Section IV: Vulnerability from Sea Level Rise and Extreme Events

March 2012

Purpose

The purpose of this section of the *Guidance* document is to assist grantees and Conservancy staff in understanding and applying the Conservancy's adopted *Climate Change Policy* and *Project Selection Criteria* related to sea level rise and extreme events. The sea level rise policy and project selection criteria are intended to ensure that Conservancy-funded projects located in areas subject to future sea level rise are designed and sited to minimize damage from hazards, to protect habitats to the extent practical, and to avoid inadvertent impacts to natural resources or infrastructure. To this end, the guidance provides a process for assessing these impacts and vulnerabilities, and describes design and adaptive management measures that can be taken to reduce the risks.

Approach

For projects located along or in close proximity to the shoreline, the Conservancy will use a risk analysis approach to evaluate the ability of proposed projects to adapt or cope with projected ranges of sea level rise over time. A key component of the risk analysis is a vulnerability assessment. The Conservancy staff can help you determine whether an assessment is needed, and what level of detail you should be basing the vulnerability assessment on. We highly recommend that you contact Conservancy staff before undertaking this assessment as we may be able to provide you with technical services to identify:

1. Potential threats from sea level rise and extreme events;
2. How to incorporate needed risk reduction measures;
3. Whether remaining risks, if any, are acceptable and outweighed by the project benefits; and,
4. Potential modifications to the project design or adaptive management strategies to incorporate in order to reduce risks and ensure project benefits during the anticipated lifetime of the proposed project.

A risk analysis will help establish whether the changing conditions under a warming climate are likely to reduce the utility and sustainability of your project over its normal expected time period. When a project's sustainability is expected to be lessened due to sea-level rise and extreme events, the Conservancy will conduct an analysis of project benefits to determine whether the project objectives provide enough significant benefits and values in the short or medium term that it remains a high priority for Conservancy funding. For example, a high priced public accessway with a medium term life span may provide sufficient benefits if located in an area of high need and expected public use. A salt marsh restoration project that may not be sustainable beyond the mid-term may incorporate project design features that provide for habitat evolution that results in other significant functions and values over time (*e.g.* shallow water habitat and carbon sequestration from submerged salt marsh sediments), and therefore may still be a high priority for Conservancy funding.

The other reason to contact the Conservancy early about your potential project is that State agencies and non-state entities implementing projects funded by the state are now urged (by the Ocean Protection Council's adopted Sea Level Rise Resolution) to coordinate amongst themselves when selecting values of sea level rise, with agency discretion to use higher projections and apply a safety factor as necessary.
The Conservancy can provide you assistance in coordinating with other agencies regarding the projections of sea level rise, thereby potentially streamlining the evaluation and review process of agencies that have permit authority for your project.

Conservancy's Policy and Project Selection Criteria

The Conservancy's *Climate Change Policy* identifies significant vulnerabilities to coastal resources as a result of sea level rise and climate driven processes and includes the following specific policy related to sea level rise and extreme events:

> **Sea Level Rise and Extreme Events:** The Conservancy will consider flooding and erosion due to sea-level rise, and extreme events such as tsunamis in assessing project vulnerability and, to the extent feasible, reduce expected risks and increase adaptive capacity using current scientific information and state guidance documents.

Similarly, the Conservancy's Project Selection Criteria includes the following required criterion:

> **Sea Level Rise Vulnerability** Consistent with Executive Order S-13-08, for new projects located in areas vulnerable to future sea level rise, planning shall consider a range of sea-level rise scenarios in order to assess project vulnerability and, to the extent feasible, reduce expected risks and increase resiliency to sea level rise.

Suggested Steps to Evaluate and Address Vulnerability to Sea Level Rise and Extreme Events

The scope and level of detail of the vulnerability analysis for each project will depend upon the project type, location, size, and cost, the stage of the project, the potential consequences of sea level rise and extreme events, and the availability of existing information about potential vulnerabilities at your project location. Conservancy staff will be best able to assist you in conducting this analysis if you contact us early in the project's planning and design process.

Some or all of the needed vulnerability analysis may already be completed as part of the CEQA or NEPA evaluation of the project. The CEQA initial checklist, Appendix G to the *CEQA Guidelines*, requires an assessment of the risk of loss, injury or death involving flooding (Item IX (i)) for non-exempt projects. Similarly, recent guidance by the Council on Environmental Quality states that climate change effects should be considered in the analysis of projects that are designed for long-term utility and located in areas that are considered vulnerable to specific effects of climate.[1] Where a negative declaration or environmental impact report will be developed in relation to the project, the environmental document should address the issue of sea level rise if it is identified as having a potential for significant environmental effect.

Step 1: Initial Assessment

Is your proposed project vulnerable to sea level rise or associated impacts of coastal flooding or erosion?

As a basic first step to determining whether your project is vulnerable to sea level rise and extreme events, we recommend that you consult currently available maps to determine whether your project site is located within an area that has been shown in a simplistic assessment to be vulnerable to future inundation or erosion. As you consult these maps and reports, keep in mind that these documents provide estimates based on many assumptions,[2] and that site-specific vulnerability will be influenced by factors such as:

1. Local trends for land uplift or subsidence (due to seismic activity, groundwater withdrawals, etc.), which affect the local relative sea level change;
2. Local geology (*e.g.* how erosive are the surrounding landforms?);
3. Projections for extreme events/storm impacts;
4. Topography of land surrounding the project site; and
5. Location, condition and design of existing or proposed sea level rise adaptation measures, such as setbacks from shorelines, structural shoreline protection, use of wetlands to buffer storm impacts, etc.

