STAFF REPORT

Bay Fill for Habitat Restoration, Enhancement, and Creation in a Changing Bay

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1. Executive Summary

Sea level rise presents an unprecedented threat to Bay Area ecosystems. Sea level rise projections for the state of California indicate that valuable habitats, including tidal marshes, mudflats, and upland transition zones will experience more frequent inundation and rising average water levels. Subtidal habitats such as oyster and eelgrass beds will be exposed to deeper waters that could threaten their survival. To restore these ecosystems to their natural state or raise their elevation to make them more resilient to sea level rise, placement of potentially large volumes of Bay fill may be necessary.

BCDC's San Francisco Bay Plan (Bay Plan) policies currently restrict the amount of fill or dredged sediment that can be used for habitat projects in the Bay to a "minor" amount. These policies add restrictions to habitat projects beyond what is required for all projects proposing fill under the McAteer-Petris Act—that "the fill should be the minimum necessary to achieve the purpose of the fill…" The "minor fill" policies found in the Bay Plan could become problematic in the near future as more innovative and large-scale habitat restoration measures are proposed. Techniques such as constructing horizontal levees (a levee with a broad, shallow slope connecting to lower habitats, providing flood protection and habitat features), sediment augmentation to the marsh plain, marsh and subtidal habitat creation, among others, will be important sea level rise adaptation measures for Bay habitats, but may not be permissible to the extent necessary under current policies. Staff proposes that the "minor amount of fill" language should be removed from Bay Plan policies, but will still be subject to the McAteer-Petris Act fill requirements, thus ensuring that projects will not use excessive amounts of fill and must justify the fill volume that they are using is necessary. However, allowing more fill in the Bay for habitat projects could result in some impacts and habitat type conversions, such as marsh to upland or mudflat to marsh, the consequences of which are difficult to predict. To address uncertainties regarding project design and potential project impacts, staff recommends that detailed monitoring and adaptive management plans should be developed and carried out. This background report addresses the potential need to change BCDC's natural resource policies regarding fill in habitat projects, and the associated scientific and policy considerations. Next steps and external efforts to improve restoration of habitat projects in the Bay Area are also described herein.

2. The Changing Bay

Climate Change and Sea Level Rise

In California, climate change has resulted in myriad environmental changes which are expected to intensify in the coming century, including rising temperatures, ocean acidification, more frequent storms, changes in precipitation, more wildfires, and rising sea level.[1] In coastal areas, sea level rise is of particular concern as it threatens to permanently inundate priceless coastal ecosystems and billions of dollars of infrastructure. Sea level rise is caused by increasing releases of greenhouse gases that warm the planet, causing a combination of thermal

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[1] *Louise Bedsworth et al., "Statewide Summary Report," (California's Fourth Climate Change Assessment, December 21, 2018.)*

expansion of seawater and melting land ice and polar ice sheets.[2] This phenomenon presents a great threat to coastal ecosystems and human communities as more frequent flooding and inundation of the current coastline occurs, and contributes to increased erosion of both natural and hardened shorelines.

While sea level rise is a global phenomenon, sea levels will continue to vary locally. The State of California has undertaken several efforts to understand how climate change and sea level rise will specifically affect its major regions. Key reports include Rising Seas in California,[3] a document that synthesizes the state of the science on sea level rise, and the State of California Sea-Level Rise Guidance*: 2018 Update.*[4] Both of these reports predict the most likely scenarios for sea level rise in the state and assess some of the effects that sea level rise is likely to have in California. They provide local projections and historical summaries of sea level rise for the twelve major active tide gauges along the California Coast, including the San Francisco Bay Area tide gauge.

The evidence summarized in these reports suggests that sea level in the San Francisco Bay Area (Bay Area) has already risen eight inches in the last 100 years,[5] and is likely to rise anywhere between 2.8 and 4.1 feet in the next century. Extreme ice melt scenarios suggest that sea level rise may be as much as 14.2 feet by 2120.[6] Sea level rise visualization tools have been developed by organizations around the Bay Area, including BCDC, to assess the relative geographic impacts of sea level rise flooding and/or the combination of sea level rise with storm-induced flooding. Maps and projections produced by these tools indicate that large swaths of the Bay shoreline will have to increased flooding in the next 10 to 15 years, and that will become more frequent by the end of the century given local geography. Localized sea level rise projections indicate that the extent of flooding and shoreline erosion will vary greatly for different areas around the Bay. Given the Bay's highly urbanized shoreline and the high value natural resources that line it, the impacts of sea level rise in some areas are likely to be extreme.

Threatened Bay Ecosystems

This report focuses primarily on the impacts of rising seas and increased flooding on natural ecosystems around the Bay. Bay ecosystems are some of our best defenses against shoreline erosion and flooding, and provide essential habitat to wildlife and other organisms throughout the region, the state, and the entire Western Hemisphere for migratory birds. Bay ecosystems provide multiple additional co-benefits, including carbon sequestration, recreational

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[2] *G Griggs et al., "Rising Seas in California: an Update on Sea-Level Rise Science," (California Ocean Science Trust, April 14, 2017.)*

[3] *Griggs et al., "Rising Seas in California: an Update on Sea-Level Rise Science."*

[4] California Ocean Protection Council, "State of California Sea-Level Rise Guidance: 2018 Update," March 2, 2018, 1–84.

[5] *David Ackerly et al., "San Francisco Bay Area Summary Report," (California's Fourth Climate Change Assessment, December 13, 2018.)*

[6] *California Ocean Protection Council, "State of California Sea-Level Rise Guidance: 2018 Update."*

opportunities, and water quality improvement. Sea level rise poses the risk that these important habitats and all of their essential services may be lost altogether, or at least significantly altered.

Some of the key natural habitats in the Bay that provide these ecosystem services are tidal marshes, tidal flats, shallow subtidal habitats (including oyster and eelgrass beds), and beaches. Shallow subtidal habitats are found between 0 and minus 18 feet mean lower low water (MLLW) These habitats consist of muddy Bay bottom, shell fragments, oyster beds, artificial oyster reefs, eelgrass beds, seaweed beds, rocky outcroppings, and more. Shallow bays and channels account for about two-thirds of the Bay's area.[7] Tidal flats include mudflats, sandflats, and shellflats, and occur from MLLW to Mean Tide Level. These areas are typically submerged at high tide. Tidal marsh is vegetated wetland that is (1) subject to tidal action, (2) extends bayward to the lowest elevation that plants can grow and (3) extends landward to the highest area that area affected by the highest tides. Sandy beaches are considered a type of ecotone between shallow subtidal habitats and upland or marsh. These habitat types are described in more detail in Chapter 6 of this report, in the Baylands Ecosystem Habitat Goals Report (1999) and Appendix E of the Baylands Ecosystem Habitat Goals Science Update.[8]

While sea level rise poses a significant threat to these natural ecosystems, they are also resilient and capable of migrating landward with rising sea levels if space is available and if they are functioning as part of a healthy, complete system. In the Bay Area, however, many ecosystems have been altered by human actions and do not exhibit the suite of functions necessary to adapt to sea level rise. A key issue that will affect ecosystem resilience to rising sea level is the lack of sufficient sediment for marshes, mudflats, and other habitats to naturally gain elevation.

Decreasing Sediment Supply

Suspended sediment supply to the Bay has significantly declined in the past several decades. This decreased sediment supply results from several changes, including the waning pulse of sediment from the hydraulic mining during the Gold Rush, flood protection efforts that have disconnected the tributaries from the Bay and its marshes, development and impervious services, better management of local runoff and land surface erosion, and the damming of many of the Bay's watersheds, which captures sediment moving downstream and prevents it from entering the Bay. Schoellhamer (2011) demonstrated that a step decrease in the volume of suspended sediment entering the Bay through the San Francisco-San Joaquin River Delta, previously considered the source of about two-thirds of the Bay's suspended sediment, occurred in the late 1990's.[9] This step decrease means that much less suspended sediment has been available to Bay ecosystems for the past two decades. This reduction in suspended sediment entering the Bay through the Delta has put increased importance on suspended

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[7] *Goals Project, "Baylands Ecosystem Habitat Goals," (U.S. Environmental Protection Agency and San Francisco Bay Regional Water Quality Control Board, March 11, 1999.)*

[8] *Goals Project, "Baylands Ecosystem Habitat Goals Science Update Appendix E: Habitat Types," 2016.*

[9] *Schoellhamer, D.H. (2011) Sudden Clearing of Estuarine Waters upon Crossing the Threshold from Transport to Supply Regulation of Sediment Transport as an Erodible Sediment Pool is Depleted: San Francisco Bay, 1999. Estuaries and Coasts (34): 885-899.*

sediment entering the Bay from local tributaries. However, many of the streams and rivers that could supply much-needed sediment to the Bay are channelized and not connected naturally to marshes and mudflats as they once were. This disconnection further reduces the supply of sediment.

It is still unclear how sediment supply to the Bay will change in the coming years with climate change. This trend will depend on future shifts in precipitation, wildfires, and temperature.[10] More tidal marsh restoration on the horizon will create an even greater demand for limited sediment supply. Therefore, sediment will be an ever more necessary resource in building resilient ecosystems in the coming years, and to help maintain habitats that otherwise may be submerged and lost with sea level rise if sediment concentrations remain at their current level.

Fragmented Wetland Ecosystems

While the connection between streams and rivers to wetlands are an important factor in providing sediment to wetlands, reconnecting wetlands to upland areas is also important to provide migration space and prevent coastal squeeze. As sea level rises, wetlands may have the capacity to naturally migrate inland, so long as there is sufficient open space that can accommodate wetland flora and fauna and slowly transform into wetlands over time. If wetlands are directly adjacent to developed areas, this open space does not exist, and thus once existing wetlands are inundated, the habitat may be lost altogether in a given area. Connection to uplands via upland transition zones provides an important opportunity for wetland migration as sea level rises. Wetlands then may become patchier and less connected to each other around the Bay, which may present challenges for wildlife and ecosystem integrity.[11] Isolated wetlands have more edge habitat, which increases vulnerability to predation and other anthropogenic stressors. Patchy habitat can also reduce population connectivity for organisms that rely on these habitats, which makes individual populations more susceptible to loss as well.[12] Therefore, connection to uplands via upland transition zones provides an important opportunity for wetland migration as sea level rises.

Mitigating Change

The combination of rising sea level, decreased suspended sediment supply, and incomplete or fragmented ecosystems will threaten Bay ecosystems over the next century. Making vulnerable Bay habitats more resilient to sea level rise will involve restoring complete ecosystems including adequate sediment supply and habitat connectivity; ensuring as much sediment as possible is retained within the Bay system; reducing the erosive forces that will further degrade and reduce the size of Bay habitats; and placing sediment in areas where it is needed the most to ensure that susceptible habitats are not permanently inundated and restored areas can rapidly vegetate and become self-sustaining. All of these efforts may require placement of large volumes of sediment or other similar materials in the Bay. This placement of

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[10] *D Schoellhamer et al., "Sediment Supply to San Francisco Bay, Water Years 1995 Through 2016:," Regional Monitoring Program for Water Quality in San Francisco Bay, June 2018.*

[11] *Goals Project, "Baylands Ecosystem Habitat Goals Science Update Appendix E: Habitat Types," 2016.*

[12] *Ibid.*

various types and amounts of materials in the Bay is regulated by BCDC as "fill." BCDC defines fill as earth or any other substance or material placed in the Bay; this is described in more detail in Chapter 5.

3. Forty Years of Habitat Restoration in the Bay

Before sea level rise became a prominent issue, ecosystems around the Bay had already been extensively impacted by other human activities. Tidal marshes were diked and converted to agricultural land, salt ponds, or managed wetlands. Tidal marshes and mudflats were filled to create new development. Sewage and industrial wastewater was dumped in the Bay. Oyster beds are thought to have been prominent in the Bay in the 19th century and declined for unknown reasons by the early twentieth century,[13] but poor water quality likely played a role. When BCDC was created in 1965 to stop the indiscriminate diking and filling of the Bay, the Bay had already lost 90 percent of the tidal marsh that existed prior to 1850.[14] Early pioneers in wetland science observed this extensive habitat loss and degradation and recognized that the trajectory had to change. In the early 1970's, legislators at the state and federal level passed legislation that provided additional important environmental protections for the Bay, including the California Environmental Quality Act (1970), the National Environmental Protection Act (1970), the California and Federal Endangered Species Acts (1970 and 1973), the Clean Water Act (1972), and the Suisun Marsh Preservation Act (1977). Once BCDC was established and these legislative protections took effect, slowing damage to the Bay, the first restoration practitioners took the opportunity to begin reversing the damage that had been done. Thus began a new era of habitat restoration, which resulted in the planned, ongoing, or completed restoration of over 35,000 acres of tidal marsh by 2015.[15]

Early habitat restoration in the Bay Area was primarily focused on tidal marsh restoration. At that time, planting vegetation was considered the most important factor, while careful project design considering physical factors and gradual evolution of a dynamic system was not well understood. The first two tidal marsh restoration projects, Faber Tract, which used dredged sediment to raise elevations near East Palo Alto, and Pond 3 near the Eden Landing Ecological Reserve, primarily consisted of planting cordgrass (*Spartina spp*). Initially the focus was on re-creating physical features of mature tidal marshes (e.g. filling to final marsh plain elevation and dredging channels), but not on restoring wetland physical process. However, as many of these projects did not perform as expected, the restoration community realized that clear objectives and success criteria were important, and that physical parameters should be considered in project design. This realization also highlighted that fully functional wetlands would require more time to evolve than was initially expected.[16]

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[13] Chela J Zabin et al., "San Francisco Bay Subtidal Habitat Goals Report Appendix 7-1: Shellfish Conservation and Restoration in San Francisco Bay: Opportunities and Constraints," April 29, 2010.

[14] Goals Project, "Baylands Ecosystem Habitat Goals."

[15] Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."

[16] Philip Williams and Phyllis Faber, "Salt Marsh Restoration Experience in San Francisco Bay," Journal of Coastal Research no. 27, no. 27 (2001): 203–11.

Also during this time, perspectives were shifting on the management and disposal of dredged sediment, which was used in tidal marsh restoration to some extent but would later become increasingly important. In the 1980s, disposal of dredged sediment at the supposedly dispersive Alcatraz Island disposal site formed a large mound which limited its capacity and created navigational hazard. Additionally, representatives from the fishing and environmental communities raised concerns over the environmental impacts of dredged sediment disposal on the Bay's natural resources. At this time, BCDC began proposing beneficial reuse of dredged sediment rather disposing of it as a waste, working with state and federal partners to maximize dredge sediment use. These issues "highlighted the need for improved management of and alternative disposal options for dredged sediment."[17] In 1990, six federal and state agencies — U.S. Environmental Protection Agency (USEPA), the U.S. Army Corps of Engineers (USACE), the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), BCDC, the State Water Resources Control Board (SWRCB), and the State Lands Commission (SLC)— joined with navigation interests, fishing groups, environmental organizations, and other interested parties to form the Long Term Management Strategy for the Placement of Dredged Material in the Bay Region (LTMS).

The LTMS goals are to:

- maintain in an economically and environmentally sound manner navigation channels in San Francisco Bay;
- conduct dredged material disposal in the most environmentally sound manner;
- maximize the use of dredged material as a resource; and
- maintain the cooperative permitting framework for dredging/disposal.

The LTMS program has succeed in the beneficial use of over 25 million cubic yards of dredged sediment since its implementation and continues to facilitate the use of dredged sediment at large wetland restoration projects throughout the region, and thus is a key program that supports successful restoration in the Bay Area.

As restoration practitioners learned from early projects, the Bay Area entered a "second generation" of wetland restoration, characterized by a focus on reestablishing function and physical processes that gradually restore wetlands. Recognizing that deeply subsided diked baylands would benefit from sediment placement to raise site elevations, new methods were used to facilitate marsh development. Beginning with Sonoma Baylands, sediment was added to raise subsided baylands to just below marsh plain elevation, allowed to settle and consolidate, and then the sites were breached to the Bay to allow natural sedimentation to form marsh plain and channel networks over time. This practice shortened the period of time needed for plants to vegetate the site because of the large volumes of sediment that were placed, rather than waiting for it to come in on the tides. Sonoma Baylands also implemented the practice of using monitoring data from other restored sites to inform the design of new projects, creating generations of projects built on the knowledge gained by predecessors.

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[17] *US Army Corps of Engineers et al., "Long-Term Management Strategy for the Placement of Dredged sediment in the San Francisco Bay Region Management Plan," September 25, 2001.*

Project monitoring plans became part of the project design and permitting process. Another key aspect of the "second generation" of wetland restoration was the advent of restoration on a landscape scale. Previously, individual projects had been completed without much coordination among practitioners and without an overarching vision for restoration in the region. But by the mid to late 1990's, restoration practitioners and scientists began sharing what they had learned in earnest, and in doing so, realized the importance of restoration at a large scale.[18] This shared practice and new consideration resulted in the development of the Baylands Ecosystem Habitat Goals in 1999, which established the first regional habitat restoration goals.

Tidal marsh restoration projects grew in number, size and volume of fill used during the second generation. While first generation projects were typically 150-200 acres in size, some projects by the 1990s were nearly double that. Throughout this period, most restoration projects, but especially the large ones, were sited in former salt ponds (e.g. Napa Sonoma Salt Ponds and South Bay Salt Ponds) or deeply subsided diked baylands (e.g. Montezuma Wetlands, Hamilton Wetlands, and Bair Island), all of which were historically tidal marshes. Fill is important to restore these subsided sites to raise them closer to marsh plain elevation, so that channel and marsh plain development occurs quickly – especially in light of rising seas. Thus, large projects that restore diked baylands often corresponded with the need for significant volumes of dredged sediment. Bair Island used both dredged sediment and upland soils, and the South Bay Salt Pond Restoration Project is also targeting both types of material.

Wetland Restoration Project	Year Initially Authorized	Approximate Size (acres)	Volume of Fill (cubic yards)
Napa Pond 2A	1995	545	NA
Sonoma Baylands Project	1996	300	2 million
Montezuma	2001	2,300[19]	17 million*
South Bay Salt Pond	2003	15,000[20]	900,000*
Cullinan Ranch	2004	1,550	2.8 million*
Napa-Sonoma Salt Pond	2004	7,410	NA
Inner Bair Island	2006	270[21]	1.5 million
Hamilton	2008	1,600[22]	5.8 million

*dredged sediment placement not yet complete

Subsided diked baylands are not in BCDC's Bay jurisdiction, and placement of dredged sediment or upland soil during construction is therefore not considered Bay fill because they are not part of the Bay until they are breached. Placement of dredged sediment and soils is an important restoration technique, so long as the material does not have elevated levels of

[18] *Williams and Faber, "Salt Marsh Restoration Experience in San Francisco Bay."*

[19] *Montezuma Technical Review Team Report, n.d., https://www.sfei.org/projects/montezuma-technical-review-team#sthash.nH1F6Oaf.dpbs.)*

[20] *John C Callaway et al., "Tidal Wetland Restoration in San Francisco Bay: History and Current Issues," San Francisco Estuary and Watershed Science 9, no. 3 (December 2011): 1–12.*

[21] *San Francisco Bay Joint Venture, n.d. Bair Island. SF Bay Bair Island Project*

[22] *State Coastal Conservancy, n.d. Hamilton/Bel Marin Keys Wetland Restoration. Hamilton Wetlands*

contaminants or debris. However, if these projects were proposing to place the same volume of sediment *after* the sites were breached, the Bay Plan policies limiting fill would be in effect, requiring that the project use only a “minor amount of fill.” Under existing policies, placing large volumes of fill in tidal ecosystems that are part of the Bay is problematic, even if the fill is for habitat enhancement, creation, or restoration.

While projects like those described above did not need large amounts of Bay fill, one exception authorized during this period was the U.S. Army Corps of Engineers and Port of Oakland’s Middle Harbor Enhancement Project (Middle Harbor), part of the 50-Foot Deepening Project for the Port of Oakland’s Federal Navigation Channel. The Middle Harbor project placed 5.6 million cubic yards of dredged sediment in the Bay in a decommissioned U.S. Navy berthing area, raising the elevation of that subtidal area to shallow water such that it could support eelgrass. The full Middle Harbor Project consists of the creation of eelgrass beds, a small salt marsh, bird roosting islands, and a sandy beach.[23] The most novel and controversial aspect of the project was the placement of the large volume of dredged sediment from the channel deepening into the deep-water basin to create shallow water habitat. This is the largest subtidal restoration in the region and was part of an agreement to beneficially reuse the remaining sediment from the deepening project at Montezuma and Hamilton Wetland Restoration projects rather than dispose of the sediment as waste, and consistent with the LTMS Program. Because the project proposed such large volumes of Bay fill, substantially larger than any since the inception of BCDC, the project raised concerns about potential impacts, likelihood of success, and that this project may lead to an era of significant Bay fill and habitat conversion. To respond to these concerns, the Commission amended the Bay Plan in 2000 to ensure that additional large projects using dredged sediment for Bay restoration could not occur until the Middle Harbor project was successfully completed (BPA 3-00.) The Middle Harbor project is currently about 14 years behind schedule in completing the habitat features, but will be planting eelgrass in 2019.

By the mid-2000’s, realizations of the severity of projected climate change and sea level rise impacts, as well as changing sediment dynamics, began to shift the conversation on habitat restoration in the Bay. Numerous other impacts related to climate change were recognized as well, including changing land use, increased water demand, increased pollution, new invasive species, and the potential for seasonal shifts in estuarine salinities related to climate change.[24] At the same time, there was a focus on the need to better understand the Bay’s subtidal ecosystems. Discussions between the restoration community and agencies increasingly recognized the limited knowledge about subtidal areas and habitat extent, their connections with wetlands, and their restoration needs. The State Coastal Conservancy (Conservancy), NOAA National Marine Fisheries Service, and BCDC began to study subtidal areas and to develop subtidal goals for the region. This effort was formalized with the publication of the

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[23] *BCDC, “Staff Report on Middle Harbor Enhancement Project,” October 24, 2014.*

[24] *Callaway et al., (2011) “Tidal Wetland Restoration in San Francisco Bay: History and Current Issues.”*

Subtidal Habitat Goals Report in 2010,[25] which mirrored the Baylands Ecosystem Habitat Goals Report of 1999, but focused on the additional research needs to better understand this diverse subtidal habitat.

Perspectives on habitat restoration approaches continued to shift in the "third generation" of wetland restoration, and came into focus around 2015, continuing into the present day. Wetland restoration practioners are now increasingly considering restoration of "complete ecosystems," which include all aspects from subtidal habitats, to mudflats and tidal marsh, to upland transition zones (the area that connects a marsh to uplands areas). A greater focus on restoring wetlands processes at the landscape scale is being included in projects and has become prominent in regional ecosystem planning documents and is beginning to appear in projects. Restoration of complete systems includes increasing habitat diversity, ecological function, and resilience to the threats of climate change. In response to these changing perspectives, to address climate change, and incorporate resilient design principles into the region's restoration goals, an update to the Baylands Ecosystem Habitat Goals was released in 2015.[26]

To achieve regional restoration goals and improve efficiency in the design, construction, and management of large areas of tidal marsh, large, coordinated restoration projects, including the South Bay Salt Ponds Project, have been planned and are in construction.[27] Because landscape-scale restoration projects aim to restore multiple habitat features and support numerous species, phasing and adaptive management is necessary to avoid potential harmful effects from rapidly altering existing habitats, even if in their current state they provide only degraded habitat. These projects often feature experimental elements that improve our knowledge of untested methods. These projects will become increasingly important as we address the uncertainty of sea level rise[28, 29] and habitat conversion. Pilot projects that test concepts and new methodologies at a small scale will also be important as the region looks advance its restoration and adaption efforts.

Pilot projects that have been constructed in tidal waters and are subject to Bay fill policies include the San Francisco Bay Living Shorelines Project (San Rafael, Hayward Shoreline, and Giant Marsh sites), construction of seasonal wetlands and tidal pannes at Hamilton Wetlands, Aramburu Island, and testing of thin lift placement at Novato Creek (outside BCDC jurisdiction. An additional research project that tests how thickly sediment can be placed on a marsh, without burying and killing the marsh plants, is being conducted in Manzanita Marsh. Other new methods that may be tested are detailed in Chapters 6 and 7 of this report.

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[25] *San Francisco Bay Subtidal Habitat Goals Project, "San Francisco Bay Subtidal Habitat Goals Report," (State Coastal Conservancy, 2010.)*

[26] *Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."*

[27] *Callaway et al., "Tidal Wetland Restoration in San Francisco Bay: History and Current Issues."*

[28] *Roger Leventhal, "Overview of Fill Types for Habitat Restoration Projects in SF Bay," presented at BCDC Commission Meeting on February 7, 2019.*

[29] *Michelle Orr, "Lessons Learned From 40 + Years of Fill for Wetland Restoration in San Francisco Bay," presented at BCDC Commission Meeting on February 21, 2019, 1–34.*

4. Challenges for Restoration Implementation

Habitat restoration in the Bay Area has been advanced significantly since its advent in the 1970s, yet there are still many challenges that slow or hinder the achievement of the habitat restoration targeted by the 1999 Baylands Habitat Restoration Goals, the 2010 Subtidal Habitat Goals, and the 2016 Baylands Ecosystem Habitat Goals Update. The updated Baylands Goals highlighted climate change and rising sea level rise as a major factor that will influence the success of restoration projects and impact existing and restored habitats over time. The predictions for sea level rise identify a significantly increasing rate of sea level rise after 2030, after which time wetlands that are not already in place and fully functioning will face even higher risk of failure. This prediction has increased the urgency to complete as many restoration projects as possible, and to identify adaptive measures for these habitats.

