March 2010

Preliminary Study of the Effect of Sea Level Rise on the Resources of the Hayward Shoreline

Prepared for *Hayward Area Shoreline Planning Agency*

Prepared by *Philip Williams & Associates, Ltd.*

PWA

PRELIMINARY STUDY OF THE EFFECT OF SEA LEVEL RISE ON THE RESOURCES OF THE HAYWARD SHORELINE

Prepared for

Hayward Area Shoreline Planning Agency

Prepared by

Philip Williams & Associates, Ltd. (PWA)

March 2010

PWA REF. 1955.00

Services provided pursuant to this Agreement are intended solely for the use and benefit of the Hayward Area Shoreline Planning Agency.

No other person or entity shall be entitled to rely on the services, opinions, recommendations, plans or specifications provided pursuant to this agreement without the express written consent of Philip Williams & Associates, Ltd., 550 Kearny Street, Suite 900, San Francisco, CA 94108.

TABLE OF CONTENTS

FIGURES

1. INTRODUCTION

1.1 BACKGROUND

Sea level is anticipated to rise by as much as 55 inches over the next century, which will have major implications for many of the cities that surround San Francisco Bay. The Hayward Shoreline, from San Leandro Creek to the Alameda Creek Flood Control Channel, is a typical East San Francisco Bay low-lying shoreline which provides vital ecological, industrial and residential functions yet is already vulnerable to inundation from both tidal and fluvial sources (Figure 1.1).

The Hayward Area Shoreline Planning Agency (HASPA) wishes to determine the impact of the anticipated sea level rise in San Francisco Bay, on the Hayward Shoreline and the actions that can be taken to protect both the wetlands and shoreline development in this area. The planning of the South Bay Salt Pond Restoration Project by the U.S. Fish and Wildlife Service will address the projected change in sea level within the HASPA planning area to the south of Highway 92. This leaves the area north of Highway 92 to San Leandro Creek (the Sea Level Rise Study Area) to be addressed in this report (Figure 1.2).

The 4.3 mile-long Sea Rise Study Area is composed of several successful wetland mitigation and enhancement projects that have been in existence for many years. These mitigation areas were developed based upon a consistent tidal regime to provide habitat and forage for many species. These areas also form a tidal ‘buffer’ that protects both public and private improvements and facilities built along the inboard levees, and hence their continued existence is critical to the protection of this shoreline.

1.2 PURPOSE

Over the next 50 years there is the potential for accelerated sea-level rise to expose the currently buffered reaches of the shoreline to wave action and potential flooding. The goal of this project is to provide HASPA with a preliminary assessment of the possible impacts and strategies to manage the affects of sea-level rise on both the natural and developed resources in the Sea Level Rise Study Area.

figure ***1.1***
HASPA Sea Level Rise Study

Sea Level Rise Study Area

PWA Ref# 1955.00

PWA

Source: City of Hayward

figure ***1.2***
HASPA Sea Level Rise Study

Ownership Map

PWA Ref# 1955.00

2. SHORELINE RESPONSE TO SEA LEVEL RISE

2.1 GEOLOGICAL PERSPECTIVE

Sea level rise is not a recent phenomenon in San Francisco Bay. The intertidal wetland habitats of the South Bay evolved over the last 4,000 years, as gradually rising relative sea level inundated the gently sloping margins of the Bay (Figure 2.1). Tidal marshes kept pace with rising relative sea level by sedimentation and the accumulation of organic material, such as peat, within marsh soils at about the elevation of the mean higher high water (MHHW) (Atwater *et al* 1979; Watson 2004). As relative sea-level rose, at a rate of about 10 cm (4 in) per century, tidal marshes migrated inland, creating extensive vegetated marsh plains drained by a complex network of large sinuous tidal channels. Each tidal channel has a tidal "watershed", the marsh area that each channel fills and drains, and their scale dictates the size and density of the tidal channel system formed in equilibrium with the tidal prism of upstream marshes (Orr *et al* 2003). These watersheds are distinguished by very subtle changes in elevation, and in the ancient marshes of San Francisco Bay marsh plain ponds can occur at the watershed divide (Collins and Grossinger 2004). They receive tidal inflow only on the highest tides and can become hypersaline in the summer. At the inland edge of the transgressing marsh seasonal salt pans also form where tidal drainage is least effective.

With adjustment of the estuary to rising sea-level, both marshes and mudflats moved inland. Strong wind-wave action gradually eroded the bayfront marsh edge eventually forming the extensive shallows and mudflat margin of the South Bay, while the landward edge of the marsh advanced inland. The slope of this erosional platform maintains an equilibrium form with the long-term wave climate, sediment supply, and sea-level rise (Roberts *et al* 2000). Because this erosional platform consists of cohesive sediments of the buried ancient marsh, it is highly consolidated, and in the more wave-exposed areas can be covered by a veneer of sand and shell.

Wave action was strongest, and hence shallows most extensive, on the eastern shore. Here wave action was sufficient to deposit ridges of sand, shell, and wrack that blocked small tidal channels creating extensive natural salt flats.

As the South Bay evolved over time scales of centuries, the area of intertidal wetland habitats changed. With gradually rising sea-level the area of subtidal habitats increased, the area of wave-dominated mudflats expanded with increasing wave fetch, and the area of tidal marsh expanded or contracted depending on fluctuations in sediment supply and whether the rate of inland migration was greater or less than the rate of marsh edge erosion induced by relative sea-level rise (Atwater *et al* 1979). As sea level rose, the estuary expanded and the main subtidal channel was "drowned", creating an internal sediment sink that captured a portion of the sediment recirculating within the estuary.

2.2 HUMAN INTERVENTIONS

European-American colonization over the last 200 years has transformed not only the landscape of the estuary, by diking, filling, and groundwater pumping, it has also changed the processes that sustain wetland habitats of the estuary by altering the sediment budget (interactions between sources and sinks), hydrodynamics, and salinity distribution.

Sediment supply to the South Bay, both from local watersheds and possibly the Sacramento River, changed significantly over the last 200 years. With 19th century grazing, agriculture, and logging it is likely that sediment delivery from local watersheds increased significantly. In addition many local creeks that formerly dissipated flood flows and sediment at the Bay margin were channelized directly to the Bay (Collins and Grossinger 2004). Later, dams on the major local streams reduced sediment inflow (Wright and Schoellhamer 2004).

Hydraulic mining and watershed disturbance in the Sierra in the 19th century substantially increased sediment delivery and the frequency of flood pulses to the North and Central Bay (Gilbert 1917). However, it is still not clear how much of this sediment reached the South Bay. Over the last 50 years, sediment delivery from the Central Valley has substantially decreased due to reservoir construction, recovering watersheds, reduction of flood peaks, and diminishment of the hydraulic mining pulse.

Over the last 60 to 150 years most of the South Bay's tidal marshes were diked off. This obliterated vegetated tidal marsh functions and associated habitats, specifically marsh plain ponds, perimeter salt pans, transitional marshes, and the large tidal channels within the marshes. Diking of the marshes also affected estuarine processes. The tidal prism was reduced, allowing tidal sloughs to silt in and narrow as fringing marsh between the levees expanded. Rip-rapped levees precluded the opportunity for eroding mudflats to migrate inland. Diking of the marshes eliminated a sediment sink allowing more sediment to be recirculated within the estuary, probably resulting in increased suspended sediment concentrations and higher rates of siltation in the subtidal channel.

The sediment budget of the South Bay has also been altered by dredging to maintain flood control channels, navigation, and to provide construction materials. Since the 1970's, a series of restoration projects have created new sediment sinks at the Bay margin.

2.3 SHORELINE RESILIENCE TO SEA LEVEL RISE

The resilience of marshes to sea level rise is defined by how the wider coastal system, as a whole, responds to sea level rise. Some marshes will continue to respond resiliently to sea level rise if they have 'sufficient' sediment in circulation and have space for wetlands to migrate. They may also erode due to reduced sediment supply caused by engineering activities that have created sinks within the estuary that draw and remove sediment from circulation that would otherwise feed marshes and mudflats.

Existing tidal marshes accommodate sea level rise with only minor long-term or progressive conversion of tidal habitat types, and a gradual landward shift in position (Figure 2.2). Vertical accretion rates will depend upon the sediment supply, rate of organic production, and the rate of sea level rise. If sea level rise continues to accelerate, at some point it will outstrip the rate of accretion and the marsh will start to ‘drown’. If the vertical accretion of marshes cannot keep pace with sea level rise then the wetlands habitats will tend to migrate (or “transgress”) landward.

The horizontal rate of transgression will depend upon the rate of sea level rise and the slope of the upland transition zone. Past levee construction has steepened coastal gradients, converting gently sloping bayland edges that rise towards the land into steep linear borders backed by basins (Figure 2.3). Sea level rise acts very differently on gentle, continuous slopes (where it gradually shifts tidal habitat zones upland and landward) and on discontinuous, artificial diked bayland topography (where it forces either acceleration of maintenance and repair of dikes, or “overstepping” the barrier – abruptly flooding the diked basin and radically shifting the shoreline and shore processes landward). If the marsh is bounded by a steep slope (such as an inboard levee) then the transition zone available for transgression will be much reduced and marsh habitat will be lost through ‘coastal squeeze’.

Human disturbance to the landscape can affect the natural resiliency of the estuarine systems. Loss of space by diking not only causes a direct loss of habitat but also modifies or disrupts hydrologic and geomorphic processes. As a result sediment pathways adjust, redirected from historic sinks to new locations and an adjustment in the self-organization of the landscape. This may increase the sensitivity of remaining habitats to the impacts of climate change.

Examples of human impacts that have cumulative impacts on coastal environments include:

- <u>Levee Construction</u>: results in a combination of direct wetland losses and modification to hydrodynamics. With sea level rise, landward migration of coastal habitats is prevented leading to “coastal squeeze’, the loss of intertidal habitats between rising waters and hard landward edge.

- <u>Maintenance Dredging</u>: creates artificial sinks for sediment circulating around the system. A portion of sediments that migrate to fill these artificial sinks will be derived from adjacent mudflats and marshes directly; in effect, preferentially capturing the available sediment. To reduce the frequency of dredging and associated costs, typical maintenance dredging protocols call for sediment to be removed from the local area, which inadvertently causes progressive impacts to adjacent wetlands. Maintenance dredging may also impact estuarine hydrology and sediment circulation patterns.

- Channelization: promotes sedimentation offshore in deeper water. This in turn reduces the available supply of sediment to mudflats and marshes.

2.4 MARSH RESPONSE TO SEA LEVEL RISE

There are a number of (qualitative) evolutionary scenarios relevant to long-term planning in East Bay wetlands:

a. Equilibration, dynamic stability: existing tidal marshes accommodate sea level rise with only minor long-term or progressive conversion of tidal habitat types, and a gradual landward shift (horizontal displacement or landward estuarine “transgression”) in position. This familiar scenario is associated with very gradual (historic) rates of sea level rise and net positive sediment budgets (due in part to effects of diking, artificial loss of tidal prism). This scenario is not likely to occur in a regime of rapidly accelerating sea level rise and neutral or negative sediment budgets.

b. Gradual evolution: gradual submergence of tidal marsh habitats with marsh type conversion ("downshifting" zones: high marsh to middle marsh, middle to low, low marsh to unvegetated tidal flat); expansion of tidal marsh pans and enlargement of tidal channels; mudflat erosion (loss of elevation); progressive but slow erosional retreat of marsh edges (wave-cut marsh “cliffs” or scarps); and either dike overtopping, erosion, and breaching, or dike raising, armoring, and increased artificial bayland drainage. The “gradual evolution” scenario is compatible with coastal planning adaptation through modification of planning policies that anticipate bayland changes and build ahead to accommodate them or at least to avoid worsening foreseeable conflicts.

c. Collapse (abrupt conversion of ecosystem to alternative modes and habitat types): in this worst-case scenario associated with early onset of accelerated sea level rise at the upper end of projected rates, sea level rise would overstep marsh platforms, causing wholesale drowning of marshes: marsh plains initially respond by converting to low marsh (cordgrass), but fail as rapid marsh vegetation dieback forms extensive pans that “swallow” fragmented marshes and expand to tidal flats. This is analogous with contemporary tidal marsh loss in Gulf of Mexico and the Mississippi Delta. Rapid marsh edge and levee erosion (or recurrent “emergency” reactive armoring and repair), increased flooding of diked baylands or undiked adjacent lowlands, and the rapid loss of critical high marsh habitat and upland buffer integrity are likely to occur in this scenario.

There will probably be a variable mix of a) and b) for the first 50 years, unless there is an abrupt, rapid acceleration in sea level rise (i.e. abrupt changes in ocean temperature or ice sheet collapse). Maintaining existing marsh zones with no conversion would be an optimistic projection because as marsh plain drainage decreases with submergence, so does marsh plant growth and vegetation height. Reduced marsh vegetation growth will mean less plant stem height and density for trapping and stabilizing suspended sediment and less production of organic matter in the soil profile.

The pace of coastal habitat changes due to sea level rise, even in “gradual” scenarios, may not be uniformly gradual. Average sea level represented in models deviates from significant annual fluctuations in sea level, which may reach up to approximately 8 inches above average levels during strong El Niño events, due to thermal expansion of warm Pacific waters. In addition, intense storms associated with El Niño events may be expected to achieve many years or even decades’ worth of “average” erosion in extreme storms or series of storms. Thus, the coastal habitat changes expected with sea level rise, regardless of the long-term sea level curve, may not be expected to occur in a linear or incremental pattern. The biological responses to habitat change caused by sea level rise may similarly be expected to occur in pulses, or reflect dominant influences of extreme storm events. Local extirpation of species with limited dispersal ability, high site fidelity, or close dependence on narrowly distributed critical habitats, is a particular concern for threshold changes in habitat driven by storm events during long-term sea level rise.

2.5 CHANNEL RESPONSE TO SEA LEVEL RISE

Many characteristics of channels are linked to the tidal prism of the tidal watershed that it drains. With gradual sea level rise, intertidal surfaces can keep pace with the increase in high water elevations and the tidal prism may stay relatively constant. With low rates of sea level rise therefore there may not be large changes in channel form. However, with rapid sea level rise, the rate of vertical accretion may be insufficient to keep pace with high water elevations, and the mean depth and tidal prism of the marshes will increase. In addition the size of the estuary will increase as marshes transgress landward, increasing the area of subtidal and intertidal contributions to the tidal prism. With increasing tidal prism the downstream channel cross-section, its width and depth, will increase. There may also be changes in its planshape as discharges increase.

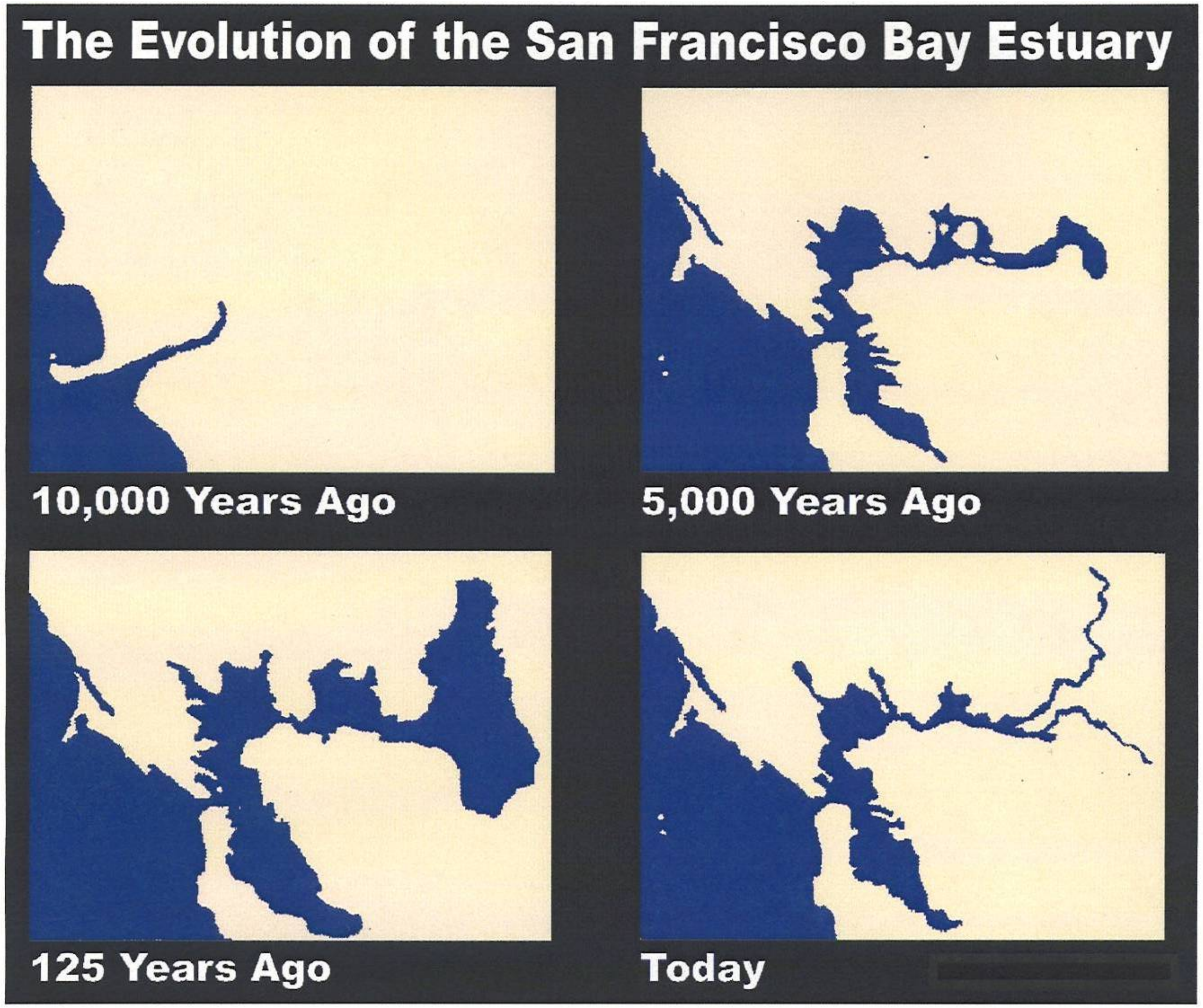
It is observed in accreting marshes that channel density varies with elevation and hence age of the marsh:

- low or young marsh, where marsh plain elevations are low and tidal prism is large, tends to have higher drainage density, more small channels and complex drainage patterns;

- higher or older marsh, where tidal prism is reduced and drainage density decreases, tends to have a less complex drainage pattern with fewer small channels.

The elevation of maximum channel density is usually estimated to be around the elevation of the neap high tide in semi-diurnal tidal regions (Steel and Pye 1997). It is unlikely that this pattern works in reverse if higher marshes drown, rather it is possible that pan formation will capture channels, obliterating the existing dendritic pattern and expanding to tidal flats.

The changes that might be expected in the channels are controlled by the tidal prism and so are related to the elevation of the marsh. The success of channels in responding to sea level rise is therefore dependent on measures that promote marsh evolution which, in turn, minimize changes in tidal prism.



