NEW OPPORTUNITIES

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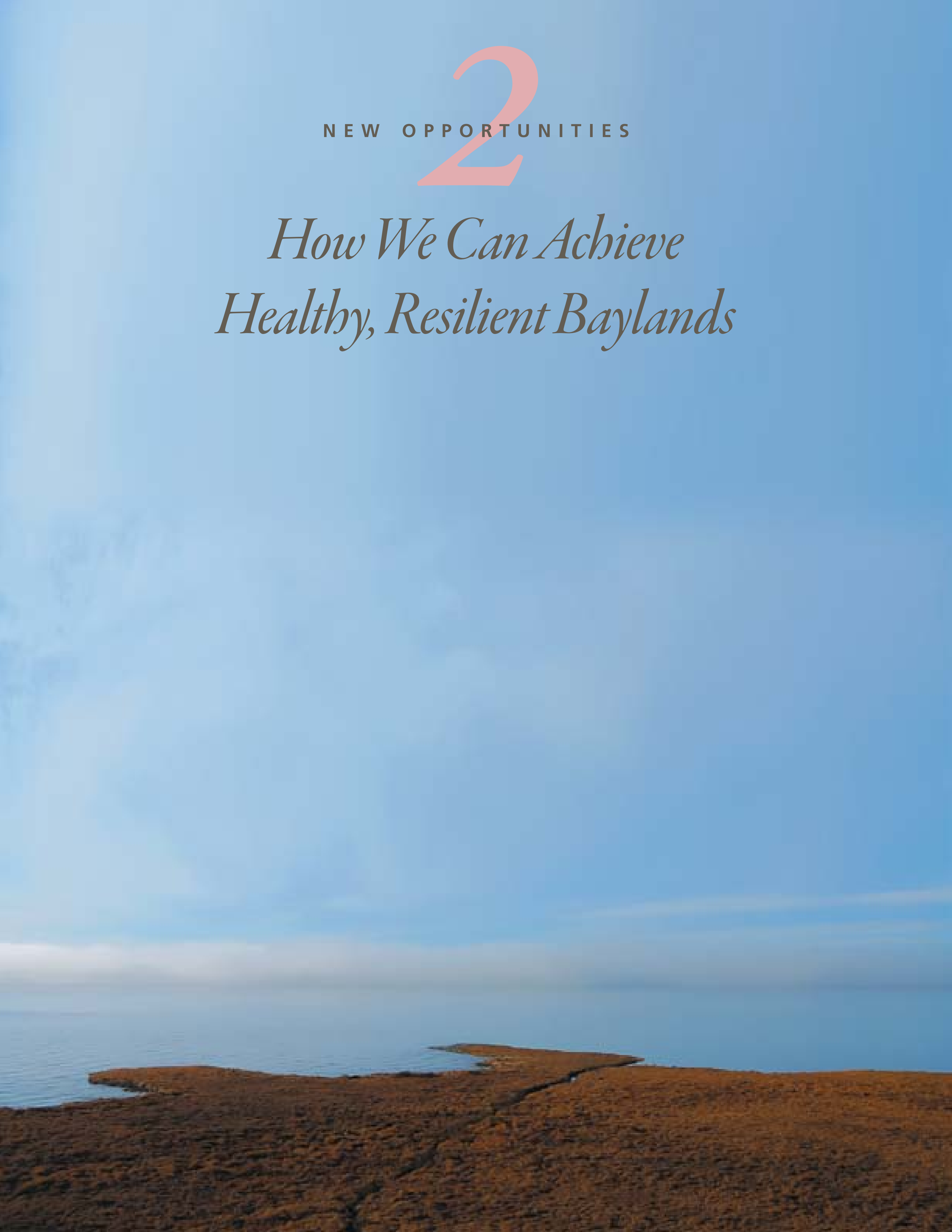
How We Can Achieve Healthy, Resilient Baylands



NEW OPPORTUNITIES

How we can achieve healthy, resilient baylands

Climate change threatens the baylands and their wildlife. It increases the magnitude and complexity of the challenges to achieving a sustainable baylands ecosystem, with urbanization, pollution, and invasive species continuing to pose significant obstacles as well. A corresponding increase in innovation, partnerships among stakeholders, and monetary investment is required to achieve ecological health in the baylands and to maintain the ecosystem services they provide to human communities.

INTRODUCTION

As human communities are threatened by climate change, so are the baylands and their wildlife. In the absence of mitigating human action, rising bay waters, reduced sediment supplies, warmer temperatures, lower freshwater inputs, more intense storms, and other changes are likely to cause significant loss of the baylands and their wildlife. If swift and sustained action is taken to achieve the project goals, as recommended here, then healthy baylands can persist into the future while protecting human communities from floods, improving water quality, and providing the recreational opportunities and wildlife habitat that are highly valued attributes of the Bay Area. Healthy and resilient baylands will help sustain healthy and resilient Bay Area communities.

A Snowy egret forages in the baylands.

Restoration practitioners strengthen the resilience of the baylands and their wildlife by restoring, enhancing, or emulating natural, dynamic physical and biological processes. Such actions rely on monitoring the baylands, taking innovative approaches, and applying a knowledge of past practices—and on these becoming a part of accepted restoration procedures and policies. To be successful, these actions also require more resources, closer collaboration among stakeholders, and quicker actions than before.

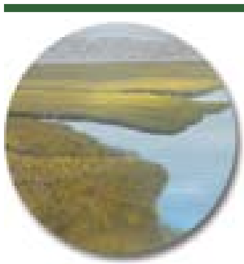
The recommended actions in this chapter update and replace those from the 1999 Baylands Goals Report. The actions are designed to preserve, protect, restore, enhance, and promote the resilience of baylands ecosystems to achieve the following vision for the next 100 years:

> *The San Francisco Estuary baylands will sustainably support robust populations of diverse native plant and animal species, while providing essential ecosystem services to human communities.*

The recommendations below lead off with overarching recommendation highlights, followed by 10 regional strategies and associated recommended actions that apply to most or all of the subregions and their segments. More detailed information for the subregions and segments follows. The recommendation highlights are the primary cross-cutting ideas that emerged from the scientific synthesis. The regional strategies elaborate on these ideas in more detail and include other recommended actions. The segment write-ups provide important contextual information about particular stretches of the baylands and indicate the most important recommended actions to take in each area.

HIGHLIGHTS

The following five highlights are the most critical overarching ideas from the recommendations. They will foster resilience to climate change so that the baylands can function as a healthy ecosystem and support native wildlife and human communities. The first two highlights directly increase baylands resilience, while the latter three improve the efficacy of resource stewardship and management.



1. Restore estuary–watershed connections that nourish the baylands with sediment and freshwater.

Finding

Sediment and freshwater are essential resources for restoring and maintaining the baylands. The rerouting of creeks, raising of levees, and building of infrastructure have removed the physical connections that deliver these resources to the baylands from their watersheds. Sediments allow baylands elevations to keep pace with sea-level rise, and freshwater is critical for moving watershed sediments directly into marshes. Freshwater also creates salinity gradients that increase biodiversity, help wildlife survive dry years, and support brackish marshes that rapidly accumulate peat, helping marshes maintain their elevation as sea levels rise and sequester carbon from the atmosphere. Historically the form of these watershed connections differed from creek to creek. Some forms of these freshwater connections can generate complex habitat mosaics of wetland types that further increase biodiversity and transition zone services. Protecting diverse watershed connection types where they exist and restoring the diversity of such connections as appropriate for local conditions and processes is important for fostering complexity (see highlight 2 below).

Watershed connections will become increasingly important to baylands sustainability.

Recommended Actions

- Restore and protect diverse types of sediment and freshwater connections as appropriate for local conditions and processes. In some cases, a connection could be restored as a natural landscape feature, such as a creek entering a marsh through a slough. In others, more artificial means may be needed to move sediment and water, such as dredging sediment from a flood channel and placing it on or near the baylands.
- Reconnect streams, and the sediment loads they carry, to the baylands. Determine how other freshwater sources, like treated wastewater effluent and stormwater, may be safely reconnected to the baylands through carefully monitored pilot projects.
- Use suitable dredged or excavated sediments (that have contaminant concentrations within acceptable limits) to the greatest extent possible within the baylands.

2. Design complexity and connectivity into the baylands landscape at various spatial scales.

Finding

A complex, connected landscape facilitates short-term population persistence and long-term species survival by enabling wildlife to adapt to a changing environment. Landscape complexity and connectivity are key to providing access to a variety of habitats that allow some portion of wildlife populations to survive hot years, dry years, extreme flooding, and other variability that is expected to increase. In addition, complex and connected landscapes promote the genetic and phenotypic diversity that is critical for wildlife to evolve in keeping with rapid environmental change. Finally, complex channel networks draining marsh plains allow natural water circulation that protects water quality.

Recommended Actions

- Restore and protect complex, connected landscapes that include topographic and salinity gradients; diverse habitat types; habitat mosaics, such as those found at the base of alluvial fans or in mature tidal marshes; variation within habitats, such as a complex of managed ponds with diverse salinities and depths; multiple habitat combinations (for example, a variety of transition zone types bordering tidal marsh); natural transitions between the habitats; and connections, like transition zone corridors or appropriately managed agricultural or parklands adjacent to baylands, that allow wildlife to pass from one area to another.
- Create connected gradients around the perimeter of the estuary. For example, connect marshes along the shoreline from salt marshes in the South Bay to brackish marshes in Suisun. At a smaller scale, protect and restore the watershed connections to the baylands. For example, maintain riparian corridors on creeks and broad transition zones between marshes and adjacent terrestrial habitats.
- Design baylands landscapes to be heterogeneous and connected at multiple spatial scales and across projects, so that no one area or project must provide all options, yet the full portfolio of complexity is represented across the region. Use local natural processes and historical and projected habitat configurations to design and create large-scale, self-maintaining, connected landscapes that support diverse native species.

3. Increase coordination among baylands stakeholder organizations to promote the successful implementation of the recommendations in this report.

Finding

Accelerating climate change drives a need for the immediate and efficient implementation of these recommendations before change becomes too rapid. The longer it takes to restore the baylands and undertake the other actions described here, the less likely it is that the ecological health of the baylands will be achieved and maintained. Environmental policies, regulations, and interjurisdictional relationships will need to evolve in keeping with new scientific information to enable the innovation and adaptive management necessary to implement the recommendations of this report successfully.

Recommended Actions

- Coordinate an adaptive management program that is based on testing hypotheses and learning from previous actions. It should (1) monitor the baylands landscape and wildlife to track ambient change and the effects of implemented actions, (2)

New scientific information drives innovation.

develop targeted applied studies, including modeling, to answer management questions and develop new approaches to restoration, and (3) develop projects to test hypotheses and new approaches and technologies.

- Centralize data access, statistical analysis, and interpretation through a consolidated effort managed by all key stakeholders that is supported by a long-term commitment to achieve regional goals with consistent funding. Apply local models like the Regional Monitoring Program for Water Quality, the Long-Term Management Strategy for Dredged Material, and the South Bay Salt Ponds Adaptive Management Program when designing the interjurisdictional partnerships.
- Facilitate and support dialogue between environmental scientists, managers, and regulators to promote the rapid diffusion of new information that allows policy to evolve in keeping with science. Create and support advisory forums to facilitate the incorporation of current science and the implementation of these recommendations into project design and management. Bring scientists together to build a better understanding of watershed processes, stream sediment dynamics, and the relationship of these factors to the accretion of sediment in the baylands.
- Coordinate more closely with the organizations that are stakeholders of delta environmental health to achieve better outcomes across the single estuary comprising the bay and delta.
- Incorporate the Science Update recommendations where appropriate in local and regional plans and resilience strategies.

Informed dialogue will improve restoration plans.

4. Create plans that factor in ecological outcomes after extreme events and other disasters.

Finding

Catastrophes in the Bay Area that are caused by extreme weather events and earthquakes are predictable in type and location but not in timing. Floods, drought, heat waves, and other environmental extremes are a significant risk to the ecological health of the baylands, and human responses to these events could impose an even greater risk over time. Planning ahead for such catastrophes can enable the development of nature-based flood-protection and other landscape designs that protect human communities while also protecting and even enhancing baylands ecosystems. Without such plans, engineered solutions may be implemented after a disaster that do not optimize the ecosystem services and ecological functions of the baylands, since these solutions are under the purview of agencies that often lack the requisite ecological mission or expertise. For example, after a flood some areas of shoreline might end up with hardened seawalls next to deep water even though a design with intertidal wetlands and subtidal habitats might offer a more optimal and durable solution for adjacent human communities.

Recommended Actions

- Integrate implementation of the actions recommended here as appropriate into response plans for catastrophes that are likely to affect the ecological functioning of the baylands, either through the catastrophe itself or the response to the catastrophe (such as building sea walls or raising levees). Opportunities for this may include updates to general plans and capital-improvement programs for cities, counties, and flood-control districts.
- In these plans, detail approaches that rely on natural processes to protect and restore ecosystem services and ecological functions. Such approaches—for

example, restoring physical processes that allow marshes to persist over time and protect the developed shoreline from erosion—will also create resilience to future events.

- Establish and cultivate relationships among the agencies entrusted with stewardship of the baylands and those that implement infrastructure changes after disasters, such as cities, counties, and flood-control districts.

5. Engage the citizenry in the baylands.

Finding

Successful implementation of the recommendations in this report is unlikely without a long-term increase in funding, education, and advocacy for the baylands. A strategy to develop the necessary level of resources must include efforts to inform and empower the local citizenry, elected officials, policy makers, and funding organizations to make decisions that promote healthy, resilient baylands. Directly engaging local residents in the baylands through recreation, volunteerism, and other field activities is another way to promote advocacy.

Recommended Actions

- Conduct outreach to voters and policy makers by framing messages about the baylands in terms the public can connect with (clean water, flood protection, recreational opportunities, water sustainability, climate change resiliency, wildlife) and providing clear and concise actions they can take.
- Partner more closely with educational organizations to transfer knowledge about baylands ecosystem services, threats to those services, the history of environmental change in the baylands, stories about local innovation and success in restoring ecological health, and interesting features of the baylands landscape and wildlife. Target audiences are registered voters in Bay Area counties, teachers in the K–12 and university-level educational system, and people who live, work, or own businesses on or near the baylands.
- Build direct engagement of the citizenry into implementation planning through appropriate recreational access to the baylands, citizen science contributions to monitoring (including crowdsourcing), volunteer labor for restoration projects, adventure learning, regional science competitions based on the challenges facing the baylands, and other such activities.

Stakeholder of the future baylands

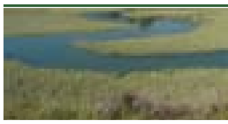
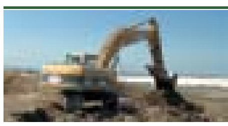
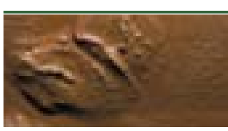
Figure 24 Artist's rendering of an envisioned future baylands depicting implementation of the regional strategies to promote resilience in the baylands landscape, its habitats, and wildlife. Here a local creek has been reconnected to the baylands, *delivering sediment and freshwater* directly into the marsh, which helps the marsh rise in elevation as sea level rises. This restored connection also creates a *gradient of fresh to brackish to salt marsh*, providing different habitats for wildlife. The salt marsh has a *robust, complex channel system*, pannes, and an undeveloped transition zone to the upland. *Protected and enhanced transition zone* supports native plants and animals, and provides a place for the *marsh to migrate landward* as sea level rises. The continuous transition zone

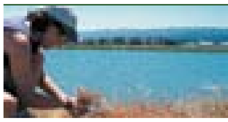
around the baylands and up the creek is a *corridor for wildlife movement* and a place for marsh animals to find *refuge from high water and predators*. A managed pond with constructed islands adds *complexity to the landscape mosaic* of habitats, providing essential support for water birds. This *complete tidal wetland system* also includes a mudflat, barrier beach and oyster reef on the bay side, all of which *support greater biodiversity and physically protect* the adjacent marsh and shoreline. The marsh restoration in progress at the far right *uses dredged sediment* to allow the restored marsh to *achieve a higher elevation* prior to sea-level rise acceleration around midcentury, which will *better sequester carbon* and create a continuous corridor of marsh for wildlife movement along the shore. *Integrated management and monitoring* allows for thriving natural systems in close proximity to urban citizens.

REGIONAL ACTIONS

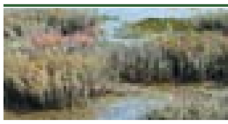
Regional recommended actions are grouped below into 10 strategies to promote the long-term resilience of the baylands and their wildlife. An abbreviated version of each strategy is provided in the table below for easy reference, and the full description of each strategy follows the table. Each action is stated only once for brevity, even though some actions are interconnected and mutually supportive and could be placed under multiple strategies. The scientific rationale for the actions and other background information is provided in the Science Foundation chapters.

REGIONAL STRATEGIES TO PROMOTE RESILIENCE IN THE BAYLANDS LANDSCAPE, HABITATS, AND WILDLIFE

	**1.**	**Restore estuary–watershed connections that nourish the baylands with sediment and freshwater.**
	**2.**	**Design complexity and connectivity into the baylands landscape.**
	**3.**	**Restore and protect complete tidal wetlands systems.**
	**4.**	**Restore the baylands to full tidal action before 2030.**
	**5.**	**Plan for the baylands to migrate.**
	**6.**	**Actively recover, protect, and monitor wildlife populations to avoid bottlenecks and to buffer population sizes.**
	**7.**	**Develop and implement a comprehensive regional sediment-management plan.**
	**8.**	**Invest in planning, policy, research, and monitoring as key elements of implementing these actions effectively.**



9. **Develop a regional transition zone assessment program.**



10. **Improve carbon management in the baylands.**

1. Restore estuary–watershed connections that nourish the baylands with sediment and freshwater. (This follows from recommendation highlight 1 above.)

Take advantage of sediment transport processes in local rivers and streams that nurture the vertical accretion of tidal marsh, create alluvial fans, and create more riverine transition zones.

A. Prioritize tidal marsh restoration in areas with high sediment loads from local rivers and streams. Realign some stream courses where necessary and feasible to restore natural sediment-delivery processes. Protect land, working with willing sellers as needed.

B. Identify ways to increase the availability of watershed sediment to tidal marshes and mudflats. Develop a better understanding of watershed sediment-transport processes, including sediment storage, transport, and delivery to the baylands. Preserve and re-create natural patterns of sediment transport in local streams. Restore and protect local stream hydrology to provide the flow regimes necessary to move fine sediments to the bay while protecting stream health. Evaluate ways of accessing sediment trapped behind dams.

C. Use suitable sediment from various sources (excavated or dredged) for baylands restoration and management. Identify approaches to placing sediment that mimic natural accretion processes. Research and test innovative approaches for applying sediment to baylands, such as thin layers that do not cause unacceptable impacts to biological processes. Place sediment in volumes and frequencies that mimic natural processes.

D. Identify and implement opportunities for taking advantage of treated wastewater and stormwater to create salinity gradients and maximize peat accumulation in the baylands, while protecting water quality and minimizing nutrient loading. Accumulate peat in diked baylands prior to breaching to increase elevations and sequester carbon.

2. **Design complexity and connectivity into the baylands landscape at various spatial scales (follows from recommendation highlight 2 above).** Create a baylands landscape of diverse, complex, and connected habitat mosaics with patches of tidal marsh several hundred acres in extent. In the process of creating this landscape, consider how changes in habitat type due to climate change or restoration will affect different wildlife groups, and compensate for these trade-offs.

   A. Connect large baylands habitat mosaics to each other and to local watersheds with a functionally connected transition zone around the perimeter and riverine riparian corridors that enable wildlife migration and dispersal. Restore and enhance gently sloped transition zones adjacent to tidal marsh and design them to support native wildlife species. Build naturalistic riverine levees as part of functionally connected riparian corridors along the bay's tributary streams to provide a high-functioning transition zone now and into the future. Incorporate agricultural land and managed wetlands as part of the matrix surrounding tidal wetlands.

   B. Preserve or create high channel complexity in tidal marshes, or restore the processes that allow complex channels to develop. Complex channel networks have several orders of channel size, are sinuous, have a channel density appropriate to the local salinity regime, and exhibit point bars, slump blocks, undercut banks, and other physical attributes that create valuable habitat and natural water circulation that maintains high water quality. Where appropriate, provide large, deep channels in restored marshes for fish, invertebrates, diving and dabbling ducks, and other aquatic animals. Maximize the habitat value of channel complexity by promoting structurally diverse native vegetation to provide cover and high-tide refuge for wildlife such as Ridgway's rails.

   C. Actively manage and restore diverse habitats for waterbirds and small mammals. Manage ponds in public ownership in the North and South Bay to maintain a range of salinities and water depths for waterbird foraging. Manage low-marsh vegetation, including native cordgrass) and establish beds of eelgrass, sago pondweed, widgeon grass, and native Olympia oysters to support waterbirds. Where possible, provide sufficient habitat for waterfowl, shorebirds, and small mammals by modifying managed ponds and taking advantage of opportunities to convert salt ponds to managed ponds and managed marsh. Ponds managed to support wildlife should be located in areas that facilitate operations and maintenance, as well as the long-term viability of the pond. They should also be located near other habitat resources (such as tidal mudflats for foraging) needed by the target species (generally waterbirds).

   D. Reduce landscape barriers to wildlife movement by modifying roads, highways, levees and similar structures to allow the successful dispersal of native plants and animals, while proactively managing against the spread of invasive species and nuisance predators. Where feasible, create corridors of native plantings and open space through suburban and urban areas to make these areas more permeable and hospitable to native wildlife. For example, create species-appropriate passages for wildlife under or over freeways at critical points for habitat connectivity, and take advantage of opportunities to re-landscape parks and greenways to provide greater wildlife support.

3. **Restore and protect complete tidal wetlands systems** to provide habitat and physical resilience. Include all the following components appropriate to the local setting: submerged aquatic vegetation (SAV) beds, oyster beds, algal beds, rocky habitats, beaches, mudflats, low marsh, marsh plain, high marsh, complex channel networks, and transition zones, including natural levees along channels, creeks, and waterways, and broad transitions to adjacent wetlands and uplands.

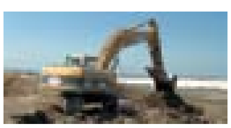
   A. Create high-water-refuge areas, including marsh mounds, restored and enhanced transition zones with appropriate vegetative cover, and diked wetlands where needed for wildlife such as salt marsh harvest mice.

   B. Provide buffers on undeveloped and agricultural lands (especially ones devoted to small grains, hay, and grazing areas) adjacent to the baylands to reduce disturbance and provide refugia from high water and other extreme conditions for wildlife, and to create the habitat mosaics needed for species that combine baylands and terrestrial habitats in their home range (e.g., northern harrier, dabbling ducks, and vernal pool species).

   C. Encourage where relevant the creation of appropriate wildlife habitats in developed areas adjacent to the baylands, and where feasible connect them through habitat islands and corridors to protected lands higher in the watersheds. Work with municipalities, land development companies, landscape architects, and others to incorporate habitat restoration, native plant landscaping, and other natural features that maximize support of baylands wildlife.

   D. Restore and create beaches, natural salt ponds, tidal marsh pans, and other diverse components of the baylands ecosystem to enhance wildlife support.

   E. Use restoration designs that integrate natural landscape characteristics and dynamics to maximize successful and sustainable outcomes and increase resilience, while minimizing long-term operational and maintenance costs.



4. **Restore the baylands to full tidal action before 2030** in strategic areas to maximize marsh accretion before the expected acceleration in sea-level rise and to sequester carbon sooner rather than later.

   A. Consider available information, including local sediment supply, erosion regimes, marsh-accretion models, and landscape position, to prioritize areas for restoration that are likely to persist as marsh for many decades.

   B. Accelerate funding and streamline the implementation of projects that restore the baylands to tidal action.

   C. Encourage baylands restoration as an outcome of, and a reason to accelerate, the realignment of infrastructure at risk from sea-level rise, including railroads, transmission lines, roads, fuel lines, and wastewater treatment systems.

5. **Plan for the baylands to migrate** by using projections of sea-level rise and other changes to identify shifts in habitat location and connectivity over time. Encourage the implementation of relevant recommendations from this report as part of plans for upgrading levees, railroads, highways and other roads, bridges, wastewater treatment plants, utility corridors, and other public works infrastructure that will affect outcomes in the baylands.

   A. Identify and protect existing and projected transition zone lands or flood easements. Focus on broad, minimally developed areas adjoining existing tidal marshes that support high native-species diversity or are wildlife source habitats. Prioritize areas projected to retain biodiversity across a range of future climate scenarios. Plan ahead for the likelihood that, as sea levels rise and transition zones become marsh, there will be a loss of transition zone habitat for sensitive species, such as vernal pool wildlife and burrowing owls.

   B. Inventory intact patches of wetland and nonwetland habitat types that adjoin the present transition zone, including grasslands, seasonal wetlands, and forests. These should be fully protected to prevent further degradation and a loss of transition zone extension and enhancement opportunities.

   C. Identify the habitat patches likely to be used in the future for a suite of umbrella species and other species of concern. Establish movement corridors between current habitat patches, and plan how to ensure connectivity to future habitat patches. Design corridors for intermittent or permanent connectivity that minimize the impact of nuisance predators and invasive species. Prioritize the connectivity of patches that can provide recruits or propagules to move into new areas as they become suitable. Compensate for habitat loss due to climate change in one area by providing it in another (for example, if mudflats are lost in one area, encourage mudflat formation elsewhere for use as harbor seal haul-outs).

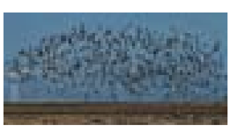
   D. Conduct a large-scale, long-term planning effort across the bay, delta, Central Valley, and other key areas of California to ensure that waterbirds that use the Pacific Flyway have sufficient habitat over the coming decades. Planning for restoration and conversion of waterbird habitats should be coordinated, so that

View of Salt Pond A20, which was restored to tidal flow in 2006

Salt pond breach

an optimal landscape (considering financial cost, habitat benefit, and implementation feasibility) can be pursued at the large scale that is biologically relevant for these highly mobile animals.

E. Encourage the modification and relocation of existing assets and infrastructure that are in the present and future flood-hazard zone to allow the reestablishment of physical processes such as full tidal flows. Discourage the development of new assets and infrastructure in present and future flood-hazard zones, as they may constrain restoration and other adaptation options that may help protect adjacent communities. Build in designs that allow wildlife to pass over, under, or through areas of infrastructure development to promote habitat connectivity and gene flow.



6. **Actively recover, protect, and monitor wildlife populations to avoid bottlenecks and to buffer population sizes** against extreme events. The regional actions recommended in this section should benefit wildlife by enhancing their habitats and the ecological functioning of the landscape as a whole. In addition, the actions below are specific recommendations for managing the wildlife populations themselves. As a rule, invasive or hands-on wildlife management (such as the lethal control of native predators and the translocation of individuals) should be pursued only as a last resort, after other solutions based on habitat and natural-process improvements have been implemented and found to be insufficient. There will likely be trade-offs between managing for different species, and taking action will require careful judgment of these trade-offs.

A. Emphasize protection efforts during and after extreme weather or other events that may cause population crashes.

- Emphasize nonnative and nuisance-predator control during and following times of short-term, stressful climatic conditions.
- In critical areas, construct systems that impede water flows for short time periods to reduce high water levels in times of acute stress.
- Monitor indicator species more frequently to know when and where such intervention is warranted. Use a rigorous process to identify key indicator species for the baylands to enable coordinated and comprehensive monitoring across the region.

B. Provide appropriate breeding and refuge habitat for species that need targeted management.

- Identify, conserve, and manage refugia for native baylands plants that may otherwise lose significant habitat due to sea-level rise. Focus on unique or core populations of rare or endangered species, especially in low marshes.
- Manage or create vernal pools of various sizes, depths, and salinities to facilitate a metapopulation structure for vernal pool plants and animals. Inoculate pools with nearby source populations of shrimp species and amphibian tadpoles. Control weeds and seed pools with vernal pool vegetation for several years until established.
- Provide spawning areas for fish, particularly open sandy beaches for grunion and clean, rough substrates in brackish waters of appropriate salinity for Pacific herring. Consider removing creosote pilings, and build new marine structures in the Suisun and San Pablo Bays with roughness, light availability, and other environmental characteristics in mind.
- Ensure that suitable ponds are appropriately inundated throughout the reproductive season for amphibians, with a focus on the needs of California red-legged frogs and California toads. Infrastructure, such as wells and pumps or water lines, may be necessary to provide additional water to ponds.
- Manage islands and levees and adjacent water levels to provide nesting, foraging, roosting, and high-tide-refuge habitat for birds. Add nesting substrate (such as sand and shell) to islands in the South Bay and, potentially, Suisun Bay for shorebirds. Minimize changes in water levels in seasonal wetlands during the breeding season to avoid flooding nests.

C. Maintain and enhance genetic diversity using active management when the passive landscape-design methods described earlier are insufficient.

- Translocate species requiring assistance (such as tidewater gobies or shrews) into newly created habitats or into formerly occupied patches after an extreme event causes extirpation.

- Assist the dispersal of high-marsh annual forbs and dispersal-limited or founder-limited populations of uncommon baylands plants of the high-marsh and transition zone to unoccupied locations near historic or existing populations. Assist their dispersal to restored marshes before nonnatives invade to facilitate their recovery after invasive species are eliminated, and keep seed sources restricted to local or subregional origin.

- Acquire more information about the genetic structure of baylands species with limited dispersal ability, including the ways that landscape barriers and corridors influence gene flow.

D. Reduce excessive predation impacts to sensitive species by managing nonnative and problematic native predators (such as red fox, cats, California gulls, crows, and ravens), and reducing predator access.

- Use integrated pest-management techniques over an appropriate time period, which is often the entire breeding season. Reduce impacts from cats by educating cat owners and working with animal shelters and trappers to remove feral cat feeding stations to areas of least impact and to handle nuisance animals properly. Emphasize mosquito-source-control methods based on natural physical and biological processes such as wind-generated waves and ripples, tidal flushing, and foraging by native insectivores. Minimize mosquitofish plantings during the California red-legged frog breeding season and avoid mosquitofish use in sensitive amphibian habitat.

- Remove or modify features that facilitate predator access to, and hunting in, the baylands (such as derelict fencing and utility towers used as perches by raptors). Reduce access from levees and other upland areas, and design any new levees to impede predator access. Where feasible, eliminate garbage dumps near the baylands. Provide cover from predators, especially during periods of exposure (e.g., extreme tides).

Plainfin midshipman

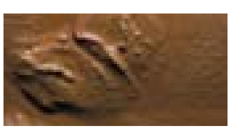
E. Manage and eliminate invasive plants, and use preventive measures in restoration projects and future transition zones. Avoid persistent soil-active herbicides that jeopardize seed banks of desirable plant species. Consider and minimize impacts to marsh fauna (including black rails, baylands shrews, and salt marsh harvest mice) from control measures.

Native gray fox

- In the near term, complete the elimination of invasive *Spartina* phenotypes (plants that act in the environment like the invasive hybrid), and prevent their reemergence. Where invasive phenotypes persist, focus efforts on lessening the impacts of invasive characteristics while promoting the long-term development of in-marsh structural complexity and native plant species abundance and diversity.
- Contain perennial pepperweed, and eliminate populations near the transition zone. Control pepperweed to prevent its spread into mature brackish tidal marshes that are not yet heavily infested.
- Aggressively control yellow flag, black rush, and Algerian sea lavender before they become a serious problem.

F. Reduce other stressors, mainly human disturbance and contaminant exposure.

- Design and manage recreational access to avoid and minimize disturbance to wildlife, especially during critical periods of their life cycle, such as nesting seasons, and during extreme high tides.
- Reduce wildlife exposure to contaminants, including methylmercury, pyrethroids, polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), and other organic contaminants.



7. Develop and implement a comprehensive regional sediment-management plan, building on existing regional sediment-management work that emphasizes the use of all suitable dredged or excavated sediment from the estuary, local rivers and streams, flood-control channels, local reservoirs, and other watershed sources. This comprehensive sediment-management system should be developed in close partnership with the bay dredging community.

A. Conduct research and monitoring to quantify (1) all potential sediment sources to the baylands, in particular their magnitude and spatial and temporal patterns of delivery, and (2) sediment transport and fate dynamics in baylands ecosystems, particularly mudflats and marshes.

B. Investigate if there will be enough sediment to maintain current marshes, mudflats, and managed ponds under specified sea-level rise projections and sediment-supply parameters, including local and Central Valley watersheds, until

2070 and 2100. In considering this question, studies should address the following scenarios:

- currently planned tidal marsh restoration
- the additional acreage needed to reach the 100,000-acre Baylands Goal for tidal marsh
- maintenance over time of the acreage goals for managed ponds
- planned restoration in the delta (specifying acreage, bathymetry, timing)
- potential extensive levee failure in the delta, Suisun, or North Bay
- beneficial reuse of all suitable dredged sediment from the estuary
- beneficial reuse of suitable excavated dirt from the watershed
- increasing watershed sources of sediment to the baylands (such as accessing sediment behind dams and other watershed management approaches)

C. Manage coarse bay sediment at the regional level for use in the baylands. Allow sand to move through the bay under natural forces to create and replenish barrier beaches.

8. Invest in planning, policy, research, and monitoring as key elements of implementing these actions effectively (follows from recommendation highlight 3 above).

A. Revisit these recommendations every 10 years and issue updates based on the understanding that has developed through research and adaptive management in the intervening time.

Active revegetation at Cogswell marsh

B. Develop designs and implementation plans for the management and restoration of large stretches of baylands to maximize the positive synergies among individual projects. Identify the appropriate boundaries of these areas based on the scale of natural processes, such as watersheds or patterns of sediment deposition and erosion along shorelines.

C. Adapt current policies to allow for the development and application of new, environmentally safe approaches that increase the ecological resiliency of the baylands. Existing regulations and policies have limitations on the use of bay fill to create habitat and on the reuse of dredged material. They also do not include specific recommendations or best management practices for new techniques such as sediment placement or the use of shells and other materials for subtidal restoration, horizontal levees, and improvements (like creosote removal or encapsulation) to living seawalls, living docks, and other existing infrastructure. Thoughtful experiments and data analyses of the new approaches listed here are needed, which will mean changes to existing policies and regulations.

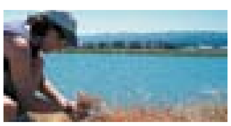
D. Consider all the elements of complete tidal wetland systems (including mudflats, the transition zone, and adjacent subtidal and terrestrial habitats) to be integral parts of baylands restoration at all scales, and encourage their inclusion in relevant regulatory framework and planning efforts.

E. Develop compatible approaches to baylands conservation for wildlife, public recreation, and traditional indigenous uses. Limit or restrict public access to areas with sensitive wildlife habitat value, particularly during breeding seasons. Where appropriate, provide access for wildlife-dependent activities such as fishing, hunting, wildlife observation, wildlife photography, interpretation, and environmental education. Develop other compatible public access in appropriate locations. Provide interpretive signage describing habitat values and promoting proper wildlife-viewing etiquette.

F. Ensure the continuity of programs to detect, manage, and eliminate invasive species. Establish and implement early-detection, rapid-response plans for novel outbreaking populations of invasive plants and animals to prevent their spread. This could be accomplished by reinitiating the Bay Area Early Detection Network (BAEDN) or providing similar capacity. Develop adaptive strategies for anticipated or newly arrived invasive species, including those that arrive because of climate-driven range shifts. Anticipate and prepare for the consequences of the impending invasion of the estuary by quagga and zebra mussels.

G. Conduct research and modeling to answer key science questions that will affect management decisions. One initial effort should be to model planned tidal restoration throughout the bay and delta, as well as changes to precipitation and reservoir operations, in order to estimate future salinity regimes and hydrodynamic changes.

The Don Edwards San Francisco Bay Refuge Environmental Education Center



9. **Develop a regional transition zone assessment program** as part of the actions described in recommendation highlight 3.

   A. Develop a collaborative program of potential transition zone site assessment, project tracking, performance evaluation, applied research, and public reporting. Consider basing the program on the Wetland and Riparian Area Monitoring Plan and the tool set of the State Water Resources Control Board. The assessment program should, at the outset, provide a map of the full extent of transition zones as defined in the report, structured in a way that it can be updated as needed. The program should also allow local agencies to contribute to the updates. Methods to assess the existing and restored transition zone should be standardized, such that projects can be compared with each other and with background or ambient conditions over time. Information about the location and status of transition zone restoration projects should be readily available online, and the overall condition and prognosis of the transition zone throughout the region should be regularly explained to the public.

   B. Establish a standing team of technical experts through an independent science organization to give advice on transition zone design, restoration, management, and assessment, such that these efforts are consistent with this and future updates of the Baylands Goals.

C. Develop a comprehensive portfolio of strategies for the conservation, restoration, and management of various transition zone types.

- Aim for consistency with natural landscape characteristics and dynamics in order to restore high levels of transition zone services when selecting and designing transition zone components. These include vernal pools, other seasonal depressional wetlands, moist grasslands and other slope wetlands, riparian forests along streams, tidal marsh, natural salt ponds, barrier beaches and berms, dunes, and shallow lagoons.
- Where appropriate, partially fill diked baylands and consider filling subtidal areas to create a transition zone on the bay side of levees.
- Develop methods to prepare terrestrial areas that will become transition zones. Conduct applied research on ways to encourage tidal-channel formation, topographic complexity, and native plant communities of the transition zone. Develop guidance for improving the management of agricultural baylands as an existing and future transition zone.