Implementing restoration projects is complex by nature and involves many actors, many uncertainties, and substantial investment of time, money and energy to plan each project. First and foremost are the cost and logistics involved in acquiring land, designing, planning, environmental review, permitting, construction, monitoring, and maintaining these projects. In addition, these projects are often sites in sensitive habitats or involve threatened and endangered species which require special measures to protect them. Further, the dynamic changes facing the region due to climate change and uncertain increases the complexity of planning, execution and maintenance of projects. Part of the challenge project sponsors face is applying for and obtaining permits and other authorizations for these projects.

While restoration projects face many challenges, BCDC can assist in reducing difficulties and improving permitting outcomes by updating its policies. The policy challenges have primarily surrounded the issues associated with rising seas and the need to adapt habitat projects over time, with uncertain futures and outcomes. BCDC is addressing these issues by updating policies to allow more fill in tidal areas to restore and enhance habitat, adaptive measures, and pilot projects and experimentation that will inform the region on the efficacy of new techniques. Due to the uncertainty of both future conditions and how habitats, existing and restored, will respond, monitoring and adaptive management plans are important tools that should be employed. The permitting process may also improve through the implementation of the proposed amended policies.

The permitting process is just one of the logistical challenges of restoration projects. In the Bay Area, restoration projects regularly are required to seek permits and/or approval from up to seven regulatory and resource agencies, including the U.S. Army Corps of Engineers (permit), the U.S. Fish and Wildlife Service (Endangered Species Consultation), NOAA National Marine Fisheries Service (Endangered Species and Essential Fish Habitat Consultation), the State Lands Commission (lease if property is owned by the State), the San Francisco Bay Regional Water Quality Control Board (Waste Discharge Requirements or Water Quality Certification), the California Department of Fish and Wildlife (Lake and Streambed Alteration or Incidental Take Permit) and BCDC (Permit or Federal Consistency Concurrence.)

Each agency has laws and policies that they must adhere to in permitting decisions. As a result, agencies emphasize different aspects of projects or require different monitoring, minimization, and mitigation measures, which when not aligned with other agencies' requirements can cause confusion and increase costs of project development, monitoring, or management. For example, agencies may have different requirements for monitoring, given the focus of their law. When not coordinated, inconsistencies occur and the applicant often must work between agencies to seek resolution, or has to find a way to comply with all conditions.

Restoration and habitat enhancement projects are often sited in sensitive habitats and involve sensitive species. Projects that propose to place fill in tidally active areas would also be sited in sensitive areas, not only from a species perspective, but also in terms of constructability. Because of the proximity to sensitive species and habitat, agencies with mandates to protect them include minimization measures and often mitigation measures, which can increase construction costs and timeframes. These requirements are instituted to be protective, however delays may mean that important future habitat is not provided as quickly as possible. Restoration practioners point out that the projects are meant to benefit these same species and habitat, and therefore are seeking improvements in permitting practices and requirements.

A significant challenge for both the restoration and regulatory community is the timing and extent of sea level rise. Agencies are seeking to protect existing habitat for current species populations while authorizing measures that would provide adaptive capacity over time. Restoration practioners are seeking to construct projects that will be successful and have the ability to adapt to rising seas, or risk having years of effort lost. Long-term project planning that assesses risk and response to sea level rise can be particularly challenging to address as many of these outcomes are difficult to predict and involve judgment calls. Additionally, consensus on some issues, such as allowing conversion of habitat type, is inherently difficult to achieve because they involve analysis of tradeoffs which differ depending on value judgments and estimations of uncertain outcomes. Monitoring and adaptive management of projects is a path forward to address these uncertainties, though pilot projects will undoubtedly play a role in regional learning.

As is often the case in the Bay Area, communities have come together to address these and other challenges. Funding has always been limited for restoration projects, hindering progress while waiting for grant funds. Regulatory and resource agencies struggle with staffing constraints. In 2016, Bay Area residents affirmed their values for a healthy Bay, and voted yes on Measure AA, taxing themselves to provide $500 million dollars of funding for habitat, water quality, and public access projects, over 25 years. A small portion of these funds, and funds from other agencies will support a new regulatory effort to coordinate permitting of restoration projects similar to that of the LTMS Program, the multi-agency Bay Restoration Regulatory Integration Team (BRRIT). This effort is intended to improve the application and permitting process through increased communication and coordination among agencies and applicants. Similarly, the San Francisco Estuary Partnership is working with partners to develop a regional wetland monitoring program that would increase coordination and data sharing, identify regional monitoring opportunities, and potentially reduce monitoring costs, while increasing regional understanding of habitat status and trends. These efforts taken together with BCDC policy improvements hold promise for a more streamlined permitting process.

5. "Bay Fill" and BCDC's Associated Policies

"Fill" is defined in the McAteer-Petris Act, Section 66632 as "earth or any other substance or material, including pilings or structures placed on pilings, and structures floating at some or all times and moored for extended periods, such as houseboats and floating docks." Fill is further defined in the summary section of the Bay Plan, providing a slight modification that specifically includes piers and other floating structures. These definition of fill applies to all areas of BCDC's jurisdiction. Moreover, Bay fill specifically refers to fill in BCDC's Bay jurisdiction, which is defined as,

> All areas that are subject to tidal action from the south end of the bay to the Golden Gate (Point Bonita-Point Lobos) and to the Sacramento River line (a line between Stake Point and Simmons Point, extended northeasterly to the mouth of Marshall Cut), including all sloughs, and specifically, the marshlands lying between mean high tide and five feet above mean sea level; tidelands (land lying between mean high tide and mean low tide); and submerged lands (land lying below mean low tide).[30]

Suisun Marsh, while governed by the Suisun Marsh Preservation Act, is also subject to the McAteer-Petris Act and the Bay Plan's definition of fill. The Suisun Marsh Preservation Act includes a definition of development that includes "the placement or erection of any solid material or structure...." which is similar to the McAteer Petris Act definition of fill, and is used to determine if a marsh development permit is necessary.

Fill placed in salt ponds and managed wetlands is subject to different policies than fill in BCDC's Bay jurisdiction, in that these two sets of policies encourage the restoration of these sites to tidal marsh or subtidal habitat, and consider the use of sediment and aggregate to assist in restoration. Subsided diked baylands, where many wetland restoration projects have occurred, are in BCDC's shoreline band's jurisdiction where fill is not specifically limited to the minimum amount necessary for the purpose of the fill. Instead the focus of permitting in the shoreline band jurisdiction providing the maximum feasible public access to the Bay. This Bay Plan Amendment is specifically addressing issues associated with fill habitat projects in the Bay and its tidal waters.

As discussed in Chapter 2, placing potentially large volumes of sediment and other materials in the Bay to facilitate habitat adaptation to sea level rise may be essential in the coming years. However, BCDC's current findings and policies in the Major Conclusions and Policies section of the Bay Plan do not address the need for Bay fill for habitat restoration/adaptation and the benefits that fill can provide to the Bay's ecosystems. Instead, these existing conclusions only address the potential impacts of Bay Fill and justifiable uses of Bay Fill focused on the built environment:

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[30] *McAteer-Petris Act Section 66610. Specification of Areas of Jurisdiction of San Francisco Bay Conservation and Development Commission; Definition as Prescribing Jurisdiction; Construction; Areas Excluded From Jurisdiction, n.d.*

4. **Justifiable Filling.** Some Bay filling may be justified for purposes providing substantial public benefits if these same benefits could not be achieved equally well without filling. Substantial public benefits are provided by:
    a. Developing adequate port terminals, on a regional basis, to keep San Francisco Bay in the forefront of the world's great harbors during a period of rapid change in shipping technology.
    b. Developing adequate land for industries that require access to shipping channels for transportation of raw materials or manufactured products.
    c. Developing new recreational opportunities—shoreline parks, marinas, fishing piers, beaches, hiking and bicycling paths, and scenic drives.
    d. Developing expanded airport terminals and runways if regional studies demonstrate that there are no feasible sites for major airport development away from the Bay.
    e. Developing new freeway routes (with construction on pilings, not solid fill) if thorough study determines that no feasible alternatives are available.
    f. Developing new public access to the Bay and enhancing shoreline appearance—over and above that provided by other Bay Plan policies—through filling limited to Bay-related commercial recreation and public assembly.
5. **Effects of Bay Filling.** Bay filling should be limited to water-oriented purposes, however, because any filling is harmful to the Bay, and thus to present and future generations of Bay Area residents. All Bay filling has one or more of the following harmful effects:
    a. Filling destroys the habitat of fish and wildlife. Future filling can disrupt the ecological balance in the Bay, which has already been damaged by past fills, and can endanger the very existence of some species of birds and fish. The Bay, including open water, mudflats, and marshlands, is a complex biological system, in which microorganisms, plants, fish, waterfowl, and shorebirds live in a delicate balance created by nature, and in which seemingly minor changes, such as a new fill or dredging project, may have far-reaching and sometimes highly destructive effects.
    b. Filling almost always increases the danger of water pollution by reducing the ability of the Bay to assimilate the increasing quantities of liquid wastes being poured into it. Filling reduces both the surface area of the Bay and the volume of water in the Bay; this reduces the ability of the Bay to maintain adequate levels of oxygen in its waters, and also reduces the strength of the tides necessary to flush wastes from the Bay.
    c. Filling reduces the air-conditioning effects of the Bay and increases the danger of air pollution in the Bay Area. Reducing the open water surface over which cool air can move in from the ocean will reduce the amount of this air reaching the Santa Clara Valley and the Carquinez Strait in the summer—and will increase the frequency and intensity of temperature-inversions, which trap air pollutants and thus cause an increase in smog in the Bay Area.
    d. Indiscriminate filling will diminish the scenic beauty of the Bay.

This language does not accurately represent current understanding of Bay ecosystems and evolving approaches to restoration. BCDC has recognized the risk of inundation and degradation of habitat from sea level rise and the important role that fill will play in ensuring that susceptible Bay habitats remain resilient. Accordingly, supplementing and potentially modifying the language in the Major Conclusions and Policies section to reflect the benefits and nuance of the impacts of Bay Fill for restoration would portray a more consistent and accurate perspective consistent with current understanding.

Other policies actually restrict the permissible volumes of fill allowed in the Bay for adaptation of habitat projects. A set of three similar policies which appear in different sections of the Bay Plan do not allow more than “a minor amount” of fill for habitat restoration, enhancement, or creation projects in wildlife refuges, tidal marshes, tidal flats, and subtidal areas. These policies were added to the Bay Plan as part of an amendment process to update the natural resource findings and policies that was initiated in 2001 and took effect in 2003. The policies were added because BCDC had recognized that *some* fill was necessary at times for habitat projects to be successful, but the idea of placing larger volumes of fill in the Bay for habitat restoration was still considered problematic. Additionally, sea level rise had not yet been recognized as a major concern, so the idea that more fill could be necessary for habitat adaptation was not considered. The policies are:

- Fish, Other Aquatic Organisms, and Wildlife Policy 5: The Commission may permit a minor amount of fill or dredging in wildlife refuges, shown on the Plan Maps, necessary to enhance fish, other aquatic organisms and wildlife habitat or to provide public facilities for wildlife observation, interpretation and education.
- Tidal Marshes and Tidal Flats Policy 8: Based on scientific ecological analysis and consultation with the relevant federal and state resource agencies, a minor amount of fill may be authorized to enhance or restore fish, other aquatic organisms or wildlife habitat if the Commission finds that no other method of enhancement or restoration except filling is feasible.
- Subtidal Areas Policy 6: Based on scientific ecological analysis and consultation with the relevant federal and state resource agencies, a minor amount of fill may be authorized to enhance or restore fish, other aquatic organisms or wildlife habitat if the Commission finds that no other method of enhancement or restoration except filling is feasible.

While initially intended to provide some fill as needed, these policies now prevent more than a minor amount of fill in the specified parts of the Bay. According to the Bay Plan, “The wildlife refuges, shown on the Bay Plan Maps, include national wildlife refuges, state wildlife areas and ecological reserves, as well as other shoreline sites around the Bay whose primary purpose is: (1) the protection of threatened or endangered native plants, wildlife, and aquatic organisms; (2) the preservation and enhancement of unique habitat types or highly significant wildlife habitat; or (3) the propagation and feeding of aquatic life and wildlife.”[31] Areas of the

[31] *San Francisco Bay Plan. Fish, Other Aquatic Organisms, and Wildlife Finding*

Bay that fit this description are subject to the "minor amount of fill" policy, with few exceptions. Likewise, the Subtidal Areas section of the Bay Plan contains "Findings and Policies concerning Subtidal Areas in the Bay," and therefore only applies to subtidal areas of the Bay.

A similar policy in the Dredging section of the Bay Plan limits the beneficial reuse of dredged sediment for habitat restoration, enhancement, or creation to a "minor amount", until three specified conditions are met. Dredging policy 11b states that:

B. To ensure protection of Bay habitats, the Commission should not authorize dredged sediment disposal projects in the Bay and certain waterways for habitat creation, enhancement or restoration, except for projects using a minor amount of dredged sediment, until:

   1. Objective and scientific studies have been carried out to evaluate the advisability of disposal of dredged sediment in the Bay and certain waterways for habitat creation, enhancement and restoration. Those additional studies should address the following:

      a. The Baywide need for in-Bay habitat creation, enhancement and restoration, in the context of maintaining appropriate amounts of all habitat types within the Bay, especially for support and recovery of endangered species;

      b. The need to use dredged sediments to improve Bay habitat, the appropriate characteristics of locations in the Bay for such projects, and the potential short-term and cumulative impacts of such projects;

   2. The Commission has adopted additional Baywide policies governing disposal of dredged sediment in the Bay and certain waterways for the creation, enhancement and restoration of Bay habitat, which narratively establish the necessary biological, hydrological, physical and locational characteristics of candidate sites; and
   3. The Oakland Middle Harbor enhancement project, if undertaken, is completed successfully.

Of these conditions, the first has been partially completed in that BEHGU,[32] the Subtidal Habitat Goals Report,[33] and SFEI and SPUR's recently released San Francisco Bay Shoreline Adaptation Atlas[34] have identified potential locations where use of sediment maybe beneficial. BEHGU and the Subtidal Goals Report both address the need for in-Bay habitat creation, enhancement, and restoration, but this is not in the context of "maintaining the appropriate amounts of all habitat types within the Bay". BEHGU and the Adaptation Atlas highlight the need to use dredged sediments to improve Bay habitat, and address the appropriate locations in the Bay for these projects, but the criteria for project location assessment do not fully align

[32] Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."
[33] San Francisco Bay Subtidal Habitat Goals Project, "San Francisco Bay Subtidal Habitat Goals Report."
[34] SFEI & SPUR, "San Francisco Bay Shoreline Adaptation Atlas," May 2, 2019.

with the requirement in this condition. Existing literature addresses the potential short-term impacts of this work (discussed in Chapter 7), but most of these studies do not examine impacts on the Bay or assess cumulative impacts of these projects.

The second condition has not yet been completed. No additional Baywide policies have been adopted by BCDC to establish the necessary characteristics of candidate sites. The third condition refers to an ongoing project that has not yet been completed. The Middle Harbor Enhancement Project is part of the Port of Oakland 50-foot Deepening Project, a U.S. Army Corps of Engineers and Port of Oakland federal navigation channel deepening effort that restored a deep water berth to shallow water habitat and was the subject of a consistency determination that BCDC concurred with in 2000. The project is described in more detail in Chapter 3 of this report. While the project has progressed since its initial construction, it is still significantly behind schedule and the regulatory agencies, Save the Bay, the Sierra Club, Audubon Society, and others are concerned that it will not meet its proposed habitat enhancement goals. Thus, it is difficult to assess whether and when all of the conditions of Dredging Policy 11b will be completed, resulting in concern that this policy will likely continue to limit the amount of dredged sediment that can be used in habitat projects in the Bay.

In addition to the policies described above, BCDC's law also restricts the amount of fill that can be used for any project in BCDC's jurisdiction. Section 66605 of the McAteer Petris Act states in part that "the water area authorized to be filled should be the minimum necessary to achieve the purpose of the fill". This law applies to all projects, including habitat projects. However, this law has the potential to allow much more fill than the "minor amount" of fill allowed under Bay Plan policies. The law in practice is not interpreted strictly as the bare minimum amount, but instead as the minimum amount necessary for the project to meet its goals. Additionally, this law serves to safeguard against the placement of excessive amounts of fill, and requires that applicants justify the amount of fill used in the project, in order to balance habitat protection with well-justified improvement projects.

The Bay Plan policies that restrict fill or beneficial reuse of dredged sediment in the Bay were added to the Bay Plan through two amendment processes in the early 2000s. An amendment to the Bay Plan was initiated in 2000 in part as a stipulation of permitting the Fifty-Foot Deepening Project and the Middle Harbor Enhancement Project component (BPA 3-00). Fill had never been placed in the Bay at this scale for a habitat project since the creation of BCDC because this type of fill placement was novel in the Bay, and there were many unknowns. The environmental and environmental justice communities wanted to ensure that in-Bay disposal of sediment at this scale did not become a regular practice, and that the West Oakland Community would receive benefits—not just the additional burdens from the deepening project. Therefore, policies were added to limit beneficial reuse of dredged sediment in the Bay for habitat restoration projects until monitoring of the Middle Harbor Enhancement Project showed it would be successful and benefits of such action could be identified.

Additionally, Bay Plan Amendment No. 1-01 was the first major reassessment of BCDC's natural resource policies since the Bay Plan was created. The amendment process resulted in the creation of the Subtidal Areas policies and the addition of several new natural resource policies in other sections of the Bay Plan. The amendment also resulted in the addition of the “minor fill” language being applied to existing habitat, constructing high tide refugia and transitional habitat, or living shoreline projects in the Bay. Both of these policy amendments were indicative of the recognition that some fill may provide habitat benefits and of the cautious attitude toward fill in the Bay that existed in the early 2000’s.

Since that time, restoration projects involving large volumes of fill have typically occurred in subsided diked baylands and salt ponds (e.g. Hamilton Wetlands, South Bay Salt Ponds, Bair Island, Montezuma Wetlands, and more), so these projects were not located in BCDC’s Bay jurisdiction. Instead they were either subject to federal consistency determinations and therefore were examined for “effects to the coastal zone,” in the Commission’s shoreline band, or in BCDC’s salt pond jurisdiction, and thus not subject to the minor fill policies. Additionally, of the limited number of restoration projects that have used fill in the Bay (as opposed to in salt ponds, diked baylands, or managed wetlands), only Middle Harbor Enhancement Area proposed adding volumes of fill that were considered more than a “minor” amount.

The main example when the “minor amount of fill” restriction became problematic was the Sonoma Creek Enhancement project in 2014 (BCDC Consistency Determination C2014.004.00.) The Sonoma Creek project was authorized to dredge and place the 24,200 cubic yards of sediment dredged to create channels in the marsh plain to create a 10-acre ecotone levee. The project resulted in the conversion of an approximately 3-acre area from tidal marsh to transition/upland refugia habitat.[35] However, the initial volume of fill proposed was debatably more than a “minor amount”, so the levee design was ultimately scaled down to use a smaller volume of fill. In another example, the Aramburu Island Enhancement Project (BCDC permit M2010.032) placed approximately 7,650 cubic yards of sand, gravel, rock and oyster shell over approximately a 2.17 acre area of the Bay to create a beach, promote oyster colonization, and create micro-groins to help retain sediment and foster beach development on an old dredged sediment disposal island with disturbed ruderal vegetation, which was considered “minor fill”. Other projects that have placed fill for habitat in the Bay since the “minor fill policies” were added include the Living Shorelines Project sites at San Rafael, Hayward Shoreline, and Giant Marsh (M2012.005.00 and M2016.026.00) and the SF Estuary Invasive Spartina Project’s creation of high tide habitat refuge islands.[36] In each of these projects, a determination that the fill was a minor amount consistent with the project was made. Whether these projects limited the proposed fill due to these policies is unknown.

Despite the limited effect of the “minor amount of fill” policies to date, these policies may become problematic as larger volumes of fill become necessary to restore, enhance, or create ecosystems in the Bay and to adapt to sea level rise. Continuing to limit fill in this way may result in the loss of valuable Bay habitats, a situation which these policies were initially created to prevent.

Additionally, because the suspended sediment concentration in the Bay is predicted to be insufficient to allow habitats to keep pace with accelerating sea level rise after 2050, it is important to use as much sediment as possible in these efforts. Because of the limited

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[35] *BCDC. “Staff Recommendation for Consistency Determination No. C2014.004.00 for the U.S. Fish and Wildlife Service’s Sonoma Creek Enhancement Project”. November 26, 2014.*
[36] *BCDC, “Listing of Pending Administrative Matters,” November 21, 2012.*

sediment supply, finding enough sediment for restoration projects will become increasingly difficult. The limitation on the use of dredged sediment in tidal waters conferred in Dredging Policy 11b will make it difficult to use sediment in the Bay for in water restoration projects or augmentation of sediment in areas already breached to the Bay.

Beyond these fill-specific laws and policies, the Bay Plan contains many other findings and policies that provide detailed information on project design, assessing project impacts, monitoring projects, mitigating for projects, assessing climate change impacts on projects, and other relevant issues. Although many of these policies are not specific to fill for habitat restoration projects, they still apply to habitat restoration projects that place fill, and can facilitate or complicate the permitting of these projects. Thus, in assessing how current policies will allow, support, and safeguard against harm to the Bay, it is important to consider other sections of the Bay Plan as well. The specific policies that should be amended to allow more Bay fill in a strategic and relatively cautious way are detailed throughout the rest of this Background Report.

6. Fill for Habitat in a Changing Bay

A. Habitat-Specific Challenges and the Need for Fill

The San Francisco Bay estuary is home to numerous diverse natural ecosystems. Some of these areas are common all around the Bay, and some are confined to specific sub-regions and are quite rare. Each of these ecosystems provides its own unique suite of benefits and ecosystem functions to the humans and living organisms that call the Bay home. These ecosystems are also vulnerable to the changing environment of the Bay, and intervention may be necessary to ensure their survival and continued of function into the future. This section presents an overview of key Bay habitats that are susceptible to degradation or loss from climate change and other stressors, and which are likely to require Bay fill for restoration, enhancement, or creation. For each habitat type, details are provided on ecosystem functions; past, current and desired future extent; risks to habitat loss or degradation; and solutions to increase resilience.

<u>Subtidal Areas</u>

While wetlands are the best-recognized aquatic ecosystem in the Bay, a wealth of diverse and vital habitats lie beneath the Bay's surface. More than 90 percent of subtidal areas of the Bay consist predominantly of soft-bottom substrates, but also include shellfish beds, submerged aquatic vegetation, shell deposits, rocky bottom, underwater pinnacles, and macroalgal beds.[37] This suite of habitats provides essential ecosystem services to natural and human communities throughout the Bay, but despite their importance, there are still many knowledge gaps about them, including their historic and natural distribution and the ecosystem services they provide. In an effort to examine the challenges they face, synthesize the knowledge gaps and identify opportunities for restoration, protection, enhancement, and further research in the future, the Subtidal Habitat Goals Report released in 2010. This report addressed whether and where these ecosystems should be restored or protected, but did not

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[37] *San Francisco Bay Subtidal Habitat Goals Project, "San Francisco Bay Subtidal Habitat Goals Report."*

set priorities among habitats, or prescribe the necessary mix of subtidal habitats to maintain and enhance the ecosystem services that these areas provide, because the information necessary to make these determinations is unknown.

This background report focuses primarily on artificial oyster reefs and eelgrass beds, as those are the subtidal habitats that are most likely to involve substantial amounts of fill for habitat restoration, creation, and/or enhancement. Native Olympia oysters do not form tall reefs with structural complexity, but if three-dimensional substrate is provided, they can settle on these structures. The physical heterogeneity provided by these structures can provide important habitat for other benthic invertebrates, which then serve as food sources for various species of fish, birds, and crabs. Eelgrass creates spatial heterogeneity, which provides habitat, food and shelter for fish species including pipefish, staghorn sculpin, and three-spine stickleback, and can serve as a spawning and nursery habitat for important species including Pacific herring. Both oyster reefs and eelgrass beds reduce current speeds and trap sediment, which are two important factors in shoreline protection and stabilization.[38] Both of these habitats can also sequester carbon and reduce nutrient or other pollution in the water. Finally, subtidal areas and the wildlife communities that they support provide sources of beauty and recreation in the Bay, including wildlife observation, hunting, fishing, and enjoyment while engaging in outdoor activities along the Bay's shoreline. The extent and value of these ecosystem services are examined in more detail in Part C of this section – Economic Analysis.

Olympia oyster beds are thought to have been widespread throughout the Bay historically, although the exact extent of oyster beds in the past is unknown. Reports from the late 19th through early 20th centuries indicate the native Olympia oyster was still quite abundant in the Bay at that time,[39] and produced 150 tons of oyster meat per year from 1888 to 1904.[40] The extent of current oyster beds is also not definitively known, although it seems that the oyster populations are much more limited than they were a century ago. Surveys in the early 2000s found numerous individual oysters on hard substrates in the Central Bay, and some additional oysters in the San Pablo and South Bays.[41] The specific reasons for the decline in oyster populations are not clear, yet there is a range of anthropogenic impacts that may have contributed, which are detailed below.