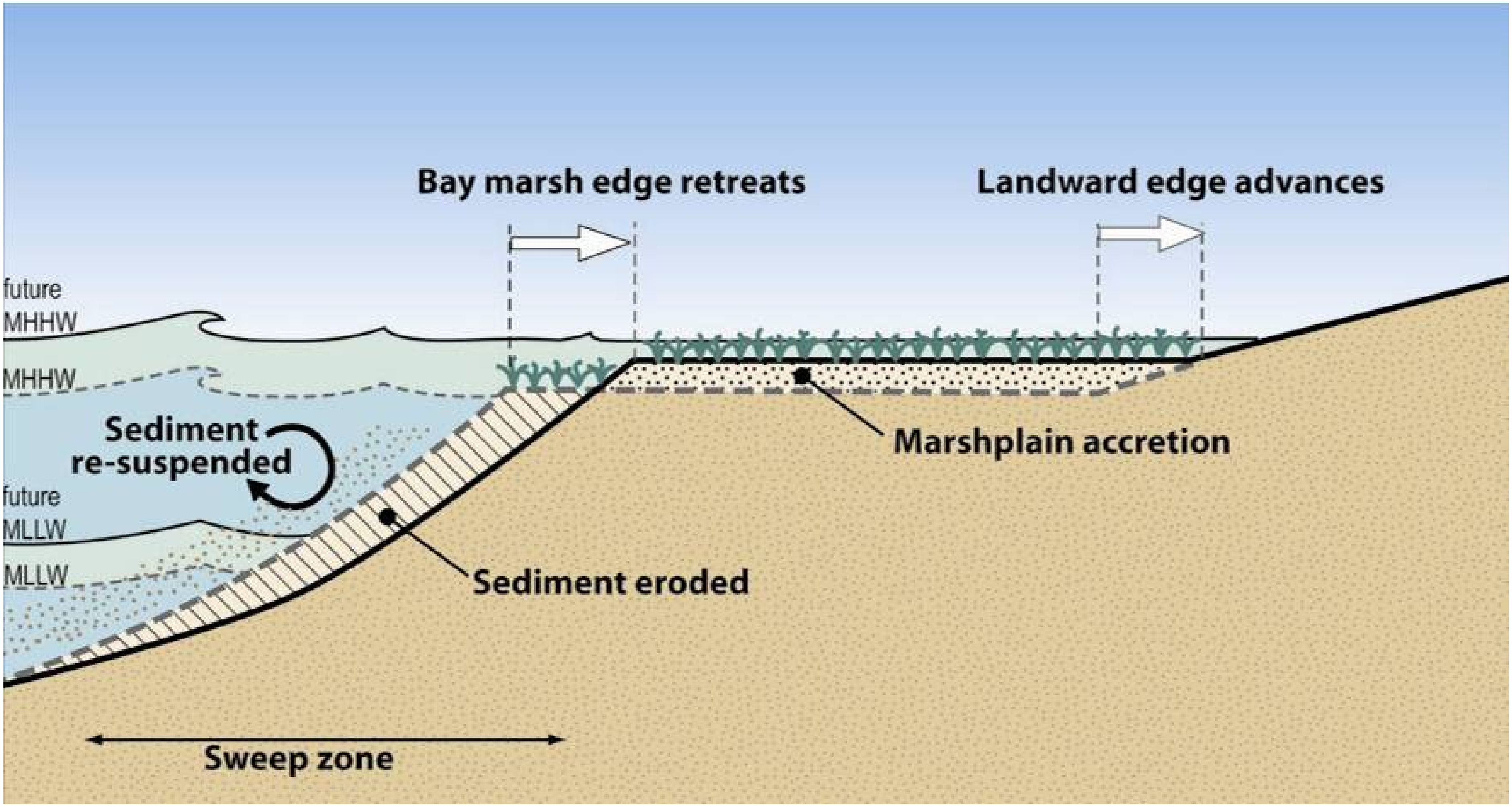
Source: Atwater *et al* (1979)

figure ***2.1***
HASPA Sea Level Rise Study

Evolution of San Francisco Bay

PWA Ref# 1955.00

PWA



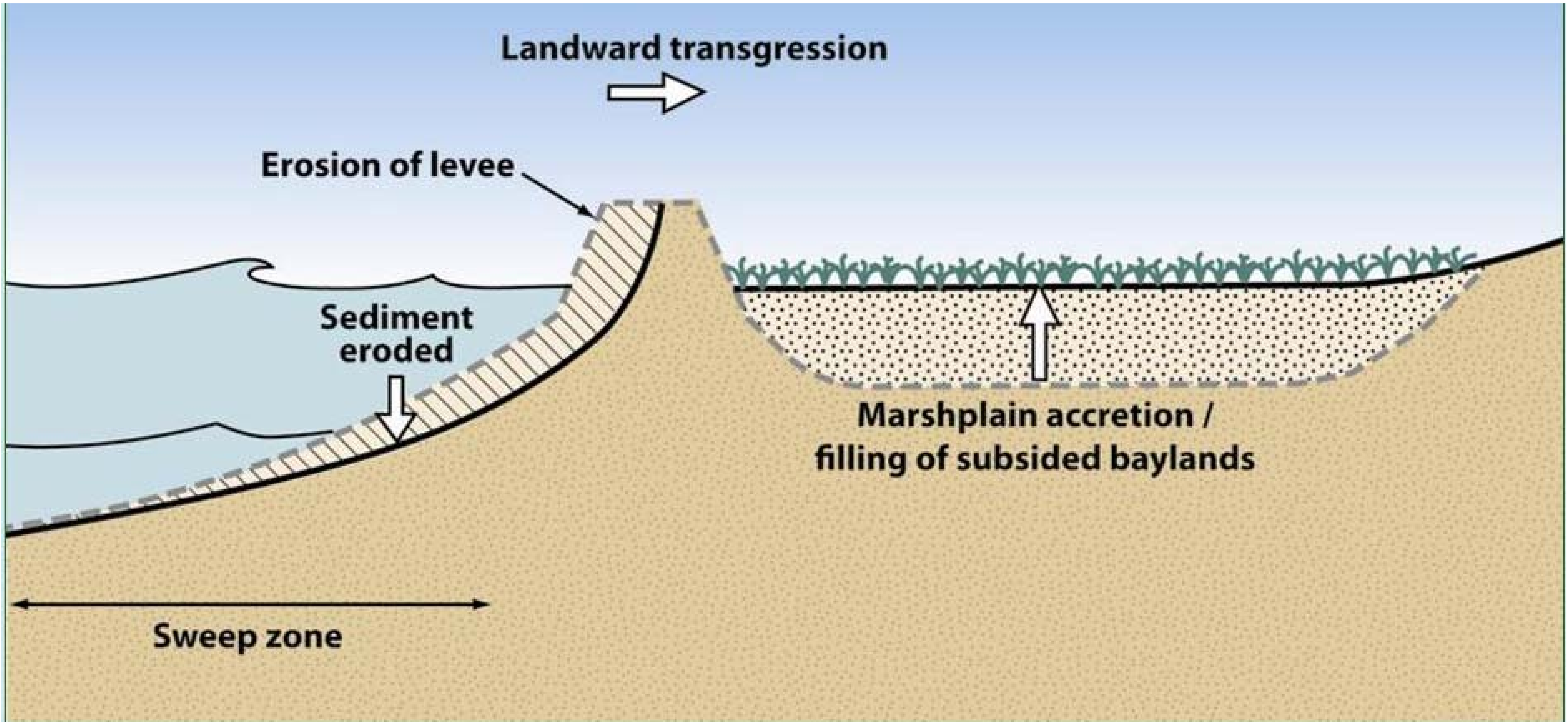
Source:

figure **2.2**
HASPA Sea Level Rise Study

Natural Shoreline Evolution

PWA Ref# 1955.00

PWA



Source:

figure **2.3**
HASPA Sea Level Rise Study

Erosion of Bay shore levees

PWA Ref# 1955.00

PWA

3. STATE GUIDANCE FOR ADAPTATION PLANNING

Accelerated rates of sea level rise will bring new challenges to the management of the Hayward shoreline for both flood management and environmental protection. As the shoreline migrates landward so habitats and flood hazard areas will also shift. Traditional planning approaches based upon a static landscape will have to be replaced with a more flexible approach which can accommodate dynamic shifts in the shoreline. Planning will have to be based on a moving frame of reference. However, past development of residential, commercial, and public access infrastructure has locked out much potential flexibility for set-backs or adjustments to the Hayward shoreline.

Further intensifying conflicts in shoreline planning, is the interaction between sea level rise and artificially steep topography (fill slopes, levee slopes) at the bayshore, and the tendency for public land uses and private real estate values to reach maximum levels at bayshore edges (e.g., coastal views, coastal access, open space adjacency as drivers of land prices). Steep fill slopes at the bayshore compress high marsh and upland transition zones to artificially narrow and homogeneous, linear strips, which reduce both their ecological and flood protection value. They leave almost no "accommodation space" for sea level rise, which inevitably shifts the high tide-linked habitat zones landward and vertically. Planning will therefore have to address the conflict between the "movable" and the "immovable", in particular the issues of upland buffers and "coastal squeeze".

In their report "Living with a Rising Bay" (BCDC 2009), BCDC discuss how the vulnerabilities of the Bay shoreline and ecosystems to sea level rise and other climate change impacts will create new technical challenges for shoreline planning, and require difficult decisions to prioritize protection of shoreline development and Bay resources. They conclude that while local government and other management agencies, especially in cities and counties, have broad authority over shoreline land use,

> "…they lack policy incentives, resources and regional guidance for addressing climate change impacts in land use planning. To address these gaps, local governments need information about the Bay-related impacts of climate change that is region-specific and site-specific. The information should include a regional model that projects 50-100 years into the future or the expected "life of a project." The projections should be developed through a public, inclusive process in order to be widely accepted and used throughout the region." (BCDC 2009, p. 133)

In the last year (2009) the State has begun to provide guidance to local government on how to approach issues related to sea level rise. Such guidance is being continually updated as policy is being developed and projections and vulnerabilities better understood. The following is a summary of some of the key guidance issued so far based largely on Polgar (2009).

3.1 EXECUTIVE ORDER S-13-08 (NOVEMBER 2008)

This Executive Order, issued November 14, 2008, has three main directives. Firstly, it sets up a process to provide a comprehensive assessment of sea level rise for California to be undertaken by the National Academy of Sciences (NAS) due to be completed at the end of 2010. This will provide a consistent set of sea level projections to be used by the State. The assessment is likely to include recommendations on a process for updating such projections on a regular basis.

The Executive Order also requires that all state agencies that are planning construction projects in areas vulnerable to future sea level rise shall consider a range of sea level rise scenarios for the years 2050 and 2100 in order to assess project vulnerability and, to the extent feasible, reduce expected risks and increase resiliency to sea level rise. In the absence of the NAS report, the projections developed in Cayan *et al* (2008) and discussed in Section 4 and Appendix A of this report are being used by multiple state agencies (e.g. BCDC, the Coastal Conservancy, and the California Coastal Commission)

3.2 CALIFORNIA CLIMATE ADAPTATION STRATEGY (DECEMBER 2009)

Executive Order S-13-08 also directed the California Resources Agency, through the Climate Action Team, to develop a Climate Adaptation Strategy for the State. The strategy summarizes the best known science on climate change impacts to California, assesses California's vulnerability to the identified impacts and then outlines solutions that can be implemented within and across state agencies to promote resiliency.

The strategy provides guiding principles for adaptation and establishes a state policy to avoid future hazards due to climate change and protect critical habitat. Specifically,

1. the strategy recommends that State agencies "consider project alternatives that avoid significant new development in areas that cannot be adequately protected from flooding due to climate change,";

2. that "State agencies should generally not plan, develop, or build any new significant structure in a place where that structure will require significant protection from sea level rise, storm surges, or coastal erosion during the expected life of the structure.";

3. "significant state projects, including infrastructure projects, must consider climate change impacts, as currently required under CEQA Guidelines Section 15126.2.";

4. the strategy also recognizes that some vulnerable shoreline areas have, or are proposed to have, development of "regionally significant economic, cultural, or social value" that may need to be protected, and that "in-fill development in these areas should be accommodated.";

5. communities with General Plans and Local Coastal Plans should begin when possible to amend their Plans to assess climate change impacts, identify areas most vulnerable to these impacts, and to develop reasonable and rational risk reduction strategies.

3.3 STATE COASTAL CONSERVANCY PROJECT SELECTION CRITERIA

The Coastal Conservancy has adopted criteria for project selection to address climate change. Project applicants are now required to consider a range of sea level rise scenarios for the years 2050 and 2100 in order to assess project vulnerability and, reduce expected risks and increase resiliency to sea level rise. The Conservancy will "look favorably" upon projects for which the project objectives, design and siting consider and address other climate change vulnerabilities, not just sea level rise (Polgar 2009).

3.4 BCDC BAY PLAN: CLIMATE CHANGE POLICIES

BCDC has developed a report that analyzes vulnerabilities to climate change in the Bay and on the shoreline and recommended new and updated San Francisco Bay Plan Findings and Policies (BCDC 2009). The Commission is scheduled to vote on the policy recommendations in 2010. Once adopted by the Commission, the new policies will likely affect design and siting requirements for some projects requiring permits from BCDC, and staff will develop guidance for applicants on the changes (Polgar 2009).

3.5 CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA)

As directed by SB97, the Natural Resources Agency adopted Amendments to the CEQA Guidelines for greenhouse gas emissions on December 30, 2009. These amendments are available at (http://ceres.ca.gov/ceqa/guidelines). On February 16, 2010, the Office of Administrative Law approved the Amendments, and filed them with the Secretary of State for inclusion in the California Code of Regulations. The Amendments will become effective on March 18, 2010.

It affirms that "the EIR should evaluate any potentially significant impacts of locating development in other areas susceptible to hazardous conditions (e.g., floodplains, coastlines, wildfire risk areas) as identified in authoritative hazard maps, risk assessments or in land use plans addressing such hazards areas."

4. SEA LEVEL RISE PROJECTIONS

Climate change simulations project a substantial rate of global sea level rise over the next century due to thermal expansion as the oceans warm and runoff from melting land-based snow and ice accelerates. With sea level rise there will always be different sets of projections due to:

- the uncertainty of the modeling,
- when the projection was made (the science is rapidly evolving), and
- choice of future emission scenarios.

There are three sets of projections that are common in the Bay – Intergovernmental Panel on Climate Change (IPCC 2007), the State of California (Cayan *et al* 2008) and the U.S. Army Corps of Engineers (USACE 2009). These projections are detailed in Appendix A. All apply to the Hayward shoreline and so we would recommend using all three in their own way:

- for long-term planning purposes (i.e. a high-end projection for 2100) the projections of Cayan *et al* (2008) should be used which gives **16" by 2050** and **55" by 2100**. This is the guidance used by the State of California for projects undertaken by their agencies (Coastal Conservancy, etc.).
- if the USACE are involved in the project, then their guidance on intermediate and lower estimates (Appendix A, Table A.3) should be followed as well.
- the IPCC projections are very important in that they represent the consensus of the worlds' scientists of what the latest scientific evidence shows. It is updated every 5-7 years. Since it is a consensus it will always be a conservative estimate. It will also be lower than more recent high-end values (Appendix A, Table A.3). However, IPCC is the foundation for national studies (such as USACE 2009) and regional studies (such as Cayan *et al* 2008). The next IPCC set of projections in 2012-2013 will probably be higher, that may well trigger different national and regional projections.

There is currently a lack of consistency among state, county and city planners on the state-wide projections of sea-level rise to be used for policy purposes. For California, global sea level rise projections developed by the state are being confirmed by a National Academy of Science (NAS) study. The final NAS Sea Level Rise Assessment Report, due at the end of 2010, will advise how California should plan for future sea level rise. The report will include relative sea level rise projections specific to California, taking into account issues such as coastal erosion rates, tidal impacts, El Niño and La Niña events, storm surge and land subsidence rates and the range of uncertainty in selected sea level rise projections.

5. PROJECTED SHORELINE INUNDATION BY SEA-LEVEL RISE

Inundation maps for San Francisco Bay have been developed for the Bay Conservation and Development Commission (BCDC) by the U.S. Geological Survey (Knowles 2008). Data from the latest tidal epoch (1996-2007) were used to determine the highest average monthly tide and 100-year storm elevation. The sea level rise estimates of Cayan *et al* (2008) and described in Section 4, were added to the tidal datum. A numerical hydrodynamic model was then used to interpolate local sea level rise estimates at different locations around the Bay. These local sea level rise estimates were projected onto a digital elevation model of the land surface. The resulting maps show the limits of inundation for 2050 and 2100 (Figure 5.1).

The inundation maps show the areas that are vulnerable to sea level rise, however there are limitations for their use:

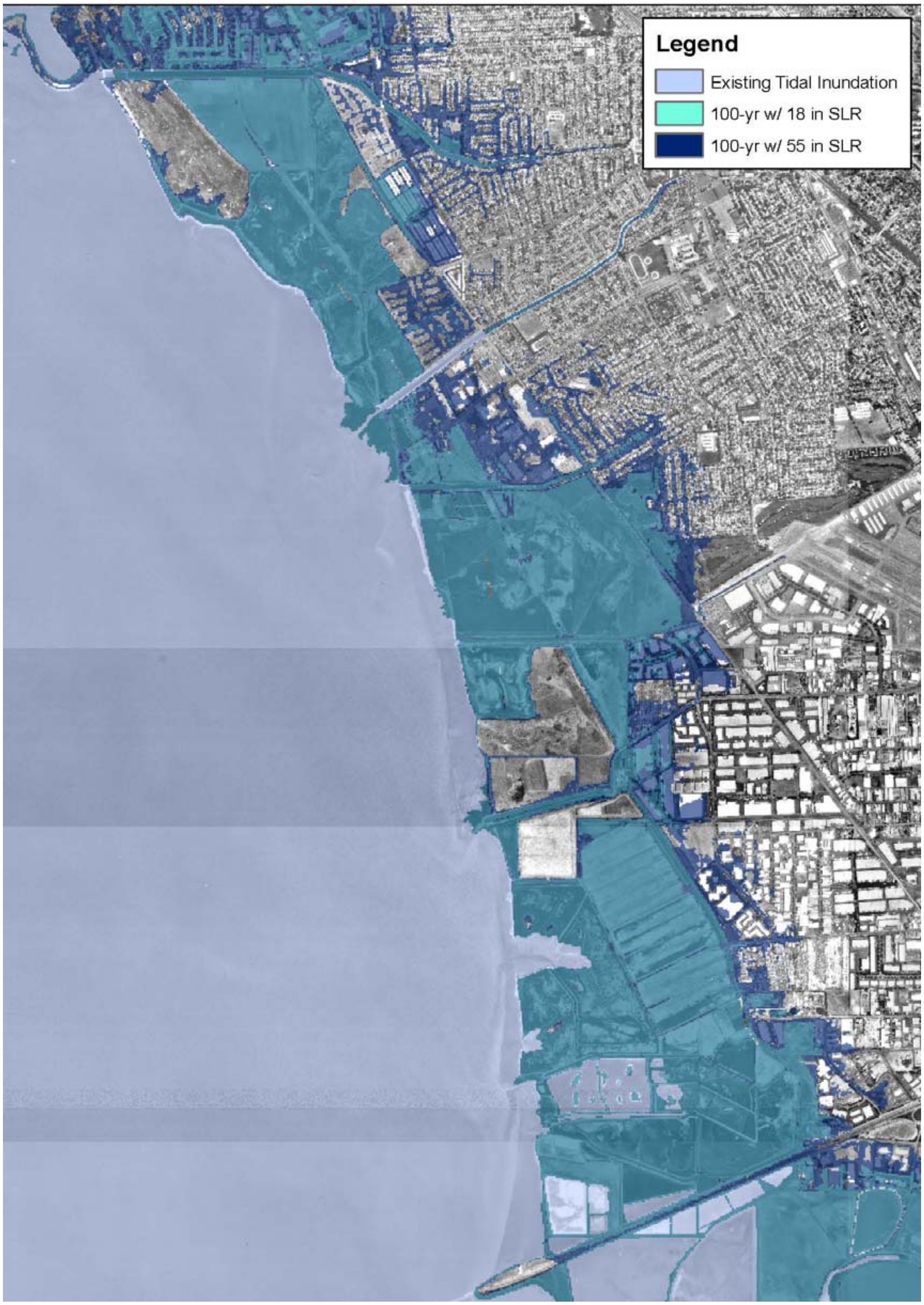
- the data was developed using tidal data and do not include wave activity that occurs during storms. Consequently, an area that floods from wave activity during winter storms is not shown as vulnerable.

- where the elevation of land is below the water level, it is shown as vulnerable, whether or not levees to protect it exist. This is because adequate information was not available on levee heights or strength.

- low-lying land located inland or depressions in upland areas may also appear vulnerable, even without a route for water to reach the areas isolated from the Bay.

- the effects of high Bay water levels on erosion, loading of structures, stream water levels, effect on drainage and ground water levels were not considered.

Given these caveats, the maps are reliable for drawing conclusions about the region's vulnerability to sea level rise and storm surge.



Source: Knowles 2008

Shows 100-year flood level in addition to sea level rise.

figure ***5.1***
HASPA Sea Level Rise Study

100-Year Water Level Inundation Map

PWA Ref# 1955.00

PWA

6. VULNERABILITY

The Hayward shoreline is already vulnerable to inundation from coastal flooding – a combination of tides, storm surges, wave run-up and storm water runoff. With higher sea levels, storm surge conditions may combine to create short-term extremely high water levels that can inflict damage to areas that were not previously at risk. Figure 5.1 shows the potential area of inundation by 2050 and 2100. Within this area there are a large number of parcels owned by public and private entities which serve a number of different functions.

In addition to the residential and commercial properties that are threatened by potential inundation, the Hayward shoreline has important infrastructure close to the Bay shore. For example, the Oro Loma Wastewater Treatment Plant on Grant Avenue is vulnerable to both coastal and fluvial flooding as well as rising groundwater. The East Bay Dischargers Authority (EBDA) pipeline transports water from the Hayward and Union City treatment facilities, to the south of Hayward, northwards to the Bay outfall through the HASPA area. Other utilities such as PGE transmission lines, railroads, high pressure gas lines and fiber optic cables also cross the area and will have to be considered in adaptation strategies. Landfills occupy the center of the HASPA area and these will have to be protected from wave erosion and water infiltration that could compromise containment. Sea level rise could potentially impact groundwater plumes associated with former landfills.

The Bay shore is also crossed by a number of storm drainage channels, such as San Leandro Creek, Bockman Channel and Sulfer Creek, all potential sources of fluvial flooding and all likely to be impacted by backwater effects due to rising sea levels. Storm drain systems, designed to flow by gravity, the tide gates on channels, and storm water pump stations will have to accommodate higher sea levels. Groundwater levels are affected by tidal fluctuations and sea level. Stormwater treatment measures which rely on infiltration may therefore be affected by higher groundwater elevations. Higher groundwater elevations may impact existing buildings and infrastructure such as cables, pipes and sewers.

The following tables summarize the vulnerability of each of the main functions within the HASPA planning area. This is an initial broad assessment based upon the available mapping of properties, projected inundation and site visits. Each function is describe in terms of location, types of hazard, proximity to hazard, mode of failure, severity of damage, risk of damage and vulnerability. Possible adaptation measures are described as well as information needs for making planning decisions.

