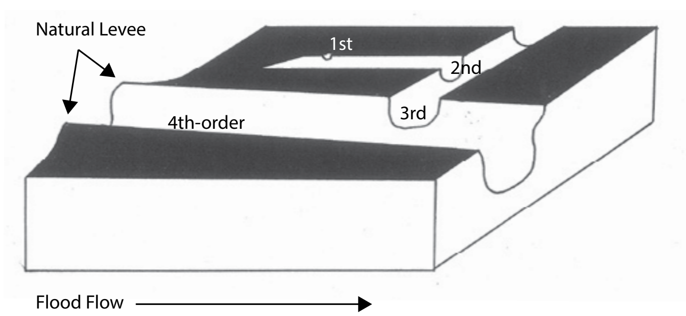
The Relative Amount of Geomorphic Influence of Biotic and Abiotic Processes.



The influence of abiotic processes, such as tidal erosion and deposition of sediment, decreases with elevation and distance across the marsh plain away from channel banks. Conversely, the relative influence of biotic processes, such as peat production and vegetative reproduction, increases with elevation and distance across the marsh plain. The relative influence of biotic processes increases as marshes gain elevation.

F9. Marsh Geomorphology 3: Channel Network Form and Physical Function

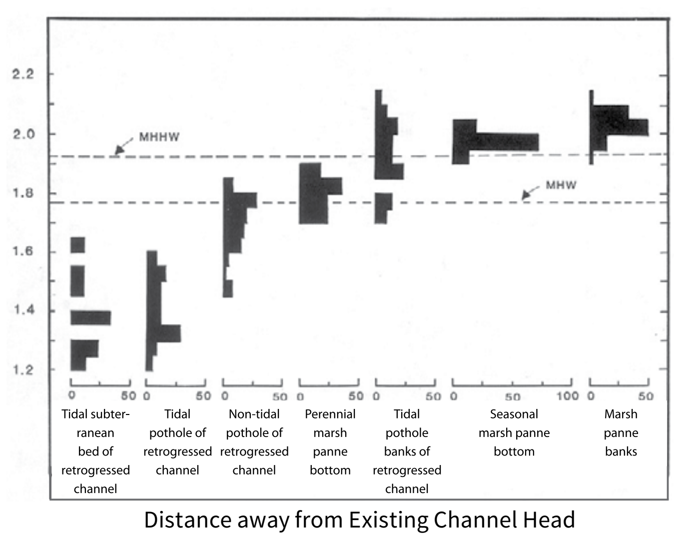
Channel Network as Sediment Decanter



Flood tides enters large channels as turbulent flow that maintains sediment concentrations in the upper water column, thus delivering it to bank tops, resulting in natural levees along the large channels. Flow becomes laminar upstream, allowing sediment to settle from the column, and causing levees to diminish in height. Smaller-order channels intercept larger channels as hanging beds. Since sediment is settling in the water column as the water is rising and flowing upstream, the hanging beds decant the sediment, which is flushed from the network during ebb tide.

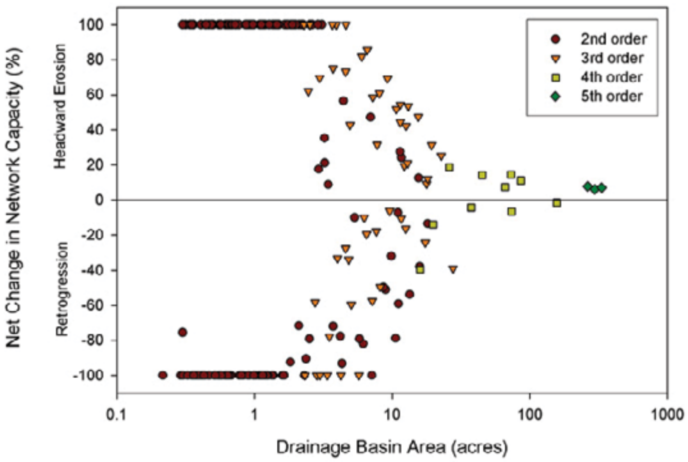
F10. Marsh Geomorphology 4: Distribution of Marsh Plain Features

Distribution of Tidal Marsh Features of the High Marsh Plain



The common geomorphic features of a mature, high-elevation tidal marsh plain are predictably distributed over elevation and with distance from the banks and heads of tidal channels. Natural retrogression of 1st-order channels results in potholes as channel remnants. Pannes form on drainage divides between the upstream reaches of 1st-order channels. The tops of panne banks are the highest places on the plain.