The following is a description of some of the online maps that can offer a quick assessment of your project's vulnerability to sea level rise:

> Pacific Institute Maps
> These maps were funded by the State of California to provide basic information on areas that may be at risk from a 100-year coastal flood event currently or with a 55-inch (1.4 meter) sea level rise (the average SLR projection for the year 2100). For Northern and Central California, the maps also show an estimate of the inland extent of coastal erosion in 2100. Note that these maps have a number of limitations and are not intended to serve as a comprehensive indication of vulnerability to sea level rise. They provide a useful initial indication of the need to further evaluate sea level rise for different locations.
> http://www.pacinst.org/reports/sea_level_rise/maps/

[1] CEQ, *Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions* (2010, to be finalized soon), available at http://ceq.hss.doe.gov/nepa/regs/Consideration_of_Effects_of_GHG_Draft_NEPA_Guidance_FINAL_02182010.pdf.

[2] Inundation maps or "bathtub models" can offer a superficial idea of the potential exposure to risks from SLR. These maps are usually created by simulating flooding of a particular sea-level elevation over the digital elevation model of an area (often with aerial photography superimposed) to depict areas that will be slowly inundated by a given rate of SLR. But such maps should be used with a great deal of caution since inundation maps do not account for storm surge, storm waves, beach and bluff erosion, sediment budgets, subsidence, topography and coastal geology, and other components of coastal processes.

Tsunami Inundation Maps
It is anticipated that sea level rise will exacerbate tsunami inundation at some locations. Therefore, it is important to assess if your project is in an area subject to tsunamis. The California Emergency Management Agency and California Geological Survey produced these maps for local jurisdictional and coastal evacuation planning uses, but they can provide a basic indication of whether your project site is located in an area subject to flooding from a tsunami. These maps were created without consideration of sea level rise.
http://www.consrv.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Statewide_Maps.aspx

FEMA Flood Maps
The current FEMA flood maps can provide a general indication of proximity to areas historically vulnerable to flooding. They do not currently incorporate consideration of SLR and changes in frequency and intensity of storms that are being observed as a result of climate change, but at the initial assessment stage you can presume that bay and coastal areas now vulnerable to flooding are likely to be increasingly vulnerable as sea level rises.
https://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1

Local or Regional Maps
Refer to the local or regional maps listed in Appendix VI.3, or consult with Conservancy staff on the availability of local maps that may assist in your initial assessment of SLR for your project area.

Step 2: More Comprehensive Assessment of Vulnerability

If your initial assessment indicates that your project is located in an area vulnerable to future flooding or other sea level rise associated impacts, we encourage you to complete a more comprehensive vulnerability assessment. A description of specific steps to be taken to complete a more detailed assessment are described below, but for additional information, see *Section III: (Adaptive Management)* of this *Guidance*, which provides a framework for conducting vulnerability and risk assessments, and *Appendix VI.3* which describes additional key resources pertaining to conducting comprehensive assessments. Two of these resources include *Adapting to Sea Level Rise: A Guide for California's Coastal Communities*, which is intended to assist local governments in completing vulnerability assessments and adaptation plans, and Technical Considerations for Use of Geospatial Data in Sea Level Change Mapping and Assessment (NOAA NOS September 2010).

Recommended Steps and Important Considerations to Complete a Vulnerability Assessment Using the Best Available Science:

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STEP 2A: Sea Level Rise Projections: In most cases, we recommend that you use the sea-level rise projections in the table below (which represent the current state guidance[3]), as a basis for conducting your vulnerability assessment.

Table 1. Sea Level Rise Projections using 2000 as the Baseline

Type of Project	Year	Risk	Sea Level Rise Range Projections
Minimum for all projects	**2030**		5-8 in (13-21 cm)
	2050		10-17 in (26-43 cm)
	2070	**Low**	17-27 in (43-70 cm)
		Medium	18-29 in (46-74 cm)
		High	20-32 in (51-81 cm)
Acquisitions	**2100**	**Low**	31-50 in (78-128 cm)
		Medium	37-60 in (95-152 cm)
		High	43-69 in (110-176 cm)

The time horizon that you should apply for a particular project will depend on the project's objectives, type, and its life span. For example:

- Projects that involve construction of substantial improvements, such as environmental education facilities, piers, or other normally long-lasting materials should consider a long lifespan (e.g. 50 years).
- Trails constructed of gravel, dirt or other soft materials would normally be expected to have a lifespan of 30 years.
- Habitat restoration projects are distinctive in that the habitats we seek to establish are created over time as a result of dynamic responses to changing environmental conditions. Identifying the likely ecological processes and functions over different time periods (e.g. 2030, 2050 and 2100) will help to ascertain whether your project objectives are attainable. Out of necessity, project objectives and functions may change over time. We recommend considering how to design and adaptively manage the project to support processes and species movements that will continue to achieve project objectives for as long of a period of time as possible (*e.g.* support biodiversity by removing barriers to migration of species to higher elevations).

Once you have determined which time horizon to use, we recommend incorporating both the high and low range of the sea level rise projections in your project's vulnerability assessment. These projections represent ranges that were recommended by experts based on recent modeling, but do not account for many factors, such as extreme events, that could result in even greater amounts of sea-level rise. Therefore, we recommend that you focus your analysis on the upper end of the range of projections[4] if your project is:

[3] State of California Sea-Level Rise Interim Guidance Document (refer to Appendix 3).
[4] Refer to the Interim Guidance Document in Appendix VI.3 for discussion of consequences, adaptive capacity and risk.