6.1 MANAGED TIDAL SYSTEM

Function	**Managed Tidal System**
Location	There are a number of managed tidal systems in the HASPA planning area: to the south there is the Oliver Brothers property, Hayward Marsh, Alkali Flats and Oxidization Ponds; further north there is Triangle Marsh, and Frank's Dump East and West.
Types of Hazard	Tidal inundation, sea level elevation, wind wave erosion and fluvial flooding
Proximity to Hazard	All the managed tidal systems are close to the Bay and to storm water channels.
Mode of Failure	There are five main modes of failure: • Erosion and breaching of outboard levees by wind waves will increase regular tidal inundation and prevent the management of water elevations and flows. • Overtopping of levees by wind waves will temporarily increase the salinity and depth of the ponded areas. In the longer term, overtopping will erode levee crests and back slopes. • Overtopping of levees by fluvial flooding will temporarily decrease the salinity and increase the depth of the ponded areas. In the longer term, overtopping will erode levee crests and back slopes. • Gates control the water elevation within the ponded areas. These gates may not operate correctly as base levels in the Bay rise. • Ponded areas will become more difficult to drain as mean low low waters rise.
Severity of Damage	Failure of the levees will prevent the planned operation of the muted tidal systems and will cause severe damage to the system. Rising base levels will be less damaging; however, the correct operation of the system will become more difficult over time.
Risk of Damage	The risk of damage will increase overtime as both sea level rises and damage to the outboard levees accumulates.
Adaptation Measures	Maintaining the existing muted tidal systems will become difficult as sea level rises. Gates can be reset to accommodate changes in the tidal elevation. Levees can be strengthened and heightened. However marsh elevation will be difficult to increase given the low sediment supply. Alternatively, changes to allow a fully tidal system, with consequent changes to the type of habitat, may be a longer term solution.

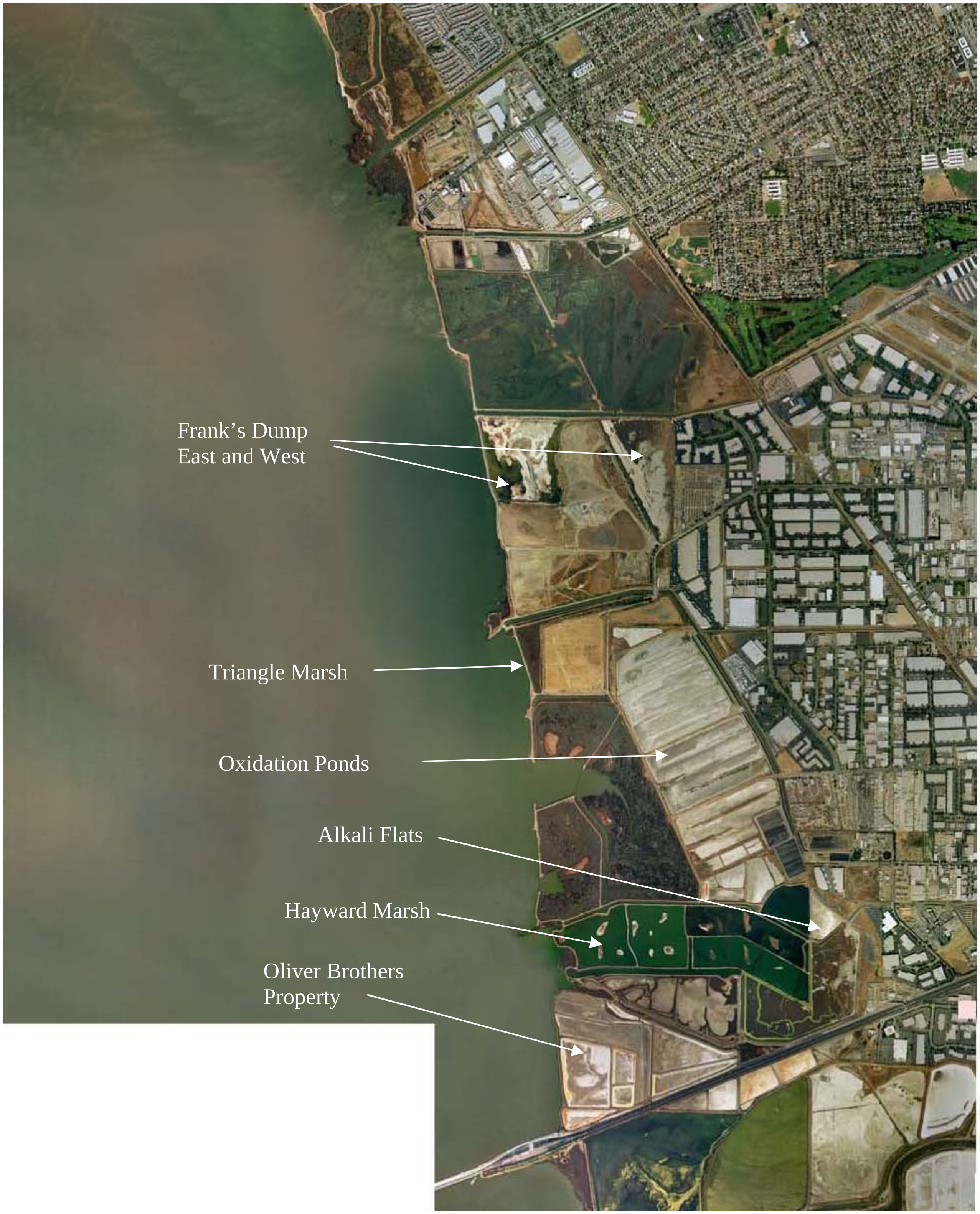


figure ***6.1***
HASPA Sea Level Rise Study

Managed Tidal Systems

PWA Ref# 1955.00

6.2 FULLY TIDAL SYSTEM

Function	Fully Tidal System
Location	There are a number of fully tidal systems in the HASPA planning area: to the south there is Cogswell Marsh; to the north there is Oro Loma Marsh. There are marshes and mudflats outboard of the Bayshore levee along the length of the planning area, including Hayward's Landing and Johnson's Landing.
Types of Hazard	Wind wave erosion and sea level elevation.
Proximity to Hazard	All the fully tidal systems are close to the Bay.
Mode of Failure	There are five main modes of failure: • Rapid sea level rise coupled with low sedimentation rates will lead to 'drowning' and conversion of salt marsh to mudflat. • Erosion of salt marsh edge by wind waves will 'squeeze' salt marsh against outboard levees. • Erosion and breaching of outboard levee by wind waves may lead to erosion of salt marsh behind. • Overtopping of levees by wind waves will erode levee crests and back slopes. • Overtopping of levees by fluvial flooding will temporarily decrease the salinity and increase the inundation of salt marshes. In the longer term, overtopping will erode levee crests and back slopes.
Severity of Damage	Erosion of the salt marsh edge, and drowning of the salt marsh will increase as sea level rises. Wave attenuation will decrease leading to increased damage of the levees.
Risk of Damage	The risk of damage will increase overtime as sea level rises, mudflat and marsh are lost and damage to the outboard levees accumulates.
Adaptation Measures	Adaptation requires either sediment to allow accretion to occur or space to allow transgression to occur. The management of sediment and the realignment of the levee line would both assist in the maintenance of the marsh system. Maintaining mudflats in their present vertical and horizontal position will become increasingly difficult.

figure ***6.2***
HASPA Sea Level Rise Study

Fully Tidal Systems

PWA Ref# 1955.00

PWA

6.3 STORM DRAINAGE SYSTEM

Function	Storm Drainage System
Location	Five channels cross the planning area – San Lorenzo Creek, Bockman Channel, Sulfer Creek (Line 'K'), Line 'A' and the Northwest Channel of Hayward Marsh. In addition, there is a culvert that runs under Highway 92, connecting with the salt ponds to the south.
Types of Hazard	Sea level elevation and flood hydrograph.
Proximity to Hazard	All the channels are, by definition, close to the Bay.
Mode of Failure	There are three main modes of failure: • Overtopping of levees by fluvial flooding will erode levee crests and back slopes. • Flap gates limit tidal waters flowing into the channels. These gates may not operate correctly as base levels in the Bay rise. • Channels will become more difficult to drain as Mean Low Low Water rise.
Severity of Damage	Failure of the levees will prevent the planned operation of the storm water drainage systems. Rising base levels will be less damaging; however, the correct operation of the system will become more difficult over time.
Risk of Damage	The risk of damage will increase overtime as both sea level rises and damage to the channel levees accumulates.
Adaptation Measures	Historically there were few channels crossing the salt marsh to the Bay. There may be opportunities to consolidate the channel system so that fewer channels are required. This would also reduce the length of levee to be maintained. As base levels rises, so pumping may be necessary, which may facilitate the consolidation of the system. There may be opportunities for storage of flood flows higher up in the system that would serve to buffer the flows and reduce the peak of the hydrograph.

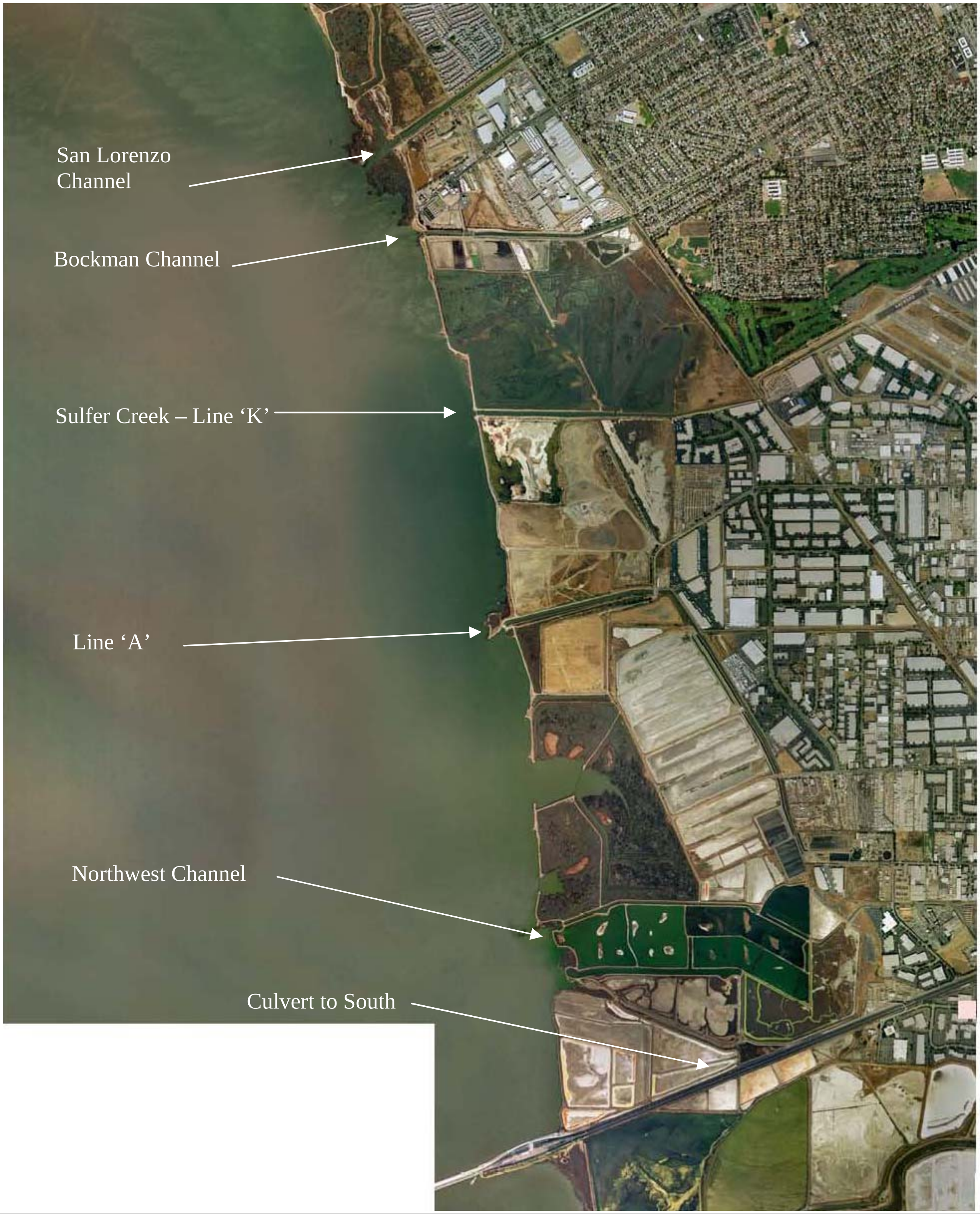


figure ***6.3***

HASPA Sea Level Rise Study

Storm Drainage Systems

PWA Ref# 1955.00

PWA

6.4 LAND FILLS

Function	**Land Fills**
Location	Land fills are located in the center of the planning area directly behind the Bayshore levee.
Types of Hazard	Tidal inundation, sea level elevation, wind wave erosion, ground water elevation.
Proximity to Hazard	Land fills are located directly behind the Bayshore levee.
Mode of Failure	There are five main modes of failure: • Erosion and breaching of outboard levees by wind waves may allow erosion of the land fill itself. • Overtopping of levees by wind waves will erode levee crests and back slopes. • Overtopping and erosion of levees may impact integrity of the the land fill drainage system. • The land fill drainage system will become more difficult to drain as Mean Low Low Water rises. • Groundwater elevations are likely to rise which may change the flow paths of any contaminated water from the land fill.
Severity of Damage	Failure of the levees may result in erosion of the land fill itself. Rising base and groundwater elevations will make the correct operation of the land fill drainage more difficult over time.
Risk of Damage	The risk of damage will increase overtime as both sea level and groundwater rises and damage to the channel levees accumulates.
Adaptation Measures	The levees that protect the land fills may have to be raised and improved with additional armor. Cutoff walls could be constructed to prevent groundwater intrusion from the Bay. Pumping may be necessary as base levels rise.

figure ***6.4***
HASPA Sea Level Rise Study

Land Fills

PWA Ref# 1955.00

PWA

6.5 WASTEWATER TREATMENT

Function	Wastewater Treatment
Location	The Oro Loma Wastewater Treatment Plant is located in the north of the planning area. It includes a solar drying ponds within the Oro Loma marsh. The City of Hayward wastewater treatment facility is located in the south of the planning area. In addition, the East Bay Dischargers Authority (EBDA) pipeline runs through the planning area connecting East Bay water treatment plant to the Bay outfall.
Types of Hazard	Tidal inundation, sea level elevation, wind wave erosion, ground water elevation.
Proximity to Hazard	Wastewater treatment plant is located close to the Bayshore levee. The solar drying ponds are located within the Ora Loma Marsh, separated by low mud berms. The EBDA pipeline runs through the Oro Loma marsh and along the landward side of the oxidation ponds.
Mode of Failure	There are six main modes of failure: • Erosion of outboard levees by wind waves may threaten the integrity of the water treatment plant. • Overtopping of levees by wind waves may flood the water treatment plant. • Rising groundwater may damage utilities, pipes and structures associated with the plant. • Erosion and overtopping of the mud berms surrounding the solar drying ponds. • Channel downcutting may increase risk of exposure of the pipeline. • Access to the pipeline for maintenance may be constrained by rising tidal elevations.
Severity of Damage	Failure of the levees may result in disruption of water treatment plant operations. Damage to the pipeline may be limited but access to repair a damaged pipeline will be more difficult.
Risk of Damage	The risk of damage will increase overtime as both sea level and groundwater rises, levee damage accumulates, and channels increase in depth.
Adaptation Measures	The East Bay wastewater treatment system connects a number of treatment plants with a single pipeline. This makes the system vulnerable to a single break. Passing the treated water through local treatment marshes, close to the plant, rather than transporting the water northward may reduce this vulnerability and create brackish marshes closer to the Bay which are more resilient to sea level rise.

figure ***6.5***
HASPA Sea Level Rise Study

Wastewater Treatment

PWA Ref# 1955.00

PWA

6.6 UTILITY CORRIDORS

Function	Utility Corridors
Location	In addition to the EBDA pipline, there are a number of other utilities that cross or border the planning area. Running close to the EBDA pipeline are the PGE transmission lines. Almost parallel, but at the landward edge of the planning area is the railroad which also acts as a corridor for a high-pressure gas line and fiber-optic communication cables.
Types of Hazard	Tidal inundation, sea level elevation, wind wave erosion.
Proximity to Hazard	The EBDA pipeline and PGE transmission lines run through the Oro Loma marsh, along a low berm, and along the landward side of the oxidation ponds. The railroad lies at the landward side of the Oro Loma Marsh on a low berm.
Mode of Failure	There are two main modes of failure: • Increased periods of inundation and rising groundwater may damage utilities, and associated pipes and structures. • Access to the PGE transmission lines for maintenance may be constrained by rising tidal elevations.
Severity of Damage	Failure of the levees may result in damage to the utilities. Access to repair a damaged utility line will be more difficult.
Risk of Damage	The risk of damage will increase overtime as both sea level and groundwater rises, levee damage accumulates.
Adaptation Measures	Ideally, the utilities would be rerouted to the landward edge of the planning area, outside the hazard zone. The railroad berm may have to be raised and armored depending upon how well the Oro Loma marsh keeps up with rising sea levels.

figure ***6.6***
HASPA Sea Level Rise Study

Utility Corridors

PWA Ref# 1955.00

PWA

6.7 BAY TRAIL

Function	Bay Trail
Location	The Bay Trail follows the Bayshore levee for most of the length of the planning area. At Cogswell Marsh it turns inland and over a wooden bridge before returning to the Bayshore. The levee trail also acts as emergency route for West Winton Avenue
Types of Hazard	Tidal inundation, sea level elevation, wind wave erosion and fluvial flooding
Proximity to Hazard	The Bay Trail follows the Bay shore.
Mode of Failure	There are five main modes of failure: • Erosion and breaching of outboard levees by wind waves will damage the trail. • Overtopping of levees by wind waves will damage the trail. • Bridge structures that cross breaches at the Oro Loma and Cogswell marshes may be subject to wind wave and tidal erosion.
Severity of Damage	Breaching of the levees will cut the trail which may require rerouting. Damage caused by overtopping or erosion may not cut the trail but damage it sufficiently to close it to the public.
Risk of Damage	The risk of damage will increase overtime as both sea level rises and damage to the outboard levees accumulates.
Adaptation Measures	Maintaining the existing levee system will become difficult as sea level rises. Levees can be strengthened and heightened. Bridge structures can be armored. Rerouting of the trail would be part of a plan to realign the levees.

figure ***6.7***
HASPA Sea Level Rise Study

Bay Trail

PWA Ref# 1955.00

PWA

7. ADAPTATION MEASURES

The dynamic response of the shoreline to sea level rise means that, in the future, planning will have to accommodate a moving frame of reference. Mudflats, marshes and beaches will all tend to transgress landward as sea level rises; flood hazard zones will enlarge as water surface elevations and wave run-up increase; erosion hazard zones will enlarge as wave energy on the shoreline increases. In the past, buffers of fixed width were generally adequate to accommodate likely changes in shoreline position. However, with projections of sustained sea level rise over at least the next two centuries it is likely that long stretches of the shoreline will tend to transgress landward. Planning for the shoreline therefore needs to take this dynamism into account.

While all the projections show sea level will rise, the projections of the rate at which it will rise vary widely. The consequence of this is that there is uncertainty in the extent of hazard zones at a given date in the future. Since the uncertainty in the projections is unlikely to decrease in the near future, the advice that is being proffered by State and Federal agencies is to ‘plan for uncertainty’.

7.1 HOLD THE LINE

The ‘Hold the Line’ option protects land and infrastructure from erosion, inundation and flooding by the use of structures such as levees and sea walls. The Hayward shoreline is already defended by levees, with breaks at Oro Loma and Cogswell marshes (Figure 7.1).

To hold the line in the future, the crest elevation of the levees will have to be raised to keep pace with rising sea levels and increasing wave run-up elevations. In many cases, levees constructed on poorly compacted Bay Mud will be unable to support the additional weight of material required for raising the crest (PWA 2005). As sea level rises and water depths at the toe of the structure increase so wave heights on the structure will increase. To maintain the stability of the levee with higher wave forces will require the use of larger armor rock. The larger waves, combined with reflection of wave energy from the armored levee will result in erosion and lowering of the mudflat in front of the levee (Figure 7.2). To counter the lowering of the mudflat, more rock will have to be placed at the toe of the levee slope extending the structure further into the Bay (PWA 2005, Heberger *et al*, 2008).

Holding the line therefore results in an increasingly steep slope (up to 1:3) on the shoreline – the crest increases in height, the toe lowers and the levee stays in the same location. The increased wave energy is dissipated over a shorter distance, increasing the erosion of the mudflats and increasing the forces on the levee. Any salt marsh or mudflat in front of the levee will be squeezed against the steep slope.

Holding the line is attractive because the engineering standards for their design and implementation are well developed and widely used (Parris and Lacko, 2009). However this option is expected to have high construction and ecologic costs. The levees would have to be continually maintained and improved by both raising and strengthening the structures. These costs are in addition to the loss of the mudflat and salt marsh, which have both ecological and flood protection functions, as they are “squeezed” against the levees.

The required increase in levee crest elevations to maintain existing protection is on the order of sea level rise, plus subsidence resulting from added fill. The stable rock size to prevent erosion will increase with the depth of water at the toe of the structure. The rate of cost increase is expected to be greater than the rate of sea level rise, which is projected to be exponential! The cost of renovating such structures for existing conditions could roughly be estimated in the range of $100 to $1000 per linear foot, while the cost to withstand future conditions is likely an order of magnitude (ten times) higher (e.g. $10,000 per linear foot). Unfortunately, improving the levees will not mitigate effects to groundwater and drainage issues. Ecologic cost is difficult to quantify in dollars, but can be conceptualized by assuming the intertidal areas on the Bay side of the levees will be drowned. Groundwater changes can affect the ecology landward of the levees as well.