Quantitative information on the extent of eelgrass beds in the San Francisco Bay prior to 1980 does not exist. However, comparison of recent eelgrass surveys to the first survey conducted in 1986 indicate that more eelgrass beds have appeared since then and that existing eelgrass beds have been growing in area. The most recent estimates show that approximately 3,700 acres of eelgrass beds currently exist throughout the estuary.[42] About half of this total acreage is comprised by a large eelgrass bed located along the shoreline between Point San Pablo and Point Pinole in the East Bay. Other large beds are in San Pablo Bay and Richardson

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[38] *San Francisco Bay Subtidal Habitat Goals Project, "San Francisco Bay Subtidal Habitat Goals Report."*
[39] *ibid.*
[40] *Barrett, E.M. 1963. The California oyster industry. CDFG Fishery Bulletin 123.*
[41] *Zabin, C.J., S. Attoe, C. Coleman-Hulbert, and E.D. Grosholz. 2009. Shellfish Restoration Goals: A Draft Report for the Subtidal Goals Committee.*
[42] *Merkel and Associates, Inc. 2010. San Francisco Bay Eelgrass Inventory October–November 2009. Submitted to: California Department of Transportation and National Marine Fisheries Service. 12 pp.*

Bay, with smaller beds are scattered between the Carquinez Strait and the Eden Landing Ecological Reserve. It is thought that the decrease in suspended sediment concentrations since the late 1990's and general improvement in water quality since the passage of the Clean Water Act could have led to this increase.

There are numerous anthropogenic impacts that may have contributed to declining oyster populations in the past, and that still affect both oyster and eelgrass beds today. These disturbances include water pollution; freshwater diversions; activities that remove or disturb bay bottom, including dredging, sand and shell mining, addition of artificial structures to the Bay, vessel and anchor movement, docking, and propeller wash; and fishing.[43] Many of these same issues will likely continue to challenge restoration of these habitats.

Subtidal habitats will be susceptible to sea level rise and other climate impacts as well, and thus it is important to consider the climate-related risks that subtidal restoration projects will face. However, the risks posed to these systems are somewhat different than those that tidal wetlands face. In tidal wetlands, the most pressing climate-induced risk is drowning. If tidal wetlands cannot accrete sediment or migrate at the same pace that sea level is rising, we may lose much of the Bay's thousands of acres. On the other hand, for subtidal habitats, the more pressing climate-induced risks are the physiological and ecological challenges that may be brought on by warming waters, salinity changes, turbidity changes, and ocean acidification. There is also some risk that oyster and eelgrass beds will suffer as water deepens if they are not able to migrate into shallower water naturally because of seawalls or rock revetments limiting their available substrate.[44] The relative scarcity of oysters and eelgrass beds in the Bay underlines the need to protect them to ensure that these habitats persist and reduce barriers to restoring them.

The major risks to these subtidal habitats can potentially be addressed with Bay fill to some extent by creating new suitable substrate in water of appropriate depths. Both oysters and eelgrass beds should theoretically have the ability to migrate naturally into shallower waters, but this migration would be dependent on substrate quality and availability. Therefore, more Bay Fill may be necessary in the coming years to provide suitable substrate for these habitats to migrate with sea level rise.

Bay fill may be warranted for these ecosystems because (1) in general, it may be important to restore them for habitat and other ecosystem services value, and (2) they may provide other climate change protection services that will be important for human communities and other Bay ecosystems. These habitats, particularly constructed oyster reefs, could potentially attenuate wave energy hitting marshes and shoreline protection structures, which would somewhat reduce erosion along the marsh edge and reduce damage to seawalls, levees, and breakwaters. They can also trap sediment, which stabilizes the shoreline and maintains sediment in mudflats and shallow areas where it can be retained as part of the wetland system. Although the extent and value of the benefits that can be derived from these ecosystems in the

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[43] Ely, E. and Viani, L.O. (2010) Subtidal Habitat Goals Report Appendix 1-3: Anthropogenic Impacts on San Francisco Bay and its Subtidal Habitat

[44] Wim Kimmerer and Melissa Weaver, "San Francisco Bay Subtidal Habitat Goals Report Appendix 2-2: Report on Climate and Other Long-Term Changes Likely to Affect the Future of Subtidal Habitats," January 13, 2011.

San Francisco Bay is not well-known, it is widely recognized that they have great value, and are difficult to restore due to the very precise conditions needed to survive. But it will not be possible to assess their hypothetical value until more experimental work is conducted. Thus, it will be important to continue the experimental restoration of these habitats, and to protect and maintain existing oyster and eelgrass beds as well.

Given the limited scientific consensus around oyster and eelgrass beds, for the time being, the Subtidal Goals Report recommends protection of these existing habitats and limited placement of hard substrate and restoration as an information gathering mechanism. If these ecosystems prove to provide substantial benefits as their extent increases through small, pilot-scale restoration projects, more large-scale restoration may be warranted. It is also important to note that because so little is known about the historic distribution of oyster and eelgrass beds, the restoration goals of the Subtidal Habitat Goals Report "do not attempt to restore the bay to historical conditions but are designed to improve the condition of the subtidal ecosystem. The baseline for the project is 2010, and the planning horizon is 50 years."[45]

The targets for oyster restoration as stated in the 2010 Subtidal Habitat Goals are to increase native oyster populations within 10 acres of subtidal area within 5 years (by 2015), within 400 acres of subtidal area within 10 years (by 2020), and within 8,000 acres of subtidal area within 50 years. Oysters would be restored at a subset of locations within these larger areas, and restoration would only expand to the next larger phase if the first phase proved that the restoration was successful in providing important ecosystem services. For eelgrass restoration, 23,440 acres of potentially suitable eelgrass habitat have been identified throughout the Bay.[46] Within this suitable habitat area, the targets for eelgrass restoration were set to increase native eelgrass habitat by 25 acres within 5 years (by 2015), 100 acres within 10 years (by 2020), and up to 8,000 acres within 50 years, at 35 locations.

The San Francisco Bay Living Shorelines Project has experimented with placement of artificial oyster reefs in a number of different ways. Some early restoration used bags of oyster shell. Methods have also tested the construction of complex, 3-D oyster reef settlement structures in the shape of pyramids or spheres. These structures have been formed out of various concrete-like substances, including "Baycrete," which is a novel amalgam of crushed oyster shell, Bay sand and sediment, and a small amount of concrete. Eelgrass restoration typically consists primarily of the eelgrass planting, and includes such structures as frames, planting stakes, and seed buoys, which all constitute only a small amount of fill. Eelgrass restoration in San Francisco Bay, other than Middle Harbor Enhancement Project, has not yet included placement of sediment or mud to establish proper bathymetry and benthic conditions, but this could be proposed in the future. In some rare cases, larger volumes of fill to change the bathymetry or decrease water depth to create suitable eelgrass habitats may be suggested or pursued.[47] The Middle Harbor Enhancement project included placement of 5.6 million cubic

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[45] *Subtidal Habitat Goals Project, "San Francisco Bay Subtidal Habitat Goals Report."*

[46] *Merkel and Associates, Inc. 2005. Baywide eelgrass (Zostera marina) inventory in San Francisco Bay: Eelgrass bed characteristics and predictive eelgrass model. Report prepared for the State of California Department of Transportation in cooperation with NOAA Fisheries. Available at www.biomitigation.org*

[47] *Kimmerer and Weaver, "San Francisco Bay Subtidal Habitat Goals Report Appendix 2-2: Report on Climate and Other Long-Term Changes Likely to Affect the Future of Subtidal Habitats."*

yards of dredged sediment to create shallow subtidal areas suitable for eelgrass, and, as described, above will include plantings as it moves towards completion. Some new fill materials or approaches to placing appropriate substrate for oysters or eelgrass may evolve through the adaptive restoration plan proposed by the Subtidal Goals Report, but for the most part, the types of fill will be similar to those that already occur in the Bay. The amount of fill proposed by this work will likely change, however, as first stage pilot restoration projects produce quantifiable results and are scaled up accordingly. Since these projects are largely experimental, careful consideration must be given to the results of smaller pilots and potential risks that projects may pose before more Bay fill is permitted.

Beaches

Estuarine beaches are typically small and composed of sand, gravel, cobblestone, shell hash, or some mix of these components. Beaches in their natural state include a back-beach area, often including sand dunes, presence of a beach crest and berm which sit above the mean high tide line, and a flatter "low tide terrace" that is intertidal.[48] One specific type of beach, the barrier beach, occurs at the bayward margin of tidal marshes.[49] Beaches attenuate wave energy, so their presence in front of levees, marshes, or other infrastructure can provide shoreline protection benefits. As habitat, beaches provide important nesting, roosting, and foraging grounds for the organisms that rely on them, including many species of shorebirds such as terns, sandpipers, black-necked stilts, and American avocets. They also provide spawning habitat for grunion and haul out areas for harbor seals.[50] Beaches can provide connectivity to other Bay and high tide refugia for organisms as well.[51]

While some types of beaches are more common in the Bay, sandy beaches were never a widespread habitat, although they were once more prominent than they are now. There were once 23 miles of sandy beach, and now there are about seven miles. According to mapping conducted as part of the Baylands Ecosystem Habitat Goals, "sandy beaches were common only in Central Bay and on the eastern shore of North Bay, where winds and waves could deposit coarser sediments, including sands, along the shoreline." The Baylands Ecosystem Habitat Goals (1999) and its Science Update (2015), the Subtidal Habitat Goals Report (2010), and the Adaptation Atlas (2019) have all recognized beach restoration and creation as an important aspect of restoring complete Bay ecosystems. Beach restoration is also an important multi-benefit approach that will both create habitat and confer shoreline and tidal marsh protection.

The design and materials used for beach restoration can vary depending on the goals of the project. Predominantly coarse beaches can be smaller and steeper than composite or fine beaches. Coarse beaches are characterized by a wave-deposited beach ridge or crest, which can be designed at various elevations based on the wave height hitting that area and sediment

[48] SFEI and SPUR, "San Francisco Bay Shoreline Adaptation Atlas."
[49] Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."
[50] Goals Project, "Baylands Ecosystem Habitat Goals."
[51] Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."

availability. Beach restoration often includes groins or other retention structures[52] to hold sand in place, but may result in erosion of adjacent areas due to loss of sediment transport. Beach restoration has been authorized in the Bay, but on a limited basis. The largest beach restoration project authorized by BCDC was Crown Beach on Alameda Island. This project used 200,000 cubic yards of sand to construct the beach, maintains the sand through annual trucking and redistribution, and nourishment of approximately 80,000 cubic yards of sand every 20 years. The last episode of beach nourishment cost approximately seven million dollars. Otherwise it has occurred in relatively small volumes (e.g. 7,650 cubic yards at Aramburu island.) Bay fill for beach restoration may increase in coming years as more multi-benefit beach creation or nourishment projects are proposed, especially if these projects are larger and more extensive than preceding projects and would require mining of subtidal shoals for sand. Creating beaches in areas where they currently do not exist would require a thorough examination of the physical processes necessary to support them.

Tidal Marshes and Tidal Flats

Estuarine wetlands provide a wealth of services to wildlife and human communities. Wetlands primarily consist of tidal marshes and tidal flats. Tidal marshes are vegetated areas subject to tidal action that stretch on the Bayward side from the lowest extent of vegetation, and on the landward side to the top of the intertidal zone[53]. Mature, well-developed tidal marshes have dense, sinuous channels; marsh pans (ponds that form in the marsh plain); multiple zones of marsh vegetation; vegetative diversity; and physical heterogeneity. Healthy tidal marshes with channels and sloughs can provide habitat and foraging grounds for a wide variety of fish, including splittail, Delta smelt, Chinook salmon, longfin smelt, topsmelt, several species of goby, sculpins, and stickleback; birds, including egrets, rails, sparrows, willet, northern harrier; and mammals, including the salt marsh wandering shrew, Suisun shrew, and salt marsh harvest mouse,[54] among other species.

Tidal flats include mudflats, sandflats, and shellflats, although they primarily consist of mudflats throughout the Bay Area. Tidal flats are sparsely vegetated shallow water environments that occur below Mean Lowest Low Water (MLLW) and above Mean Tide Level.[55] Sediment supply and wave energy together determine the shape and elevation of mudflats.[56] Tidal flats are inextricably linked with tidal marshes and influence them in several ways. For example, mudflats serve as a sediment source to adjacent marshes. Mudflats also regulate the amount of wave energy reaching the marsh as a function of their depth, which in turn controls the amount of sediment reaching the marsh, so the topography of a mudflat can influence the balance between marsh erosion and progradation.[57] Mudflats consist of fine-grained silts and

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[52] *SFEI and SPUR, "San Francisco Bay Shoreline Adaptation Atlas."*
[53] *Goals Project, "Baylands Ecosystem Habitat Goals."*
[54] *ibid.*
[55] *ibid.*
[56] *Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."*
[57] *ibid.*

clays, which support rich invertebrate and algal communities that in turn provide a key source of prey for fish, waterfowl, and shorebirds. Longfin smelt, staghorn sculpin, and starry flounder forage there at high tide, and American avocet, willet, marbled godwit, semipalmated plover, western sandpiper, and dunlin, among others, feed there when the tides are low.[58]

Besides the habitat functions mentioned above, tidal marshes and tidal flats provide several other important ecosystem services to the Bay. Tidal marshes and tidal flats both diffuse wave energy and stabilize sediment, two key aspects of shoreline protection and shoreline stabilization. Tidal marshes can also provide flood water accommodation space. Tidal marshes are important for sequestering carbon dioxide, which reduces net greenhouse gas emissions. They also improve water quality by filtering nutrients and other pollutants out of the water. Finally, tidal marshes, tidal flats, and the wildlife communities that they support provide sources of beauty and recreation in the Bay, including wildlife observation, hunting, fishing, and enjoyment while engaging in outdoor activities along the Bay's shoreline. All of these services provided by wetlands and their relative values are explained in more detail below in Section C—Economic Benefits.

Mapping efforts have estimated that approximately 190,000 acres of tidal marsh and approximately 50,000 acres of tidal flats once lined the San Francisco Bay.[59] However, development beginning with the Gold Rush and Industrial Revolution in the mid-19th century rapidly degraded and eliminated 90 percent of these habitats. Diking and filling of the Bay were common during this time, and contributed to the greatest loss of wetland habitats, with 137,000 acres of baylands diked and 50,000 acres of baylands filled.

As described in Chapter 3, the McAteer-Petris Act and a suite of other environmental protection legislation were passed in the 1960's and early 1970's, and wetland restoration started shortly thereafter in the 1970's. Restoration of tidal marshes became common practice in the Bay Area by the mid-90's. These legislative protections, coupled with an active restoration program, began to reverse the trend of wetland degradation, and by 1998, 4,000 acres of tidal marshes had been restored, resulting in a new total of approximately 40,000 acres of tidal marsh.[60] By 2015, an additional 28,000 acres of restoration were underway or planned. If regional restoration goals are successful, there will eventually be 100,000 acres of tidal marsh around the Bay.[61,62]

Even though restoration projects have made significant strides toward this goal, and many more restoration projects are on the horizon, the Bay's vital wetlands ecosystems are at risk from climate change and its effects in conjunction with other stressors. One of the most imminent threats posed to wetlands is sea level rise, which puts wetlands at risk for drowning. Additionally, suspended sediment concentrations entering the Bay have declined in recent

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[58] *Goals Project, "Baylands Ecosystem Habitat Goals."*
[59] *ibid.*
[60] *Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."*
[61] *Goals Project, "Baylands Ecosystem Habitat Goals."*
[62] *Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."*

years, so sediment supply may not be adequate to sustain marshes. Drowning occurs when a marsh is inundated by sea level rise at a faster rate than it can accrete sediment and accumulate vegetative matter. Climate change is predicted to increase salinity in the Bay, which in turn decreases organic matter accumulation rates, and thus makes marshes even more susceptible to drowning. The accumulation of organic matter will be important for marshes to maintain elevation capital. Tidal marshes in the Bay are currently accreting enough sediment to keep pace with sea-level rise, but models show that this may change by mid-century as sea level rise accelerates.

Erosion along the marsh edge is common and can be caused by many factors, but is primarily a results of wave energy created either by wind, tides and currents, and/or boat wakes. Erosion may proceed at a faster rate and along more of the marsh edges if more frequent storms or flooding result from climate change. Increased storm intensity could increase the power of wind-waves that erode marsh edges. Higher water levels over and around marshes could also increase the intensity of waves reaching marshes because much of the wave energy is dissipated in shallow water.[63] The lack of intact mudflats or other subtidal habitats that diffuse wave energy also increases marsh susceptibility to erosion.

Wetlands are dynamic systems that are able to migrate naturally when they are healthy, complete, and fully functional. This means that marshes could theoretically continue to migrate inland and upland as sea level rises. However, wetlands in the Bay area are frequently backed by flood control levees or development. This phenomenon, known as coastal squeeze, could result in marshes becoming narrower and narrower around the edges of the Bay as sea level rises until they drown altogether. All of these forces make wetlands vulnerable to further degradation and loss. Despite the substantial risks that wetlands face in coming years, early recognition of these impending changes is working in our favor. The science, restoration, and regulatory communities have already recognized these issues, started to formulate potential solutions, and developed frameworks to facilitate the process of initiating wetland protection measures.

Wetland restoration and adaptation approaches are multi-faceted and may involve grading the wetland surface to create desired features, including high tide refugia, dredging channels, and planting vegetation in transitional areas. Some wetland restoration approaches, including reconnecting marshes to watersheds via channel reconfiguration, try to maximize the potential of natural processes to bring necessary sediment to the site. However, many wetland restoration projects involve some amount of onsite fill, though most have been behind historic bayfront levees. It is likely that restoration of wetlands in the coming years will involve increasing amounts of fill located behind levees, in existing marshes, and in the Bay. Projects proposing fill in tidal waters may involve methods that have not been tested in the San Francisco Bay Area, , such as ideas to maintain marsh plain elevation if wetlands are not receiving enough sediment from natural sources to keep pace with sea level rise.

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[63] *ibid.*

One of the most well-tested methods for maintaining/increasing marsh plain elevation is the thin layer placement of dredged sediment, which has been used for many years in other parts of the United States.[64] Thin layer placement entails spraying a sediment and water slurry in a "thin layer" directly onto the marsh's surface in order to elevate the surface by a desired amount, which can vary in thickness.[65] This method has variable impacts on marsh organisms, depending on the thickness of sediment applied, the method for spraying, the extent of spraying, and more, although many times marsh organisms can recover after sediment placement, as discussed in Chapter 7. Thin layer placement provides a relatively high degree of certainty in delivering sediment to the marsh's surface, but the sediment cannot always reach the parts of the marsh where it is needed, and dispersal of sediment using this method is not well-aligned with natural processes of sediment deposition (i.e. sediment distribution is clumpier). In California, thin layer placement is being tested as a technique for marsh augmentation at the Seal Beach National Wildlife Refuge,[66] and at Novato Creek in the San Francisco Bay Area.[67] Both of these projects are being monitored for outcomes and to determine if the effort was successful.

An approach being discussed as a test for augmentation that could increase sediment supply to both marshes and mudflats entails placing a semi-continuous source of sediment in shallow water areas or tidal channels near the marsh and allowing natural resuspension and tidal flows to move the sediment onto the marsh. This has been suggested in the "Mud Motor" pilot project.[68] Similarly, a method has been proposed that entails piping sediment to the mouth of a channel and pumping it into the site. This method is not expected to have as much direct impact on the mudflat and marsh as thin layer placement would but could have impacts on the shallow water areas/tidal channels where the material is placed.

Beyond sediment augmentation, in some cases, marshes or mudflats that have already been eroded and converted to another habitat type may require fill placement for mudflat or marsh re-creation. In several places in the U.S., dredged sediment has been used to create new mudflats[69] and saltmarshes,[70,71] which ultimately function like natural systems. Additionally, placement of sediment on marshes may be a solution to create high tide refugia. For example,

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[64] *Gary L Ray, "Thin Layer Placement of Dredged sediment on Coastal Wetlands: a Review of the Technical and Scientific Literature," (U.S. Army Corps of Engineers, December 2007.)*

[65] *Sam Whitin, "Thin-Layer Placement of Dredge Material for Marsh Nourishment, Restoration, and Response to Sea Level Rise," 2018, 1–20.*

[66] *Kaelin J McAtee, "Impact of Sediment Augmentation on Plant and Invertebrate Communities in a Southern California Coastal Wetland," January 2018.*

[67] *Roger Leventhal, "Demonstration Projects on the Eastern Shoreline - Past, Present, and Future," May 2017.*

[68] *Martin J Baptist et al., "Beneficial Use of Dredged Sediment to Enhance Salt Marsh Development by Applying a 'Mud Motor'," Ecological Engineering 127 (February 1, 2019): 312–23, doi:10.1016/j.ecoleng.2018.11.019.*

[69] *Ray, G.L. (2000.) Infaunal assemblages on constructed intertidal mudflats at Jonesport, Maine (USA.) Mar. Pollut. Bull. 40, 1186-1200.*

[70] *Posey, M.H., Alphin, T.D., Powell, C.M. (1997) Plant and infaunal communities associated with a created marsh. Estuaries 20, 42-47.*

[71] *Streever, W.J. (2000.) Spartina alterniflora marshes on dredged sediment: a critical review of the ongoing debate over success. Wetl. Ecol. Manag. 8, 295-316.*

the Invasive Spartina Project created 22 refuge islands on marshes around the Bay using marsh mud excavated from a nearby tidal slough channel.[72]

All of these methods have been tested to some extent in other parts of the world (or in some cases in the Bay), but they are still experimental in many regards. Therefore, pilot or demonstration projects would likely be necessary before these methods can be used to place fill in the Bay at a large scale.

Besides placing fill in the Bay to directly restore or manage wetlands, fill may be placed to protect wetlands in more indirect ways. For example, fill will likely be proposed to create other habitat features that can reduce wetland edge erosion and/or stabilize the shoreline adjacent to wetlands. This includes oyster reef and beach creation, both of which are detailed in the subsequent sections. Thus, the restoration and management of wetlands will likely be an endeavor that involves Bay fill in various forms and amounts in the coming years.

Transition Zones

Transition zones, or "ecotones," are broadly defined to include the transition between tidal marsh and subtidal areas, or between shallow subtidal areas and deep subtidal areas. Transition zones exhibit large variations in width and features depending on the habitats that they connect.[73] These areas provide essential physical and ecological connections between the various Bay and terrestrial habitats, and often support particularly diverse communities of vegetation and wildlife.

Transition zones, and particularly tidal-terrestrial transition zones (also called upland transition zones), provide a plethora of ecosystem functions. Some of the key functions include linking wetlands and diked baylands to local watershed processes, providing high tide refugia, providing movement corridors and habitat heterogeneity for terrestrial and/or aquatic wildlife, providing accommodation space for tidal marsh expansion upland and inland as sea level rises, providing flood control through channels, floodplains, and floodwater storage space, and improving water quality through nutrient absorption[74]. Transition zones can provide shoreline and community protection benefits as well, especially when they are re-constructed as part of a "horizontal levee," or levee with a shallow slope that creates transitional habitat between the marsh and top of the levee.

Upland transition zones are a natural component of complete wetlands ecosystems, yet development and levee creation around the Bay has resulted in significant elimination of these important areas. Our understanding of the historical extent of transition zones throughout the Bay is limited and has been primarily informed by SFEI's project to assess the historical size and characteristics of tidal-terrestrial transition zone habitat around the South Bay[75]. The current

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[72] *H.T. Harvey & Associates (2015.) High Tide Refuge Islands for the San Francisco Estuary Invasive Spartina Project Year-2 Monitoring Report. Project #3415-04. Prepared for California Coastal Conservancy, Oakland, CA.*
[73] *Goals Project, "Baylands Ecosystem Habitat Goals."*
[74] *Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."*
[75] *SFEI (2013.) Historical Tidal-Terrestrial Transition Zone in South Sf Bay. Retrieved May 22, 2019 at https://www.sfei.org/TZone_SouthSFBay#sthash.fPFyDbXp.iznfMguz.dpbs.*

extent of transition zones around the Bay has been mapped by the San Francisco Bay Joint Venture (SFBJV) using the SFBJV baseline Transition Zone GIS dataset. The goal was to develop a baseline that can be used to understand how future changes will affect the overall extent and distribution of upland transition zones in the Bay Area. Regionally, this project found that there are currently 870 acres of transition zones in the South Bay, 150 acres in the Central Bay, 1251 acres in San Pablo Bay, and 1060 acres in the Suisun Marsh.[76]

It is unknown exactly how much transition zone has been lost throughout the Bay, but the unnatural state of tidal marsh connections to upland sites is a testament to the changes that have occurred. At most restoration sites, tidal marshes lie directly adjacent to development or flood control levees, resulting in limited connectivity to uplands and watershed processes, that causes a lack of ecosystem services provided by these transition zones. Moreover, existing transition zones and those that are restored will continue to be threatened by climate change and the lack of connectivity to the landscape. Sea level rise will force habitats to move upland and inland, but because many wetlands and transition zones lack migration space, this may not be possible. Transition zones are thus likely to shrink in many areas, thus reducing their connectivity.

The restoration of natural, gradual upland transition zones and the processes that they support will be an essential feature of restoring a resilient Bay ecosystem and adapting to sea level rise and climate change in the coming years. Regional restoration frameworks such as the Baylands Ecosystem Habitat Goals Update[77] and the Adaptation Atlas[78] have prioritized the restoration of upland transition zones throughout the Bay, and recommended sites have been identified in the Adaptation Atlas.

Many approaches—both natural and engineered—have been suggested to facilitate the restoration and creation of upland transition zones.[79] Current horizontal levee construction requires large volumes of material on the landward edge of restoration projects to provide transition habitat for the restored tidal marsh. Horizontal levees are intended to provide a long and gradual slope into upland habitats, and fill will be important for building this elevation. In the few instances where horizontal levees have been built or are planned for construction, the slope has ranged from 1:10 to 1:100, and fill material has consisted of aggregate and excess soil from construction projects (South Bay Salt Pond and Shoreline Projects) and aggregate and dredged sediment (Hamilton and Port of Oakland). However, designing and constructing properly sized horizontal levees in existing marshes or tidal flats becomes complicated because construction on soft Bay mud in tidally active areas is difficult, and the weight of a large transition zone would likely subside and potentially create “mud waves.” Further, creating a

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[76] *San Francisco Bay Joint Venture (2018.) SF Bay Transition Zone Baseline Map. Retrieved May 22, 2019 at http://www.sfbayjv.org/project-transition-zone-baseline-map.php*

[77] *ibid.*

[78] *SFEI and SPUR, “San Francisco Bay Shoreline Adaptation Atlas.”*

[79] *Goals Project, Chapter 4: Transition Zones. “The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015.”*

transition zone in these areas results in the filling of healthy marsh or mudflat habitat affecting special status species. Therefore, horizontal levees may often end up smaller and steeper than ideal and could end up not providing the target suite of ecosystem services and functions.