1. Expensive (*e.g.* greater than $1 million);
2. Involves high consequences to human health and safety, endangered species, or high populations of wildlife;
3. Involves releases of hazardous materials if flooded or damaged from inundation or erosion; or
4. Has a low adaptive capacity.

If damage to your project from sea level rise or extreme events would have exceptionally high consequences (including possible loss of significant public funds), your evaluation of impacts should include a scenario of an additional 20% added to the upper limit of predicted sea level rise for the project's time horizon.

STEP 2B: NOAA Sea Level Rise and Coastal Inundation Impacts Viewer. NOAA is processing new and previously generated high resolution maps (LIDAR data) to include all of California's coastal and bay regions in the Sea Level Rise and Coastal Inundation Impacts Viewer. This tool will enable users to visualize inundation under various levels of SLR. Information on CA is expected to be available in fall of 2012, with the Bay Area available in summer of 2012.

a. Go to the NOAA Sea Level Rise and Coastal Inundation Impacts Viewer website at http://www.csc.noaa.gov/digitalcoast/tools/slrviewer/index.html and save a copy of the maps of your project location using SLR values that are closest to the endpoints of the range of SLR values that you selected in Step 2A. (The tool currently only allows you to select SLR values based on whole numbers between 1-6 feet.) Include copies of these maps with your Conservancy grant application.

STEP 2C: Local Relative Sea Level Trends. Relative sea level is the sea level relative to the elevation of the land. In California, the land elevation along the coast is changing due to factors including tectonic activity and subsidence. See below for a table of trends in mean sea level (MSL Trend) for tidal gauge (water level recorder) data up to 2006[5].

Station Location	**Mean Sea Level Trend (mm/yr)**	**95% confidence Interval (mm/yr)**
North Spit	4.73	+/- 1.58
Rincon Island	3.22	+/- 1.66
Newport Beach	2.22	+/- 1.04
Point Reyes	2.10	+/- 1.52
La Jolla	2.07	+/-0.29
Port Chicago	2.08	+/- 2.74
Redwood City	2.06	+/- 3.12

[5]For a more detailed explanation of these trends, refer to this website: http://tidesandcurrents.noaa.gov/sltrends/index.shtml.

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San Diego	2.06	+/- 0.20
San Francisco	2.01	+/- 0.21
Santa Monica	1.46	+/- 0.40
Monterey	1.34	+/- 1.35
Santa Barbara	1.25	+/- 1.82
Los Angeles	0.83	+/- 0.27
Alameda	0.82	+/- 0.51
Port San Luis	0.79	+/- 0.48
Crescent City	-0.65	+/- 0.36

a. Identify which of the above locations is closest to your project and include the information on the local relative mean sea level trend in your response to Question #11. Note any information available on whether the project location is subsiding or subject to uplift and whether the local relative trend in mean sea level indicates that your project site may be more or less susceptible to SLR.

<u>STEP 2D: Addressing Impacts from Storms.</u> *The CO-CAT Interim Guidance Document* includes the following recommendation regarding consideration of the impacts from storms and other extreme events:

> Future sea level will be a starting point for many different types of analysis for project design. For example, in determining wave impacts, future mean sea level combined with tides, storm surge and El Niño-Southern Oscillation forcing will establish the elevated water level that will be the input for determining wave forces and wave run-up. Where feasible, consideration should be given to the extreme oceanographic conditions that can occur, given the highest water levels projected to result from SLR over the expected life of a project.

Information on changes to your project area from past storm events can help to provide information on likely future flooding and shoreline change.

a. Refer to Appendix VI.3 for references on inventories of impacts and damage from El Nino events in 1978, 1983 and 1997-98 (California Coastal Commission, 1978; Domurat, 1978; Swisher, 1983; Griggs and Johnson, 1983; Seymour, 1998; Storlazzi and Griggs, 1998). As part of your response to Question #11, include information on past impacts from storms to your project vicinity.

b. Include copies of any local historic photographs, maps and other information on these past storm events that can help provide information on vulnerability to storm events and include a summary of this information in your response to Question #11.

<u>STEP 2E: Shoreline Change</u> As part of a more comprehensive assessment of SLR, it is important to use the references listed below or other local sources of information to consider changes to the shoreline (erosion or accretion). Refer to *Adapting to Sea Level Rise: A Guide for California's Coastal Communities* (see Appendix VI.3) for recommendations on conducting shoreline change assessments.

a. Look up your project location in one the relevant following reports and provide information on shoreline change in Question 11 of the Conservancy's application: U.S. Geological Survey report on shoreline changes for California's beach habitat[6] http://pubs.usgs.gov/of/2006/1219/, and U.S. Geological Survey report on shoreline changes for California's bluff habitat[7] http://pubs.usgs.gov/of/2007/1133/.

b. Consult *Living with the Changing California Coast* (See Griggs et. al, 2006 in Appendix VI.3), and include a copy of the hazard maps for your project region, and note the historic erosion rate where available and regional descriptive information.

c. (Optional) Consult the database on coastal armoring and historic erosion rates that is available through the California Coastal Commission (see Dare, 2005 in Appendix VI.3) and include information in your response to Question #11.

