



memorandum

date May 30, 2018

to Bonny O'Connor, AICP

cc Tina Wehrmeister

from James Jackson, PE; Bob Battalio, PE

subject Alternative Adaptation Strategies per Sub-area for Pacifica Sea Level Rise LCP Update

Purpose of this Memo

This memo is an interim deliverable that discusses suggested adaptation strategies to be incorporated into the Draft Adaptation Plan. The alternative adaptation strategies discussed in this memo are considered feasible from an engineering and land use perspective as well as reflect community and Coastal Commission feedback to date and City Council adopted project goals. Community Work Group (CWG) and Technical Work Group (TWG) meetings are scheduled to be held on May 31, 2018 to discuss this memo. The goal of the CWG and TWG meetings is to obtain feedback on identified adaptation strategies before conducting economic and legal analyses and preparing the Draft Adaptation Plan.

It is important to note that the alternatives presented in this memo and the future Adaptation Plan is meant to inform the LCP policies to be developed. These adaptation alternatives are defined through time to enable the cost-benefit analysis, and are dependent on SLR projections from State guidance. In reality, erosion and sea-level rise will not likely behave as modeled for the alternatives analysis. That said, the adaptation alternatives analysis process and results provide an indication of what may be feasible in the future and illuminates the scale of funding that will be needed to adapt.

Background

The City of Pacifica received grant funding from the Coastal Commission and the Coastal Conservancy to update the City's Local Coastal Plan (LCP) pursuant to the California Coastal Act with special emphasis on addressing impacts from climate change and sea level rise. In the 2016 project grant application, the City Council approved several Project Goals regarding sea level rise adaptation planning. On March 26, 2018, the City Council unanimously adopted the following to clarify and formalize the goals for the Draft Local Coastal Land Use Plan Update and Adaptation Planning to clarify and formalize the goals:

1. **Bolster efficacy of public safety efforts.** Evacuations of bluff top homes have been necessary to protect the health, safety, and wellness of residents. The Adaptation Plan will assist the City to protect human life, property, and critical infrastructure in response to a catastrophic event.
2. **Respond to climate change.** The Adaptation Plan will allow Pacifica to prepare for sea level rise and climate change impacts by identifying policies that enhance the coastal zone’s adaptive capacity.
3. **Preserve Existing Neighborhoods and Promote Environmental Justice and Local Economic Vitality.** Pacifica’s Coastal Zone, i.e. the land area west of Highway 1, includes:
 - 12% of the City’s population
 - The majority of older, and therefore more affordable, housing stock
 - Five of six hotels (80% of the rooms) that generate transient occupancy tax revenues for City operations and bring visitors who patronize businesses
 - More than half of commercial businesses, which provide vitality to the community and tax revenue for City operations
 - Public facilities that include City Hall, North Coast County Water District, Ingrid B. Lacy Middle School, the Pacifica Pier, drainage outfalls, waste water pumping stations, sewer force mains, and the Calera Wastewater Treatment Plant
 - Significant historical and public recreational assets including beaches, coastal trails, the Beach Blvd. promenade, parks and golf course.

The loss or disruption of these assets could have far reaching impacts and affect everyone in Pacifica, not just those living or doing business in the Coastal Zone. The Adaptation Plan will allow the city to create policies that will protect these areas from the impacts of sea level rise, erosion, and coastal flooding. Consistent with the Coastal Act, the Adaptation Plan shall protect existing homes, businesses, and infrastructure in Pacifica.

4. **Preserve and enhance coastal access.** Beach and bluff access to the coastline is a crucial element of Pacifica’s coastal character and is valued by the community. The Adaptation Plan will allow the city to identify where bluff erosion, sedimentation, and sea level rise may threaten coastal access.

Since the kickoff of the LCP Update, the City has held several meetings to collect input from various stakeholders regarding the Draft Vulnerability Assessment and the introduction memo for the Draft Adaptation Plan. Table 1 lists the meetings held since the kick-off of the project:

TABLE 1. MEETING SUMMARY

Date	Group	Subject
January 23, 2018	Technical Work Group	Vulnerability Assessment
	Community Work Group	Vulnerability Assessment
February 13, 2018	Public Work Shop	Vulnerability Assessment
April 26, 2018	Public Meeting with CWG	Introduction to Adaptation Strategies
May 10, 2018	Public Meeting with CWG	Economic Analysis Methodology

Amending Pacifica’s Local Coastal Program – 4 Steps

The Coastal Act requires local governments in the State’s Coastal Zone, such as the City of Pacifica, to create and implement LCPs to manage coastal development and protect coastal resources. Pursuant to the California’s Coastal Commission LCP Update Guide (CCC 2013), the City’s LCP should include policies and regulations that ensure new development minimizes risks to life and property in areas of high geologic, flood, and fire hazard consistent with Coastal Act section 30253. The best scientific estimates of projected sea level rise should be considered and factored into the City’s LCP standards that require new development to evaluate and avoid or minimize risks from flooding, wave run-up, coastal erosion, and extreme events such as tsunamis.