Slough channel and mudflats at sunset

10. Improve carbon management in the baylands to prevent further subsidence, increase organic matter accumulation, reduce greenhouse gas emissions, and sequester more carbon.

A. In appropriate areas of managed freshwater marshes, promote the accumulation of belowground carbon by enhancing plant productivity while maintaining anaerobic soil conditions to inhibit decomposition. This can be achieved by gradually raising water levels. Maintain soil salinities close to 18 ppt to reduce the likelihood of methane emissions.

B. On diked baylands with organic soils that are drained permanently or seasonally, raise the water tables to reduce soil carbon loss, fill ditches to reduce methane emissions, and reduce fertilizer or cattle densities, if appropriate, to reduce soil methane and nitrous oxide emissions.

C. Develop approaches to make use of compost from recycled food waste, possibly integrated with wastewater disposal, on diked and other baylands as appropriate.

D. Conduct applied research to inform better carbon and greenhouse gas management as a part of baylands restoration designs and management approaches. Quantify the greenhouse gas emissions from baylands of different habitat types, land uses (including all drained organic soils), and water-management regimes across the salinity gradient. Focus in particular on drained wetlands in Suisun, where peat is likely to be oxidizing and causing subsidence. Measure soil depths in current wetlands across the estuary so that existing pools of soil organic carbon can be calculated. Improve the understanding of the fate of carbon and nitrogen released from eroding tidal wetlands.

E. Develop a more detailed plan for prioritizing activities to incorporate climate change mitigation into baylands management.

SUBREGION VISIONS AND SEGMENT ACTIONS

The following pages present the recommendations in greater detail by providing landscape visions for each subregion and actions for portions, or segments, of each subregion. There are 20 segments total; they are listed alphabetically (fig. 25) as shown on the map on the next page.

The subregional landscape visions provide a picture of what each subregion could look like if our recommendations were implemented. The recommended actions for segments are divided into two groups: (1) actions for habitats and the landscape in general to benefit baylands wildlife communities overall, and (2) actions for particular wildlife populations that need extra attention.

Fringing marsh along slough next to ponds

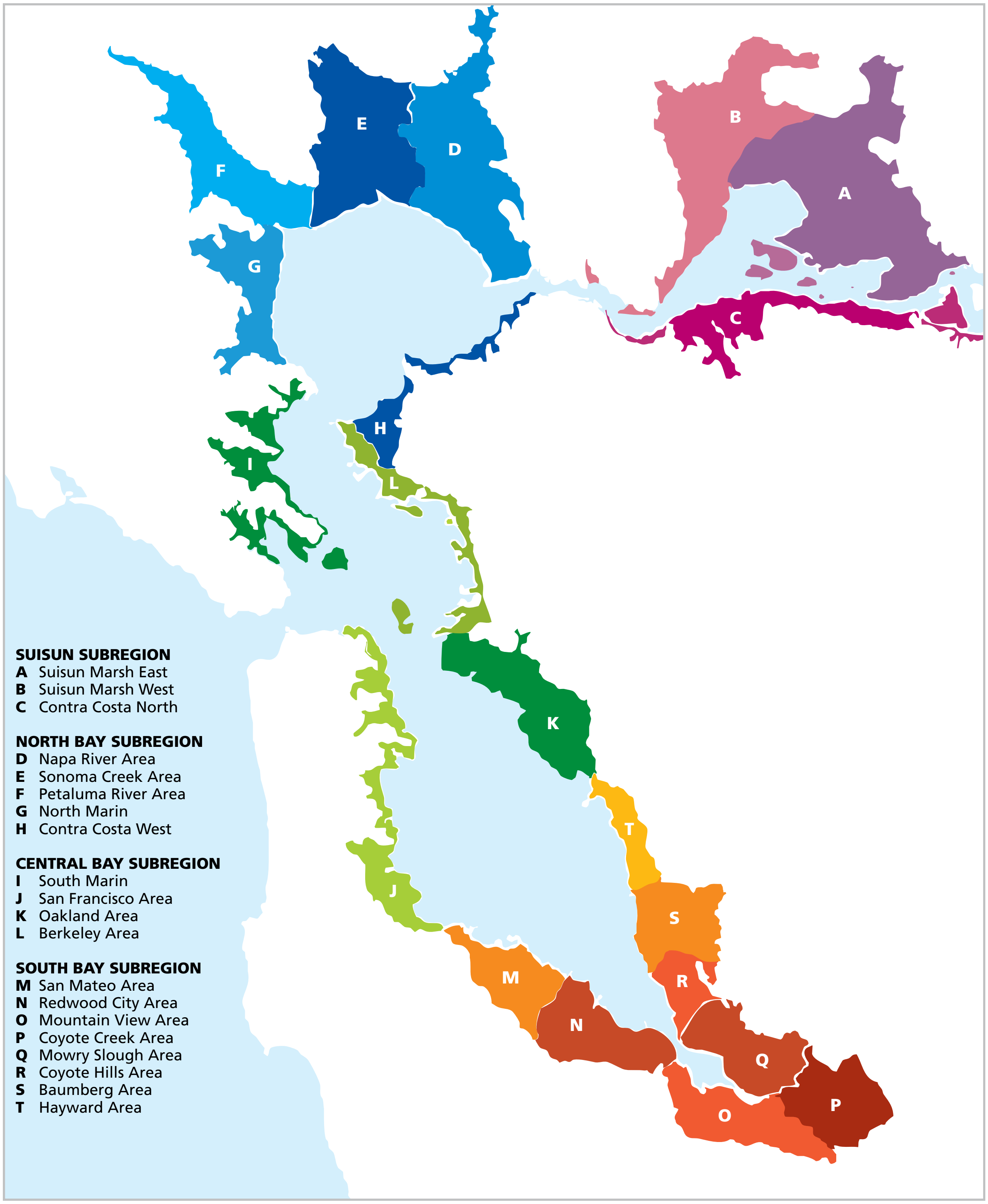
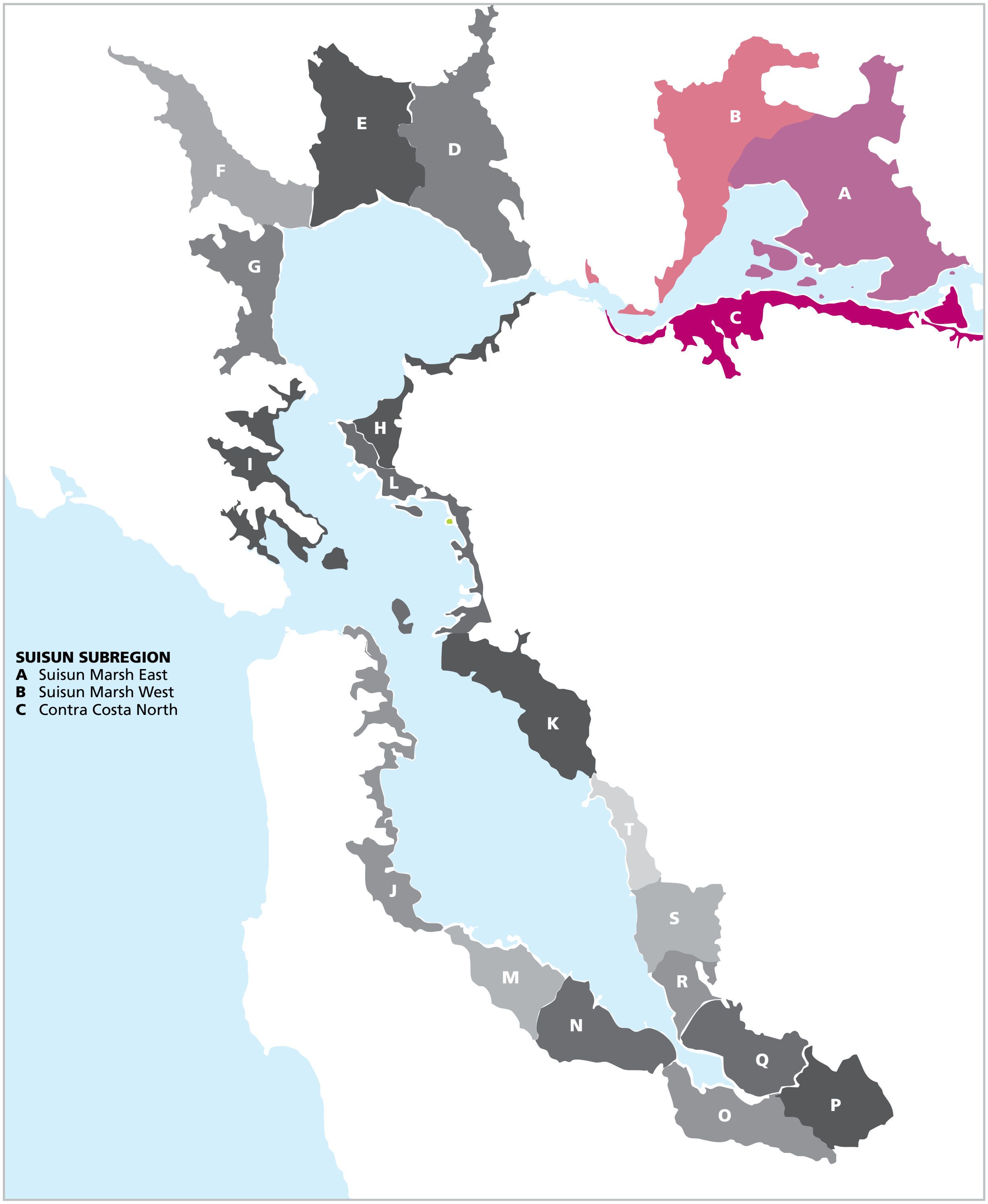


Figure 25 Project Area with Subregions and Segments

Suisun Subregion



Suisun Subregion

LANDSCAPE VISION

The Suisun subregion provides abundant opportunities to restore large patches of tidal marsh that adjoin broad transition zone areas while maintaining large tracts of diked marsh for intensive waterfowl management. The goal for the Suisun subregion is to restore large connected areas of tidal habitat in Suisun Marsh and along the Contra Costa shore; to conserve and enhance adjacent terrestrial areas and associated seasonal wetlands; and to enhance the remaining managed marsh habitat. Tidal marsh restoration should be prioritized adjacent to terrestrial areas with space for landward marsh migration.

Recommended Actions

- In Suisun Marsh, restore a functionally connected band of tidal marsh along the transition zone, providing space for landward marsh migration from the easternmost to the westernmost extent of the marsh. Blend the restored tidal marsh gradually with the adjacent grasslands to maximize plant diversity in the transition zone. Conserve low-intensity agricultural lands adjacent to tidal areas for future marsh and transition zone migration. Prioritize the areas near Nurse Slough, Hill Slough, and the head of Cordelia Slough that have naturally gentle slopes ideal for landward marsh migration. Restore tidal marsh in Suisun Marsh west of the railroad in conjunction with enlarging the small openings beneath the railroad tracks to accommodate current water flows and future sea-level rise.
- On the periphery of Suisun Marsh, enhance grasslands with vernal pools and enhance riparian vegetation along the tributary streams. These habitats should be protected and maintained with hydrological and ecological connectivity to the baylands.
- Along the southern edge of Suisun Marsh, restore a broad band of tidal marsh and open water habitat, in part to improve fish habitat and productivity. Restore a continuous tidal marsh corridor along Suisun Slough, providing connected marsh from Grizzly Bay to the slough's upstream extent and Hill Slough.
- Enhance diked unrestored areas of Suisun Marsh to tidal marsh by using best management practices to increase waterfowl diversity and carrying capacity, manage mosquitoes, reduce subsidence, and improve water quality. Best management practices may include increasing water-management capabilities, encouraging the diversification of seasonal wetland vegetation growth, and, where appropriate, promoting the accumulation of belowground carbon by enhancing plant productivity while maintaining anaerobic soil conditions to inhibit decomposition.
- On the Contra Costa shoreline, restore full tidal action to muted and diked marshes to create a tidal marsh corridor along the shore, including broad transition zones with diverse plant communities. Create terrestrial buffers along this corridor to protect baylands habitats and wildlife from disturbance. Restore riparian vegetation along as many stream corridors as possible.

Suisun Bay

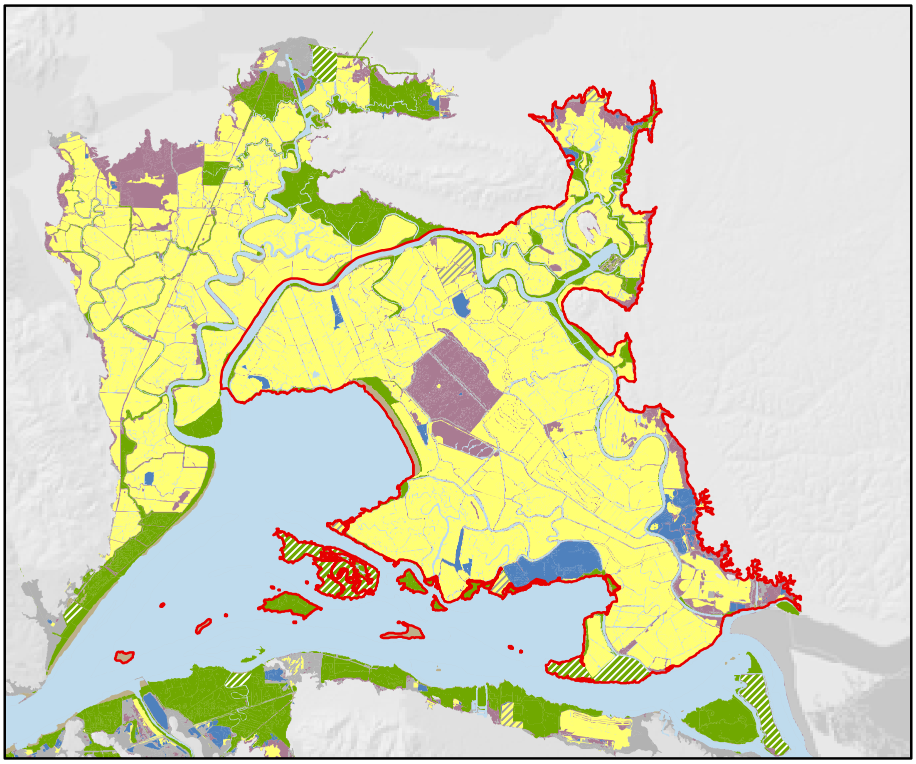
RECENT RESTORATION

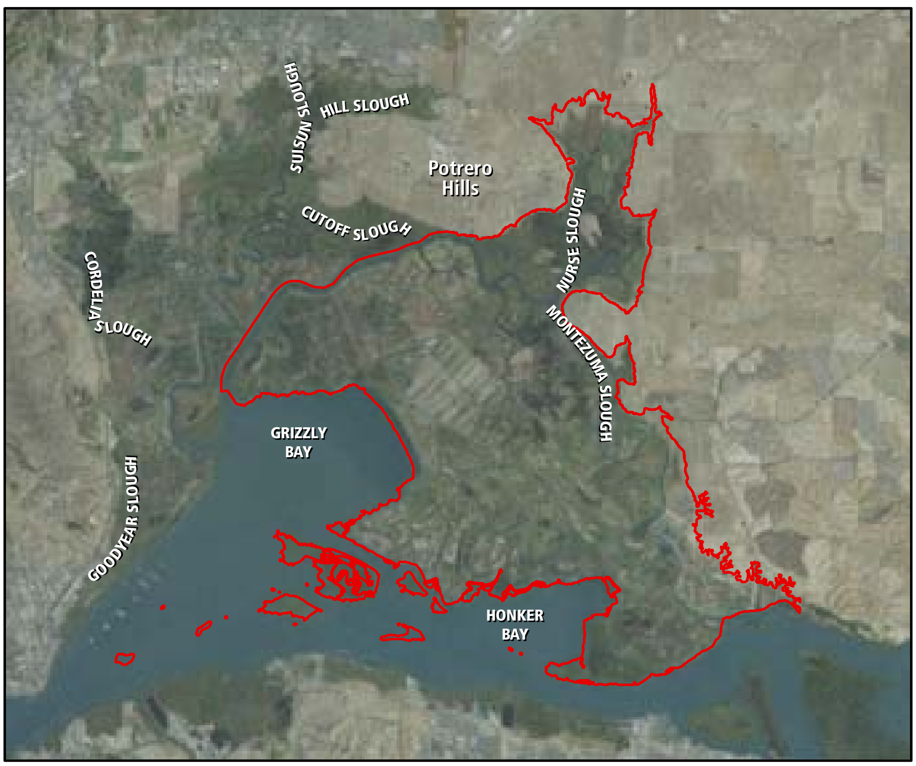
Since 1999, only one tidal restoration project of approximately 70 acres has been completed in Suisun Marsh; one large tidal restoration project, the 2,200-acre Montezuma Project, is under construction; several other tidal restoration projects are being actively planned; and several unplanned partial breaches have occurred. The recently completed Suisun Marsh Plan (SMP) of November 2011 set a target of 5,000 to 7,000 acres of tidal restoration to be accomplished within the next 30 years. Additionally, the Fish Restoration Program Agreement (FRPA) requires the completion of 8,000 acres of intertidal and associated subtidal habitat, including a minimum of 800 acres within the Suisun subregion. The impacts of salinity changes due to tidal restoration in Suisun Marsh and the western delta should be assessed, as there are water-quality regulations (e.g., SWRCB D-1641) that must be met or reassessed in both areas.

CHALLENGES

Achieving the Suisun vision is subject to significant infrastructure constraints (including those posed by Highway 680, Highway 12, railroads, natural gas production infrastructure and pipelines, and petroleum pipelines); the arrival of invasive species (mainly clams, pepperweed, and certain submerged aquatic plants, such as *Egeria*); and subsidence in potential tidal marsh restoration areas. Private landowners and public entities will need to be willing to convert some duck clubs to tidal marsh in Suisun Marsh, to restore marshes to full tidal action on the Contra Costa shoreline, and to retrofit infrastructure in keeping with ecosystem health.

The Suisun subregion consists of segments A, B, and C.





SUISUN MARSH EAST

Eastern portion of Suisun Marsh

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment A.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Segment A's large size, current protected status (through the Suisun Marsh Preservation Act of 1977), and relative isolation make it an ideal location for habitat protection, enhancement, and restoration. Because of its location in the upper reach of the estuary, this segment offers a good opportunity to restore large areas of tidal marsh along the full salinity gradient. This segment contains the Montezuma Project currently under construction. Restoring tidal marsh at the periphery of Suisun Marsh would provide opportunities to reestablish the range of listed plants species, including the endangered soft bird's-beak and Suisun thistle. There are also opportunities to restore vernal pools with tadpole shrimp in the adjacent uplands. Many diked wetlands in this segment are well suited for continued management for waterfowl and other species.

Segment Features and Setting

Historically, this area was predominantly tidal fresh and brackish marsh, arrayed as low-lying islands in Suisun Bay and as wide plains between the bay and the adjacent uplands. Inside this broad expanse of marshes were sloughs, channels, ponds, and small bays. Except for parts of Suisun Bay, the segment had relatively few areas of tidal flat. Adjoining the baylands, especially along Montezuma Slough and near Potrero Hills, were extensive areas of moist grasslands with vernal pools. The relatively steep topography of Potrero Hills provided a unique and narrow marsh–upland transition zone.

Today, this segment is one of the least urbanized areas of the baylands ecosystem. Most of the marshes are diked and are managed as duck clubs, but some tidal marsh occurs in Suisun Bay, along the edge of Grizzly Bay, and in many of the sloughs. There are extensive tidal flats in Grizzly Bay. There are alkaline-saline vernal pool complexes in the surrounding grasslands that grade into the upper tidal marsh zone. Water and soil salinity in the diked areas are intensively managed, and the natural variability of channel water salinities are influenced by delta outflow and water project operations. For example, the salinity control gates in Montezuma Slough are operated to maintain channel salinity levels similar to levels that would have occurred before the start of water diversions from the delta.

Suisun Bay

Implications of Drivers of Change

The main drivers of change for segment A are climate change, sea-level rise, changes in upstream water quality and quantity, and managed wetland activities. As managed wetlands are converted to tidal wetlands, the regional water quality is expected to change, along with ecosystem functions. Salinity throughout segment A will likely be elevated for a longer duration each year as a consequence of sea-level rise and tidal restoration. Additionally, numerous areas within this segment are subsided and, with sea-level rise, current tidal and future restored tidal areas may become subtidal habitats. Wetland plant diversity in the managed and tidal habitats is expected to decrease with increasing salinities.

Ultimately, opportunities for restoration in this segment may be largely shaped by climate change and sea-level rise (SLR). Some managed wetlands may become unsustainable because of changes in flood-event frequency, unanticipated levee failures, high levee maintenance costs, subsidence, and so on. Changes in upstream water quality (sediment supply, salinity, contaminants, temperature, etc.) or quantity (the amount of freshwater water coming into segment A) can significantly affect ecosystem function and the effectiveness of restoration projects. The presence of a portion of Highway 12 and natural gas production facilities and pipelines in this segment presents an added challenge. As the impacts of these main drivers of change become more pronounced, some existing regulatory obligations (e.g., the Water Rights Decision 1641 mandating salinity standards) may become unachievable, thereby necessitating a revision of some regulatory obligations.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The target of 5,000 to 7,000 acres of tidal restoration set forth in the Suisun Marsh Plan (SMP) is to be accomplished within the next 30 years. Contributions to this acreage could come from the Fish Restoration Program (FRP) and the Ecosystem Restoration Program (ERP), which are funded efforts. The Bay–Delta Conservation Plan (BDCP), if it is approved and funded, could also contribute to the SMP's restoration acreage goal. A large portion of this tidal restoration acreage is likely to fall within segment A.

The impacts of salinity changes due to tidal restoration locally (within Suisun Marsh) and regionally (particularly in the western delta) should be assessed, as there are water-quality regulations—e.g., State Water Resources Control Board (SWRCB) D-1641—that must be met in both Suisun Marsh and the delta. For managed wetlands, waterfowl habitat should be improved following best management practices, and general management practices should be promoted that reduce land subsidence and improve water quality.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

The long-term vision for segment A is less certain. While achieving some tidal restoration goals is likely—such as restoring the remaining acreage described in the Fish Restoration Program Agreement (FRPA) or BDCP, restoration opportunities may be largely shaped by climate change and sea-level rise as managed wetlands become less sustainable because of changes in flood-event frequency, unanticipated levee failures, high levee maintenance costs, subsidence, and so on. As managed wetlands are converted to tidal wetlands, significant impacts to upstream water supply (e.g., more saline water) and ecosystem functions throughout Suisun Marsh and the delta are likely. Plans to contend with these challenges will be necessary for both large-scale tidal restoration and for the continued operation of managed wetlands.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large tidal marshes along the eastern side of Montezuma Slough, in the Nurse Slough area, near Denverton Creek, and at sites adjacent to Honker Bay.

Provide a tidal marsh corridor along the base of Potrero Hills between Nurse Slough and the marshes to the west.

- Enhance and restore a natural transition zone. Draft plans for a future connection to the Jepson Prairie, focusing on tidal marsh transitions, incorporating protective buffers wherever possible, and thus creating shoreline migration space.
- Optimize managed marshes (duck clubs) to ensure continued support for a diverse suite of waterbirds, prevent subsidence, protect water quality, store carbon, and accumulate peat in the face of increasing salinities, sea-level rise, and other changes.
- Protect and enhance existing vernal pools and other seasonal wetlands adjacent to Montezuma Slough, in the Nurse Slough area, and north of Potrero Hills.

FOR PARTICULAR WILDLIFE POPULATIONS

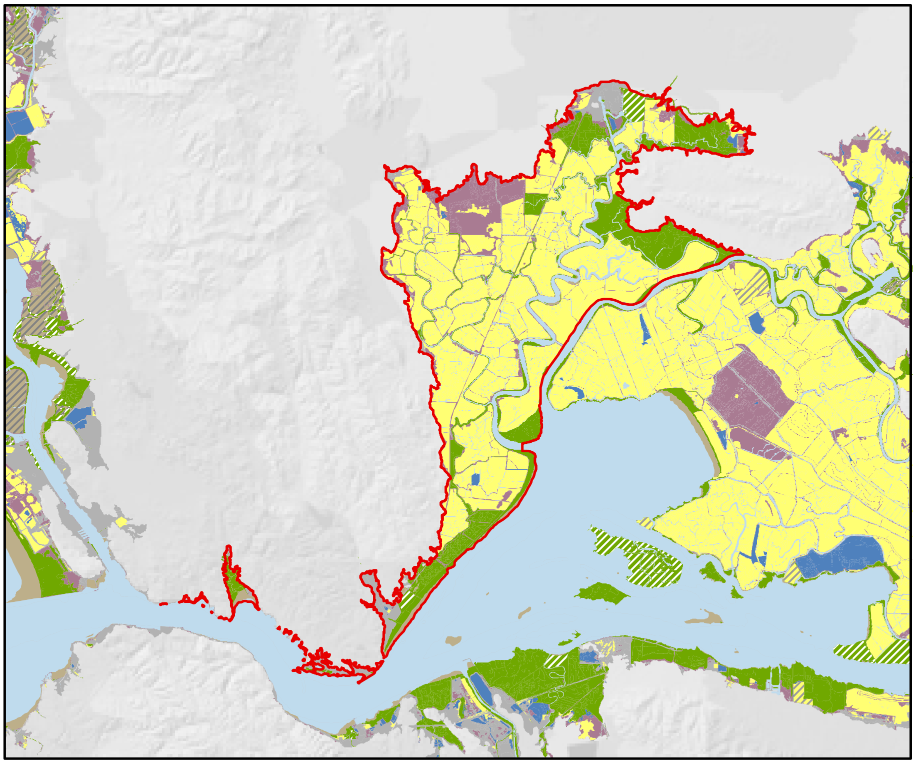
- If duck clubs are converted to other habitat types, compensate for the loss of managed marsh habitat for waterbirds.
- Contain perennial pepperweed, eliminate populations in proximity to marsh–terrestrial transition zones and in high-elevation marsh, and prevent the spread of invasives coincident with marsh migration. In particular, exclude pepperweed from mature brackish tidal marshes that are not yet heavily infested. Avoid persistent soil-active herbicides that jeopardize the seed banks of desirable species.
- Implement aggressive control measures for the invasive plant yellow flag, which could become a serious problem.

Restoration Benefits

Restoring tidal marshes in this segment would benefit the black rail, Suisun song sparrow, and other tidal marsh species. It also would increase detrital input to this very productive part of the estuary and increase habitat for aquatic organisms, including delta smelt, longfin smelt, striped bass, outmigrating salmon, and other fishes. Restoring large amounts of tidal marsh along the Montezuma and Suisun Sloughs would increase tidal flow and thus improve water circulation and reduce the need for dredging. Expanding tidal marsh along the estuarine–terrestrial transition zone would provide opportunities for restoring plant communities. Enhancing vernal pools and other seasonal wetlands on the periphery of the Suisun Marsh would help restore their declining plant and animal communities. Improving the managed marsh would benefit waterfowl, other waterbirds, songbirds, and a variety of mammals.

CHALLENGES

Flood-control considerations, levee maintenance, sedimentation of tidal creeks, water-salinity management, and water-quality impacts are of concern. Key regional restoration plans that involve this segment include the Suisun Marsh Plan, Delta Plan, BDCP, and FRPA.



SUISUN MARSH WEST

Western portion of Suisun Marsh

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment B.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

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Miles

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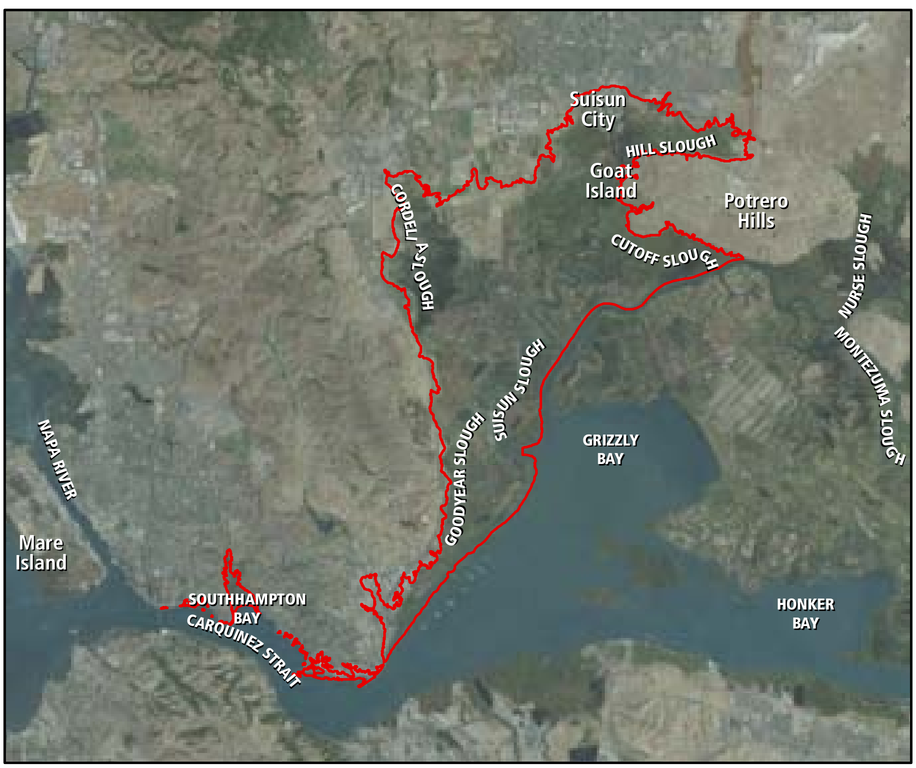


Unique Opportunities

Segment B provides opportunities to restore large patches of tidal marsh adjacent to areas of moist grasslands and vernal pools and to enhance wide natural transitions between these habitat types. An existing large tract of tidal marsh can be expanded, and marsh migration facilitated, at Rush Ranch. Riparian vegetation can be restored and enhanced along streams, several of which support steelhead, that flow into the marsh from the north. Management of diked wetlands can be improved for waterfowl and other waterbirds. As with the eastern segment of the Suisun Marsh (segment A), this area's large size, current protected status, relative isolation, and location on the estuarine salinity gradient all increase its potential restored habitat value.

Segment Features and Setting

Historically, this part of Suisun Marsh was largely fresh and brackish marsh, with conditions more saline in the western portion. The marshland extended from Potrero Hills westward to the upper end of Carquinez Strait. Myriad channels and sloughs meandered through the marsh, and along the western side were many large tidal marsh ponds. Adjacent to the tidal marshes north of Potrero Hills were large areas of moist grassland with vernal pools. Moist grassland lay in scattered patches along the base of the hills to the west. Riparian woodland lined several of the larger creeks that flowed into the marshes from the north. Like the eastern part of Suisun Marsh (segment A), this segment had few areas of tidal flats.

Today, this segment is nearly all diked wetland that is managed as seasonal waterfowl habitat. An area in the northwestern portion is managed agricultural baylands. Tidal marshes are limited and are generally confined to areas along the Hill, Peytonia, Montezuma, Suisun, and Cutoff Sloughs and to First and Second Mallard Branches. None of the historical marsh ponds remain except in low areas in diked baylands, and the tidal channels have narrowed markedly or disappeared. A native species of submerged aquatic vegetation, sago pondweed,is distributed in the shallow subtidal areas adjacent to tidal marsh edges. Water regimes are highly managed primarily to regulate salinity. Only remnants of the moist grasslands and areas of vernal pools remain, and most have been degraded by years of grazing. The area is a stronghold for endangered soft bird's-beak and the site of the only known population of Suisun thistle.

Implications of Drivers of Change

The main drivers of change for segment B are climate change, sea-level rise, changes in upstream water quality and quantity, and managed wetland activities. Salinity throughout segment B will likely be elevated for a longer duration each year as a consequence of sea-level rise and tidal restoration. Numerous areas within this segment are subsided and, with sea-level rise, current tidal and future restored tidal areas may become subtidal habitats. Additionally, as managed wetlands are converted to tidal wetlands, regional water quality is expected to change, along with ecosystem functions.

Ultimately, opportunities for restoration in this segment may be largely shaped by climate change and sea-level rise as some managed wetlands become unsustainable because of changes in flood-event frequency, unanticipated levee failures, high levee maintenance costs, subsidence, and so on. Changes in upstream water quality (sediment supply, salinity, contaminants, temperature, etc.) and changes in water quantity (the amount of freshwater water coming into segment B) can significantly affect the ecosystem function and effectiveness of restoration projects. Furthermore, areas of limited hydrological connectivity to major sloughs within this section have questionable restoration benefits to fish species targeted for conservation or mitigation requirements. The presence of the railroad tracks, petroleum pipelines, and the proximity of I-680 and Suisun City present additional challenges to restoration. Investments will need to be made to update this infrastructure for sea-level rise. These upgrades may provide opportunities for improving landscape processes important to maintaining the baylands. As the impacts of these main drivers of change become more pronounced, some existing regulatory obligations (e.g., SWRCB D-1641 water-salinity standards) may become unachievable, thereby necessitating the revision of some regulatory obligations. With increasing salinity levels, wetland plant diversity in the managed and tidal habitats is expected to decrease.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The target of 5,000 to 7,000 acres of tidal restoration set forth in the SMP is to be accomplished within the next 30 years. Contributions to this acreage could come from the Fish Restoration Program (FRP) and the Ecosystem Restoration Program (ERP), which are funded efforts. The Bay Delta Conservation Plan (BDCP), if it is approved and funded, could also contribute to the SMP's restoration acreage goal. A smaller portion of this tidal restoration acreage is likely to fall within segment B than in segment A.

Nonetheless, impacts of salinity changes due to tidal restoration locally (within Suisun Marsh) and regionally (particularly in the delta) should be assessed as water-quality regulations (e.g., SWRCB D-1641) must be met in both Suisun Marsh and the delta. For managed wetlands, waterfowl habitat should be improved following best management practices, and general management practices should be promoted that reduce land subsidence and improve water quality.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

Similar to the vision for segment A, the long-term vision for segment B is uncertain. While additional tidal restoration requirements are likely (such as remaining requirements of the FRP or BDCP), restoration opportunities may be largely shaped by climate change and sea-level rise as managed wetlands become less sustainable because of changes in flood-event frequency, unanticipated levee failures, high levee maintenance costs, subsidence, and so on). As managed wetlands are converted into tidal wetlands, significant impacts to upstream water supply (e.g., increased salinity) and ecosystem functions throughout Suisun Marsh and the delta are likely. The replacement or relocation of major infrastructure (e.g., portions of Highway 680, the railroad tracks, and petroleum pipelines) will likely be needed due to higher water levels. Plans to contend with these challenges to large-scale tidal restoration will be necessary.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large tracts of tidal marsh in the Hill Slough and upper Suisun Slough areas (including Goat Island), on Morrow Island south of the confluence of Goodyear and Suisun Sloughs, and at Southampton Bay. Connect these large areas of restored tidal marsh via a tidal marsh corridor along Cordelia Slough or other appropriate corridor location.
- Enhance and restore the natural transition zone, focusing on tidal marsh transitions, incorporating protective buffers wherever possible and thus creating shoreline migration space.
- Optimize managed marshes (duck clubs) to ensure continued support for a diverse suite of waterbirds, prevent subsidence, protect water quality, store carbon, and accumulate peat in the face of increasing salinities, sea-level rise, and other changes.
- Restore and enhance riparian vegetation along streams that flow into the marsh.
- Protect and enhance sago pondweed beds in the western portion of the segment. Study the ecosystem services and functions of beds, including the provision of habitat refugia and corridors for fish and aquatic species moving between the Carquinez Straight and tidal marshes, the provision of food to wildlife, and any other values associated with wave attenuation and shoreline protection.

FOR PARTICULAR WILDLIFE POPULATIONS

- If duck clubs are converted to other habitat types, compensate for the loss of managed marsh habitat for waterbirds.
- Contain perennial pepperweed, and eliminate populations in proximity to marsh–upland transition zones and in high-elevation marsh. In particular, exclude pepperweed from mature brackish tidal marshes that are not yet heavily infested. Use methods that do not jeopardize seed banks of desirable plant species by avoiding persistent soil-active herbicide.
- Complete the eradication of the invasive *Spartina* at Benicia State Park. Implement aggressive control measures for the invasive plant yellow flag, which could become a serious problem.
- Study the impacts of invasive feral pigs to determine appropriate control measures. Feral pigs disturb marsh vegetation. These disturbances may cause long-term damage, or they may enhance the recruitment of particular marsh plants.