STEP 2F: Other Sea Level Rise Impacts. Although flooding and erosion will be the main impacts from SLR to Conservancy-funded projects, rarely SLR will also cause other types of impacts that should be considered. For example, consider whether the project objectives will be vulnerable due to saltwater intrusion (*e.g.* making water supplies too saline for existing riparian vegetation or for continued irrigation of agriculture), changes in salinity regimes (*e.g.* converting a brackish marsh into a more saline marsh) or increased intertidal ranges (*e.g.* stressing species such as eelgrass).

a. As part of your response for Question #11, identify whether your project may be vulnerable to impacts from SLR other than flooding and erosion.

b. Consult with Conservancy staff to help identify local experts and look for relevant studies through the search function on www.climatechange.ca.gov. Include a description of the impact as part of your response to Question #11.

Reducing Risks and Increasing Adaptive Capacity

There are many ways that a project can be designed to reduce risks from climate change or increase the project's ability to cope with or adapt to those impacts. As you design your proposed project, we recommend that you evaluate options for increasing the adaptive capacity of the project in order to achieve the project objectives over time as the climate changes. For example, consider whether the project could be located further inland or whether a trail corridor could be widened to allow for inland migration.
The *CO-CAT Interim Guidance Document* (Appendix VI.3) describes adaptive capacity as follows:

[6] Cheryl Hapke et. al, *National Assessment of Shoreline Change Part 3: Historical Shoreline Change and Associated Coastal Land Loss along Sandy Shorelines of the California Coast* (U.S. Geological Survey Open File Report 2006-1219, 2006).
[7] Cheryl Hapke et. al, *National Assessment of Shoreline Change Part 4: Historical coastal cliff retreat along the California coast* (U.S Geological Survey Open File Report 2007-1133, 2007).

> *Adaptive capacity* is the ability of a system to respond to climate change, to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.[8] A project that has high adaptive capacity and/or low potential impacts will experience fewer consequences. For example, an unpaved trail built within a rolling easement with space to retreat has high adaptive capacity (because the trail can be relocated as sea level rises) and therefore will experience fewer harmful consequences. In contrast, a new wastewater treatment facility located on a shoreline with no space to relocate inland has low adaptive capacity and high potential impacts from flooding (related to public health and safety, public investments, and the environment). The negative consequences for such a project of failing to consider SLR would therefore be high.

Examples of projects that the Conservancy funds that would have low adaptive capacity include environmental education and rest room facilities that cannot be easily relocated and are not designed to withstand flooding.

The *2009 California Climate Adaptation Strategy* presents guiding principles and many recommendations regarding adaptation strategies and actions. We recommend that you consult the "Ocean and Coastal Resources" chapter and follow the recommendations in designing your project, including an adaptive management approach, if relevant (see Section III of this Climate Change Guidance for a discussion of adaptive management). The Conservancy staff will support applicants in seeking funding from other sources to conduct monitoring and adaptive management.

The Conservancy will continue to support projects that are identified as high priority in our strategic plan and other policy documents, and that meet our statutory requirements, and we will work with applicants to identify adaptive management approaches to maximize their resiliency in the changing environment. We encourage you to explore options for adapting to a range of possible future SLR scenarios, since we cannot know for certain how quickly SLR will change relative to land elevations at the proposed project location.

As part of your response to Question #11 in the Conservancy's grant application, please provide a description of the adaptive capacity of the proposed project. Include an evaluation of the ability of the project objectives to continue to be met given a range of SLR and describe adaptive management approaches. If you've already done an analysis on adaptive management and monitoring, please include this information. We recommend that you refer to Section V, Vulnerability from Other Climate Change Impacts for assistance in developing and implementing climate change adaptation strategies.

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[8] Definition of adaptive capacity used in the 2*009 California Climate Adaptation Strategy*, based upon definition provided in *Climate Adaptation: Risk, Uncertainty and Decision-making*, UK CIP (2003), UKCIP Technical Report, Oxford, Willows, R. I. and R. K. Cornell (eds.).

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Adaptation Options

The following section presents information on sea level rise adaptation that is relevant for specific types of projects that the Conservancy funds. Consult the bibliography in Appendix VI.5 for additional resources and information.

Managed Retreat

One adaptation option that over time will become more important, yet challenging to implement, is managed retreat. Managed retreat includes a number of potential tools and approaches to ensure that the coastline can evolve and function naturally in the face of climate impacts. It may involve relocating structures and other improvements out of harm's way, promoting restoration of natural shoreline features and processes, or allowing flooding or tidal action into areas that are currently dry, such as engineered levee breaches to allow marsh migration into upland areas.

The Conservancy's Climate Change Policy encourages innovative projects that would relocate development or infrastructure inland from an area likely to be affected by flooding, as well as ones that would remove development as hazards encroach into a developed area. Several tools are available to relocate or remove at-risk structures. These include:

1. Acquisition of a future interest in adjacent land, conservation easement, deed restriction or negative easement that acknowledges the right to move inland to some point with sea level rise;
2. Acquiring of upland development rights;
3. Working with willing owners to buy and demolish existing development;
4. Designing new structures so they could be easily moved or relocated; and
5. Requiring new projects to agree to remove or retire the structure or improvement at the end of their prescribed economic life, or setting zoning restrictions which discourage any new development in the hazardous area.

Another approach that may be implemented at the local level involves expanding the horizons of local land use planning to incorporate climate projections for the next 30, 50 or 100 years. This would involve limiting future development in areas that are at risk from sea-level rise and coastal erosion. As an example, setback zones could be established to promote natural flood protection or allow wetlands, estuaries or beaches to migrate inland as the sea rises.

As Gary Griggs and his colleagues have noted, "Anticipating the consequences of sea-level rise now is likely to preserve more natural shorelines than reacting later, because once an area is developed it is too late, and even rolling easements require a lead time of a few decades to be effective" (Griggs, Patsch and Savoy 2005).