Pacifica’s Sea-Level Rise Adaptation Plan establishes local adaptation goals and policies to address the identified vulnerabilities. The Adaptation Plan will assume a long-range planning horizon and take a phased approach that will involve future updates to the Adaptation Plan as needed. Preparation of the Pacifica Sea-Level Rise Adaptation Plan followed the steps outlined in the CCC’s Sea Level Rise Policy Guidance document as follows:

Step 1. Establish the Projected Sea-Level Rise Ranges

Table 2 shows projected future sea-level rise from the latest guidance from the State of California (CalNRA & OPC 2018). The rate of sea-level rise is projected to accelerate in the future. The sea-level rise projections are based on the latest “best available science” for/by the State of California based on the state-commissioned study “Rising Seas in California: An Update on Sea-Level Rise Science” by Griggs et al (2017). Values for 2100 were selected within the range of low and high emissions. Background and additional information on SLR can be found in the memo Future Conditions Scenarios for Pacifica LCP Update (ESA 2017)¹.

TABLE 2
SEA-LEVEL RISE SCENARIOS USED IN THIS STUDY, WITH PROBABILITY OF OCCURRENCE (CALNRA & OPC 2018)

Year	Low Risk (17% chance)	Med-High Risk (0.5 % chance)	Extreme risk (n/a)*
2050	1 ft	2 ft	2.7 ft
2100	3 ft	6 ft	10 ft

* The 2050 Extreme SLR scenario was not examined and is only provided for consistency. SLR of 6 ft at 2075 was considered in place of 10 ft at 2100 to assess flooding impacts under the Extreme scenario.

The Pacifica Sea-Level Rise Adaptation Plan will acknowledge that the processes causing sea-level rise and the science of projecting sea-level rise are inherently uncertain. For example, the rate of sea-level rise is highly dependent on whether global greenhouse gas emissions will continue to increase or whether global emissions will be reduced. The rate of sea-level rise could be higher, or lower, than the above projections. Given the uncertainties, the Adaptation Plan will, therefore, not be tied to specific timeframes or years, but rather uses thresholds based on amounts of sea-level rise of up to 5.5 feet and responses to climate change, such as flood event frequency and erosion.

¹ Future Conditions Scenarios Memorandum can be found online here: <https://tinyurl.com/futureconditions>. Community Work Group members received a hardcopy of this document in their binders.

Step 2. Identify Potential Impacts from Sea Level Rise

Based on the best available hazard data from USGS (CoSMoS) and the Pacific Institute, the potential hazards for the City were identified in the Future Conditions Scenarios Memorandum (ESA 2018)². Dominant coastal hazards in Pacifica include the following:

- long-term shoreline erosion
- storm-event coastal erosion of bluffs and beaches
- coastal flooding associated with major wave events
- rising groundwater levels in Linda Mar
- flooding in West Sharp Park and Linda Mar

Each of these hazards will increase with sea-level rise without action. The adaptation plan will set forth approaches to prepare for and manage impacts from each hazard source.

Step 3. Assess the Risks and Vulnerabilities to Coastal Resources and Development

In the Sea-Level Rise Vulnerability Assessment (ESA 2018)³, the following assets were determined to experience some form of existing or future risk and related vulnerability to sea-level rise (e.g. coastal erosion and/or flooding):

- A. Property (private homes, hotels, businesses, etc.)
- B. Roads (local and regional)
- C. Water system
- D. Sewer pipes and pump stations
- E. Stormwater pipes and pump stations
- F. Parks, trails, coastal public access
- G. Beach and wetland habitats
- H. Other Utilities (e.g. communications, electricity, gas)

The City is currently vulnerable to coastal flooding and erosion, with significant damages experienced in the recent past (ESA 2018b). With future climate change and sea-level rise, the City's current vulnerabilities are projected to increase in both frequency and intensity, which can result in greater damages to much of Pacifica including low-lying areas and areas near coastal bluffs.

Step 4. Identify Adaptation Measures

The Pacifica Sea-Level Rise Adaptation Plan will be considered a “toolbox” with a variety of adaptation measures that can address the short-term and long-term needs of property owners (public and private) for

² Future Conditions Scenarios Memorandum can be found online here: <https://tinyurl.com/futureconditions>. Community Work Group members received a hardcopy of this document in their binders.

³ Draft Vulnerability Assessment and appendices can be found online here: <https://tinyurl.com/PacificaDraftVA> and <https://tinyurl.com/PacificaDraftVAAppendices>. Community Work Group members received a hardcopy of this document in their binders. A Final Vulnerability Assessment will be available online in June 2018 here: www.cityofpacifica.org/sealevelrise.

protection, accommodation, and retreat as necessary to keep development safe and resilient, avoid flooding and erosion hazards, and incorporate safe setbacks. Consistent with Coastal Commission Guidance, the Adaptation Plan includes a variety of adaptation approaches, nature based or green infrastructure solutions, and multi-objective measures that incorporate environmental considerations and a holistic approach, rather than focusing on independent solutions to protection.