F11. Marsh Geomorphology 5: Unit Landscape Concept

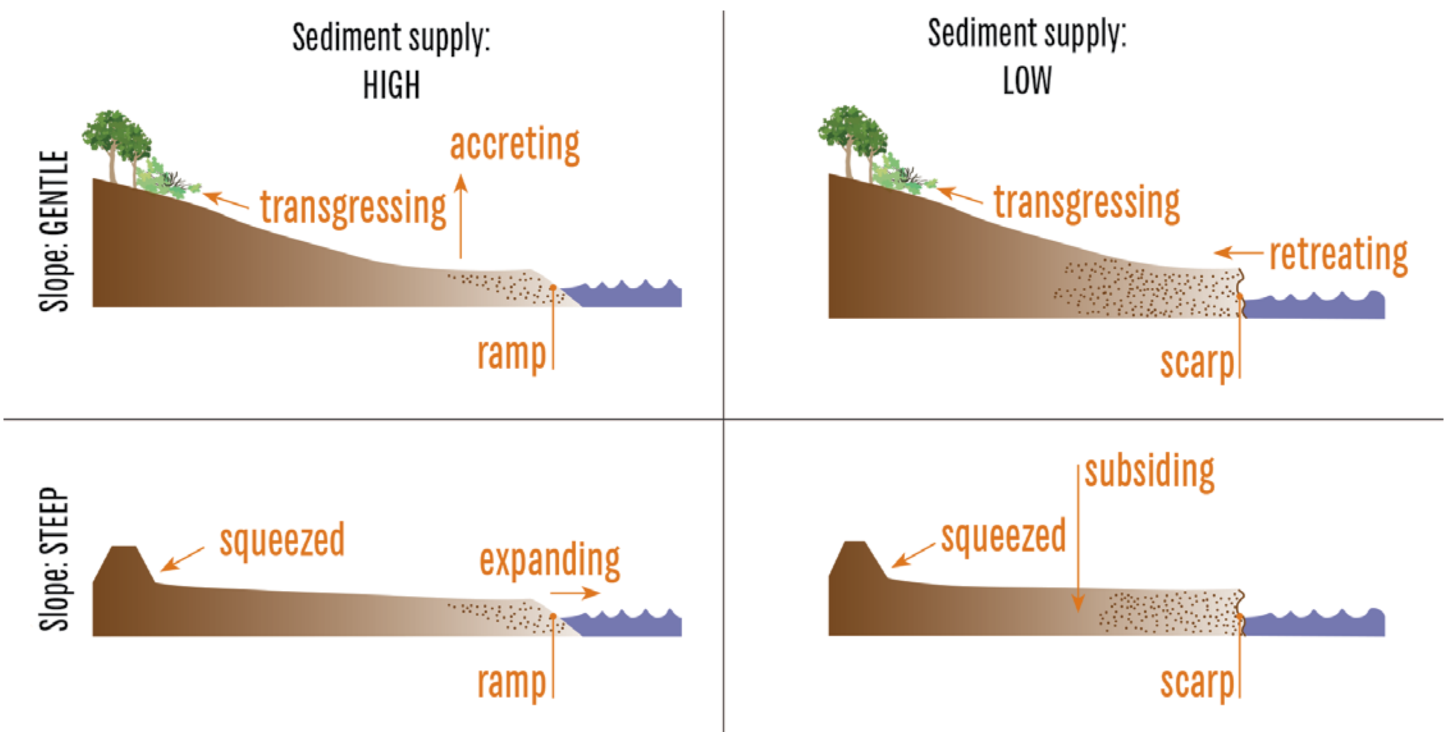


Tidal prism conservation (Collins & Grossinger, 2004)