The Conservancy has already funded construction of some demonstration projects (*e.g.* Surfer's Point in Ventura and Pacifica State Beach/Linda Mar in Pacifica) involving managed retreat where there were significant public access and habitat benefits. These projects provide useful examples of what can be done to address the hazards and damage associated with sea level rise using methods that preserve natural processes.

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Surfer's Point, below, is located near the Ventura Pier. It is a popular surfing beach and recreational destination that was experiencing severe beach erosion. The project involved a 10-year collaborative effort to design public improvements that would remain sustainable as the ocean levels rises. Construction of the project's Phase One has been completed, and the recreational improvements are experiencing extensive public usage. When the remaining phases are constructed, the project accomplishments will include: a parking area and bike path relocated 60-100 feet inland; natural systems and engineering solutions that treat and improve storm water quality; permeable parking areas constructed from recycled asphalt and concrete; creation of a flexible structure constructed of 40,000 cubic yards of river cobble placed above the beach to withstand scour; a multi-use path; restored dune habitat; and an oceanfront park area. More information on this project can be obtained from the City of Buenaventura or www.rrmdesign.com.

Ribbon Cutting Ceremony - July 2011

Planning for restoration and managed retreat at **Pacifica/ Linda Mar State Beach** in the City of Pacifica began in 1989. Flooding and coastal erosion had been a recurring problem at the mouth of San Pedro Creek for decades. Structural stabilization techniques, including dirt berms and rip rap failed to mitigate these hazards, resulting in damage to nearby houses and critical infrastructure.

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(Linda Mar State Beach before project implementation, showing creek mouth and houses on beach that were removed)

The Pacifica State Beach Master Plan included a managed retreat strategy, involving removal of two residential structures and installation of soft stabilization techniques to reduce flooding threats, preserve the beach, and improve steelhead habitat. The plan was implemented through a partnership of agencies, the City of Pacifica, community groups, scientists and engineers (much of the design was developed by Phil Williams and Associates). It involved purchasing and removing two homes, rebuilding the degraded sand dunes, utilizing soft stabilization techniques, and restoring the beach, creek banks, and tidally-influenced wetland. The project resulted in a reduction of flood hazards, enhanced steelhead habitat, expanded recreational opportunities and a restored functioning wetland.

(Linda Mar State Beach in 2009 after houses removed and natural features restored)

Shoreline Protection

The Conservancy strongly discourages any coastal project that would require the construction or long-term maintenance of a seawall, riprap revetment or other coastal armoring and would fund such a project only in extraordinary circumstances. Where feasible, the Conservancy's climate change policies encourage the use of *living shoreline projects* which restore and enhance nearshore and tidal habitats such as tidal wetlands, eelgrass and native oysters, to promote sedimentation and protect against shoreline erosion.

Conservancy-funded projects should incorporate living shorelines and other soft solutions to shoreline protection where feasible, or incorporate other design features to increase adaptive capacity (such as set-backs). Soft measures could include dune restoration and recreation, re-vegetation with dune grasses, marsh creation and planting, and installation of submerged aquatic vegetation. Along shorelines that can support it, marsh and transitional upland vegetation can help dampen wave energy, incorporate natural habitat, and maintain tidal wetland functions. An ambitious, comprehensive project along the Chesapeake Bay, for example, has created a 'living shoreline' of marshes at 300 fringe sites to control erosion and reduce land lost to sea level rise. The marshes were created with sand fill and stabilized through the planting of marsh grasses and the use of soils, stones, gravels, and biodegradable protective materials. These nonstructural solutions create a vegetative buffer for the land, improve water quality and provide habitat to many species (US EPA, Synthesis of Adaptation Options for Coastal Areas, 2009).

Closer to home, the Conservancy has participated in funding the development of a **Master Plan for Ocean Beach**, a five-mile long urban beach currently suffering from erosion (in the south reach) and a lack of public amenities. The draft plan recommendations, presented to stakeholders in October of 2011, address major issues and processes at Ocean Beach including climate change and sea level rise; erosion; natural resources protection; public access and recreation; vehicular, bicycle, and pedestrian access and circulation; and implementation, management and maintenance. The key recommendations include re-routing and reducing the width of the Great Highway at specific locations, improving sand nourishment and management, using cobble berms covered by sand to dissipate wavers and protect infrastructure, dune restoration, and improving visitor amenities including new trails, low-impact sand ladders and modular boardwalks. The report recommendations state that the design assumptions will need to be revisited in 2030, and that additional adaptation measures may be required at that time.