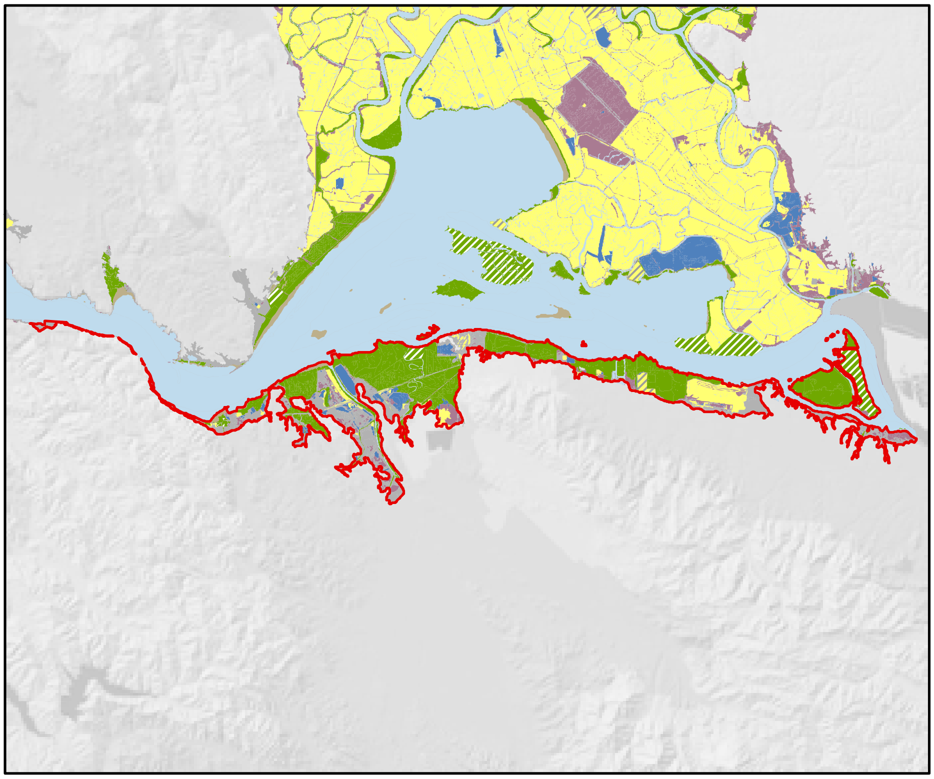
Duck hunter checking in

Restoration Benefits

Restoring tidal marshes in this segment would benefit many estuarine and anadromous fish species, including Chinook salmon, steelhead, and delta smelt. It would also benefit the Ridgway's rail. Restoring natural marsh–upland transition zones would improve conditions for endangered plant species, such as the soft bird's-beak, especially along the segment's northern edge. Protecting subtidal sago pondweed beds adjacent to marshes may help to improve habitat corridors for fish, provide additional habitat complexity and food resources, and play a role in protecting tidal marsh edges against erosion. Mammals that depend on transition areas for high-water-escape habitat would also benefit. The lower-elevation tidal marshes would provide habitat and food-web support for aquatic invertebrates and habitat for diving ducks. The remaining managed marshes would continue to provide waterfowl and shorebird habitat, and habitat for small mammals. Restoring tidal action to the upper reaches of Cordelia Slough would enhance habitats, improve channel flood-control capacity, and improve water conveyance to duck clubs.

Challenges

Posing the main challenges are Southern Pacific railroad tracks, industrial areas in the southwest portion, flood-control considerations, levee maintenance, sedimentation of tidal creeks, water salinity management, and water quality impacts. Effective tidal restoration on the west and north sides of segment B will be challenging due to limited hydroconnectivity and the constraints of Highway 680, railroad tracks, Suisun City, and petroleum pipelines. Key regional restoration plans that involve this segment include the Suisun Marsh Plan, Delta Plan, BDCP, and FRPA.

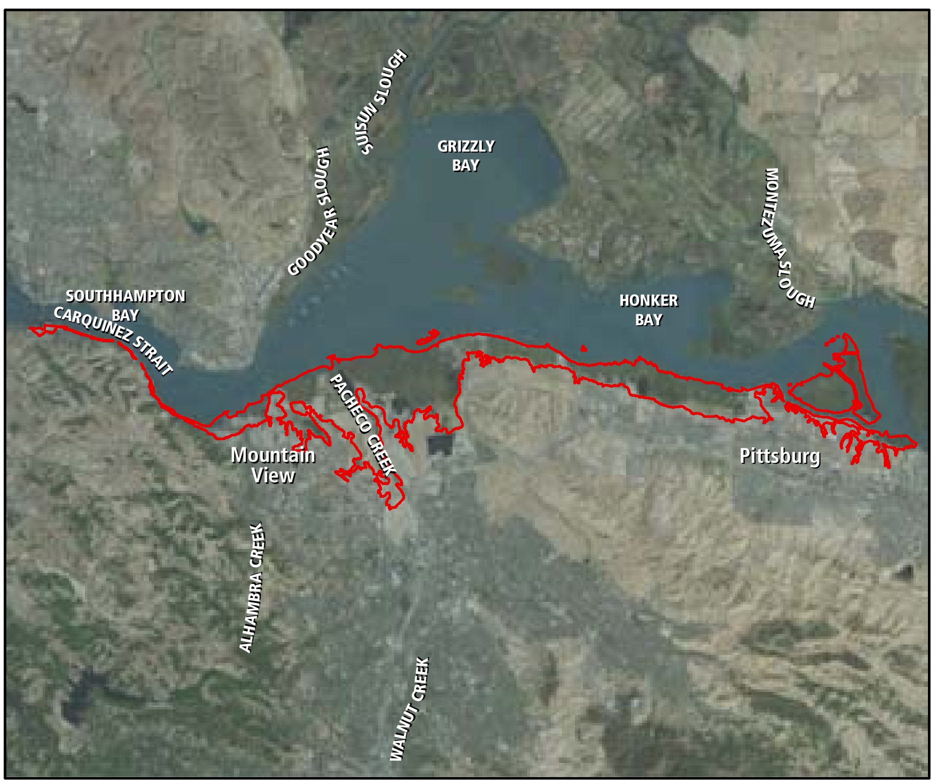


CONTRA COSTA NORTH

Southern edge of Suisun Bay between Carquinez Bridge and Broad Slough/San Joaquin River

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas



Red line shows the boundaries of Segment C.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Many of Segment C's historical tidal marsh areas, although degraded by years of grazing, agriculture, and other activities, can be restored to full tidal action. Likewise, several of the seasonal diked wetlands are suitable for tidal restoration or enhancement. Lands adjacent to many of the streams are undeveloped and have high potential for riparian restoration and enhancement.

Segment Features and Setting

Historically, tidal brackish marsh lay along nearly the entire length of this segment except for the western portion along the Carquinez Strait. The area where the strait narrows is characterized by fast-moving waters, and sediments here reflect the sandy substrate typical of constrained areas with no adjacent marsh or tidal flats. These tidal marshes to the east of the strait along the southern shore extended into the lower reaches of several local streams, including Hastings Slough, Alhambra Creek, and Pacheco Creek. Tidal flats lay near the mouth of Pacheco Creek and at a few locations on the shoreline upstream toward the delta. Within the Walnut Creek watershed were several areas of moist grassland and large stands of willow groves and riparian forest.

Today, most of the tidal marsh in this segment has been diked, and several cities, numerous industrial plants, and a military facility sit on or near the shoreline. However, many tidal marshes remain, especially near Martinez and Pittsburg. Although most of these are degraded, some have significant populations of soft bird's-beak and salt marsh harvest mouse. Native eelgrass beds grow offshore, especially in the western and sandier portions of this segment. Only a few remnants of riparian forest remain.

Implications of Drivers of Change

Without enhancement , the existing tidal marshes may be unable to keep up as the rate of sea-level rise increases, resulting in increased inundation of the marsh plain. High marsh that is flooded only during spring tides may downshift to mid and low marsh that is regularly flooded, depending on sediment supply and accretion rates. Increasing tidal submergence coupled with wave erosion may ultimately result in the conversion of tidal marsh to mudflat and, where unconstrained, landward migration of the shoreline.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

In the near term, when sea-level rise rates will still be relatively low, immediate actions to enhance the existing baylands can provide ecological benefits that maximize resilience in this segment. Opportunities to partner with the industrial and residential communities along the shoreline might be pursued to create habitat bayward of flood-protection levees through horizontal levees, living shorelines, or other green infrastructure.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the long term, the sea-level rise may outpace vertical accretion, and marshes in this segment generally do not have enough space to migrate landward to survive. Prior to reaching that point, a plan for restoring or relocating the functions within the existing tidal marshes out of the hazard zone should be developed and implemented.

Recommended Actions

FOR HABITATS AND LANDSCAPE IN GENERAL

- Restore large areas of tidal marsh in diked and muted tidal marsh areas.
- Where tidal marsh cannot be restored, improve water management to enhance diked wetlands through realigning levees and drainage ditches and connecting historic sloughs.
- Enhance and restore the natural transition zone, focusing on tidal marsh transitions, incorporating protective buffers wherever possible, particularly around the base of alluvial fans to provide sediment to the terrestrial side of marshes.
- Restore riparian vegetation, particularly willow sausals where appropriate, along small and large streams.
- Restore areas of historic pans where salt-making plants are no longer active.
- Protect and restore native eelgrass beds along the Carquinez Strait from the Carquinez Bridge to Pittsburg.
- Realign railways to allow for migration of the baylands with sea-level rise.

FOR PARTICULAR WILDLIFE POPULATIONS

- Contain perennial pepperweed and eliminate populations in proximity to marsh–upland transition zones and in high-elevation marsh. In particular, exclude pepperweed from mature brackish tidal marshes that are not yet heavily infested. Use methods that do not jeopardize seed banks of desirable plant species by avoiding persistent soil-active herbicide. Prevent the spread of invasive species coincident with marsh migration.
- Implement aggressive control measures for the invasive plant yellow flag, which could become a serious problem.

Restoration Benefits

Implementing these recommendations would improve habitat conditions for a variety of plants and animals. Restoring tidal marsh along the shoreline of Suisun Bay would improve habitats for estuarine and anadromous fishes, and would increase detrital input to aquatic habitats. Restored marshes would also provide improved habitat for Ridgway's rail, black rail, and salt marsh harvest mouse. Restoring the marsh–upland transition zone would benefit populations of soft bird's-beak, Mason's lilaeopsis, and delta tule pea.

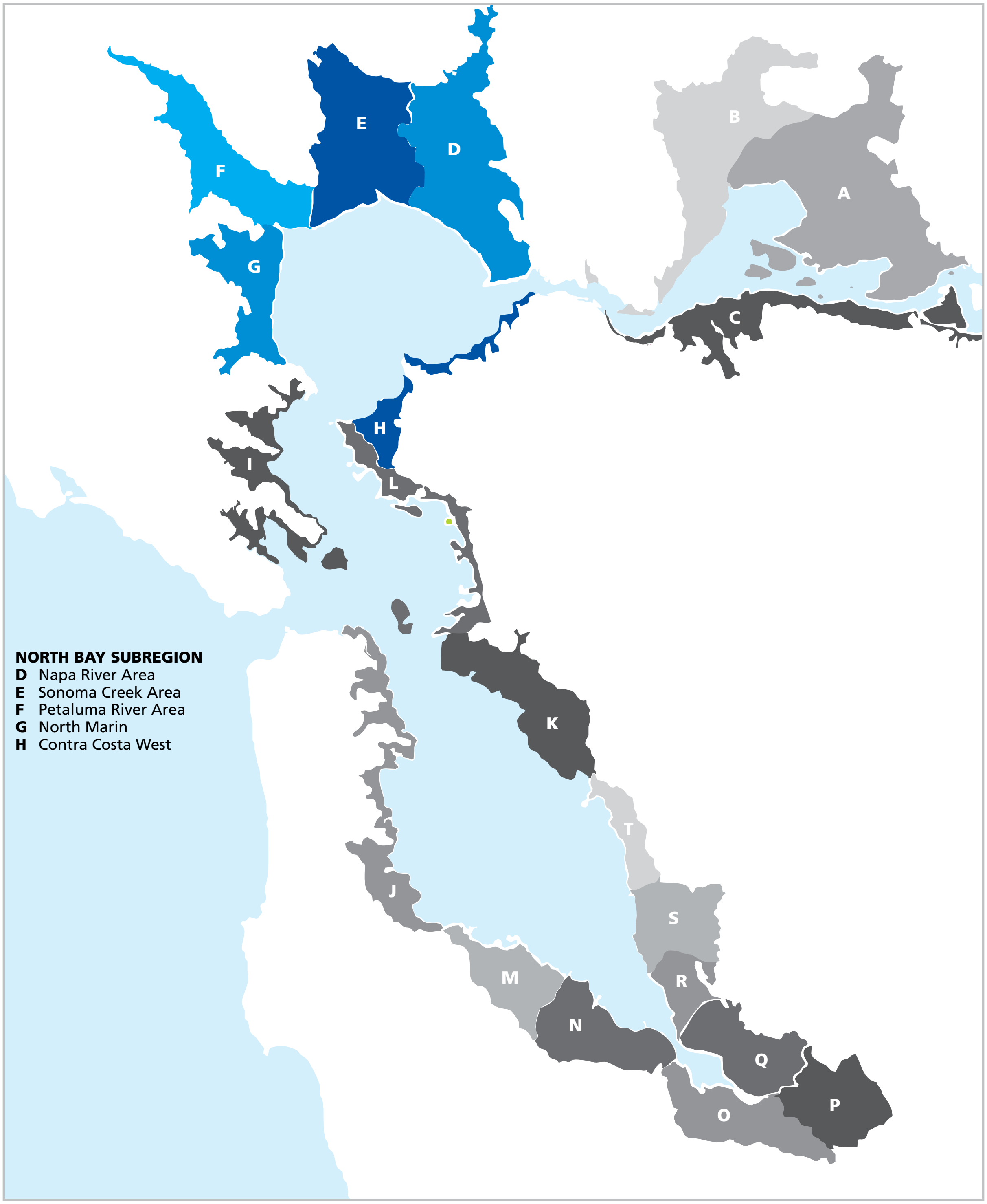
Lower Walnut Creek
Restoration Project

Reestablishing riparian vegetation along streams would provide corridors for amphibians, fish, small mammals, and birds, thereby improving the ecological connections between the baylands and the adjacent watersheds. Protecting subtidal eelgrass beds adjacent to marshes may improve habitat corridors for fish, provide additional habitat complexity and food resources, and play a role protecting tidal marsh edges against erosion.

Challenges

Challenges are posed by railroads and roadways, flood management concerns, major pipelines, sewer lines, the Concord Naval Weapons Station, adjacent heavy industry (e.g., PG&E's Pittsburg power plant), and on-site contaminants. On the Contra Costa shoreline, achieving habitat goals will depend on the willingness of corporate, military, and private landowners to restore many marshes to full tidal action. Achieving the goals in Suisun will also depend on the willingness of transportation corridor managers to retrofit infrastructure for sea-level rise in a way that is compatible with wetland goals. Key regional restoration plans that involve this segment include the BDCP and FRPA.

North Bay Subregion



North Bay Subregion

LANDSCAPE VISION

The North Bay is envisioned as encompassing large restored tidal marshes as part of a mosaic of dynamic, diverse, connected habitats from the bay to the watersheds, along with enhanced managed ponds. Achieving this vision involves restoring, protecting, and improving the natural processes necessary to sustain resilient habitats that can accommodate climate change. The North Bay has extensive agricultural and other relatively undeveloped lands with fairly intact natural processes, compared with other parts of the bay. Napa River, Sonoma Creek, Petaluma River, Tolay Creek, and Novato Creek provide significant freshwater inputs and deltas. As a result, the North Bay has significant opportunities to connect the baylands to their watersheds.

Recommended Actions

- Restore a broad swath of tidal marsh along the shore as soon as possible, with the widest marshes being in the Napa–Sonoma Marsh. Manage the fringing marsh bordering northern San Pablo Bay to sustain high marsh as sea levels rise by minimizing artificial drainage obstructions and maximizing wave processes that deposit coarser sediment. Protect and enhance native submerged aquatic shellfish and vegetation beds (including native oysters and eelgrass in the southern extent of this subregion), taking advantage of opportunities that arise as turbidity declines. Incorporate interior tidal ponds suitable for widgeon grass and pond-weed in the restoration along tributaries.

Napa Ponds

- Reconnect major tributaries (Napa River, Sonoma Creek, Novato Creek, Tolay Creek, and Petaluma River) to extant tidal wetlands well into the watersheds. Restore riparian corridors, including floodplains, to connect the baylands to the lower watersheds. Protect wet meadows, vernal pools, and swales in the lowlands adjacent to the baylands and increase their connectivity to the baylands. Work with willing sellers to conserve valleys and plains with low-intensity agriculture adjacent to tidal areas for future marsh and transition zone migration.
- Elevate Highway 37 and modify or realign rail lines and other infrastructure to allow the full passage of water, sediment, and wildlife. Avoid placing new infrastructure on the baylands, and discourage new vineyards on diked baylands, where groundwater is likely to become saltier. Over time, eliminate barriers to stream flow and stop the exports of water from streams to irrigate vineyards.

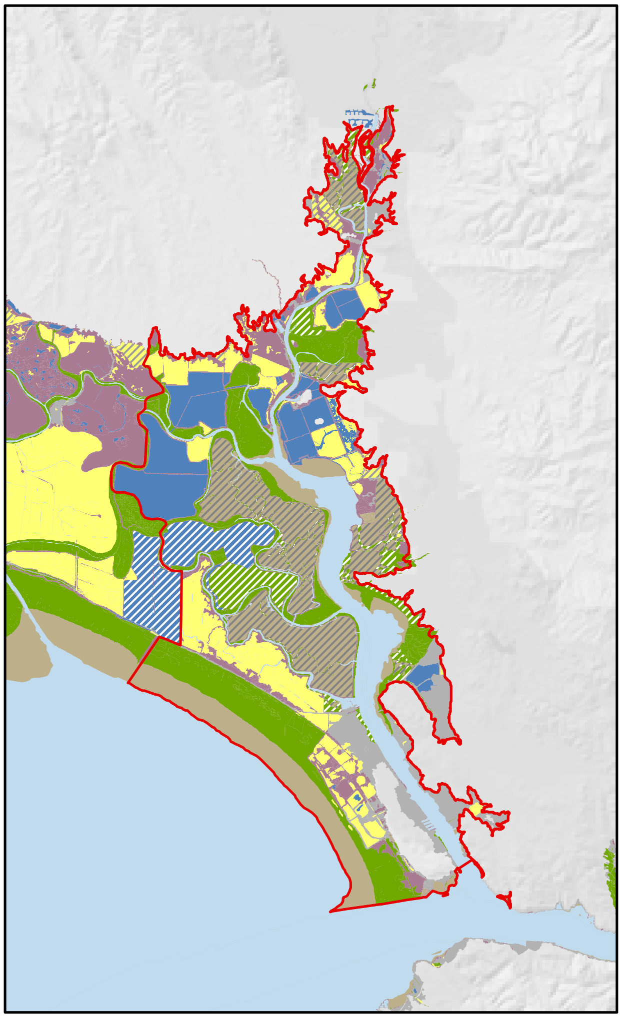
RECENT RESTORATION

Significant progress toward this vision is under way in the Napa–Sonoma Marshes, at the former Hamilton Air Force Base, and elsewhere in Marin, Sonoma, Solano, and Contra Costa Counties, such as Sears Point, Skaggs Island, Cullinan Ranch, and Breuner Marsh. Some managed ponds are being managed to optimize waterbird habitats, and others are being restored to tidal marsh. Tributary streams and riparian vegetation are being protected and enhanced.

CHALLENGES

Achieving the North Bay vision is subject to significant infrastructure constraints, the presence of invasive species, extensive subsidence in potential tidal marsh restoration areas (and the subsequent need for significant amounts of sediment to raise elevations), and the need to address flood-management issues for adjacent lands. Private landowners and public entities will need to be willing to retrofit infrastructure like Highway 37 and SMART rail lines in keeping with ecosystem health and to conserve and restore lowland migration space for the baylands. Control of pepperweed, Pacific bentgrass, and stinkwort are of particular concern in the North Bay. Groundwater pumping depressions near El Verano and the city of Sonoma have the potential to induce an intrusion of brackish water from the baylands into groundwater.

The North Bay subregion includes segments D through H.



NAPA RIVER AREA

Northern side of San Pablo Bay, extending from the Carquinez Bridge westward to the salt pond intake channel

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment D.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

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Unique Opportunities

Segment D presents an excellent opportunity to restore several large patches of tidal marsh adjacent to a large riverine system—a vision that has largely been captured by the Napa-Sonoma Marsh Restoration Project. It is also a place where marsh can be restored around a major intact remnant of historic tidal marsh (Fagan Slough and Coon Island). Along the bayland edge are opportunities (e.g., the eastern side of Napa River near American Canyon) to ensure natural transitions between restored tidal marsh and the adjacent terrestrial areas. Also, along the periphery of the segment on both sides of the Napa River are opportunities to improve seasonal wetlands. Recycled water is already used in some ponds to maintain salinity gradients, and this use could be extended.

Segment Features and Setting

Historically, this segment was almost entirely tidal salt marsh and tidal brackish marsh dominated by the hydrology of the lower Napa River. Extensive sloughs and channels connected it to the lower portion of Sonoma Creek to the west. Tidal salt marsh extended to the bay, but there was very little bordering tidal flat except along the Napa River. Many of the tidal marshes along the eastern side of the Napa River reached into small valleys and swales and were bordered with moist grasslands.

Today, this segment remains relatively undeveloped. Managed ponds on the western side of the Napa River dominate its landscape. The Napa-Sonoma Marsh Restoration Project has seen significant progress since the 1999 Baylands Goals. The project has involved the restoration of nearly 10,000 acres of wetlands and associated habitats within the former Cargill salt pond complex in the North Bay. The first two phases were completed in 2006 and 2007, and the third is in progress. Phase I, completed in 2006, resulted in the opening of 3,000 acres of managed ponds (ponds 3, 4, and 5) to full tidal action. Phase II, completed in 2007, restored 1,700 acres (ponds 1/1A, and 2) to managed ponds to provide waterfowl and shorebird habitat. Phase III involves the restoration of the final 1,900 acres (ponds 6/6A, 7/7A, and 8) and bittern removal from pond 7. Narrow strips of tidal marsh lie on the outboard sides of the levees that border these managed ponds and also at several sites along the Napa River. Significant populations of Ridgway's rail and black rail inhabit Fagan Slough, Coon Island, and White Slough.

Extensive tidal flats border the salt marsh south of Highway 37. The Highway 37 Strip Marsh East lies on the outboard side of the highway near Mare Island and is part of the San Pablo Bay National Wildlife Refuge. The 1,400-acre strip marsh is recognized as one of the most ecologically significant tidal marshes in San Pablo Bay; until recently, its exceptionally dense, tall pickleweed vegetation of the high-marsh terrace supported what is likely the largest population of the endangered salt marsh harvest mouse in the North Bay. However, the marsh has experienced accelerating degradation over the past two decades due to artificial-drainage impediments that have caused prolonged flooding and extensive dieback of marsh vegetation. This intensified flooding has greatly reduced the ecological function of this important habitat area for the salt marsh harvest mouse.

Diked wetlands lie along the northern side of Highway 37 and along the base of the hills near Huichica Creek. At the bayland edge there are many localities of rare or extirpated species of high-marsh plants. Eelgrass and oysters can be found near the mouth of the Napa River.

Implications of Drivers of Change

Without enhancement, existing tidal marshes may be unable to keep up as the rate of sea-level rise increases, resulting in greater inundation of the marsh plain. High marsh that is flooded only during spring tides may downshift to mid and low marsh that is regularly flooded, depending on sediment supply and accretion rates. Increasing tidal submergence coupled with wave erosion may ultimately result in the conversion of tidal marsh to mudflat and landward migration of the shoreline.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The near term, as the Napa–Sonoma Marsh Restoration Project is completed and suspended-sediment concentrations are still sufficient to sustain marsh-building processes, presents significant opportunities to enhance and increase the resiliency of large areas of tidal marsh south of Highway 37. This site is a distinct marsh type—a high-marsh terrace sustained by wave overwash and episodic sediment deposition—and thus requires a new approach to establish natural, sustainable drainage patterns and high-marsh topography. Studies should explore the facilitation of drainage according to the natural morphology and provide elevation and drainage gradients within the prograded, wave-built marsh terrace.

Previous efforts to improve drainage and sedimentation have been temporary, as these channels rapidly filled with sediment. For example, breaches were cut in the natural levee; they headcut as expected, which resulted in massive sedimentation in the marsh interior. The cuts became unstable and were rapidly closed by wave sediment deposition within two years. Improved understanding of the distinctive morphology, drainage, and geomorphic processes operating at this wave-exposed high salt marsh should support practical management strategies to maintain it as a persistent major high salt marsh habitat. The Highway 37–Mare Island high-marsh terrace may provide a model for other similar sites and may be among the most resilient to sea-level rise during the coming century.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

While improved drainage will enhance the marshes to the south of Highway 37 in the short term, the long-term maintenance of the supratidal marsh terrace (a modern salt marsh berm built by waves, despite the erosional morphology of its scarp) is probably at least as important for resilience to sea-level rise. This may be the first opportunity in the bay to get the right processes (high wave energy and high suspended sediment combined at the same location) identified in the context of managing a sustainable high salt marsh. Sediment demand from the restored Napa–Sonoma marshes north of Highway 37 will increase as sea levels rise. An important factor to consider while making such land-use decisions is whether it is possible to enhance the natural sediment transport from San Pablo Bay through Sonoma Creek and the Napa River and reestablish pathways from watersheds to tidal marsh areas to help maintain marsh elevations.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large areas of managed pond to tidal marsh (e.g., the Napa–Sonoma Restoration Project, Cullinan Ranch).
- Consider ways to increase sediment supply to the tidal baylands. For example, dredged sediments can be placed directly on adjacent mudflats to be reworked by wave and tidal action in order to increase local suspended-sediment concentrations and marsh-accretion rates. Improve sediment supply to the restored marshes north of Highway 37, and consider methods of increasing their trapping efficiency to increase accretion rates. Consider the beneficial reuse of dredged material to elevate restored ponds such as at Cullinan Ranch.
- Optimize the management of ponds for a diverse suite of waterbirds and consider relocating, reconfiguring, or enhancing ponds to accommodate sea-level rise. Revisit the acreage of ponds needed based on changes in the overall acreage of different habitat types (e.g., mudflats along Napa River).
- Enhance existing shoreline tidal marsh ecosystems and their function by reconnecting drainages that run parallel to the bay shore from Cullinan and the top of the centennial strip marsh, and by providing connectivity between strip-marsh units (Sonoma Creek and west units).
- Elevate Highway 37 to a causeway and remove other barriers to achieve unimpeded tidal and other hydrological connectivity.
- Enhance and restore transition zone habitat adjacent to tidal marsh, including natural levees on creeks.
- Enhance and restore eelgrass and oyster beds at the mouth of the Napa River and nearby areas.
- Facilitate the long-term maintenance of the supratidal marsh terrace of the Highway 37–Mare Island marsh by providing sufficient space and coarser sediment for the wave-built salt marsh berm to function and evolve.
- Increase the use of recycled water to improve salinity gradients.

FOR PARTICULAR WILDLIFE POPULATIONS

- Enhance seasonal wetlands at the Mare Island dredged-material-disposal ponds to improve shorebird habitats.
- Reduce the runoff of agricultural contaminants and nutrients from agricultural activities to improve water quality for the aquatic food web in the adjacent wetlands.
- Identify, conserve, and manage selected refugia for native bayland plants. Focus on unique or core populations of uncommon plants, especially in low marshes and in transition zones.
- Contain perennial pepperweed and eliminate populations in proximity to marsh–upland transition zones and in high-elevation marsh. In particular, exclude

pepperweed from mature brackish tidal marshes that are not yet heavily infested and from restoration areas soon to be opened to tidal influence. Use methods that do not jeopardize seed banks of desirable plant species by avoiding persistent soil-active herbicide. Prevent the spread of invasive species coincident with marsh migration.

- Continue to control invasive *Spartina* in Strip Marsh East–Mare Island.

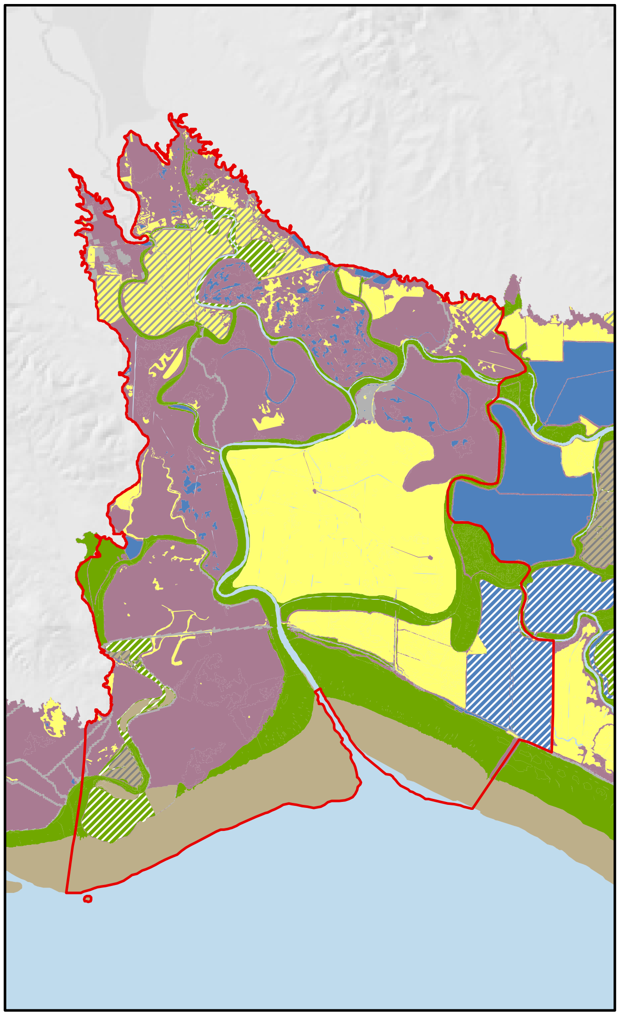
Restoration Benefits

Implementing these recommendations would improve habitat conditions throughout the segment for tidal marsh-dependent species, such as the salt marsh harvest mouse, Ridgway's rail, and soft bird's-beak. It also would improve habitats for species associated with seasonal wetlands. Large-scale restoration would widen and deepen many of the tidal channels, and this would benefit fish, diving ducks, and shorebirds as well as water circulation. Improving managed-pond habitat would also provide valuable deep-water foraging and resting habitat for diving ducks. Restoring riparian vegetation would benefit many amphibians, birds, and small mammals. Enhancing estuarine–terrestrial transitions would improve conditions for several rare and endangered plants. Conserving and reconnecting transition zones with the baylands ecosystem would provide critical migration space for high tidal marsh and brackish marsh to migrate as sea levels rise toward the end of the 21st century. Reestablishment of salinity gradients to tidal marsh will also provide critical brackish buffers to increasing salinity, thereby supporting tall emergent vegetation that forms essential high-tide cover. Recycled water could also enhance seasonal and brackish marsh habitat types that are rare in this part of the bay. Protecting subtidal eelgrass and oyster beds may help improve habitat corridors for fish from the Napa River to San Pablo Bay, provide additional habitat complexity and food resources, and help protect tidal marsh edges from erosion.

Napa Ponds

Challenges

Challenges for the existing marshes and future transition zone include California Northern railroad tracks, Highway 37, and PG&E power lines. Highway 37 tends to parallel the shoreline within the transition zone, making it a challenge to migration because in the near term it will prevent significant landward movement of the baylands. The Napa–Sonoma Marsh Restoration Project and the San Pablo Bay National Wildlife Refuge are the key regional entities for this segment. Planning will require coordination with local agencies and organizations, including the San Pablo Bay National Wildlife Refuge, California Department of Fish and Wildlife (CDFW), Napa County, Solano County, and Caltrans.



SONOMA AREA

Northern side of San Pablo Bay, extending from salt pond intake channel to just west of Tolay Creek

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment E.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

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Unique Opportunities

Segment E provides considerable opportunities to protect undeveloped land and restore diked wetlands to tidal marshes, which are more resilient to climate change. It also presents opportunities to restore extensive tidal marsh and natural marsh–upland transition zones. In addition to restoring large patches of tidal marsh (some as isolated marsh islands and others with natural transitions to the adjacent terrestrial habitats), wetlands restoration can also be integrated with watershed management in Sonoma and Tolay Creeks, thereby taking advantage of associated freshwater and sediment pathways. Finally, several large areas are well suited to be managed as diked wetlands for shorebirds and waterfowl.

Segment Features and Setting

Nearly all of the lands within this segment were once tidal salt marsh or tidal brackish marsh. Some limited areas of moist grasslands lay to the north and west, along upper Sonoma Creek, and in the drainages around and below Lake Tolay. A large area of vernal pool soils existed on the western side of upper Sonoma Creek.

Today, this segment is relatively undeveloped except for agriculture, and several restoration efforts have been made to enhance and restore tidal flows to diked wetlands along the periphery of the segment since the 1999 Baylands Goals. At Tolay Creek and Lower Tubbs Island, tidal marsh, subtidal, and marsh–upland transition zones have been restored by improving hydrological flow and tidal flushing, reestablishing connections between marsh areas, and restoring native plants along the transition zone. Internal levees and sills, which formed barriers to tidal flow and circulation, were breached or removed, and new channels that reconnect marsh areas to existing drainages were excavated. Projects at Skaggs Island, Sears Point, and adjacent to Sonoma Creek are under way with substantial areas slated for restoration. Tidal marsh is limited to the bay edge near Sonoma Creek and along the outboard sides of levees along the remaining channels. There are some muted tidal lagoons in Lower

Sandpipers and dowitchers at low tide

Tubbs Island and adjacent to Highway 37 and Tolay Creek. Spawning Chinook salmon have been observed in Sonoma Creek.

A Caltrans stakeholder process is under way to improve Highway 37, and the initial consensus among stakeholders (including the CDFW, US Fish and Wildlife Service, Regional Water Quality Control Board, and Ducks Unlimited) is to widen it to four lanes, plus bike lanes, into a causeway like the Yolo Bypass I-80 and I-5 designs. This process is encouraged for its significant benefits to baylands habitat and climate-change adaptation.

The Sonoma Resource Conservation District (RCD) conducts a permit program for 29 landowners who maintain over 60 miles of levee in the Sonoma Creek and Petaluma River Area segments. Each year, the Sonoma RCD gathers information from each landowner on the work done in the previous year and the work to be done the coming year and submits it to the permitting agencies. The permits restrict the extent and timing of levee-maintenance work and outline a series of best management practices to protect habitats for threatened and endangered species.

Implications of Drivers of Change

The United States Geological Survey (USGS) has collected site-specific baseline elevation, vegetation, and tidal data to assess elevation changes over 12 years for the Tolay Creek restoration. These results indicate that the tidal marshes and mudflats along the creek were accreting sediment during the past 12 years, and most of the site had accretion rates that outpaced sea-level rise during the study period. Thus, the area may keep pace with sea-level rise over the next few decades. However, in the longer term, the rates of sea-level rise are expected to increase, and sediment accretion is much less likely to keep pace, resulting in greater inundation of the marsh plain. High marsh that is flooded only during spring tides may downshift to mid and low marsh that is regularly flooded, depending on sediment supply and accretion rates. Increasing tidal submergence coupled with wave erosion may ultimately result in the conversion of tidal marsh to mudflat and landward migration of the shoreline. Finally, sea-level rise will put pressure on managed systems designed and maintained for particular water levels. For example, as water depths increase, outboard levees will be subject to increasing wave action and the damage associated with erosion and overtopping.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

In the near term, the acquisition of key agricultural lands from willing sellers and the restoration of tidal action by breaching levees and removing barriers should be pursued while suspended-sediment concentrations are still sufficient to sustain marsh-building processes. Improving drainage conditions in the fringing tidal marsh along Sonoma Creek south of Highway 37 and creating transition zones will help create a mosaic of habitat types, including critical high-tide refugia as sea levels rise. Existing and planned levees that are integrated with the San Francisco Bay Trail should be designed not to impede the objectives of tidal marsh connectivity, improved hydrology, and marsh migration.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

The long-term vision is to reduce the impact of migration barriers such as highways and railroads and to reconnect the baylands with watershed inputs of sediment and water. The goal is to reduce the flood risk to shoreline communities and infrastructure while increasing the resilience of the baylands to climate change. Sediment demand to maintain marsh elevations will increase as sea levels rise. It is important to consider enhancing the natural sediment transport through Sonoma Creek and the Napa River to tidal marshes to help maintain marsh elevations. Managed ponds and other diked baylands providing important bird habitat may need to be resituated in locations that will required less maintenance, including levee repairs.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large connected patches of tidal marsh across the entire sweep of San Pablo Bay, particularly near the mouths of sloughs and major streams. Protect and enhance the marshes on the bay side of Highway 37 to ensure connectivity between marshes along the full perimeter of San Pablo Bay. Improve drainage from Sonoma Creek East through a connection to Sonoma Creek. Allow full hydrological connections between diked areas (i.e., Lower Tubbs Island and Tolay Creek).
- Increase sediment supply to the tidal baylands, where appropriate for stream and watershed health. Reconnect stream channels in the Tolay Creek watershed into marshes, increase sediment supply to the restored marshes north of Highway 37, and augment the trapping efficiency of tidal baylands to foster accretion, as appropriate.
- Protect and restore agricultural lands and other open space to reestablish a transition zone adjacent to the tidal marsh and provide space for future landward migration.
- Elevate Highway 37 to a causeway and elevate, modify, or remove other barriers, such as the railroad, to achieve unimpeded tidal and other hydrological connectivity.
- Design and implement improved flood protection for adjacent developed areas that takes advantage of the natural infrastructure and promotes ecological resilience.
- Protect, restore, and enhance riparian habitat along Sonoma Creek in the Schellville area, in the Tolay Creek watershed, and along other waterways.