Adaptation Alternatives Analysis

To start the conversation on coastal adaptation alternatives to address coastal erosion, flooding and sea-level rise, ESA prepared a memo titled Pacifica Sea Level Rise Adaptation Background and Example Strategies (2018c). The memo includes a summary of Pacifica's recent experience adapting to coastal hazards, background information on the range of adaptation measures that may be appropriate in Pacifica, as well as example strategies for each of the City planning sub-areas. The public and Community Work Group convened on April 26, 2018 to discuss the memo and provide comments and input to the City and consultants.

Considering feedback from the public and workgroups on the Adaptation Background and Example Strategies memo and engineering feasibility, ESA coordinated with the City to develop a selection of adaptation alternatives for each sub-area that address the coastal flooding and erosion vulnerabilities identified in the Vulnerability Assessment. These alternatives will be discussed with work group members and the public at the next round of work group meetings on May 31, 2018.

Overview and Process

Given the uncertainty in sea-level rise projections and erosion/flooding model limitations, planning for sea-level rise follows a phased approach, providing a structure for sequencing adaptation measures using sea-level rise or other geomorphic thresholds. The phased approach provides a way to manage the inherent uncertainty in timing and extent of potential sea-level rise impact. Thresholds are used to help guide the planning and implementation of specific adaptation strategies (alternatives). For example, thresholds related to the extent of flooding or frequency of damages might be used to indicate that an adaptation action is needed to reduce or avoid future damage. The process should continue to involve the local community, and reflect the Pacifica community's risk tolerance, local conditions, and adaptation vision.

The Adaptation Plan will provide a framework for the City to prepare for identified vulnerabilities, monitor effects of coastal erosion and flooding with sea-level rise, and choose from a toolbox of adaptation measures. The Adaptation Plan will provide flexibility for the City to choose appropriate adaptation measures over time as specified thresholds for action are reached. Project-level planning and approvals will be required to further develop and implement the adaptation measures included in the Adaptation Plan. The Adaptation Plan will identify the lead times for project-level planning of adaptation measures so that the City can begin planning for adaptation in advance of when implementation is needed.

In accordance with CCC guidance, the Pacifica Adaptation Plan will:

- Be based on the best science and adaptation practices available today;
- Acknowledge that sea-level rise science and practices are evolving and that the City will evaluate future decisions and take action based on the best-available science and technology at the time; and
- Include a range of sea-level rise adaptation measures within the three general categories of adaptation: Protect, Accommodate, and Retreat.

The CCC further guides that, after evaluating vulnerability and establishing policies for areas with identified hazards, communities can begin the process of evaluating and choosing adaptation strategies for specific areas. In most cases, especially for LCP land use and implementation plans, multiple adaptation strategies will be needed and every community will need to assess their risks and their potential options. There are a number of options for how to address the risks and impacts associated with sea-level rise.

Adaptation Alternatives Development

To develop the preferred adaptation strategies, ESA and the City reviewed the potential adaptation measures with respect to each sub-area, and considered the following factors:

- Does the measure protect existing development (where applicable)
- Does the measure align with community values (input received throughout project to date)
- Compatibility with geographic/morphologic setting (is there space/right conditions for success)
- Does the measure support existing recreational and ecological functions

Error! Reference source not found.3 below lists all adaptation alternatives that were compiled for Pacifica Sea Level Rise Adaptation Background and Example Strategies (2018c), with measures that have been selected for one or more sub-area alternatives shown in bold. Pros and Cons are listed for each measure that is also ranked as positive (+), neutral (=) or negative (-) in terms of suitability in each sub-area considering the factors listed above and whether the measure protects existing development (a top priority for the City). Managed retreat will be considered generally for each sub-area, even in developed areas, at the direction of the Coastal Commission.