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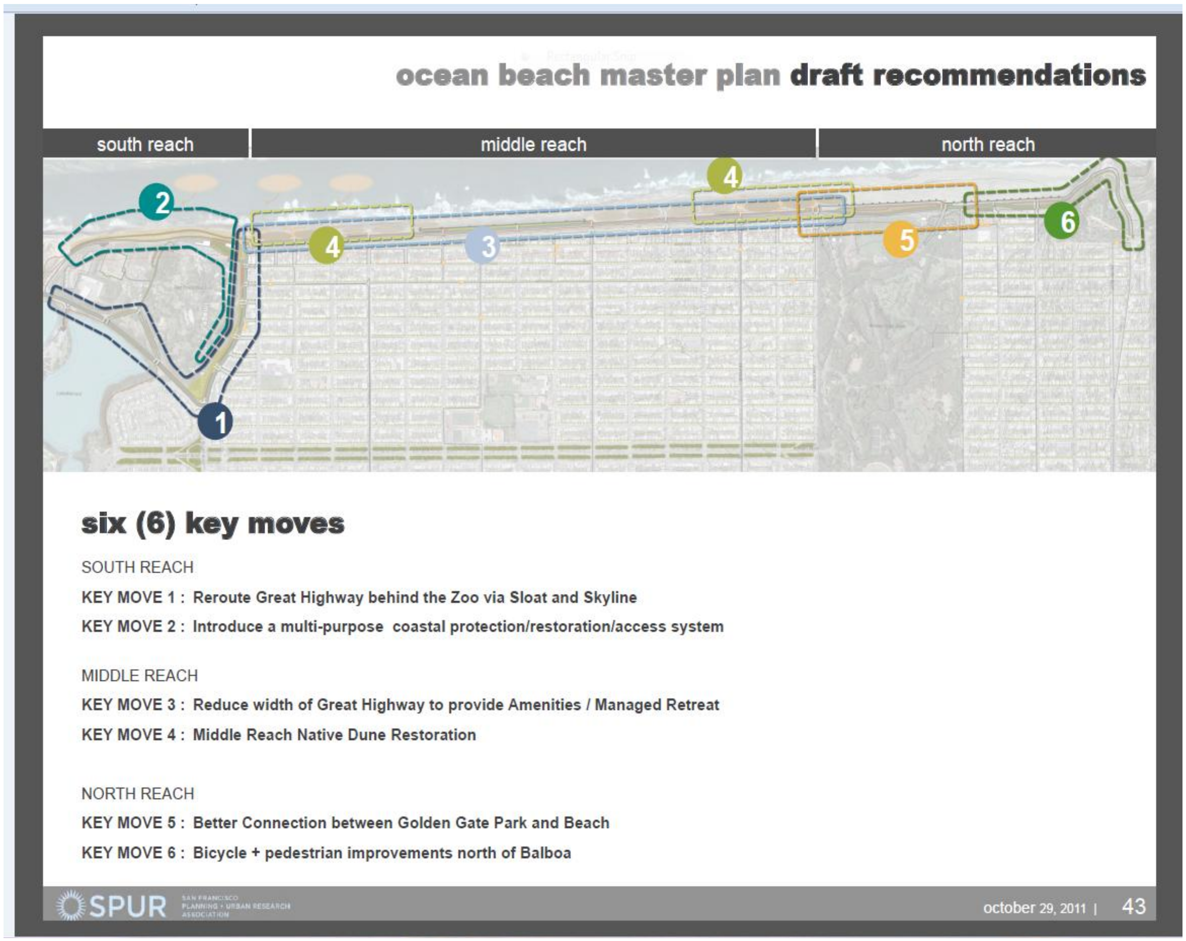
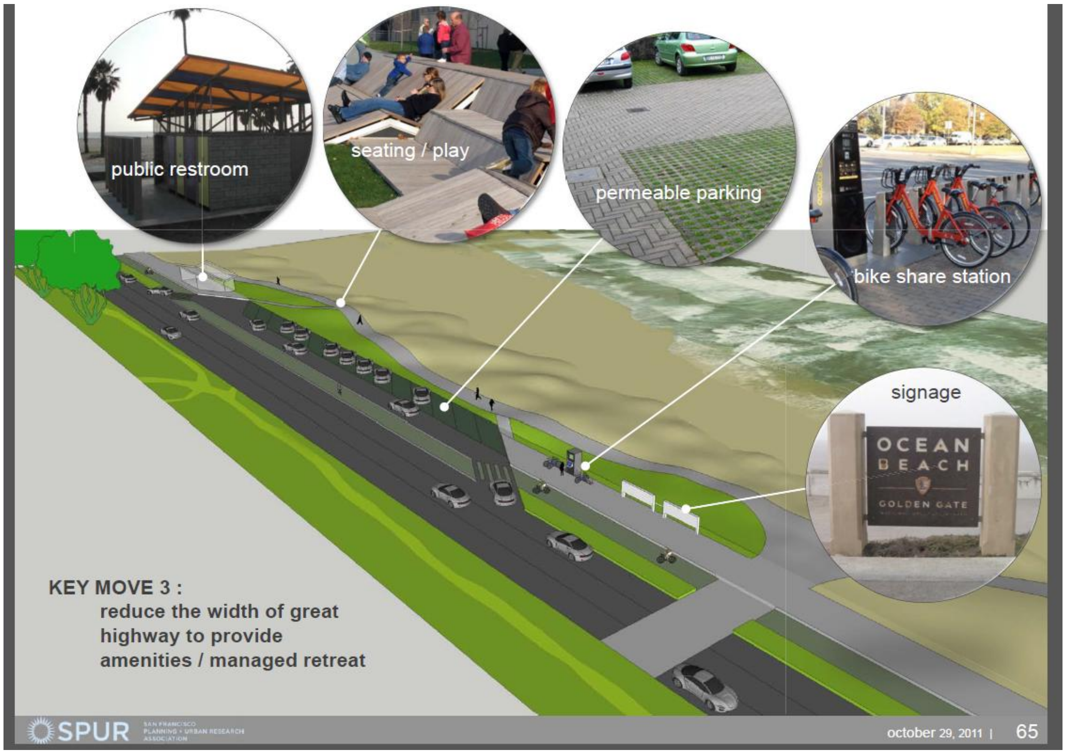


<u>Trails, Public Access and Infrastructure Projects</u>

In general, all public access and infrastructure projects seeking a Conservancy grant should be sited, designed, managed and maintained to avoid significant adverse impacts from sea level rise, coastal erosion and shoreline flooding. New trail, recreational facility and other infrastructure projects along the coast should be set back above the calculated 100-year flood level and be specifically designed to tolerate sea level rise, coastal erosion, and other changes in coastal processes.