While fill to create or enhance transition zones has been used in several projects around the Bay (Sears Point and Hamilton Wetlands), fill has primarily been placed in diked wetlands prior to breaching the site to the Bay. The only project that has placed fill to create a marsh to upland transition zone in a tidally influenced marsh (BCDC Bay jurisdiction) is the Sonoma Creek Enhancement Project (C2014.004.00) discussed earlier in this document. The Sonoma Creek project was authorized to place 24,200 cubic yards of sediment dredged from channels at the Sonoma Creek marsh site to create transitional habitat adjacent to an existing levee.

Future transitional habitat features are ideally larger and incorporate more innovative design elements, as is already the case for some horizontal levee projects outside of tidal waters. For example, a horizontal levee that is providing a wastewater treatment function, such as the Oro Loma wastewater treatment levee, may be proposed.[80] The South Bay Salt Ponds project is experimenting with ecotone levee design to test the most effective transition zone slope and material for wave attenuation, habitat and wildlife usage, and plant growth. In Marin County, engineers have proposed the idea of transitional habitat consisting of high marsh at the bayward side of the levee, an area of salt marsh behind this berm, and finally a transition zone gradually sloping landward behind the marsh.[81] All of these variations of transitional habitat require different types and amounts of fill that will need to be carefully considered before being allowed on a large scale in the Bay. Ultimately, the creation of transitional habitat on a large scale will increase the resilience of Bay habitats by providing physical connectivity, migration space, and essential high tide refugia for marsh species.

B. A Landscape-Scale Approach

Bay ecosystems have become fragmented—they are cut off from each other and the vital processes that sustain them. Tidal marshes once lined the Bay almost continuously, but now they are much more patchily distributed. Marshes were also previously connected to the Bay and upland areas, and fed with sediment from streams, rivers and mudflats. A diversity of habitats was provided by subtidal areas, structurally complex marshes and channels, and well-connected upland transition zones. However, this complexity and connectivity has been greatly reduced through extensive human modifications over the past several centuries.[82]

If Bay ecosystems are to keep pace with sea level rise and continue to provide useful and functional habitat to the Bay's organisms, complexity and connectivity need to be restored among these fragmented pieces. First, different habitat types need to be re-connected to each other to create complete ecosystems. This includes re-connecting marshes to mudflats and re-connecting both to the Bay by removing levees and restoring marshes to tidal action; connecting oyster beds, eelgrass beds, and other subtidal habitats to marshes and mudflats by joining subtidal habitats in appropriate locations (e.g. for oyster reefs, in areas where rock and

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[80] *Leventhal, "Overview of Fill Types for Habitat Restoration Projects in SF Bay."*
[81] *ibid.*
[82] *Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."*

hard substrates exist subtidally); connecting marshes to upland by restoring or creating ecotones and upland transition zones; and re-connecting channels and creeks to marshes by re-routing these watersheds. Restoring this complete ecosystem will re-connect the vital sustaining processes of sediment supply and freshwater flow to Bay tidal ecosystems. Complete ecosystems will also be more capable of maintaining function and migrating naturally with sea level rise. Connectivity must also be restored among adjacent habitats to allow for wildlife movement and dispersal among the various Bay habitats. Restoring complexity is necessary to restore diverse and variegated vegetation and wildlife assemblages, and to provide habitat connectivity to some extent.[83] Many of these restoration efforts will involve much more fill in the Bay throughout the region.

While restoration of wetland connectivity and complexity is essential, all habitats cannot and should not be restored to the same degree throughout the Bay. Certain areas cannot sustain every habitat type, so restoration needs to be strategic in where and which habitats are restored. Consideration of large-scale geomorphic and physical processes is especially important when considering fill and the dynamics of fill placement.[84] For example, it would not be prudent to place millions of cubic yards of fill for restoration in an area where currents and erosion would simply carry it away to other parts of the Bay. Likewise, it would not make sense to plant eelgrass in an area where it could not survive because of high turbidity and low light penetration.

Additionally, different parts of the Bay have different habitat needs, and the Bay as a whole has certain habitat needs, so this must also be considered in how and where fill in accordance with the above restoration principles is carried out. Finally, certain parts of the Bay present more opportunity than others in terms of land availability and extent of development lining the shoreline. Ideal restoration sites for a given habitat type should be chosen based on need for that habitat type and the ability of natural processes to sustain that habitat in the proposed locations (i.e. sediment supply for marshes, turbidity for eelgrass, oyster larvae for oyster beds), and the opportunity to construct a restoration project in that area.

Because of the many complex, system-wide factors involved, choosing appropriate sites and extent for fill for restoration requires that projects are designed with consideration of the regional, landscape-level scale context and utilize decision-making frameworks that take these complex factors into account. Regional assessments and guidance help restoration practitioners to prioritize areas that make the most sense for fill to accomplish specific goals and provide the most habitat benefits to the region. Several framework documents have been developed to provide recommendations for habitat restoration throughout the region based on these principles. The key frameworks are the Baylands Ecosystem Habitat Goals, [85] and its science update; [86] the Subtidal Habitat Goals Report,[87] and SFEI's Adaptation Atlas[88]. These documents

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[83] *ibid.*
[84] *SFEI and SPUR, "San Francisco Bay Shoreline Adaptation Atlas."*
[85] *Goals Project, "Baylands Ecosystem Habitat Goals."*
[86] *Goals Project, "The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015."*
[87] *Subtidal Habitat Goals Project, "San Francisco Bay Subtidal Habitat Goals Report."*
[88] *SFEI and SPUR, "San Francisco Bay Shoreline Adaptation Atlas."*

establish a scientific consensus on habitat restoration goals for the region, and specifically *where* there is need, opportunity, and likelihood of success for restoration projects of different types (subtidal, marsh, etc.). For example, the Baylands Ecosystem Habitat Goals Update recommends connecting marshes along the shoreline to reduce fragmentation. The Adaptation Atlas notes that certain areas may not be ideal sites to augment a marsh because the proper physical and geomorphological conditions to sustain the marsh are not present, and therefore is not a priority for augmentation. Thus, regional goals help to set regional priorities for restoration practitioners. These documents represent the advent of a new era of habitat restoration, in which ideally each project is considered within a regional context and how it will contribute to the overall health and resilience of the Bay ecosystem at large.

While these documents represent significant advances in our understanding and thinking about regional restoration, there are additional aspects of fill for restoration on a regional scale that are not considered thoroughly in these frameworks. One of these aspects is the assessment of how projects will affect each other, including consideration of the chronological progression of various projects. For example, if multiple projects convert mudflat to marsh in one area of the Bay, how might that affect species and habitat availability? This issue will be discussed in more detail in Chapter 7, Impacts and Habitat Type Conversion. This could also apply to benefits across projects—for example, how could one restoration project maximize the benefits of a nearby restoration project? The interaction of subtidal and marsh restoration was considered in the design of the Giant Marsh Living Shorelines project (BCDC permit M2016.026.00.) The project is investigating how oyster reef installations and eelgrass restoration can maximize the likelihood of success of restoring an adjacent marsh. This level of detail for spatial benefits is somewhat captured in current restoration frameworks, but potential impacts of projects on one another (both based on spatial and temporal proximity) is not assessed. Indeed, it may be difficult to capture because it is largely site-specific and dependent on unpredictable events, such as the specific sequencing and location of various proposed projects. Further research on these topics will be important to inform the best and least impactful approaches to conducting habitat projects throughout the region.

Restoration projects have already started to work within existing regional frameworks and use them as guides for how much and where restoration should occur. The restoration community has also come together more and more at a regional scale to partner or coordinate on projects, and to share lessons learned. Beyond the idea of individual restoration projects integrating into regional frameworks, a new paradigm for restoration projects is beginning to emerge as well: large, multi-part, multi-phase habitat restoration projects that are able to apply this regional/landscape-scale thinking within the context of a single project. The primary examples of this type of project are the South Bay Salt Ponds Restoration Project (C2003.010.00), the closely coordinated South Bay Shoreline Project (C2015.006.00), and, to an extent, the Napa Salt Ponds Project (C2011.002.00 and 2004.008.00).

As more fill is allowed in the Bay for habitat projects and as BCDC and other regulatory agencies make permitting decisions, it will be important to consider landscape processes, such as natural sediment supply, and how they affect project sustainability and the interaction of projects with each other, as BCDC and regulatory agencies make permitting decisions. As described in Section A, large amounts of fill will be entering the Bay in novel ways, and thus thorough evaluation of these projects in a regional context will be essential. Regulatory agencies can rely on the recommendations of regional frameworks to some extent, but ultimately decisions will have to be made in the specific context of ongoing regional restoration efforts at that time.

BCDC has language in the Bay Plan that requires that projects to be assessed in a regional context, and to consider regionwide habitat goals and landscape-scale processes in assessing the feasibility and sustainability of a project:

- Fish, Other Aquatic Organisms, and Wildlife Finding i: The Baylands Ecosystem Habitat Goals report provides a regional vision of the types, amounts, and distribution of wetlands and related habitats that are needed to restore and sustain a healthy Bay ecosystem, including the improvement of the well-being of many plant and animal species currently at risk of extinction.
- Tidal Marshes and Tidal Flats Finding a: San Francisco Bay is comprised of a diversity of habitats. These habitats were formed and are sustained by the global forces of climate and sea level change, as well as the more local effects of topography; the ebb and flow of the daily tides; the volume, timing and location of fresh water inflow; and the availability and types of sediments on the bottom of the Bay and suspended in the water column. Bay habitats include subtidal areas, tidal flats, and tidal marsh; Bay-related habitats include diked baylands, such as salt ponds, managed marsh and agricultural baylands. Plants and animals require a variety of habitats to survive. For example, topsmelt (a fish species) utilize the shallow, protected sloughs of tidal marshes of the Bay, as well as open water during different times in their life cycle and daily feeding routine. The topsmelt is also food for many species of birds that inhabit the tidal marshes and upland areas surrounding the Bay.
- Tidal Marshes and Tidal Flats Finding g: The Baylands Ecosystem Habitat Goals report provides a regional vision of the types, amounts, and distribution of wetlands and related habitats that are needed to restore and sustain a healthy Bay ecosystem, including restoration of 65,000 acres of tidal marsh. These recommendations were based on conditions of tidal inundation, salinity, and sedimentation in the 1990s. While achieving the regional vision would help promote a healthy, resilient Bay ecosystem, global climate change and sea level rise are expected to alter ecosystem processes in ways that may require new, regional targets for types, amounts, and distribution of habitats.
- Tidal Marshes and Tidal Flats Finding h: Tidal marshes, which include brackish and salt marshes, are vegetated wetlands subject to tidal action that occur throughout much of the Bay extending from approximately Mean Sea level to the maximum height of the tides. Established tidal marshes provide an essential and complex habitat for many species of fish, other aquatic organisms and wildlife. In the early 1800s, before diking and filling had begun, tidal marshes covered some 190,000 acres on the fringes of the Bay. Tidal marsh bordering the Bay now totals approximately 40,000 acres-a loss of approximately 80 percent of the Bay's historic tidal marshes.

- Tidal Marshes and Tidal Flats Finding l: Sedimentation is an essential factor in the creation, maintenance and growth of tidal marsh and tidal flat habitat. Scientists studying the Bay have observed that the volume of sediment entering the Bay annually from the Sacramento and San Joaquin Delta is declining. As a result, the importance of sediment from local watersheds as a source of sedimentation in tidal marshes is increasing. As sea level rise accelerates, the erosion of tidal flats may also accelerate, thus potentially exacerbating shoreline erosion and adversely affecting the ecosystem and the sustainability of ecosystem restoration projects. An adequate supply of sediment is necessary to ensure resilience of the Bay ecosystem as sea level rise accelerates.
- Tidal Marshes and Tidal Flats Policy 4: Where feasible, former tidal marshes and tidal flats that have been diked from the Bay should be restored to tidal action in order to replace lost historic wetlands or should be managed to provide important Bay habitat functions, such as resting, foraging and breeding habitat for fish, other aquatic organisms and wildlife. As recommended in the Baylands Ecosystem Habitat Goals report, around 65,000 acres of areas diked from the Bay should be restored to tidal action to maintain a healthy Bay ecosystem on a regional scale. Regional ecosystem targets should be updated periodically to guide conservation, restoration, and management efforts that result in a Bay ecosystem resilient to climate change and sea level rise. Further, local government land use and tax policies should not lead to the conversion of these restorable lands to uses that would preclude or deter potential restoration. The public should make every effort to acquire these lands for the purpose of habitat restoration and wetland migration.
- Tidal Marshes and Tidal Flats Policy 5: The Commission should support comprehensive Bay sediment research and monitoring to understand sediment processes necessary to sustain and restore wetlands. Monitoring methods should be updated periodically based on current scientific information.
- Tidal Marshes and Tidal Flats Policy 6: Any ecosystem restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria, and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) how the system’s adaptive capacity can be enhanced so that it is resilient to sea level rise and climate change; (b) the impact of the project on the Bay’s sediment budget; (c) localized sediment erosion and accretion; (d) the role of tidal flows; (e) potential invasive species introduction, spread, and their control; (f) rates of colonization by vegetation; (g) the expected use of the site by fish, other aquatic organisms and wildlife; (h) an appropriate buffer, where feasible, between shoreline development and habitats to protect wildlife and provide space for marsh migration as sea level rises; and (i) site characterization. If success criteria are not met, appropriate adaptive measures should be taken.

- Subtidal Areas Policy 3: Subtidal restoration projects should be designed to: (a) promote an abundance and diversity of fish, other aquatic organisms and wildlife; (b) restore rare subtidal areas; (c) establish linkages between deep and shallow water and tidal and subtidal habitat in an effort to maximize habitat values for fish, other aquatic organisms and wildlife; or (d) expand open water areas in an effort to make the Bay larger.
- Subtidal Areas Policy 4: Any subtidal restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) the scientific need for the project; (b) the effects of relative sea level rise; (c) the impact of the project on the Bay's sediment budget; (d) localized sediment erosion and accretion; (e) the role of tidal flows; (f) potential invasive species introduction, spread and their control; (g) rates of colonization by vegetation, where applicable; (h) the expected use of the site by fish, other aquatic organisms and wildlife; and (i) characterization of and changes to local bathymetric features. If success criteria are not met, corrective measures should be taken.

However, in allowing more fill in the Bay for habitat restoration through Bay Plan revisions, findings and policies need to go a step further to ensure that projects are sustainable in their proposed locations, and that the impacts and benefits of projects are considered concomitantly to consider regional habitat needs.

C. Economic Benefits of Habitat Restoration

Habitat restoration projects not only provide essential living space for the Bay’s organisms, but provide a wealth of ecosystem services both to inhabitant organisms and to human communities around the Bay (summarized above in part A.) It is important to note that many of these ecosystem services provide substantial economic benefits as well. Some of the most valuable ecosystem services provided by habitats in the Bay include shoreline protection/stabilization, flood control, carbon sequestration, recreation (including hunting and fishing), and water quality improvement. Fill may be required to enhance/restore functional areas that provide all of these ecosystem services, and in many cases will be necessary to maintain or increase the extent of existing ecosystems that provide them. The process of restoring and maintaining habitats also provides local jobs, which further contributes to economic benefits of these projects.

This analysis focuses primarily on the habitats that are the most likely to involve fill for restoration, creation, or enhancement in the Bay. The habitat types that may require fill are tidal wetlands (salt tidal marshes, mudflats, and transition zones/ecotones to some extent), artificial oyster reefs, and eelgrass beds. This section assesses the cost of restoring these projects and the economic benefits of Bay fill for habitat. The value of benefits includes the potential value added by the ecosystem services created when these habitats are preserved, restored or created, and the potential lost value of the ecosystem services should these habitats disappear.

The cost of restoration projects varies depending on the habitat, size of the project, novelty of the approaches used, region, and more. The average cost of saltmarsh restoration in developed countries is $67,128 per hectare ($165,806 per acre) in 2010 US dollars.[89] The cost of completing wetland restoration goals for the San Francisco Bay was also estimated by Steere.[90] In that report, a conservative cost for region-wide tidal wetland restoration was estimated at $5,000 per acre, and it was estimated that larger, more complicated tidal restoration projects could cost up to $100,000 per acre.[91] With these costs considered, the total estimated cost of restoring tidal wetlands in the Bay in accordance with the Regional Goals Report (restoring 60,000 acres total to meet the goal of 100,000 total acres of wetlands) is $561,000,000, or $577,800,000 with monitoring.

A global analysis of the costs of oyster reef and seagrass restoration showed that costs in developed countries are on average $66,821 per hectare ($165,047 per acre) in 2010 US dollars and $106,782 per hectare ($263,752 per acre) in 2010 US dollars, respectively.[92] These values are much lower than the cost of early oyster reef and eelgrass restoration projects in the San Francisco Bay. For example, the restoration of less than one acre (6,813 square feet) of oyster reef and eelgrass habitat at the San Rafael and Hayward Living Shorelines Project sites cost over $2 million dollars[93] (BCDC permit M2012.005.00). It is important to note that pilot and demonstration projects include extensive monitoring and experimental design. While some of these costs are high, the economic value of benefits provided by restored ecosystems can be substantially higher than the cost of completing these projects. For example, the South Bay Salt Ponds Restoration Project has thus far cost approximately $8.07 million, but the estimated lifetime value of the benefits provided by the restored ecosystem ranges from $68.9 - $220 million, making the benefit to cost ratio 18.45.[94]

The value of ecosystem services provided by existing, restored, or newly created habitats can be estimated for all ecosystem services cumulatively, or on a service-by-service basis. Some cumulative estimates exist for the key ecosystems discussed here. For wetlands, the cumulative estimated value of ecosystem services per acre per year differ depending on the part of the marsh being considered. Values ranged from $9,000 - $14,000 per acre per year for low marsh, and $3,000 - $10,000 per acre per year for high marsh.[95] The overall value of oyster reef services along the East Coast of the United States and in the Gulf of Mexico is predicted to range from $10,325 - $99,421 per hectare per year depending on the location and services

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[89] *Elisa Bayraktarov et al., "The Cost and Feasibility of Marine Coastal Restoration," Ecological Applications 26, no. 4 (2016): 1055–74.*
[90] *John Steere, "Estimating Wetland Restoration Costs at an Urban and Regional Scale: the San Francisco Bay Estuary Example," 2005, 1–11.*
[91] *ibid.*
[92] *Bayraktarov et al., "The Cost and Feasibility of Marine Coastal Restoration."*
[93] *San Francisco Bay Restoration Authority, "Examples of Projects Anticipated to Be Eligible for Restoration Authority Grants.," June 30, 2017.*
[94] *Michael Conathan, Jeffrey Buchanan, and Shiva Polefka, "The Economic Case for Restoring Coastal Ecosystems," April 2014, 1–54.*
[95] *Jeremy Lowe et al., "Analysis of the Costs and Benefits of Using Tidal Marsh Restorationas a Sea Level Rise Adaptation Strategy in San Francisco Bay," February 22, 2013.*

provided by the reef.[96] The value of eelgrass ecosystem services was estimated at $33,730 per hectare per year by Grabowski et al.[97] It is important to note, however, that these calculations were either made based on areas that are not in the San Francisco Bay estuary, or based on an average of many areas around the U.S. or the world. Valuations of ecosystem services can vary greatly depending on the location and the variations in the ecosystem functions provided by these habitats in different locales. This is important to keep in mind even when considering the value of specific ecosystem benefits. Averaged data from many areas, or data from outside of the Bay region, must be taken as a rough estimate of the value of the Bay's ecosystem services.

Shoreline Protection, Shoreline Stabilization, and Flood Control

Several of the most valuable ecosystem services provided by Bay habitats are shoreline protection, shoreline stabilization and flood control. Shoreline protection constitutes a spectrum of strategies from purely natural, "green" solutions to hardened, "grey" solutions to stabilize and reduce wave energy hitting the shoreline.[98] Shoreline protection strategies can also be combined to varying degrees. Development of adequate shoreline protection measures is especially valuable in the San Francisco Bay Area, where 13 percent of the population and 13 percent of the GDP (approximately $62 billion) is at risk of flooding.[99] The estimated cost of protecting these vulnerable people and property with levees (either levee maintenance or new construction) is approximately $5.7 billion.[100] Levees and other structural shoreline protection/flood control infrastructure, such as seawalls, breakwaters, and jetties, are vulnerable to erosion over time. These protection structures can also be overtopped when wave energy and/or storm surge are high enough. However, when marshes and other habitats line the Bayward side of hardened structures, they can provide significant shoreline protection and flood risk management benefits. These benefits include wave attenuation, mitigation of shoreline erosion, and conveyance and accommodation of the flow of flood waters (depending on the ecosystem).[101] Tidal marshes can attenuate up to 70 to 80 percent of wave energy over 300 feet, and mudflats can dissipate 20-30 percent of wave energy.[102] Even small strips of salt marsh can reduce wave height by almost half.[103]

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[96] *Jonathan H Grabowski et al., "Economic Valuation of Ecosystem Services Provided by Oyster Reefs," BioScience 62, no. 10 (October 2012): 900–909, doi:10.1525/bio.2012.62.10.10.*

[97] *ibid.*

[98] *SAGECoast (2015.) Natural and Structural Measures for Shoreline Stabilization. SAGECoast Living Shoreline Brochure.*

[99] *Heberger, M., Cooley, H., Moore, E. and Herrera P. 2012. The Impacts of Sea Level Rise on the San Francisco Bay. California Energy Commission. Publication number: CEC-500-2012-014.*

[100] *ibid*

[101] *Jeremy Lowe et al., "Analysis of the Costs and Benefits of Using Tidal Marsh Restorationas a Sea Level Rise Adaptation Strategy in San Francisco Bay," February 22, 2013.*

[102] *Cooper, N.J. 2005. 'Wave Dissipation Across Intertidal Surfaces in the Wash Tidal Inlet, Eastern England', Journal of Coastal Research, Vol 21, Issue 1, p28-40.*

[103] *Möller, I and Spencer T., 2002, Wave dissipation over macro-tidal saltmarshes: Effects of marsh edge typology and vegetation change. Journal of Coastal Research, SI 36, pp. 506-521.*

These mechanisms of wave diffusion can provide significant economic benefits if marshes are placed strategically. A study conducted by Lowe et al.[104] assessed the potential value of marsh creation as a structural protection mechanism along the Hayward Shoreline in the San Francisco Bay, and found that building even a narrow 25-foot marsh on the outboard side of a levee could result in a cost savings of over $6 million/mile on levee maintenance over a 50-year period. The addition of an upland transition zone to the marsh could lower the levee maintenance costs even more. The addition of the upland transition zone, and/or making the marsh wider, would result in lower overall cost savings, but the larger marsh size and transition zone could enhance other ecosystem services and ultimately provide even more economic benefit in the long run.

Tidal marsh restoration projects can also increase property values by reducing flood risk to Bayside communities. The South Bay Salt Pond Restoration Project has been estimated to provide a small reduction in the flood risk to properties in the South Bay counties of Santa Clara and Alameda, which could result in a total increase of property values by $857,300 – $27.97 million.[105]

Other Bay habitats, especially oyster reefs, are also expected to reduce erosion of other estuarine habitats and of hardened shoreline protections structures. The structural complexity of oyster reefs can attenuate wave energy and increase sedimentation rates.[106] Oyster reef habitat has been estimated to provide up to an $86,000 value per year per hectare for shoreline stabilization. This estimate is based on cost savings of using the oyster reef as natural, self-maintaining shoreline protection infrastructure rather than built structures. While seagrass and eelgrass are also expected to attenuate some wave energy and increase sedimentation, economic estimates of these services have not been calculated.[107]

<u>Carbon Sequestration</u>

Tidal marshes and eelgrass beds sequester carbon by removing carbon dioxide from the atmosphere or water as plants grow, where it is stored in living vegetative growth and buried as organic matter in the sediment as living vegetation dies. Average global estimates indicate that tidal wetlands sequester about 0.9 tons of carbon per acre per year, meaning that salt marshes around the world sequester millions of tons of carbon annually.[108] This service has been valued at $15 - $220 per acre per year, based on the value of reducing greenhouse gas emissions per ton of carbon stored[109,110]. Based on these values, wetlands in the San Francisco Bay area would

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[104] *ibid.*

[105] *Conathan, Buchanan, and Polefka, "The Economic Case for Restoring Coastal Ecosystems."*

[106] *Meyer DL, Townsend EC, Thayer GW. 1997. Stabilization and erosion control value of oyster cultch for intertidal marsh. Restoration Ecology 5: 93–99.*

[107] *Edward B Barbier et al., "The Value of Estuarine and Coastal Ecosystem Services," Ecological Monographs 81, no. 2 (October 12, 2011): 169–93.*

[108] *Chmura, G.L. and S.C. Anisfeld. 2003. "Global Carbon Sequestration in Tidal, Saline Wetland Soils." Global Biogeochemical Cycles. Vol. 17, no. 4, pp. 1111-1122.*

[109] *ibid.*

[110] *Lowe, Battalio, Brennan, Holmes, Niemi, and Toms, "Analysis of the Costs and Benefits of Using Tidal Marsh Restorationas a Sea Level Rise Adaptation Strategy in San Francisco Bay."*

sequester 90,000 tons of carbon per year if the Baylands Habitat Goals are accomplished, which would be valued at $1.5 million - $22 million per year. Specifically, the South Bay Salt Ponds project is estimated to have contributed $54,303 in carbon sequestration services to date.[111] The extent of carbon sequestration by eelgrass beds in Sweden was calculated by Cole and Moksnes et al.[112] They found that over a 50-year period, eelgrass beds sequester 98.6 tons of carbon per hectare, valued at $290.25 per hectare per year. Based on this calculation, the per acre value of carbon sequestration by eelgrass falls within the range of values estimated for tidal marsh carbon sequestration. However, because the extent of tidal marshes is so much greater in the Bay Area, these numbers are likely to be trivial for eelgrass beds, even with restoration. It is thought that oyster reefs may also be carbon sinks in some cases,[113] but values for carbon sequestration of oyster reefs are not available.