Table 3. Adaptation Measure Suitability Matrix

Measures	Pros	Cons	Protects Existing Development	Fairmont West	West Edgemar and Pacific Manor	Northwest Sharp Park	Sharp Park, West Fairway Park and Mori Point	Rockaway Beach, Quarry and Headlands	Pacifica State Beach	West Linda Mar	Pedro Point and Shelter Cove
Setbacks for Development	Avoid hazards, enables natural shoreline, sustains beach	development at risk if erosion is worse than estimated, need open space	-	+	-	-	-	+	-	-	-
Deed Restrictions and Conservation Easements	Conserves views, natural shoreline and beach,	Needs open space to initiate	-	=	-	-	-	=	+	-	-
Rolling Easements	Conserves views, natural shoreline and beach,	Complicated once easement reaches development, need open space	-	+	-	-	-	+	+	-	-
Fee Simple Acquisition	Avoid hazards, enables natural shoreline, sustains beach	Expensive, requires landowner agreement.	-	=	-	=	-	=	=	=	=
Managed Realignment or Relocation	Avoid hazards, enables natural shoreline, sustains beach	Expensive in developed areas, legal challenges, need place to relocate.	-	+	-	-	=	=	+	-	-
Transfer of Development Rights	Avoid hazards, enables natural shoreline, sustains beach	Land must be undeveloped	-	+	-	-	-	+	-	-	-
Beach Nourishment	Habitat and recreational value, buffers against erosion	Limited sand available, high rates needed with SLR.	+	+	+	+	+	+	+	+	n/a
Dune Restoration / Nourishment	Habitat value, buffer against erosion and flooding forces	Require space, monitoring	+	-	-	-	=	-	+	n/a	-
Horizontal Levee (Ecotone Levee)	Habitat value, buffer against erosion and flooding forces	Require space, monitoring	+	-	-	-	=	-	-	-	-
Structural Adaptation/Elevation	Raise structure above flood hazard zone, limit damages	costly, alters exposure landward of structure, may need to raise again	=	-	-	+	+	+	+	+	+
Elevate / Reconstruct Road	Reduces flood exposure, uses available space.	May need wider easement to raise on fill, does not address erosion alone.	=	-	-	=	=	=	+	+	-
Seawalls and Revetments	Familiar/in use, prevents erosion, maintains property in place	Costly construction and maintenance, esp. with sea level rise, loss of beach on eroding shores	+	+	+	+	+	+	=	+	+
Sand Retention Structures	Helps retain sand, potential recreation and habitat function	costly, not effective without beach, requires maintenance with sea level rise, ocean impacts	+	+	+	+	+	=	=	n/a	-
Traditional Levee	Prevents flooding	Require space, not suitable for wave action.	+	-	-	-	+	-	-	=	-

Notes:
Bold Text - Adaptation Strategies that have been selected for one or more sub-area alternatives shown in bold
 (+) positive, (=) neutral or (-) negative - suitability in each sub-area relative to the factors listed on page 6 of this memo.
 n/a – adaptation strategy not applicable to sub-area

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Explanation of Adaptation Measures Selected for Further Study

The alternative adaptation strategies that are presented in this memo, employ various adaptation measures originally presented in the memo on Pacifica Sea Level Rise Adaptation Background and Example Strategies (ESA 2018c). Most strategies are hybrids that include more than one measure that fall into the protect, accommodate or retreat categories specified in the Coastal Commission guidance. Measures that are a part of any alternative are described below (with reference to the sub-areas in which they are analyzed).

Setbacks for Development / Hazard Avoidance (Erosion in Rockaway sub-area; Quarry; Fairmont)

Use of setbacks is a long-used technique in California, implemented at a local policy level and by the state Coastal Commission, which requires new development to be located so that it can be safe from erosion and slope failure for some identified time period – typically the expected economic life of the development. Eventually the development can be expected to be at risk from erosion, and there will be the future question about whether the development should be removed or whether it should be protected. Setbacks are relevant for all areas with private property and most relevant for any coastal parcel potentially facing erosion and flood hazards being developed or redeveloped.

The cost of development setbacks is relatively minor compared to some of the other land use planning tools. The largest cost is likely to be the engineering analysis needed to obtain the site specific erosion rate and/or vegetation line data necessary to calculate the setback distance. A major benefit of development setbacks, in addition to keeping lives and property safe, is that they maintain natural shoreline dynamics, including preserving beaches for recreational and ecological value.

Managed Realignment or Relocation of Buildings and Facilities (Erosion in Fairmont West sub-area)

Managed Retreat is a broad strategy that can encompass the use of all erosion mitigation measures while allowing long term shore recession over time, requiring the removal or relocation of structures and infrastructure, realignment of roads, etc. Often, managed retreat is really “retreat and then manage” over a period of decades until erosion hazards become significant again. ESA has completed various projects in the past that implemented retreat of oceanfront development to restore beaches and shoreline habitat^{4,5,6,7}. The cost of these managed retreat projects ranged from about \$4.5 Million per acre of beach to \$45 Million per acre: The lower value is associated with built assets that are public and limited (e.g. parking lot) while the higher value entails high-value utilities. The costs for retreat in areas consisting of private property are not well defined by this project data, but could be approximately estimated by assessing the value of the property, and the compensation mechanism (e.g. purchase, easement, etc.). One of the most difficult elements of this measure is uncertainty over who pays and who benefits, and quantification of benefits. Typically, this measure is part of a strategy that includes public cost to rebuild public infrastructure and compensate private property owners for their property net the costs associated with

⁴ Philip Williams & Associates, Ltd. (PWA) PACIFICA STATE BEACH RESTORATION PHASE 1 Prepared for RRM Design Group and City of Pacifica, January 16, 2002, Amended May 22, 2002, PWA Ref. # 1547

⁵ Philip Williams & Associates, Ltd. (PWA) SURFER'S POINT MANAGED SHORELINE RETREAT & ACCESS RESTORATION Preliminary Design Prepared for RRM Design Group and the City of Ventura, August 2, 2005 PWA Ref. # 1708.