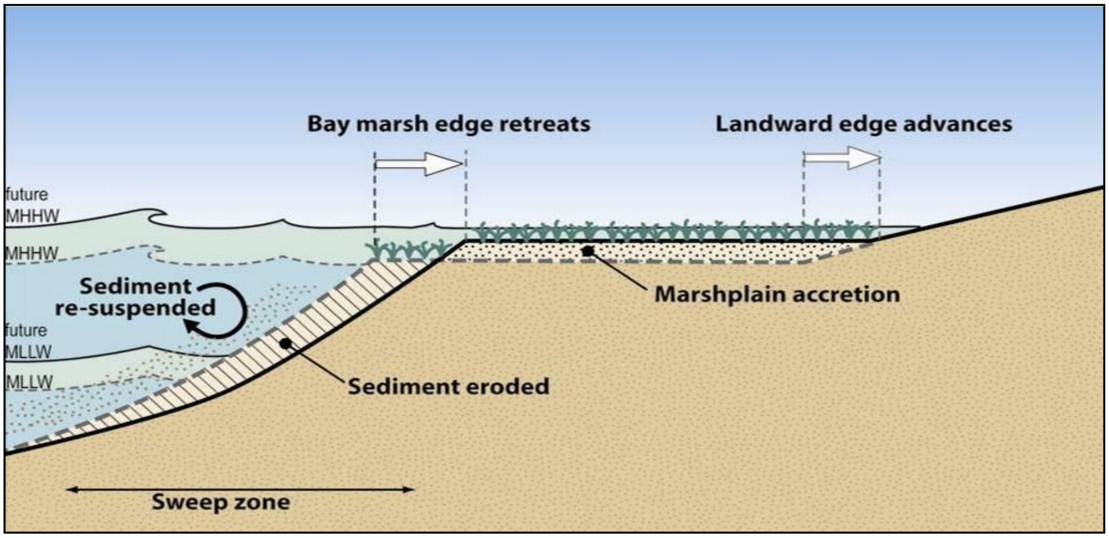
Low-cost public access projects (such as trails) with only a limited probable life span may still be funded if they will serve a significant immediate public need. Infrastructure projects that provide significant public benefits but have limited location options may be funded if you have developed a suitable and implementable plan to relocate the facility over the long term.

The graphic below depicts the benefits that could be realized if the width of the Great Highway along the middle reach of Ocean Beach is reduced from four to two lanes as recommended in the *Draft Ocean Beach Master Plan*. Elimination of the south bound lanes would provide space for dunes restoration and landward migration, along with the addition of many public amenities that in the near-term would be protected from coastal waves and erosion by the restored sand dunes. The Draft Plan assumes it will be necessary to revisit the design assumptions and possibly adapt infrastructure configurations by 2030, and again after 2050 when alternative armoring and land use options may be necessary.



<u>Wetlands</u>

Coastal wetlands will need to migrate landward and upward, and/or accrete sediment at a sufficient rate in order to maintain its size in the face of rising seas. As the illustration below shows, a well established marsh could withstand inundation by migrating landward towards higher elevations.



Phillip Williams & Associates

For this reason, the best long-term strategy for protecting coastal wetlands is to protect their migratory paths and eliminate other barriers to migration. Open space lands that are adjacent and upland of tidal marshes provide habitat to a number of wetland-related species that rely on such areas, and over time will become critical refugia during high tides and extreme storm events. Acquiring purchase options or future interests from willing sellers who own existing low impact developments that surround existing wetlands would allow public agencies to conserve and restore those sites at the end of the useful life of that development.

Recently restored sites will either accumulate enough sediment to build in elevation and develop as a vegetated marsh, or they'll be unable to accumulate enough sediment to reach threshold elevations for plant establishment and remain as un-vegetated mudflats (Callaway, Parker, et al 2007). Since tidal marshes are efficient at trapping sediment, the sooner a marsh is restored with vegetation, the better chance it will have of maintaining the elevation needed to sustain it as the sea level rises.

Marshes may also evolve to more inundation-tolerant plant communities. Increasing the adaptive capacity of a particular tidal wetland to withstand rising sea level will require a site-specific analysis of many physical and biological features. Resource managers should look for opportunities to build up marsh elevations with sediment reuse, and to incorporate other management activities such as small-scale sediment fences, wind and wave barriers, and other features which could maximize sediment retention within restored tidal marshes (Callaway, Parker, et al 2007).