FOR PARTICULAR WILDLIFE POPULATIONS

- Establish managed marsh or enhanced seasonal pond habitat (especially for shorebirds) where feasible on agricultural baylands that are not restored to tidal marsh. Locate seasonal diked wetlands in close proximity to tidal flats to provide high-tide roosting habitat for shorebirds.
- Reduce the runoff of contaminants and nutrients from agricultural activities to improve water quality for aquatic food webs in the adjacent wetlands.

- Identify, conserve, and manage selected refugia for native bayland plants. Focus on unique or core populations of uncommon plants, especially in low marshes. Consider relocating rare plants to more appropriate areas as flooding and salinity conditions change.
- Increase the populations of threatened and endangered species through methods such as farming best practices to meet specific conservation objectives to buffer future impacts.
- Continue to control invasive *Spartina* along Sears Point, Sonoma Baylands, and Tolay Creek and Tubbs Island.

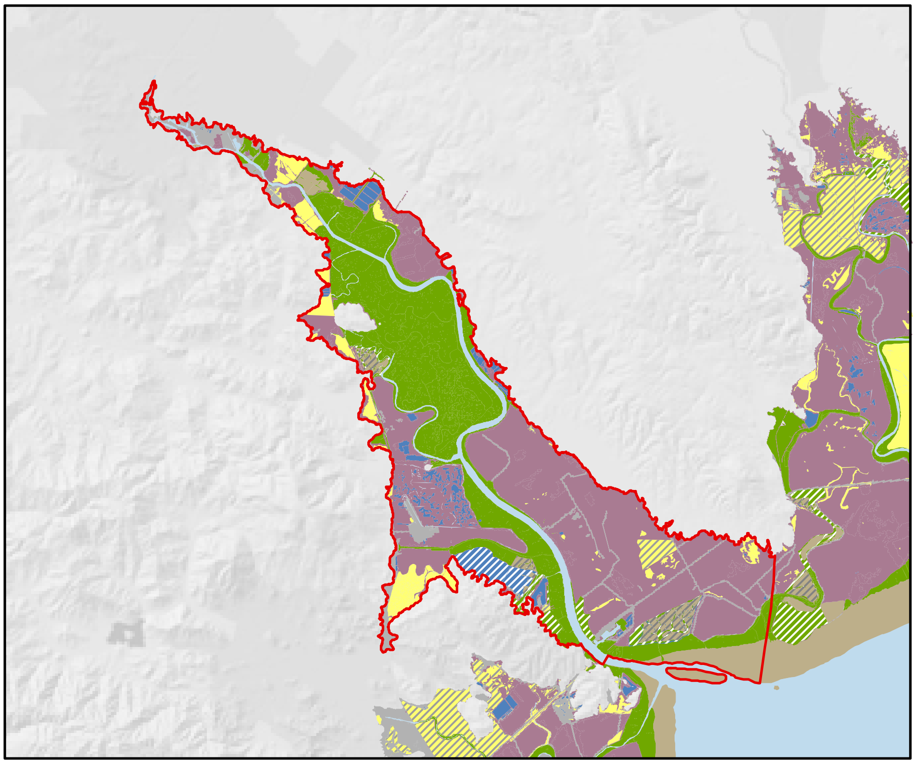
Restoration Benefits

Implementing these recommendations would increase the area of tidal marsh and expand suitable habitat and habitat connectivity for endangered tidal marsh species, such as the Ridgway's rail and the salt marsh harvest mouse. Restoring tidal marsh in this segment would also greatly enlarge the area of shallow- and deep-channel habitat for many fish species and diving ducks. Restoring marsh at the periphery of the baylands, where natural transitions to adjacent terrestrial habitats could develop, would benefit several rare plants as well as birds, mammals, and amphibians that depend on the transition zone. Furthermore, the conservation of transition zones and their reconnection with the baylands ecosystem provides critical migration space for high tidal marsh and brackish marsh to migrate as sea levels rise toward the end of the 21st century. Large areas of tidal marsh can reestablish the hydrological gradients between Sonoma Creek and the Napa River, greatly improving water circulation. Large areas of managed diked wetlands would provide important roosting and foraging habitat for shorebirds and waterfowl.

Challenges

Challenges for the existing marshes and future transition zone include California Northern railroad tracks, Highway 37, and PG&E power lines. Highway 37 tends to parallel the shoreline within the transition zone, making it a serious challenge because in the near term it will prevent any significant landward movement of the baylands. Planning will require coordination with local agencies and organizations, including Sonoma County, Sonoma RCD, San Pablo Bay National Wildlife Refuge, CDFW, the Sonoma Land Trust, Northwestern Pacific Railroad, SMART rail, and Caltrans.

Groundwater considerations also need to be addressed. Two groundwater-pumping depressions are apparent in the deep-zone groundwater elevation contour map southeast of the city of Sonoma and around El Verano. The pumping depression southeast of Sonoma has the potential to induce an intrusion of brackish water from the baylands area, which may be exacerbated by sea-level rise.



PETALUMA RIVER AREA

Northwestern edge of San Pablo Bay and lands in the lower Petaluma River drainage

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment F.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2

Miles

N

Unique Opportunities

Segment F provides opportunities to restore extensive tidal marsh and natural marsh–upland transition zones near the subregion's largest brackish marsh. It also provides opportunities to expand remnant populations of rare plants, such as the soft bird's-beak, into restored tidal marsh areas. There is the unique opportunity to enhance the transition zone between San Antonio Creek and tidal habitats, one of the few places where such restoration can take place. Opportunities also exist to significantly increase and enhance seasonal wetland habitats in the diked baylands and adjacent uplands, particularly on the eastern side of the Petaluma River. This segment also provides opportunities to restore and enhance current and future transition zones, particularly with oak woodlands.

Segment Features and Setting

Tidal marsh was once the dominant habitat type in this segment. Salt marsh existed near the mouth of the Petaluma River and became brackish upstream. There were relatively small tidal flats at the river mouth, but several large areas upstream at False Bay. Small patches of moist grassland dotted the northeastern edge of the baylands, and a very large area of this habitat lay near Petaluma. The Petaluma Estuary exhibits a low-energy wave system with high sediment availability, characterized by extensive high and mid-marsh plains served predominantly by tidal sloughs; mudflats are limited. Due to low wave energy, the main controlling factors determining wetland form and function are the tidal range and tidal prism of the system.

Today, this segment remains relatively undeveloped, and it contains Petaluma Marsh, the largest intact tidal marsh within the estuary. However, almost all of the extant transition zone is either separated from the tidal marsh by dikes and roads or agriculturally modified for cattle grazing or viticulture. This marsh exhibits many of the features that were characteristic of the estuary's historical marshes: pans, a system of extensive channels, and natural transitions to adjacent uplands. These are not readily apparent in most other bay marshes. This marsh includes brackish and salt marsh areas and supports a great diversity of native plant species, important populations of Ridgway's rails, black rails, waterfowl, and shorebirds. Adjacent to the baylands, the landscape retains much of the historical character of moist grassland bordered by oak woodland. Portions of the Petaluma Marsh are connected to hillslopes (such as Burdell Island), and portions border dikes or railroad berms that sever the marsh from terrestrial lowland valleys and flats. These lowland valleys in grazing lands, like those north of Gallinas Creek, still support natural fresh-to-brackish surface drainage and subsurface (groundwater) connections to the baylands. The segment receives freshwater flows from San Antonio Creek, which supports extensive riparian habitat, and from the Petaluma River and Adobe Creek, which support runs of steelhead.

Much of the marsh plain has been diked and drained. As a consequence of draining, the deep peats have subsided considerably. Fringing marshes along the Petaluma River remain, and these have maintained their position relative to the tide. As a result, the Petaluma River is bordered by relatively high marshes, behind which are large areas of lower-lying land cut off from tidal action.

The North Novato baylands include mature, wide, topographically complex tidal marsh and creek systems (the Toy/Green Point Marsh and outer Bahia marshes along

Northern shoveler

the Petaluma River) that support dense and large populations of Ridgway's rails and black rails. The wide fringing mature brackish-to-salt-marsh gradient along Black John Slough is also an important habitat for black rails and (particularly toward the east) Ridgway's rails. The Bahia tidal lagoon (silted former marina) and channel also support Ridgway's rails adjacent to the recent tidally restored Central Bahia baylands. The Central Bahia baylands (including former Mahoney Spur) are currently in early tidal mudflat–salt marsh succession following tidal restoration. These baylands support abundant waterbirds and are expected to provide extensive additional habitat for an expansion of the adjacent Ridgway's rail populations. The East Bahia lagoon supports an important foraging habitat for bay ducks, diving ducks, wading birds, and shorebirds. The filled peninsulas surrounding the East Bahia lagoons support ruderal (weedy) upland vegetation and seasonal wetlands. The West Bahia lagoon is a damped tidal brackish lagoon that supports extensive submerged aquatic vegetation (widgeon grass) beds and waterfowl and wading bird habitat. Nontidal seasonal and perennial fresh–brackish wetlands also support important waterfowl and shorebird roosting and foraging habitats in the former dredged-sediment-disposal and decant pond sites.

Since the 1999 Baylands Goals, the area of tidal marsh has increased in the segment following the restoration of tidal action to diked wetlands through initiatives such as the Sonoma Baylands Project, Bahia Marsh Restoration Project, and Petaluma Marsh Expansion Project. Additional efforts are under way, including the Sears Point Restoration Project, which encompasses 1,000 acres of future tidal marsh and critical transition zones that provide high-tide refugia and space for landward migration, as well as seasonal wetlands and vernal pool habitat north of the SMART rail and Highway 37.

Implications of Drivers of Change

The Petaluma Marsh area is expected to undergo divergent responses to sea-level rise, depending on its position within the sedimentation gradient along the Petaluma River and its initial topography (diked bayland or tidal marsh). The southern reaches of this subregion, which are relatively rich in suspended-sediment supply, are more likely to sustain fringing tidal marshes where they exist today, and to support tidal marsh restoration currently in progress. Subsided diked baylands (especially in northern reaches of the Petaluma Marsh in Marin County) are likely to undergo more frequent levee overtopping, breaching, or failure (conversion to open water) and to develop a greater demand for drainage where levees do not fail. The extensive tidal slough and marsh plains of the Petaluma Marsh may be subject to bank erosion along the river, and an expansion of pans and low marsh within the marsh plain as tidal energy increases. Prehistoric tidal marsh remnants are likely to shrink and to lose native species diversity as lower marsh zones expand and upper marsh zones contract. Undeveloped agricultural lands with valley gradients or gentle hillslopes bordering tidal marshes in this subregion (including areas that are currently diked nontidal wetlands) will provide some of the best opportunities to restore and conserve tidal marsh ecosystems that retain all the critical subhabitats and species of concern during an accelerated sea-level rise. Populations of invasive plant species are likely to expand where levees are armored or maintained more frequently.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

If current suspended-sediment concentrations persist, existing natural and restored tidal wetlands will likely be resilient to sea-level rise even at higher rates. If additional areas are opened up for restoration, they are also likely to evolve resiliently, particularly if they are connected to the natural gradually sloping topography of the estuary margin. Alternatively, high-value artificial habitat can be created through the management of water, creating shallow wetlands such as those at Rush Creek.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

Over time, with rising sea levels and potentially more extreme storms, flood protection along leveed edges will decline. In response to climate change, the options are either to improve flood protection along the existing levees or, as an adaptation strategy, selectively and opportunistically realign existing levees and concentrate flood protection along critical infrastructure (such as Highway 101). The railway will also come under progressive risk from tidal waters and will likely require upgrading. At such time, it would be beneficial to improve tidal connectivity to gradually sloping uplands, which would allow for the restoration of a potentially high-quality buffer habitat that with adequate space would be more resilient to sea-level rise.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Protect and restore tidal marsh on both sides of the Petaluma River, particularly on the eastern side, between Highway 37 and False Bay (Dustman Road), which is already vulnerable to flooding.
- Protect, restore, and manage agricultural lands and other open space to reestablish a transition zone and buffers adjacent to tidal marsh and to provide space for landward migration. Create transition zone habitats on gentle slopes in front of flood-risk-management levees.
- Enhance the stream–marsh transition zone between San Antonio Creek and tidal habitats, one of the few places where such restoration can take place.
- Consider ways to increase the sediment supply to tidal baylands. Reconnect stream channels into marshes, and augment the trapping efficiency of tidal baylands to foster accretion, as appropriate.
- Protect and enhance moist grassland habitats on the eastern portion of this segment.
- Elevate Highway 37 to a causeway, and remove, realign, or elevate other barriers (such as the SMART rail) to achieve unimpeded tidal and other hydrological connectivity.

FOR PARTICULAR WILDLIFE POPULATIONS

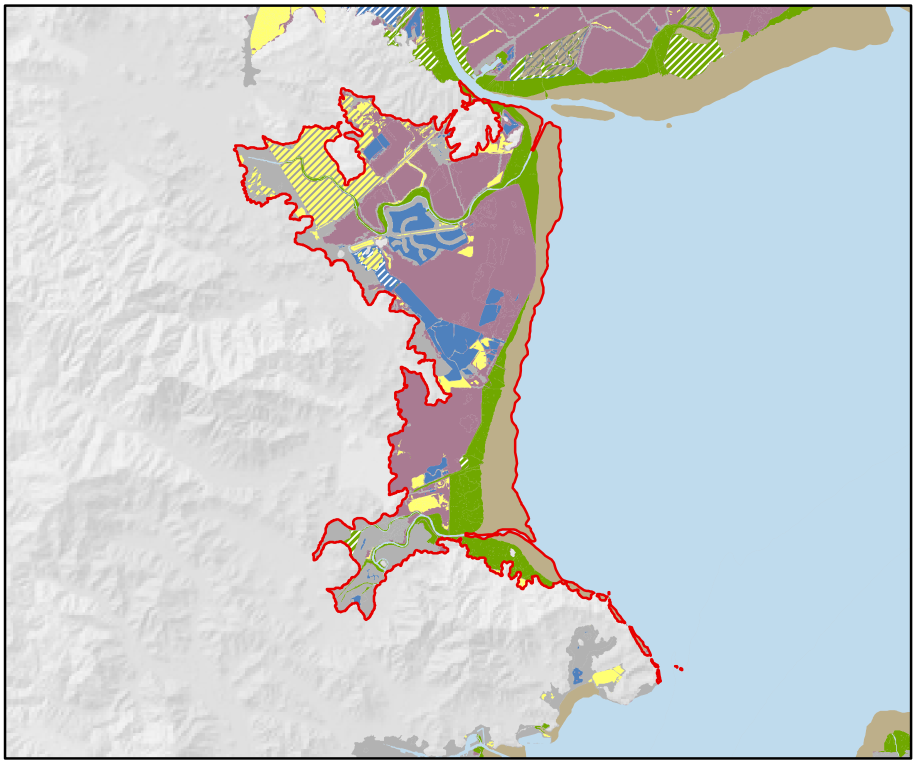
- Identify, conserve, and manage selected refugia for native bayland plants. Focus on unique or core populations of uncommon plants, especially in low marshes.
- Reduce the runoff of agricultural contaminants and nutrients from agricultural activities to improve water quality in the adjacent wetlands.
- Control perennial pepperweed invasions in otherwise intact tidal brackish marsh to prevent a loss of high-marsh plant diversity.
- Continue to control invasive *Spartina* in the Petaluma River and other tidal areas in this segment.

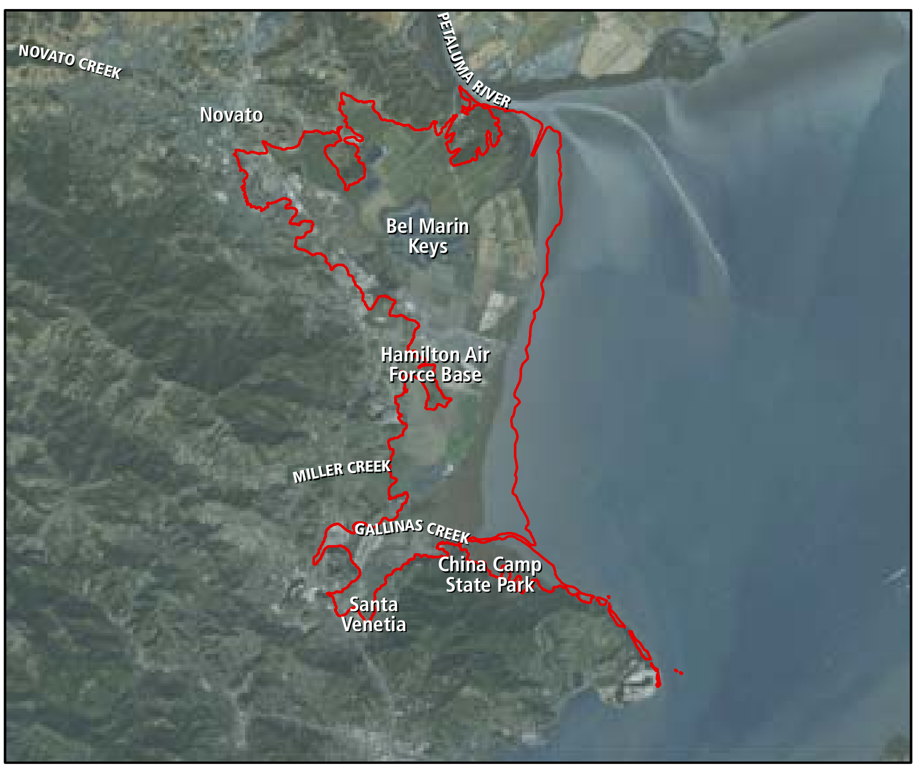
Restoration Benefits

Significant benefits for tidal marsh species such as the Ridgway's rail, black rail, and salt marsh harvest mouse could be achieved in this segment. Restoring tidal marsh would also improve nursery habitat for salmon, steelhead, starry flounder, and other aquatic species. Restoring and enhancing a fluvial/riparian–tidal marsh transition zone along San Antonio Creek and possibly Adobe Creek would benefit fish, amphibians, and plants. Restoring the estuarine–terrestrial transition zone would improve conditions for rare high-marsh and transition zone plant species. Furthermore, the conservation of transition zones and their reconnection with the baylands ecosystem would provide critical migration space for high tidal marsh and brackish marsh to migrate as sea levels rise toward the end of the 21st century.

Challenges

Challenges for the existing marshes and future transition zones are similar to those of the other segments between Novato Creek and the Napa River, namely, California Northern Railroad tracks, Highway 37 and Lakeville Highway east of the Petaluma River, and PG&E power lines. The Redwood Landfill was built in 1958 on historic marshes just north of Novato. It is bordered on three sides by San Antonio Creek. As with many other landfills, leachate drainage could be exacerbated if groundwater levels rise. The need to maintain and protect the landfill would be a constraint on the management of San Antonio Creek marshes with rising sea levels. Another area that will need to be protected is CBS Tower Field and the adjacent airfield at Gnoss Field. Here the drainage of the adjacent marshes has been considerably modified. Vineyard development on the adjacent hill slopes, changing the agricultural land use from low to high intensity, may constrain the options for managed realignment and flood protection. Planning will require coordination with local agencies and organizations, including Sonoma County, the Sonoma RDC, San Pablo Bay National Wildlife Refuge, CDFW, Sonoma Land Trust, Northwestern Pacific Railroad, SMART rail, and Caltrans.





NORTH MARIN

Western side of San Pablo Bay extending from the mouth of the Petaluma River to Point San Pedro

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment G.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2

Miles

N

Unique Opportunities

Segment G provides a unique opportunity to enhance tidal marsh in areas where natural terrestrial transition zones exist (e.g., China Camp State Park). In addition, transition zones can be secured in areas of low-intensity development because these zones will become the platform for tidal marshes by the late 21st century. The upper edges of transition zones will provide the foundation for limited high-marsh and brackish-marsh zones. Furthermore, riparian and tidal restoration along Novato, Gallinas, and Miller Creeks could enhance tributary streams for fish and amphibians.

Segment Features and Setting

Historically, this segment supported large areas of tidal marsh that were bordered by the widest mudflats in San Pablo Bay. The most extensive marshes lay between Novato and Gallinas Creeks and were exposed to significant wave action due to the orientation of the shoreline. Marsh berms formed along the shoreline, and ponds were abundant within the marsh plain as a result of the minimal internal drainage. The marshes north and south of Novato and Gallinas Creeks are more sheltered from wave action and formed well-drained plains with complex, sinuous channels. While Novato and Gallinas Creeks were the largest of the streams that flowed into and through the marshes, numerous ephemeral streams draining smaller watersheds flowed into the back of tidal marshes. Wide alluvial valleys supported riparian habitats through which steelhead and possibly coho salmon passed. Oak woodlands dominated the upland landscape. The Coast Miwok had permanent as well as seasonal village sites in the valleys and along the bayshore. This segment provided significant habitats for a variety of threatened and endangered species, including steelhead, Ridgway's rail, salt marsh harvest mouse, black rail, and tidewater goby.

Presently, much of the area near the bay is pasture or cultivated for oat hay, and residential developments have been established at Bel Marin Keys and several sites to the south. Since the original Baylands Goals report, the restoration of approximately 750 acres of wetlands on the former Hamilton Air Force Base has been completed, with restoration plans progressing on the adjacent 1,700-acre Bel Marin Keys property. A fairly large remnant marsh remains at the mouth of Gallinas Creek, including China Camp, which supports what appears to be the largest population of Ridgway's rails in the North Bay. Large freshwater emergent marshes are found along the western side of Novato Creek north of Highway 37 and at Pacheco Pond.

Implications of Drivers of Change

The primary driver of change in this segment will likely be the impacts of sea-level rise on flood protection in the city of Novato, the Santa Venetia community, and the Bel Marin Keys residential areas, where pressure to build engineering defenses against flooding and wave erosion, regardless of habitat impacts, may increase. However, tidal marsh restoration could be used to enhance flood protection. Without enhancement, existing tidal marshes may be unable to keep up as the rate of sea-level rise increases, resulting in greater inundation of the marsh plain. High marsh that is flooded only during spring tides may downshift to mid and low marsh that is regularly flooded, depending on sediment supply and accretion rates. Increasing tidal submergence coupled with wave erosion may ultimately result in the conversion of tidal marsh to mudflat and landward migration of the shoreline.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

As restoration projects are implemented and suspended-sediment concentrations are still sufficient to sustain marsh-building processes, the near term presents significant opportunities to restore large areas of tidal marsh with wide transition zones from China Camp to the Petaluma River. Since wave erosion is likely to increase as the bay deepens, coarse sediment nourishment may be needed in front of marsh scarps to reduce shoreline retreat. Similarly, along developed residential or commercial shorelines, narrow transition zones could be created to provide buffers against wave erosion and high-tide refugia. Restoring tidal marsh would provide opportunities to expand and reintroduce populations of rare plant species, such as northern salt marsh bird's-beak and salt marsh owl's-clover. Ridgway's rail could also expand into wide marshes remote from predator outposts and corridors. Reengineering levees to create gently sloping transition zones will buffer storm-wave runup and erosion, and lower the flood risk as well as facilitate landward migration of the marsh.

Lower Novato Creek Watershed

Large areas of public lands could be restored to a combination of tidal, seasonal, and riparian wetlands to create a mosaic of habitat types, including a large transition zone and a mix of fluvial–tidal habitats. This restoration would expand the tidal prism and reduce the need for dredging to maintain flood-channel capacity. Large freshwater marshes along the western side of Novato Creek north of Highway 37 and at the Pacheco Pond could also be enhanced as transition zone features. Similarly, treated wastewater and stormwater discharges might be realigned for diffuse discharge along wide, sloping engineered terraces on flood-control levees to provide some surrogate transition zone biogeochemical functions (nutrient transformation, sequestration, etc.). Simmonds Slough baylands (Atherton), currently managed as nontidal seasonal wetlands, may be hydrologically modified to restore tidal flows and establish brackish marshes influenced by wastewater discharge if upgrades are made to Highway 37.

Lower Miller Creek Watershed

The undeveloped area between the bay and Highway 101 (excluding China Camp State Park) provides rare, appropriate topography for extensive transition zone and connected high marsh. Complete tidal wetland systems should be restored here to connect the Hamilton marshes to those to the south.

Lower Gallinas Creek Watershed

Complete tidal wetland systems should be restored here to connect the marshes to the north and south. Steep artificial slopes and transition zones bordering the developed baylands of upper Gallinas Creek could be adapted to sea-level rise by engineering gentler slopes using suitable dredged flood-control-channel sediments. Again, treated wastewater could be used to create a seepage transition zone terrace and levee system, incorporating freshwater managed wetlands for waterfowl, within the existing and likely future transition zones near north Gallinas Creek baylands.

Long Term (latter half of the century, after SLR curve acceleration)

At some point the amount of sea-level rise may make it infeasible (cost ineffective) to maintain reliable flood protection for developed urban residential infrastructure in very low-lying areas. Land-use planning for a rising sea level will be imperative for cities to provide flood protection to the more densely populated areas while maintaining habitat benefits for a wide range of species. An important factor to consider while making such plans is whether it is possible to reestablish natural sediment transport from watersheds to tidal marsh areas to help maintain marsh elevations.

RECOMMENDED ACTIONS

China Camp State Park

For Habitats and the Landscape in General

- Restore an extensive transition zone and connected high marsh along the undeveloped area between the bay and Highway 101.
- Restore the large areas of public lands along lower Novato Creek to a combination of tidal, seasonal, and riparian wetlands to create a mosaic of habitat types, including a large transition zone and critical habitat at the fluvial–tidal interface.
- Protect and restore agricultural lands and other open space to reestablish transition zones and buffers adjacent to tidal marsh and provide space for landward migration, including oak woodlands and mixed evergreen forest along the entire ridge and hillslopes. Transition zone habitats can be created on gentle slopes in front of flood-risk-management levees.
- Consider ways to increase the sediment supply to tidal baylands. Improve the trapping efficiency of restored marshes to increase their accretion rates and reuse dredged sediments.

For Particular Wildlife Populations

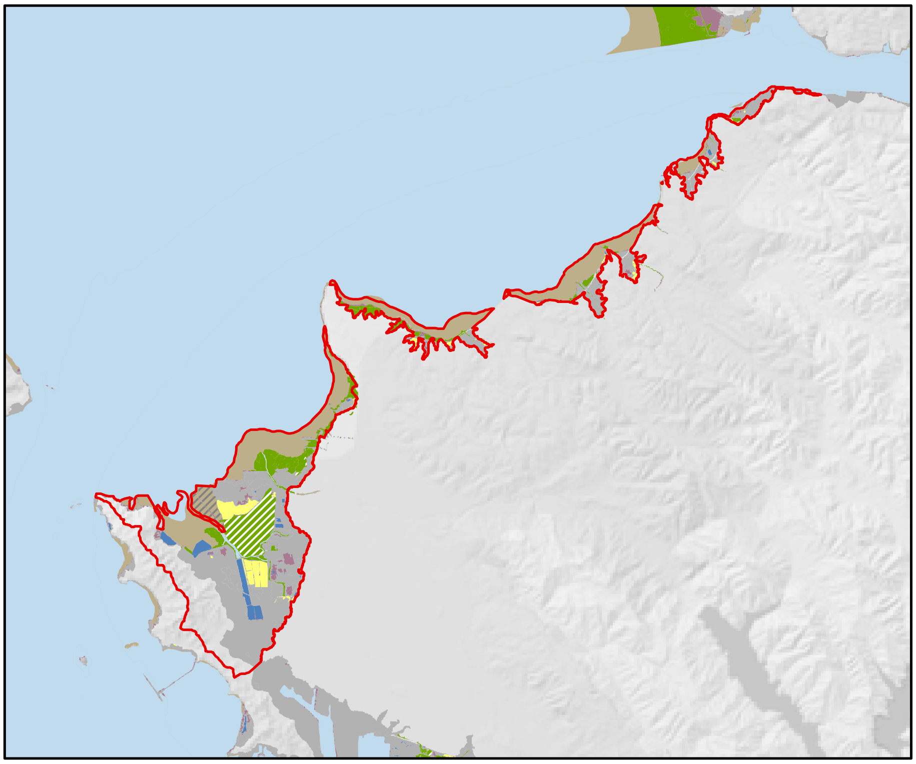
- Identify, conserve, and manage selected refugia for native bayland plants. Focus on unique or core populations of uncommon plants, especially in low marshes.
- Continue to control invasive *Spartina* in the mouth of Gallinas Creek, Hamilton Field, and other tidal marshes and restoration areas.

Restoration Benefits

Restoring tidal marshes, transition zones, and the lower reaches of streams would expand suitable habitat for many tidal marsh species, including rare and endangered plant, fish, bird, and mammal species such as the Ridgway's rail. The conservation of valleys and their reconnection with the baylands ecosystem would provide critical space for high tidal marsh and brackish marsh to migrate as sea levels rise toward the end of the 21st century. Reconnection of groundwater and surface stream discharges to tidal marsh would also provide critical brackish buffers to increasing salinity, thereby supporting tall, emergent vegetation that forms essential high-tide cover. The reuse of coarse-grained dredged sediment could simulate natural alluvial sediment transport that could help provide and enhance this groundwater–marsh connection. Wastewater flows could also be used to enhance seasonal and brackish marsh habitat types that are rare in this part of the Bay.

Challenges

Challenges include the commercial and residential developments at Bel Marin Keys, Hamilton Field, and at several sites to the south; diked intensive recreational land uses (golf) in subsided baylands at Black Point; low-lying segments of Highway 37, State Highway 101, other roads, and a railroad that may be renovated for commuter use. In some areas the railroad grade parallels the shoreline within the transition zone, making it a challenge to future migration because in the near term it will, along with other roads on the bay edge, prevent any significant landward migration of the baylands. The highway is further inland than the railroad and therefore represents a longer-term constraint. Development between the railroad and the highway is a long-term constraint as well. Each drainage channel that enters the existing transition zone or passes through areas of future transition zone presents significant flood-protection challenges. Also, multiple cultural sites relating to Coast Miwok habitation and early European and Asian settlements within the existing, near-term, and long-term transition zone must be considered during any effort to enhance, restore, or create transition zone habitat. Planning will require coordination with local agencies and organizations, including Marin County and Caltrans.



CONTRA COSTA WEST

Southeastern edge of San Pablo Bay between Point San Pablo and the Carquinez Bridge

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment H.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

In Segment H, many opportunities exist on public land, or may become available through conservation acquisitions of vacant land, to restore and enhance a wide range of subtidal offshore habitats as well as shoreline, stream, and terrestrial habitats; to restore connections among habitat types; and to set the stage for integrating habitat with shoreline protection. There is potential to restore a corridor of tidal marsh between Wildcat Marsh and San Pablo Marsh, as well as riparian vegetation along the streams that flow into these marshes. Multiple creeks (Wildcat, Pinole, and others) are already the focus of both community-based restoration efforts and US Army Corps of Engineers and Contra Costa County flood-control projects, and this work could be leveraged with additional activities that integrate climate-change adaptation techniques.

A variety of shoreline habitats could be restored on the Point Pinole and Point San Pablo peninsulas. From the north side of Point Pinole Regional Park to the Chevron refinery property, tidal and other disturbed wetlands and adjacent low-lying vacant uplands may become available for restoration, providing the opportunity to establish an extensive complex of diverse types of wetlands as well as upland transition zones, and enabling eventual wetland migration. Vacant low-lying uplands in creek floodplains could also be used as retention areas to relieve the upstream flooding of developed areas that may otherwise occur from storms of increasing intensity coupled with rising sea levels. Populations of tidal marsh plants of concern, including soft bird's-beak and salt marsh owl's-clover, could be restored. The segment also has multiple small habitat areas that include small but potentially viable populations, such as the steelhead run on Wildcat and Pinole Creeks. Conditions at some sites are suitable for native eelgrass and oyster restoration and enhancement. The largest eelgrass bed in the bay, offshore between Point Molate and Point Pinole, should be protected and enhanced.

The northeastern half of this segment will likely remain highly urbanized with limited opportunities for large-scale restoration, although there are larger opportunities southwest of Point Pinole Regional Shoreline. Many small-scale restoration and green engineering projects could be undertaken to meet the co-objectives of improving habitat quality and protecting the existing infrastructure, shorelines, and baylands. Partnerships should be pursued with the industrial and residential communities along the shoreline to create habitat bayward of their flood-protection levees through horizontal levees, living shorelines, or other green infrastructure. Pilot projects here could improve water quality and environmental health, provide preliminary data to inform similar adaptation designs in other segments, and provide benefits to the greater baylands. Point Molate Beach Park and Point Pinole Regional Shoreline provide unique, visible opportunities to educate the public about wildlife habitat needs.

Segment Features and Setting

This segment receives heavy marine influences and thus high-salinity waters. Historically, this segment was characterized by a narrow shoreline band of small tidal marshes, beaches, and extensive tidal flats. A broad tidal flat once bordered most of the portion of this segment north of Point Pinole, except along the steep shoreline near Carquinez Strait. A string of small tidal marshes lay in small coves along this shoreline and at the entrances to Garrity, Pinole, Refugio, and Rodeo Creeks. A large tidal marsh spanned much of the area between the San Pablo peninsula and Point Pinole and extended the length of lower Castro Creek. The adjacent uplands supported extensive areas of moist grassland and were dissected by numerous small streams that originated in the hills to the east. Some of these streams were bordered by riparian corridors and provided spawning and rearing habitat for steelhead. Some had lagoons at their mouth, and others terminated in willow groves.

This segment includes stretches of highly urbanized developed shorelines with a high-energy-wave environment and limited sources of local sediment. This segment has undergone considerable development, with cities, industrial areas, the Giant Powder Works plant, petroleum and natural gas facilities, wastewater treatment infrastructure, electrical utility projects, creek channelization, residential development, and transportation corridors. Landfills and other developments occupy many sites that were once tidal flat or marsh. Most of the tidal marsh in the Castro Creek basin has been filled for heavy industry (oil refinery and rail yard) and the West Contra Costa County Landfill. Some tidal marshes remain to the north and south of this landfill at the mouths of San Pablo and Wildcat Creeks, and a major tidal and seasonal wetland restoration project is under way at Breuner Marsh just south of Point Pinole. Union Pacific railroad tracks lie within a few yards of the shore for the entire distance north of Point Pinole, and almost no tidal marsh remains in this area. Tidal flats still abound throughout most of their historical distribution, and there are several sandy barrier beaches and lagoons. Small fringe beaches and rocky intertidal areas are present along many stretches of the segment, and intertidal and shallow subtidal areas support some of the most healthy and robust intertidal and subtidal eelgrass, oyster, and macroalgal beds in the bay. The largest eelgrass bed in the bay is located offshore between Point Molate and Point Pinole. Some vernal pools remain in the adjacent uplands.

Implications of Drivers of Change

The developed areas here will become increasingly difficult to protect as sea levels rise, but unlike segment L (Berkeley–Albany), this segment has some adjacent areas at appropriate elevations that could allow for the migration of baylands, particularly in the southwestern half.

Outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of the small remaining marsh edges, resulting in the narrowing and potential loss of marshes and other unique habitats such as coarse beaches and rocky intertidal areas. This largely urbanized segment has development that directly abuts the shoreline, which limits migration space and areas for restoration-based adaptation. Innovative and experimental approaches need to be tested, which

Shorebirds at sunset

may include sediment placement, the use of uncontaminated on-site fill in restoration designs, and integrated multihabitat designs with multiple biological and physical objectives.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

Immediate actions to enhance the existing baylands can help maximize resilience in this segment when sea-level rise rates will still be relatively low. Living breakwaters could be created around fringing marshes to preserve and enhance native eelgrass and oyster beds. Introducing fine sediment to recharge mudflats and marshes could increase vertical accretion rates. There are some opportunities to encourage the landward migration of marshland, but in many locations they are quite limited. However, opportunities to partner with the industrial and residential communities along the shoreline can be pursued to create habitat bayward of their flood-protection levees through horizontal levees, living shorelines, or other green infrastructure.

Diverse pocket habitats could be preserved, enhanced, or created, then linked together to form a subregional habitat corridor. Vertical enhancements could be installed in subtidal and intertidal areas where there is hardscape (living seawalls and substrate improvements to docks are two examples). Many existing habitats could be enhanced by improving tidegate management and removing trash, contaminated soils, and derelict boats.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the long term, sea-level rise rates will likely outpace vertical accretion rates, and marshes in this segment generally do not have enough space to migrate landward to survive. Prior to that point, a plan for restoring or relocating the functions within the existing tidal marshes out of the hazard zone should be implemented. Creation of wetlands bayward of the flood-protection levees, possibly using wastewater to enhance habitat on the slope, could provide space for landward migration. The planned communities built over former wetlands and open bay in Hercules and other areas will be at risk for flooding as sea levels begin to rise. If opportunities for managed retreat become available, options to restore these areas to baylands habitats should be pursued.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Design and restore complete tidal wetland systems, even at a small scale, that include tidal marshes, beaches, lagoons, and broad transition zones. Develop techniques for implementing active revegetation, high-tide refuge islands, and subtidal habitat restoration.
- Restore a tidal marsh corridor along the eastern edge of the Richmond Landfill to reconnect Wildcat Marsh and San Pablo Marsh.
- Protect and restore native oyster beds and eelgrass beds from the Carquinez Bridge to Point San Pablo.