<u>Water Quality Improvement</u>

Tidal marshes, oyster reefs, and eelgrass beds to an extent, improve water quality by filtering and storing or converting and utilizing nutrient pollutants, particularly the various forms of nitrogen and phosphorous. Tidal marshes and oyster reefs also reduce chemical pollution, such as mercury or other metals, via similar mechanisms. Oysters can also reduce turbidity by filtering sediment from the water column, and decrease the risk of harmful algal or bacterial blooms as part of their normal feeding. The total value of water quality improvement services by any of these habitats is difficult to estimate, but certain key elements have been analyzed and valued. The value of nitrogen removal has been estimated for all three of these habitats. Wetlands across the United States have been estimated to provide a minimum of approximately $12.76 billion in services that would otherwise need to be spent on the remediation or effects of nitrogen pollution[114]. Beyond nitrogen remediation, wetlands could provide $785-$15,000 cost savings per acre per year over traditional waste treatment systems.[115] Nitrogen removal by oyster reefs has been valued at $1385- $6716 per hectare per year,[116] although these values are based on much larger and well-established oyster reefs, and nitrogen regulation services by eelgrass beds are valued at $700 per hectare per year.[117]

<u>Commercial Fishing</u>

The waters of San Francisco Bay, including subtidal benthic areas and surrounding wetlands, provide important habitat for numerous species of fish and crustaceans that support valuable

[111] *Conathan, Buchanan, and Polefka, "The Economic Case for Restoring Coastal Ecosystems."*
[112] *Scott G Cole and Per-Olav Moksnes, "Valuing Multiple Eelgrass Ecosystem Services in Sweden: Fish Production and Uptake of Carbon and Nitrogen," Frontiers in Marine Science 2 (January 13, 2016): 7390–18,*
[113] *F Joel Fodrie et al., "Oyster Reefs as Carbon Sources and Sinks," Proceedings of the Royal Society B: Biological Sciences 284, no. 1859 (July 26, 2017): 20170891–99.*
[114] *Conathan, Buchanan, and Polefka, "The Economic Case for Restoring Coastal Ecosystems."*
[115] *Breaux, A., S. Farber, and J. Day. 1995. Using natural coastal wetlands systems for wastewater treatment: an economic benefit analysis. Journal of Environmental Management 44:285–291.*
[116] *Grabowski, Brumbaugh, Conrad, Keeler, Opaluch, Peterson, Piehler, Powers, and Smyth, "Economic Valuation of Ecosystem Services Provided by Oyster Reefs."*
[117] *Cole and Moksnes, "Valuing Multiple Eelgrass Ecosystem Services in Sweden: Fish Production and Uptake of Carbon and Nitrogen."*

commercial fisheries. In 2006, commercial fishing catch processed at Bay Area Ports, which includes species caught in coastal waters or offshore, totaled $12.2 million, and consisted of species including Dungeness Crab, California Halibut, Chinook Salmon, Pacific Herring, Sablefish, sole, rockfish, Bay and Brine Shrimp.[118] These species, and others, rely on the San Francisco Bay estuary for at least some portion of their life cycle. Thus, restoration of Bay habitats in general is important to maintain and increase the productivity of Bay-related fisheries. However, the various species that are fished commercially rely on specific Bay habitats at different points in their life cycle. Tidal marshes are critical to many species of juvenile fish, including Chinook salmon, as they provide protection, food, nursery areas, and a balance between saline and fresh water.[119] Also as adults, fish and invertebrates including Chinook salmon, white sturgeon, Dungeness crab, and the California Bay Shrimp utilize the channels and tributaries throughout tidal marshes. Nearby mudflats provide important habitat for Bay shrimp, white sturgeon, and Dungeness Crab. Shallow Bay habitat provides nursery, rearing, and foraging habitat for species including Chinook salmon, white and green sturgeon, striped bass, American shad, and steelhead trout, and can also provide habitat for halibut and rockfish. Within shallow water areas, eelgrass beds provide food, shelter and spawning grounds for many Bay fish and invertebrates, especially Pacific herring, juvenile Chinook salmon and juvenile Dungeness Crabs.[120] Restored oyster beds and constructed oyster reefs in subtidal areas are also thought to provide Anecdotal evidence indicates that constructed oyster "reefs" in San Francisco Bay provide foraging habitat for salmonids and egg-laying substrate for herring.[121]

There are not any economic valuations for the benefits that specific San Francisco Bay habitats provide to offshore commercial fisheries production. Studies in other regions link the economic value of fisheries to specific habitats (including wetlands, oyster reefs, and eelgrass beds) that support those fisheries, but the numbers from those regions would likely not translate well to the San Francisco Bay Area. A literature review of economic valuations of commercial fisheries supported by coastal wetlands throughout the U.S. and at some international locations revealed that the per acre value estimates vary by over three orders of magnitude based on geographic location and methods used to assess economic value.[122] Despite the lack of habitat-specific valuation for the San Francisco Bay estuary, as described above, Bay habitats provide essential habitat for many of the commercial fisheries species that spend all or part of their life cycle in the Bay. Without these habitats, the rich fisheries of the California coast would not be nearly as productive.

[118] *Batelle Memorial Institute, "San Francisco Bay Subtidal Habitat Goals Report Appendix I-2: Economic Valuation of San Francisco Bay Natural Resources Services," July 2008.*
[119] *BCDC Staff Report (2002) San Francisco Bay Ecology and Related Habitats.*
[120] *ibid.*
[121] *Zabin et al., "San Francisco Bay Subtidal Habitat Goals Report Appendix 7-1: Shellfish Conservation and Restoration in San Francisco Bay: Opportunities and Constraints."*
[122] *Richard F Kazmierczak Jr., "Economic Linkages Between Coastal Wetlands and Hunting and Fishing: a Review of Value Estimates Reported in the Published Literature," May 2001.*

Recreation

Cumulatively, habitats throughout the San Francisco Bay provide hundreds of millions of dollars annually in services related to recreation and human enjoyment.[123] This calculation is based primarily on direct use such as recreational fishing, hunting, and tourism, but the Bay also provides non-use values such as aesthetic beauty which likely benefit property values and contribute even more indirect economic value to the region as a whole. In 1966, the amount spent on recreational hunting and fishing in the Bay was estimated at $9.25 million.[124] Assuming hunting and fishing patterns have not significantly changed since that time, and adjusting for inflation, the value spent on these activities would now be approximately $70 – $196 million.[125] Value estimates for recreational services provided by specific habitats are typically associated with fishing, and those are variable and very location-dependent. For example, wetlands in Florida were estimated to provide $981 - $6471 per acre in recreational fishing opportunities,[126] and wetlands along the Gulf Coast provide $0.19 – $1.89 per acre of product for the Gulf Coast blue crab fishery.[127] The commercial fishery value of oyster reef on the East Coast was calculated as $4,123 per hectare per year,[128] but native Olympia oysters in the San Francisco Bay don't support a recreational or commercial fishery. The only site-specific valuation for the San Francisco Bay was an estimate that the South Bay Salt Pond Restoration Project provides $23,332-$29,987 in recreational and commercial fishing services per year. [129] Otherwise, the value of recreation-related services has not been calculated for specific habitats of the San Francisco Bay, but restoration or creation of wetlands, upland transition zones, eelgrass beds, oyster reefs, beaches, and more would surely enhance the already high value of recreation services provided by the Bay as a whole.

Job Creation

Habitat restoration projects involve many sectors of business, government and other industries, and ultimately create jobs. A study by Conathan et al.[130] found that restoration projects that NOAA funded through the American Recovery and Reinvestment Act of 2009 (ARRA) created 17 jobs on average for every $1 million invested in restoration. This number was notably higher than the return on investment per million dollars for industrial coastal activities such as gas development, which was only an average of 8.9 jobs. Some studies have even found that restoration projects can create as many as 39 jobs per million dollars invested. The only estimate of job creation for the San Francisco Bay region is for the South Bay Salt Pond Restoration Project, which created 12.44 jobs on average per $1 million invested.

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[123] *Batelle Memorial Institute, "San Francisco Bay Subtidal Habitat Goals Report Appendix I-2: Economic Valuation of San Francisco Bay Natural Resources Services."*

[124] *BCDC, "San Francisco Bay Plan Supplement," 1967.*

[125] *U.S. Inflation Calculator. Retrieved May 23, 2019 at https://www.usinflationcalculator.com/.*

[126] *Bell, F. W. 1997. The economic valuation of saltwater marsh supporting marine recreational fishing in the southeastern United States. Ecological Economics 21:243–254.*

[127] *Freeman, A. M., III. 1991. Valuing environmental resources under alternative management regimes. Ecological Economics 3:247–256.*

[128] *Grabowski, Brumbaugh, Conrad, Keeler, Opaluch, Peterson, Piehler, Powers, and Smyth, "Economic Valuation of Ecosystem Services Provided by Oyster Reefs."*

[129] *Conathan, Buchanan, and Polefka, "The Economic Case for Restoring Coastal Ecosystems."*

[130] *ibid.*

Thus, habitat restoration projects can be expensive, but the economic value provided by these projects through benefits and cost savings are typically much higher than the price. To truly evaluate the ratio between project cost and benefits, analysis must be done on a project-by-project basis, as there are many site-specific factors that determine the value of ecosystem services provided. Additionally, there is significant value provided by habitats that was not captured in this assessment, because many ecosystem services are still difficult to assign economic value, despite their vital contribution to the ecosystem's health, maintenance, and provision of other ecosystem services.

7. Impacts and Tradeoffs

BCDC was created to stop rampant filling in the Bay to protect the Bay's natural ecosystems, and to provide public access to it. As a result, conservation of these ecosystems is integral to BCDC's mission, laws and policies. Thus, allowing Bay fill for habitat resilience in the face of sea level rise will introduce unprecedented challenges in balancing the benefits and impacts of fill. Although large volumes of fill in the Bay may be necessary to develop landscape-scale habitat resilience, the potential consequences of fill on this scale must be taken into consideration. First, fill may have direct impacts on the habitat that it is ultimately intended to improve, which are even more difficult to predict for project types that have not been previously tested in the Bay. Second, some fill projects could result in the conversion from one habitat type to another, which should be analyzed on both a project level a regional scale because we still lack a great deal of knowledge on habitat needs for many Bay species.

While BCDC faces these difficult decisions with many unknowns, the alternative of not authorizing fill for habitat projects could have dire consequences resulting from rising seas. If the region does not act, then large areas of essential species habitat could be lost. Additionally, the sediment supply to the Bay has decreased and a limited supply of this resource is available for wetland restoration. Therefore, we will need to prioritize which habitat areas need to be made resilient and in which areas it is acceptable to allow for natural conversion to other habitat types as Bay waters rise over time. Guidance is being developed to facilitate these decisions, but until then we may need to assess priorities on a case-by-case basis.

A. BCDC laws and policies: Conservation, Protection, Avoidance and Minimization of Impacts

The Bay Plan findings and policies acknowledge and encourage conservation, protection, and safeguarding against potential impacts to Bay species and habitats. These findings and policies are used to assess impacts of fill for habitat on the Bay to ensure that the fill accomplishes these conservation, protection, and impact avoidance goals. Additionally, these findings and policies acknowledge the importance of appropriate habitat types and quantities for the wellbeing of fish, other aquatic organisms, and wildlife populations, which is important to consider in the assessment of habitat type conversion. The most relevant findings and policies are:

- Fish, Other Aquatic Organisms, and Wildlife - Finding d: Conserving fish, other aquatic organisms and wildlife depends, among other things, upon availability of: (1) sufficient oxygen in the Bay waters; (2) adequate amounts of the proper foods; (3) sufficient areas for resting, foraging and breeding; and (4) proper fresh water inflows, temperature, salt content, water quality, and velocity of the water. Requirements vary according to the species of fish, other aquatic organisms and wildlife. Conservation and restoration of these habitat components is essential to insure for future generations the benefit of fish, other aquatic organisms and wildlife in the Bay.

- Fish, Other Aquatic Organisms, and Wildlife - Finding e: All parts of San Francisco Bay are important for the perpetuation of fish, other aquatic organisms and wildlife because any reduction of habitat reduces their numbers in some measure.
- Fish, Other Aquatic Organisms, and Wildlife - Policy 1: To assure the benefits of fish, other aquatic organisms and wildlife for future generations, to the greatest extent feasible, the Bay's tidal marshes, tidal flats, and subtidal habitat should be conserved, restored and increased.
- Fish, Other Aquatic Organisms, and Wildlife - Policy 2: Specific habitats that are needed to conserve, increase or prevent the extinction of any native species, species threatened or endangered, species that the California Department of Fish and Game has determined are candidates for listing as endangered or threatened under the California Endangered Species Act, or any species that provides substantial public benefits, should be protected, whether in the Bay or behind dikes.
- Tidal Marshes and Tidal Flats - Policy 1: Tidal marshes and tidal flats should be conserved to the fullest possible extent. Filling, diking, and dredging projects that would substantially harm tidal marshes or tidal flats should be allowed only for purposes that provide substantial public benefits and only if there is no feasible alternative.
- Tidal Marshes and Tidal Flats - Policy 2: Any proposed fill, diking, or dredging project should be thoroughly evaluated to determine the effect of the project on tidal marshes and tidal flats, and designed to minimize, and if feasible, avoid any harmful effects.
- Subtidal Areas - Policy 1: Any proposed filling or dredging project in a subtidal area should be thoroughly evaluated to determine the local and Bay-wide effects of the project on: (a) the possible introduction or spread of invasive species; (b) tidal hydrology and sediment movement; (c) fish, other aquatic organisms and wildlife; (d) aquatic plants; and (e) the Bay's bathymetry. Projects in subtidal areas should be designed to minimize and, if feasible, avoid any harmful effects.
- Subtidal Areas - Policy 2: Subtidal areas that are scarce in the Bay or have an abundance and diversity of fish, other aquatic organisms and wildlife (e.g., eelgrass beds, sandy deep water or underwater pinnacles) should be conserved. Filling, changes in use; and dredging projects in these areas should therefore be allowed only if: (a) there is no feasible alternative; and (b) the project provides substantial public benefits.
- Dredging - Finding k: Each of the fish and wildlife species found in the Bay has particular habitat needs to forage, rest, take refuge, and reproduce. Although the San Francisco Bay Area Wetlands Ecosystem Goals Project comprehensively studied the baylands and

made recommendations for the extent and location of wetlands and related habitats, no such study has been performed of the need for or appropriate mix of habitat types in the waters of the Bay.

- Dredging - Finding m: Under its existing law and policies the Commission has approved minor amounts of Bay fill to create, restore or enhance habitat in the Bay. The selective deposition of dredged sediments in the Bay to extensively modify Bay habitats might enhance the habitat value for some Bay species. However, such projects could also result in significant adverse impacts to Bay water circulation and quality and to Bay habitats and organisms that depend on the Bay. Insufficient information exists about the potential benefits and adverse impacts on which to base Baywide policies governing disposal in the Bay of dredged sediment that would result in largescale modification of Bay habitats, either through an individual project or cumulatively with other projects.
- Dredging – Policy 11a: A project that uses dredged sediment to create, restore, or enhance Bay or certain waterway natural resources should be approved only if:
    1. The Commission, based on detailed site specific studies, appropriate to the size and potential impacts of the project, that include, but are not limited to, site morphology and physical conditions, biological considerations, the potential for fostering invasive species, dredged sediment stability, and engineering aspects of the project, determines all of the following:
        a. The project would provide, in relationship to the project size, substantial net improvement in habitat for Bay species;
        b. To feasible alternatives to the fill exist to achieve the project purpose with fewer adverse impacts to Bay resources;
        c. The amount of dredged sediment to be used would be the minimum amount necessary to achieve the purpose of the project;
        d. Beneficial uses and water quality of the Bay would be protected; and
        e. There is a high probability that the project would be successful and not result in unmitigated environmental harm.

A. The project includes an adequate monitoring and management plan and has been carefully planned, and the Commission has established measurable performance objectives and controls that would help ensure the success and permanence of the project, and an agency or organization with fish and wildlife management expertise has expressed to the Commission its intention to manage and operate the site for habitat enhancement or restoration purposes for the life of the project;

B. The project would use only clean material suitable for aquatic disposal and the Commission has solicited the advice of the San Francisco Bay Regional Water Quality Control Board, the Dredged sediment Management Office and other appropriate agencies on the suitability of the dredged sediment;

C. The project would not result in a net loss of Bay or certain waterway surface area or volume. Any offsetting fill removal would be at or near as feasible to the habitat fill site;

D. Dredged sediment would not be placed in areas with particularly high or rare existing natural resource values, such as eelgrass beds and tidal marsh and mudflats, unless the material would be needed to protect or enhance the habitat. The habitat project would not, by itself or cumulatively with other projects, significantly decrease the overall amount of any particular habitat within the Suisun, North, South, or Central Bays, excluding areas that have been recently dredged;

E. The Commission has consulted with the California Department of Fish and Game, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service to ensure that at least one of these agencies supports the proposed project; and

F. After a reasonable period of monitoring, if either:

1. The project has not met its goals and measurable objectives, and attempts at remediation have proven unsuccessful, or

2. The dredged sediment is found to have substantial adverse impacts on the natural resources of the Bay, then the dredged sediment would be removed, unless it is demonstrated by competent environmental studies that removing the material would have a greater adverse effect on the Bay than allowing it to remain, and the site would be returned to the conditions existing immediately preceding placement of the dredged sediment.

Although the above policies require conservation and a reduction of impacts on existing habitats, the interpretation of these findings and policies becomes challenging when also considering future sea level rise projections for the Bay Area. Projects that propose to modify existing habitat require a permit, and therefore are subject to these policies, and potentially others. Protection of bay habitats and organisms requires the consideration of placing fill, either to create new habitat or to augment existing habitats for sea level rise adaptation. That fill may have temporary or permanent impacts on habitats and wildlife. It will be necessary to evaluate to what extent fill for restoration and habitat resilience should be allowed to result in impacts to existing habitats in the Bay in order to help these habitats adapt to future environmental conditions.

B. Impacts of Fill Placement

Habitat projects will be proposed that use fill for different purposes (described in detail in Chapter 6) will have a range of different direct and indirect impacts on Bay habitats and species, some of which we can predict, and some of which are unknown. Direct impacts and stressors associated with fill for habitat projects could include burial organisms by sediment or new structural substrate (e.g. oyster reef balls), elevated suspended sediment concentrations, and potentially altered sediment composition (i.e. sediment composition could change if the material placed is different than the substrate that was there prior to fill placement), among others. In some cases, fill placement can also result in habitat type conversion, which is discussed in more detail in Section C. Indirect impacts include difficulty in breathing, loss of forage areas, and loss of cover. The various fill approaches described in Chapter 6 could involve different intensity and extent of impacts. In some cases, individual organisms and communities can recover after impacts occur, but the time to and extent of recovery varies significantly. In both the short and long term, fill-associated impacts can result in numerous downstream and adjacent impacts, such as alterations in food web or community structure. Some known impacts of burial, increased suspended sediment concentrations, or altered sediment composition, as well as recovery rates after these disturbances (where known), are summarized below for organismal communities living in different habitats: water column (pelagic), subtidal areas, mudflat, and marsh.

Water Column Communities

Of the fill-associated stressors discussed above, suspended sediment concentration would have the greatest impact on water column communities. Elevated suspended sediment concentration in the water column could result from placement of dredged sediment or soil in any subtidal, mudflat, or marsh areas. The spatial and temporal extent of the sediment plume resulting from placement varies based on the grain size of the sediment or soil and the hydrodynamic regime of the site, among other factors.[131] Any pelagic organism could be impacted to some extent by suspended sediment concentration, but those for which effects have been the most studied are fish. Potential impacts of suspended sediment concentration on fish include clogged or injured gills,[132] increased larval mortality[133], altered behavior,[134] and reduced feeding ability.[135] Elevated suspended sediment concentration could also be beneficial for certain species and size groups that are protected from predation by lower visibility associated with suspended sediment concentration,[136] however this benefit would be temporary. Very few studies have investigated the impacts of suspended sediment concentration and turbidity on fish that rely on the Bay for habitat, so safe suspended sediment concentration levels and exposure duration limits are not known. The impacts of suspended sediment concentration on fish in general are reviewed in Kjelland et al (2015),[137] and impacts of suspended sediment concentration associated with dredged sediment disposal is reviewed

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[131] NMFS, "Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation," (National Marine Fisheries Service, Southwest Region, July 13, 2010.)

[132] Nightingale, B., & C.A. Simenstad, Jr. 2001. Dredging activities: Marine issues. Seattle, WA 98105: Washing ton State Transportation Center, University of Seattle. (http://depts.washington.edu/trac/reports/reports.html)

[133] Wilber, D.H. & D.G. Clarke. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management, 21: 855-875.

[134] ECORP Consulting, Inc., "Literature Review (for Studies Conducted Prior to 2008): Fish Behavior and Response to Dredging & Dredged sediment Placement Activities ," (US Army Corps of Engineers, October 9, 2009.)

[135] Benfield, M.C. & T.J. Minello. 1996. Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish. Environmental Biology of Fishes, 46: 211-216.

[136] Utne-Palm (2002) Visual feeding of fish in a turbid environment: Physical and behavioural aspects. Marine and Freshwater Behaviour and Physiology, 35 (1-2)

[137] Kjelland, M.E., Woodley, C.M., Swannack, T.M. et al. (2015) A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. Environ Syst Decis 35: 334. https://doi.org/10.1007/s10669-015-9557-2

by Rich (2010).[138] Beyond impacts to pelagic fish, phytoplankton and other autotrophic microbes could also be impacted by suspended sediment concentration. These organisms rely on light to fix carbon and produce energy, so reduced light penetration through turbid waters could result in reduced primary production (Anchor Environmental 2003; Cloern et al. 2014.) Changes in primary production could have wide-reaching effects on food webs in other habitats as well.[139, 140]

Benthic Subtidal Communities

Fill placement methods that could impact subtidal communities include filling shallow subtidal areas to create marsh or mudflat, placement of sediment in subtidal areas to augment marsh or mudflat, placement of oyster reef structures in shallow subtidal areas, and filling deep water to create shallow water habitat. Key benthic organisms that could be impacted by sediment burial include benthic invertebrates, bottom dwelling fish, eggs of certain fish species, crabs, eelgrass, macroalgae (seaweed), and microalgae, all of which play an important role in food webs and can provide economic value as well.