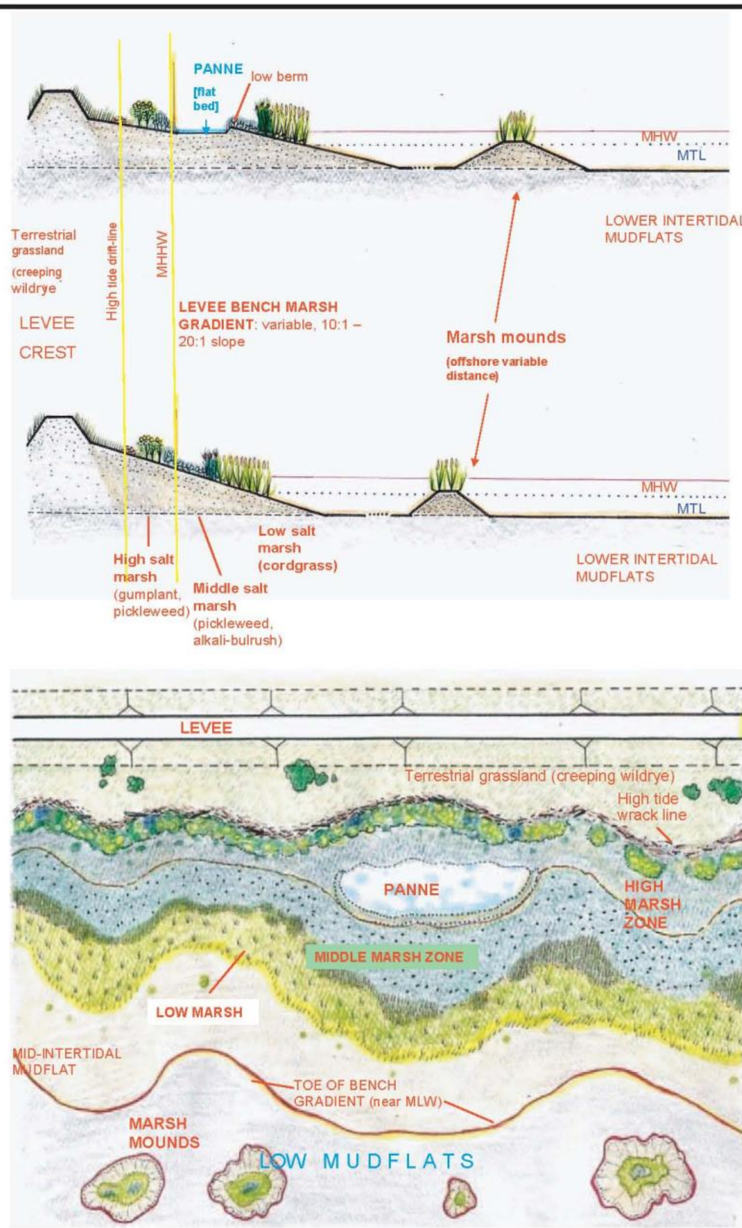
There are several examples of recently designed innovative wetland restoration projects that are testing approaches to address sea level rise. One example is **the South Bay Salt Pond Restoration Project (SBSP Restoration Project)**, which encompasses over 15,000 acres and is the largest tidal wetland restoration project on the West Coast of the United States. The project goals are to restore and enhance wetlands while providing for flood management and wildlife-oriented public access and recreation. A long term restoration plan, adaptive management plan, and environmental compliance documents were completed in 2009. These contain recommendations for adaptive management actions that, when implemented, will narrow the range of uncertainties and encourage restoration success under climate change. Some examples include:

- Project implementation will be phased (especially opening ponds to tidal action) to match the sediment supply.
- Levees will be maintained along the bayfront edge to shelter restored tidal areas from wave energy and encourage marsh formation.
- Levees along the bayfront edge will be removed to restore sustainable mudflats within ponds.
- Restoration of shorelines will use natural materials such as shell breaches and wrack lines
- Imported fill will be used to raise pond beds to elevations conducive to vegetation establishment.
- Prioritizing restoration of less subsided ponds and/or ponds close to sediment supplies within the project area.

The SBSP Restoration Project design was based on a sea level rise sensitivity analysis, using mid and high-end estimated rates. Though more recent models are predicting more rapid and extensive sea-level rise, the project plan and designs manage for this possibility through design measures, phased implementation, monitoring, and adaptive management. A habitat evolution assessment (South Bay Geomorphic Assessment, EIS/EIR, Appendix I) indicates that tidal marshes in the project area should keep pace with rising sea level if sea-level rise matches the lower to mid-range predictions and sediment availability remains high. If higher rates of sea level rise prevail, the timeframe for marsh development is likely to be delayed. Adaptive management efforts would be used to encourage marsh establishment and design features will be incorporated to accommodate accelerated sea level rise. As the drawing below demonstrates, gradually sloping marshes with an upland transition zone will be constructed to provide an elevation gradient over which the tidal marsh could shift and marsh vegetation plantings will be strategically placed to maximize sediment-trapping efficiencies and to enhance the accumulation of organic matter in the developing marsh sediments.

Flood protection for the project area is being designed by the US Army Corps of Engineers. Plans and designs will provide a strategy for accommodating low, mid, and high-end sea level rise projections. Design options being considered include (1) locate and build levees (wider at the base) that will allow for increasing the height if needed, and (2) building a higher levee at the outset. As part of the adaptive management program, sea level rise will be monitored on an on-going basis and updated sea level rise estimates will be used as future phases are designed and implemented.

Another example is the **Sears Point Restoration Project** being implemented by the Sonoma Land Trust. This nearly 1,000-acre tidal marsh project is designed to allow sediment to enter the now-subsided historic tide marsh, and capture it before it flows back to the bay. The project involves creating hundreds of windbreaks in the form of marsh mounds, sidecast ridges and counter levee mounds (see figure below). The mounds will also become islands where plants can take root and trap additional sediment. For more information on this project, go to www.SonomaLandTrust.org.



SONOMA LAND TRUST

WETLANDS AND WATER RESOURCES

HABITAT LEVEE WITH PANNES
TIDAL MARSH ALTERNATIVES
Sears Point Restoration Project
Sonoma County, California
Sonoma Land Trust, Sonoma County, California

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Graphic file: Fig-16_habitat levee with pannes_2007-0225ct.ai