- Restore vernal pools in the adjacent uplands.
- Protect land as it may become available to incorporate transition zones into restoration designs.
- Use clean on-site bay fill creatively in restoration designs, including using it to construct seasonal wetlands that may become tidal wetlands with rising seas.

FOR PARTICULAR WILDLIFE POPULATIONS

- Enhance East Brother Island for harbor seal breeding habitat as Castro Rocks becomes inundated.
- Assess predator impacts caused by West County Landfill to define specific actions for improvement.
- Protect and enhance Pacific herring spawning areas, such as Point Molate.
- Develop projects to assess effectiveness of artificial floating islands for nesting and high-tide refugia.
- Control invasive species, especially perennial pepperweed in high-marsh rare-plant associations, and invasive *Spartina* across the full tidal frame.

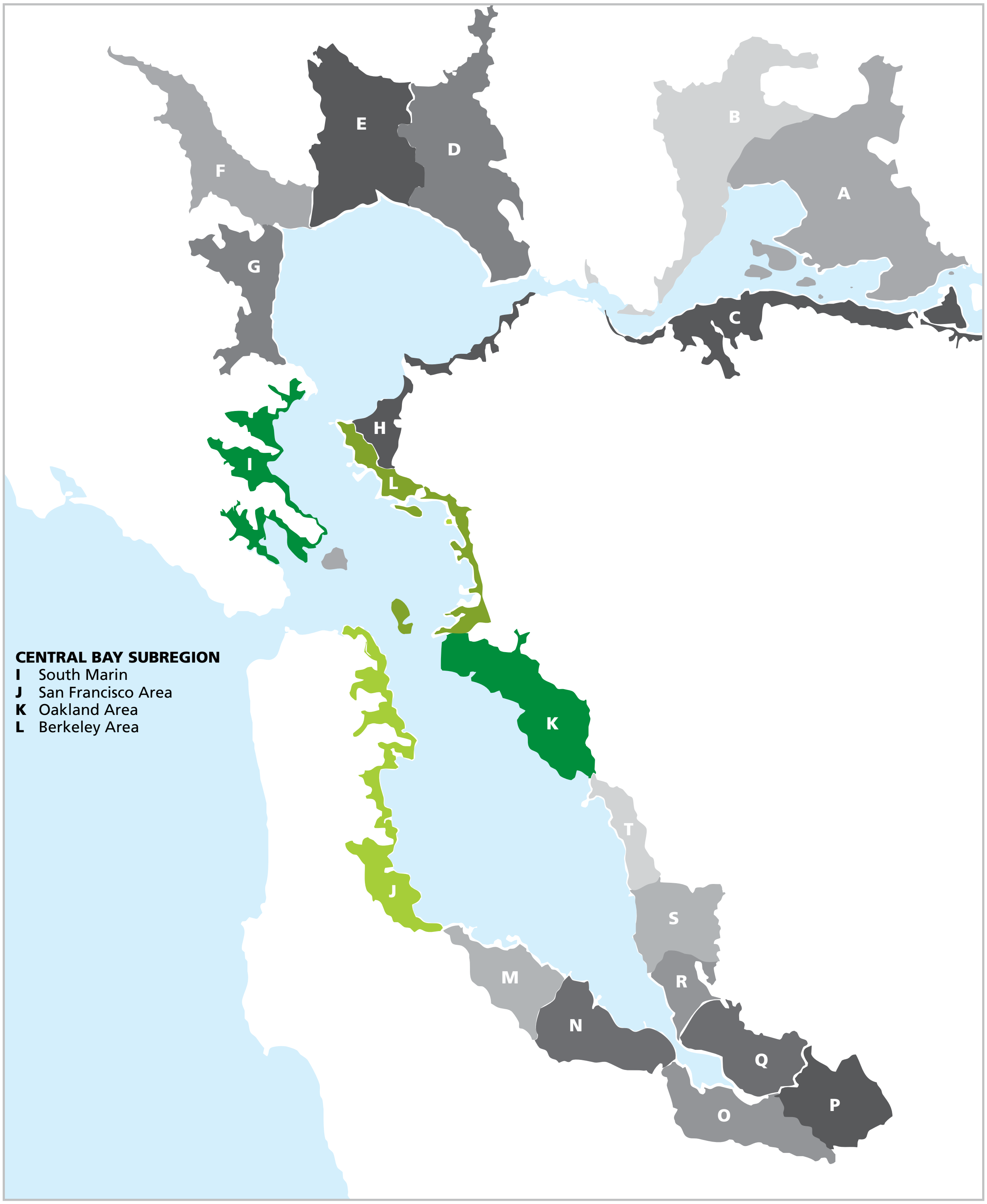
Restoration Benefits

The recommended projects for this segment would demonstrate to the public innovative techniques to restore and enhance habitats for many populations of key fish, amphibian, reptile, insect, mammal, and bird species. Restoring wetlands would enhance habitats for endangered species such as the Ridgway's rail and salt marsh harvest mouse. Reestablishing a tidal marsh corridor between the Wildcat and San Pablo Marshes would link these existing areas, increase tidal marsh acreage, and reduce the isolation of small-mammal populations. Restoring and improving marsh–upland transition zones would benefit populations of several rare plants. Restoring beach habitat could improve conditions for sensitive plant species. Protecting islands would assure suitable sites for colonial nesting birds. Restoring native oyster and eelgrass beds offshore would provide habitat for birds and fish, and might enhance food and nursery resources for species that use both wetlands and offshore shallow subtidal habitats. Living-shorelines designs might provide wave attenuation, sediment stabilization, and some flood protection in the near term for tidal marsh habitats on the shoreline.

Challenges

The major challenges in this segment are the large urban population, extensive fill along the shoreline, on-site contaminants, the existing infrastructure, bridges, and wastewater treatment plants, railroad tracks and spurs, derelict creosote wharfs and piling structures, the West County Landfill, major highways, flood-control considerations, exotic predators (e.g., rats and red fox), and invasive *Spartina*.

Central Bay Subregion



Central Bay Subregion

LANDSCAPE VISION

The Central Bay is the region's most intensively developed shoreline, yet it is home to critical bayland resources. The vision for the Central Bay is to protect and enhance extant marshes and mudflats, while connecting urban residents to the baylands with restoration projects that demonstrate how climate change adaptation can provide vital ecosystem services while improving ecological health. This subregion will likely remain highly urbanized with limited opportunities for large-scale restoration, yet there are opportunities for small-scale restoration with the co-objectives of improving habitat quality and connectivity, protecting existing infrastructure and habitats, and generating new knowledge and new public–private partnerships and community involvement.

The goal for the Central Bay is to protect and restore tidal marshes, mudflats, beaches, rocky intertidal areas, subtidal habitats, and seasonal wetlands to create an archipelago-style corridor of tidal baylands.

Recommended Actions

- Restore tidal marsh wherever possible, and particularly where streams enter the baylands. Protect, enhance, and restore streams and riparian habitats so that they pass through, rather than around, tidal marshes. Restore natural salt ponds on the East Bay shoreline, and protect and enhance shallow subtidal habitats (including eelgrass and oyster beds) and shorebird roosts. Incorporate transition zones and terrestrial buffers beyond the existing transition zone into all appropriate projects. Find opportunities to create or improve floodplains, off-channel aquatic habitat, or low marsh along flood-control channels, including upstream areas. Improve dock substrates and tidegate management. Study and consider removing derelict creosote pilings, contaminated soils, and derelict boats. Reduce and remove trash that terminates in the bay.
- Pursue opportunities to enable the baylands to persist and migrate with sea-level rise, despite limitations from steep topography and urban and industrial development. Consider creating very low-slope transition zones bayward of the flood protection levees to provide space for landward migration, possibly using wastewater to develop wetlands on the slope. Use any of the following techniques where appropriate: recharge mudflats with sediment to increase the local supply, stabilize the bayward marsh edge with a coarse beach to prevent erosion, and improve natural-sediment-transport processes to maximize vertical accretion in the landward portion of the marsh. Create living breakwaters that incorporate native eelgrass and oyster beds and protect the habitats and infrastructure behind them. Develop living seawalls and docks for the region at critical infrastructure sites, such as the Port of San Francisco. If developed baylands are abandoned due to rising tides, pursue opportunities to restore these areas to functioning habitats that provide ecosystem services.

RECENT RESTORATION

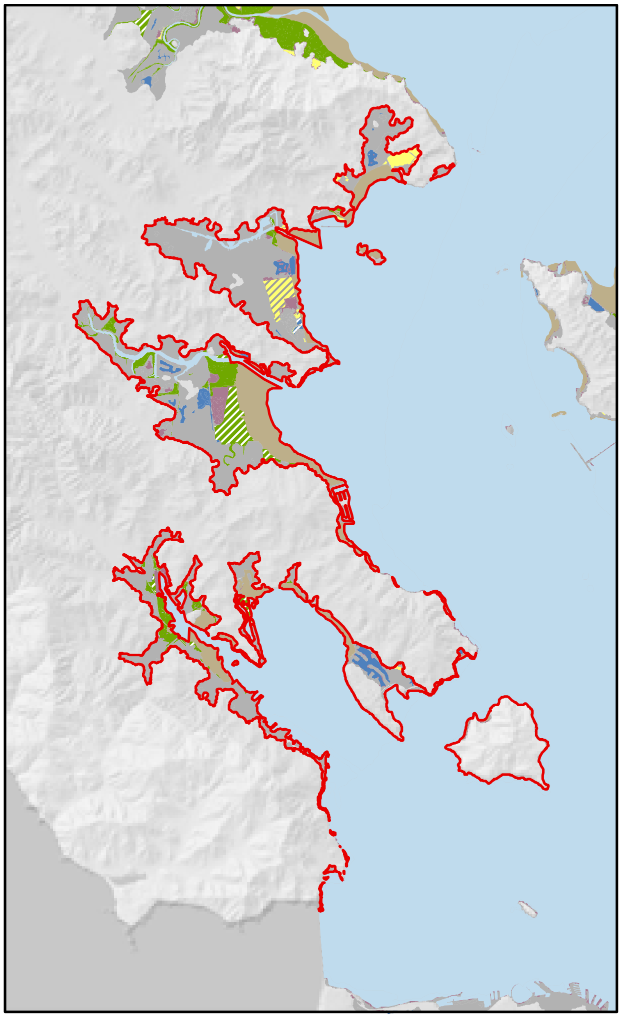
Despite the urbanization and limited baylands acreage in this region, several recent restoration projects have been completed at Crissy Field, Yosemite Slough, Lake Merritt, Martin Luther King Jr. Regional Shoreline, the Berkeley Meadow, and other areas.

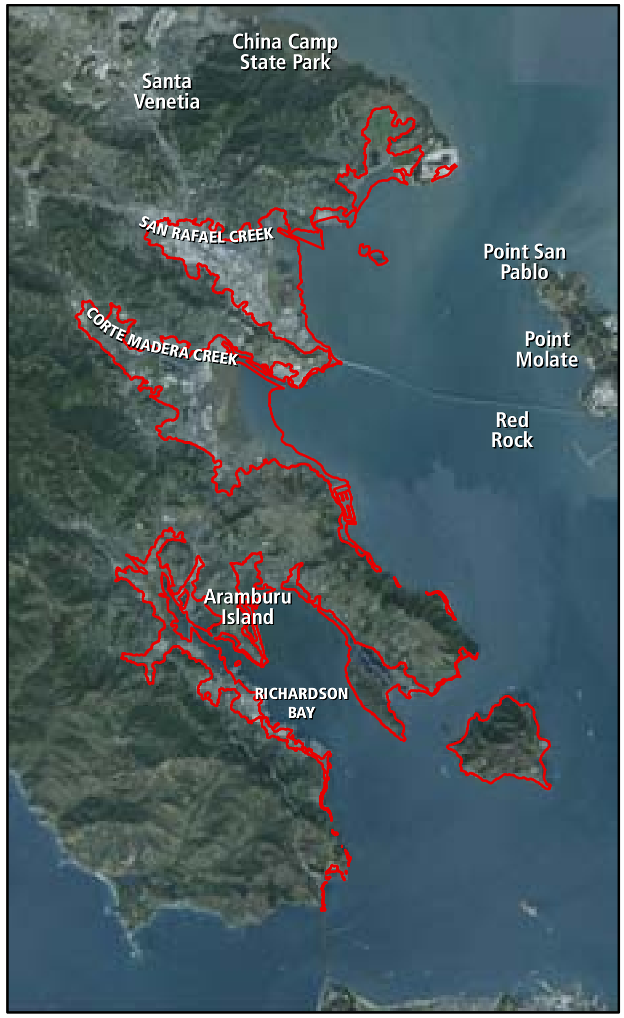
CHALLENGES

Achieving the Central Bay vision is subject to significant infrastructure constraints (e.g., those posed by ports and airports, military facilities, transportation and utility corridors, bridges, wastewater treatment plants, and landfills), the presence of invasive species (principally invasive *Spartina*), and the limitations of steep topography, urban and industrial development, and contamination at restoration sites. Private landowners and public entities will need to be willing to undertake habitat restoration and enhancement in the most urbanized portion of the baylands and to retrofit infrastructure in a manner in keeping with ecosystem health. Although largely under control, invasive *Spartina* remains a challenge for the Central Bay, including at sites such as San Leandro Bay. Other challenges include a large urban population, extensive fill along the shoreline, on-site contaminants, flood-control considerations, and exotic predators (e.g., rats and red fox).

The Central Bay subregion includes segments I through L.

Mudflats and shoreline armoring





SOUTH MARIN

Western edge of central San Francisco Bay extending from Point San Pedro to the Golden Gate

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment I.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2

Miles

N

Unique Opportunities

Segment I has low-lying urbanized lands that are not protected by large flood-control levees, and areas already subject to flooding. Thus, this segment can serve as a laboratory for testing ecological design concepts for sea-level rise adaptations that integrate flood control and habitat benefits. In particular, marshes can be used for wave attenuation, and coarse-grained beaches can buffer the impacts of wind–wave erosion. This segment is highly visible to the public. Demonstration projects could educate residents and raise awareness about the impacts of climate change and gain support for solutions to address these impacts. There are several opportunities to provide important wide transition zones and migration space for tidal salt marshes to migrate landward in response to sea-level rise. Nearshore eelgrass and oyster beds can be expanded at multiple locations as well.

Segment Features and Setting

Historically, the relatively steep bayshore topography of this segment limited large areas of tidal marsh to the lower reaches of San Rafael and Corte Madera Creeks and to the western part of Richardson Bay. In addition, there were many historic pocket and barrier beaches along sections of the Richardson Bay shoreline. The steep watersheds of Mount Tamalpais with their high sediment yields contributed fluvial sediment to the baylands.

Today, much of the baylands within this segment has been filled and developed for urban, transportation, and residential uses. Only a few remnants of the original tidal marshes remain (e.g., Heerdt Marsh and the Corte Madera Ecological Reserve). However, mature wide salt marsh habitat has regenerated near the mouth of Coyote Creek, supporting regionally rare plant populations, including some of the largest colonies of northern salt marsh bird's-beak in San Francisco Bay). The Corte Madera Ecological Reserve supports one of the densest populations of Ridgway's rails in northern San Francisco Bay; it also supports a black rail population. Important tidal mudflats remain in Corte Madera Bay (the Corte Madera Ecological Reserve), Richardson Bay (the Richardson Bay Audubon Sanctuary), and Mill Valley marshes. Eelgrass and oyster habitats occur along the length of this segment, from McNears Beach to Fort Baker.

Harbor seals formerly used the Corte Madera Marsh and Strawberry Spit areas for resting and pupping. Aramburu Island (on the north end of Strawberry Spit) has been rehabilitated with beaches next to both deep water and tidal flats to accommodate reoccupation by seals, terns, and shorebirds, but alternative seal haul-out and pupping habitats are limited in this segment.

Implications of Drivers of Change

High-tide inundation is already affecting the eastern Marin shoreline. During high-tide events the urbanized bay edge is subjected to direct flooding and roadway closures. Sea-level rise can be expected to significantly worsen these conditions as well as threaten critical infrastructure such as Highway 101. Subsidence due to development on bay mud exacerbates flooding; low-lying areas have elaborate systems of pump stations and detention ponds that are not necessarily sized to accommodate future conditions. The flood-control requirement to protect existing infrastructure and both residential and commercial areas will be a large driver of change, and the way that flood control integrates with habitat goals will be a challenge. Outboard levees, trails, and roadways in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the ongoing erosion of marsh edges, resulting in the narrowing of marshes and a loss of habitat. A reduced sediment supply also threatens the ability of the natural marshes to keep pace with sea-level rise.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The near term presents significant opportunities to build on studies completed at the mouth of Corte Madera Creek as well as in Richardson Bay (Aramburu Island). Pilot projects could demonstrate ecological design concepts for the fringing marshes and pocket beaches.

Sediments dredged from creeks for flood control could be recycled for marsh and mudflat nourishment within the sub-embayments of Richardson and Corte Madera Bays, following the natural deposition patterns that established the existing marsh landscape positions. Sediment could be placed directly as hydraulic thin-layer deposits, or placed on adjacent mudflats to be resuspended and then dispersed by tidal action through creek networks into the interior marsh plains.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the longer term, if sea-level rise accelerates and sediment supply falls as projected, providing flood protection for the highly urbanized edge will become increasingly important. Existing tidal marshes will be subject to greater erosion, further narrowing the fringing marshes. Tidal marshes may be unable to keep up with sea-level rise, resulting in more inundation of the marsh surface. This will likely lead to a habitat conversion to low marsh, mudflat, and ultimately subtidal areas. Landward migration of the marsh should be undertaken where there is room for managed retreat. Construction of a gently sloping transition zone bayward of the levee would facilitate such migration. Coarse-grained beach will need to be strengthened and perhaps augmented with larger-grained sediments as wave energy increases with rising sea levels.

At some point, the amount of sea-level rise will make protection of residential and commercial developments and infrastructure from both direct bay coastal flooding and fluvial flooding (from backwater storm-drain flooding from a higher bay level) a preeminent public safety goal. Other approaches

Harbor seals

such as muting high tides with engineered barriers may be required to maintain public safety during flooding events. Working with local governments to explore managed retreats and changes to building and planning codes should be considered in long-term planning.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Design and restore complete tidal wetland systems, even at a small scale, that include tidal marshes, beaches, lagoons, and broad transition zones. Develop techniques for implementing active revegetation, high-tide-refuge islands, and subtidal habitat restoration.
- Tidal restoration should stress wide platforms for high salt marsh and local native terrestrial transition zone (wet meadow) vegetation tolerant of infrequent tidal flooding, rather than an expanded intertidal marsh plain that is subject to drowning as the sea-level rise accelerates.
- Incorporate seasonal and perennial wetland features in the transition zone by using freshwater discharges (subsurface or diffuse sheetflow) from treated stormwater.
- Create transition zone habitats on gentle slopes in conjunction with flood-risk-management features (or other high-ground areas). Consider preparing transition zones with dredged material and treated wastewater to encourage tidal-channel formation and pan development, resulting in topographic complexity (high-tide refugia).
- Protect fringe marshes throughout the segment.
- Protect subtidal habitat including mudflats, native oyster beds, and eelgrass beds.
- Consider ways to increase sediment supply to the tidal baylands. For example, dredged sediments could be placed directly on local marshes or adjacent mudflats to be reworked by wave and tidal action to build up local suspended-sediment concentrations and marsh-accretion rates.
- Reduce the horizontal erosion of marshes by creating coarse beaches in front of marsh scarps.
- Evaluate the construction of a steep transition zone using strategically placed fill in areas of the bay to decrease wave attenuation and reduce costs for levee protection.

FOR PARTICULAR WILDLIFE POPULATIONS

- Provide additional harbor seal haul-out and pupping sites in Corte Madera Marsh and at Richardson Bay.
- Protect and enhance Pacific herring spawning areas.

- Incorporate the management of rare and uncommon estuarine plant populations (augmenting their population, giving additional colonies wider distribution) in tidal marsh restoration and management projects, including sediment nourishment.
- Preserve existing populations of rare high-marsh and transition zone plants as seed sources for future reintroduction and population management as long as feasible.
- Control the spread of pepperweed in rare high-marsh plant associations and control and prevent the reemergence of invasive *Spartina* at all locations.

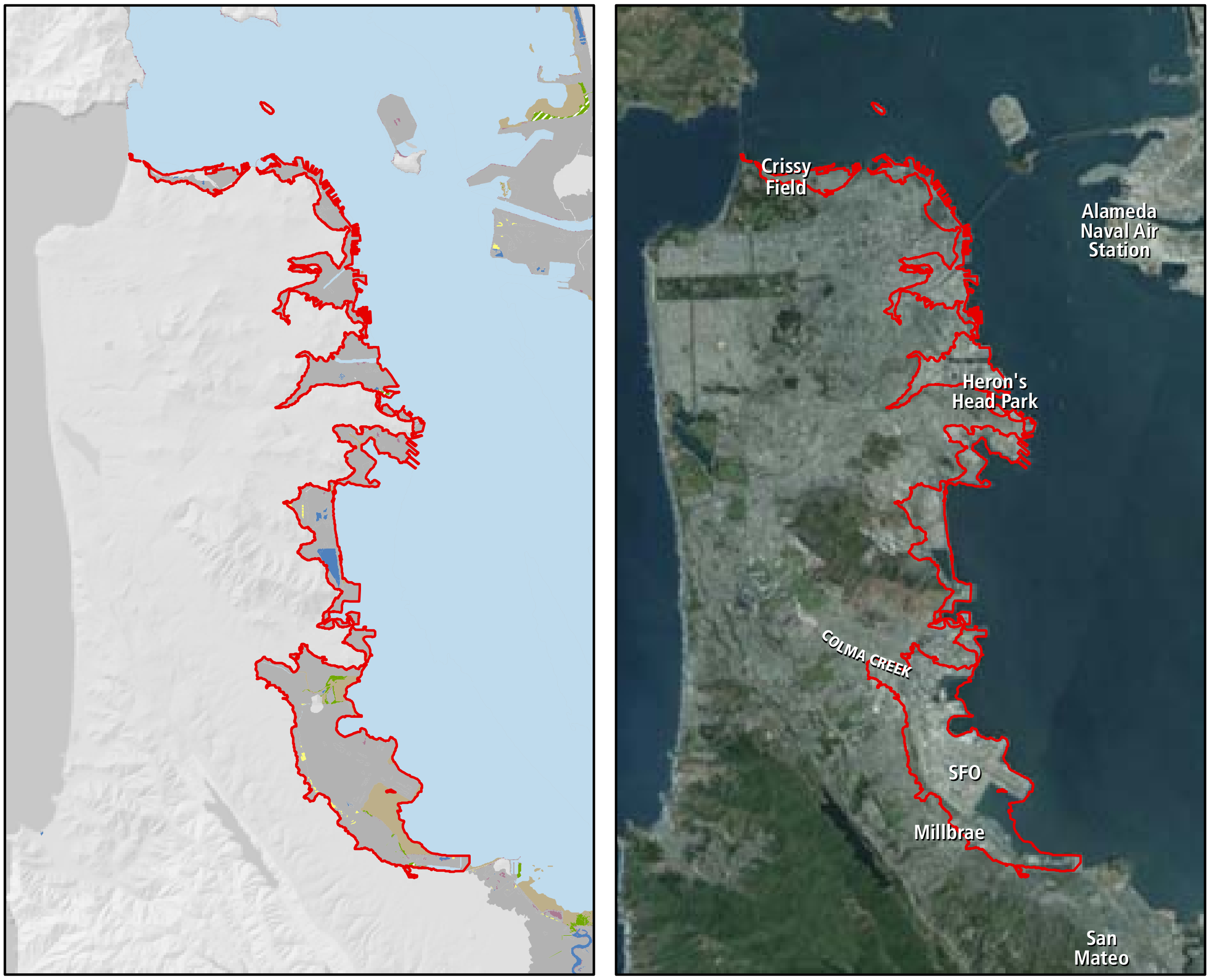
Restoration Benefits

Constructing wide terrestrial transition zones landward of existing major salt marsh habitats of the Corte Madera Ecological Reserve would significantly improve the resilience of existing Ridgway's rail and black rail populations, improve wildlife buffers along trails, and offset tidal marsh submergence and the loss of high-tide cover as existing marsh plains submerge. Implementing the recommendations for this segment would improve habitat support for harbor seals, salt marsh harvest mice, and other mammals.

Enhancing seasonal wetlands would provide improved high-tide roosting habitat for shorebirds. Enhancing riparian and instream habitats would benefit migratory songbirds and steelhead. Restoration of coarse-grained gravel beach habitat at various locations would provide high-tide roosting habitat for shorebirds and terns. Isolated (islandlike) marsh-fringing beaches may provide additional nesting sites for terns. Restoration of native oyster and eelgrass beds offshore would provide habitat for birds and fish, and might enhance food and nursery resources for species that use both wetlands and offshore shallow subtidal habitats. Living-shorelines designs may provide wave attenuation, sediment stabilization, and some flood protection in the near term for tidal marsh habitats on the shoreline.

Challenges

Challenges in this segment include Highway 101, an urbanized edge with roadways and infrastructure that currently flood (e.g., Miller Avenue, Manzanita parking areas, the Mill Valley sewer plant), Northwestern Pacific railroad tracks, flood-control considerations, erosion from the Larkspur Ferry, and exotic predators (e.g., rats and red fox), invasive *Spartina*, and on-site contaminants.



SAN FRANCISCO AREA

Western side of central San Francisco Bay between the Golden Gate and Coyote Point

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment J.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Segment J provides an opportunity to restore tidal wetlands, beaches, sand dunes, intertidal rocky areas, and subtidal habitats that enhance its ecological connections. Tidal marshes at several sites south of San Francisco can also be restored or enhanced. The locally extirpated California seablite and associated rare or uncommon high-marsh plant species can be reestablished. West of the airport are opportunities to enhance freshwater marshes and adjacent seasonal wetlands for the San Francisco garter snake and red-legged frog. Conditions at some sites are appropriate for native eelgrass and oyster restoration. Other habitats, including several roosting sites, can also be protected and restored.

The segment is highly visible to the public. Demonstration projects could educate residents, strengthen their connection to the environment, raise awareness about the impacts of climate change, and promote solutions that improve the health of the baylands and its resources. Multiple creeks (including creeks in the Presidio and Colma Creek) are already the focus of community-based restoration efforts, and this work could be leveraged with other activities integrating climate-change-adaptation techniques. Crissy Field, the San Francisco waterfront, San Francisco International Airport (SFO), and multiple large marinas provide unique, visible opportunities to educate the public about wildlife habitat needs.

This segment will remain highly urbanized, with limited opportunities for large-scale restoration, but it presents many opportunities to develop small-scale restoration and green engineering projects toward meeting the co-objectives of improved habitat quality and the protection of existing infrastructure, shorelines, and baylands. Critical infrastructure, such as SFO will need to be protected, but there are ample opportunities for small improvements that may result in enhanced habitat corridors and better linkages for species that use the bay and baylands.

Segment Features and Setting

Historically, this segment supported many kinds of habitats. Barrier beaches and marshes existed in small coves between the local headlands, often in connection with the mouths of streams. Tidal marsh was also present along the lower reaches of streams and in several small embayments at sites such as China Basin, Islais Creek, and Hunters Point. A wide band of tidal marsh extended from near Candlestick Point southward to Coyote Point. This area was one of the major historical localities of the locally extirpated California seablite.

This segment receives heavy marine influences and high salinity. It includes highly urbanized shorelines, a high-energy-wave environment, and limited sources of local sediment. Today, cities, military bases, industrial sites, marinas, and port facilities line much of the shore. The Port of San Francisco and its piers cover much of the San Francisco shoreline. SFO is in the middle of a former large tidal marsh. West of the airport is an area of seasonal wetlands and permanent freshwater marsh. At several sites along the modern shoreline, shell and sand beaches have re-formed naturally. Restoration of tidal marsh and other habitats is under way at Crissy Field, Heron's Head Park, and Yosemite Slough. Much of the shoreline south of San Francisco has been altered by Highway 101 and residential and industrial development. This area includes remnant fringe marshes, lagoons, mudflats, rocky intertidal areas, fragmented small native oyster populations, and other remnant habitats.

Implications of Drivers of Change

The developed areas in this segment will become increasingly difficult to protect as sea levels rise, and there are limited natural areas and elevations that could allow for the migration of baylands. Seawalls, piers, and communities offshore from Highway 101 in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of the remaining small marsh edges, resulting in the narrowing and potential loss of marshes and other unique habitats such as coarse beaches and rocky intertidal areas. This urbanized segment has a great deal of existing development that directly abuts the shoreline, limiting the migration space and areas for restoration adaptation. Innovative and experimental approaches need to be tested that may include sediment placement, the use of uncontaminated on-site fill in restorations, and integrated multihabitat designs with multiple biological and physical objectives.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

This segment is highly urbanized and constrained by steep shorelines and development directly adjacent to the baylands. In the near term, when sea-level rise rates will still be relatively low, actions that enhance the existing baylands and provide immediate ecological benefits will maximize shoreline resilience. Living breakwaters could be created around fringing marshes to preserve and enhance unique features like native eelgrass and oyster beds. Partnerships should be pursued with the industrial and residential communities along the shoreline to create habitat bayward of their flood-protection levees (through horizontal levees, living shorelines, or other green infrastructure).

Major land uses such as the Port of San Francisco will remain largely in current configurations, and they will need to be protected, providing opportunities for approaches that haven't yet been tried locally, such as "living seawalls." Diverse pocket habitats could be preserved, enhanced, and created, then linked together to create a subregional habitat corridor. Vertical enhancements (living seawalls, substrate improvements to docks, etc.) could be made in a few subtidal and intertidal areas where there is hardscape. Many existing habitats could be enhanced by improving tidegate management and removing contaminated soils and derelict boats. A stronger focus could be placed in removing trash that terminates in the bay. Habitats could be created along flood-control channels, floodplains, and off channels. Low-elevation marsh and wetland could be restored. Upstream opportunities are limited but should be included in any plans.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the long term, sea-level rise rates will likely outpace vertical accretion rates, and marshes in this segment generally do not have enough space to migrate landward to persist. Prior to that point, a plan for restoring or relocating the functions within the existing tidal marshes should be implemented. Creating wetlands bayward of the flood-protection levees, possibly using wastewater to enhance habitat on the slope, could provide space for landward migration. The planned communities built over former wetlands and open bay in Millbrae and other areas will be at risk for flooding as sea levels rise. If opportunities for managed retreat become available, options should be pursued to restore areas to baylands or to connect bay habitats.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Preserve, enhance, and create diverse pocket habitats that are linked in a subregional habitat corridor that encompasses sand beaches, eelgrass, oyster beds, macroalgal beds, mudflats, rocky intertidal areas, and tidal marsh.
- Design and restore complete tidal wetland systems, even at a small scale, that include tidal marshes, beaches, lagoons, and broad transition zones. Develop techniques for implementing active revegetation, high-tide-refuge islands, and subtidal habitat restoration.
- Consider ways to increase sediment supply to the tidal baylands, including reconnecting stream channels into marshes and augmenting the trapping efficiency of tidal baylands to foster accretion, as appropriate.
- Protect and restore native oyster and eelgrass beds in suitable areas.
- Protect land as it may become available to incorporate transition zones into restoration designs. This may include remediating contaminated land (wastewater treatment ponds, industrial areas, flat unfilled lands) to create habitat.

FOR PARTICULAR WILDLIFE POPULATIONS

- Protect and enhance Pacific herring spawning areas.
- Protect and enhance critical avian stopover sites.
- Reestablish the California seablite and the associated high salt marsh plant species on the sandy edges of "pocket" marshes.
- Eliminate core populations and advancing-edge populations of invasive *Spartina*.

Restoration Benefits

The recommended projects for this segment would demonstrate innovative techniques to restore and enhance habitats for many populations of key fish, amphibian, reptile, insect, mammal, and bird species. Restoring tidal marsh would facilitate the dispersal of tidal-marsh-dependent birds, such as the Ridgway's rail and black rail, by providing roosting and foraging habitat. Restoring marsh–upland transition zones would benefit both plant and animal species, including populations of several rare

San Francisco Pier 94 restoration area

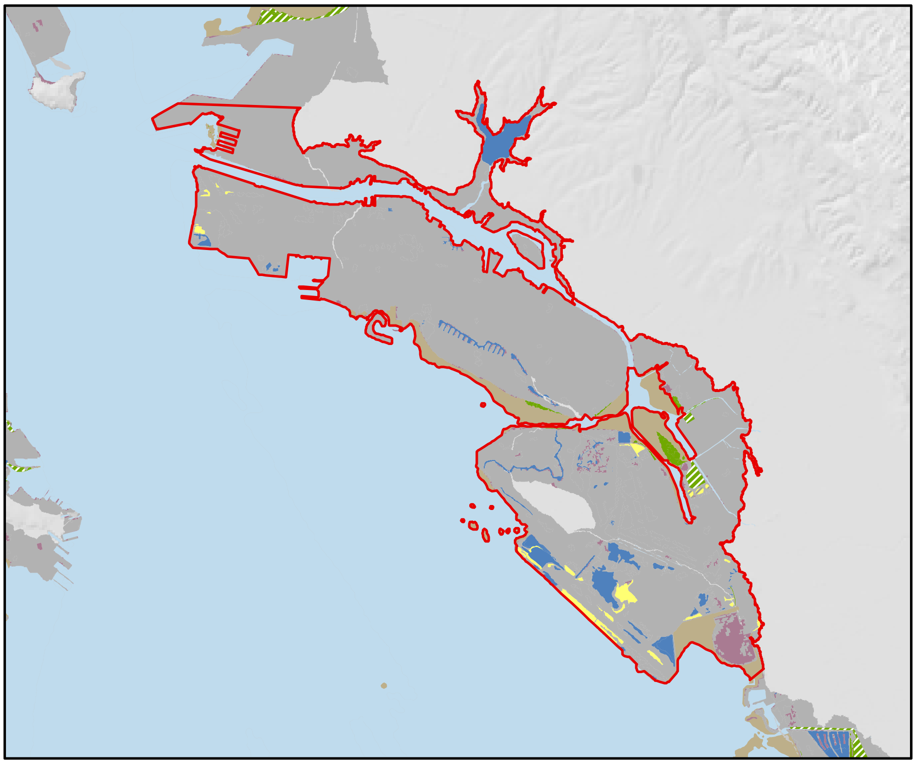
plants. Enhancing the habitats west of Highway 101 near SFO would benefit the San Francisco garter snake and the California red-legged frog. Reestablishing a tidal marsh corridor between the San Francisco and San Bruno Marshes would link these existing areas, increase tidal marsh acreage, and reduce the isolation of small-mammal populations. Restoring beach habitat could improve conditions for sensitive plant species. Protecting islands would assure suitable sites for colonial nesting birds. Restoring native oyster and eelgrass beds offshore would provide habitat for birds and fish, and might enhance food and nursery resources for species that use both wetlands and offshore shallow subtidal habitats. Living shorelines might provide wave attenuation, sediment stabilization, and some flood protection in the near term for tidal marsh habitats on the shoreline.

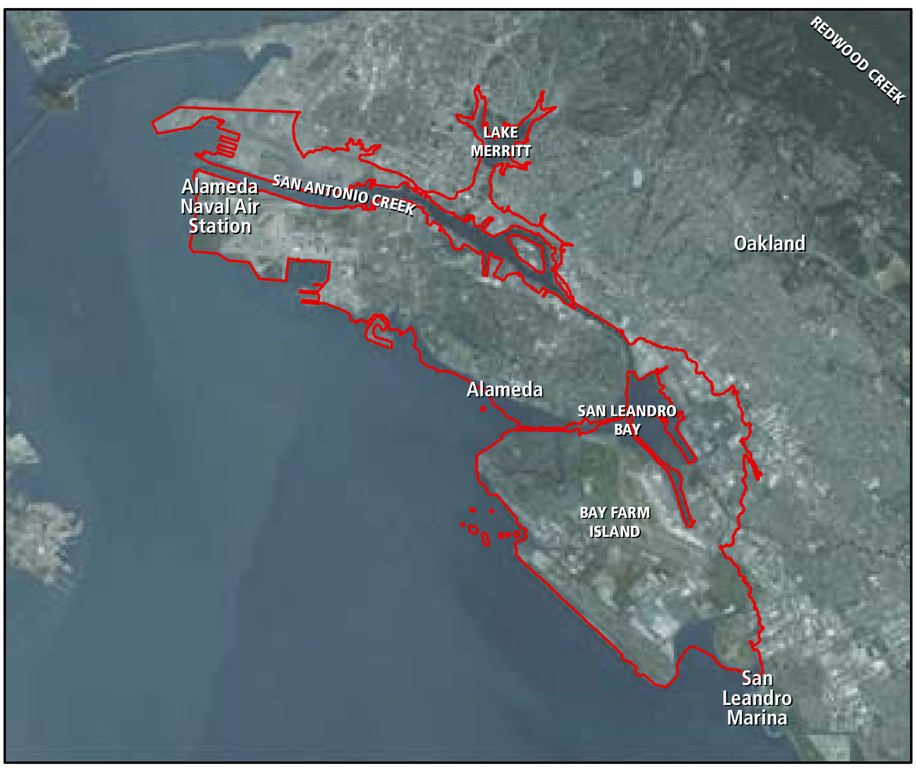
Experimental pilot projects should be conducted using new approaches that are carefully tested in phases. Integrating native oyster and eelgrass restoration adjacent to tidal wetlands, creating living shorelines, and incorporating features such as high-tide-refuge islands might improve small areas of habitat. They would also provide information on how well these approaches succeed and whether they can be scaled up to larger areas in this segment. Such information could be applied to other segment adaptation planning.