Levees can increase the risk to public safety not just by increasing erosion and preventing dynamic coastal process but also by encouraging the development in undeveloped hazard zones (Griggs *et al* 2005). In other areas of the country, providing structural shoreline protection has increased the vulnerability of the community by encouraging development directly behind the structure and generating a false sense of security (Heberger *et al*, 2008).

7.2 REALIGNMENT

An alternative to “Hold the Line” is to move the levee to a new location further inland. This allows marshes and mudflats to transgress landward naturally. This also requires relocating people and existing infrastructure out of the hazard zone while restricting new construction in vulnerable areas. Realignment takes advantage of the natural protection provided by marshes and mudflats to reduce the risk of flooding and erosion allowing smaller levees to be built (Figure 7.3).

Both mudflats and salt marshes decrease or attenuate waves. The amount of wave attenuation is governed by the water depth, bed roughness, marsh edge characteristics and vegetation characteristics. Salt marshes in particular are very efficient; achieving up to 70-80% reductions in wave height over 300 feet, compared to 20-30% over mudflats of similar widths (Cooper, 2001). Möller and Spencer (2002) measured 44% reductions in observed wave heights over narrow strips of salt marsh 30 feet wide. Having a salt marsh and mudflat in front of a levee will reduce the incident wave height at the toe of the structure reducing structural damage and the amount of wave overtopping. Levees can therefore be built lower and with less armoring, reducing the total cost of the levee by up to 30 percent in some cases (Turner and Dagley 1993).

On the Hayward shoreline, the levee line could be realigned to the landward edge of Oro Loma, Cogswell and Hayward marshes (see Figure 7.4) allowing these marshes to transgress landward naturally. The existing bayshore levee would be maintained in front of the land fills and wastewater treatment plants. Realignment would decrease the slope of the shoreline; dissipating wave energy over distances of several hundred feet or more and allowing the construction of much lower levees.

However, the fact that the bayland slopes behind the existing levees are so flat (1:1000) and tidal marsh accretion rates may not be sufficient to keep up with rising sea levels means that the rate of landward migration of the shoreline will be very rapid. For the high-end 2050 projection of 16 inch sea level rise, the shoreline may migrate landward up to 500 yards; in the following 50 years the shoreline may migrate up to a further 1,000 yards to make a total of about 1,500 yards by the end of the century.

In concert with the moving shoreline, the hazard zone associated with flooding will also move inland. Realignment over relatively flat slopes uses large amounts of land but may provide flood protection benefits for only a relatively short period, particularly if vertical accretion rates and plant establishment rates lag sea level rise.

7.3 GRADUAL STEEPENING

Even without the threat of sea level rise, the area of potential inundation on the Hayward shoreline is large. Looking ahead, the East Bay shore will become increasingly vulnerable to inundation by 2050. Ideally, any adaptation strategy to such changing conditions should:

- Dissipate wave energy over a long shallow slope;
- Provide a mechanism to increase the surface elevation at about the rate of sea level rise;
- Allow for adaptation to varying rates of rising sea levels;
- Slow down both habitat and hazard zone migration.

The Hayward shoreline has some space to realign, but also has two other opportunities to exploit. Firstly, large amounts of treated fresh water pass through the Hayward shoreline in the EBDA pipeline, from treatment plants in the south and east to be discharged at the mid-bay outfall. This pipeline running north-south across the baylands severely constrains the realignment of the levees and, since it is located in poorly consolidated Bay Mud, is vulnerable to seismic damage. Redirecting the output from the wastewater treatment plants to local treatment marshes and disconnecting the EBDA pipeline would remove a major constraint on the Hayward shoreline and improve the resiliency of the EBDA system. The input of fresh water at the inland edge of the tidal marshes would create more productive brackish marshes, with higher accretion rates, thereby better able to keep up with rising sea levels compared to saline tidal marshes.

The second opportunity is the local availability of sediment. Sediment is at present being trapped at San Leandro Marina and along the flood channels leading to the Bay. In the past this sediment would have entered the Bay and accreted on mudflats and marshes; this connection has now been broken. Levees, flood control channels, and urban development have isolated the bayland marshes from natural pulses of watershed sediments along the tidal marsh edges. Natural sediment depositional landforms such as crevasse splays (delta-like overbank sediment deposits on marshes or floodplains) and alluvial fans (washes) no longer form in diked baylands to provide natural widening and sediment nourishment in the upper tidal elevation range of the bayland edges. The sediment presently trapped could be recovered and hydraulically placed on the bayland edges. Artificial high marsh berms on the outer marsh edges could be actively maintained or managed to keep pace with sea level rise and erosion by periodically raising their crests with thin deposits of sediment (berm capping), in phases or staggered patterns to ensure continuous mature vegetative cover.

The Gradual Steepening option combines these opportunities to create a more sustainable shoreline that can accrete vertically and does not transgress landward so rapidly. It combines the virtues of the “Hold the Line” and “Realignment” options, but does not alleviate impacts to land uses and costs. Figures 7.5 is a cross-section of the Haywards shoreline showing the main elements:

- The existing bayshore levee line would be realigned further inland behind the marshes. An *impermeable berm* would be constructed, perhaps with a cut-off wall to limit saline groundwater intrusion. The crest elevation of the impermeable berm would be set by still water levels, and would be relatively low as it would not be subject to wave overtopping. If space was limited, then an *impermeable wall* could be used in place of the berm.

- A *freshwater swale* would run parallel to, and bayward of, the impermeable berm. This swale would act as a manifold, distributing freshwater from the wastewater treatment plants along the length of the shoreline.

- Forming the bayward bank of the freshwater swale would be a *seepage berm*. This would be a berm slightly lower than the impermeable berm with a long, shallow (1:100) bayward slope down to tidal marsh elevation. This berm would be constructed from a poorly sorted coarse and fine material dredged from the flood channels. Water from the swale would then seep through the berm as shallow groundwater discharge to the back of tidal marshes, above tidal elevation, where brackish marsh would form (Figure 7.6).

Figure 7.7 shows the general arrangement of the marshes, swales and berms in plan view. The saline tidal marshes would accrete and transgress naturally up the 1:100 slope while the brackish marsh will accrete more rapidly due to the greater organic production. Over time, as sea level rises, the slope should gradually steepen rather than transgress landward. This will slow down the land ward transgression and loss habitat by “squeeze” yet maintain the wave attenuation functions of the marshes. Figure 7.10 shows a possible layout of freshwater swales (in blue) and seepage berms (in green) as applied to the Hayward shoreline.

Sediment from the flood channels could be used not just to construct the original seepage berm, but also to periodically raise it. A pipe could be run on top of the berm through which would be pumped a sediment-water mixture. This mixture would be released on a regular basis in an alternating pattern of splays in small amounts so as not to bury the existing vegetation (Figures 7.8 and 7.9)

The opening up of diked baylands to full tidal inundation could provide flood storage lower in the storm water system that would reduce creek elevations during floods and reduce the need to raise levees in the future. Increased tidal inundation in the creeks will also help maintain conveyance in the lower sections of the channels. Going one step further, storm water could be rerouted to discharge through the freshwater swale rather than the existing flood channels. Flood channels would continue to collect storm water from the watershed, but they would no longer need to be routed to the Bay. Storm water would then fill the freshwater swale and spillover on to the seepage berm as diffuse sheet flow rather than as a channel (the seepage berm has a lower crest than the impermeable berm on the landward side). This would reduce the cost of maintaining the flood channels and they would not have to be modified to accommodate rising sea levels.

The "Gradual Steepening" option mimics many of the historic bay processes. Historically, most of the South Bay drained through small creeks that terminated in alluvial fans or shifting, unstable deltas grading down to tidal salt marsh. Few creeks connected to tidal sloughs; they did not discharge directly to the bay, but through riparian floodplain wetland complexes. The landward edges of many tidal marshes, where surface groundwater seepage in alluvial fans was high, supported fresh to brackish marshes with vegetation like tules. Backmarsh ponds, similar in concept to the freshwater swale, can be seen in topographic surveys undertaken in the 1850s by the United States Coast Survey in the Newark, Redwood City and Bair Island areas.

Other benefits to including a brackish marsh in the shoreline include greater nitrogen and carbon sequestration than a saline tidal marsh. The use of a freshwater swale also diffuses the flows of water and sediment; avoiding point-source concentrations of wastewater outflows and contaminants.

7.4 DIFFUSE ARMORING

Both the "Realignment" and "Gradual Steepening" options require space. This space is not available where the upland parts of the Hayward Shoreline, in particular the land fills and Oro Loma waste water treatment plant, lie close to the shoreline. In these locations, where retreat is not feasible (shown in black in Figure 7.10), a modified "Hold the Line" option may be appropriate. Even with the "Hold the Line" option, actions outboard of the levees may be desired to mitigate loss of shallow areas and to provide more cost effective wave dissipation.

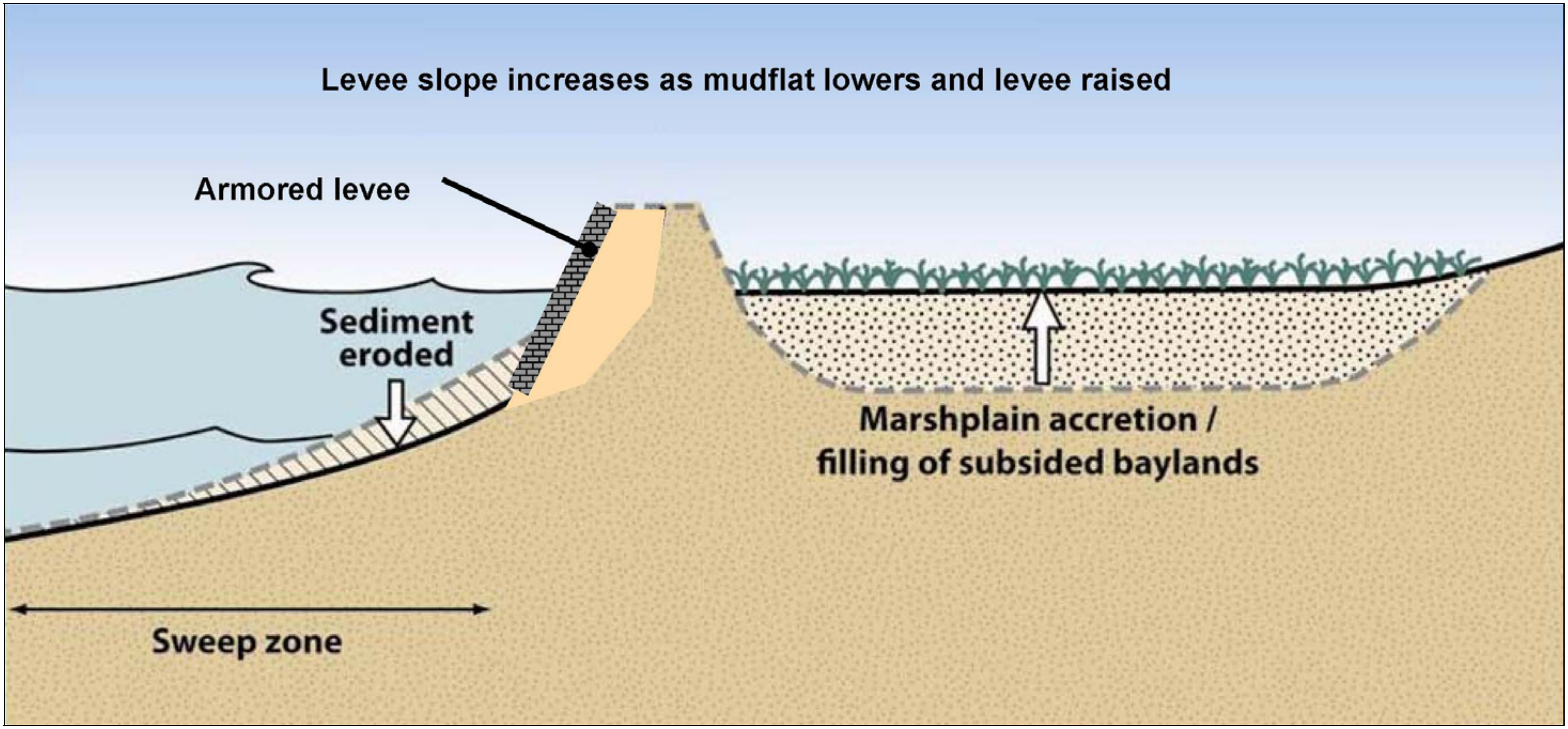
Conventional wave erosion abatement techniques are based on armoring (hardened surfaces, such as rock armor). Wave erosion buffers that emulate natural backshore wave-buffering processes, such as estuarine beaches (sand, shell, or gravel sediments at the toe of eroding marsh scarps) and coarse offshore berms (see Figure 7.11), are potential alternatives. These would be able to accommodate rising sea levels either by the addition of sediments in thin layers or by rolling landward, driven by wave forces. They may also enhance rather than conflict with ecological and aesthetic objectives for tidal wetlands, and provide additional recreational benefits in suitable locations.

figure ***7.1***
HASPA Sea Level Rise Study

Example "Hold the Line" Concept at Existing Bay Levees

PWA Ref# 1955.00

PWA

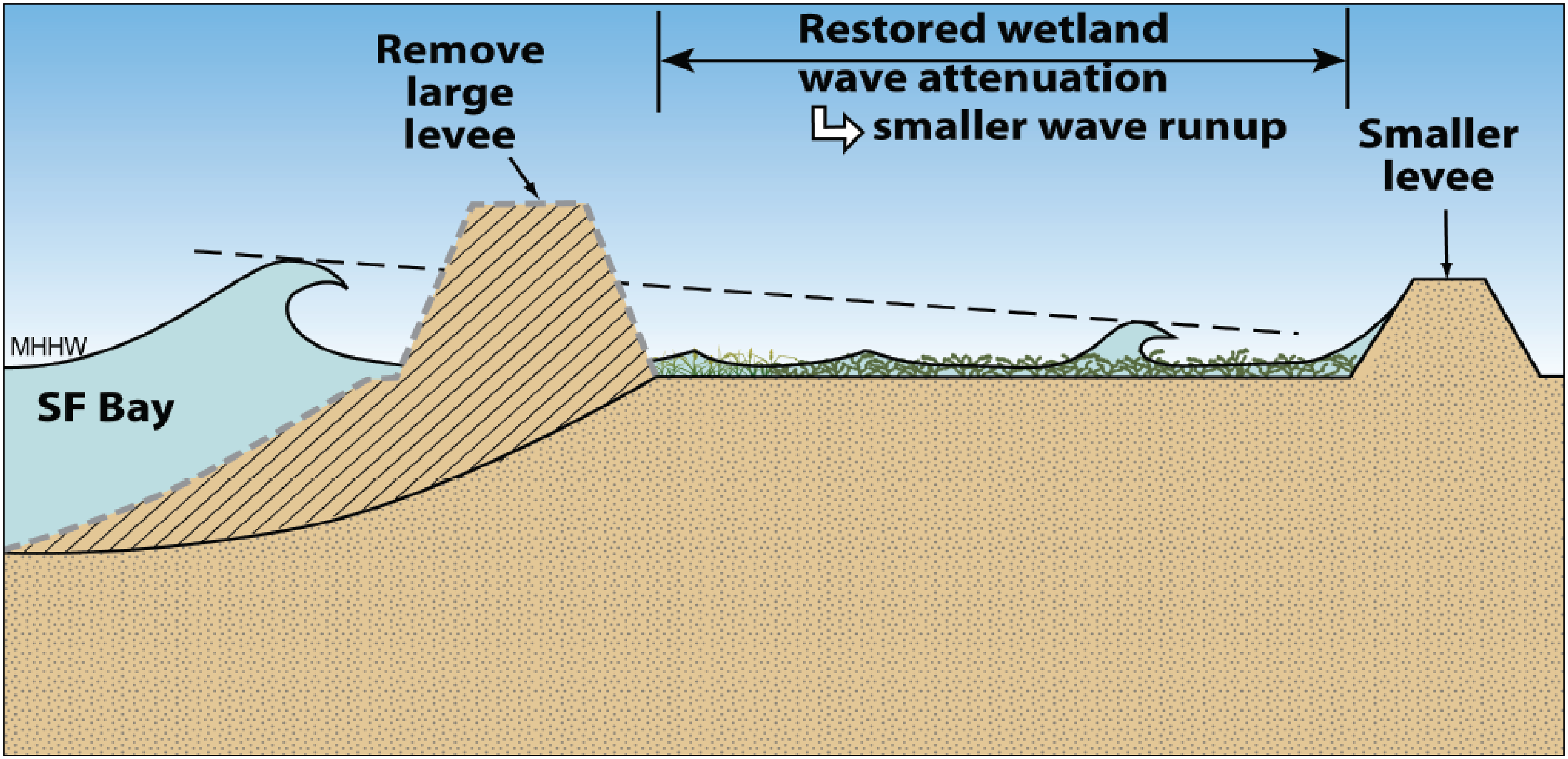


Source:

figure ***7.2***
HASPA Sea Level Rise Study

Hold the Line

PWA Ref# 1955.00



Source:

figure **7.3**
HASPA Sea Level Rise Study

Levee Realignment

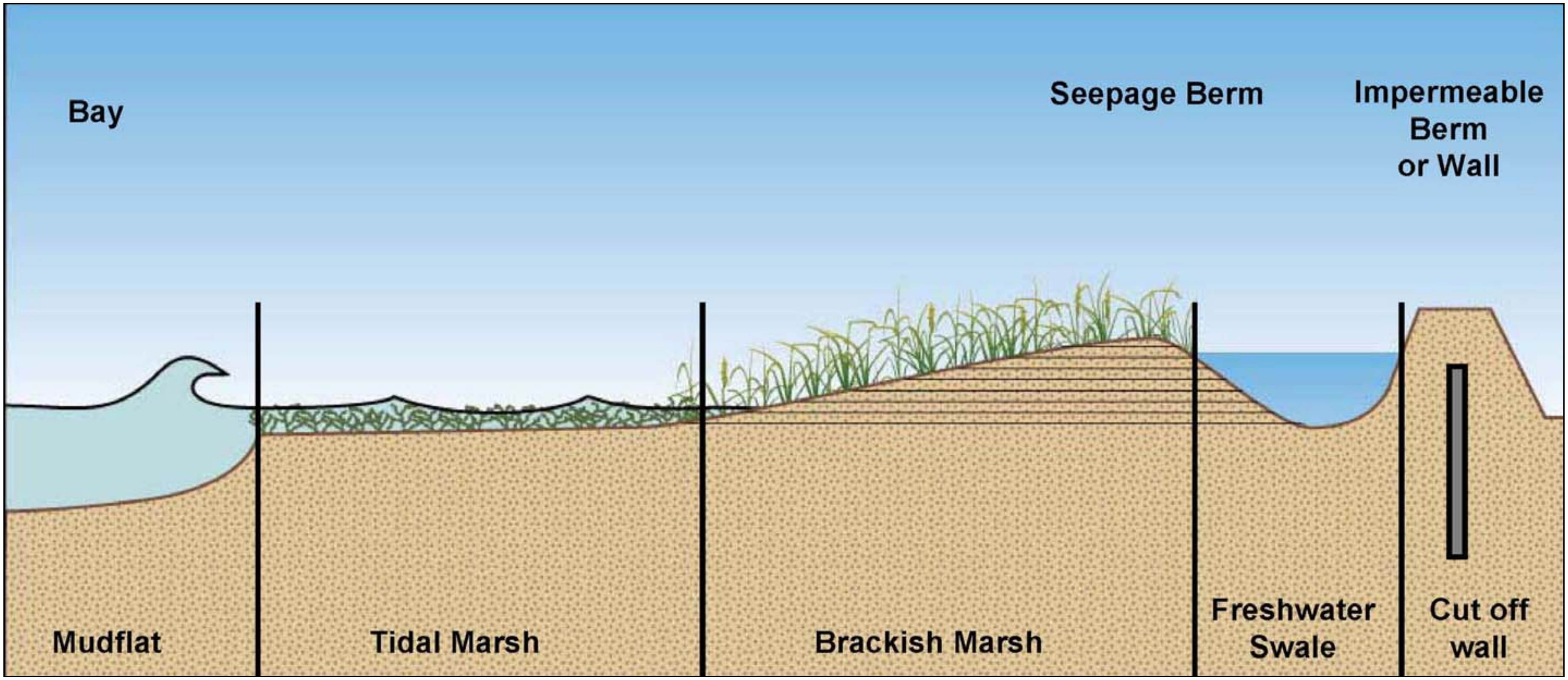
PWA Ref# 1955.00

figure ***7.4***
HASPA Sea Level Rise Study

Location of Potential Realignment

PWA Ref# 1955.00

PWA



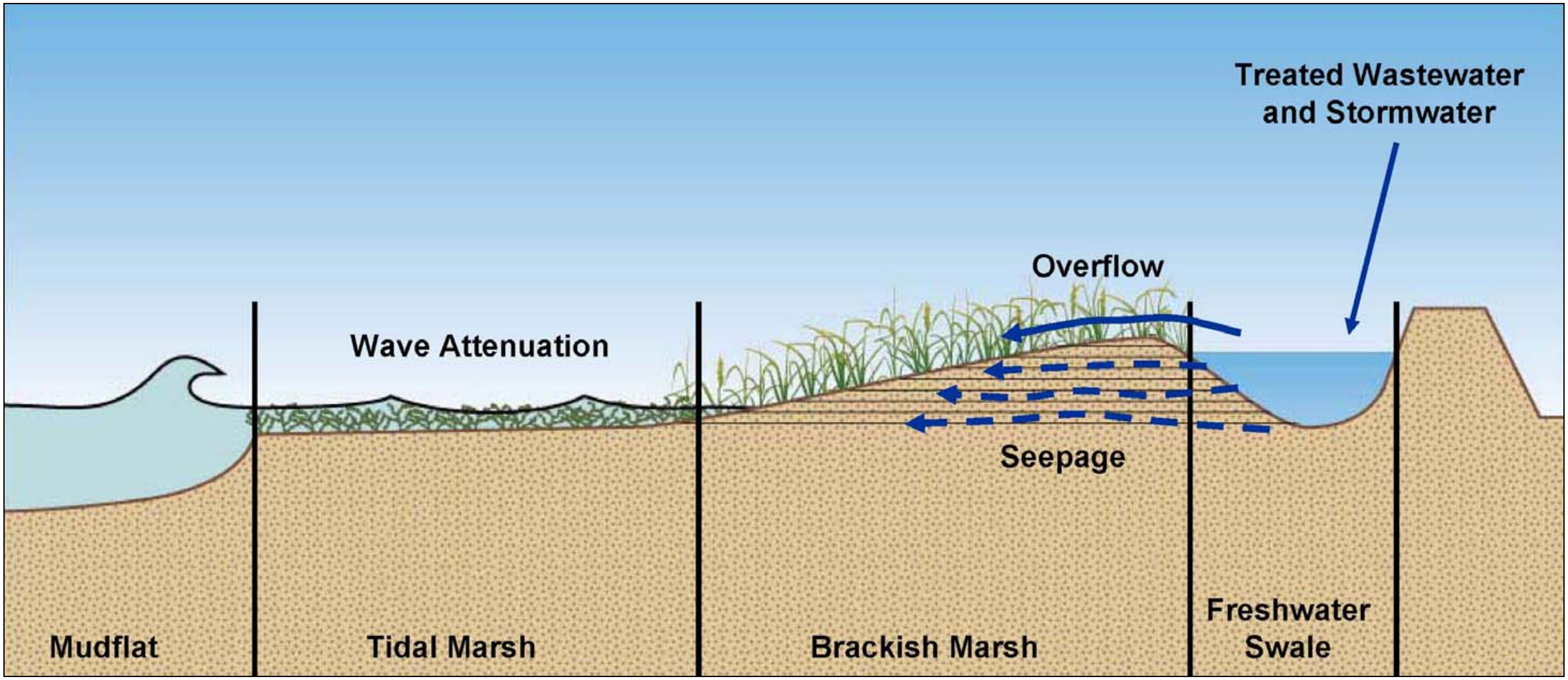
Source:

figure ***7.5***
HASPA Sea Level Rise Study

Gradual Steepening Concept

PWA Ref# 1955.00

PWA



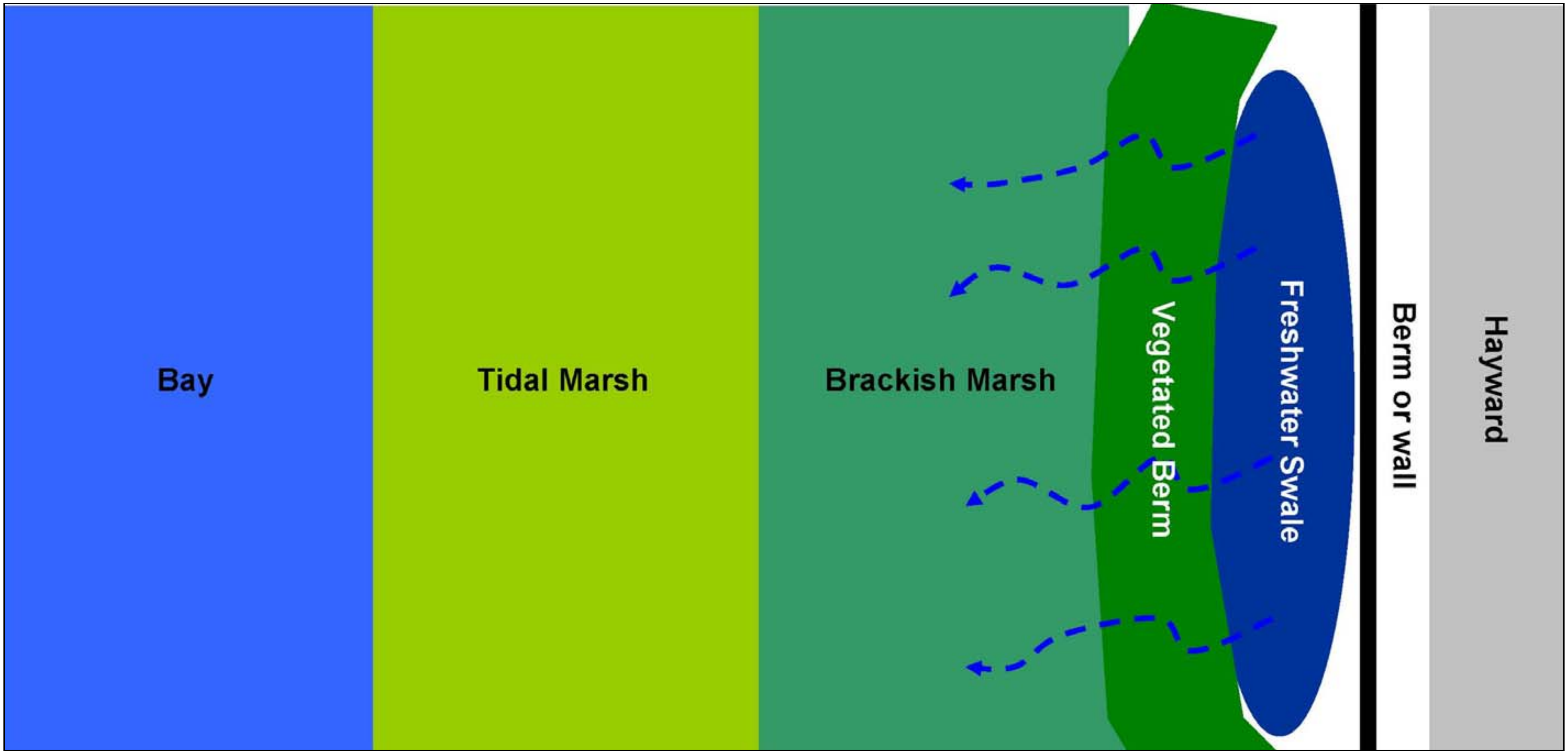
Source:

figure ***7.6***
HASPA Sea Level Rise Study

Seepage Through Vegetated Berm

PWA Ref# 1955.00

PWA



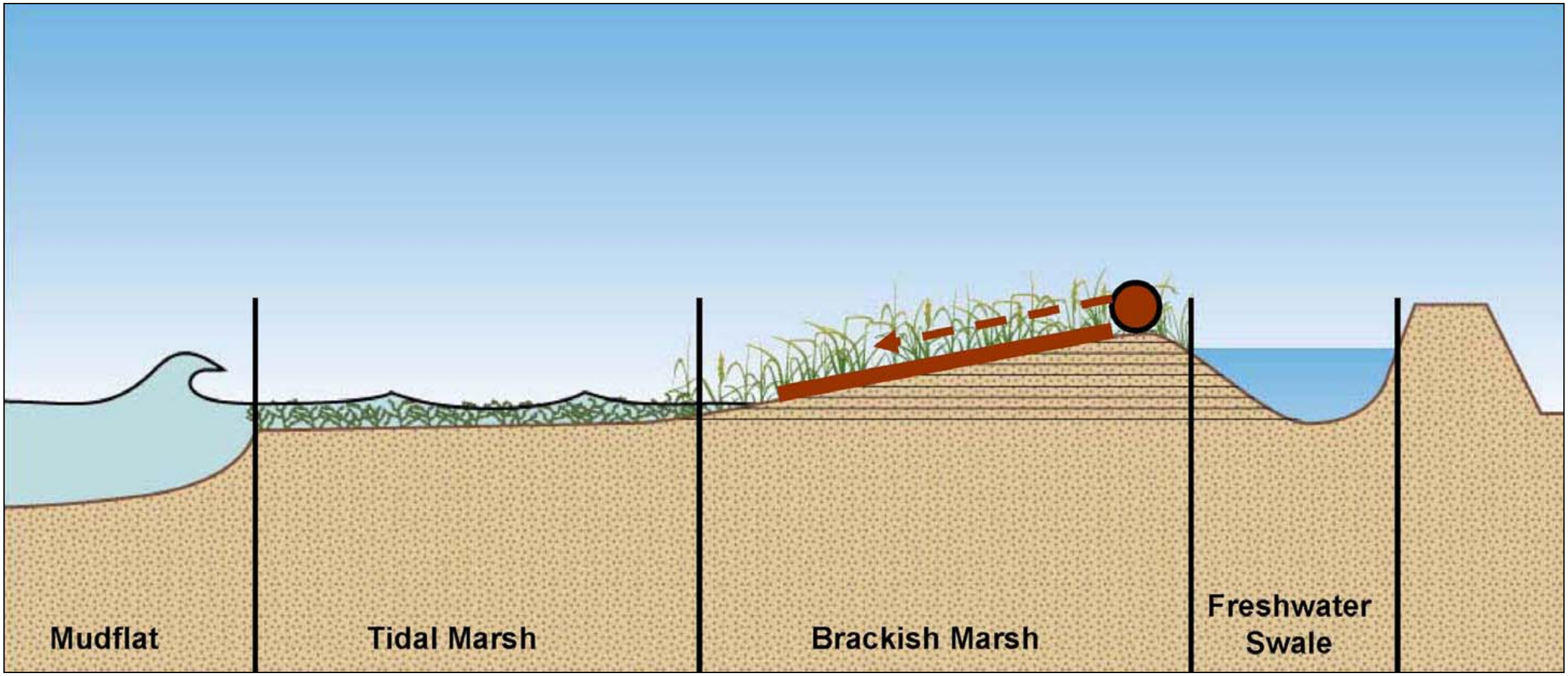
Source:

figure ***7.7***
HASPA Sea Level Rise Study

Plan View of Seepage Through Vegetated Berm

PWA Ref# 1955.00

PWA



Source:

figure ***7.8***
HASPA Sea Level Rise Study

Sediment Recharge Over Vegetated Berm

PWA Ref# 1955.00

PWA

Source:

figure ***7.9***
HASPA Sea Level Rise Study

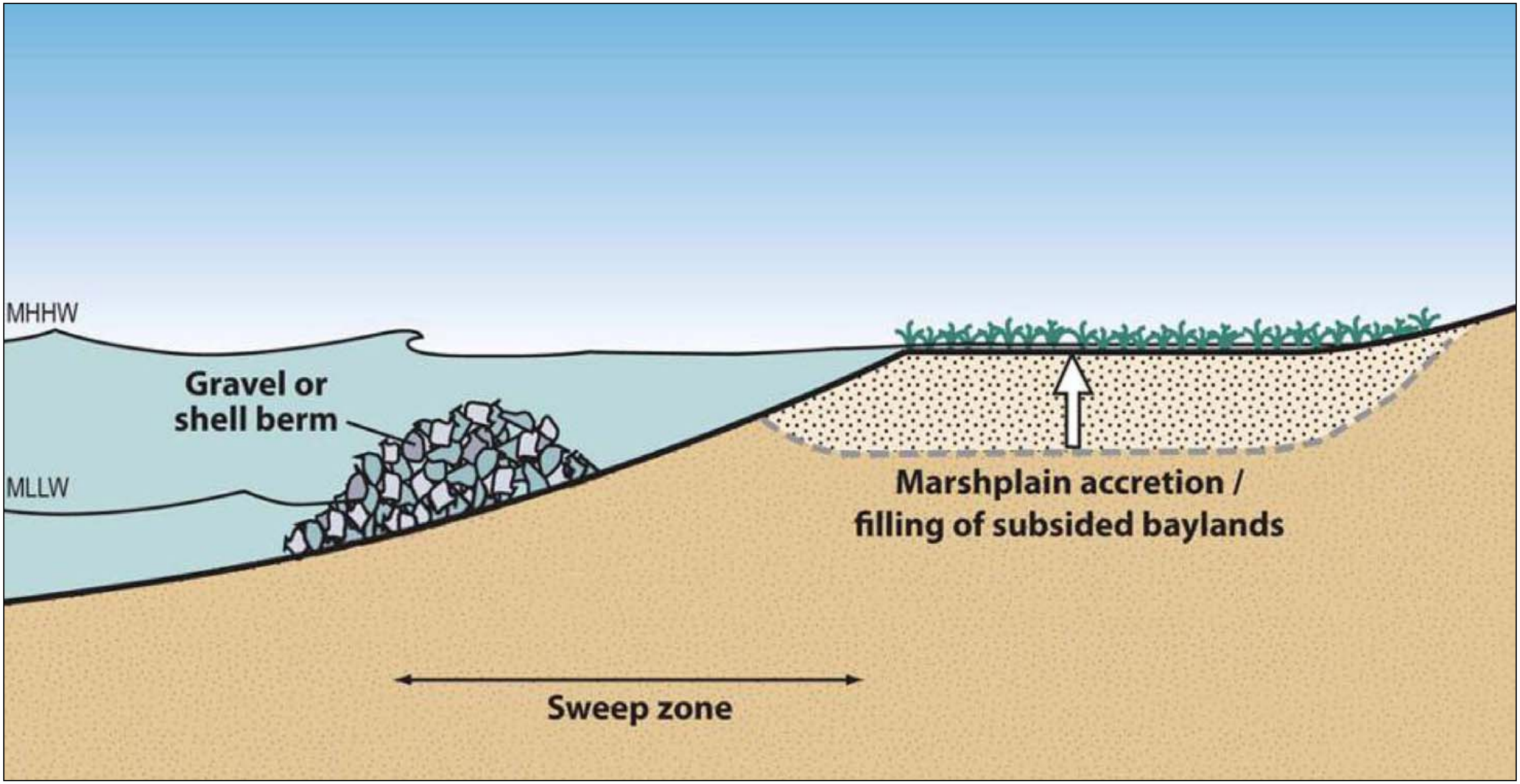
Plan View of Sediment Recharge Over Berm

PWA Ref# 1955.00

figure ***7.10***
HASPA Sea Level Rise Study

Location of Potential Gradual Steepening and Diffused Armoring

PWA Ref# 1955.00



Source:

figure ***7.11***
HASPA Sea Level Rise Study

Diffused Armoring

PWA Ref# 1955.00

PWA

8. NEXT STEPS

8.1 SHORE REALIGNMENT MASTER PLAN

Though there is uncertainty in predicting the rate of sea level rise, large increases in sea level are expected over the next century and the question we are hearing is not "how much" but "when." Therefore, planning and management needs to be an ongoing, long-term process, allowing immediate action when necessary and adaptive to changing conditions. We anticipate that adaptation will be an ongoing process of planning, prioritization and specific project implementation. It is generally accepted that the next few decades provide a period of opportunity to develop adaptation plans and actions, before sea level rise accelerates greatly.

Building on the reconnaissance level work already undertaken by HASPA in the present study, a more detailed assessment of coastal hazards to specific infrastructure should be undertaken. This would lead to the development of a Shore Realignment Master Plan, and design and implementation of specific adaptation measures.

This can be achieved economically by application of conceptual models of shore response to sea level rise. These shore response models are applied for one or more climate change scenarios and planning horizons. Future vulnerability of assets and infrastructure can then be assessed, and a strategy for adapting to climate change can be developed, with due consideration to priorities and time frames. The vulnerability assessment can also provide a framework for agency and community education and participation, feed into other planning documents, and identify funding needs.

The approach is to gauge vulnerability based on the proximity of future erosion and flooding hazard zones to facilities. Risk can be further characterized by identifying potential damage modes, corresponding proximity criteria (proximity between the shoreline and the element at risk, such as a trail or pipe), and severity of damage. The level of risk can be categorized in terms of likelihood of damage within the forecasting period and the severity of the damages. This allows planners to prioritize their response to sea level rise.

The results of the vulnerability assessment would be used as a basis for a Shore Realignment Master Plan with adaptation strategies for mitigating sea-level rise effects, elements of which could include:

- prioritized list of adaptation actions (e.g. projects), with a schedule, capital expenditure plan, and planning / regulatory framework.
- initiate field data and process analysis to form a basis of adaptive management.
- develop a regional sediment management plan.

- the interim enhancement of existing shore protection measures, including the placement of fill to increase levee height. Assess the need for the existing shore protection structures to be upgraded in the light of the other potential options.

- modifications to storm water system routing and storage. Potential storage areas for peak flows may be identified.

- modifications to wastewater treatment facilities. Opportunities for integrating wastewater treatments and wetlands will be considered if these allow a more sustainable shoreline to be developed.

- modifications to wetlands to enhance their ability to buffer the impacts from the rise in sea level. For instance, the use of muddy sediment, from Bay dredging or stream maintenance programs, to modify the intertidal morphology and make additional sediment available to create brackish marshes, enabling the whole system to keep pace with sea-level rise.

- the realignment of levees to gain more marsh and buffer areas. Assess the feasibility and potential effectiveness of setting back the line of the outboard levee to a new line inland of the original. This would modify tidal flows and provide additional buffer space for the marsh and mudflat system to migrate inland in response to sea-level rise.

8.2 COST ESTIMATES

This section describes relative cost estimates for the three adaptation strategies described in Section 7: Hold the Line, Realignment and Gradual Steepening. The major elements of each adaptation strategy are described below which together form the relative cost estimate presented in Table 8.1. For planning purposes we have provided order of magnitude estimates to allow cost comparison of alternatives. These cost estimates are intended to provide an approximation of total project costs appropriate for the conceptual level of design, and are intended to compare alternatives rather than establish a firm project budget. Given the approximate level of this estimate arrange of costs is presented, pending more detailed estimates based on further engineering. Land acquisition and easement costs are not included.

	Estimated Cost Range $M
Hold the Line	
Outboard levee upgrade	$103M - $137M
Inboard levee upgrade	$158M - $210M
Landfill armoring	$38M - $51M
Upgrade water management	$5M - $7M
Total	**$304M - $405M**
Realignment	
No outboard levee upgrade	$0
Inboard levee upgrade	$178M - $238M
No water management required	$0
Landfill armoring	$38M - $51M
Total	**$216M - $289M**
Gradual steepening	
New inboard levee	$132M - $177M
Freshwater swale / vegetated berm	$66M - $89M
No water management required	$0
Landfill armoring	$38M - $51M
Diffuse armoring of landfill	$7M - $10M
Total	**$243M - $327M**

Table 8.1. Estimated relative costs of adaptation strategies. Estimated relative costs are presented in 2010 dollars, and would need to be adjusted to account for price escalation for implementation in future years. This opinion of probable costs is based on: PWA's prior experience and prices from similar projects.

Hold the Line (see Figure 7.1) - the major cost elements are upgrading the existing outboard and inboard levee by increasing the crest height and increasing the armor on the outboard levees. These upgrades could be undertaken incrementally in line with the actual rate of sea level rise. Additional armor would have to be placed in front of the landfill and the Oro Loma water treatment facility. In addition, the managed tidal systems at the Oliver Brothers property and HARD marsh would require new water control structures. Pumping may be required in the future as low waters in the Bay rise.

Realignment (see Figure 7.4) – for the realignment option the outboard levee would be removed or allowed to degrade naturally. Additional armoring to protect the landfills would have to be placed. The inboard levee would have to be upgraded and lengthened to protect the former managed tidal areas of the Oliver Brothers property and HARD marsh, however new control structures would not be required.

Gradual Steepening (see Figure 7.10) – the inboard levee is realigned and shortened compared to the Realignment option. In addition, a freshwater swale and vegetated berm is constructed bayward of the inboard levee. Additional armoring to protect the landfills would have to be placed. In this alternative diffuse armoring is placed in front of the landfill armoring to attenuate wave impacts on the structures and enhance the ecological value of the shore.

Some common elements would occur regardless of the strategy chosen have not been included in the costs. For instance, pumping will likely be required to “lift” the storm water runoff over the barriers in order to discharge to the Bay and prevent flooding during high tides. Additional facilities such as subdrains, storage areas and increased pump capacity may be required to mitigate increased ground water levels.

In addition, some assumptions on timing have been made. Firstly, that these are costs to provide protection for a 55 inch rise in sea level which is expected to occur by 2100; additional costs may be incurred for sea level rise greater than 55 inches. Secondly, complementary projects, such as the reconfiguration of the EBDA pipeline, are assumed to have occurred by 2050 and are not included in these costs as they are driven by factors other than sea level rise (namely seismic vulnerability).

It is important to note that these are costs for large-scale construction projects and hence would require detailed analysis and engineering design that would likely lead to additional refinements. Land costs are not included at this stage, it is anticipated that all construction would be accomplished on publicly-owned land, and land and easement purchase costs are not included. Also, costs associated with environmental restrictions of construction, including timing and phasing, are not explicitly treated.