⁶ ESA, 2015. ESA, SPUR, Moffatt & Nichol, McMillen Jacobs Associates, AGS, Inc., Coastal Protection Measures & Management Strategy for South Ocean Beach, Ocean Beach Master Plan: Coastal Management Framework, Prepared for the CCSF Public Utilities Commission. Project D120925.00

⁷ PWA 2008. Goleta Beach County Park, Park Reconfiguration Alternative, Prepared for The Coastal Fund at UCSB, Surfrider Foundation – Santa Barbara Chapter, Environmental Defense Center, Prepared by Philip Williams & Associates, Ltd. November 24, 2008, PWA REF. #1940.00

shore armoring. But again, there also may be significant public benefits from a managed retreat strategy that should be weighed against the costs.

Although this may be the most straightforward adaptation strategy, it is often assumed to be technically or financially infeasible. Often there is not sufficient space or land available for the structure to be relocated. Many planned retreat efforts, therefore, often use property acquisition to remove development from inherently hazardous places. Planned retreat is easier to implement on public lands and by government agencies such as the California Department of Parks and Recreation.

Transfer of Development Rights (Erosion in Fairmont West sub-area)

Transferable Development Right (TDR) programs allow the transfer of the development rights from one parcel to another parcel. These programs are tools used to direct development away from certain sensitive areas (sender sites) and into areas that can better accommodate it (receiver sites). TDRs could be applied where undeveloped sensitive or hazardous parcels exist (to transfer potential development from) and desirable areas to transfer potential development to are available. TDR programs are widespread throughout the country and vary based on local land use planning priorities and needs. Pacifica's General Plan and Zoning Ordinance identifies sender sites (from which a development right is voluntarily transferred by the owner) and receiver sites (to which a development right is added). The owner of a sender site can sell a TDR to the owner of a receiver site. The seller typically retains ownership of the "sending" property, but relinquishes the right to develop it via a recorded property restriction, while the buyer is able to intensify development on the receiver site more than would otherwise be permitted under existing zoning. Sending sites may be sensitive land areas such as endangered species or wetlands habitat, or areas prone to coastal hazards such as erosion or landslides. Owners of sender sites receive monetary compensation from the sale of the TDR and in the form of potentially smaller property taxes, while owners of receiver sites have assurance of future development rights on their site, sometimes at a higher density than may be allowed by the base zoning. TDR programs may provide a higher level of certainty over traditional zoning efforts because of the specificity of the amount and location of future development.

Other considerations could include access to services, water limitations, agricultural conversion and zoning changes. As with other mechanisms to avoid hazardous shoreline areas, TDR programs may result in significant public benefits in the form of beach preservation.

Beach and/or Dune Nourishment (Erosion in most of Pacifica sub-areas)

Beach nourishment refers to placement of sand to widen a beach. The beach then provides flood and erosion protection to the backshore. However, it is generally assumed that the beach will diminish with time, requiring "re-nourishment". As sea level rises, the frequency of required nourishment increases because the rate of sand addition to build the beach up increases. Potential problems with beach nourishment include the construction impact to people and beach ecology, and changes to shore conditions that may result from difficulty in finding sand with the desired grain sizes. The success of the nourishment depends on the volume of nourished material, the grain size, and the proximity or use of sand retention structures. Dune nourishment would include placement of sand, graded and planted to form back beach dunes. Dune nourishment is recognized as a natural way of mitigating backshore erosion as well as maintaining a wider beach through sacrificial erosion of the dunes (sand

replenishes the beach as waves erode the dunes, slowing the overall shoreline erosion). A variant includes placement of cobble (rounded rock) which is often naturally present as a lag deposit⁸ below beaches in California.

Considered as an adaptation measure in Southern Monterey Bay (ESA PWA, 2012), Opportunistic Beach Nourishment uses sand that is extracted from a flood channel, debris basin, navigation channel, harbor area, a by-product of construction or other source, where the main reason for extracting the sand is not to use it for beach nourishment. Costs associated with Opportunistic sand can be low, especially when providing a cost savings to the entity providing the sediment source by avoiding or reducing transportation and disposal costs. Beach Nourishment may be a viable short term solution in areas with low erosion rates, but the long-term effectiveness of this measure for reducing erosion is doubtful.

Seawalls and Revetments (Erosion in most of Pacifica sub-areas)

Seawalls are vertical structures along a beach or bluff, used to protect structures from wave action as a course of last resort. A seawall works by absorbing or dissipating wave energy. They may be either gravity- or pile-supported structures. Seawalls can have a variety of face shapes. Seawalls and bulkheads are normally constructed of stone or concrete, however other materials can be used. Current seawall projects usually require design elements that allow the structure to resemble the natural environment in that area, in order to blend in with the existing geologic conditions.