Including public education and awareness components in any restoration initiative is critical to building the public and financial support that is needed to test adaptation approaches and work toward large-scale implementation of innovative techniques.

Challenges

The major challenges in this segment are its large urban population, extensive fill along the shoreline, on-site contaminants, port and military facilities, Highway 101, wastewater treatment facilities, SFO, many large shoreline fills, utility corridors, bridges, water-treatment plants, railroad tracks and spurs, landfills, flood-control considerations, exotic predators (e.g., rats and red fox), and invasive *Spartina*.





OAKLAND AREA

Eastern edge of central San Francisco Bay between the San Leandro Marina and Oakland outer harbor

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment K.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2

Miles

N

Port of Oakland

Unique Opportunities

Segment K will likely remain highly urbanized with limited opportunities for large-scale restoration, but it presents many opportunities to develop small-scale restoration and green engineering projects to meet the co-objectives of improving habitat quality and protecting the existing infrastructure, shorelines, and baylands. This segment provides the opportunity to create additional nesting habitat for California least terns, to enhance degraded nesting habitat for Caspian terns, and to restore tidal wetlands and subtidal offshore habitats in several areas. Conditions at some sites are appropriate for native eelgrass and oyster restoration. Lake Merritt and the Oakland Estuary provide unique, visible opportunities to educate the public about wildlife habitat needs.

Very few large tracts of land are available for habitat acquisition or restoration, but this segment has multiple small habitat areas that include small but viable wildlife populations such as the steelhead run on San Leandro Creek.

Segment Features and Setting

Historically, this area was predominantly tidal flat and tidal salt marsh. Most of the baylands in the Oakland Estuary were tidal flat, tidal wetlands fringed by sandy beaches, or open bay. The estuary extended well into the current site of Lake Merritt. Native eelgrass and oyster beds were distributed throughout this segment. Most of the area surrounding Bay Farm Island was tidal flat and tidal wetlands fringed by sandy beaches. Oakland, Alameda, and Bay Farm Island were major strongholds for the locally extirpated California sea-blite. Large areas of oak woodland existed on the higher lands near the estuary, and moist grassland bordered the tidal marsh in the southern half of the segment. Perennial ponds, riparian zones, and willow groves also existed here.

Today, this segment is highly developed with urban, industrial, and transportation uses, and many of its historical and unique habitat features are gone. Most of the tidal flats and marshes along the bayshore have been filled to allow the development of railroad, military base, port, shipyard, and other facilities. Lake Merritt is an urban wildlife refuge ringed by concrete walkways. The marshes and other habitats near Bay Farm Island have been filled; they are now the site of the Oakland Airport. This segment receives heavy marine influences and high salinity. It includes highly urbanized shorelines, a high-energy-wave environment, and limited sources of local sediment. It still supports oyster and eelgrass beds in limited areas.

Implications of Drivers of Change

The developed areas in this segment will become increasingly difficult to protect as sea levels rise. Outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of the small remaining marsh edges, resulting in the narrowing and potential loss of marshes and other unique habitats such as coarse beaches. This urbanized segment has a great deal of development that directly abuts the shoreline, limiting the migration space and areas for restoration adaptation. More experimental approaches to address these limits might include vertical adaptation with new techniques such as living seawalls and breakwaters.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

In the near term, when sea-level rise rates will still be relatively low, enhancing the baylands will provide immediate ecological benefits and maximize their resilience. Living breakwaters could be created around fringing marshes to preserve and enhance unique features like native eelgrass and oyster beds. Introducing fine sediment through mudflat and marsh recharge could increase vertical accretion rates. There are limited opportunities for landward migration of marshland, and it is likely that the fringing tidal marshes will drown as sea levels rise. However, opportunities exist to partner with the industrial and residential communities along the shoreline to develop green infrastructure such as horizontal levees, which would create habitat bayward of the flood-protection levees.

Major land uses, such as Highway 880, will remain largely in current configurations and will need to be protected. Innovative approaches such as living seawalls may provide an opportunity to do so. Diverse pocket habitats could be preserved, enhanced, and created, then linked together to create a subregional habitat corridor. Vertical enhancements (living seawalls, substrate improvements to docks, etc.) could be made in a few subtidal and intertidal areas where there is hardscape. Many existing habitats could be enhanced by improving tidegate management, removing contaminated soils and derelict boats, and removing trash that ends up in the bay. Habitats could be created along flood-control channels, floodplains, and off channels, and low-elevation marsh and other wetland could be restored. Upstream opportunities are limited but important to consider.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the long term, sea-level rise rates will likely outpace vertical accretion rates, and marshes in this segment generally do not have enough space to migrate landward to survive. Prior to that point, a plan for restoring or relocating the functions within the existing tidal marshes should be implemented. Creating wetlands bayward of the flood-protection levees, possibly using wastewater to enhance habitat on the slope, could provide space for landward migration. The planned communities built over former wetlands at Bay Farm Island, Alameda Island, and around the Oakland Airport will be at risk for flooding as sea levels begin to rise. If opportunities for managed retreat become available, options should be pursued to restore such areas to marshland.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Preserve, enhance, and create diverse pocket habitats that are linked in a subregional habitat corridor that encompasses sand beaches, eelgrass, oyster beds, macroalgal beds, mudflats, rocky intertidal areas, and tidal marsh.
- Develop extensive and connected segments of native tidal marsh for small mammals and marsh-dependent birds.
- Protect and restore eelgrass and oyster beds in suitable locations.
- Enhance and expand tidal and diked habitats at all potential areas throughout the segment, for example, Alameda Island, Bay Farm Island, Martin Luther King Jr. Regional Shoreline Park, and the vicinity of the Oakland Airport.
- Enhance riparian corridors along streams throughout the segment and reconnect tributary streams to the Bay.

FOR PARTICULAR WILDLIFE POPULATIONS

- Preserve salmonid habitat in all creeks, and remove barriers to fish passage in areas of known populations.
- Enhance and protect suitable habitat (e.g., barren or sparsely vegetated areas protected from predators) for the snowy plover and least tern at Alameda Naval Air Station, Oakland Airport, Bay Farm Island, and other locations.
- Enhance cover for wildlife in existing tidal wetlands through active revegetation and by constructing high-tide-refuge islands within the marsh plains. Conduct pilot projects to assess the effectiveness of artificial floating islands for Ridgway's rail nesting and high-tide refugia.
- Restore pockets of low-lying sand beaches in sheltered sites to support reintroduced colonies of California sea-blite.
- Increase habitat in and around San Leandro Bay for harbor seals.
- Continue to control invasive *Spartina* throughout the segment and especially in San Leandro Bay.

Restoration Benefits

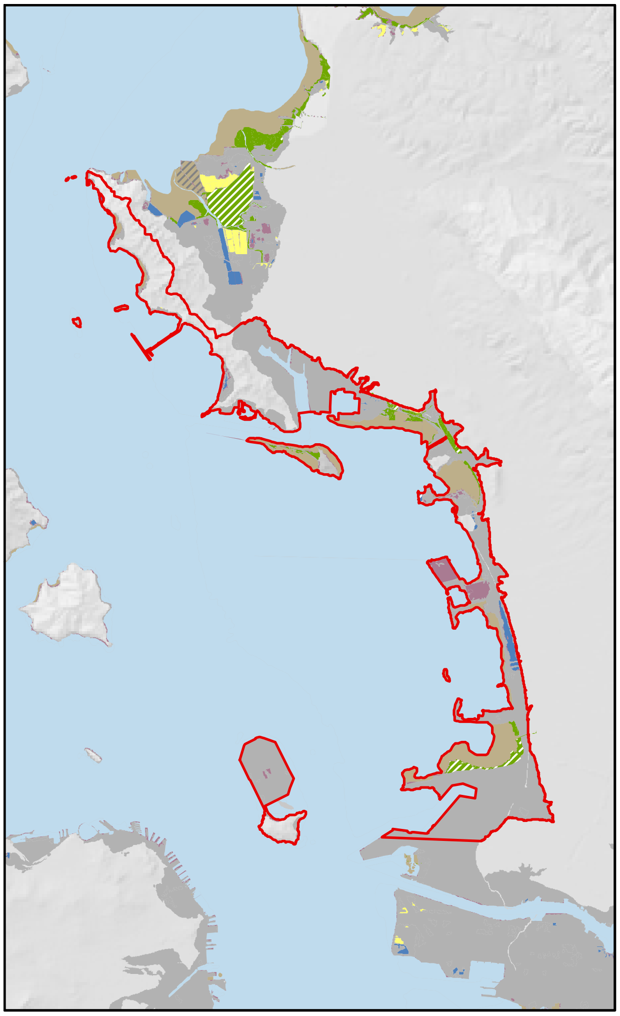
Implementing the recommended projects for this segment would demonstrate innovative techniques to restore and enhance habitat for many populations of key fish, amphibian, reptile, insect, mammal, and bird species. Restoring wetlands would enhance habitats for endangered species such as the Ridgway's rail and salt marsh harvest mouse. Restoring native oyster and eelgrass beds offshore would provide habitat for birds and fish, and might enhance food and nursery resources for species that use both wetlands and offshore shallow subtidal habitats. Living-shorelines designs might provide wave attenuation, sediment stabilization, and some flood protection in the near term for tidal marsh habitats on the shoreline.

Experimental pilot projects should be conducted using new approaches that are carefully tested in phases. Integrating native oyster and eelgrass restoration adjacent to tidal wetlands, creating living shorelines, and incorporating features such as high-tide-refuge islands might improve small areas of habitat. They would also provide information on how well these approaches succeed and whether they can be scaled up to larger areas in this segment. Such information could be applied to other segment adaptation planning.

Including public education and awareness components in any restoration initiative is critical to building the public and financial support that is needed to test adaptation approaches and work toward large-scale implementation of innovative techniques.

Challenges

Major challenges in this segment are its large urban population, extensive fill along the shoreline, bridges, water-treatment plants, railroad tracks and spurs, major highways, exotic predators (e.g., rats and red fox), and on-site contaminants. Invasive *Spartina* control remains a critical priority, constraint, and consideration for some existing marshes and for restoration planning.



BERKELEY AREA

Eastern edge of San Francisco Bay between the Oakland outer harbor and Point San Pablo

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment L.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Although very few large tracts are available for habitat acquisition or restoration, Segment L has multiple small habitat areas that include small but viable wildlife populations, such as the steelhead run on Codornices Creek. This segment will likely remain highly urbanized, with limited opportunities for large-scale restoration, but it presents many opportunities to develop small-scale restoration and green engineering projects toward meeting the co-objectives of improving habitat quality and protecting existing infrastructure, shorelines, and baylands. Critical infrastructure will need to be protected, but many improvements can be made to enhance habitat corridors and provide better linkages for species that use the bay and baylands. In several areas the ecological connections between creek mouths, tidal wetlands, and subtidal offshore habitats can be enhanced. Conditions at some sites are appropriate for native eelgrass and oyster restoration, and oysters are part of the rocky intertidal habitat being incorporated into a large-scale bank-stabilization project near Albany Beach and Brooks Island. Many tidal habitats can be restored and enhanced in this segment; examples include Hoffman Marsh, Emeryville Crescent, and the mouth of Codornices Creek. Moist grassland and seasonal wetlands such as the Richmond Field Station can also be protected and restored. Projects here could improve local water quality and environmental health, provide preliminary data to inform similar adaptation designs in other segments, and may provide benefits to the greater baylands.

The focus of the landscape vision for this segment is on creating a connection between urban residents and the environment and promoting demonstration projects that improve the health of the baylands and raise public awareness of baylands resources. Multiple creeks (Strawberry, Marin, Cordonices, etc.) are already the focus of community-based restoration efforts, and this work could be leveraged with other activities integrating climate-change-adaptation education and restoration activities. McLaughlin Eastshore State Park, the Berkeley Marina, Aquatic Park, and the Richmond shoreline provide unique, visible opportunities to educate the public about wildlife habitat needs.

Segment Features and Setting

Historically, this segment was characterized by a narrow shoreline band of small tidal marshes, sand dunes, beaches, and extensive tidal flats. The adjacent terrestrial areas supported extensive areas of moist grassland and were dissected by numerous small streams that originated in the hills to the east. Some of these streams were bordered by riparian corridors and provided spawning and rearing habitat for steelhead. Some had lagoons at their mouths, and others terminated in willow groves.

Today, this segment is highly developed with cities, industrial areas, ports, and transportation corridors, and many of its historical and unique habitat features are gone. Landfills, hotels, and other developments have taken over many sites that once were tidal flat or marsh. Several relatively small isolated tidal flats, adjoining marshes, and other features continue to provide important habitat functions. Examples of high-quality habitat in this segment are the tidal marsh and mudflats at the Emeryville Crescent and the small marshes and extensive mudflats north of Point Isabel. Small fringe beaches and rocky intertidal areas are present along almost the full length of the segment, and intertidal and shallow subtidal areas support eelgrass, oyster, and macroalgal beds. This segment receives heavy marine influences and high salinity. It includes highly urbanized shorelines, a high-energy-wave environment, and limited sources of local sediment.

Implications of Drivers of Change

The developed areas in this segment will become increasingly difficult to protect as sea levels rise. Outboard levees and fringing marshes will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will accelerate the erosion of the small remaining marsh edges, resulting in the narrowing and potential loss of marshes and other unique habitats such as coarse beaches. This urbanized segment has a great deal of development that directly abuts the shoreline, limiting the migration space and areas for restoration adaptation. More experimental approaches to address these limits might include vertical adaptation with new techniques such as living seawalls and breakwaters.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

This segment is highly urbanized and constrained by development directly adjacent to the baylands. In the near term, when sea-level rise rates will still be relatively low, enhancing the baylands will provide immediate ecological benefits and maximize their resilience. Living breakwaters could be created around fringing marshes to preserve and enhance unique features like native eelgrass and oyster beds. Introducing fine sediment through mudflat and marsh recharge could increase vertical accretion rates. There are limited opportunities for landward migration of marshland, and it is likely that the fringing tidal marshes will drown as sea levels rise. However, opportunities exist to partner with the industrial and residential communities along the shoreline to develop green infrastructure such as horizontal levees and living shorelines, which would create habitat bayward of the flood-protection levees.

Bay Trail in Richmond

Major land uses such as Highway 80 will remain largely in current configurations and will need to be protected, providing opportunities for approaches that haven't yet been tried locally, such as living seawalls. Diverse pocket habitats could be preserved, enhanced, and created, then linked together to create a subregional habitat corridor. Vertical enhancements (living seawalls, substrate improvements to docks, etc.) could be made in a few subtidal and intertidal areas where there is hardscape. Many existing habitats could be enhanced by improving tidegate management, removing contaminated soils and derelict boats, and reducing the amount of trash that terminates in the bay. Habitats could be created along flood-control channels, floodplains, and off channels. Low-elevation marsh and wetland could be restored. Upstream opportunities should be explored wherever possible in order to reconnect watershed processes with the bay.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the long term, sea-level rise rates will likely outpace vertical accretion rates, and marshes in this segment generally do not have enough space to migrate landward to survive. Prior to that point, a plan for restoring or relocating the functions within the existing tidal marshes should be implemented. Creating wetlands bayward of the flood-protection levees, possibly using wastewater to enhance habitat on the slope, could provide space for landward migration. The planned communities built over former wetlands and open bay at Powell Street in Emeryville, Marina Bay in Richmond, and other areas will be at risk for flooding as sea levels begin to rise. If opportunities for managed retreat become available, options should be pursued to restore areas to baylands or to connect bay habitats.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Design and restore complete tidal wetland systems, even at a small scale, that include tidal marshes, beaches, and lagoons, broad transition zones, and develop techniques for implementing active revegetation, high-tide-refuge islands, and subtidal habitat restoration.
- Restore, enhance, and protect a diversity of habitats, including tidal marsh, shorebird roosting sites, and seasonal wetlands.
- Create transition zone habitat where feasible at the edges of existing marshes or where land becomes available.
- Protect and restore native oyster beds and eelgrass beds throughout this segment, including the area around the Bay Bridge.
- Protect land as it may become available in order to incorporate transition zones into restoration designs.

FOR PARTICULAR WILDLIFE POPULATIONS

- Protect gull, tern, and egret nesting habitat at Brooks Island, Red Rock, and Castro Rocks.
- Implement a pilot project with citizen involvement to hang oyster-shell bags off marina docks to use later in building reefs.
- Conduct pilot projects to assess the effectiveness of artificial floating islands for nesting and high-tide refugia for Ridgway's rail.

Restoration Benefits

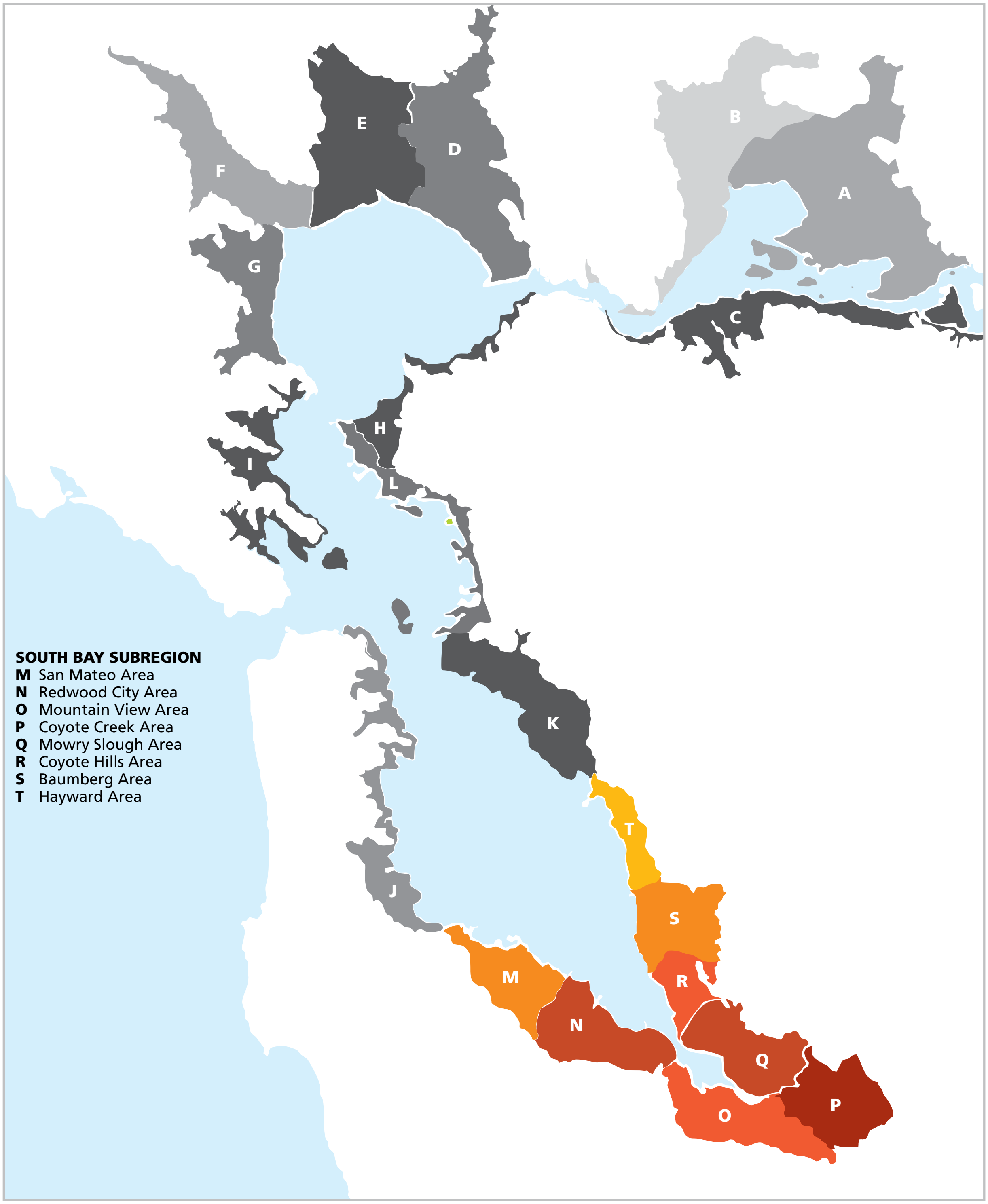
The recommended projects for this segment would demonstrate innovative techniques to restore and enhance habitats for many populations of key fish, amphibian, reptile, insect, mammal, and bird species. Restoring wetlands would enhance habitat for endangered species such as the Ridgway's rail and salt marsh harvest mouse. Restoring beach habitat could improve conditions for sensitive plant species. Protecting islands would assure suitable sites for colonial nesting birds. Restoring native oyster and eelgrass beds offshore would provide habitat for birds and fish, and might enhance food and nursery resources for species that use both wetlands and offshore shallow subtidal habitats. Living-shorelines designs might provide wave attenuation, sediment stabilization, and some flood protection in the near term for tidal marsh habitats on the shoreline.

Including public education and awareness components in any restoration initiative is critical to building the public and financial support that is needed to test adaptation approaches and work toward large-scale implementation of innovative techniques.

Challenges

Major challenges in this segment are its large urban population, extensive fill along the shoreline, bridges, wastewater treatment plants, railroad tracks and spurs, major highways, exotic predators (e.g., rats and red fox), invasive *Spartina*, and on-site contaminants.

South Bay Subregion



South Bay Subregion

LANDSCAPE VISION

The South Bay provides some of the most extensive opportunities in the region to restore baylands habitat. The goal for South Bay is to restore large tidal marshes as soon as possible.

Recommended Actions

- Given the large areas available for restoration and generally high sedimentation rates, prioritize tidal marsh restoration, including the creation of transition zones. Supplement local sediment availability to increase long-term shoreline resilience and investigate novel approaches to beneficial reuse. Reconnect local tributaries more directly to and through the tidal baylands. Protect and restore riparian corridors and willow groves wherever possible.
- Connect all types of tidal marshes with wide corridors along the perimeter of the bay. Restore natural transitions from mudflat through tidal marsh to adjacent terrestrial habitats wherever possible. Restore naturalistic, unmanaged saline ponds (facsimiles of historical hypersaline backshore pans), especially on the Hayward shoreline. Protect and enhance adjacent moist grasslands, particularly those with vernal pools. Protect undeveloped lands adjacent to the baylands, and create broad transition zones adjacent to flood-risk management levees.
- Intersperse pond complexes, managed to optimize waterbird support, throughout the subregion in locations appropriate for long-term operations and maintenance.
- Create eelgrass beds and oyster reefs wherever possible, especially adjacent to tidal mudflats and marshes or other baylands that would benefit from physical protection. Create coarse beaches, where appropriate, to reduce bay-edge erosion of marshes.

View of island ponds restored to tidal marsh

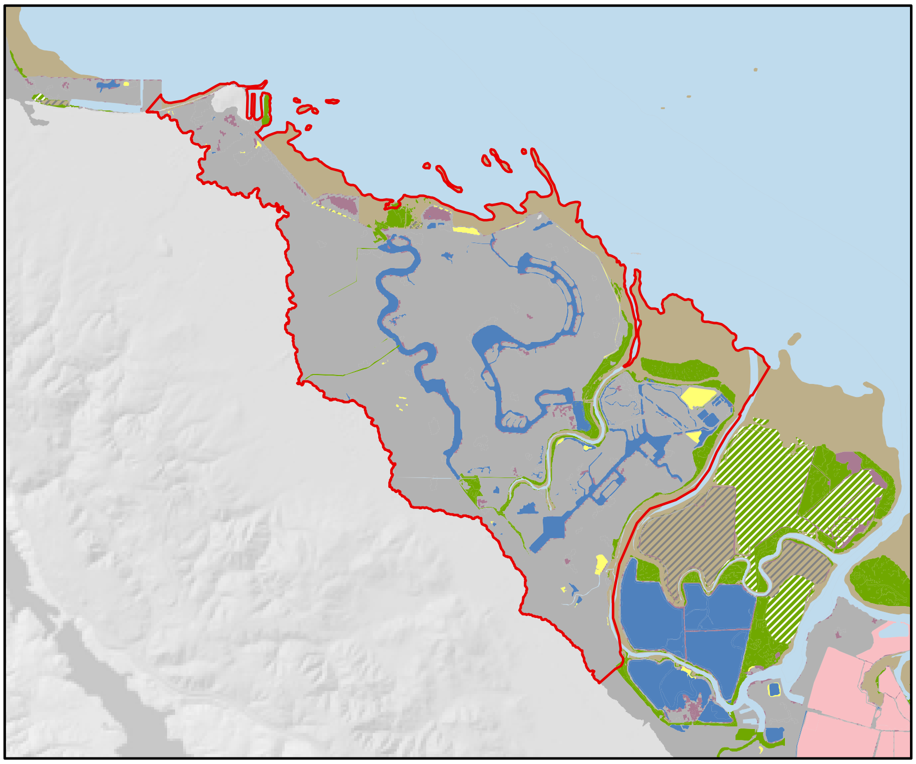
RECENT RESTORATION

Since the 1999 Goals Report, the South Bay Salt Pond Restoration (SBSPR) project has made major progress toward baylands restoration. The Cargill Salt Division, whose operations were described as a "challenge" in the 1999 Goals Report, was willing to undertake major operational changes and transfer 15,100 acres into public ownership in 2003 through a combination of purchase and donation. Since that time, the SBSPR project has completed long-term planning for this area as well as the first phase of restoration projects, resulting in over 3,700 acres of restored or enhanced habitats, and an overall new pond management regime designed to benefit wildlife. Other significant restoration projects that are completed or nearly completed include Cooley Landing and Bair Island.

CHALLENGES

Progress in the South Bay will depend on the efforts of many other private and public landowners as development pressures increase and shoreline migration space becomes scarcer. Regulatory and logistical hurdles complicate achieving regional sediment management, the beneficial reuse of sediment in the baylands, and the creation of broad transition zones. Although largely under control, invasive *Spartina* remains a challenge for the South Bay, especially as newly restored tidal areas are breached. If baylands habitat patches become smaller, human-associated predator management will become a larger challenge.

The South Bay subregion consists of segments M through T.



SAN MATEO AREA

Western edge of San Francisco Bay between Coyote Point and Steinberger Slough

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment M.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Segment M offers limited but important opportunities to protect and enhance remaining tidal marshes and other wetlands. The California sea-blite and associated rare high-marsh plant species could potentially be reintroduced around sheltered shell beaches. Historically, this segment supported extensive oyster beds, presenting an opportunity to restore the subtidal habitat offshore. This could be done by building artificial reefs to create breakwaters to protect fringing marshes, or using artificial rock groins to capture coarse material to form small beaches such as those at Seal Slough. Additionally, green infrastructure such as horizontal levees could be built as the residential communities along the shoreline invest in flood protection against future sea-level rise.

Segment Features and Setting

Most of this segment was once tidal marsh, and the marshes in this relatively flat area of the baylands included a transition zone of varying width into the coastal hills. Many of the tidal marshes had oyster shell ridges or beaches along their foreshores. Tidal flats and moist grassland were limited, as they are today.

Today, most of the former wetlands are developed urban or industrial areas (Foster City, Redwood City, and San Mateo). Because of the extensive development along the shoreline, there are few restoration opportunities in this segment. The wetlands that remain are fragmented narrow marshes, mostly along sloughs. Bird Island and the adjacent strip marshes along the levees are the most significant tidal wetlands in the segment. Generally, the transition zones of these tidal marshes exist in narrow strips along steep flood-protection levees. Small areas of diked marsh and seasonal wetlands persist in some of the developed areas (area H and the Redwood Shores Ecological Reserve in Redwood City, and Sun Cloud Park in Foster City), and at Seal Slough Mouth in San Mateo, at Bird Island, and along the Foster City shoreline at the mouth of Belmont Slough. Shell mounds and beaches were once prominent in this segment, and remnants can still be found.

Implications of Drivers of Change

The developed areas in this segment will become increasingly difficult to protect as sea levels rise. Outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of the small remaining marsh edges, resulting in the narrowing and potential loss of marshes and other unique habitats such as coarse beaches.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

In the near term, when sea-level rise rates will still be relatively low, actions enhancing the baylands will provide immediate ecological benefits and maximize their resilience. Breakwaters could be created around fringing marshes to preserve unique features like shell mounds. Introducing fine sediment through mudflat and marsh recharge could increase vertical accretion rates. The remnant oyster shell beaches provide a unique opportunity for the restoration of adjacent subtidal habitats, including native oyster and eelgrass beds. Effort should be placed on creatively building environmental considerations into flood-protection projects and upgrades and protecting small habitat pockets only where feasible. A patchwork of small habitat nodes may provide some support for particular wildlife species. Opportunities exist to partner with the residential communities along the shoreline to develop green infrastructure such as horizontal levees, which would create habitat bayward of their flood-protection levees.

One small pocket of opportunity for restoring transition zone exists along the Foster City shoreline at the mouth of Belmont Slough, where restoration could create an estuarine–terrestrial transition zone and beach habitat along the bayward edge.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the long term, sea-level rise rates will likely outpace vertical accretion rates, and marshes will need to migrate landward to survive. Prior to that point, a plan for restoring or relocating the functions of the existing tidal marshes should be implemented. Creating wetlands bayward of the flood-protection levees, possibly using wastewater to enhance habitat on the slope, could provide space for landward migration. The planned communities built over former wetlands at Foster City, Redwood Shores, and portions of San Mateo along Seal Slough will be at risk for flooding as sea levels begin to rise. If opportunities for managed retreat become available, options should be pursued to restore these areas to marsh.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Maintain and enhance tidal marsh and marsh connectivity along the shoreline.
- Protect subtidal habitat including mudflats, native oyster beds, and eelgrass beds. Protect and improve oyster shell ridges near Foster City, Seal Slough, and on the Redwood Shores Peninsula.
- Protect open space adjacent to the baylands, including developed areas that may become available in the future due to flood risk.
- Create transition zones on gentle slopes in front of flood-risk-management levees (or other high-ground areas).
- Reduce nearshore wave energy by constructing low-crested berms of gravel and shell (similar to the natural breakwaters at Seal Slough Mouth), which could roll landward as sea levels rise. Enhance existing unique features such as shell mounds and coarse beaches.
- Connect wastewater and storm water to bayland habitats where appropriate to enhance the transition zone slope and reestablish a salinity gradient within marshes
- Increase local sediment availability by placing fine sediment in areas that will be reworked by wave and tidal action to accelerate the vertical accretion of marshes.

Dredge at sunset

FOR PARTICULAR WILDLIFE POPULATIONS

- Improve the Foster City and Redwood Shores canal systems for wildlife support and water quality.
- Protect and enhance seasonal wetland areas for shorebirds and waterfowl.
- Implement aggressive control measures for invasive *Spartina*, and for the invasive plants black rush and Algerian sea lavender, which could become a serious problem.

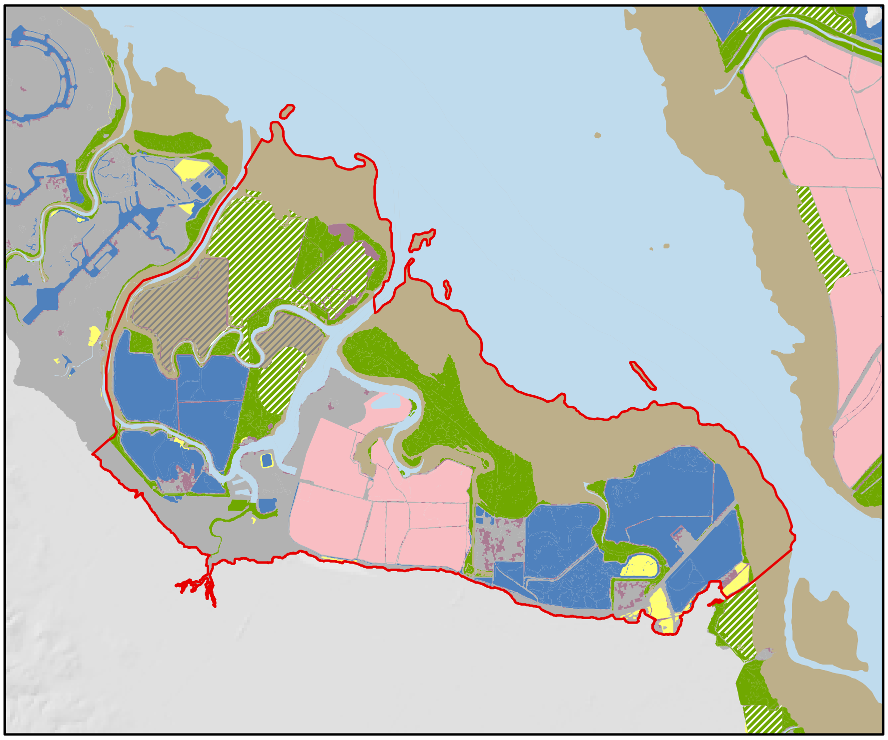
Restoration Benefits

Restoring oyster shell ridges would enhance habitat for some unique and rare plants and would provide roosting sites for shorebirds. Providing an enlarged tidal marsh corridor may facilitate the dispersal of Ridgway's rails northward from population centers in segment N to the south. The nearest northward location with significant habitat is in Marin County. However, Ridgway's rails have been known to breed in small tidal marsh pockets such as Heron Head's Park.

Restoring native oyster and eelgrass beds offshore would provide habitat for birds and fish and may provide some flood protection in the near term for developments on the shoreline.

Challenges

Challenges in this segment include an extensive urban interface, major transportation corridors, flood-control considerations, predator corridors, limited opportunity for predator management, and intensely used public access along the Bay Trail. The presence of the Atlantic oyster drill in the South Bay may inhibit the restoration of native oyster beds. Planning will require coordination with local agencies and organizations, including San Mateo County.



REDWOOD CITY AREA

Western edge of San Francisco Bay between Steinberger Slough and the Dumbarton Bridge

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment N.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Segment N has high potential for tidal marsh restoration and the enhancement of seasonal wetlands and ponds for shorebirds and waterfowl. This segment contains Bair Island, which is in the final stages of restoration. The Ravenswood pond complex offers an opportunity to maintain and enhance wetland habitat in close proximity to the large tidal flats that are critical for foraging shorebirds. Enhancing the salt pan could improve nesting habitat for the snowy plover. The Redwood City crystallizers and associated salt ponds are currently part of an operating business; however, they remain relatively undeveloped and are at elevations that make them attractive for potential future tidal habitat restoration. Bedwell Bayfront Park allows for some area of marsh migration as sea levels rise. Local sediment and water supplies could also be used for habitat creation.

Segment Features and Setting

Historically, this area was mostly tidal marsh with moist grassland habitat on the adjacent lands to the west. Large, well-developed channels and associated slough systems and numerous ponds characterized the tidal marshes in this segment. Outboard of the marshes were oyster shell beaches, large expanses of tidal flats, and oyster beds.

A natural deep-water channel at the mouth of Redwood Creek was developed into the Port of Redwood City. Due to regular deep dredging of this channel for the port, the Redwood Creek shipping channel acts as a sediment sink. Sloughs in this segment, including Steinberger, Corkscrew, and Smith, have silted in with the fill and diking off of most of the tidal marshes. A former landfill site, Bedwell Bayfront Park, is a small open space with a hilly grassland terrain that is found adjacent to the Ravenswood pond complex, Greco Island, and commercial property. Fringing tidal marsh exists in a narrow band along much of this segment.

Today, this area is highly developed, and many of the historical tidal marshes have been converted to salt ponds, managed ponds, and urban uses. Greco Island, the largest contiguous tidal marsh on the western side of the bay, is relatively protected from human disturbance; it is one of the main population centers of Ridgway's rail in South Bay. Next to Greco Island, Middle and Outer Bair Islands have recently been restored to tidal action, and all are a focus of invasive *Spartina* treatment, native *Spartina* revegetation, and enhancement projects for rails. Inner Bair Island is also nearing restoration completion and will comprise both tidal marsh and transition zone habitats. The restoration of Bair Island, combined with tidal marsh restoration of portions of the Ravenswood pond complex as part of the South Bay Salt Pond Restoration Project (SBSPRP), would improve the continuity of tidal marsh habitat between Bair Island in the north of this segment, south to the Palo Alto baylands in segment O.

Northern pintail

Outer Bair Island historically supported a variety of nesting terns (Caspian, Forster's and California least), as well as a large egret and heron rookery. The egret and heron rookery has returned, though its size has probably decreased. A large colony of cormorants can be found on the PG&E towers in Steinberger Slough. Western snowy plovers use levees and salt pan habitat in the Ravenswood pond complex year-round for nesting and overwintering. The SBSPRP has constructed islands for nesting at pond SF2 within this segment (and within segments S and P). These islands provide nesting habitat for snowy plovers, American avocets, black-necked stilts, and Forster's terns. The large isolated channels in the Corkscrew Slough area provide haul-out areas for harbor seals, and the bay's extensive tidal flats continue to provide excellent foraging habitat for shorebirds. Nearly all of the moist grassland areas have been urbanized.