In a mature, high-elevation marsh, 1st-order channels naturally retrogress, or retreat from their drainage divides, due to colonization by vegetation in their most headward reaches. The tidal prism of a retrogressed channel is shunted upstream during flood tide along the mainstem channel to one or more other 1st-order channels that erode headward to accommodate the additional prism. In large networks, retrogression and headward erosion are compensatory, such that the overall tidal prism of the network as a whole is conserved. That is, erosion divided by retrogression equals 1, or unity. Lesser systems tend to experience chronic retrogression as they evolve upwards in elevation. The area of a “unit landscape” decreases with increasing slope of the channel bed, and decreasing salinity regime.

F12. Marsh Geomorphology 6: Planform Evolution

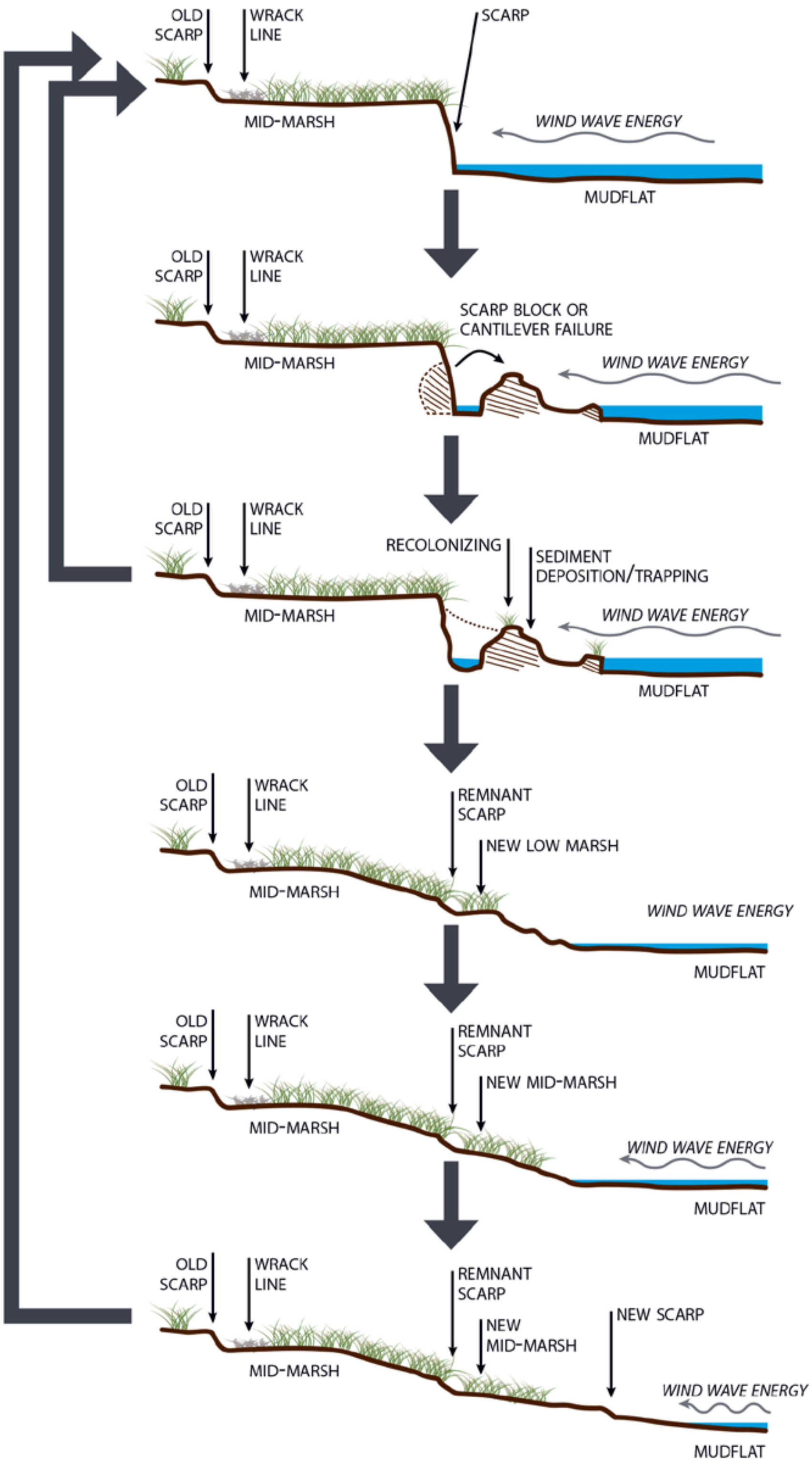
How Sea Level Rise, Slope, and Sediment Supply Interact to Drive Change in the Landward and Bayward Extents of Tidal Wetlands