8.3 REGULATORY REQUIREMENTS

The Shore Realignment Master Plan will cover a relatively large, contiguous area; will look at least 50 to 100 years ahead; cover a number of different actions including the construction of levees, ecological restoration and stormwater management; and have to be adaptable to accommodate the uncertainty in future environmental conditions. For these reasons, the regulatory compliance process may best be undertaken as a Programmatic Environmental Impact Report (EIR). A Programmatic EIR is an EIR which may be prepared on a series of actions that can be characterized as one large project and are related by geography, actions, plans or other general criteria, and having generally similar environmental effects which can be mitigated in similar ways.

A Programmatic EIR provides a more comprehensive consideration of effects, alternatives, and cumulative impacts. It allows the lead agency to consider broad policy alternatives and program-wide mitigation measures early in the process. Use of the Programmatic EIR enables the lead agency to characterize the overall program as the project being approved at that time. When individual projects within the program are proposed, the lead agency is required to examine the individual activities to determine whether their effects were fully analyzed in the Programmatic EIR. If not, supplemental documentation may be required.

The general process would comprise three phases:

- Environmental review
- Permitting
- Compliance review.

Environmental review may consist of both National Environmental Policy Act (NEPA) (if there is a federal interest) and California Environmental Quality Act (CEQA) compliance, and is typically completed first. NEPA (if required) and CEQA documents should be prepared concurrently and used as the basis upon which the regulatory and resource agencies process permits. The USACE typically serves as the lead agency under NEPA. For CEQA, several state agencies may be involved. Figures 8.1, 8.2 and 8.3 provide flow charts of the NEPA and CEQA compliance processes.

Once the environmental review is completed, the permit process begins, and the applicant submits the necessary permit applications to the appropriate agencies. There are many routes that can be taken to receive the permits necessary for a shore management project, depending on the implementing agency and the project applicant. One possible route is shown in Appendix B.

Table 8.2 below is a list of permits and approvals that are likely to be required from various resource/regulatory agencies for typical projects that may be considered under the Shore Realignment Master Plan

U.S. Army Corps of Engineers	Clean Water Act (CWA) Section 10, Letter of Permission, Section 404 Individual Permit
U.S. Army Corps of Engineers	Rivers and Harbors Act Section 10 authorization
Regional Water Quality Control Board	Clean Water Act (CWA) Section 401 Water Quality Certification and in support of Section 404 permit; and/or a Waste Discharge Requirement (WDR)
	National Historic Preservation Act Section 106 compliance in support of Section 404 permit
Bay Conservation and Development Commission	Major Permit. Shore Realignment Master Plan should be consistent with Bay Plan
U.S. Fish and Wildlife Service/	Federal Endangered Species Act (ESA) Section 7 consultation regarding project effects on wildlife species federally listed as threatened or endangered
NOAA Fisheries	Federal Endangered Species Act (ESA) Section 7 consultation regarding project effects on anadromous fish species federally

	listed as threatened or endangered
	Porter-Cologne Water Quality Act waste discharge requirements and Statewide general construction National Pollutant Discharge Elimination System (NPDES) Storm Water Pollutant Prevention Plan (SWPPP)
California Department of Fish and Game	California Endangered Species Act (CESA) compliance and coordination regarding project effects on wildlife species state listed as threatened or endangered
California Department of Fish and Game	California Fish and Game Code Section 1602 Streambed Alteration Agreement
	Magnusen-Stevenson Fishery Conservation Act Essential Fish Habitat analysis
Miscellaneous discretionary approvals potentially required from local agencies	Approval/permits may be needed from additional agencies including: Alameda County Flood Control and Water Conservation District; State Lands Commission; U.S. Coast Guard; and Bay Area Air Quality Management District.

Table 8.2. Typical list of permits and approvals

In terms of a timeline for obtaining the required permits and approvals, the two longest processes are typically associated with the Section 7 Consultation and the 404(b)(1) Alternatives Analysis. Most, if not all, of the other approvals can be obtained within the timeline for these two permits, and they can be processed on parallel tracks. As an example, the entire process for the South Bay Salt Ponds Project (SBSP) took approximately 2.5 years to complete.

8.4 POTENTIAL FUNDING SOURCES

There are a number of potential funding sources to develop and implement a Shore Realignment Master Plan.

U.S. Army Corps of Engineers

The USACE is the primary federal agency funding shoreline restoration projects. Funds are available for a wide range of projects which are typically limited to large-scale structural alternatives. The USACE may be able to participate in managed realignment projects although there is not a specific Congressional authorization similar to shore protection, flood control, and navigation. Funding mechanisms within the Corps consist of two major programs; the Continuing Authorities Program (CAP) and the General Investigations (GI) approach. For smaller projects, the Corps may act directly under CAP without authorization from Congress. CAP includes a number of standing authorities to study and construct certain specific projects. Projects that are larger in scope require congressional authorization and would fall under GI. GI recommendations go before Congress for project authorization and then for funding. Requests for projects with the USACE can be made at any time; however for new starts under the GI program, and the CAP, the requests are linked to the budget cycle. All projects funded by the USACE require reconnaissance and feasibility studies prior to implementation to determine whether a federal interest exists in the project, unless the USACE is directed by a member of Congress to move ahead with the project.

The CAP program is made up of nine individual programs that are categorized by the type of project being proposed. All projects are cost shared between the federal government and a non-federal sponsor. A non-federal partner is a legally constituted public body, such as a city, state, county, or conservancy district, which is capable of financing the project and providing for operation and maintenance of the project once completed. Sections 14, 204, and 206 could potentially provide funding for a Shore Realignment Master Plan:

- Section 14 Emergency stream bank and shore erosion: This program is authorized by Section 14 of the Flood Control Act and funds shore protection projects that protect public facilities including water and sewage treatment facilities, and roads that are in imminent danger of erosion. Private property is not eligible. Cost share requirements are 65% federal to 35% non-federal, and the maximum federal contribution is $1 million.

- Section 204 Beneficial uses of dredged material: This program is authorized by Section 204 of the Water Resources Development Act and allows the use of dredged material from new or existing federal projects to restore, protect, or create aquatic and ecologically related habitats, including wetlands. The total project cost is shared 75% federal and 25% non-federal, and the maximum federal contribution for project development and construction is $5 million.

- Section 206 Aquatic ecosystem restoration: This program is authorized by Section 206 of the Water Resources Development Act and funds aquatic ecosystem restoration projects that will improve the environmental quality, are cost-effective, and are in the public interest. The total project cost share requirement is 65% federal to 35% non-federal, and the maximum federal contribution is $5 million.

In addition to CAP funding, it is possible to get GI funding for larger projects that do not fit within the CAP program, or a collection of several smaller projects. This type of funding requires congressional authorization through either a Senate Resolution (Environment and Public Works Committee) or House Resolution (Transportation and Infrastructure Committee). Alternatively, authorization could be accomplished with language in the Water Resources Development Act which is passed by Congress and signed by the president every two years. The General Investigations process comprises four phases:

- Reconnaissance Phase: Duration 9-12 months. Corps covers full cost. This phase identifies the Project Study Plan and cost share details.

- Feasibility Phase: Duration 1-3 years. 50% to 50% cost share (up to 50%, either sponsor share or can be in-kind). Average cost is $700,000 to $1.5 million or more.

- Pre-construction Engineering and Design Phase: Duration 1-2 years. Cost share varies depending on the type of project (typically 65% to 35%, federal/non-federal).

- Construction Phase: Time varies depending on the project. Cost share varies depending on the type of project (typically 65% to 35%, federal/non-federal).

The GI process may take six years to reach the construction phase, once the funds are authorized, and then appropriated. After the reconnaissance phase there is a significant (50%) matching requirement by the local sponsor.

U.S. Fish and Wildlife Service

The USFWS administers a variety of natural resource assistance grants to government, public and private organizations, groups and individuals. One potential source of funding assistance for projects that restore wildlife habitat is the Cooperative Conservation Initiative. This program provides funding for projects that restore natural resources and establish or expand wildlife habitat. A 50% match is required of the project sponsor. The Cooperative Endangered Species Conservation Fund also provides funding for implementation of conservation projects or acquisition of habitat that will benefit federally-listed threatened or endangered species. The required match for this program is a minimum 25% of the estimated project cost by the local sponsor.

California Coastal Conservancy

The California Coastal Conservancy (Conservancy) is a state agency that uses entrepreneurial techniques to purchase, protect, restore, and enhance coastal resources, and to provide access to the shore. The Conservancy works in partnership with local governments, other public agencies, non-profit organizations, and private landowners, and has carried out more than 1,000 projects along the California coastline and in San Francisco Bay. The availability of Conservancy grant money is entirely dependent upon availability of funds (mostly bond issues). The Conservancy can fund pre-project feasibility studies, property acquisition, planning (for large areas or specific sites), environmental review, construction, monitoring, and in limited cases, maintenance.

Local/Regional Matching Funds

If HASPA is going to be successful in attracting state or federal funding, some form of revenue stream must be developed at the local/regional level in order to leverage the state and federal funds. The local sponsor is typically required to provide 50% (USACE) or a minimum of (and sometimes more) 15% of costs related to studies and construction. Revenue streams developed elsewhere to generate matching funds include a transient occupancy tax (TOT) levied on hotels (southern California and elsewhere), real estate transfer tax (RETT), tax levied on sporting goods (e.g. Texas), and parking or user fees. Other strategies that could potentially be implemented include cost-sharing among project beneficiaries and special assessment districts.

8.5 GENERAL IMPLEMENTATION STRATEGY

Development and implementation of the proposed Shore Realignment Master Plan requires a governance structure to oversee the process and execute actions. The structure should provide a platform for input from the public as well as federal, state, regional, and local agencies. HASPA is a Joint Powers Authority (JPA) with representatives from the Hayward Area Recreation and Park District, East Bay Regional Park District, and the City of Hayward. A structure is defined here using the HASPA as a JPA, with partner agencies working closely with an advisory committee.

A JPA is an institution permitted under Section 6500 of the State of California Government Code whereby two or more public authorities can operate collectively. JPAs may be used where an activity naturally transcends the boundaries of existing public authorities (such as the Hayward shore). It is distinct from the member authorities; the JPA has a separate operating Board of Directors, and the Board can be given any of the powers inherent in all of the participating agencies. In setting up a JPA, the constituent authorities must establish which of their powers the new authority will be allowed to exercise, and a term, membership and standing orders of the Board need to be specified. Also, the JPA can employ staff and establish policies independently of the constituent authorities. JPAs are flexible and can be tailored to meet specific needs, and there are many differences between individual JPAs.

An example of a JPA governance models is that adopted by San Diego Association of Governments (SANDAG). SANDAG comprises 18 cities and county governments and is a forum for decisions on a wide range of issues (not just coastal erosion). SANDAG also has the ability to issue bonds, as established in specific state legislation (SB 1703, Feb 12, 2002). The JPA is governed by a Board of Directors composed of mayors, council members and county supervisors, as well as advisory members (non-voting) from Department of Defense, Caltrans, San Diego Port District, San Diego Water Authority, and others. In addition to the Board, there is also a staff of professional planners, engineers, and research specialists.

SANDAG builds consensus, makes strategic plans, obtains and allocates resources, plans, engineers, and builds a wide range of public projects, and provides information on a wide variety of topics. Within SANDAG there is a Shoreline Preservation Working Group with staff members and a Shoreline Preservation Strategy that was adopted by their Board in 1993. The Working Group advises the Regional Planning Committee of SANDAG on issues related to the Shoreline Preservation Strategy.

For the Hayward shore, a new JPA could be formed that is focused solely on shoreline management issues. The HASPA JPA would include a multi-stakeholder advisory committee that advises the Executive Director and Board of Directors. A potential governance structure for the HASPA JPA is outlined in Figure 8.4. Consideration should be given to the geographical limits of the JPA so that it covers an area that reflects more closely the physical processes. In particular, an extension north to the developed areas of Oakland and Alameda would seem appropriate.

In this structure, HASPA acts as the lead planning and coordinating agency which adopts, seeks funds, administers grants and studies, assists with implementation activities as deemed necessary by the local implementing agencies. HASPA would receive funds, complete environmental documentation, acquire regional permits as appropriate, and plan coastal projects, as appropriate. Local land use decision-making and implementation would remain with the local agencies.

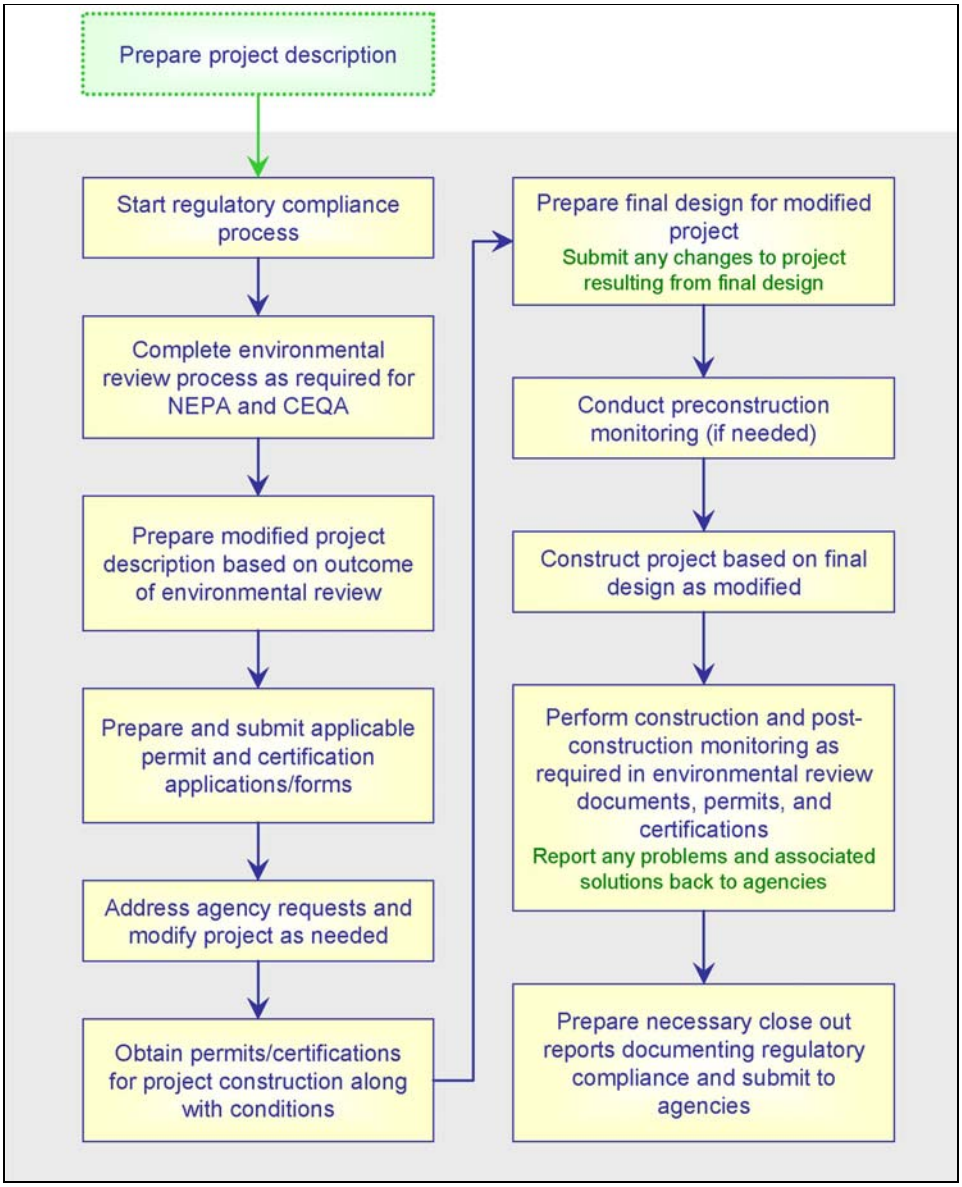
The Executive Director would be advised and guided on shore management issues by an Advisory Committee comprising engineers and planners from local cities, academic institutions and industry. The Executive Director would then report to the Board of Directors.

A number of partners are identified in the structure. Some are included because of their regulatory status, such as BCDC, the Regional Water Quality Control Board (RWQCB) and California State Lands Commission (SLC). USACE is a federal agency that funds shore protection and ecosystem restoration projects. The Corps could cost share with any non-Federal public agency. To partner with the USACE, the HASPA JPA would need to sign an agreement and demonstrate an ability to pay. Both Alameda County Flood Control and Water Conservation District (ACFCWCD) and EBDA have interests in the area.

The JPA structure has a number of advantages for HASPA:

- the JPA has the potential for raising money by issuing bonds;
- the JPA could enter into contracts for shore processes studies, planning, environmental review, permitting, engineering and construction as needed.
- it simplifies permitting of projects over multiple property parcels.

This structure may be updated as experience is gained with shore management on the Hayward shore. For instance, SANDAG found that technical staff may be desired to help local agencies to implement particular projects which require special capabilities in coastal engineering, construction contract administration, or monitoring, as needed.



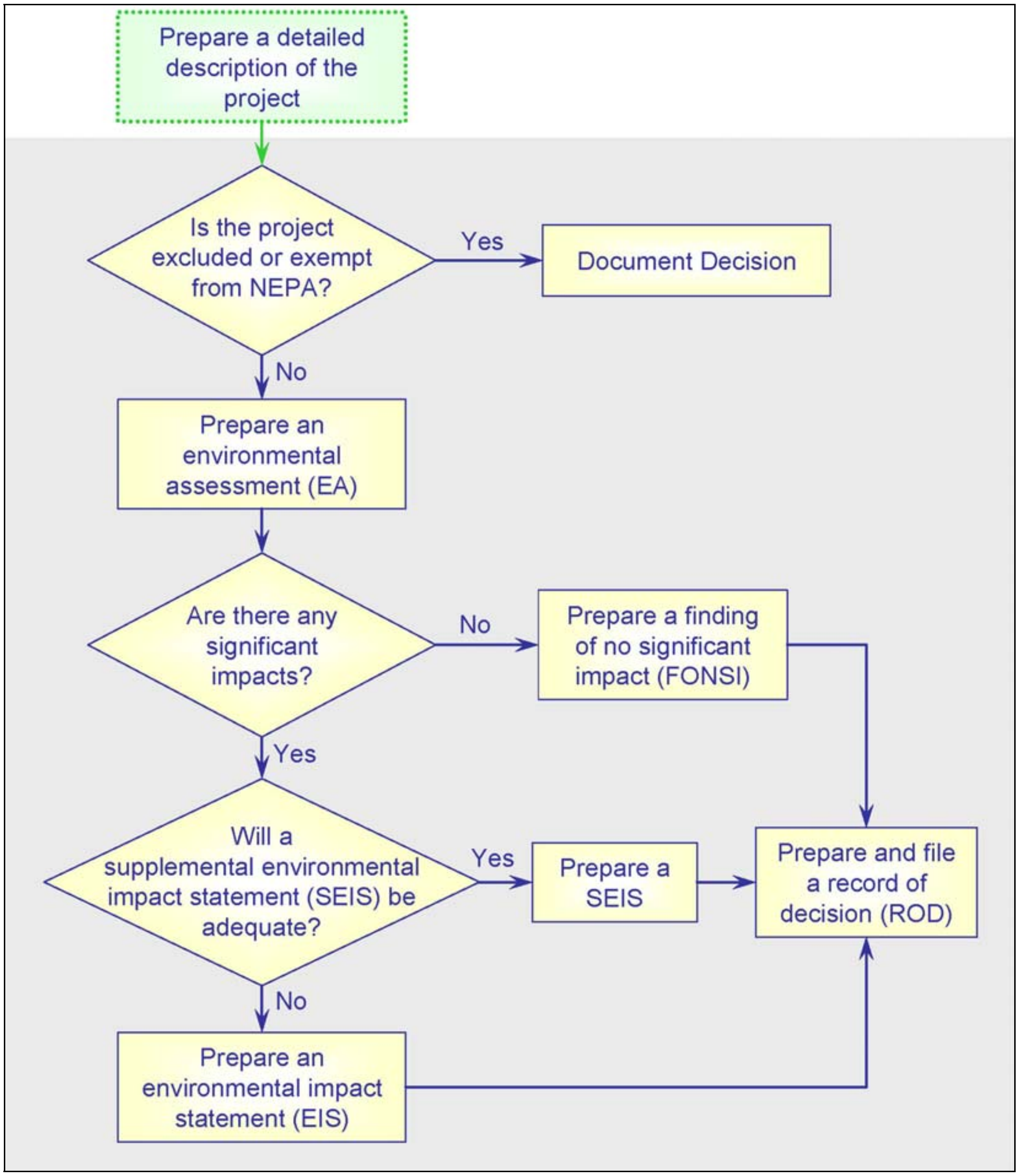
Source: Beach Restoration Regulatory Guide (EIC, 2006)