Revetments provide protection to existing slopes affronting a threatened structure, and are constructed of a sturdy material such as stone. Similar in purpose to a seawall, revetments work by absorbing or dissipating wave energy. They are made up of: an armor layer--either stone or concrete rubble piled up or a carefully placed assortment of interlocking material which forms a geometric pattern; a filter layer --which provides for drainage, and retains the soil that lies beneath; and a toe--which adds stability at the bottom of the structure. Revetments are the most common coastal protection structure along the shore of Pacifica. In comparison to seawalls, revetments tend to have greater visual impacts and require a larger footprint, which leads to a larger placement loss of beach area and impacts to public access along the shore. Both seawalls and revetments lead to the “passive erosion” loss of the beach as the erosion continues yet the back beach cannot retreat. This impact will be accelerated by sea level rise. These structures may also introduce active erosion effects which accelerate beach loss when beach width narrows and wave run-up frequently reaches the structure. As the beach disappears and sea level rises, wave run-up and overtopping will also worsen over the structure as the waves begin to discharge near or on the structure, which will require more frequent maintenance or reconstruction. Both seawalls and revetments have a high construction cost (ESA PWA 2012), and high cost to public and private beach resources.

Sand Retention Structures (Erosion in North Pacifica and Rockaway Sub-areas)

These large coastal engineering structures are often used in conjunction with large beach nourishment to retain sand. The retention structures essentially slow the rate of sand transport away from the nourishment area, thereby slowing the rate of beach width reduction. These solutions have a high construction cost.

Offshore artificial reefs consist of fill in the surf zone that reduces the wave power reaching shore and changes the pattern of sand transport, thereby conceptually reducing transport of sand from the nourished area. Artificial reefs installed to act as submerged breakwaters have received increased attention in recent years as a means of

⁸ Lag deposit refers to coarser sediments that accumulate over time at lower elevations during periods of eroded beaches, and subsequently covered by sand after the beaches recover.

shore stabilization and erosion control, primarily due to their low aesthetic impact and enhanced water exchange relative to traditional emergent breakwaters (Vicinanza et al., 2009) and the potential to enhance local surfing conditions (Ranasinghe & Turner, 2006).

Artificial headlands with stems are proposed as a large scale coastal engineering solution to manage erosion and maintain beaches along Northern Pacifica. This type sand retention structure scheme is comprised of a series of engineered rock headland units with submerged reefs and a jetty (or stem) connected to the backshore. By segmenting the coast into smaller cells, the system would aid in maintaining a wider beach for a longer period after beach nourishments, with the widest beach located updrift of each unit such has formed north of Mori Point. This concept is shown in **Figure 1** below.



Pacifica LCP 170663

SOURCE: ESA

Figure 1

Artificial headlands concept for north Pacifica (nourished beach not shown)

Traditional and Horizontal Levees (Sharp Park and West Fairway Park Flooding)

Levees have been the standard practice for flood protection in riverine and estuarine environments. Where constrained by infrastructure or commercial/residential structures, raising existing levees may be an effective adaptation strategy, but the risk to assets behind levees and maintenance costs may increase as sea level rises. Levees are typically constructed of compacted earth fill and can be susceptible to erosion if exposed to wave action. Small levees are proposed to mitigate flooding, from either coastal or riverine flooding, for West Sharp Park and West Fairway Park neighborhoods.

The horizontal levee (ecotone levee) is a barrier to coastal storm surge that combines the function of a linear flood protective device (levee) with the natural flood protection benefits of wetland habitat. Instead of a traditional levee, the horizontal levee is comprised of a levee or other structure set back from the coastline with a wide flat slope between the structure and the water that is vegetated with native wetland vegetation. The flat vegetated slope provides a natural buffer from storm surge and wave action. This concept has been developed for and applied to areas with limited wave energy, such as San Francisco Bay (USACE 2015). The horizontal levee could take the form of dune restoration and a setback levee at the Sharp Park Golf Course, for example.

Elevate / Reconstruct Road (Erosion in Fairmont West sub-area, Erosion and Flooding in West Linda Mar)

As part of the Climate Ready Southern Monterey project, ESA developed unit cost estimates for elevating roadways with bridges or trestles, as well as cost for reconstruction of a secondary roadway. Critical roadways determined at risk in the vulnerability assessment could be improved by a combination of elevation by earth fill and armoring. Roads exposed to wave action on the coast will require heavier armoring in order to be kept in

place, while roads that are not exposed to significant wave impacts may be sufficiently armored with a lower cost revetment or combined with a fronting ecotone slope.