The location and morphology of the bayward and landward edges of the marsh plain shift in response to sea level rise in different ways depending on suspended sediment supply and the slope of the adjacent estuarine-terrestrial transition zone. Where sediment supply is high and slopes are gentle, marsh plains can accrete (grow vertically), transgress over adjacent uplands, and even form ramps that expand seaward into the Bay. Where sediment supply is high but slopes are steep, the marsh can still accrete and expand seaward, but its landward limit is squeezed roughly in place. Where sediment supply is low and slopes are gentle, the landward limit of marshes can transgress, but their bayward limits erode into vertical scarps and retreat landward. Where sediment supply is low and adjacent slopes are steep, marshes shrink due to being squeezed on their landward edge and forming erosive scarps on their bayward edge (Beagle, Salomon, Baumgarten, & Grossinger, 2015; Brinson, Christian, & Blum, 1995).

Conceptual Model of Bay Edge Evolution

Shoreline morphology is not necessarily a reliable indicator of whether or not a shoreline is eroding, stable, or prograding. Beagle et al. 2015 proposes a conceptual model of Bay edge evolution that demonstrates how different marsh edge morphologies may represent different phases of evolution and marsh retreat/expansion. The WRMP should adopt indicators sensitive to shoreline morphology, sediment supply, and vegetation to assess status and trends of shoreline progradation and retreat.



Scarp without bayward vegetation (SN)

Fails under pressure from wind wave energy or wave run-up, and undercut blocks fail or cantilever, depositing sediment (with or without vegetation) in front of the scarp.

Scarp without bayward vegetation (SN)

The failed block dissipates wave energy until this deposit is scoured away and redistributed on the mudflat or marsh plain, thus creating an erosional environment as the wave energy is then directed back to the scarp.

Scarp with bayward vegetation (SV)

If the failure is large enough to redirect wave energy for longer periods of time, the failed blocks may create an environment for sediment deposition and trapping between the old scarp and the failed block.

Ramp with inflection point (RI)

A ramped profile begins to form as sediment fills in behind the failed block, building elevation, creating new low marsh and leaving behind a remnant scarp.

Ramp without inflection point (RNI)

As the ramping continues, wave energy is dissipated such that the low marsh vegetation traps sediment, building up to mid-marsh habitat.

Ramp with new bluff forming (RI)

When the new mid-marsh levels, the ramped profile steepens and wind wave energy begins to erode the new mid-marsh, creating a new scarp. And the cycle continues...

F13. Plant Zonation 1: Channel vs Marsh Plain

Vertical and Horizontal Drawdown and Recharge as Function of Distance and Channel