figure ***8.1***
HASPA Sea Level Rise Study

Regulatory Compliance Process

PWA Ref# 1955.00

PWA



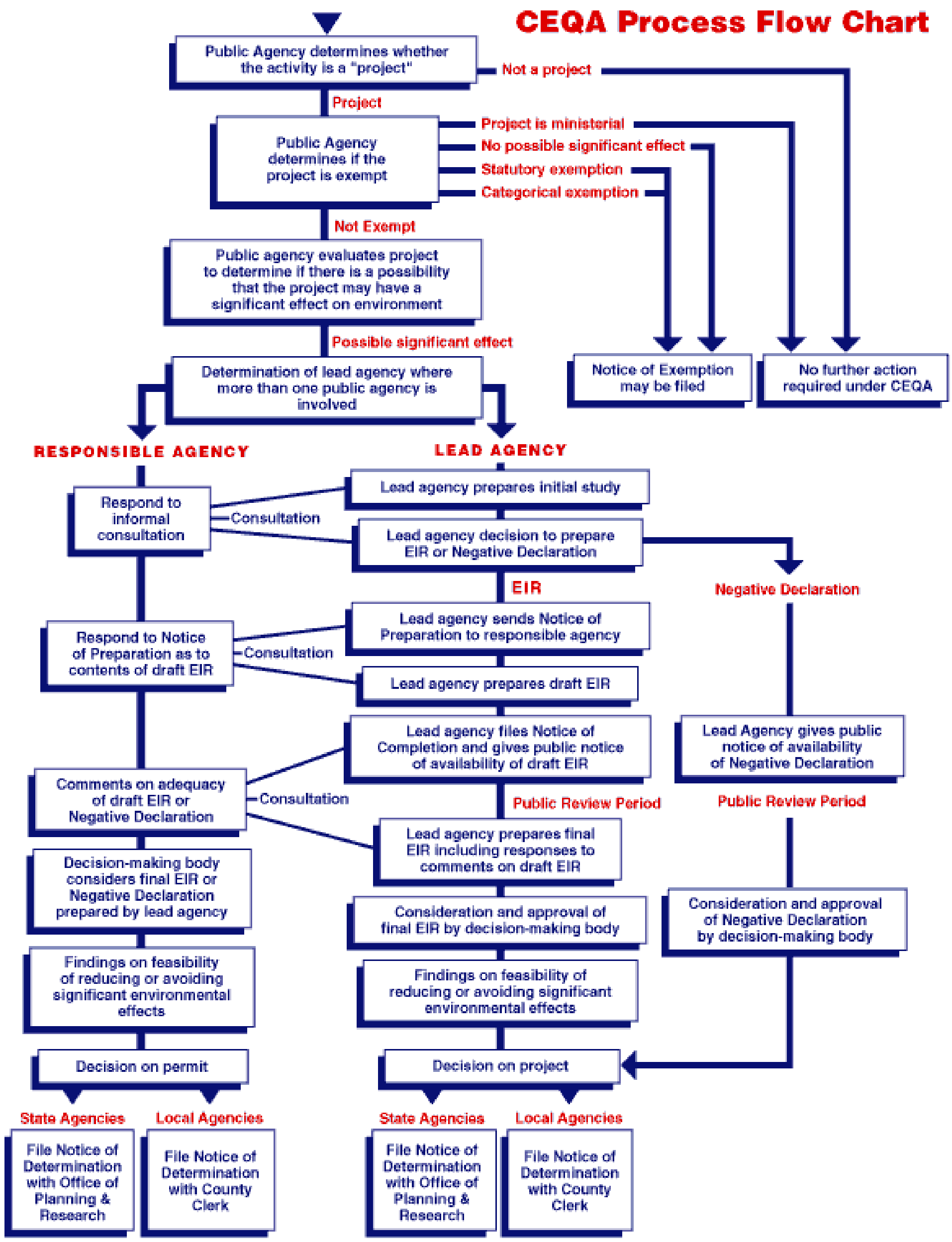
Source: Beach Restoration Regulatory Guide (EIC, 2006)

figure ***8.2***
HASPA Sea Level Rise Study

NEPA Compliance Flow Chart

PWA Ref# 1955.00

PWA



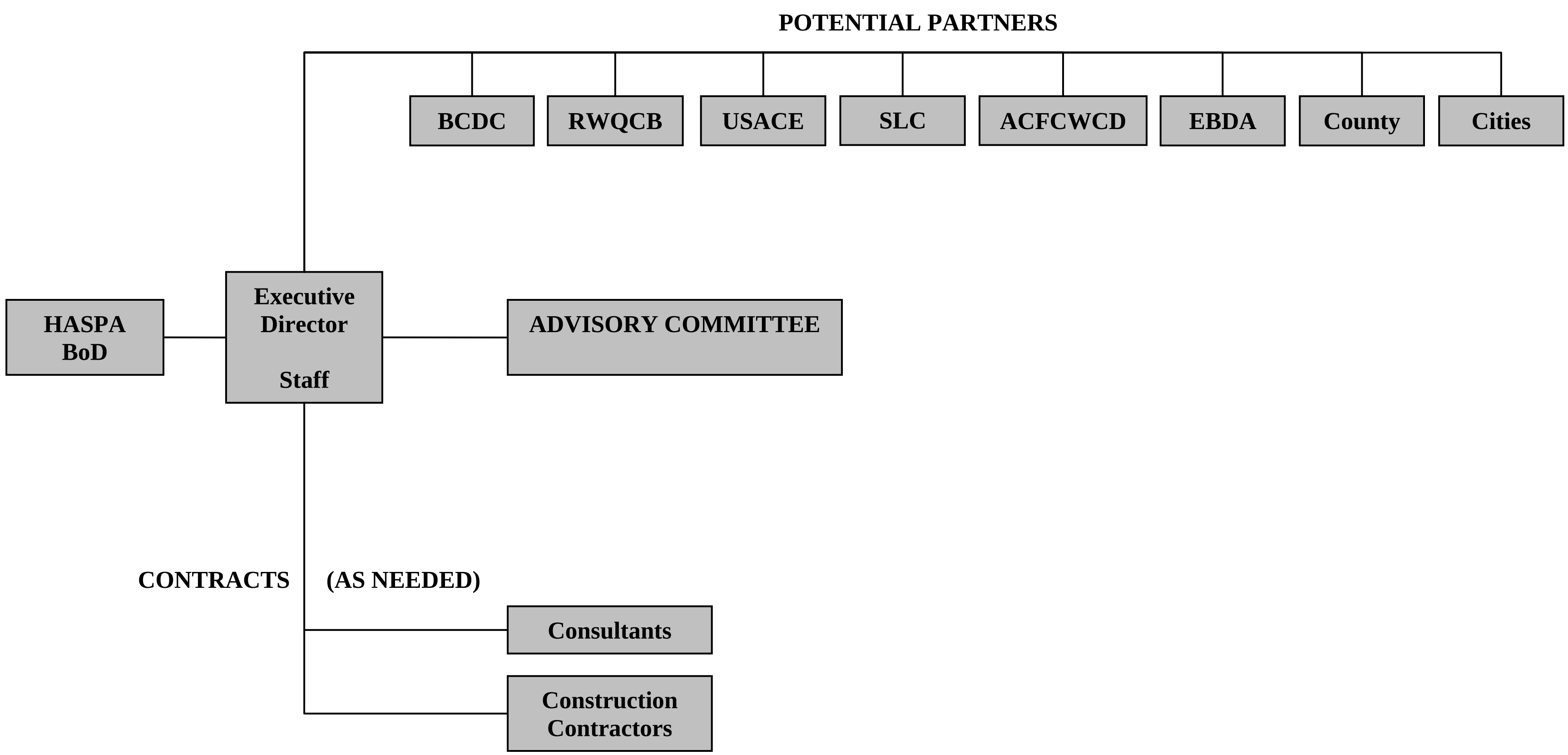
Source: http://ceres.ca.gov/images/CEQA_process_chart.gif

figure ***8.3***
HASPA Sea Level Rise Study

CEQA Compliance Flow Chart

PWA Ref# 1955.00

PWA



BCDC – Bay Conservation and Development Commission
RWQCB – Regional Water Quality Control Board
USACE – U.S. Army Corps of Engineers
SLC – State Lands Commission
ACFCWCD – Alameda County Flood Control and Water Conservation District
EBDA – East Bay Dischargers Authority

figure **8.4**
HASPA Sea Level Rise Study

Possible HASPA JPA Governance Structure

PWA Ref# 1955.00

PWA

9. REFERENCES

Atwater BF, Conrad SG, Dowden JN, Hedel CW, MacDonald RL, Savage W. 1979. History, Landforms, and Vegetation of the Estuary's Tidal Marshes. In: Conomos TJ, editor. *San Francisco Bay: The Urbanized Estuary*. San Francisco, CA: Pacific Division, American Association for the Advancement of Science. p 347-385.

BCDC., 2009. *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline*. San Francisco Bay Conservation and Development Commission. Draft Staff Report.

Cayan, D., *et al*. 2008. *Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment*. A report from the California Climate Change Center, sponsored by the California Energy Commission and the California Environmental Protection Agency.

Collins JN, Grossinger RM. 2004. Synthesis of scientific knowledge concerning estuarine landscapes and related habitats of the South Bay Ecosystem. Oakland, CA: San Francisco Estuary Institute. 91 p.

Cooper, J.A.G. 2002. The role of extreme floods in estuary-coastal behaviour: contrasts between river and tide dominated microtidqal estuaries. *Sedimentary Geology*, 150: 123-137.

Defina, A., Carniello, L., Fagherazzi, S. and D'Alaos, L.D. 2007. Self-organization of shallow basins in tidal flats and salt marshes. *Journal of Geophysical Research*. 112. F03001.

EIC (Everest International Consultants). 2006. *Beach Restoration Regulatory Guide*. Report to the California State Coastal Conservancy and Coastal Sediment Management Workgroup, December 2006.

Fagherazzi, S., Palermo, C., Rulli, M.C., Carniello, L. and Defina, 2007. Wind waves in shallow microtidal basins and the dynamic equilibrium of tidal flats. *Journal of Geophysical Research.* 112, F02024.

Griggs, G.B., K.B. Patsch, L.E. Savoy 2005. *Living with the Changing California Coast*. University of California Press. 540pp

Heberger, M.H., H. Cooley, P. Herrera, P. Gleick and E. Moore 2008. *The Impacts of Sea Level Rise Along the California Coast*. California Climate Change Center, CEC-500-2008-024-F.

IPCC, 2007. Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Knowles, N 2008. *Potential inundation due to rising sea levels in the San Francisco Bay Region*. California Climate Change Center. CEC-500-2009-023-D.

NRC, 1987. *Responding to Changes in Sea Level: Engineering Implication*s. National Research Council. National Academy Press: Washington, D.C.

Orr, M., Crooks, C., and Williams, P. 2003. 'Will Restored Tidal Marshes Be Sustainable?' In: Larry R. Brown, editor. *Issues in San Francisco Estuary Tidal Wetlands Restoration*. San Francisco Estuary and Watershed Science. Vol. 1, Issue 1 (October 2003), Article 5.

Polgar, S., 2009. *Climate Change Adaptation Efforts at the State and Bay Area Regional Levels*. Notes from Planning for Climate Change Workshops, September 22 and 23, 2009, Oakland and Sunnyvale.

PWA, 2005. Flood Management and Infrastructure Existing Conditions Report, South Salt Pond Restoration Project, San Jose, CA. Prepared for California State Coastal Conservancy, US Fish and Wildlife Service, California Department of Fish and Game.

Roberts W, Le Hir P, Whitehouse RJS. 2000. Investigation Using Simple Mathematical Models Of The Effect Of Tidal Currents And Waves On The Profile Shape Of Intertidal Mudflats. *Continental Shelf Research* 20(2000):1079-1097.

Ruggiero, P., G.M. Kaminsky, G. Gelfenbaum, and B. Voight, 2005. "Seasonal to Interannual Morphodynamics Along a High Energy Dissipative Littoral Cell." *Journal of Coastal Research*, vol 21, no 3. pp 533-578.

Schoellhamer. D, G. Shellenbarger, N. Ganju, J. Davis, and L. McKee, 2003. 'Sediment Dynamics Drive Contaminant Dynamics'. In *The Pulse of the Estuary: Monitoring and Managing Contamination in the San Francisco Estuary*. San Francisco Estuary Institute, Oakland, CA.

Science Daily. 2008. "Global Carbon Emissions Speed Up, Beyond IPCC projections." September 28, 2008. www.sciencedaily.com/releases/2008/09/080925072440.htm.

Steel, T.J. and Pye, K. 1997. The Development of Salt Marsh Tidal Creek Networks: Evidence From The U.K. *Proceedings of the Canadian Coastal Conference*, 1997 May 22-25. University of Guelph, Canada. P.267-280.

Turner, K. and J. Dagley 1993. What price sea walls? *Enact. Managing Land for Wildlife*, pp. 8-9.

USACE, 2009. *Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs*. US Army Corps of Engineers, EC 1165-2-211.

Watson, EB. 2004. Changing Elevation, Accretion, and Tidal Marsh Plant Assemblages in South San Francisco Bay Tidal Marsh. *Estuaries* 27(4):684-698.

10. LIST OF PREPARERS

This report was prepared by the following PWA staff:

Bob Battalio, Principal

Jeremy Lowe, Associate Principal

ACKNOWLEDGEMENTS

We would like to acknowledge the following individuals for their valuable contributions to this report:

Mark Taylor of East Bay Regional Park District (EBRPD) for providing detailed knowledge of the HASPA shoreline;

Mike Andersen of EBRPD and Erik Pearson of the City of Hayward for reviewing the report and providing critical comments;

Mike Connor of the East Bay Dischargers Authority (EBDA) and Paul Zolfarelli of the Oro Loma Sanitary District for giving us insight into the wastewater treatment functions in the HASPA area;

Peter Baye for his inspiring ideas on "Gradual Steepening";

Sara Polgar of the San Francisco Bay Conservation and Development Commission (BCDC) for informative discussions on the regulatory environment.

APPENDIX A

COMPARISON OF SEA LEVEL RISE PROJECTIONS

GLOBAL SEA LEVEL RISE OBSERVATIONS

Global sea level has risen approximately 120 m (400 ft) since the last glacial maximum some 18,000 years ago (Fairbanks 1989). In the last 6,000 years, the rate of sea level rise slowed from an average rate of about 50 mm (2 in) per century over the last 6,000 years, to 10 to 20 mm (0.4 to 0.8 in) per century over the last 3,000 years (Church *et al*, 2001).

Tide gauge data from the 20th century, indicates the present rate of global average sea level rise has been between 10 and 20 cm (4 and 8 in) per century. The few very long tide gauge records indicate that the rate of sea level rise was less in the 19th century. It is very likely that 20th century warming caused by anthropogenic impacts has contributed significantly to the observed sea level rise. Modeling studies indicate that both the thermal expansion of sea water and as well as widespread loss of land ice have increased sea level from 1910 to 1990 by between 3 and 8 cm (1.2 and 3.1 in) per century (Church *et al*, 2001).

COMPONENTS OF SEA LEVEL RISE

Sea level rise is generally split into two terms – a global term that is controlled by global processes, such as the warming of the oceans and the melting of ice; and a local term that is controlled by local or regional processes, such as local winds and land movements. Local sea level rise is also referred to as relative sea level rise as it combines changes in the both the sea and land elevations.

Global, or eustatic, sea level rise is the combination of two factors:

1. <u>Thermal expansion of the ocean</u>. Thermal expansion is the result of higher water temperatures leading to an increase in ocean volume while the mass remains constant. Over the past 50 years the oceans have absorbed about 80% of the heating associated with greenhouse gases. Observations suggest an average sea level rise of about 10 cm (3.9 in) per century can be attributed to thermal expansion component over recent decades (Cayan *et al*, 2006). The rate of thermal expansion will increase as global temperature increases and will continue for about 1,000 years after atmospheric temperature stabilizes, due to the slow circulation of the deep ocean (Mote *et al*, 2008).

2. <u>Melting of global ice</u>. The melting of glaciers and land grounded ice caps, such as Antarctica and Greenland, will increase the mass of water in the oceans leading to sea level rise. Observations of glaciers and ice caps suggest an average contribution to sea level rise of 2 to 4 cm (0.8 to 1.6in) per century over the last century. However, several independent measurements of Greenland and Antarctic mass balance using lasers and gravity measurements indicate that both Greenland and Antarctica have recently (2002-2006) been substantial contributors to global sea level rise (Mote *et al*, 2008).

Local sea level rise is a combination of global sea level rise together with three local factors:

1. Local atmospheric circulation. Atmospheric factors can affect regional sea levels. Wind-driven enhancement of sea level can occur on the Pacific coast due to the northward ocean currents and due to very long wavelength waves propagating up form the equator during El Nino events (Mote *et al*, 2008). Combined with Coriolis effects due to the Earth's rotation, they push ocean water toward the shore. Other phenomena associated with the El-Nino-Southern Oscillation, such as the frequency and magnitude of storms and storm surges, may be also be altered by climate change.

2. Vertical land movement. Relative sea level rise is the sum of global sea level rise and the change in vertical land movement (BCDC, 1987). Thus, if sea level rises and the shoreline rises or subsides, the relative rise in sea level could be lesser or greater than the global sea level rise. Vertical land movement can occur due to tectonics (earthquakes, regional subsidence or uplift), sediment compaction, isostatic readjustment and groundwater depletion (USACE, 2009). As rates of global sea level continue to increase with climate change, at some point, the rate of vertical land movement will become less significant in determining the impact of sea level rise. However, areas that have subsided are particularly vulnerable to sea level rise and extreme events.

COMPARISON OF GLOBAL SEA LEVEL RISE PROJECTIONS

There have been a number of recent projections of sea level rise. Each of these projections has made different assumptions in relation to the four components of sea level described above. It is important to understand these assumptions and the context in which the predictions were made.

IPCC (2007)

The United Nations' Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (AR4) provided projections of global sea level rise for six different emission scenarios (Table A.1 and Figure A.1). These included high emissions scenarios (such as A1F1 and A2) which represented a future in which economic growth is uneven and the income gap remains large between now-industrialized and developing parts of the world. In contrast, low emissions scenarios (such as B1) represented a future with a high level of environmental and social consciousness, combined with a globally coherent approach to a more sustainable development.

Each of the emission scenarios was modeled using a number of global climate models to give projected temperature and sea level rise changes. The use of multiple models reflects the uncertainty in the climate responses by greenhouse gases and other forcings and the variability amongst models in representing and calculating key processes. The results for each emission scenario were then assembled to provide an envelope of likely projections together with a mean projection.

Component	Low Emission B1	High Emission A2
	2100	2100
Thermal expansion	17 cm (6.7 in)	24.5 cm (9.6 in)
Ice sheet contributions	10.5 cm (4.1 in)	12 cm (4.7 in)
Greenland ice sheet	3 cm (1.2 in)	4.5 cm (1.8 in)
Antarctic ice sheet	-6 cm (-2.4 in)	-7.5 cm (-3.0 in)
Total global sea level rise	28 cm (11 in) ± 10 cm	37 cm (14.6 in) ± 14 cm

Table A.1. Low and high emission global sea level rise from Table 10.7 IPCC (2007).

The projections provided by AR4 are of global sea level rise and do not reflect local atmospheric circulation or tectonic movements. The projections range from ranging from 18 to 38 cm (7 to 15 in) for the lowest emissions scenarios to 26 to 59 cm (10 to 23 in) for the higher emissions scenarios.

Subsequent research has led to a reevaluation of the AR4 sea level rise projections which are now thought to be too low, and the approach used to derive the projections has been questioned. The projections were driven mostly by the thermal expansion component and excluded the significant contributions from the accelerated future melting of the Greenland and Antarctic ice sheets. The uncertainty in modeling how ice moves in large, land-based ice sheets led to the exclusion of this component and for the IPCC to state that it did

> "not assess the likelihood, nor provide a best estimate or an upper bound for sea level rise" (IPCC 2007).

The upper end of the AR4 projection is not an upper limit and it probably underestimates future sea level rise (Rahmstorf 2007; Jevrejeva *et al* 2008). Other recent publications report different global sea level rise projections to those reported AR4. For instance, Rahmstorf (2007) used a linear empirical relationship which resulted in higher global mean surface temperature and rates of sea level rise to predict sea level rise increases of 50 to 140 cm (19 to 55 in) by 2100.

Cayan *et al* (2008)

Cayan *et al* (2008) considered these higher estimates of global sea level rise in their study of sea level rise in the coastal waters of California. They defined two projections which bookended the range of likely global sea level rise, referring to these as “low” and “high”. This used the A2 (high emission) and B1 (low emission) scenarios and Rahmstorf’s methodology to project global sea level rise in 2100 (Table A.2). These projections were also adjusted to include the effects of dams on sea level rise which may have stored enough water worldwide to mask acceleration in the rate of sea level rise prior to 1993.

Component	Low Emission B1	High Emission A2
	2100	2100
AR4 projection	28 cm (11 in)	37 cm (14.6 in)
Adjustments for ice sheet loss and dam storage	22 cm (8.7 in)	103 cm (40.5)
Total global sea level rise	50 cm (19.7 in)	140 cm (55.1 in)

Table A.2. Low and high emission global sea level rise from Cayan *et al* (2008).

Both sets of global sea level rise projections (AR4 and Cayan *et al*) use a series of scenarios to bracket likely future greenhouse gas emissions. The latter study brings added sophistication, incorporating additional components such as enhanced ice sheet loss and dam storage. However the general trend is for projections of sea level rise to increase as the processes become better understood (Figure A.2). Perhaps even more noteworthy is that the estimated emissions growth for the period 2000 to 2007 was above even the most fossil fuel intensive scenario of AR4 (Science Daily 2008).