Alternative Adaptation Strategies by Sub-Area

The alternative strategies for each sub-area presented in the following pages and corresponding economic cost-benefit results (in progress) are meant to inform the Adaptation Plan and policies to be developed. The alternative strategies are defined through time to enable the cost-benefit analysis, and are dependent on SLR projections from State guidance. In reality, erosion and sea-level rise will likely not behave exactly as modeled for the alternatives analysis. That said, the adaptation alternatives analysis process and results provide an indication of what may be feasible in the future and illuminates the scale of funding that will be needed to adapt. The alternative strategies are by no means defining what the City will do to plan for sea-level rise, but hypothetical examples to test various approaches to adaptation. The specific adaptation alternatives developed for the analysis are not meant to exclude any measures from consideration in the future. As climate change science advances and new adaptation approaches are developed, future plans for adaptation in Pacifica will be reconsidered accordingly.

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Fairmont West Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Retreat	Managed retreat of infrastructure, transfer of development rights	Now: Allow bluff erosion to proceed, maintaining beach area. Assume Dollaradio armoring is maintained. Implement TDR/Hazard avoidance measures in undeveloped parcels. Future: remove road, reroute traffic north to Hwy1, relocate wastewater main away from erosion hazard. Timing TBD via shore response modeling. Maintain revetment for Dollaradio.
2 Protect / Retreat Hybrid	Beach Nourishment, remove/relocate infrastructure, transfer of development rights to inland areas	Now: Place 100ft wide beach nourishment. Maintain Dollaradio and armoring. Future: Nourish 100ft beach every time beach width falls below minimum threshold, increasing frequency as SLR accelerates to slow bluff erosion, timing TBD via shore response modeling. Assumes existing armor is maintained at Dollaradio. Backshore is allowed to erode until need to remove road, reroute traffic north to Hwy1, relocate wastewater main away from erosion hazard.
3 Protect	Beach nourishment, Sand retention structures	Now: Place 100ft wide beach nourishment. Maintain Dollaradio and armoring. Future: Place sand: 100ft beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates. Build sand retention structures, timing to be determined with shore response modeling (part of overall artificial headlands strategy for north Pacifica).

West Edgemar and Pacific Manor Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor	Now: Armor bluffs between Manor Dr and Bill Drake Way and along SF RV Resort. Future: Maintain armor as needed to remain effective, timing TBD via shore response modeling.
2 Protect	Armor with Beach Nourishment	Now: Armor bluffs between Manor Dr and Bill Drake Way, and SF RV Resort. Nourish 100ft beach and armor remaining open bluffs. Future: Maintain armor and nourish 100ft beach every time beach width falls below minimum threshold, increasing frequency as SLR accelerates, timing TBD via shore response modeling.
3 Protect	Beach nourishment, Sand retention structures, Armor	Now: Place 100ft wide beach nourishment. Maintain public armoring structures and armor between Manor Dr and Bill Drake Way (and SF RV Resort?). Future: Future: Place sand: 100ft beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates. Build sand retention structures, timing to be determined with shore response modeling (part of overall artificial headlands strategy for north Pacifica).
3 Retreat	Managed removal/relocation of assets	Now: Remove existing armoring structures and allow erosion. Future: Purchase property when buildings at risk of damage, remove buildings, utilities, roads etc as erosion progresses.

Northwest Sharp Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor	Now: Maintain existing public armor, build new armoring elsewhere. Future: Maintain armor as needed to remain effective, timing TBD via shore response modeling.
2 Protect	Armor with Beach Nourishment	Now: Maintain existing armor, build new armor elsewhere. Nourish beach by 100 feet. Future: Maintain armor and nourish 100ft beach every time beach width falls below minimum threshold, increasing frequency as SLR accelerates, timing TBD via shore response modeling.
3 Protect	Armor, Beach nourishment, Sand retention structures	Now: Maintain existing armor, build new armor elsewhere. Nourish beach by 100 feet. Future: Place sand: 100ft beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates. Build sand retention structures, timing to be determined with shore response modeling (part of overall artificial headlands strategy for north Pacifica).
3 Retreat	Managed removal/ relocation of assets	Now: Remove existing armoring structures and allow erosion. Future: Purchase property when buildings at risk of damage, remove buildings, utilities, roads etc as erosion progresses.

Sharp Park, West Fairway Park and Mori Point Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor	Now: Maintain existing public structures, extend seawall to close Clarendon gap to SPGC levee. Assumes SF will armor and maintain SPGC levee. Future: Beach erodes, maintain armoring at current elevation (wave run-up hazard continues). Close road and walkway during large wave events.
2 Protect	Armor, levees	Now: Maintain existing armor, extend seawall to close Clarendon gap to SPGC levee. Assumes SF will armor and maintain SPGC levee. Build stormwater detention basins with setback levees and pump stations at Clarendon/Lakeside Ave and end of Fairway Drive. Future: Maintain armoring, increase seawall height to limit wave overtopping.
3 Protect	Beach nourishment, Sand retention structures, levees	Now: Maintain existing armor, extend seawall to close Clarendon gap to SPGC levee. Nourish beach by 100 feet. Build stormwater detention basins with setback levees and pump stations at Clarendon/Lakeside Ave and end of Fairway Drive. Future: Maintain armoring, raise seawalls to limit wave overtopping. Place sand: repeat 100 foot beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates. Build sand retention structures, timing to be determined with shore response modeling (part of overall artificial headlands strategy for north Pacifica).
3 Retreat	Managed removal/relocation of assets	Now: Remove existing armoring structures and allow erosion. Future: Purchase property when buildings at risk of damage, remove buildings, utilities, roads etc as erosion progresses.