Subtidal benthic invertebrate communities would likely be the most directly affected by subtidal sediment or structure placement in the Bay, are impacted primarily by burial[141] and change in sediment type, whereas increased suspended sediment concentration has not typically impacted these organisms less[142,143]. Burial could result in mortality to benthic organisms, although some species are able to survive and vertically migrate after burial.[144] Thus, recovery of community structure and function could occur through re-colonization/larval settlement by organisms from adjacent areas, vertical migration through sediment after burial,

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[138] *Alice A Rich, "Potential Impacts of Re-Suspended Sediment Associated with Dredged sediment Placement on Fishes in San Francisco Bay, California," (U.S. Army Corps of Engineers, July 20, 2010.)*
[139] *Phytoplankton primary production in the world's estuarine-coastal ecosystems J. E. Cloern1 , S. Q. Foster1,*, and A. E. Kleckner1 1US Geological Survey, Menlo Park, California, USA *now at: Boston University, Boston, Massachusetts, USA Correspondence to: J. E. Cloern (jecloern@usgs.gov) Received: 17 October 2013 – Published in Biogeosciences Discuss.: 15 November 2013 Revised: 10 March 2014 – Accepted: 17 March 2014 – Published: 7 May 2014*
[140] *Literature review of effects of resuspended sediments due to dredging operations – Anchor Environmental 2003. Prepared for Los Angeles Contaminated Sediments Task Force.*
[141] *Stefan George Bolam, "Burial Survival of Benthic Macrofauna Following Deposition of Simulated Dredged sediment," Environmental Monitoring and Assessment 181 (December 29, 2011): 13–27, doi:10.1007/s10661-010-1809-5, and sources therein.*
[142] *Zoë L Hutchison Kim S Last Vicki J Hendrick, "Sediment Burial Intolerance of Marine Macroinvertebrates," February 13, 2016, 1–17, doi:10.1371/journal.pone.0149114.*
[143] *Rubin SP, Miller IM, Foley MM, Berry HD, Duda JJ, Hudson B, et al. (2017) Increased sediment load during a large-scale dam removal*
changes nearshore subtidal communities. PLoS ONE 12(12): e0187742. PLos ONE Research Article
[144] *Elizabeth K Hinchey et al., "Responses of Estuarine Benthic Invertebrates to Sediment Burial: the Importance of Mobility and Adaptation," Hydrobiologia 556, no. 1 (February 2006): 85–98, doi:10.1007/s10750-005-1029-0.*

or both[145,146,147] though the larger the area impacted, the slower the recovery may occur from adjacent areas. Immediately after disturbance, subtidal areas are vulnerable to colonization by invasive species.[148] Many studies have examined the recovery time of subtidal communities after dredged sediment disposal, although none of these studies have been carried out in the Bay, and recovery estimates could vary depending on different definitions of recovery and statistical approach used.[149] The extent of and time to recovery is variable with the full recovery of the benthic community taking the longest to establish the diversity, richness and abundance of a mature community. Recovery can depend on numerous factors, including the availability of colonizing organisms, site-specific bathymetry, hydrodynamics, rate and depth of deposited sediments, scale of disturbance, and season.[150, 151]

For subtidal communities, recovery time after sediment disposal can range from 1 month to 2.5 years or more.[152] In some cases, it is unclear whether these communities ever truly "recover." Comparison among numerous subtidal and intertidal dredged sediment disposal sites within the same region (the coastline of England and Wales) has revealed that impacts are site-specific,[153] and thus it will likely be difficult to predict how Bay subtidal invertebrate communities would be impacted by fill placement. Shifts in subtidal benthic invertebrate community structure could have effects on fish and birds that rely on these communities for prey and habitat, and on other ecosystem functions, such as nutrient and biogeochemical cycling and primary productivity in the overlying water column.[154]

Eelgrass beds are also negatively impacted by sediment burial or structural disturbance. Experimental eelgrass burial in Beaufort, North Carolina demonstrated that increasing percentages of plant burial significantly increased mortality and decreased productivity. Total mortality was observed at 75 percent burial.[155] Another study similarly found that even low

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[145] *ibid.*

[146] *Bolam, S.G., Whomersley, P., 2003. Invertebrate recolonisation of fine-grained beneficial use schemes: an example from the south-east coast of England.. J. Coast. Conserv. 9, 159e169.*

[147] *Bolam, S. G., Schratzberger,M., &Whomersley, P. (2004.) Macrofaunal recolonization in intertidal mudflats: The effect of organic content and particle size. Journal of Experimental Marine Biology and Ecology 306(2): 157-180.*

[148] *NMFS, "Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation."*

[149] *Dara H Wilber and Douglas G Clarke, "Defining and Assessing Benthic Recovery Following Dredging and Dredged Material Disposal."*

[150] *Dara H Wilber and Douglas G Clarke, "Defining and Assessing Benthic Recovery Following Dredging and Dredged sediment Disposal ," March 29, 2007, 1–16.*

[151] *Bolam, "Macrofaunal Recovery Following the Intertidal Recharge of Dredged sediment: a Comparison of Structural and Functional Approaches," Marine Environmental Research 97, no. c (June 1, 2014): 15–29, doi:10.1016/j.marenvres.2014.01.008.*

[152] *Wilber and Clarke, "Defining and Assessing Benthic Recovery Following Dredging and Dredged sediment Disposal ."*

[153] *Bolam, S.G., Rees, H.L., Somerfield, P., Smith, R., Clarke, K.R., Warwick, R.M., Atkins, M., and Garnacho, E. (2006.) Ecological consequences of dredged sediment disposal in the marine environment: a holistic assessment of activities around the England and Wales coastline. Mar Pollut Bull, 52(4): 415-26.*

[154] *Erik Kristensen et al., "Influence of Benthic Macrofauna Community Shifts on Ecosystem Functioning in Shallow Estuaries," Frontiers in Marine Science 1 (September 23, 2014): 331, doi:10.3389/fmars.2014.00041.*

[155] *Mills, K.E., and Fonseca, M.S. (2003.) Mortality and productivity of eelgrass Zostera marina under conditions of experimental burial with two sediment types. Mar Ecol Prog Ser 255: 127 – 134.*

burial depths (5 cm) resulted in higher shoot mortality, delayed growth and flowering, and lower carbohydrate storage.[156] Eelgrass has also been damaged and lost by boat anchor disturbance, which could indicate that other structural fill could also be harmful to eelgrass beds.[157]

In addition to direct burial and disturbance impacts, subtidal vegetation (including eelgrass) could be impacted by elevated suspended sediment concentrations. Elevated suspended sediment concentrations could impact eelgrass resulting from any fill (even on mudflats or marshes) near or adjacent to eelgrass beds. Eelgrass relies on sufficient light levels for photosynthesis, and elevated suspended sediment concentrations could increase light attenuation/decrease the amount of light reaching eelgrass on the bottom of the Bay. Although eelgrass in the Bay is adapted to growing in low light environments, reduced light availability further and for longer periods would reduce eelgrass carbon stores, alter growth periods, and even cause mortality in some cases.[158] Duration of impact and light available to eelgrass should thus be considered in determining acceptable levels of suspended sediment concentrations resulting from projects that place fill.

Shift in sediment composition is another stressor that could be caused by the placement of fill. Shifts in sediment composition as a result of dredging have been shown to affect the recovery rate of benthic organisms (see Cooper 2013 and sources therein),[159] so fill-associated shifts in sediment could potentially have similar impacts. However, other research has shown that sediment composition does not always correlate with benthic community structure.[160]

Mudflat Communities

Mudflat communities are most likely to be affected by fill placement directly on mudflats to raise elevation, or that convert mudflats to beaches, marshes, or other habitat (described in Chapter 6.) Of the main fill-related impacts, burial and shifts in sediment composition are expected to be the primary direct impacting mudflat communities. These areas are intertidal and characterized by frequent resuspension of sediment, so suspended sediment concentrations and turbidity are regularly fluctuating in this environment,[161] but these studies were completed for aggregate mining activities and the disturbance mechanisms are different from fill placement. The organisms that would most likely be directly impacted by mudflat filling

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[156] *Munkes et al. (2015.) Experimental assessment of critical anthropogenic sediment burial in eelgrass Zostera marina. Marine Pollution Bulletin: 100(1): 144-153*

[157] *Kelly, J.J., Orr, D. & Takekawa, J.Y. (2019.) Quantification of damage to eelgrass (Zostera marina) beds and evidence-based management strategies for boats anchoring in San Francisco Bay. Environmental Management.*

[158] *Zimmerman, R. C., J. L. Reguzzoni, S. Wyllie-Echeverria, M. Josselyn & R. S. Alberte. 1991. Assessment of Environmental Suitability for Growth of Zostera-Marina L (Eelgrass) in San-Francisco Bay. Aquatic Botany, 39: 353-366.*

[159] *Setting limits for acceptable change in sediment particle size composition: testing a new approach to managing marine aggregate dredging.*
Marine pollution bulletin, ISSN: 1879-3363, Vol: 73, Issue: 1, Page: 86-97

[160] *Seiderer, L. J. and Newell, R.C. (1999.) Analysis of the relationship between sediment composition and benthic community structure in coastal deposits: Implications for marine aggregate dredging*
ICES Journal of Marine Science 56(5):757-765 ·

[161] *ibid.*

are benthic invertebrates, microalgae, and potentially some species of fish. Bay-specific studies have investigated the response of mudflat invertebrate communities to eelgrass and oyster enhancement (some oyster reef structure placement involved “fill”) and found that communities generally responded positively to the treatments,[162] but the studies were focused on dredged sediment disposal in subtidal areas . Bay-specific studies have not examined the response of sediment placement on mudflats. Potential mechanisms of mudflat invertebrate community recovery are the same as those outlined in the subtidal areas section above, and many of the factors influencing ability to or rate of recovery are the same as well, with the added challenges of heat and desiccation faced in this environment. Re-colonization of some species after fill placement or other disturbance can occur relatively quickly (days-months) for.[163] However, full functional recovery of these communities can take years.[164] As noted in the subtidal areas section, comparisons among numerous dredged sediment disposal sites even within the same region reveal that sediment placement impacts are site-specific,[165] and community recovery time after sediment placement is dependent on how studies define recovery.[166] Thus, it will likely be difficult to predict from other studies how exactly Bay intertidal invertebrate communities would be impacted by sediment placement. Benthic invertebrate community structure also varies with sediment grain size, so shifts in sediment composition of fill, for example sand, placed on mudflats would impact benthic community structure.[167]

Shifts in mudflat benthic community structure could have broad implications for other Bay species, as benthic invertebrates are a very important component of the diet and for many species of invertebrates, such as crabs, birds, and juvenile and adult fish.[168,169] VanDusen

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[162] Susan E. W. De La Cruz, Ashley Smith, Tanya Graham, and Laura Hollander, “SF Bay Living Shorelines Project—2014 Monitoring Report Summary Appendix 3: Avian and Benthic Invertebrates”.

[163] Bolam, “Macrofaunal Recovery Following the Intertidal Recharge of Dredged sediment: a Comparison of Structural and Functional Approaches.”, and sources therein.

[164] ibid.

[165] Bolam, S.G., Rees, H.L., Somerfield, P., Smith, R., Clarke, K.R., Warwick, R.M., Atkins, M., and Garnacho, E. (2006.) Ecological consequences of dredged sediment disposal in the marine environment: a holistic assessment of activities around the England and Wales coastline. Mar Pollut Bull, 52(4): 415-26.

[166] Wilber and Clarke, “Defining and Assessing Benthic Recovery Following Dredging and Dredged sediment Disposal .”

[167] Beth M VanDusen, Stephen R Fegley, and Charles H Peterson, “Prey Distribution, Physical Habitat Features, and Guild Traits Interact to Produce Contrasting Shorebird Assemblages Among Foraging Patches,” ed. Jan Geert Hiddink, PLoS ONE 7, no. 12 (December 20, 2012): e52694–14, doi:10.1371/journal.pone.0052694.

[168] Evans, P.R., Ward, R.M., Bone, M., Leakey, M., 1998. Creation of temperate-climate intertidal mudflats: factors affecting colonisation and use by benthic invertebrates and their bird redators. Mar. Pollut. Bull. 37, 535e545.

[169] Hiscock, K., Marshall, C., 2006. Dossier on ecosystem structure and functioning characterization and importance for management: intertidal mudflats. In: Hiscock, K., Marshall, C., Sewell, J., Hawkins, S.J. (Eds.), The Structure and Functioning of Marine Ecosystems: an Environmental Protection and Management Perspective. Marine Biological Association of the UK, Plymouth. Report to English Nature from the Marine Life Information Network (MarLIN.) English Nature Research Reports, ENRR No. 699.

(2012)[170] found that shorebird foraging was significantly influenced by tidal flat invertebrate community structure. Additionally, invertebrate bioturbation of sediments can play a major role in biogeochemical cycling in these areas.[171, 172, 173]

Marsh Communities

Marsh communities are the most likely to be impacted by thin layer placement or other methods that directly place sediment on the marsh surface to augment elevation, or by the construction of habitat enhancement features like transition zones or high-tide refuge islands. The major fill-related impacts to tidal marshes are burial and shifts in surface sediment composition. Vegetation growth and community composition could be negatively affected by placement of sediment that differs in composition from the native sediment.[174] Vegetation could also be smothered and killed by burial, although research has shown that sediment placement can sometimes have no impact or in some instances may even stimulate growth[175] if placed in thin layers. Vegetation recovery after burial can occur by vegetation growing through the sediment over time, or by recolonization of the site by adjacent vegetation populations/through seed dispersal. The recovery rate of vegetation after sediment placement depends on the depth of sediment placement, type of sediment, method of placement, and more, and can range from months to 10 years or more after placement, and even then some areas do not fully recover during the time monitored.[176,177,178] However, in many cases, marsh vegetation has fully recovered after sediment placement, and occasionally vegetative density has even increased.[179,180,181] While most studies on marsh vegetation response to various sediment placement approaches come from the East or Gulf Coasts and study marshes

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[170] *ibid.*

[171] *Boudreau, B.P., 1998. Mean mixed depth of sediments: the wherefore and the why. Limnol. Oceanogr. 43, 524e526.*

[172] *Bolam, S.G., Fernandes, T.F., Huxham, M., 2002. Diversity, biomass and ecosystem processes in the marine benthos. Ecol. Monogr. 72 (4), 599e615.*

[173] *Biles, C.L., Paterson, D.M., Ford, R.B., Solan, M., Raffaelli, D.G., 2002. Bioturbation, ecosystem functioning and community structure. Hydrol. Earth Syst. Sci. 6 (6), 999e1005.*

[174] *Byrd, K.B. and M. Kelly. 2006. "Salt Marsh Vegetation Response to Edaphic and Topographic Changes from Upland Sedimentation in a Pacific Estuary." Wetlands 26 (3): 813–29.*

[175] *e.g. Deng, Z., S. An, C. Zhao, L. Chen, C. Zhou, Y. Zhi, and H. Li. 2008. "Sediment Burial Stimulates the Growth and Propagule Production of Spartina alterniflora loisel." Estuarine, Coastal and Shelf Science 76 (4): 818–26.*

[176] *Reviewed in Wilber and Clarke, "Defining and Assessing Benthic Recovery Following Dredging and Dredged sediment Disposal ."*

[177] *Wilber, P. 1992. Thin-layer disposal: Concepts and terminology. Environmental Effects of Dredging. Information Exchange Bulletin D-92-1. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.*

[178] *Schrift, A.M., I.A. Mendelssohn, and M.D. Materne. 2008. Salt marsh restoration with sediment-slurry amendments following a drought induced large scale disturbance. Wetlands 28: 1071-1085.*

[179] *Ford, M.A., D.R. Cahoon, and J.C. Lynch. 1999. "Restoring marsh elevation in a rapidly subsiding salt marsh by thin-layer deposition of dredged sediment". Ecological Engineering 12: 189-205.*

[180] *Slocum, M.G., Mendelssohn, I.A. & Kuhn, N.L. Estuaries (2005) 28: 519. https://doi.org/10.1007/BF02696063*

[181] *DeLaune, R.D., Pezeshki, S.R., Pardue, J.H., Whitcomb, J.H., and Patrick, Jr., W.H. (1990.) Some influences of sediment addition to a deteriorating salt marsh in the Mississippi River Deltaic Plain: a pilot study. Journal of Coastal Research, 6(1.)*

dominated by cordgrass (*Spartina alterniflora)*, study of marshes dominated by pickleweed (*Salicornia pacifica)* found that pickleweed, which is prevalent in some tidal marshes around San Francisco Bay, was able to recover within 7 months of burial by 10 cm of sediment.[182]

Beyond vegetation, birds and mammals that reside in marshes could be affected to some extent by fill placement depending on the scope and extent of fill, although birds and animals that are mobile could theoretically escape burial or other encounters with sediment. However, small mammals, reptiles and invertebrates would likely not escape, and nests would be directly buried or destroyed by any fill placement activities if present. The fill placement would reduce or eliminate prey availability until the site was recolonized. Additionally, shifts in vegetative structure caused by burial or altered sediment composition would leave animals exposed to predation, and alter the availability of habitat necessary for nesting, shelter, feeding, etc.

Most of the research on impacts to marshes is not specific to the Bay Area, as adaptation strategies involving Bay fill have been used to a very limited extent in the Bay. A recently completed thin layer placement project at the Seal Beach National Wildlife Refuge in Orange County, California provides a more similar analog for the effects of fill placement in the Bay than examples from the East Coast. At Seal Beach, 25 cm of sediment was applied over 8.5 acres in 2016. Monitoring demonstrated that after two years, sediment depth had not changed as much as expected, and that there was little change in sediment characteristics. Tidal creeks had not yet re-established.[183] Both plant and invertebrate communities were negatively impacted by the initial sediment placement. Plant communities began to recover by 1 year after sediment placement, but invertebrate recolonization has been slow. At the fill site, invertebrate communities shifted and became dominated by insect larvae, rather than polychaetes and oligochaetes which dominated invertebrate communities at a control site.[184]

Minimizing Fill for Habitat Impacts

Ultimately, the impacts of fill will depend on placement methods, volume, type of fill, and the biological characteristics of the habitat and community that is affected. The amount, frequency, duration, spatial extent, and time of year of placement could all change the extent of both direct and indirect impacts on fish, wildlife, plant, and invertebrate populations. Most research on sediment placement impacts does not consider multiple applications, so repeated applications could have further effects that are not well known. Fill during certain times of the year could have much higher impacts because of seasonal life-history processes, including nesting, spawning, or presence in certain areas based on migratory patterns. And different depths of fill can have drastically different impacts on various species, ranging from full recovery to complete mortality. Beyond the approach to fill that is used, the sensitivity and resilience of the organisms being affected will influence their ability to recover from fill placement impacts. Thus, it is important to consider ways to minimize the impacts of this work.

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[182] *Allison, S.K. 1995. "Recovery from Small-Scale Anthropogenic Disturbances by Northern California Salt Marsh Plant Assemblages." Ecological Applications 5 (3): 693–702.*

[183] *Richard Ambrose, "Soil and Marsh Creek Evolution at a Marsh Augmentation Project in Seal Beach CA," 2018, 1–36.*

[184] *Kaelin J McAtee, "Impact of Sediment Augmentation on Plant and Invertebrate Communities in a Southern California Coastal Wetland," January 2018.*

All of these factors must be assessed in deciding the least harmful placement methods, and whether and the extent of compensatory mitigation that may be necessary.

In many cases it will be challenging to assess the least harmful placement methods, as there are still many knowledge gaps for the San Francisco Bay estuary regarding the impacts to and recovery time of organisms after disturbance by various fill placement methods. To address these uncertainties, it will be important to utilize pilot projects, robust monitoring regimes, and adaptive management with the goal of ensuring that we learn over time and identify ways to add fill for habitat projects in the most effective and least harmful way.

C. Habitat Type Conversion and Habitat Tradeoffs

In addition to shorter term stressors caused by fill, habitat-related fill could potentially have lasting and wide-reaching effects by converting large amounts of one habitat type into another. Since fill for habitat work is permitted on a project-by-project basis, this work could gradually and inadvertently lead to large-scale habitat change if not considered carefully. Habitat type conversion resulting from fill in the Bay would most likely result from habitat creation projects, as opposed to augmentation projects that are simply intended to elevate and maintain an existing habitat. However, some enhancement projects, such as constructing transitional habitat, could also result in type conversion. Habitat creation strategies that involve fill resulting in habitat type conversion could include converting mudflat to marsh, converting deep water to shallow water habitat, converting mudflat to oyster or eelgrass bed, and converting mudflat or marsh to beach. The extent to which these strategies are used throughout the Bay, and the sites that are chosen, could result in local changes in habitat availability, shifts in regional habitat availability (i.e., relative amount of mudflat, marsh, transition zone, etc. in the Bay), and shifts in the distribution and connectivity of that habitat (i.e., more mudflat than before in the North Bay, and not as much mudflat as before in the South Bay).

Type conversion has already occurred as a result of projects in the Bay when projects have converted habitat as part of their restoration, enhancement or creation efforts. Some habitat projects that used fill and resulted in type conversion are the San Francisco Bay Living Shorelines Project; the Sonoma Creek Enhancement Project; and the Middle Harbor Enhancement Project. Type conversion has also occurred regularly when managed wetlands, salt ponds, or diked baylands, such as Sonoma Baylands, the South Bay Salt Ponds Restoration Project, and Hamilton Wetlands Restoration Project. For all of these projects, biological assessments have evaluated the site-specific impacts of the type conversion, but it is unclear and very difficult to determine whether these conversions have had wide-reaching negative effects within the Bay or beyond.

The Montezuma Wetland Restoration Project was the first large project to phase restoration, followed by the South Bay Salt Pond Restoration Project that proposed to sequentially convert large amounts of salt pond into tidal wetland. The South Bay Salt Pond Restoration Project is an essential component of wetland restoration for the region. The 15,000-acre salt ponds planned for conversion provide valuable habitat to about 93 species of breeding, wintering, and migratory birds.[185] Therefore, initial discussions about the project design questioned how extensively the salt ponds should be converted to tidal marsh. To assess this difficult decision, several modeling efforts and frameworks were developed to evaluate the restoration alternatives and provide more substantial information on which to base the decision.[186,187] The project developed three potential alternatives for the degree of conversion that would occur—no action, a managed pond emphasis alternative in which 50 percent of the project area was restored to tidal habitat and 50 percent remained as managed pond, and a tidal marsh emphasis in which 90 percent of the project area was restored to tidal marsh habitat and 10 percent remained as managed pond. The decision-making framework guides which alternative to pursue, with monitoring and adaptive management using the available data and current science.[188] Researchers also sought to identify ways to maximize bird use of smaller managed pond areas, which included experiments on how to best design and create nesting islands. Nesting island creation involved habitat type conversion as well – the placement of fill on managed wetland water/benthos to create islands.

In 2018, the SBSP project released a summary of major findings from Phase 1, which comprised its first 10 years of work, and the conversion of approximately 1,560 acres of managed wetland to tidal habitat, which is about 10 percent of the total project area. To address the effects of habitat type conversion, researchers sought to understand whether the existing number and diversity of migratory and breeding shorebirds and waterfowl could be supported in a reduced salt pond habitat area. Data indicate that the trends in numbers of diving ducks, ruddy ducks, and least terns are still uncertain, although trends are positive for the two duck types. The reduced area of managed ponds is still providing sufficient breeding habitat for snowy plovers. It is still uncertain, although trending positive, whether enough foraging and roosting habitat is provided for migratory shorebirds, and whether the new pond configuration will increase prey and pond use by waterfowl, shorebirds, and phalaropes/grebes. However, it appears that the creation of pond islands is not meeting expectations for maintaining numbers and reproductive success of terns, avocet, and stilts. Although there is still uncertainty surrounding the impacts of this type conversion, it appears that generally the conversion to tidal marsh that has happened so far has not had a notable negative impact on bird populations and bird use in the area.[189]

The San Francisco Bay Living Shorelines Project is an ongoing pilot project that has placed oyster reefs and eelgrass beds in various experimental configurations at three main sites around the Bay—Eden Landing Ecological Reserve, San Rafael Bay, and Giant Marsh along Pinole Regional Shoreline. The San Rafael and Hayward Shoreline sites have both been

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[185] *U S Department of the Interior and U S Geological Survey, "Phase 1 Studies Summary of Major Findings of the South Bay Salt Pond Restoration Project, South San Francisco Bay, California," March 31, 2018, 1–68.*
[186] *Diana Stralberg et al., "Building a Habitat Conversion Model for San Francisco Bay Wetlands: a Multi-Species Approach for Integrating GIS and Field Data," 2005.*
[187] *Diana Stralberg et al., "Habitat-Based Modeling of Wetland Bird Communities: an Evaluation of Potential Restoration Alternatives for South San Francisco Bay," (PRBO Conservation Science, Petaluma, CA, December 2006.)*
[188] *Philip Williams & Associates, EDAW, H.T. Harvey & Associates, Brown & Caldwell. (2006.) South Bay Salt Ponds Restoration Project Final Alternatives Report.*
[189] *U S Department of the Interior and U S Geological Survey, "Phase 1 Studies Summary of Major Findings of the South Bay Salt Pond Restoration Project, South San Francisco Bay, California."*

monitored extensively, while the Giant Marsh permit was only recently granted and constructed in 2018 and 2019. Researchers did not explicitly measure the impacts of "habitat type conversion", but they did measure the use of the sites by fish, birds, and epibenthic and benthic invertebrates both before and after the placement of treatments (eelgrass and oyster reefs.) Fish, invertebrate, and avian abundance and diversity was impacted variably by the habitat treatments. The response of communities depended on sampling time, treatment (oyster reef verses oyster reef and eelgrass), and location. Species richness and abundance were improved by the addition of new habitat features in some cases, but the trends were not consistent. In some cases, substantial shifts in community composition were observed. For example, at the San Rafael site, treatment sites were dominated by polychaetes, whereas control sites were dominated by bivalves.[190] This data indicates that conversion of habitat from mudflat to oyster reef or eelgrass bed results in increased local habitat availability in some cases for certain species, but has variable impacts that should be studied further before undertaking these approaches at a larger scale.

The Sonoma Creek Enhancement Project dredged a tidal channel in an existing marsh with poor drainage, used the dredged sediment to construct a transitional ecotone habitat along the backside of the marsh, and created mounds providing high tide refugia on the marsh plain (BCDC Permit C2014.004.00) (previously described in more detail.) Many parts of the transition zone were then seeded and planted resulting in a vegetated transition zone within a couple of years. Monitoring data is still preliminary, and there is insufficient quantitative information to determine how the habitat type conversion has altered species use of the area. However, initial qualitative data revealed that birds were present on the transitional habitat and mounds, with many birds using them for high tide refugia. Once more data has been collected, it can be compared to pre-construction monitoring data to determine whether any negative shifts in habitat use on the site have occurred.[191]

The Middle Harbor Enhancement Project placed 5.6 million cubic yards of dredged sediment from the Port of Oakland Deepening project to convert a deep-water berthing area (-40 feet MLLW) that had historically been tidal wetlands to shallow subtidal habitat, as described in more detail above). Monitoring of the site has indicated that the project has generally succeeded in establishing a subtidal area of the appropriate depth for eelgrass. To date, only test eelgrass plots have been planted, but the first full phase of eelgrass planting is scheduled for summer 2019. Monitoring wildlife's use of the site is limited. Therefore, it is impossible to determine the effects of the habitat type conversion, as the monitoring program has not commenced, and it is difficult to evaluate the tradeoffs of this type conversion, as the intended habitat benefits have not been provided yet.

The habitat conversions described above, and those that have been suggested for adaptation in the future, are generally well-justified. Future projects that may involve type conversion have the potential to provide important functions by creating much-needed habitat

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[190] *Latta, M. and Boyer, K. (2015.) San Francisco Bay Living Shorelines: Nearshore Linkages Project Summary of Key Findings Two Years Post-Installation. SF Bay Living Shorelines Document*

[191] *Courtney Gutman, "Sonoma Creek Enhancement Project; Creating Functionality in a Centennial Marsh of Sonoma, California Final Project Report," 2016, 1–25.*

or increasing ecosystem resilience. Indeed, some existing type conversion projects have resulted in positive local effects. Because these projects were expected to create, restore, and enhance habitat and provide net benefits to Bay ecosystems, they may be self-mitigating. However, it is difficult to know how these relative benefits and impacts might play out at a larger scale. Accomplishing regional restoration goals for wetlands and subtidal habitats may result in type conversions on a larger scale than it has occurred in recent years. Regional restoration recommendations are primarily based on where there is opportunity for restoration, and not necessarily based on strategic formulations of exact habitat needs—both in amount and distribution—for all of the species that use the Bay's resources. Without a regional understanding of habitat needs, it is difficult to determine whether habitat type conversions could unintentionally harm certain species by altering the availability or distribution of certain habitat types.