Comparison With USACE Circular

The US Army Corps of Engineers (USACE) issued circular EC 1165-2-211 in July 2009 which provides guidance for the incorporation of direct and indirect physical effects of projected future sea level rise (USACE, 2009). Planning studies and engineering designs should evaluate alternatives against a range of local sea level rise projections which are defined by “low”, “intermediate” and “high” rates of local sea level rise.

The “low” local sea level rise projection is the historic sea level trend as observed at a long-term gauge. A minimum of 40 years of data is considered necessary to justify extrapolating into the future and use as a baseline for projecting future sea levels. This “low” projection is atypical of sea level rise projections as it does not consider future emission scenarios, unlike AR4 and Cayan *et al* (2008) discussed above. Maintenance of the historic sea level rise rates into the future is unlikely given the overwhelming evidence of accelerated sea level rise in the future. The “low” projection serves more a baseline against which to compare the more reasonable estimates of accelerated sea level rise given by the “intermediate” and “high” projections.

The “intermediate” global sea level rise projection is based on the average of the central values from the six scenarios used in AR4. Rather than use the AR4 values, the USACE circular suggests using curves developed in the 1987 National Research Council study *Responding to Changes in Sea Level* (NRC, 1987). This study used a series of three sea level curves (NRC-I, II and III) that bracketed the then estimates of sea level rise by 2100. These same curves have been used in the USACE circular but modified to reflect the increase in the present rate of global sea level rise to 1.7 mm per year. Rather than reflect a particular emission scenario, the curves (modified NRC-I, II and III) are set equally across the range of then modeled predictions to reflect sea level rises of 50 cm (19.6 in), 100 cm (39.4 in) and 150 cm (59 in) (Figure A.3). The AR4 projections for 2100 bracket the modified NRC-I curve and the guidance is to use NRC-I for the “intermediate” global sea level rise projections for 2100, a value of 50 cm (19.6 in).

In a similar vein to Cayan *et al* (2008), the USACE “high” global sea level rise projection takes account of increased ice sheet loss beyond the projections of AR4. Modified NRC-III curve is used to give a sea level rise of 150 cm (59 in) by 2100 (Figure A.3). The rationale provided for the use of the curve is that:

> “This ‘high’ rate exceeds the upper bounds of IPCC estimates from both 2001 and 2007 to accommodate for the potential rapid loss of ice from Antarctica and Greenland.” (USACE, 2009)

Table A.3 shows that NRC-III does give values close to that of Rahmstorf (2007) and Cayan *et al* (2008).

Component	**“low”**	**“intermediate”**	**“high”**
	2100	**2100**	**2100**
AR4 projection	18 cm (7.1 in)	34 cm (13.4 in)	59 cm (23.2 in)
Cayan *et al* (2008)	50 cm (19.7 in)		150 cm (59 in)
USACE (2009)	historic	34 cm (13.4 in)	93 cm (36.6 in)

Table A.3. Projections of global sea level rise from IPCC (2007), Cayan *et al* (2008) and USACE (2009). The terms “low”, “intermediate” and “high” are used differently in each study, in some cases it reflects the emissions scenario, in other cases it brackets a possible range.

BCDC (1987) and USACE (2009) provides guidance on how to calculate local vertical land movement from historic sea level observations so that local sea level rise estimates may be incorporated into the “intermediate” and “high” projections.

REFERENCES

BCDC (1987). *Future Sea Level Rise: Predications and Implications for San Francisco Bay*. Prepared for San Francisco Bay Conservation and Development Commission by Moffatt and Nichol and Wetland Research Associates.

Cayan, D., *et al*. 2008. *Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment*. A report from the California Climate Change Center, sponsored by the California Energy Commission and the California Environmental Protection Agency.

Church J. A., J. M. Gregory, P. Huybrechts, M. Kuhn, K. Lambeck, M. T. Nhuan, D. Qin, and P. L. Woodworth, 2001: "Changes in Sea Level". Chapter 11 of the *Intergovernmental Panel on Climate Change Third Assessment Report*, Cambridge University Press, Cambridge, 639–694.

Fairbanks, R. G., 1989: "A 17,000-year Glacio-eustatic Sea Level Record: Influence of Glacial Melting Rates on the Younger Dryas Event and Deep-Ocean Circulation." *Nature* vol 342: no 6250, pp 637–642.

IPCC, 2007. Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jevrejeva, S., J. C. Moore, A. Grinsted, and P. L. Woodworth. 2008. Recent global sea level acceleration started over 200 years ago? *Geophysical Research Letters* 35:8715.

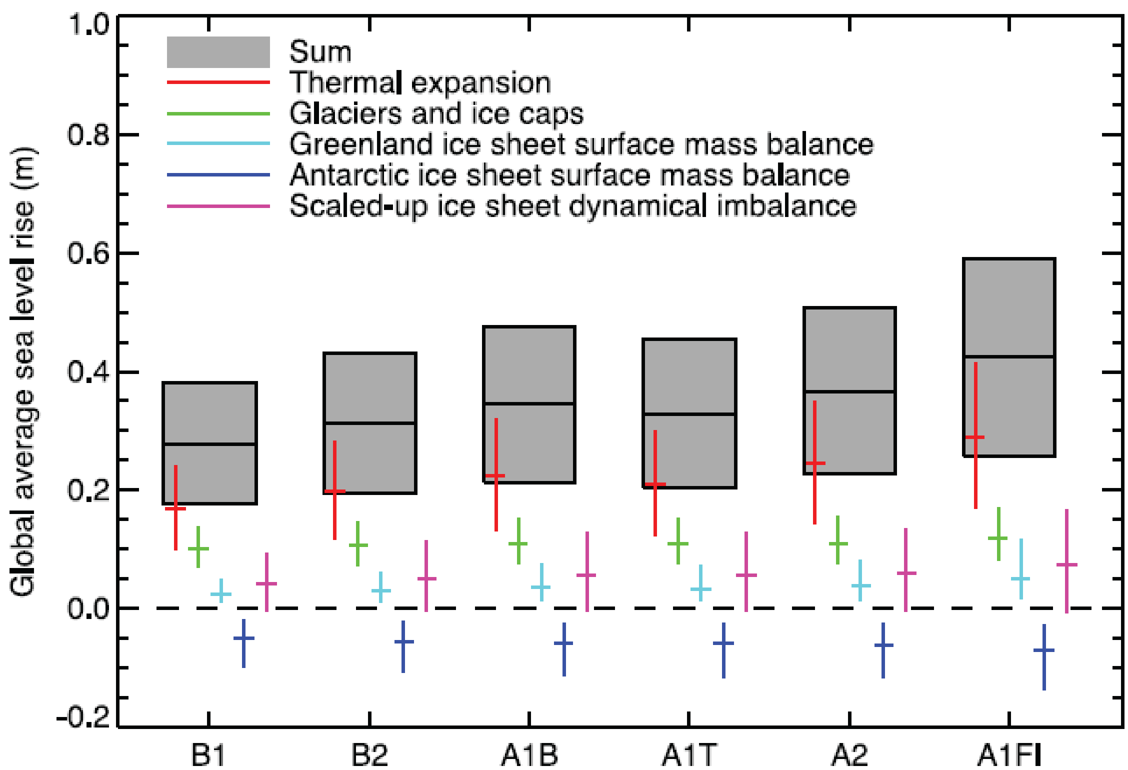
Mote, P., A. Peterson, S. Reeder, H. Shipman, L. Whitely Binder, 2008. *Sea Level Rise in the Coastal Waters of Washington State*. University of Washington Climate Impacts Group and the Department of Ecology.

NRC, 1987. *Responding to Changes in Sea Level: Engineering Implication*s. National Research Council. National Academy Press: Washington, D.C.

Rahmstorf, S., 2007. A Semi-Empirical Approach to Projecting Future Sea Level Rise. *Science*, vol. 315. pp 368-370.

Science Daily. 2008. "Global Carbon Emissions Speed Up, Beyond IPCC projections." September 28, 2008. www.sciencedaily.com/releases/2008/09/080925072440.htm.

USACE, 2009. *Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs*. US Army Corps of Engineers, EC 1165-2-211.



Source: IPCC (2007).

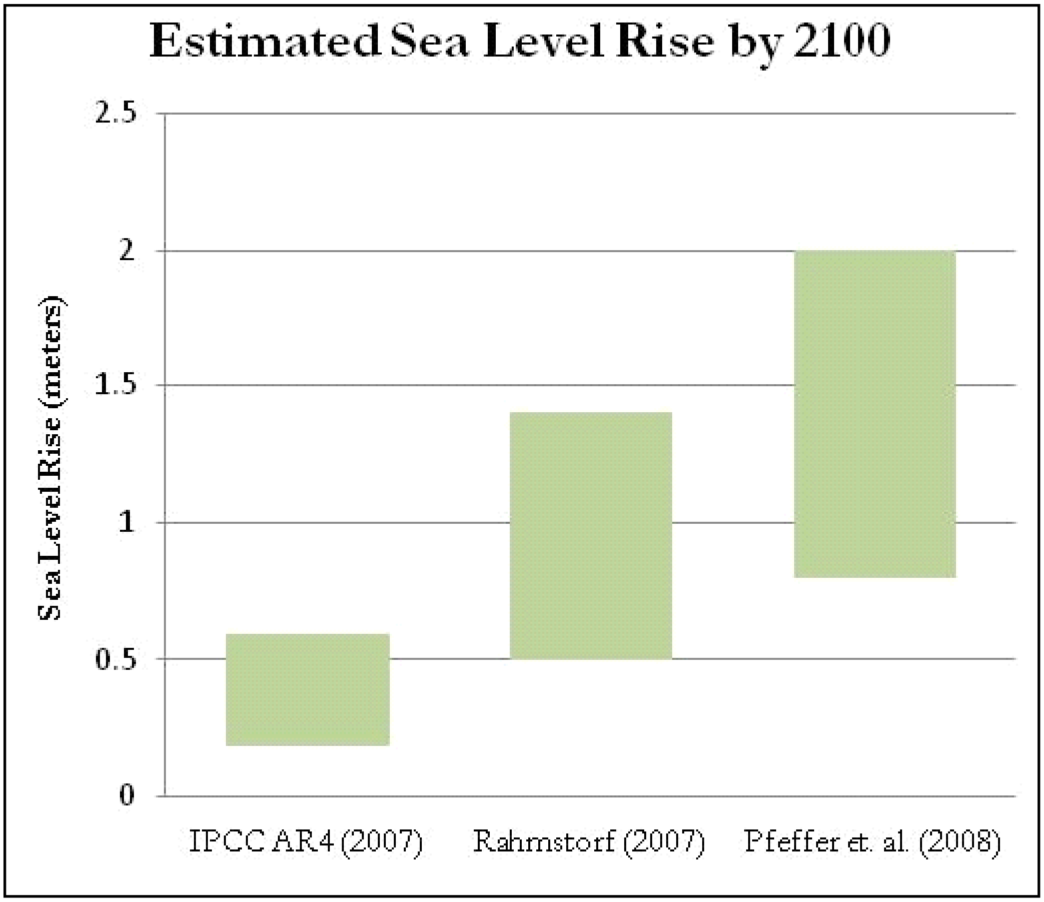
Projections and uncertainties (5% to 95% ranges) of global average sea level rise and its components in 2090 to 2099 (relative to 1980 to 1999) for the six emission scenarios

figure ***A.1***
HASPA Sea Level Rise Study

Projections of Global Sea Level Rise

PWA Ref# 1955.00

PWA



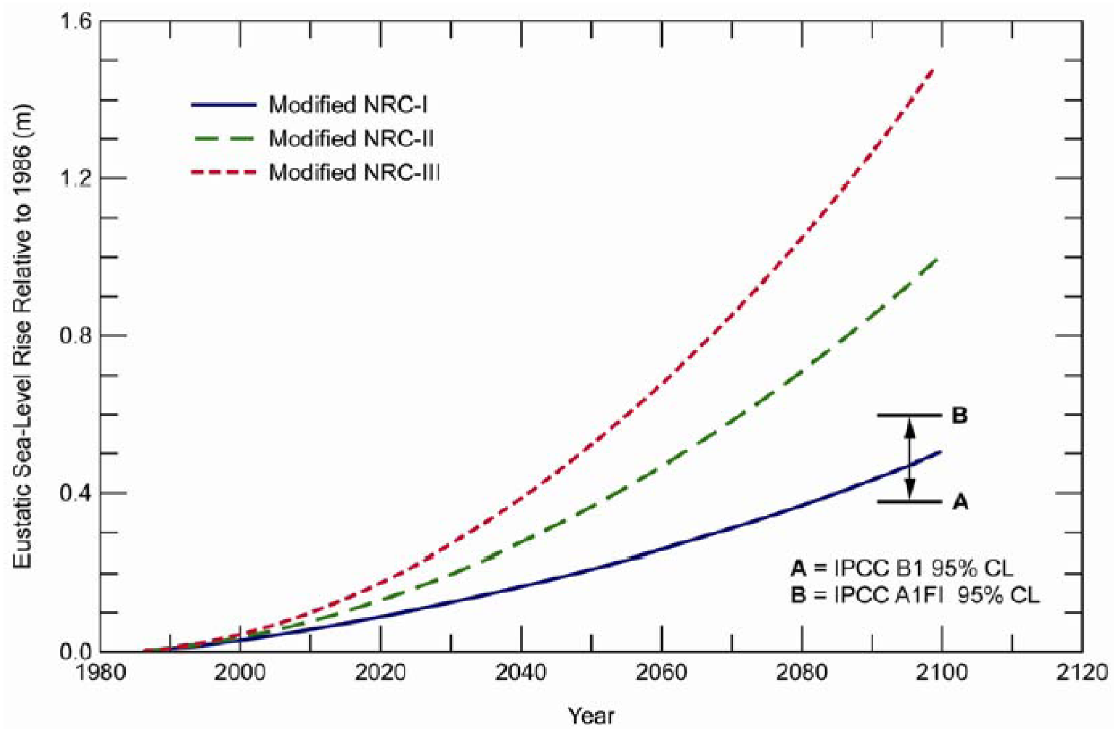
Source: Pew (2009)

figure ***A.2***
HASPA Sea Level Rise Study

Recent Estimates of Sea Level Rise

PWA Ref# 1955.00

PWA



Source: USACE (2009)

figure A.3
HASPA Sea Level Rise Study

National Research Council (1987) Global Sea Level Rise Scenarios

PWA Ref# 1955.00

APPENDIX B

REGULATORY COMPLIANCE PROCESS

REGULATORY COMPLIANCE PROCESS

The following is a typical regulatory compliance process for an estuarine shore project. The project has been split into a number of phases:

1. CEQA DOCUMENTATION
2 PROJECT PERMIT APPLICATIONS AND NEGOTIATIONS
3 FINAL PLANNING PROCESS

The CEQA document is presumed to be an EIR. It is assumed the USACE would prepare the NEPA document, if required. If this assumption proves incorrect, the steps necessary to prepare a NEPA document (an EA or EIS) would be added. Data collection would extend to those environmental factors not previously studied, but are necessary for compliance with CEQA.

1. CEQA DOCUMENTATION

1.1. Task 1 Data Collection

a. Collect and review background information.
b. Conduct preliminary field reconnaissance surveys for various environmental issues, such as cultural resources, land use, etc.
c. Provide an initial list of additional data needs including a brief description of how each data gap would affect the EIR analysis and schedule.
d. Develop a schedule for filling in data gaps (if necessary)
e. Review data gaps and schedule.
f. Conduct protocol surveys and further investigations (e.g., cultural resources, aesthetics/visual, land use, geological, recreational, traffic, etc).
g. Prepare draft reports on surveys/investigations.
h. Review draft reports and submit comments.
i. Prepare final reports on surveys/investigations.

1.2. CEQA Initial Study/NOP

a. Prepare preliminary draft project description.
b. Review draft project description.
c. Prepare draft final project description.
d. Prepare draft Notice of Preparation (NOP), Initial Study and Checklist.
e. Review draft NOP, Initial Study and Checklist.
f. Prepare final NOP, Initial Study, and Checklist copies.
g. Prepare mailing list and state clearinghouse form.
h. Submit final NOP, Initial Study, and Checklist copies to state clearinghouse, agencies and interested public for public review.
i. 30-day public review period.

j. Convene one public meeting during 30-day public review period and arrange for space. Present project.
k. Prepare presentation materials for public meeting; prepare draft notes of public meeting.
l. Client to review draft notes.
m. Finalize notes.

1.3. Administrative DEIR
a. Review responses to NOP
b. Develop final project description.
c. Prepare Administrative DEIR.
d. Review administrative DEIR.

1.4. Preliminary DEIR
a. Revise administrative DEIR and submit Preliminary DEIR.
b. Review preliminary DEIR.

1.5. Screencheck DEIR/Public Review DEIR
a. Revise preliminary DEIR and submit screencheck DEIR.
b. Review screencheck DEIR.
c. Prepare mailing list and state clearinghouse form.
d. Prepare public review DEIR.
e. Submit public review DEIR copies to state clearinghouse, agencies and interested public for public review.
f. 45-day public review period.
g. Convene one public meeting during 45-day public review period and arrange for space. Present project. Arrange for court reporter.
h. Prepare presentation materials for public meeting; prepare draft notes of public meeting.
i. Review draft notes.
j. Finalize notes.
k. Court reporter to prepare transcript.

1.6. Administrative FEIR
a. Review comments to public review DEIR.
b. Discuss comments and proposed responses.
c. Prepare draft responses to comments, changed text, and mitigation and monitoring reporting plan (MMRP).
d. Review draft responses to comments, changed text, and MMRP.

1.7. Preliminary FEIR
a. Revise administrative FEIR and submit Preliminary FEIR.

b. Review preliminary FEIR.

1.8. Screencheck FEIR/FEIR

a. Revise preliminary FEIR and submit screencheck FEIR.
b. Review screencheck FEIR.
c. Prepare mailing list and state clearinghouse form.
d. Prepare FEIR.
e. Submit FEIR copies to state clearinghouse, and those agencies and public that commented on the DEIR 10 days prior to certification.

1.9. Certification of FEIR

a. Prepare draft findings and statement of overriding considerations for Client.
b. Prepare Notice of Determination (NOD) for Client.
c. Prepare final findings and statement of overriding considerations.
d. Certify FEIR.
e. File NOD along with County and California Department of Fish and Game (CDFG) filing fees.

2. PROJECT PERMIT APPLICATIONS AND NEGOTIATIONS

2.1. Biological Reports/Studies

a. Prepare preliminary draft biological assessment (BA).
b. Review preliminary draft BA.
c. Prepare final draft BA and submit to USACE and USFWS (and NMFS if necessary).
d. Conduct field meeting with USACE and USFWS.
e. USACE and USFWS submit comments on final draft BA.
f. Review comments.
g. Revise and submit final BA.
h. USFWS issues biological opinion (BO).

2.2. Wetland Delineation

a. Conduct wetland delineation and prepare preliminary draft report.
b. Client review preliminary draft report.
c. Revise preliminary wetland delineation and submit draft report to the USACE.
d. Conduct field review of delineated area with USACE.
e. Revise draft report based on USACE comments and submit final report.
f. USACE issues verification of jurisdictional determination.

2.3. Applications

a. Attend a pre-application meeting.

b. Prepare draft applications for the USACE (assuming the project will require an individual permit), a CDFG Streambed Alteration Notification, and a Regional Water Quality Control Board (RWQCB) Report of Waste Discharge for Waste Discharge Requirements (WDR) and National Pollutant Discharge Elimination System (NPDES) permits.
c. Client to review draft applications.
d. Revise and submit draft applications to aforementioned agencies.
e. Conduct field meeting with USACE, CDFG, and RWQCB.
f. Receive comments on draft applications.
g. Revise and submit final applications.

2.4. Section 106 Inventory/Evaluation Report

a. Establish area of potential effect (APE)
b. Submit APE to USACE for review and submittal to the State Historic Preservation Office (SHPO) for verification
c. Conduct cultural resources studies in accordance with Section 106 guidelines
d. Review preliminary draft cultural resources report.
e. Conduct Native American consultation via the Native American Heritage Commission (NAHC)
f. Revise and submit draft Section 106 inventory/evaluation report to USACE and SHPO.
g. Meet with USACE and SHPO.
h. Revise and resubmit Section 106 inventory/evaluation report.
i. Prepare archaeological research design/treatment plan (ARD/TP)
j. Prepare administrative draft memorandum of understanding (MOU).
k. Review administrative draft MOU.
l. Revise and submit draft MOU to USACE/SHPO.
m. Revise and submit final MOU to USACE/SHPO.

2.5. Additional Products

a. Prepare an administrative draft alternative analysis and determine least environmentally damaging practicable alternative (LEDPA) per Section 404(b)(1) Guidelines.
b. Review alternatives analysis and LEDPA.
c. Revise and submit alternatives analysis and LEDPA to USACE.
d. Prepare administrative draft Integrated Biological Resources Mitigation and Monitoring Program (IBRMMP).
e. Review administrative draft IBRMMP.
f. Revise and submit draft IBRMMP.
g. Meet with USACE, CDFG, USFWS, and RWQCB to discuss IBRMMP.
h. Meet with Client to discuss agency meeting outcome.
i. Revise and resubmit IBRMMP to agencies.

3. FINAL PLANNING PROCESS

3.1. /NEPA process

3.2. Complete property-related tasks (easements/land ownership/etc)

3.3. Apply for FEMA flood map revision

3.4. Secure funding for construction