Implications of Drivers of Change

Managed ponds in this segment will become increasingly difficult to maintain and operate at their current elevations. As sea levels rise, levees protecting the ponds will need to be maintained and raised, tide gates will have to be modified, and gravity-driven systems will have to be supplemented by pumping. Outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate erosion of marsh edges, resulting in a narrowing of marshes. Sedimentation rates on existing and inside restored tidal wetlands are expected to slow over time as suspended-sediment concentrations in the bay decrease.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The near term offers significant opportunities to restore tidal marsh in managed ponds that will help create a continuous corridor of tidal marsh along the bayshore. The potential for land-use change at the Redwood City crystallizers should be monitored. The SBSPRP planning process has identified ponds R4, R1, and R2 as suitable for restoration in the near term. This restoration would include the reconnection of complex channel networks, incorporating topographic variation by placing material to mimic features such as natural levees, and could incorporate shallow pans. To accelerate the accretion of marsh surface in the subsided ponds, dredge sediment could be placed either directly within ponds or on adjacent mudflats to be taken by wave and tidal action into the ponds. Slopes to create elevation gradients and a transition zone between tidal marsh and lowland areas (as well as the upland habitats at Bedwell Bayfront Park) could be created adjacent to existing levees to provide buffer and high-tide refugia as well as habitat in its own right.

While rates of sea-level rise are low, some of the ponds could continue to be managed to provide habitat for shorebirds and waterfowl by changing their water levels and salinity (within the infrastructure limits). Levees surrounding the ponds would have to be built up to maintain these ponds for waterbirds as sea levels rise further. Snowy plover habitat in the Ravenswood pond complex would need active management to be maintained.

Bair and Greco Islands are generally of uniform elevation and will be threatened as sea levels rise. A levee will need to be built to protect Highway 101 along the western side of Inner Bair. A levee will also be needed next to the Ravenswood pond complex to prevent flooding Highway 84 and adjacent urban development.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the longer term, if sea-level rise accelerates and sediment supply falls as projected, marsh plains will probably give way to narrower fringing marshes. Tidal marshes may be unable to keep up with the rising sea level, resulting in increased inundation of the marsh surface. This may lead to habitat conversion, perhaps to low marsh and mudflat. In addition, landward migration of the marsh is expected, and a gently sloping transition zone bayward of the levee would facilitate such a migration. If the area were to become available, restoring the Redwood City crystallizers could help provide large areas of restored tidal marsh, transition zone, and snowy plover habitat.

At some point in the future, the degree of sea-level rise may make it unrealistic to maintain the managed ponds to benefit waterbirds. Prior to that point, a plan for restoring or relocating the functions of these ponds should be implemented that would move them outside the hazard zone. Simply restoring tidal action to the managed ponds late in the century may result in the creation of tidal ponds. To alleviate this, "warping up" the ponds could be undertaken during the earlier part of the century, allowing the accretion of the pond to be managed as well.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large areas of tidal marsh with gradual bayside slopes, providing a continuous band along the bayfront for the entire length of the segment.
- Restore and enhance oyster beds and eelgrass beds at appropriate locations within this segment.
- Create transition zones on gentle slopes in front of flood-risk-management levees (or other high-ground areas).
- Protect lands adjacent to baylands to increase habitat and decrease flood risk to properties within the baylands. Work with willing landowners to protect undeveloped diked baylands as future tidal habitats and transition zone.
- Reduce the horizontal erosion of marshes by creating shell beaches in front of marsh scarps.

FOR PARTICULAR WILDLIFE POPULATIONS

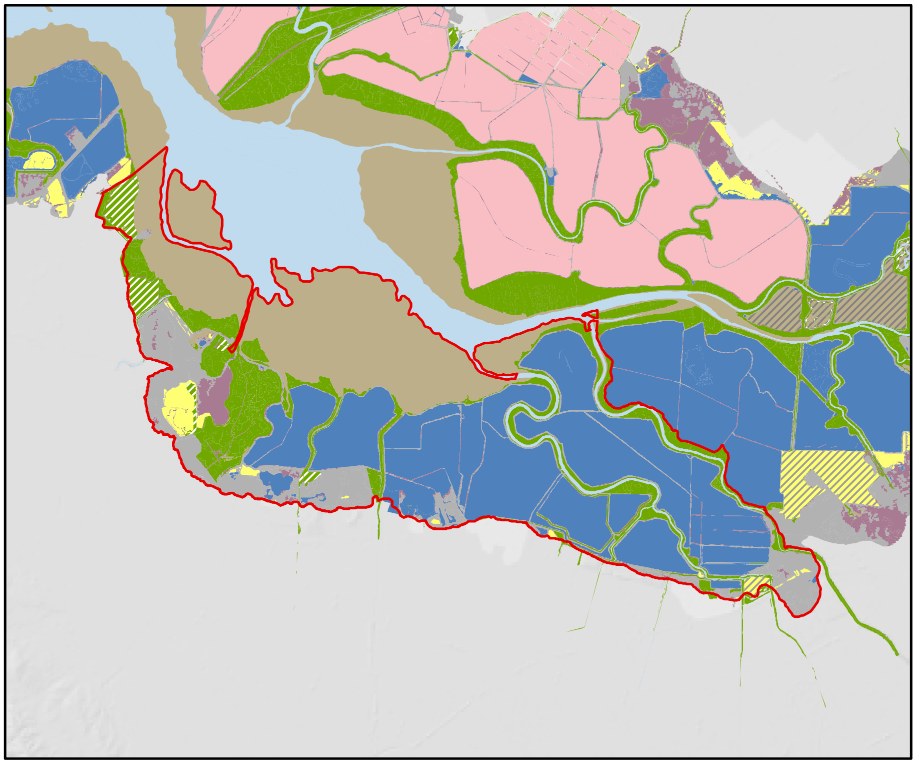
- Manage select ponds and areas to enhance snowy plover breeding success.
- Reintroduce rare and uncommon high-marsh plant species at sheltered shell ridges.
- Develop SBSPRP operation plans of managed ponds to maximize utility to waterbirds.
- Partner with current landowners of properties with current or potential benefits to wildlife and their habitat (e.g. Cargill, Bedwell Bayfront Park, Facebook). Partner with local municipalities to manage stormwater in Ravenswood ponds to benefit wildlife.
- Maintain and enhance pond management and predator management for snowy plovers and other waterbirds.
- Implement aggressive control measures for invasive plants including Algerian sea lavender, which could become a serious problem.
- Continue treatment of invasive *Spartina* at Bair Island and other sites, and continue revegetation plantings and other enhancements, such as high-tide-refuge islands.

Restoration Benefits

Implementing the recommendations would provide a large tidal salt marsh core area that would maintain and enhance the associated channel system. This would benefit harbor seals and several fish species. The tidal salt marsh restoration would directly benefit the salt marsh harvest mouse and the Ridgway's rail. Enhancing and restoring ponds would benefit shorebirds and waterfowl and would provide an opportunity to create or improve snowy plover nesting habitat.

Challenges

Challenges in this segment include PG&E transmission lines, substation, and other utility corridors; flood protection for urbanized areas and associated infrastructure (e.g., Highways 84 and 101); residential development adjacent to natural areas; the Port of Redwood City and adjacent development; other commercial industry; and the need for long-term predator management (including the political power to eliminate feral cat colonies). The depredation of snowy plover nests continues to be an issue where nesting habitat exists. Ongoing hazing and removal of predators is needed to reduce the nest-habitat displacement and depredation of snowy plovers. Invasive *Spartina* remains a critical priority, constraint, and consideration for some existing marshes and for restoration planning in this segment. Oyster drill populations could limit native oyster restoration. The SBSPRP is one of the key regional plans for this segment. Planning will require coordination with local agencies and organizations, including Caltrans, the US Fish and Wildlife Service, Menlo Park, Redwood City, the San Francisquito Creek Joint Powers Authority, PG&E, and Cargill.



MOUNTAIN VIEW AREA

Western edge of San Francisco Bay between Dumbarton Bridge and Alviso Slough

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment O.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Segment O presents opportunities to enlarge existing marshes and to provide dispersal corridors (where none now exist) that link the eastern and western parts of South Bay for tidal-marsh-dependent species. Ponds could be managed for the benefit of large numbers of shorebird species that forage on nearby mudflats. Retaining and modifying managed ponds would also benefit nesting snowy plovers, postbreeding least terns, and waterfowl. Enhancing tributary streams such as San Francisquito Creek and the Guadalupe River could benefit riparian-dependent species and could help restore steelhead runs.

Segment Features and Setting

Historically, this segment contained large expanses of tidal flats. Next to these flats were tidal salt marshes that intergraded into moist grasslands in the adjacent uplands. These marshes supported extensive channel systems and an abundance of tidal pans. Many of the marshes had backshore pans along the transition zone. Much of the moist grassland habitat supported seasonal ponding in the rainy season. Streams that drained the coastal hills were bordered with riparian vegetation. Many of the streams did not reach the bay, and streams in some willow groves and ponds terminated near the baylands. Limited zones of brackish marsh were present along the tidal reaches of San Francisquito Creek and the Guadalupe River, both of which supported steelhead runs.

Today, most of the segment is managed ponds, sewage-treatment ponds, managed flood basins, or urban development, except for a few tidal marshes in the Palo Alto area. These tidal marshes are limited in extent, but they are the most productive and densely populated marshlands in the Bay Area for Ridgway's rails. These marshes are essentially "islands" isolated from other tidal marshes by managed ponds and human development. The mudflats along the bay margin in this segment provide important feeding and roosting habitat for shorebirds.

Since the initial Goals Report, all the managed ponds in this segment have become part of the Don Edwards San Francisco Bay National Wildlife Refuge and the South Bay Salt Pond Restoration Project (SBSPRP). These ponds are particularly important for wintering and migratory waterfowl due to their depth and low salinity. The managed ponds in this area provide postbreeding habitat for least terns, and foraging and roosting habitat for shorebirds and for very large numbers of waterfowl in the deeper ponds.

California vole

The SBSPRP has initiated tidal-marsh-restoration actions in segment O. Pond A6 was breached to tidal flows on December 6, 2010, and high sediment-accumulation rates were observed in the first year with an average of 23 cm/year. These results indicate that high suspended-sediment concentrations in the South Bay can, if sediment supplies remain as they have historically, sustain marsh restoration and sustainability to some extent into the future. The SBSPRP has also begun to experiment with reconfiguring ponds to increase habitat quality for foraging, roosting, and nesting waterbirds and restoring muted tidal action to ponds with legacy mercury contamination; it is also planning further tidal marsh restoration in the Mountain View area. The San Francisquito Creek Joint Powers Authority is also developing both fluvial and tidal flood-control projects in segment O.

The SBSPRP, in the first 10 years that ponds have been managed to benefit waterbirds, has seen greater numbers of shorebirds and dabbling ducks and steady numbers of diving ducks. The project has also constructed features that could enhance the carrying capacity of the managed ponds to benefit migratory, wintering, and breeding waterbirds.

Implications of Drivers of Change

Managed ponds in this segment will become increasingly difficult to maintain and operate at their specified elevations and salinities. As sea levels rise, levees protecting the ponds will need to be maintained and raised. Tide gates will have to be modified, and gravity-driven systems supplemented by pumping. The outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of marsh edges, resulting in a narrowing of marshes. Sedimentation rates on existing and restored tidal wetlands are expected to slow over time as suspended-sediment concentrations in the bay decrease.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The near term presents significant opportunities to restore tidal marsh in managed ponds that will help create a continuous corridor of tidal marsh along the bayshore. The SBSPRP planning process has identified ponds A1 and A2W as potentially suitable for restoration. This restoration would include the reconnection of complex channel networks, incorporating topographic variation by placing material to mimic features such as natural levees and islands, and could incorporate shallow pans. To accelerate the accretion of marsh surface in the subsided ponds, dredge sediment could be placed either directly within the ponds or on adjacent mudflats to be taken by wave and tidal action into the ponds. Slopes to create elevation gradients along the transition zone between tidal marsh and terrestrial areas could be created next to existing levees to provide buffers and high-tide refugia as well as habitat in its own right. Charleston Slough could also become marsh habitat by increasing tidal flows and connecting a restored pond A1.

While rates of sea-level rise are low, some of the managed ponds could continue to be managed to provide habitat for shorebirds and waterfowl by changing their water levels and salinity (within the infrastructure limits). Levees surrounding the ponds would have to be built up to maintain these ponds as sea levels rise further.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the longer term, if the sea-level rise increases and sediment supply decreases as projected, it seems likely that the marsh plains will give way to narrower fringing marshes. Tidal marshes may be unable to keep up with the rising sea level, resulting in increased inundation of the marsh surface. This may lead to habitat conversion, perhaps to low marsh and mudflat. In addition, landward migration of the marsh is expected, and a gently sloping transition zone bayward of the levee would facilitate such a migration. Since there is considerable infrastructure in this segment, consideration should be given to filling in some of the managed ponds with material to create a gently sloping transition zone bayward of the levee. This would create space for marsh migration in the long term (and high-tide refugia in the short term).

At some point in the future, the degree of sea-level rise may make it unrealistic to maintain the managed ponds to benefit waterbirds. Prior to that point, a plan for restoring or relocating the functions of these ponds should be implemented that would move them outside the hazard zone. Simply restoring tidal action to the managed ponds late in the century may result in the creation of deep tidal ponds. To alleviate this, "warping up" the ponds could be undertaken during the earlier part of the century, allowing the accretion of the pond to be managed as well.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large areas of tidal marsh prior to 2030 and create a continuous corridor of tidal marsh along the bayshore. Protect all undeveloped diked baylands as future tidal habitats and transition zones.
- Optimize the management of ponds for a diverse suite of waterbirds, including shorebirds and waterfowl. Modify pond management as necessary to accommodate sea-level rise and other changes by modifying water-control structures, managing ponds to facilitate warping, and reconfiguring or relocating ponds as necessary.
- Consider ways to increase sediment supply to the tidal baylands. Methods could include managing the sediment-delivery potential of local watersheds, placing sediment directly in marshes or placing dredged sediments on adjacent mudflats to be reworked by wave and tidal action to increase local suspended-sediment concentrations and marsh-accretion rates.
- Enhance and restore natural transition zone and landward buffers, including natural levees on creeks, while focusing on tidal marsh transitions. Create transition zone habitats on gentle slopes in front of flood-risk-management levees.
- Reestablish native vegetation and otherwise enhance the riparian corridor along San Francisquito Creek, Guadalupe River, and other tributary streams.
- Maintain current mudflat habitat and buffers from human disturbance.
- Enhance and restore native oyster beds at suitable areas.

FOR PARTICULAR WILDLIFE POPULATIONS

- Continue hazing and predator management at sensitive nesting habitats.
- Enhance the seasonal wetlands and burrowing owl habitat in the Sunnyvale baylands.
- Continue treatment of invasive *Spartina* at the Knapp Tract and other sites, and continue revegetation plantings and other enhancements, such as high-tide-refuge islands.

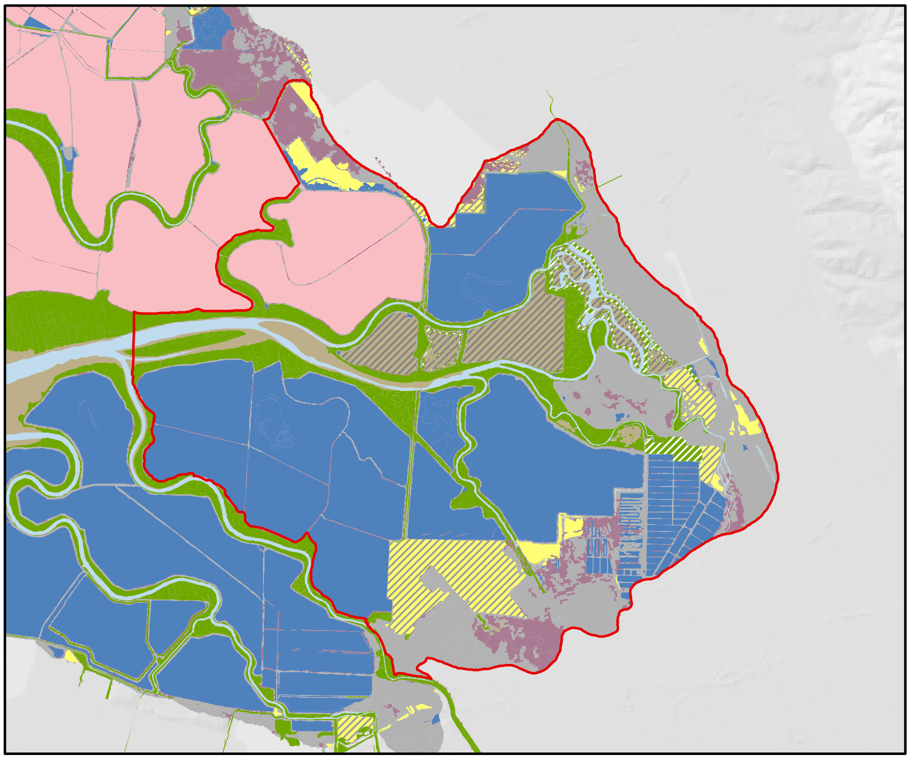
Restoration Benefits

Linking the eastern and western portions of South Bay and restoring tidal marsh along the bayshore would provide dispersal corridors (where none now exist) for the Ridgway's rail and the salt marsh harvest mouse, allowing these species to move between neighboring segments while minimizing predation and decreasing their vulnerability to local extinction. Restoring and enhancing tributary streams would improve riparian habitat and benefit anadromous fishes, amphibians, small mammals, and birds.

Enhancing managed ponds would provide high-tide foraging and roosting habitat for shorebirds and waterfowl. This could also provide postbreeding foraging habitat for least terns and nesting habitat for the snowy plover and other resident shorebirds and terns.

Challenges

Challenges in this segment include legacy mercury contamination, PG&E transmission lines and other utility corridors, flood-protection considerations, historical land subsidence, freshwater outflow from wastewater-treatment facilities, and predator management. Invasive *Spartina* remains a critical priority, constraint, and consideration for some existing marshes and for restoration planning. Oyster drill populations may limit native oyster restoration. The SBSPRP is one of the key regional plans for this segment. Planning will require coordination with local agencies and organizations, including NASA Ames; the cities of Santa Clara, Mountain View, and Palo Alto; the San Francisco Public Utilities Commission; the San Francisquito Creek Joint Powers Authority; the US Fish and Wildlife Service; and the Santa Clara Valley Water District.



COYOTE CREEK AREA

Southern end of San Francisco Bay between Alviso Slough and Albrae Slough

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment P.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Segment P provides excellent opportunities to develop large patches of tidal salt marsh along a major salinity gradient. This is one of few South Bay segments where it is possible to restore tidal brackish marsh. It is the only segment in South Bay that has a large area of vernal pools near the baylands. It also is the only area where a wide transition zone can be re-created between restored tidal marsh and a complex of vernal pools.

Segment Features and Setting

Historically, most of this segment was tidal marsh. There were numerous sloughs and ponds throughout the marshes, but very little adjacent tidal-flat habitat. Salinity was strongly influenced by high seasonal freshwater flows through Coyote Creek, one of the major tributaries to the subregion. On the northern edge of the segment was the only large area of vernal pools in South Bay, currently encompassing 719 acres and 250 ponds in the Warm Springs vernal pool unit of Don Edwards San Francisco Bay National Wildlife Refuge. Moist grasslands bordered much of the eastern side of the segment.

Today, much of this segment is developed. Managed ponds dominate the landscape, along with large landfills and the largest local sewage-treatment facility. Some narrow strips of tidal marsh occur outboard of the pond levees, and year-round discharge from the sewage-treatment plant creates brackish marsh in areas. Although the Warms Springs vernal pool area still exists, nearly all of the moist grassland in this segment has been developed for light industry or housing. Since the initial Goals Report, nearly all of the managed ponds in this segment have become part of the Don Edwards refuge and the South Bay Salt Pond Restoration Project (SBSPRP). These ponds are particularly important for wintering and migratory waterfowl due to their depth and low salinity.

The managed ponds in this area provide foraging and roosting habitat for shorebirds and for very large numbers of waterfowl in the deeper ponds. Some islands and levees in managed ponds and diked marshes also provide nesting habitat for snowy plovers (A22, A23), American avocets, black-necked stilts, double-crested cormorants, California gulls, Caspian terns, and Forster's terns.

The SBSPRP, in the first 10 years that ponds have been managed to benefit waterbirds, has seen greater numbers of shorebirds and dabbling ducks and has maintained the number of diving ducks using the managed ponds. The SBSP has also constructed islands for nesting at pond A16 within this segment (and within segments S and O) and other features that have the potential to enhance the carrying capacity of the managed ponds to benefit migratory, wintering, and breeding waterbirds.

The SBSPRP initiated tidal marsh restoration actions in adjacent areas starting with the breaching of ponds A21, A20, and A19 in the spring of 2006. Sedimentation was rapid, with some locations in pond A21 accumulating more than 220 mm in two to three years. These results indicate high suspended-sediment concentrations in the South Bay can, if sediment supplies remain as they have historically, sustain marsh restoration and sustainability to some extent into the future. Pond A17 was breached in October 2012.

The Warm Springs area of the SBSPRP (ponds A22 and A23) supports nesting snowy plovers. The depredation of snowy plover nests continues to be an issue where nesting habitat exists, particularly in this area adjacent to grassland and landfills, both of which attract common ravens and other predators. Ongoing hazing and removal of predators is needed to reduce the depredation of snowy plovers.

The South San Francisco Bay Shoreline Study conducted by the US Army Corps of Engineers and the Santa Clara Valley Water District is also making progress. It has drafted plans for a tidal flood-protection levee to be constructed on the inland side of ponds A12, A16, and A18, with proposed tidal marsh restoration on some of the outboard ponds (pending further data on waterbird numbers in response to restoration actions). Construction is scheduled to begin on the levee in 2017.

The city of San Jose manages the San Jose–Santa Clara Water Pollution Control Plant (WPCP) and surrounding plant lands, totaling about 2,680 acres. The city prepared a Plant Master Plan to identify WPCP improvements needed to address the aging infrastructure, changing regulations, and odors, and to develop a comprehensive land-use plan for the site. The master planning effort yielded a preferred alternative that included near-term and long-term (to 2040) improvements to the plant, and various environmental, economic, and recreation uses for the plant lands. The city certified an environmental impact report and adopted the Plant Master Plan in November 2013. It is proceeding with the implementation of near-term WPCP improvements.

Implications of Drivers of Change

Managed ponds in this segment will become increasingly difficult to maintain and operate at their specified elevations and salinities. As sea levels rise, levees protecting the ponds will need to be maintained and raised. Tide gates will have to be modified, and gravity-driven systems supplemented by pumping. The outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of marsh edges, resulting in a narrowing of marshes. Sedimentation rates on existing and restored tidal wetlands are expected to slow over time as suspended-sediment concentrations in the bay decrease.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The near term presents significant opportunities to restore tidal marsh in managed ponds that will help create a continuous corridor of tidal marsh along the bayshore. This restoration would include the reconnection of complex channel networks, incorporating topographic variation by placing material to mimic features such as natural levees, and could incorporate shallow pans. To accelerate the accretion of marsh surface in the subsided ponds, dredge sediment could be placed either directly within the ponds or on adjacent mudflats to be taken by wave and tidal action into the ponds. Slopes to create elevation gradients along the transition zone between tidal marsh and terrestrial areas could be created next to existing levees to provide buffers and high-tide refugia as well as habitat in its own right.

Dumbarton Cutoff Line —Newark Slough Swing Bridge

While rates of sea-level rise are low, some of the managed ponds could continue to be managed to provide habitat for shorebirds and waterfowl by changing their water levels and salinity (within the infrastructure limits). Levees surrounding the ponds would have to be built up to maintain these ponds as sea levels rise further.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the longer term, if the sea-level rise increases and sediment supply decreases as projected, it seems likely that the marsh plains will give way to narrower fringing marshes. Tidal marshes may be unable to keep up with the rising sea level, resulting in increased inundation of the marsh surface. This may lead to habitat conversion, perhaps to low marsh and mudflat. In addition, landward migration of the marsh is expected, and a gently sloping transition zone bayward of the levee would facilitate such a migration. Since there is considerable infrastructure in this segment, consideration should be given to filling in some of the managed ponds with material to create a gently sloping transition zone bayward of the levee. This would create space for marsh migration in the long term (and high-tide refugia in the short term).

At some point in the future, the degree of sea-level rise may make it unrealistic to maintain the managed ponds to benefit waterbirds. Prior to that point, a plan for restoring or relocating the functions of these ponds should be implemented that would move them outside the hazard zone. Simply restoring tidal action to the managed ponds late in the century may result in the creation of deep tidal ponds. To alleviate this, "warping up" the ponds could be undertaken during the earlier part of the century, allowing the accretion of the pond to be managed as well.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore tidal marsh throughout most of the segment prior to 2030, providing a continuous corridor of tidal marsh along the shore across a gradient of salt to brackish marsh.
- Create transition zones on gentle slopes in front of flood-risk-management levees (or other high-ground areas). Protect open space, including landfills, as it becomes available to incorporate into future transition zone designs.
- Optimize the management of ponds for a diverse suite of waterbirds, including shorebirds and waterfowl. Modify pond management as necessary to accommodate sea-level rise and other changes by modifying water-control structures, managing pond to facilitate warping, and reconfiguring or relocating ponds as necessary.
- Reestablish native riparian vegetation and otherwise improve the riparian corridor along Coyote Creek in conjunction with the City of San Jose Plant Master Plan.
- Restore vernal pools near baylands, and develop methods to enhance freshwater inputs to them in the event of prolonged extreme drought conditions.

- Consider ways to increase sediment supply to the tidal baylands. Methods could include placing sediment directly in marshes or placing dredged sediments on adjacent mudflats to be reworked by wave and tidal action to increase local suspended-sediment concentrations and marsh-accretion rates.
- Enhance and restore native oyster beds at suitable areas.
- Remove or elevate the railroad currently bisecting habitat.

FOR PARTICULAR WILDLIFE POPULATIONS

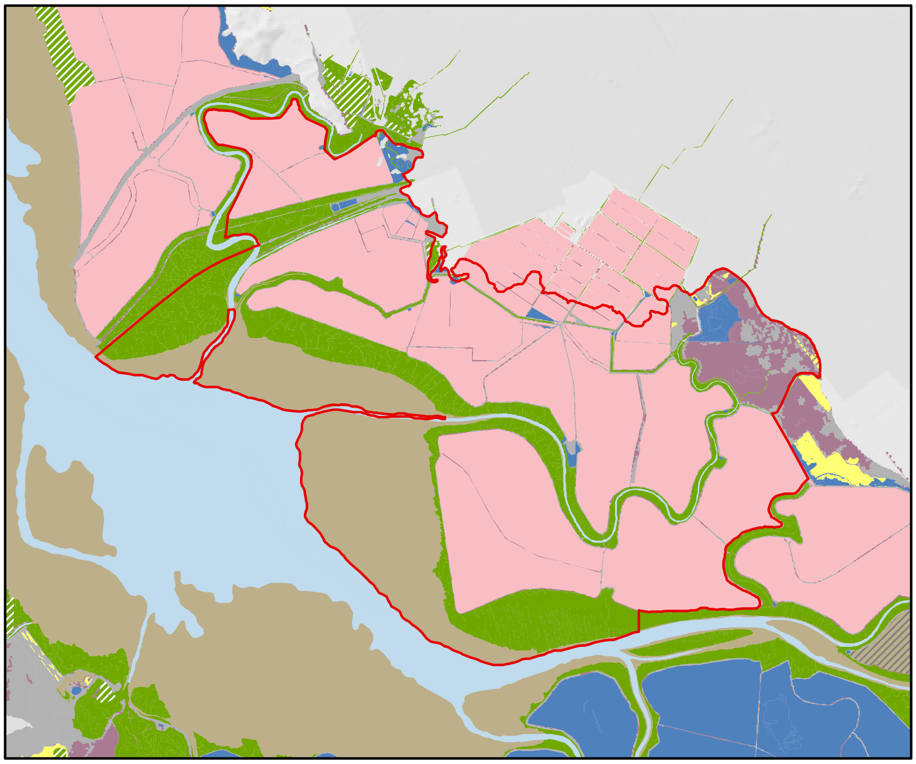
- Modify and manage ponds to enhance snowy plover breeding success in ponds A22 and A23, and islands in A16, as well as habitat for other waterbirds on islands and levees in managed ponds.
- Continue predator management at waterbird nesting habitats.
- Continue treatment of invasive *Spartina*, and consider revegetation plantings, high-tide-refuge islands, and other enhancements.

Restoration Benefits

Restoring tidal marsh along the shore would provide dispersal corridors (where none now exist) for the Ridgway's rail and the salt marsh harvest mouse, allowing these species to move between neighboring segments while minimizing predation and decreasing their vulnerability to local extinction. Implementation of the recommendations would increase rare plant species populations by enhancing the tidal marsh–moist grassland transition zone and vernal pools in the Warm Springs area. This would benefit the only remaining populations of California tiger salamander and tadpole shrimp near the baylands. Enhancing in-stream conditions in Coyote Creek could benefit steelhead populations. Freshwater discharges from the San Jose treatment facility should be managed to minimize large-scale conversion of saline–brackish tidal marsh while maintaining the large heron and egret rookery in Artesian Slough.

Challenges

Challenges in this segment include legacy mercury contamination, PG&E transmission lines and other utility corridors, flood-protection considerations, historical land subsidence, freshwater outflow from wastewater-treatment facilities, landfills as a source of avian predators, the presence of heavy metals in some of the older sewage-treatment ponds, the operation and maintenance of salt ponds in the absence of salt production, the loss of snowy plover habitat, and predator management. Invasive *Spartina* remains a critical priority, constraint, and consideration for some existing marshes and for restoration planning in this segment. Oyster drill populations may limit native oyster restoration. The SBSPRP is one of the key regional plans for this segment. Planning will require coordination with local agencies and organizations, including the Don Edwards San Francisco Bay National Wildlife Refuge, San Jose Water Pollution Control Plant, Santa Clara Valley Water District, and the community of Alviso.



MOWRY SLOUGH AREA

Eastern edge of San Francisco Bay between Albrae Slough and Highway 84 (Dumbarton Bridge)

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment Q.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

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Miles

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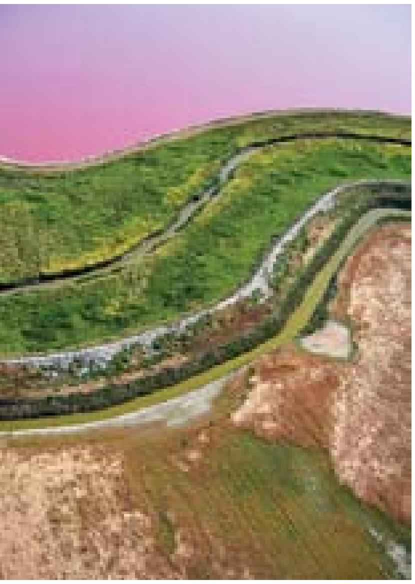


Mowry Slough

Unique Opportunities

Segment Q provides an opportunity to restore and enlarge the Dumbarton–Mowry marsh complex of tidal wetlands, potentially expanding available habitat for a core population of the Ridgway's rail. Managed ponds could be modified and maintained for the benefit of large numbers of shorebird species that forage on nearby mudflats, as well as high-salinity specialists such as eared grebes. There are opportunities to restore historic tidal marsh–upland transition zones and associated vernal pool habitat at the upper ends of Newark, Plummer, Mowry, and Albrae Sloughs. This segment has a considerable amount of open space that could be used as transition zone, including the former Pintail Duck Club and Newark areas 3 and 4 (the upper end of Mowry Slough).

Segment Features and Setting

Nearly all the wetlands within this segment were historically tidal salt marsh. These marshes supported extensive channel systems and numerous tidal marsh pans, including backshore pans along the transition zone. The mudflats outboard of the tidal marshes in the segment were moderate in size, with channel and shallow bay habitat more abundant than today. In the adjacent uplands, extensive areas of poorly drained moist grasslands supported vernal pools. Few streams entered the bay in this area; consequently, riparian habitat was limited. Alameda Creek may have variously entered the bay north of Coyote Hills or south, in the vicinity of present-day Plummer Creek.

Today, the majority of the area is composed of diked salt ponds that are still being operated for salt production. However, this segment does contain some of the largest acreage of natural tidal marsh in South Bay, including the Dumbarton, Mowry, and Calaveras Point Marshes. These marshes are important for the Ridgway's rail and the salt marsh harvest mouse. Mowry Slough provides an isolated haul-out area and pupping site for harbor seals. Newark Slough likewise provides a harbor seal haul-out site. The expansive mudflats in this segment are important foraging areas for shorebirds. Fringing marshes in this area have been very stable in recent decades, perhaps due to the lower wave energy and higher deposition rates in extant and restoring marshes than in other sections north of segment Q. Large numbers of California gulls nest along the levees and on islands in the southern portion of this segment. Small numbers of Forster's terns, American avocets, and killdeer nest on internal levees and islands.

Implications of Drivers of Change

Salt-evaporation ponds in this segment will become increasingly difficult to maintain and operate at their specified elevations and salinities. As sea levels rise, levees protecting the ponds will need to be maintained and raised. The outboard levees in particular will be subject to increasing wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of marsh edges, resulting in a narrowing of marshes. Sedimentation rates on existing and restored tidal wetlands are expected to slow over time as suspended-sediment concentrations in the bay decrease.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The ponds in this segment are owned in fee title by the Don Edwards San Francisco Bay National Wildlife Refuge. However, Cargill is still actively producing salt in this area and has indicated that it does not plan to make any changes. If that situation changes for any reason, the property would almost certainly be the subject of a large restoration effort. Restoring tidal marsh would help create a continuous corridor of tidal marsh along the bayshore. These restorations could include the reconnection of complex channel networks while incorporating topographic variation by placing material to mimic features such as natural levees, and could incorporate shallow pans.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

At some point the degree of sea-level rise may make it unrealistic to maintain the pond levees. Prior to that point, a plan for restoring or relocating the ecological functions of these ponds should be implemented that would move them outside the hazard zone. Simply restoring tidal action to the managed ponds late in the century may result in the creation of deep tidal ponds. To alleviate this, "warping up" the ponds could be undertaken during the earlier part of the century, allowing the accretion of the pond to be managed as well.

If tidal restoration is not an option for the short term, and the sea-level rise accelerates and sediment supply falls as projected, the marsh plain shoreline will likely give way to narrower fringing marshes over the longer term. Tidal marshes may be unable to keep up with the rising sea level, resulting in increased inundation of the marsh surface. This may lead to habitat conversion, perhaps to low marsh and mudflat.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore and enhance tidal marsh along the bayfront to provide a continuous corridor of tidal marsh for the entire length of the segment, particularly around Dumbarton Point (contiguous with segment R).
- Work with willing sellers to protect open space as it becomes available for conservation. Evaluate the feasibility of restoring tidal marshes in this area should ponds not remain in salt production.
- Optimize the management of ponds for a diverse suite of waterbirds, including shorebirds and waterfowl. Modify pond management as necessary to accommodate sea-level rise and other changes by modifying water-control structures, managing ponds to facilitate warping, and reconfiguring or relocating ponds as necessary.
- Elevate or remove the railroad and Hetch Hetchy pipeline and remove other barriers to achieve unimpeded tidal and other hydrological connectivity and reduce predator access to the marsh.
- Protect and enhance the tidal marsh–upland transition zone at the upper end of Mowry, Newark, Plummer, and Albrae Sloughs and in the area of the former Pintail Duck Club.

- Create transition zone habitats on gentle slopes in front of flood-risk-management levees (or other high-ground areas)
- Enhance and restore native oyster beds at suitable areas.

FOR PARTICULAR WILDLIFE POPULATIONS

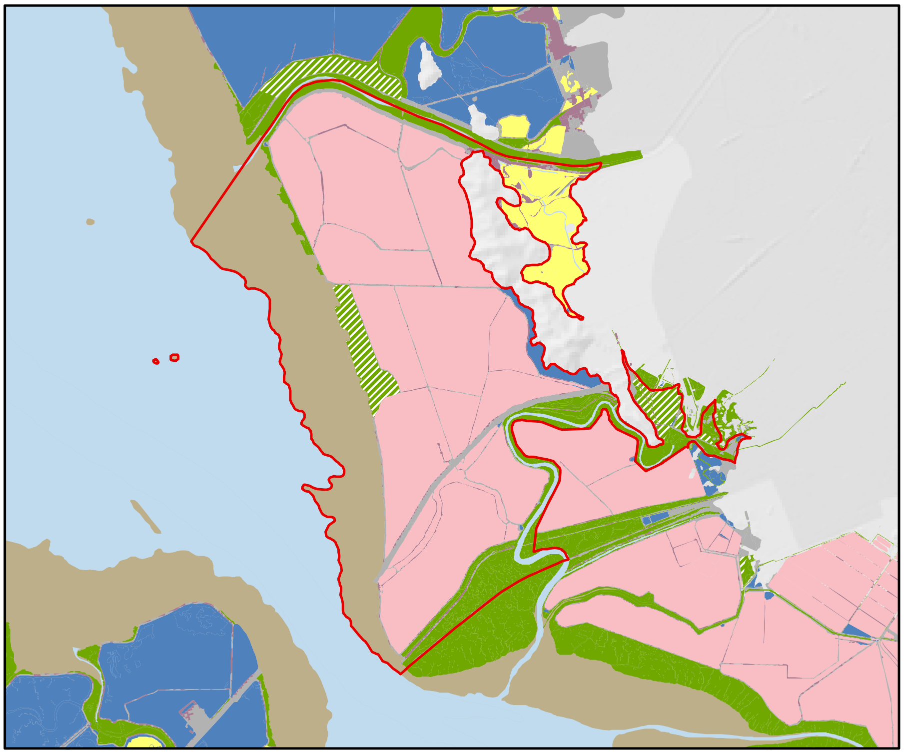
- Protect the area of harbor seal haul-out along lower Mowry Slough and at the mouth of Newark Slough.
- Continue treatment of invasive *Spartina* at Calaveras Marsh and other sites, and consider revegetation plantings, high-tide-refuge islands, and other enhancements.