For example, if many individual projects propose to convert mudflat to oyster reef, or convert mudflat to marsh, etc., the cumulative amount or distribution of those habitats being converted could be reduced/altered without fully understanding the consequences. This becomes even more difficult when considering sea level rise and small-scale variability within habitats. Foraging habitat provided by mudflats is variable even within a single mudflat. Shorebird foraging is impacted by variations over a small spatial scale, including grain size, invertebrate distribution, and more.[192] A recent analysis of the predicted effects of sea level rise on available functional foraging habitat (as opposed to mudflat as a whole) for two sites in the Bay demonstrated that Eden Landing may lose all mudflat foraging habitat available for small shorebirds by 2100, whereas Dumbarton would only lose about half.[193] In this situation, mudflat loss from type conversion could then compound these issues, and result in insufficient habitat available for current populations of shorebirds to be supported. While this is only one example, similar situations could occur for other habitats throughout the Bay, especially if there is no comparable level of detailed data on small scale variability in habitat benefits provided to organisms.

Establishment of a regional plan or enhanced regional coordination to address the question of habitat needs, especially in light of sea level rise, would be beneficial. However, it is difficult to achieve because there are many unknowns regarding exact habitat needs of many of the Bay's organisms. It is known that many bird species have very specific needs in terms of mudflat[194] or wetland[195,196] habitat. However, this kind of specific habitat association is not well studied for many other species, and so type conversion could eliminate functional habitat that we don't even know is important. Thus, assessing whether habitat type conversion is

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[192] *VanDusen, Fegley, and Peterson, "Prey Distribution, Physical Habitat Features, and Guild Traits Interact to Produce Contrasting Shorebird Assemblages Among Foraging Patches."*

[193] *De la Cruz et al., in prep, from: Woo, I. and de la Cruz, S. (2019) Tidal Wetland Habitats and Wildlife. Presentation at BCDC Commission Meeting. March 7, 2019.*

[194] *ibid.*

[195] *John Y Takekawa et al., "Avian Communities in Tidal Salt Marshes of San Francisco Bay: a Review of Functional Groups by Foraging Guild and Habitat Association," San Francisco Estuary and Watershed Science, December 16, 2011, 1–25.*

[196] *Zhijun Ma et al., "Managing Wetland Habitats for Waterbirds: an International Perspective," Wetlands 30, no. 1 (December 9, 2009): 15–27, doi:10.1007/s13157-009-0001-6.*

appropriate in any given scenario will undoubtedly be difficult because of a lack of information, the need to directly compare benefits and impacts of type conversion, and the potential need to prioritize among species/habitats based on climate change predictions that include a high degree of uncertainty. Currently, tools are being developed which may facilitate type conversion decisions, but a lot of work is required to assess the appropriateness of extensive habitat type conversion projects throughout the region.

D. What is the Alternative?

Despite the potential risk of impacts and type conversion associated with allowing more fill in the Bay, the risk of inaction in many locations is severe. Projections of potential habitat alterations with different sea level rise and sediment availability scenarios reveal that major shifts in habitat amount and distribution are likely regardless of the scenario.[197] Some habitats may fare better than others depending on the environmental dynamics over the next century. With these inevitable changes in mind, restoration and interventions to sustain valuable habitats with the available time and resources should proceed, recognizing that there will inevitably be ecological trade-offs.

Despite a great deal of uncertainty, we must use what we do know in order to decide the most temporally and spatially appropriate sites for restoration projects that minimize the impacts or type conversion. This includes consideration of practices that are already in place, such as avoiding work during certain seasons, and using lower impact methods wherever possible. Large and potentially disruptive projects should avoid areas that are known to have sensitive species or rare habitat. It will also be important to avoid cumulative impacts, such converting a particular habitat type through multiple projects around the region. For larger projects that involve a great deal of uncertainty, it is advisable to complete projects in a stepwise, adaptive fashion, as is being done with the South Bay Salt Ponds Project, so that impacts of type conversion can be monitored and observed before any drastic or irreparable changes occur.

Deciding which type conversion or impacts are acceptable on a regional scale will require learning from existing examples where available, and prioritization among many unknown outcomes. These prioritizations can be supported by a variety of tools and decision frameworks, some of which are being developed and some of which would be beneficial to develop in the future. The US Environmental Protection Agency Region 9 – Pacific Southwest San Francisco Office is leading an effort to develop a Wetlands Type Conversion Guidance document. Initial versions of this framework identify factors like ecological lift potential and relative habitat value based on contribution to regional goals, risk assessment, historic distribution, etc. as components of the type conversion evaluation. Decisions on acceptable type conversions or impacts could consider the value of the habitat or services gained in comparison to the habitats or services lost.

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[197] *Diana Stralberg et al., "Evaluating Tidal Marsh Sustainability in the Face of Sea-Level Rise: a Hybrid Modeling Approach Applied to San Francisco Bay," ed. Julian Clifton, PLoS ONE 6, no. 11 (November 16, 2011): e27388–19, doi:10.1371/journal.pone.0027388.*

Vulnerability assessments, such as the San Mateo County Wetlands Vulnerability Study,[198] can determine which parts of the shoreline will be most immediately at risk, and where critical ecosystem services (services provided to humans by the natural environment), including habitat, carbon sequestration, and wave attenuation, are the most at risk. This information could then be compared to predicted risks of converting or augmenting those sites to determine where the benefits of conversion greatly outweigh the risks. Similarly, BCDC's Adapting to Rising Tides (ART) Bay Area collaboration with the Natural Capital Project is assessing ecosystem services provided the Priority Conservation Area network and comparing these to the value of ecosystem services provided by non-priority conservation areas. The results of the study will address whether the right places and habitats are being protected to ensure the delivery of key ecosystem services (in this case, recreation, storm water retention, coastal protection, and wildlife habitat) regionally, and how the delivery of these services could change with sea level rise. Assessments like this can highlight areas that are the most important for focused sea level rise protection efforts now and identify locations where some loss from habitat type conversion may be acceptable because the risks associated with inaction are so high.

These assessments can be taken a step further by the use of models to assess which management approaches or policy decisions (e.g. conservation of certain areas, different degrees of site conversion, different climate adaptation measures) would maximize the desired outcomes (e.g. provide the most ideal habitat for the most species; maximize ecosystem services; or choose the measures that are the most likely to succeed.) Modeling like this has been conducted for several specific management questions in different regions around the world. For example, these techniques were used to assess: (1) how various land use and restoration policies impact ecosystem services in the Yanhe watershed of China;[199] (2) how to optimize habitat availability and reduce species incompatibilities for bird species in Wisconsin;[200] and (3) how two different land use strategies would affect various ecosystem services in Peak District National Park in the UK.[201] Habitat type conversion modeling has examined scenarios in the Bay Area as well. Stralberg et al. 2005[202] developed models to assess various degrees of type conversion and the impacts of these scenarios on bird populations for the South Bay Salt Pond Restoration Project. The development of models like these to assess the impacts of Bay-wide habitat conversion for a variety of taxa would provide a useful and much-needed tool for assessing which habitat type conversions would result in various

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[198] Maya Hayden, "San Mateo County Wetlands Vulnerability Study," 2019, 1–19.
[199] Yang, S., Zhao, W., Liu, Y., Wang, S., Wang, J., and Zhai, R. (2018.) Influence of land use change on the ecosystem service trade-offs in the ecological restoration area: Dynamics and scenarios in the Yanhe watershed, China. Science of the Total Environment 644: 556-566.
[200] Beaudry, F., Ferris, M.C., Pidgeon, A.M., and Radeloff, V.C. (2016.) Identifying areas of optimal multispecies conservation value by accounting for incompatibilities between species. Ecological Modeling, 332: 74-82.
[201] Mark S Reed et al., "Anticipating and Managing Future Trade-Offs and Complementarities Between Ecosystem Services," Ecology and Society 18, no. 1 (2013): 5–20, doi:10.5751/ES-04924-180105.
[202] Stralberg et al., "Building a Habitat Conversion Model for San Francisco Bay Wetlands: a Multi-Species Approach for Integrating GIS and Field Data."

outcomes for species. These models would be extremely complex, but having a better sense of the potential outcomes of type conversion on groups or species of organisms would facilitate more informed type conversion discussions.

Even with the assistance of sophisticated models, these decisions would still be challenging. Different stakeholders and agencies have different priorities, so there would inevitably still be some variation in opinion of which outcomes are the most desirable, and thus which actions are priority. Questions that need to be considered include: When is it appropriate to prioritize habitat conversion that benefits one species but reduces habitat for another? How do you choose which species or ecosystem services are higher priority? Answering these questions will be difficult, but it is important to recognize that even if we try to manage type conversion and impacts to maximize the benefits to all species, some habitat shifts, and corresponding wildlife community shifts, are inevitable. Ultimately, finding solutions would involve modeling, experimenting, monitoring, adaptive management, and prioritization/consensus building among agencies and stakeholders.

8. Moving Forward with Uncertainty

Even with precautions to protect against potential harm, there will inevitably be uncertainty and risk associated with fill for habitat restoration projects of the future. We have to assess the relative risks to habitats posed by fill and sea level rise, and to the best of our ability choose the course of action that causes the greatest benefit and least lasting damage to essential Bay ecosystems. But this assessment is not easy considering the uncertainty around the many variables we must consider. Will approaches to fill that have not been tested in the Bay be successful? How might fill projects impact existing ecosystems? Are projects meeting their expected goals? How should we respond if projects do fail? We must try to answer these questions and manage the level of risk around fill for habitat projects by employing a strategic approach to the design, monitoring, and adaptive management of these projects. This includes encouragement of experimental work, such as pilot or demonstration projects, that can inform larger-scale processes at a lower level of risk.

A. Design

Habitat restoration projects, like any project in BCDC jurisdiction, must submit a project design as part of the permit application. Design is informed by project goals and/or objectives of the project, the siting of the project, geological features, available materials, funds, and other factors. The Design Guidelines for Tidal Wetland Restoration in San Francisco Bay[203] is a succinct document that addresses many of the unique considerations for restoration in the region, that is based on years of experience and monitoring projects, learning which approaches are successful in restoring functional tidal wetland ecosystems. Recently, the California Natural Resources Agency released guidance for nature based shoreline protection benefits titled *Toward Natural Shoreline Infrastructure to Manage Coastal Change in California*, which includes an assessment of oyster reefs, eelgrass beds, and tidal marshes, and beaches

[203] Philip Williams & Associates, Ltd. and Phyllis M Faber, "Design Guidelines for Tidal Wetland Restoration in San Francisco Bay," (The Bay Institute and California State Coastal Conservancy, December 29, 2004.)

through case studies and provides guidance for design, construction, and monitoring, as well as appropriate settings for different approaches.[204] Additionally, pilot projects like the Living Shoreline Project are testing designs for eelgrass and oyster restoration which will inform future iterations of these projects.

Design considerations related to fill for habitat projects typically address whether fill is necessary, and if so how much is needed, how often it has to be placed, what aerial extent it should cover, when it should be placed, what type of material should be used, geotechnical information, what methods for placement should be used, and more. For projects that aim to accomplish typical restoration objectives under standard circumstances (e.g. restoring a subsided diked wetland to a complete tidal marsh under current environmental conditions), these considerations can be informed by past experience. However, even in these more straightforward situations, there are still many aspects of project design that result in uncertain outcomes.

Design parameters habitat projects are informed by knowledge of similar projects, but require analysis of the landform, geology, hydrodynamics, expected settlement rate, sedimentation, and consolidation of materials. These analysis consider existing site information, but also require some extrapolation and estimates of how different forces will act on the project as it develops. The longer the timescale for project development the difficult predicting outcomes is. For example, engineers can calculate the rates of sediment accretion or channel formation at a given site based on the hydrodynamics and benthic topography of the site; or biologists can estimate the rate of vegetation colonization. However, these calculations are based on modeled data, and unexpected environmental changes could alter the outcome.

This uncertainty of which design is the best to yield a given outcome becomes even greater when considering sea level rise and changing suspended sediment concentrations. Predicting how a project will perform over the long-term with widely ranging projections of environmental variables is difficult. Accurately incorporating these factors into project design will be very challenging, and both project analysts and project engineers/architects have to accept that fill for habitat projects are likely to have somewhat different outcomes than those expected when the project was designed. Uncertainty will also be high as fill techniques and approaches that have not been previously used in the Bay are tested. Techniques for marsh augmentation such as those described in Chapter 6 have been used in other regions of the U.S. and other parts of the world but have not been executed in the San Francisco Bay estuary. Design for these projects can account for specifications that were used in these other areas and try to incorporate unique aspects of the SF Bay environment, but the potential range of outcomes may still be quite variable.

At BCDC, habitat project design is reviewed by permit analysts, who work with applicants to ensure that the design is consistent with BCDC's laws and policies and is appropriate to successfully meet project goals. Projects are typically brought to BCDC with varying levels of design completion. If a project's design is well-developed, it is easier to determine the project's

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[204] *Sarah Newkirk et al., "Toward Natural Shoreline Infrastructure to Manage Coastal Change in California," (California Natural Resources Agency, September 4, 2018.)*

consistency with BCDC laws and policies and its likelihood of success. However, these designs are also harder to modify if needed to address a policy issue or design flaw. Early stages of project design can often be permitted but require additional review as the designs and plans are further refined to ensure they remain consistent with the permit.

For projects that have public safety implications related to fill or a structure on fill, or that involve significant public access features, BCDC's Engineering Criteria Review Board (ECRB) and the Design Review Board (DRB), respectively, assess specific aspects of the project's design and provide input to the Commission. These boards consist of experts who review projects to ensure that the architectural and aesthetic design (in the case of the DRB), or the structural soundness of the project (in the case of the ECRB) are acceptable. Analysts, applicants, and the boards work together to ensure that the project adheres to BCDC laws and policies and has the greatest potential for success.

Bay Plan policies specifically list some design objectives, as well as some design parameters that applicants must provide to demonstrate that design is appropriate for the stated goals. The following policies outline objectives that should be achieved by project design for projects in tidal marshes/tidal flats and subtidal areas:

- Tidal Marshes and Tidal Flats Policy 2: Any proposed fill, diking, or dredging project should be thoroughly evaluated to determine the effect of the project on tidal marshes and tidal flats, and designed to minimize, and if feasible, avoid any harmful effects.
- Tidal Marshes and Tidal Flats Policy 3: Projects should be sited and designed to avoid, or if avoidance is infeasible, minimize adverse impacts on any transition zone present between tidal and upland habitats. Where a transition zone does not exist and it is feasible and ecologically appropriate, shoreline projects should be designed to provide a transition zone between tidal and upland habitats.
- Subtidal Areas Policy 1: Any proposed filling or dredging project in a subtidal area should be thoroughly evaluated to determine the local and Bay-wide effects of the project on: (a) the possible introduction or spread of invasive species; (b) tidal hydrology and sediment movement; (c) fish, other aquatic organisms and wildlife; (d) aquatic plants; and (e) the Bay's bathymetry. Projects in subtidal areas should be designed to minimize and, if feasible, avoid any harmful effects.
- Subtidal Areas Policy 3: Subtidal restoration projects should be designed to: (a) promote an abundance and diversity of fish, other aquatic organisms and wildlife; (b) restore rare subtidal areas; (c) establish linkages between deep and shallow water and tidal and subtidal habitat in an effort to maximize habitat values for fish, other aquatic organisms and wildlife; or (d) expand open water areas in an effort to make the Bay larger.

Additionally, policies outline analyses that must be provided to permit analysts for assessment of restoration project design in tidal marshes/tidal flats and subtidal areas:

- Tidal Marshes and Tidal Flats Policy 6: Any ecosystem restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria, and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) how the system's adaptive capacity can be enhanced so that it is resilient to sea level rise and climate change; (b) the impact of the project on the Bay's sediment budget; (c) localized sediment erosion and accretion; (d) the role of tidal flows; (e) potential invasive species introduction, spread, and their control; (f) rates of colonization by vegetation; (g) the expected use of the site by fish, other aquatic organisms and wildlife; (h) an appropriate buffer, where feasible, between shoreline development and habitats to protect wildlife and provide space for marsh migration as sea level rises; and (i) site characterization. If success criteria are not met, appropriate adaptive measures should be taken.

- Subtidal Areas Policy 4: Any subtidal restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) the scientific need for the project; (b) the effects of relative sea level rise; (c) the impact of the project on the Bay's sediment budget; (d) localized sediment erosion and accretion; (e) the role of tidal flows; (f) potential invasive species introduction, spread and their control; (g) rates of colonization by vegetation, where applicable; (h) the expected use of the site by fish, other aquatic organisms and wildlife; and (i) characterization of and changes to local bathymetric features. If success criteria are not met, corrective measures should be taken.

Permit analysts look to these and other Bay Plan policies to determine whether a project will meet BCDC's fill tests, not harm the environment in accordance with BCDC law and policies, and successfully meet project goals. However, based on the level of design provided and any uncertainty with that design, these determinations may be difficult. As mentioned above, uncertainty surrounding design will intensify in the future as we begin working with unprecedented environmental variables and untested project approaches. This uncertainty is exemplified by deciding appropriate project design in accordance with BCDC's law on amount of fill allowed for projects. As detailed in Chapter 2, the McAteer-Petris Act requires "that the water area authorized to be filled should be the minimum necessary to achieve the purpose of the fill."

When assessing habitat project design, there is some subjectivity in determining whether the amount of fill proposed is the "minimum amount necessary". This is expected to be particularly difficult when considering projects with longer lifetimes that attempt to include sea level rise adaptation in their design. The minimum amount necessary for a project to be successful now may be different than the minimum amount necessary for the project to be sustainable into the future. Similarly, adaptable habitat projects may require repeated applications of fill, and determination of the minimum amount necessary in this approach is difficult as well. A guidance document addressing how to determine what is "minimum" given project objective, and which project designs are appropriate to meet project goals and adhere to this requirement, would be helpful to applicants and analysts. BCDC plans to produce a guidance document addressing the long-term sustainability of habitat projects in the near future, and guidance on "minimum" fill could be detailed in this document.

Compounding the difficulty in obtaining high degrees of certainty in project design is the fact that thorough assessment of appropriate designs is costly and time-consuming for restoration practitioners. BEHGU recommends that as much complete baylands systems as possible of the 60,000-acre restoration goal be restored/constructed by 2030 in order to achieve regional habitat restoration goals in advance of predicted sea level rise.[205] Thus the time required to analyze a project or revise a project design detracts from time that these projects could be in the ground evolving. While increasing design requirements could reduce some of the uncertainty around project outcomes/appropriateness, it could also slow down the implementation of habitat projects. Therefore, it is important to strike a balance between asking for sufficient levels of design to assess whether a project is compliant with the Bay Plan and understanding that there will be a certain degree of uncertainty and unpredictability with all restoration projects.

Upcoming restoration projects will need to account for major sources of uncertainty, such as new methods and the variability of environmental change, and ultimately it will be difficult to know exactly how the projects will turn out. Project design will likely have to change and evolve through adaptive management, described in more detail below, to account for changing environmental conditions as the project is constructed and progresses through time. Less complete design could theoretically be problematic, as this makes it difficult to determine the project's likelihood of success and adherence to goals. However, the reliance on strong monitoring and adaptive management plans can alleviate the need to determine these things up front, as it provides a mechanism for real time assessment and adjustment of the project's progress in order to correct issues as they arise.

B. Monitoring

Monitoring is essential to understand how restoration projects evolve through time, whether projects are "successful" and meeting goals, and what unexpected benefits and impacts have occurred. This information is then applied by 1) validating project design and/or informing how project design can be improved in subsequent work and 2) feeding into adaptive management frameworks. Monitoring needs vary greatly depending on the level of uncertainty involved in the project's outcomes, project goals, and more. Based on the goals, monitoring may be required at different frequencies, over various periods of time, and for different physical and biological parameters of the project.

Monitoring will be particularly important for fill for habitat projects in the Bay that use fill, as these projects will likely be testing new approaches for sea level rise adaptation in the region. As described in Chapter 7, the impacts and cumulative effects of habitat type conversion caused by these anticipated projects are difficult to predict, so monitoring will be important to ensure that projects are not resulting in unintended consequences. Additionally, monitoring projects that test new approaches to fill will be essential to understand how the fill performed, and whether design could be improved for future projects.

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[205] *Goals Project, "Baylands Ecosystem Habitat Goals Science Update: Science Foundation Chapter 1 - the Dynamic Workings of the Baylands," October 14, 2015, 1–426.*

BCDC has very few policies regarding monitoring of habitat projects in the Bay. Considering the likelihood of adding larger volumes of Bay fill for habitat projects, it is important to examine whether BCDC's current approach to monitoring projects in tidal waters will be sufficient to gain the information we need about these projects.

- Tidal Marshes/Tidal Flats Policy 5: The Commission should support comprehensive Bay sediment research and monitoring to understand sediment processes necessary to sustain and restore wetlands. Monitoring methods should be updated periodically based on current scientific information.
- Tidal Marshes/Tidal Flats Policy 6: Any ecosystem restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria, and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) how the system's adaptive capacity can be enhanced so that it is resilient to sea level rise and climate change; (b) the impact of the project on the Bay's sediment budget; (c) localized sediment erosion and accretion; (d) the role of tidal flows; (e) potential invasive species introduction, spread, and their control; (f) rates of colonization by vegetation; (g) the expected use of the site by fish, other aquatic organisms and wildlife; (h) an appropriate buffer, where feasible, between shoreline development and habitats to protect wildlife and provide space for marsh migration as sea level rises; and (i) site characterization. If success criteria are not met, appropriate adaptive measures should be taken.
- Subtidal Areas Policy 4: Any subtidal restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) the scientific need for the project; (b) the effects of relative sea level rise; (c) the impact of the project on the Bay's sediment budget; (d) localized sediment erosion and accretion; (e) the role of tidal flows; (f) potential invasive species introduction, spread and their control; (g) rates of colonization by vegetation, where applicable; (h) the expected use of the site by fish, other aquatic organisms and wildlife; and (i) characterization of and changes to local bathymetric features. If success criteria are not met, corrective measures should be taken.
- Dredging Policy 11a: A project that uses dredged sediment to create, restore, or enhance Bay or certain waterway natural resources should be approved only if: …
    - The project includes an adequate monitoring and management plan and has been carefully planned, and the Commission has established measurable performance objectives and controls that would help ensure the success and permanence of the project, and an agency or organization with fish and wildlife management expertise has expressed to the Commission its intention to manage and operate the site for habitat enhancement or restoration purposes for the life of the project;…

Using these policies as a baseline, permit monitoring requirements are detailed in a project's permit and/or monitoring plan on a case-by-case basis. BCDC's current monitoring policies allow for flexibility and discretion on the part of the permit analyst and the project proponent in determining what information is needed to properly assess a project's progress. Because of the flexibility provided by current monitoring policies, the language as it is written is expected to be sufficient to require the aspects of monitoring fill for habitat projects considered important by permit analysts. Under the current policies, monitoring could be required for any duration that the permit analyst deems appropriate, and can include any parameters that the analyst considers necessary to assess the success of the fill.

However, because the policies are flexible and the extent of guidance provided is limited, inconsistency across monitoring requirements for various projects can occur. BCDC recently assessed its restoration project monitoring program, including how monitoring reports were submitted and tracked; which monitoring reports were present; what parameters were consistently monitored across projects; what timespan and frequency were used across projects; and what trends in habitat restoration project progression could be gleaned from monitoring reports. This assessment demonstrated that BCDC has required variable monitoring requirements depending on the project. For restoration projects (whether the purpose was mitigation, voluntary restoration, or research), the required monitoring duration ranged from 2 to 15 years, with the majority of projects requiring 5 years of monitoring. Nearly all of these projects required submission of monitoring reports annually. Additionally, success criteria and parameters monitored differed greatly across monitoring reports. Common parameters monitored include hydrological conditions, vegetative cover, bird surveys, erosion, and sedimentation. As noted in the report, the inconsistency across monitoring reports makes it difficult to compare directly among projects and synthesize regionwide trends.

To provide a more consistent framework for the development of monitoring requirements, the development of a monitoring guidance document is recommended, potentially as part of the guidance on long-term sustainability of habitats which is already slated for development (described in the Design section above.) This document would contain a level of detail that is more specific than policy but would also not be binding and could be updated as necessary. Additionally, as described in the above section on project design, there will be some uncertainty about which parameters are the best to monitor. There also may be aspects of a project that were not written into the original monitoring plan but are later decided would be important to monitor. For this reason, monitoring plans should also be adaptive in nature, and allow flexibility based on the results that are gathered.

Like finalizing project design, monitoring can be costly for restoration practitioners. While BCDC permit analysts have the flexibility to assess the level of monitoring necessary, it is important to consider that projects often have limited funding available for carrying out these monitoring requirements. This is similarly a difficult balance to strike—how do we require the level of monitoring necessary to ensure that the project is successfully managed, yet still consider the realities of funding availability? As was noted in the Design section of this chapter, monitoring requirements should differ considering the project at hand. Smaller, lower risk/less impactful restoration projects may not need as much monitoring as larger, higher risk projects, or as pilot/demonstration/research projects, which are aimed at learning from monitoring. The amount of monitoring required (including monitoring duration, extent, and frequency) should also scale with the project's purpose, size, risk/potential impacts, and expected duration. Another way to ensure that funding availability matches monitoring requirements is to ask applicants to provide a funding plan or proposed funding structure to demonstrate that they can comply with the permit requirements. While this does add some extra burden to the applicant, it is important to ensure that the long-term funding needs of the project have been considered, and that the project can perform the tasks required to meet its goals. Finally, some funding needs for monitoring efforts may be alleviated by the establishment of regional monitoring programs (described in more detail below).