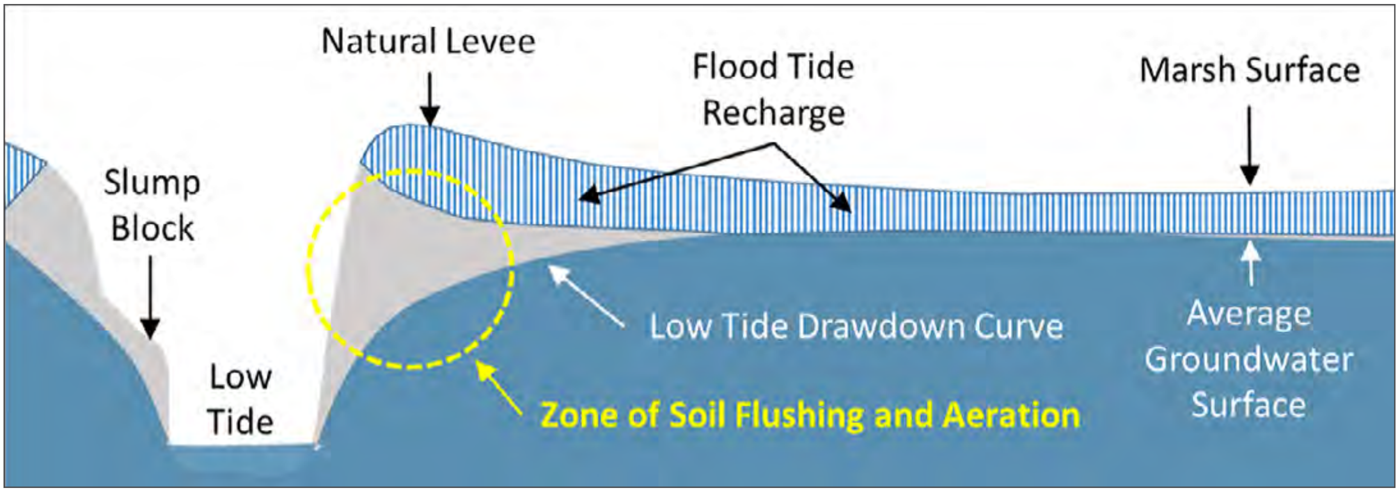
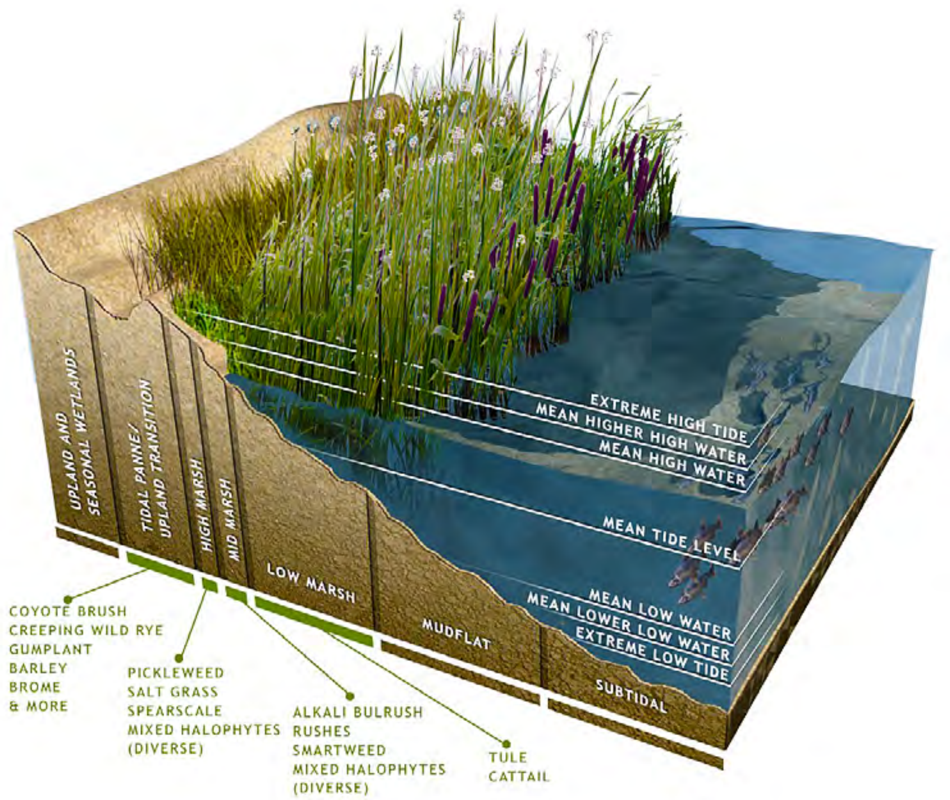