Restoration Benefits

The Dumbarton and Mowry Marshes contain a large population of Ridgway's rail. This species could potentially colonize any restored tidal marsh in this segment. (Ridgway's rails have colonized several small diked wetlands that were recently restored to tidal action in the upper reaches of Newark Slough.) One of the contributing factors to the health of Ridgway's rail populations in this segment is that the marshes are large and have not been fragmented by levees as much as in other segments. This makes them relatively resistant to terrestrial mammalian predators due to the absence of main travel corridors (with notable exceptions such as the Hetch Hetchy Aqueduct and the railroad tracks). Modifying and managing a system of seasonal ponds (dry in summer) or islands would increase nesting habitat for the snowy plover as well as other waterbirds.

Challenges

Challenges in this segment include the Union Pacific railroad tracks; PG&E transmission lines, Hetch Hetchy Aqueduct, and other utility corridors; flood-control considerations; the need for continued operation and maintenance of salt ponds; the presence of bittern in some ponds; and predator corridors along levees and other linear features. Controlling invasive *Spartina* remains a critical priority, constraint, and consideration for some existing marshes and for restoration planning. Oyster drill populations could limit native oyster restoration. The South Bay Salt Pond Restoration Project is one of the key regional plans for this segment. Planning will require coordination with local agencies and organizations including the US Fish and Wildlife Service, Cargill, the San Francisco Public Utilities Commission, Alameda County, and the cities of Fremont and Hayward.



COYOTE HILLS AREA

Eastern edge of San Francisco Bay between Highway 84 and Alameda Creek Flood Control Channel

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment R.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

A corridor of tidal marsh along the bayshore could be restored in this segment. This corridor would connect the Dumbarton Marsh with the existing marsh to the north along the Alameda Creek Flood Control Channel. Salt ponds adjacent to the restored marshes could be managed to provide habitat for waterbirds. La Riviere Marsh and Mayhew's Landing and the adjacent lands offer opportunities for marsh enhancement and migration inland. Both of these harbor salt marsh harvest mice, and La Riviere has a substantial number of Ridgway's rails. Black rails have also been found in La Riviere Marsh in recent years. The hill where the Don Edwards refuge headquarters is located also offers marsh–upland transition zone migration opportunity. This segment has excellent opportunities for restoring a natural marsh–upland transition zone on the western edge of Coyote Hills. On the eastern side of Coyote Hills are seasonal wetlands, grasslands, and willow grove habitat that could be restored or enhanced to allow for marsh migration inland.

Segment Features and Setting

This area is dominated by Coyote Hills and salt ponds. Historically, the majority of the segment was tidal marsh. The marshes were expansive, with well-developed channels and high marsh and abundant tidal marsh pans. The marshes encircled Coyote Hills except to the east, where moist grassland bounded the upper margin of the marsh. These grasslands were characterized by springs and seeps, willow groves, seasonal ponds, and a permanent freshwater pond at the foot of the eastern slope of the hills. Alameda Creek may have variously entered the bay south of Coyote Hills, in the vicinity of present-day Plummer Creek, or just north of this segment. Outboard of the marshes were extensive tidal flats that continued north through segments S and T.

Today, the majority of the area is composed of diked salt ponds that are still being operated for salt production. Very little fringe marsh exists along the salt ponds, with the exception of Ideal Marsh. Coyote Hills and the large Alameda Creek Flood Control Channel are unique features. The diked baylands east of Coyote Hills support the largest remaining willow groves in the baylands ecosystem, seasonal and diked wetlands, and a permanent freshwater pond. The realignment of Alameda Creek through the northern portion of this segment has dramatically altered the hydrology of the area. The mudflats in this segment are very important foraging areas for shorebirds. California gull colonies and much smaller Caspian tern colonies nest on interior levees in this segment. Small numbers of Forster's terns, American avocets, and killdeer nest on internal levees and islands.

Implications of Drivers of Change

Salt-evaporation ponds in this segment will become increasingly difficult to maintain and operate at their specified elevations and salinities. As sea levels rise, levees protecting the ponds will need to be maintained and raised. The outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of marsh edges, resulting in a narrowing of marshes. Sedimentation rates on existing and restored tidal wetlands are expected to slow over time as suspended-sediment concentrations in the bay decrease.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The ponds in this segment are owned in fee title by the Don Edwards San Francisco Bay National Wildlife Refuge. However, Cargill is still actively producing salt in this area and has indicated that it does not plan to make any changes. If that situation changes for any reason, the property would almost certainly be the subject of a large restoration effort. In the near term, there are significant opportunities to restore tidal marsh in existing ponds that would help create a continuous corridor of tidal marsh along the shore. These restorations could include the reconnection of complex channel networks while incorporating topographic variation by placing material to mimic features such as natural levees, and could incorporate shallow pans.

Tidal channel in La Riviere Marsh

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

At some point the degree of sea-level rise may make it unrealistic to maintain the pond levees. Prior to that point, a plan for restoring or relocating the functions of these ponds should be implemented that would move them outside the hazard zone. Simply restoring tidal action to the managed ponds late in the century may result in the creation of deep tidal ponds. To alleviate this, "warping up" the ponds could be undertaken during the earlier part of the century, allowing the accretion of the pond to be managed as well.

In the longer term, if the sea-level rise accelerates and sediment supply falls as projected, marsh plains will probably give way to narrower fringing marshes. Tidal marshes may be unable to keep up with the rising sea level, resulting in increased inundation of the marsh surface. This may lead to habitat conversion, perhaps to low marsh and mudflat. This area could be targeted for a managed pond landscape that meets the needs of specific wildlife species in the longer term.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large areas to tidal marsh, creating a continuous corridor of tidal marsh around Dumbarton Point (contiguous with segment Q).
- Create transition zone habitat where feasible at the edges of existing marshes at Coyote Hills, on gentle slopes in front of flood-risk-management levees, and other suitable locations.
- Maintain and manage a small complex of salt ponds for shorebirds and waterfowl. Modify pond management as necessary to accommodate sea-level rise and other changes by modifying water-control structures, managing ponds to facilitate warping, and reconfiguring or relocating ponds as necessary.

- Work with willing sellers to protect open space as it becomes available for conservation. Evaluate the feasibility of restoring tidal marshes in this area should ponds not remain in salt production.
- Protect and enhance existing willow groves and seasonal wetlands.
- Consider removing the flood-control levees on the north side of the Alameda Creek Flood Control Channel's lower reaches as part of restoration planning for this area.
- Restore and enhance oyster beds and eelgrass beds at appropriate locations.
- Reduce the horizontal erosion of marshes by creating shell beaches in front of marsh scarps and by creating coarse beaches and berms in front of the outboard levee to protect managed ponds.
- Explore the use of creative flood-management techniques that take advantage of the benefits of restored tidal wetlands.

FOR PARTICULAR WILDLIFE POPULATIONS

- Control invasive *Spartina* to minimize its spread to newly restored neighboring marshes.

Restoration Benefits

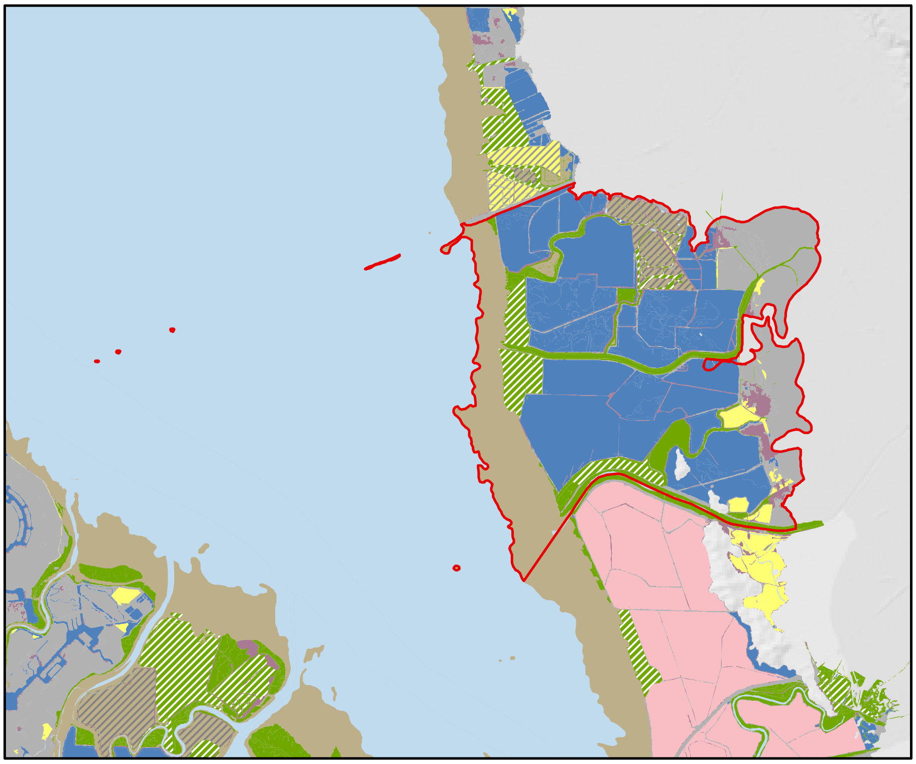
Restoring tidal wetland along the bayshore west of Coyote Hills would provide a dispersal corridor for Ridgway's rails and salt marsh harvest mice between the Dumbarton and Ideal Marshes and the marshes north of the Alameda Creek Flood Control Channel. Restoring the tidal marsh–upland transition zone would provide high-tide refugia for tidal species and increase habitat for rare plants.

On publicly owned ponds, maintaining and managing a system of seasonal ponds and islands would provide snowy plover nesting habitat and roosting and foraging habitat for other shorebirds and waterfowl.

Challenges

Challenges in this segment include the presence of invasive *Spartina*, flood-protection considerations, Highway 84, predator corridors along numerous levees, the potential for oyster drills to limit oyster restoration, the continued planned operation of salt production, and station KGO.

The South Bay Salt Pond Restoration Project is one of the key regional plans for this segment. Planning will require coordination with local agencies and organizations, including Alameda County, the US Fish and Wildlife Service, Cargill, the East Bay Regional Park District, Caltrans, and the cities of Hayward and Fremont.



BAUMBERG AREA

East Bay between Alameda Creek Flood Control Channel and Highway 92

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment S.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2
Miles

N

Unique Opportunities

Tidal marsh in Segment S could be restored to provide a dispersal corridor for salt marsh harvest mice, Ridgway's rails, and other native marsh species where no corridor currently exists. The excavation of small, shallow depressions to restore backshore pan habitat was included within the muted tidal eastern portion of Mount Eden Creek as part of tidal restoration plans for the original Eden Landing Ecological Reserve (ELER) Baumberg Tract. Pond complexes could be further reconfigured, modified, and managed to provide foraging and roosting habitat for resident and migratory shorebirds and waterfowl. Finally, the southern extent of the segment provides opportunities for projects to reconnect anadromous fish runs in the Alameda Creek Flood Control Channel to nursery tidal areas. Freshwater outflow (including treated water from the Union Sanitary District and East Bay Dischargers Authority) may be discharged locally for the restoration of more brackish tidal marsh. Large areas of restorable managed ponds between the bay and the developed environment provide an opportunity for innovative flood-risk-management techniques that use the storage capacity and wave-damping effects of marshes to assist in tidal flood protection.

Segment Features and Setting

Most of this segment was historically tidal marsh. These tidal marshes were very broad, with well-developed channels and abundant and large tidal marsh pans, including some backmarsh pans in the ELER Baumberg area. Outboard of the tidal marsh were large areas of tidal flat. At the upland boundary of the marshes were grasslands, of which a limited area was moist grassland capable of supporting seasonal ponding. The majority of this habitat was associated with the backshore pans near Eden Landing. Alameda Creek, a major tributary to South Bay, entered the bay in this segment. Due to its size, the creek provided a significant zone of brackish tidal marsh, a well-developed riparian habitat, and a run of steelhead. Turk Island, a northern extension of Coyote Hills, is in the southern portion of the segment.

Almost all of the tidal marsh has been converted to managed ponds. Currently they mainly remain managed, with a number of them recently restored to tidal action. (These include the Baumberg Tract, Mount Eden Creek, and North Creek Marshes; and areas E8A, E9, and E8X as part of the South Bay Salt Pond Restoration Project.) The largest extant tidal marsh is Whale's Tail Marsh, which was diked for salt production but abandoned in the 1920s. The other tidal marsh in the segment is just north of the Alameda Creek Flood Control Channel. This area was a managed pond restored with dredged material from the construction of the channel. Inadvertently, the restoration created a tidal marsh–upland transition zone by placing fill material above the intertidal zone on the eastern end of the site. Diked marshes in this area (including the Munster Tract, part of the refuge) and other duck hunting clubs exist here east of the Eden Landing Ecological Reserve.

Most of the snowy plover nesting in the South Bay subregion occurs in this segment, north of Old Alameda Creek, with limited nesting also in segment T to the north, segment P to the south, and segment N across the bay. The managed ponds in this area are important foraging and roosting habitat for migratory shorebirds and some waterfowl that use the nearby tidal flats. Some islands and levees in managed

Near the mouth of Mt. Eden Creek

ponds also provide nesting habitat for small numbers of American avocets, black-necked stilts, and Forster's terns.

Implications of Drivers of Change

Managed ponds in this segment will become increasingly difficult to maintain and operate at their specified elevations and salinities. As sea levels rise, levees protecting the ponds will need to be maintained and raised; tide gates will have to be modified, and gravity-driven systems supplemented by pumping. The outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of marsh edges (including coarse beaches), resulting in a narrowing of marshes. Sedimentation rates on existing and restored tidal wetlands are expected to slow over time as suspended-sediment concentrations in the bay decrease.

Considerations for Implementing the Actions

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

The near term offers significant opportunities to restore tidal marsh in managed ponds in the Eden Landing Ecological Reserve that will help create a continuous corridor of tidal marsh along the shore between Old Alameda Creek and the Alameda Creek Flood Control Channel, as well as inland to the urban edge. The following areas have been deemed suitable for tidal restoration in conjunction with appropriate flood-risk-reduction measures: all former salt ponds between the creek and channel, as well as some of the diked wetlands and detention areas used by the Alameda County Flood Control District. Tidal restoration actions could include the reconnection of complex channel networks while incorporating topographic variation by placing material to mimic features such as natural levees and high-ground transition zones, and could incorporate shallow pans. Preliminary planning for flood-risk management involves building up the existing berm at the edge of the bay and using restored marshes to damp the incoming tides.

To accelerate the accretion of the marsh surface in the moderately subsided ponds, dredge sediment could be placed either directly within the ponds or on adjacent mudflats to be redistributed by wave and tidal action into the ponds. Slopes to create elevation gradients along the transition zone between tidal marsh and adjacent upland areas could be created within existing ponds (prior to restoration) or adjacent to existing high ground and levees to provide buffers and high-tide refugia as well as habitat in its own right. In addition, salinity gradients could be re-created by seeping treated wastewater effluent from the Union Sanitary District site through created transition zones in order to incorporate brackish tidal marsh. Old Alameda Creek and the Alameda Creek Flood Control Channel could be connected to the adjacent marshes by levee breaches or water-control structures that accommodate fish passage, creating fish nursery grounds and allowing water, plant propagules, and sediment to enter the marshes from the creek.

While rates of sea-level rise are low, the water level and salinity of some of the managed ponds could continue to be managed to provide habitat for shorebirds and waterfowl. The SBSPRP planning process has identified a portion of the ponds north of Old Alameda Creek as suitable for this type of management. The ponds would require continued protection of the outboard levee to ensure its integrity. This may be an opportunity to create coarse sediment beaches, berms, and estuarine–terrestrial transition zones at the bay's edge to reduce erosion of the levee and re-create historical habitat that has been missing from the bay. Such a coarse beach could also be continued south along the marsh scarp or any flood-control features constructed on the bay's edge.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the longer term, if the sea-level rise accelerates and sediment supply falls as projected, marsh plains will probably give way to narrower fringing marshes. Tidal marshes may be unable to keep up with the rising sea level, resulting in increased inundation of the marsh surface. This may lead to habitat conversion, perhaps to low marsh and mudflat, and may accelerate the need for imported material. In addition, inland migration of the marsh is expected, and a gently sloping transition zone would facilitate such a migration. At the same time the coarse beach would be expected to roll landward as sea levels rise.

At some point the degree of sea-level rise may make it unrealistic to maintain the managed ponds. Prior to that point, a plan for restoring or relocating the functions of these ponds should be implemented that would move them outside the hazard zone. Simply restoring tidal action to the managed ponds late in the century may result in the creation of deep tidal ponds. To alleviate this, "warping up" the ponds could be undertaken during the earlier part of the century, allowing the accretion of the pond to be managed as well.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Restore large areas of managed ponds to tidal marsh connected to the Alameda Creek Flood Control Channel, Old Alameda Creek, and Mount Eden Creek.
- Maintain and manage a small complex of managed ponds for shorebirds and waterfowl. Modify pond management as necessary to accommodate sea-level rise and other changes by modifying water-control structures, managing ponds to facilitate warping, and reconfiguring or relocating ponds as necessary.
- Restore natural (e.g., Turk Island) and created marsh–upland transition zones. Fill ponds at the landward edge prior to tidal restoration to create a transition zone.
- Restore willow groves, seasonal wetlands, and natural salt pans where possible.
- Restore and enhance oyster beds and eelgrass beds at appropriate locations.
- Connect waste- and stormwater to bayland habitats where appropriate to enhance the transition zone slope and reestablish a salinity gradient within marshes.
- Reduce the horizontal erosion of marshes by creating coarse beaches in front of marsh scarps; these would roll landward with sea-level rise. Fortify the bay edge to ameliorate marsh erosion and facilitate restoration.

FOR PARTICULAR WILDLIFE POPULATIONS

- Protect existing muted tidal wetland for the salt marsh harvest mouse as insurance against fully tidal wetland being lost as a result of sea-level rise.
- Target the management of ponds for nesting snowy plovers and foraging small and medium-size shorebirds.
- Control invasive *Spartina* before restoring large diked areas to tidal marsh.

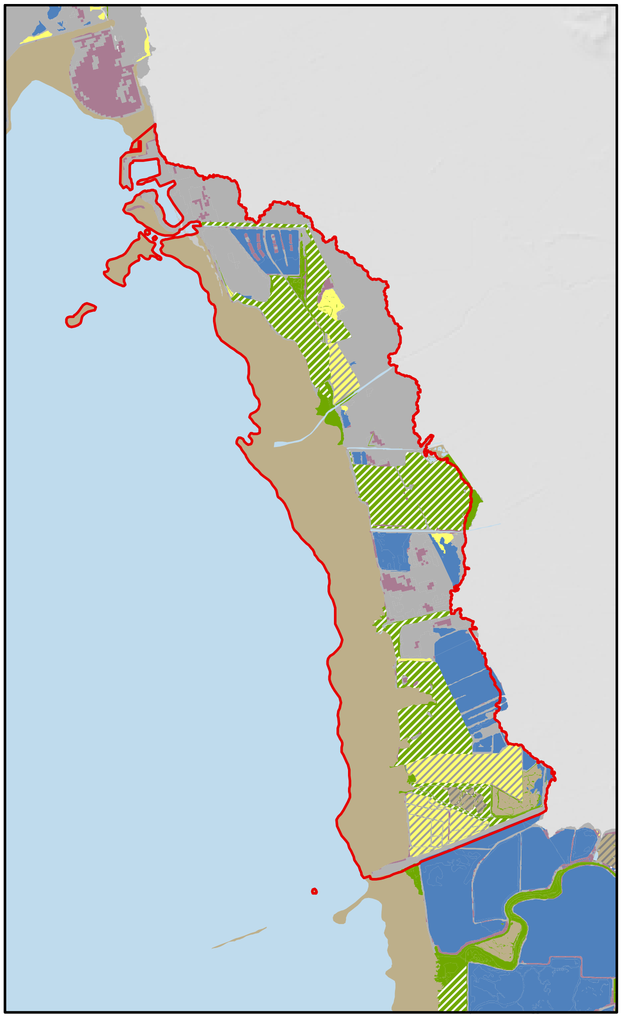
Restoration Benefits

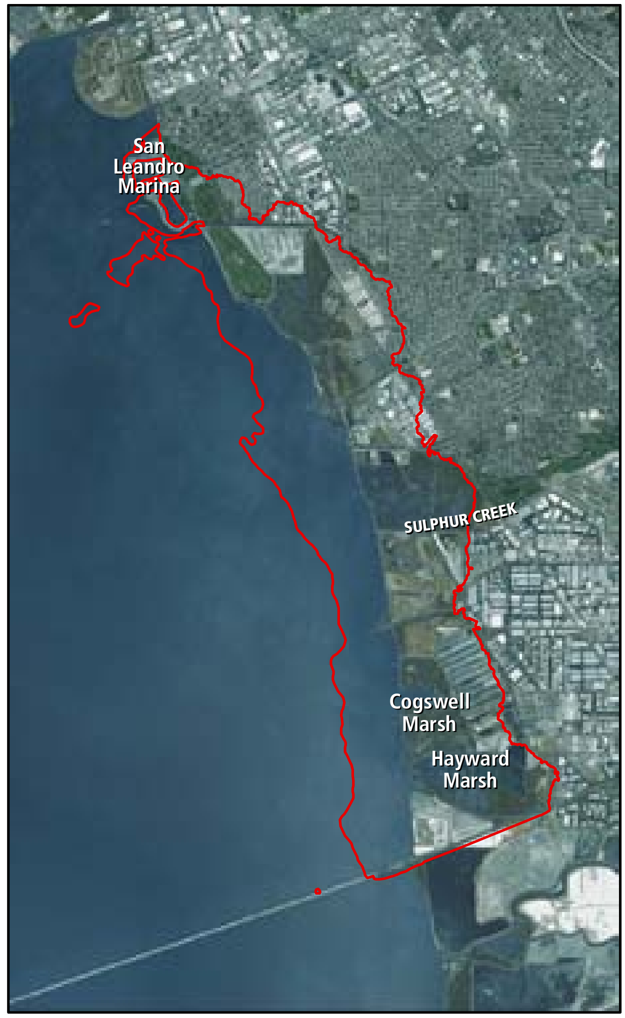
Restoring tidal marsh and the associated tidal marsh and backshore pans as well as coarse barrier beaches could benefit sensitive plant species and provide refugia for tidal marsh species and shorebirds. Managing a system of seasonal ponds (dry in summer) would provide nesting habitat for snowy plovers and other resident shorebirds. Ponds managed with year-round open water and exposed berms and islands would provide nesting, foraging, and roosting habitat for terns; they also would provide waterfowl habitat at the correct depth and salinity. Connecting the Alameda Creek Flood Control Channel to restored tidal marshes would enhance in-channel efforts for fisheries.

Challenges

Challenges in this segment include invasive *Spartina*, flood-protection considerations, the East Bay Dischargers Authority wastewater pipeline, PG&E transmission lines and other utility corridors, major predator access corridors, the potential for oyster drills to limit oyster restoration, the operation and maintenance of managed ponds in absence of salt production, and public access and recreation. The South Bay Salt Pond Restoration Project is one of the key regional plans for this segment. Planning will require coordination with local agencies and organizations, including the California Department of Fish and Wildlife, Alameda County, the Union Sanitary District, Caltrans, the East Bay Regional Park District, and the cities of Hayward, Union City, and Fremont.

BAYLANDS SEGMENT T





HAYWARD AREA

Eastern edge of San Francisco Bay between Highway 92 and San Leandro Marina

Baylands 2009

- Bay/Channel
- Diked Wetland
- Salt Pond
- Managed Pond
- Tidal Flat
- Tidal Marsh
- Agriculture and Other Undeveloped Areas
- Developed Areas

Red line shows the boundaries of Segment T.

Hatching indicates areas where restoration activities had occurred as of 2009. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes BAARI (v1, 2009) Baylands and Wetlands, NLCD 2006, and wetland tracker data.

Imagery: ESRI World Imagery (updated 2015)

0 2

Miles

N

Unique Opportunities

Segment T offers several opportunities to restore and enhance tidal habitats and to strengthen the linkages between subtidal, baylands, creeks, and terrestrial habitats. Other habitats such as moist grassland and seasonal wetlands adjacent to the Roberts Landing area, as well as several roosting sites, could also be protected and restored. Multiple creeks (Saulfur and others) are already the focus of community-based restoration efforts, and this work could be leveraged with additional activities integrating climate-change-adaptation techniques. The San Leandro Marina, Oro Loma Marsh, and the Hayward Regional Shoreline provide unique, visible opportunities to educate the public about wildlife habitat needs. Conditions at some sites are appropriate for native eelgrass and oyster restoration, and existing eelgrass and oyster beds offshore from Oyster Point Regional Shoreline and Hayward Regional Marsh could be enhanced.

Segment Features and Setting

Most of this segment was historically tidal marsh and large natural salt ponds, including Crystal Salt Pond. Along the foreshore of the bay were narrow sandy beaches near San Leandro and a continuous band of mudflats that became progressively wider moving south. Along the backshore were large areas of freshwater seeps and seasonal wetlands in the extensive moist grasslands. Several willow groves existed adjacent to Sulfur and San Lorenzo Creeks.

In the 1850s, much of the tidal marsh was diked to create land for salt production, and landings were established to move salt and other agricultural products to San Francisco. After salt production ceased in the 1940s, many of these diked wetlands became seasonal wetlands and have been recently restored to tidal action. The area north of Roberts Landing was restored to mostly muted tidal systems (e.g., Citation Marsh) in the 1990s for mitigation. To the south, within the Hayward Regional Shoreline, Cogswell Marsh, the Hayward Area Recreation District (HARD) Marsh, and Oro Loma Marsh represent large systems restored to tidal action in the 1980s and 1990s to improve habitat values. Multiple active revegetation enhancement projects are under way to increase native *Spartina* and marsh gumplant populations at Oro Loma, Cogswell, and HARD Marshes. The Hayward Regional Shoreline also contains multiple managed marsh and pond systems: Triangle Marsh, Hayward Marsh, and a five-basin managed fresh and brackish system that relies on secondary treated wastewater from the Union Sanitary District, Salt Marsh Harvest Mouse Preserve, and Oliver Salt Ponds. Oliver Salt Ponds used to provide important snowy plover habitat. However, the berms are increasingly overtopped, and Eden Landing provides superior habitat.

Today, there is considerable industrial development in this segment, with cities, industrial areas, natural gas lines, wastewater treatment infrastructure, electrical utility projects, creek channelization, residential developments, and transportation corridors. Landfills, managed ponds, parks, the San Leandro Marina, and other developments occupy sites that once were tidal flat or marsh.

Tidal flats still exist throughout most of their historical distribution, and there are several sandy barrier beaches and lagoons. Small fringe beaches and rocky intertidal areas are present along almost the full length of the segment, and intertidal and shallow subtidal areas support eelgrass, oyster, and macroalgal beds. Some vernal pools remain in the adjacent uplands.

The South Bay's only existing California least tern colony is in this segment on an island in one of the Hayward Regional Shoreline treatment ponds. Snowy plovers also nest on this island, albeit in small numbers and with limited success. A large Forster's tern colony nests on an adjacent island, and a heron and egret rookery is present, although it may have been declining in recent years. The water-treatment ponds have been suffering from repeated outbreaks of avian cholera and avian botulism for the past few years, causing large numbers of dead waterfowl and a possible population decline in the rookery. New management plans for these ponds are being considered by the East Bay Regional Park District.

Implications of Drivers of Change

Sea-level rise will increase the erosion caused by storm surges and wave energy, and increase the depth, duration, and frequency at which baylands are inundated.

The developed areas will become increasingly difficult to protect as sea levels rise but, unlike segment L (Berkeley–Albany), this segment has some adjacent areas at appropriate elevations that could allow for baylands migration. Increasing wave energy will increase the ongoing marsh edge erosion, while increasing inundation coupled with declining sediment supply will lead to a downshifting of bayland habitats and eventual drowning. The water levels and salinities of muted tidal marshes and ponds will become increasingly difficult to manage. Outboard levees in particular will be subject to greater wave action as water depths increase, allowing larger waves to propagate inshore. Increasing wave action will also accelerate the erosion of the small remaining marsh edges, resulting in the narrowing and a potentially complete loss of marshes and other unique habitats such as coarse beaches and rocky intertidal areas. This urbanized segment has a high degree of existing development that directly abuts the shoreline, resulting in limited accommodation space and limited areas for restoration adaptation. There is a need for innovative and experimental approaches that may include sediment placement, the use of uncontaminated on-site fill in restoration designs, and integrated multihabitat designs with multiple biological and physical objectives.

Considerations for Implementing the Actions

Significant restoration investment has already been made along the shoreline. The remaining opportunities involve select areas that could be evaluated to provide tidal marsh and transition zone habitat. The East Bay Dischargers Authority (EBDA) pipeline runs along the back of the Hayward Regional Shoreline from Hayward's Landing to Highway 92, and there may be co-benefits associated with preparing transition zone slopes for landward migration and treating wastewater. Modifying the managed pond systems could also provide for a broader range of habitat and species needs. The fact that the Hayward Regional Shoreline is a recreation destination may bolster public engagement in its restoration. Because the area is managed by a joint-powers authority (the Hayward Area Shoreline Planning Agency) it may be easier to raise funds, initiate studies, and go through the environmental review process for restoration projects.

NEAR TERM (NOW TO MIDCENTURY, PRIOR TO SLR CURVE ACCELERATION)

In the near term, when sea-level rise rates will still be relatively low, actions enhancing the baylands will provide immediate ecological benefits and maximize their resilience. Low-crested berms could reduce nearshore wave energy, coarse beaches could be created to reduce marsh-edge erosion, and the introduction of fine sediment through mudflat and marsh recharge could increase vertical accretion rates. Generally, restored marshes in this segment have dendritic tidal-channel networks, and the existing habitat is of fairly high quality, but the marsh plains could be further enhanced by active revegetation to speed up tidal-marsh-plant establishment. In addition, the construction of features such as high-tide-refuge mounds or artificial floating islands could be explored to create additional high-tide refugia within existing marsh plains. Living breakwaters could be created around fringing marshes to preserve and enhance unique features like native eelgrass and oyster beds.

This segment is highly urbanized, and landward migration of marsh is constrained by development directly adjacent to the baylands. Major land uses such as the city of Hayward's Water Pollution Control Facility adjacent to Hayward Marsh will need to be protected with approaches that haven't yet been tried locally, such as co-objective projects like the Hayward Shoreline–East Bay Dischargers Authority project noted earlier. Diverse pocket habitats could be preserved, enhanced, and created, then linked together to create a subregional habitat corridor. Vertical enhancements (living seawalls, substrate improvements to docks, etc.) could be made in a few subtidal and intertidal areas where there is hardscape. Many existing habitats could be enhanced by improving tidegate management, removing contaminated soils and derelict boats, and removing trash that ends up in the bay. Habitats could be created

Forster's terns

along flood-control channels, floodplains, and off channels. Low elevation marsh and wetland could be restored. Upstream opportunities are limited but should be included in any plans.

LONG TERM (LATTER HALF OF THE CENTURY, AFTER SLR CURVE ACCELERATION)

In the long term, sea level rise rates will likely outpace vertical accretion rates, and marshes in this segment generally do not have enough space to migrate landward to survive. Prior to that point, a plan for restoring or relocating the functions of the existing tidal marshes should be implemented. Creating wetlands bayward of the flood-protection levees, possibly using wastewater to enhance habitat on the slope, could provide space for landward migration. Simply restoring tidal action to the managed ponds late in the century may result in the creation of deep tidal ponds. To alleviate this, "warping up" the ponds could be undertaken during the earlier part of the century, allowing the accretion of the pond to be managed as well. The planned communities built over former wetlands and bay will be at risk for flooding as sea levels begin to rise. If opportunities for managed retreat become available, options should be pursued to restore areas to baylands or to connected bay habitats.

Recommended Actions

FOR HABITATS AND THE LANDSCAPE IN GENERAL

- Design and restore complete tidal wetland systems, even at a small scale, that include tidal marshes, beaches, and lagoons, broad transition zones, and develop techniques for implementing active revegetation, high-tide-refuge islands, and subtidal habitat restoration.
- Work with willing landowners to protect area landward of tidal marshes to create a transition zone and future tidal marsh habitat where feasible. A few opportunities may exist to acquire private shoreline land along the length of this segment.
- Reduce marsh-edge erosion by creating coarse beaches (with a sand foreshore transitioning to a coarse sand and gravel berm in front of the existing marsh scarp), which could also roll landward as sea levels rise.
- Increase local sediment availability by placing fine sediment in areas that will be reworked by wave and tidal action to increase suspended-sediment concentrations, which could then increase vertical accretion rates.
- Manage water levels in ponds for depth and salinity, and modify water-control structures to accommodate sea-level rise, which may require increasing the sedimentation in ponds (warping) to avoid having overly deep ponds. Ponds may need to be reconfigured or relocated over the long term.
- Create transition zone habitats on gentle slopes in conjunction with flood-risk-management features (or other high-ground areas). Consider transition zone preparation that reuses dredged material or treated wastewater, and encourages tidal-channel formation and pan development, resulting in topographic complexity (high-tide refugia). Fill ponds at the landward edge prior to tidal restoration to create a transition zone.

- Protect, enhance, and restore intertidal and subtidal habitats, including native oyster beds and eelgrass beds.

FOR PARTICULAR WILDLIFE POPULATIONS

- Target the management of ponds for nesting snowy plovers and foraging small and medium-size shorebirds.
- Control invasive *Spartina* before restoring large diked areas to tidal marsh.

Restoration Benefits

Restoring tidal marsh and transition zone habitat could benefit shorebirds and sensitive tidal marsh plant and animal species, as well as provide critical high-tide refugia. The use of dredged material to create the transition zone slopes and the local reuse of treated wastewater would repurpose to the fullest extent possible resources that are currently not reused. Constructing wide terrestrial transition zones landward of existing major salt marsh habitats would significantly improve the resilience of existing Ridgway's rail and black rail populations and their habitats as sea-level rise accelerates. Providing wide terrestrial transition zones would also improve wildlife buffers along trails and offset tidal marsh submergence and the loss of high-tide cover as existing marsh plains submerge. Implementation of the recommendations for this segment would improve habitat support for harbor seals, salt marsh harvest mice, and other mammals.

Enhancing seasonal wetlands would improve high-tide roosting habitat for shorebirds. Enhancing riparian and instream habitats would benefit migratory songbirds and steelhead. Restoring coarse-grained gravel beach habitat at various locations would provide high-tide roosting habitat for shorebirds and terns. Isolated (island-like) marsh-fringing beaches may provide additional nesting sites for terns. The use of treated wastewater to create freshwater and brackish marsh–terrestrial transition zone habitat at sites such as the existing marsh complex at Oro Loma–Hayward Shoreline would provide dense, tall, and extensive high-tide cover for rail species and would attenuate tidal flooding and wave runup. Restoring native oyster and eelgrass beds offshore would provide habitat for birds and fish, and may enhance food and nursery resources for species that use both wetlands and offshore shallow subtidal habitats. Living-shorelines designs may provide wave attenuation, sediment stabilization, and some flood protection in the near term for tidal marsh habitats on the shoreline.

Integrating native oyster and eelgrass restoration adjacent to tidal wetlands, creating living shorelines, and incorporating features such as high-tide-refuge islands could improve small areas of habitat. This would also provide information on how well these approaches succeed and whether they can be scaled up to larger areas in this segment. Such information could be applied to other segment adaptation planning.

Including public education and awareness components in any restoration initiative is critical to building the public and financial support that is needed to test adaptation approaches and work toward large-scale implementation of innovative techniques.

Challenges

Challenges in this segment include Highway 880, an urbanized edge with roadways and infrastructure, railroad tracks, flood-control considerations, exotic predators (e.g., rats and red fox), the potential for oyster drills to limit oyster restoration, invasive *Spartina*, and on-site contaminants. The shoreline has eroding bayfront levees and is crisscrossed with a variety of regionally critical infrastructure, including landfills, wastewater-treatment facilities, storm drainage channels, high-voltage electrical transmission lines, railroads, and freeways. As both sea level and groundwater rise, the risk of levee failure and a resulting damage to these utilities will increase over time. Planning will require coordination among agencies and organizations, including the Hayward Area Shoreline Planning Agency (which consists of the Hayward Area Recreation and Park District, East Bay Regional Park District, and city of Hayward), the Union Sanitary District, the Oro Loma Sanitary District, the East Bay Dischargers Authority, the city of San Leandro, Alameda County, and Union Pacific.