BCDC's current monitoring policies and requirements are focused on project-based monitoring. Project-based monitoring entails a monitoring program designed to monitor the progress and outcomes of one specific project. This kind of monitoring is important for determining whether a project meets its goals and objectives, and for informing project-based adaptive management decisions. However, project-based monitoring can only go so far in terms of informing the health and needs of ecosystems at a larger scale, especially because different data collection approaches and extent of monitoring for different projects make it difficult to compare across projects and detect regional trends. Additionally, not every project needs the same degree of monitoring, especially if projects are small, fairly routine in nature, and/or not explicitly testing new design aspects. In this case, an elaborate project-based monitoring program may not be necessary and could result in an inefficient use of regional restoration funds.

Regionally coordinated monitoring can address these issues. Regional monitoring programs have the potential to reduce redundancy of efforts and decrease overall project costs. In many cases, individual projects could contribute funds to a pool to gain economies of scale in monitoring (typically a source of significant costs), and monitoring could be performed strategically in locations and at times that generate the most informative and necessary data. Regional monitoring also could ensure coordination and consistency in monitoring approaches and data gathered, which facilitates the regionwide synthesis of monitoring data. This type of program will be necessary to refine regional habitat goals (i.e. BEHGU) and to understand regionwide impacts of habitat type conversion.

Water quality in the San Francisco Bay has been monitored since 1993 via the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). This RMP program, managed by the San Francisco Estuary Institute, has detected trends in estuarine contaminants through time, and provided data that has informed management decisions throughout the Bay[206]. There have been several efforts to establish a regionwide monitoring program to assess the estuary's wetlands, none of which has been successful so far. However, the recently initiated Wetlands Regional Monitoring Program (WRMP) offers promise to fill this void. The major driving force in the development of the WRMP is the need to "improve the design and assess the effectiveness of publicly funded tidal marsh restoration projects"[207]. Depending on whether and how the WRMP is implemented, this program has the potential to reduce the

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[206] *SFEI SF Bay Regional Monitoring Program*

[207] *Wetland Regional Monitoring Program (2018.) Wetland Regional Monitoring Program Prospectus.*

intensity of monitoring requirements for many wetlands restoration projects throughout the Bay. Moreover, the program could provide much-needed information on the regionwide benefits and impacts of wetlands restoration projects (some of which may involve large amounts of Bay fill).

BCDC's policies do not acknowledge the importance of regional monitoring, nor do they encourage or require the analysis and sharing of monitoring data among restoration practitioners, permitting agencies, and other interested parties throughout the region. However, this approach will be important to assess the success of, need for, and impacts of fill for habitat restoration on a regional scale. The monitoring data required by BCDC rarely feeds into regionwide monitoring or other information sources. A formalized statement of the importance of regional monitoring, and BCDC's commitment to ensure that its monitoring data contributes to regional efforts, would be an important step toward accomplishing these goals. To solidify BCDC's support of these regional efforts, and to ensure that restoration practitioners throughout the region have access to monitoring data required by BCDC permits, updated policies should include a requirement that monitoring data be provided as a part of regional data collection and synthesis programs.

C. Adaptive Management

Adaptive management is defined in the Delta Reform Act as "a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management, planning, and implementation of a project to achieve specified objectives."[208] Definitions of adaptive management differ slightly from this depending on the source,[209,210] but generally, the key components of adaptive management are developing project goals and appropriate design elements to address those goals; monitoring to understand how a project is progressing; and adjusting management actions based on the results of monitoring in order to achieve desired outcomes. Adaptive management is described in the Bay Plan as "a cyclic, learning-oriented approach that is especially useful for complex environmental systems characterized by high levels of uncertainty about system processes and the potential for different ecological, social and economic impacts from alternative management options. Effective adaptive management requires setting clear and measurable objectives, collecting data, reviewing current scientific observations, monitoring the results of policy implementation or management actions, and integrating this information into future actions."

Adaptive management has the potential to address concerns about uncertain project outcomes because projects with adaptive management frameworks periodically reassess performance, and corrective actions are taken to ensure that the project's goals are accomplished. Thus, adaptive management will be an important component of addressing the uncertainty surrounding experimental projects and habitat projects that use fill to address

[208] Delta Reform Act, Water Code Section 85052, 2009.

[209] Ronald M Thom, "Adaptive Management of Coastal Ecosystem Restoration Projects," Ecological Engineering 15 (July 8, 2000): 365–72.

[210] Adaptive Monitoring and Assessment for the Comprehensive Everglades Restoration Plan, (National Research Council, 2003.)

changes associated with climate change. Many restoration projects do not develop adaptive management plans, however, and most regulatory agencies don't require these plans. BCDC requires an adaptive management plan for projects that will remain in place longer than mid-century:

- Climate Change Policy 3: To protect public safety and ecosystem services, within areas that a risk assessment determines are vulnerable to future shoreline flooding that threatens public safety, all projects—other than repairs of existing facilities, small projects that do not increase risks to public safety, interim projects and infill projects within existing urbanized areas—should be designed to be resilient to a mid-century sea level rise projection. If it is likely the project will remain in place longer than mid-century, an adaptive management plan should be developed to address the long-term impacts that will arise based on a risk assessment using the best available science-based projection for sea level rise at the end of the century.
- Climate Change Policy 7: Until a regional sea level rise adaptation strategy can be completed, the Commission should evaluate each project proposed in vulnerable areas on a case-by-case basis to determine the project's public benefits, resilience to flooding, and capacity to adapt to climate change impacts. The following specific types of projects have regional benefits, advance regional goals, and should be encouraged, if their regional benefits and their advancement of regional goals outweigh the risk from flooding:

  a. Remediation of existing environmental degradation or contamination, particularly on a closed military base;

  b. A transportation facility, public utility or other critical infrastructure that is necessary for existing development or to serve planned development;

  c. A project that will concentrate employment or housing near existing or committed transit service (whether by public or private funds or as part of a project), particularly within those Priority Development Areas that are established by the Association of Bay Area Governments and endorsed by the Commission, and that includes a financial strategy for flood protection that will minimize the burdens on the public and a sea level rise adaptation strategy that will adequately provide for the resilience and sustainability of the project over its designed lifespan; and

  d. A natural resource restoration or environmental enhancement project.

  The following specific types of projects should be encouraged if they do not negatively impact the Bay and do not increase risks to public safety:

  a. Repairs of an existing facility;

  b. A small project;

  c. A use that is interim in nature and either can be easily removed or relocated to higher ground or can be amortized within a period before removal or relocation of the proposed use would be necessary; and

  d. A public park.

However, many restoration projects do not meet the criteria outlined here that require the development of an adaptive management plan. For example, many restoration projects are not in areas where risk assessment shows that flooding is a threat to public safety. Also, not all restoration projects are intended to remain in place longer than mid-century. Therefore, this policy does not often apply to restoration projects, and will not apply to many fill for habitat restoration projects that use fill in the coming years.

Other policies require that adaptive/corrective actions should be taken for restoration projects if success criteria are not met:

- Tidal Marshes and Tidal Flats Policy 6: Any ecosystem restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria, and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) how the system's adaptive capacity can be enhanced so that it is resilient to sea level rise and climate change; (b) the impact of the project on the Bay's sediment budget; (c) localized sediment erosion and accretion; (d) the role of tidal flows; (e) potential invasive species introduction, spread, and their control; (f) rates of colonization by vegetation; (g) the expected use of the site by fish, other aquatic organisms and wildlife; (h) an appropriate buffer, where feasible, between shoreline development and habitats to protect wildlife and provide space for marsh migration as sea level rises; and (i) site characterization. If success criteria are not met, appropriate adaptive measures should be taken.
- Subtidal Areas Policy 4: Any subtidal restoration project should include clear and specific long-term and short-term biological and physical goals, and success criteria and a monitoring program to assess the sustainability of the project. Design and evaluation of the project should include an analysis of: (a) the scientific need for the project; (b) the effects of relative sea level rise; (c) the impact of the project on the Bay's sediment budget; (d) localized sediment erosion and accretion; (e) the role of tidal flows; (f) potential invasive species introduction, spread and their control; (g) rates of colonization by vegetation, where applicable; (h) the expected use of the site by fish, other aquatic organisms and wildlife; and (i) characterization of and changes to local bathymetric features. If success criteria are not met, corrective measures should be taken.

However, these policies do not require the development of an adaptive management plan. Taking corrective or adaptive actions if success criteria are not met is very different than establishing an adaptive management plan and adaptive management framework from the project's outset. "Corrective measures should be taken" can also be interpreted very loosely, and could be quite inconsistent across projects and involve different levels of evaluation and action. Moreover, all of BCDC's policies on adaptive management do not specify what should be included or addressed in an adaptive management plan when one is created, so these plans also are not held to any standard.

The flexibility of BCDC's current laws and policies allow for some adaptive management actions to be written into a permit (i.e. applicants could make small changes to the project based on the adaptive management plan without having to return to BCDC for additional approval). However, for major changes, even those in accordance with the adaptive management plan, the applicant would likely have to return to BCDC to get a plan approval or permit amendment. Another strategy for permitting adaptive management actions is to permit the project in phases in accordance with the adaptive management plan. This approach was used by the South Bay Salt Ponds Project, which finalized project design for the second phase of work based on monitoring information gathered in the first phase, and then returned to BCDC for a permit for the second phase.

Although it is possible to permit adaptive management of projects with BCDC's current laws and policies, the lack of established adaptive management recommendations and process could be problematic in the future when adaptive management will be the best tool to address uncertainty. The incentive for many projects to complete an adaptive management plan is also low as this is another major cost for restoration practitioners. The expense of designing and executing an adaptive management plan could end up adding significant costs to the project. As described for monitoring and design, this issue could be addressed by requiring the complexity of an adaptive management plan to scale with the purpose, size, level of impact, and lifetime of the project. Similarly, for projects that develop adaptive management plans, applicants should have to demonstrate a proposed funding plan or funding structure to ensure that the plan can be carried out.

BCDC is not comprehensively assessing adaptive management as part of the Fill for Habitat Amendment Process because a separate Bay Plan amendment and guidance document are planned to more specifically address this issue. Adaptive management for habitat projects will be considered further through these processes. However, before those processes are complete, the changes recommended through the Fill for Habitat Bay Plan Amendment could result in permit applications for habitat projects that would greatly benefit from an adaptive management plan. Thus, several resources are recommended below that could be useful in assessing the key elements that adaptive management plans should consider. When adaptive management policies and guidance are developed, BCDC could draw from the recommended process and components of adaptive management described in the literature and used by other agencies.

The Delta Plan (a comprehensive, long-term management plan for the Sacramento San Joaquin Delta) is required by the Sacramento-San Joaquin Delta Reform Act of 2009 to use "science-based, transparent, and formal adaptive management strategies for ongoing ecosystem restoration and water management decisions."[211] In Appendix C of the Delta Plan,[212] key aspects of this process (including "Best Available Science" and "Adaptive Management") are defined and described. The Delta Stewardship Council has outlined a three-phase and nine-step adaptive management framework that it will use to review proposed actions involving ecosystem restoration and water management. The nine actions are: 1) Define/redefine the problem, 2) Establish goals and objectives, 3) Model linkages between objectives and proposed

[211] *Water Code section 85308(f)—referenced in The Delta Plan Appendix C: Adaptive Management and the Delta Plan, August 9, 2013.*
[212] *The Delta Plan Appendix C: Adaptive Management and the Delta Plan, August 9, 2013.*

actions, 4) Select action(s)—research, pilot, or full scale—and develop performance measures, 5) Design and implement action(s), 6) Design and implement monitoring plan, 7) Analyze, synthesize, and evaluate, 8) Communicate current understanding, and 9) Adapt. Other iterative feedback processes like this have been outlined in the literature,[213, 214] many of which could be adapted by BCDC to identify important components to recommend in adaptive management plans. While there are many permutations of this cyclical process, a simpler statement of the needs of an effective restoration adaptive management program is captured by Thom: "The three main ingredients of an effective adaptive management plan in a restoration project are: 1) a clear goal statement; 2) a conceptual model; and 3) a decision framework." [215] The various versions of the adaptive management process all rely on these elements at the core.

Another key aspect of adaptive management plans should be the inclusion of recommended management actions if a project ultimately fails. This should include a definition of "failure." At what point should we say that a project has failed? What if a project meets 70 percent of its goals, but appears unable to accomplish the other 30 percent? It will be important for adaptive management plans to assess these various outcomes, and propose solutions to address various degrees of "failure."

D. Pilot and Demonstration Projects

One of our best tools for addressing uncertainty regarding habitat projects that use fill in their design and potential impacts/outcomes of new approaches will be pilot projects. "Pilot" projects can be defined in many ways, but for the purposes of this background report, the term is interchangeable with "demonstration" or "experimental" projects. In this context, these terms refer to projects for which a major objective is learning how types or approaches to fill in habitat projects with uncertain outcomes will function, and what impacts these various project types/approaches will have on the Bay. These projects have the potential to improve habitat project design and monitoring in preparation for an uncertain and dynamic future environment. However, pilot/demonstration projects also have high levels of uncertainty surrounding project outcomes, and therefore potentially higher than usual risk of project failure.

Because of the high uncertainty/high risk nature of pilot projects, they are often much smaller than a typical project designed to achieve the same goals would be. This smaller size means that the potential risks and impacts are reduced, and that, should the project fail, not as many resources would be used on a project that ultimately didn't provide benefits. To accomplish the goal of learning from pilot projects, these projects typically require more thorough monitoring and design as well.

Not all pilot or demonstration projects that have been permitted in the Bay in tidal waters were officially described as such, and in fact one could argue that in a sense every project includes some of the characteristics of pilot projects. However, key examples that are generally considered "pilot" or "demonstration" projects include the San Francisco Bay Living Shorelines

[213] *Carol Murray and David Marmorek, "Adaptive Management and Ecological Restoration," in Ecological Restoration of Southwestern Ponderosa Pine Forests the Science and Practice of Ecological Restoration Series, 2003, 417–28.*
[214] *References within The Delta Plan Appendix C: Adaptive Management and the Delta Plan.*
[215] *Thom, "Adaptive Management of Coastal Ecosystem Restoration Projects."*

Project (all sites) and Aramburu Island. It has been possible to permit these projects in the Bay for various reasons. Some pilot projects that could influence restoration practices in the Bay have also been conducted outside of BCDC's Bay jurisdiction. Marin County has worked on the Novato Basin Dredged Sediment Beneficial Reuse Project, which is a demonstration project investigating the efficacy of repeated dredged sediment placement to create sea level rise levees.[216]

Additionally, the permitting of pilot/demonstration projects has been facilitated by BCDC's findings and policies that encourage the support of research on various topics:

- Tidal Marshes Policy 5: The Commission should support comprehensive Bay sediment research and monitoring to understand sediment processes necessary to sustain and restore wetlands. Monitoring methods should be updated periodically based on current scientific information.
- Subitdal Areas Policy 5: The Commission should continue to support and encourage expansion of scientific information on the Bay's subtidal areas, including: (a) inventory and description of the Bay's subtidal areas; (b) the relationship between the Bay's physical regime and biological populations; (c) sediment dynamics, including sand transport, and wind and wave effects on sediment movement; (d) areas of the Bay used for spawning, birthing, nesting, resting, feeding, migration, among others, by fish, other aquatic organisms and wildlife; and (e) where and how restoration should occur.
- Dredging Finding w: More information on Bay sediment dynamics is needed to (1) better determine the impacts of dredging and dredged sediment disposal projects and (2) identify long-term trends in Bay sedimentation that relate to dredging needs and potential impacts to Bay resources, such as wetland and mudflats.
- Climate Change Policy 5: Wherever feasible and appropriate, effective, innovative sea level rise adaptation approaches should be encouraged.

These policies could be used to permit many pilot or demonstration projects with lower degrees of certainty. However, the existing Bay Plan policies on research-based projects are not all-inclusive, and do not offer a statement on the importance and need for pilot/demonstration projects as an information gathering mechanism for habitat projects in a future with sea level rise. Therefore, it is recommended to add additional findings and/or policies acknowledging the important role that these projects play in addressing uncertainty and allowing us to move forward with bold sea level rise adaptation approaches.

9. Next Steps and Complementary Efforts

Regulatory agencies in the Bay Area have and will continue to experience an influx of restoration project proposals due to several recent developments. The successful vote to pass Measure AA (The San Francisco Bay Clean Water, Pollution Prevention, and Habitat Restoration Measure) in 2016 raises approximately $25 million annually to fund restoration projects, which has been a major impetus for ensuring that restoration projects can be efficiently permitted. The completion of the Baylands Ecosystem Habitat Goals Update in 2015 was also an important

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[216] *Leventhal, (2016) "Demonstration Projects on the Eastern Shoreline - Past, Present, and Future."*

driving force, as it offers recommendations for restoration throughout the estuary that considered climate resilience. The Fill for Habitat Bay Plan Amendment is one aspect of current systemwide attempts to improve policies to address restoration projects in preparation for sea level rise. However, to facilitate the permitting of projects that will use more Bay fill for habitat, other changes or developments both within BCDC and externally will be necessary. Some of these complementary efforts and next steps are mentioned throughout this report, but they are more comprehensively described in this section.

A. Future BCDC Actions

Beyond the Bay Plan, regulatory documents that could be amended are the McAteer-Petris Act, BCDC's authorizing legislation, and its regulations, which provide detailed guidance and interpretation of the law and Bay Plan policies. While it is possible to amend the McAteer-Petris Act, this is not expected to be necessary to achieve the goals of allowing habitat projects that use fill and/or streamlining restoration in general. The law requires that projects meet the fill tests of Section 66605, including that "the water area authorized to be filled should be the minimum necessary to achieve the purpose of the fill". This requirement has been used with discretion by permit analysts in the past, and it can allow more than a "minor amount" of fill for a sea level rise adaptation project, as long as that fill is the amount required to achieve the project's purpose. However, long-term considerations of how Bay habitats will adapt to rising sea level may require changes to the McAteer-Petris Act. The Act could be updated to better address sea level rise, and could potentially be changed to expand BCDC's jurisdiction beyond public access in the 100 foot shoreline band. This latter change may be especially important when considering managed retreat and long-term options for tidal marsh migration.

BCDC's regulations[217] do not directly limit the amount of fill that can be used in the Bay for restoration projects. However, the regulations designate which projects can be permitted as administrative permits (permits that are granted by BCDC staff without official review from the Commission) as opposed to be analyzed as major permits (permits that require Commission approval). The major permitting process can be more in-depth and lengthy, therefore it would be ideal to have the ability to authorize restoration projects administratively. However, the current definitions of administrative and major permits in the Regulations complicate the administrative permitting of restoration projects. To be classified as a "minor repair or improvement" (and thus classified as an administrative permit), projects have to fall into categories outlined in Chapter 6, Subchapter 1, Article 1 (10601 – Minor Repairs or Improvements), none of which include restoration projects. One provision states that "any other activity similar to those listed in paragraphs (a), (b), (c), and (d) of this section that would have no greater adverse impact on the Bay than the listed activities" could also qualify, but this adds an extra complication, as analysts must then determine which approved activity is similar to restoration in order to grant an administrative permit. Another provision also quantifies "minor fill", stating that minor fill for improving shoreline appearance or public access cannot exceed 1,000 square feet in area if a permit is still to be considered administrative. An examination of these regulations is currently underway, and many of these issues will likely be

[217] *California Code of Regulations Title 14, Division 5*

addressed through the regulation review process. Once the Commission approves the Bay Plan amendment, the regulations would need to be reviewed and amended in accord with the new policies.

Many of BCDC's existing policies and the proposed policies do not provide significant guidance for permit analysts in analyzing complex proposals. To aid in the interpretation of these policies, the development of several guidance documents is recommended. BCDC guidance documents are generally internal, less formal documents that are created to provide resources for staff and increase consistency in staff analyses of certain project components, but are not legally binding. Through the amendment process, BCDC has concluded that guidance should be developed to better inform the decision on what is a "minimum amount of fill necessary for the project," especially considering sea level rise and future project trajectories. Guidance on best practices for monitoring, both for fill for habitat projects and beyond, would be useful as well. Additionally, guidance should be developed on the use of best available science in assessments of a project's regional context, including its sustainability, benefits provided at the regional scale, and potential impacts at the regional level with a reference library that is continually updated to provide that scientific knowledge.

Several guidance documents that will also be beneficial for interpretation of the updated fill for habitat policies have already been slated as an outcome of BCDC's Commissioner Workshops on Rising Sea Level (2017) and other subsequent staff discussions. These documents include guidance on BCDC's climate change policies, guidance for long-term sustainability of habitat projects (specifically adaptive management and resilience), and guidance on minimum design, monitoring, and information required for experimental projects.

As noted in Chapter 8, the uncertainty surrounding best design and project outcomes for fill for habitat projects is expected to provide some challenges in the permitting process. To assess whether project design is appropriate and how it could be improved, expert review may be helpful in some cases. Such review could be provided by an existing body, such as the Design Review Board (DRB). This would entail expanding the purview of the DRB, whose current function is to "advise the Commission and the staff on the appearance and design of projects for which a Commission permit or consistency determination is needed, particularly as the project affects public access to the Bay and shoreline."[218] Another option is the creation of a new review board to specifically assess the design and feasibility of restoration projects. Although this could be part of the BCDC review process, it could be more beneficial as an external entity to review project design overall, not specifically in accordance with BCDC's laws and policies. The San Francisco Bay Joint Venture did oversee a voluntary Design Review Program to provide technical support on project design and management for projects around the Bay,[219] although the program had significant challenges and has not been active recently. The inclusion of this type of program in the review process could be another avenue for ensuring adequate technical review of project design.

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[218] *California Code of Regulations Title 14, Division 5, Chapter 2, Article 7—10270*

[219] *SF Bay Projects*

Policy issues associated with the fill for habitat amendment will also be addressed in more detail through four other Bay Plan Amendment processes that BCDC has planned to complete over the next four years. These Bay Plan Amendments, which were discussed during the Commission's Public Workshops on Rising Sea Level (2016 - 2017), include amendment of the Beneficial Reuse Policies, Mitigation Policies, Adaptive Management Policies, and Fill for Flood Protection Policies. All of these amendments have the potential to further improve the Commission's ability to permit fill for habitat projects in a smart and efficient way.

B. External Improvements to Restoration Project Permitting

Outside of BCDC, numerous efforts to improve habitat restoration project policies and permitting are ongoing or starting in the near future, many of which will complement BCDC's process and inform solutions to many of the challenges described throughout this document. The San Francisco Bay Regional Water Quality Control Board has started a process to reassess its restoration and fill policies in light of climate change and sea level rise. This process has targeted many of the same issues that BCDC is addressing through the Fill for Habitat Bay Plan Amendment process. Since restoration projects must get a permit from multiple regulatory agencies in the Bay Area, BCDC's new policies could result in little overall improvement if other agencies' policies do not align with these changes. Thus, the Water Board policy updates, in conjunction with BCDC's amendment, will be important to have consistency at the State level.

Two processes that can provide resources for BCDC permit analysts in implementing new policies are the Environmental Protection Agency's (Region 9) Wetland Type Conversion Framework document (which is in development), and the San Francisco Estuary Partnership's Wetland Regional Monitoring Program. These efforts, where applicable, can further inform BCDC staff in assessing the impacts of new fill for habitat projects and determining appropriate conditions for permits.

As discussed in Chapter 3, In direct response to the need for improving the permit process for restoration projects that arose with the availability of measure AA funds, the San Francisco Bay Restoration Authority (SFBRA) convened the formation of two interagency collaborative groups—the Policy Management Team (PMT) and the Bay Restoration Regulatory Integration Team (BRRIT). The BRRIT was established "to improve the permitting process for multi-benefit wetland restoration projects and associated flood management and public access infrastructure by dedicating agency representatives to review project information and prepare permit applications for consideration as a team in the most efficient manner."[220] This team, which is currently being formed, will consist of one regulatory analyst from each of the six agencies with regulatory authority in the Bay. In addition to the BRRIT, the PMT was created "to coordinate with the BRRIT as necessary to resolve policy issues and provide direction for any elevated project decisions."[221] This team similarly consists of managerial staff from each of the six agencies with regulatory authority in the Bay, and the Environmental Protection Agency as well. The Policy Management Team has developed a prioritized policy improvement list and begun addressing habitat type conversion. Other issues include fill for habitat, wetland monitoring,

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[220] *SFBRA site--http://sfbayrestore.org*
[221] *ibid*

public access and wildlife compatibility, and more. Together, the PMT and the BRRIT have the capacity to increase permitting efficiency and maximize use of available resources for habitat projects in the Bay.

Sustainable Conservation, a nonprofit that works to unite people to solve tough environmental challenges in the state of California, also has a large effort underway to streamline and accelerate the permitting of restoration projects. Sustainable Conservation has worked with the National Oceanic and Atmospheric Administration National Marine Fisheries Service, the State Water Resources Control Board (WRCB), and other state and federal agencies to develop programmatic permits for small (5 acres or less) restoration projects. Programmatic permits are pre-written permits that can be applied to multiple qualifying projects, and thus greatly reduce the time it takes to permit restoration projects. The use of programmatic permits for restoration projects by agencies that regulate in the Bay could complement the efforts of the BRRIT and PMT to streamline permitting of essential habitat projects in this area.

Finally, discussions on restoration in the Bay have been coordinated for some time by entities such as the San Francisco Bay Joint Venture and the San Francisco Estuary Partnership. These forums could be continually and increasingly used for exchanging information, consolidating processes, and making regional decisions about restoration efforts throughout the Bay.