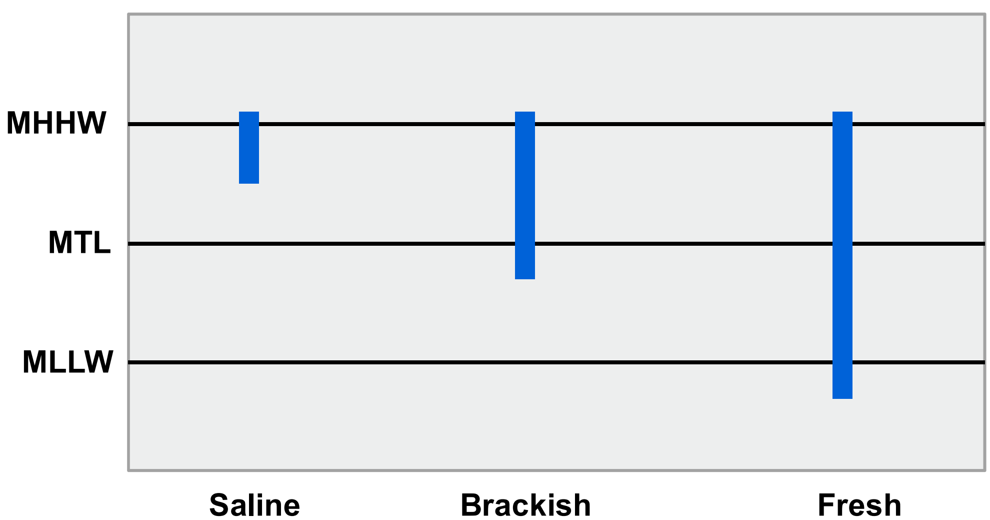
Diagram of the characteristics processes and features of a mature tidal marsh channel (Balling & Resh, 1982; Collins, Collins, & Leopold, 1987; Collins & Grossinger, 2004). Distance from channel is a proxy for decreased bulk density (increased peat) and thus increased permeability. High clay content of soils along banks inhibits infiltration. Region of flushing and aeration is relatively more sensitive to seasonal changes in aqueous salinity, creating gradient of increased salinity between channel bank and marsh plain. Flushing aeration also coincides with distribution of deep-rooted woody vegetation like gumplant and coyote brush.

F14. Plant Zonation 2: Low vs High Marsh

Vertical Zonation Cross Section in Suisun Tidal Marshes (Siegel, Toms, Gillenwater, & Enright, 2010)



Vertical Distribution of Marsh Vegetation by Salinity Regime (Atwater & Hedel, 1976)



APPENDIX G: GLOSSARY OF TERMS

The following definitions are based on the Wetland and Riparian Area Monitoring Plan (WRAMP) produced by the Wetland Monitoring Workgroup of the California Water Quality Monitoring Council, and referenced in the State Wetland Program Plan, or other best available information and sources. These definitions are meant to be broad to encompass all the activities that contribute to maintaining healthy marshes.

Ambient Condition

Ambient condition is the status of any or all aspects of the distribution, abundance, diversity, form, structure, and biotic composition of one or more areas of tidal marsh for a prescribed time period.

Baseline Condition

The baseline condition of one or more areas of tidal marsh is their ambient condition at the beginning of a series of consecutive monitoring periods.

Status and Trends

The status and trends of one or more areas of tidal marsh is the comparison of their current and previous ambient conditions, relative to their baseline conditions.

Assessment

An assessment is a report of the ambient condition or status or trends of one or more areas of tidal marsh, using the monitoring and assessment methods of the WRMP.

Monitoring

Monitoring consists of documented observations of tidal marsh condition repeated through space or over time using the WRMP methods. There is no minimum or maximum size of the monitored area or length of the monitoring period. The WRMP recognizes three kinds of monitoring:

- Compliance Monitoring is a permit, grant, or contract requirement that is used to determine whether permittees, grantees, and contractors are complying with their permits, grants, or contracts.
- Project Monitoring is used to assess the status and trends of a single tidal marsh project, relative to its performance criteria and ambient condition.
- Ambient Monitoring is used to assess the ambient condition of one or more areas of tidal marsh (see definition of ambient condition). Ambient monitoring is necessary to assess the effects of regional conditions on local projects, as well as the effects of projects on regional conditions, and to assess the effectiveness of policies and programs used to protect and restore tidal marshes.