Rockaway Cove, Quarry and Headlands Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Protect / Accommodate Hybrid	Armor, development setbacks, managed removal of assets	Now: Maintain existing armoring structures, allow erosion in south cove. Future: Erosion continues in south cove until Hwy 1 threatened, assume Caltrans armors embankment. Relocate south cove public facilities as needed. Development setbacks for quarry property. Armor will be upgraded in the future as needed to maintain efficacy as beaches narrow and wave impacts on the armor increases with sea level rise. The schedule of upgrades/repairs will be determined by shore response modeling. Armoring upgrades could include raising armor to prevent overtopping with sea level rise. Development setbacks for quarry property.
2 Protect / Accommodate Hybrid	Beach Nourishment, armor	Now: Place sand: 100ft beach initially and every time beach width falls below minimum threshold. Future: Nourish 100ft beach every time beach width falls below minimum threshold to delay need to armor Hwy 1 and reduce maintenance needs for existing armor, increasing nourishment frequency as SLR accelerates, timing TBD via shore response modeling. Development setbacks for quarry property.
3 Protect / Accommodate Hybrid	Beach Nourishment, Artificial reef, armor	Now: Nourish beach by 100 feet. Maintain existing armoring structures. Future: Repeat 100-foot beach nourishment every time beach width falls below minimum threshold. Timing TBD via shore response modeling. Build offshore reef to improve sand retention. Timing TBD via shore response modeling. Development setbacks for quarry property.
3 Retreat	Managed removal/relocation of assets	Now: Remove existing armoring structures and allow erosion. Future: Purchase property when buildings at risk, remove buildings, utilities, roads etc as erosion progresses.

Pacifica State Beach Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor/Accomodate	Now: Maintain existing armoring structures, build new armor on private lands south parking and pump stations, allow erosion of public lands north of parking. Future: Floodproof pump stations. Raise and armor Highway 1 to counteract erosion and wave overtopping exposure for West Linda Mar, timing TBD via shore response modeling.
2 Retreat / Hybrid	Managed Retreat, Armor	Now: Allow erosion Future: Remove parking and relocate pump stations. Raise and armor Highway 1 (part of West Linda Mar hybrid strategy) to counteract erosion and wave overtopping exposure, timing TBD via shore response modeling.
3 Protect	Armor, Beach Nourishment	Now: Maintain existing armoring structures. Allow erosion of dunes. Future: Nourish 100' beach and dunes when beach width falls below the minimum beach width, timing TBD via shore response modeling. Assumes Caltrans Raises and armors Hwy 1 as needed. Floodproof pump stations as needed.

West Linda Mar Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Protect	Accomodate	No action taken along Highway 1 could expose western neighborhood to wave overtopping, Flooding from San Pedro Creek is and will remain a hazard. Future: Install subdrain and pump station to manage rising groundwater levels.
2 Protect	Armor/Flood Protect	Future: Assumes Caltrans raise Highway 1 (with armor) to protect west neighborhood from wave overtopping. Build levee/floodwall along San Pedro Creek to limit river flooding exposure and coastal exposure with future SLR. Add pump station and subdrain to manage rising groundwater with SLR in lowest areas of neighborhood.
3 Accommodate	Elevate	Now: Elevate homes above river flood hazard elevation. Future: install pump station to manage rising groundwater with SLR. (~120 structures affected by 2100 groundwater, ~300 structures affected by 2100 coastal storm (100-yr))
3 Retreat	Managed removal/relocation of assets	Now: Start buyout of lowest lying properties. Future: Purchase properties and demolish, restore to wetlands.

Pedro Point and Shelter Cove Sub-area



Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor	Now: Assume existing private armoring structures are maintained and expanded along Shoreside Dr. Future: Armor toe of headland. Shelter Cove not considered.
2 Protect / Accommodate Hybrid	Beach nourishment, raise structures.	Now: in conjunction with Pacifica SB nourishment, nourish 100' beach along Shoreline Dr waterfront area. Future: Nourish 100' beach when beach width falls below the minimum beach width, increasing frequency as SLR accelerates, timing TBD via shore response modeling. Raise buildings above coastal flooding elevation. Bluff erosion allowed; homes and roads/infrastructure removed when eroded.
3 Retreat	Managed removal/relocation of assets	Now: Remove existing armoring structures, allow erosion. Future: Purchase property when buildings at risk, remove buildings, utilities, roads etc as erosion progresses.

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