Monitoring reveals patterns of change in tidal marsh condition through space and over time. These patterns of change can be translated into hypotheses about their causes and effects. Research is needed to test the hypotheses. In short, monitoring reveals how conditions change, whereas research explains why.

The WRMP may employ a variety of data collection plans. Every plan will involve collecting data at specific locations within different areas of tidal marsh. The approach for collecting data, however, will depending on the question(s) being addressed by the monitoring. The general approaches for collecting data will consist of the following:

- Random monitoring assumes that every monitoring location has an equal chance of being selected for the monitoring program. Random monitoring is especially useful for assessing how conditions vary within and among different areas of tidal marsh.
- A probabilistic survey employs a random selection of monitoring locations, but accounts for their different chances of being selected, based on the different sizes of their encompassing tidal marsh areas. Probabilistic surveys can reveal the proportion of all the tidal marsh areas having any particular condition and are therefore especially useful to assess ambient conditions for a very large number of areas.
- Targeted monitoring focuses on locations of special interest that are not selected randomly. Targeted monitoring is especially useful for continuous monitoring of change over time, since changing locations would disrupt the continuous monitoring record.

Project

A project is any on-the-ground human action that creates, restores, enhances, rehabilitates, or maintains one or more areas of tidal marsh. The WRMP recognizes four kinds of projects:

- Actions that impact aquatic resources (i.e., impacts)
- Actions that mitigate for impacts to tidal marsh or other aquatic resources (e.g., compensatory mitigation) by creating, restoring, enhancing, or rehabilitating one or more areas of tidal marsh
- Non-compensatory, voluntary actions to create, restore, enhance, or rehabilitate one or more areas of tidal marsh
- Field-based aquatic resource monitoring or research

San Francisco Bay (or Bay)

The San Francisco Bay (or Bay) refers to the geographic area comprised of the five WRMP subregions including Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay.

San Francisco Bay, Sacramento-San Joaquin River Delta (or San Francisco Estuary)

The San Francisco Bay, Sacramento-San Joaquin River Delta (or San Francisco Estuary) refers to the geographic area comprised of the San Francisco Bay defined above and the Sacramento-San Joaquin River Delta or Delta.

Transition Zone

A transition zone is defined as the area of existing and predicted future interactions among tidal and upland terrestrial or subtidal fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems (Goals Project, 2015).

Tidal Marsh

Tidal marsh is any area of the intertidal zone that is at least 25% covered with rooted, living, vascular vegetation. Tidal marsh areas are defined cartographically as unique polygons of tidal marsh in Bay Area Aquatic Resource Inventory (BAARI) or Delta Aquatic Resource Inventory (DARI), for which the minimum mapping unit for tidal marsh is 0.25 acres. In the field, there is no minimum or maximum size of a tidal marsh area. The complete tidal marsh ecosystem includes an area of tidal marsh plus other adjoining intertidal areas and their adjoining subtidal area to a depth of minus twelve feet (relative to local Mean Lower Low Water), plus the transition zone that adjoins the tidal marsh area.

Baylands

The baylands of the San Francisco Estuary include the existing intertidal areas plus any other areas of the Estuary that would be intertidal if levees, sea walls, tide gates, and other features that completely or partially obstruct the landward excursion of the usual daily flood and ebb of the tides were removed.

Beneficial (or Designated) Uses

Beneficial (or designated) uses are required by the Clean Water Act and are utilized to set water quality criteria. Each state, territory and authorized tribes are required to specify goals and expectations for how each water body is used. Typical beneficial/designated uses include:

- Protection and propagation of fish, shellfish and wildlife
- Recreation
- Public drinking water supply
- Agricultural, industrial, navigational and other purposes

Ecosystem Services

Ecosystem goods and services produce the many life-sustaining benefits we receive from nature—clean air and water, fertile soil for crop production, pollination, and flood control. These ecosystem services are important to environmental and human health and well-being.

Living Shoreline

A living shoreline is a coastal edge constructed of natural materials such as native vegetation or cobble that protects the shoreline from erosion while providing habitat for fish and other wildlife.

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