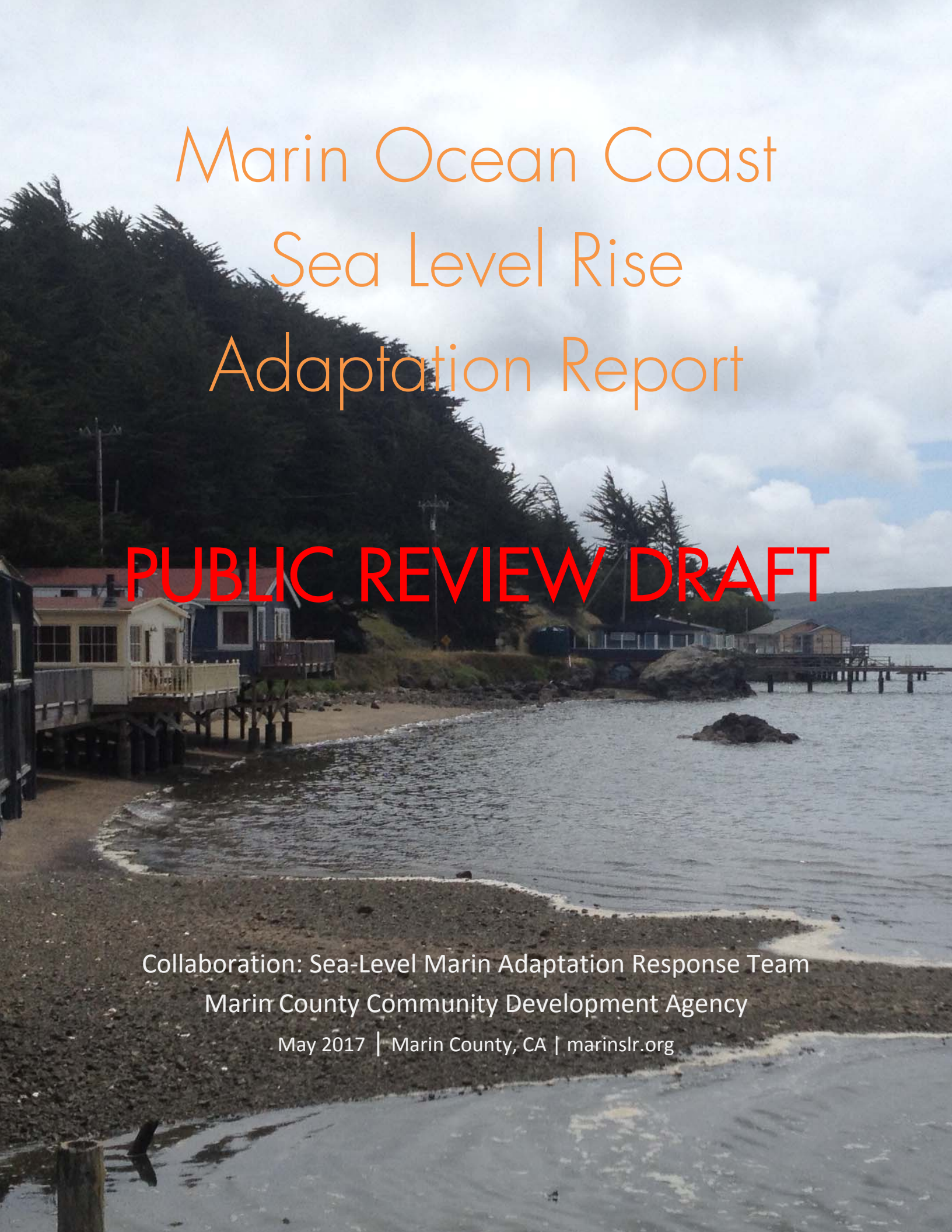

Marin Ocean Coast Sea Level Rise Adaptation Report

PUBLIC REVIEW DRAFT

Collaboration: Sea-Level Marin Adaptation Response Team

Marin County Community Development Agency

May 2017 | Marin County, CA | marinslr.org

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Cover Photo: Tomales Bay, December 2014. Credit: Marin County CDA

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And over 100 community members!

List of Acronyms

BARC……Bay Area Regional Collaborative

BCDC……San Francisco Bay Conservation and Development Commission

BFE……Base Flood Elevation

Caltrans…….California Department of Transportation

CalOES……California Office of Emergency Services

CCAN…….California Coastal Adaptation Network

CCC……California Coastal Commission

CDA……Marin County Community Development Agency

CMAQ …….Congestion Mitigation and Air Quality

COS……Center for Ocean Solutions

CoSMoS…….Coastal Storm Modeling System

C-SMART…….Collaboration Sea-level Marin Adaptation Response Team

CSP……California Department of Parks and Recreation

CWP……Countywide Plan

DEM……Digital Elevation Model

DFW……State Department of Fish and Wildlife

DPW……Marin County Department of Public Works

EPA…… Environmental Protection Agency

ESA……Environmental Science Associates

FEMA…….Federal Emergency Management Agency

FIRM…….Flood Insurance Rates Maps

GFNMS……..Greater Farallones National Marine Sanctuary

GGNRA……..Golden Gate National Recreation Area

MALT…….Marin Agricultural Land Trust

MTC……Marin Transportation Commission

NGO……Non-governmental Organization

NOAA…….National Oceanic and Atmospheric Administration

NPS……National Park Service

NRC……..National Research Council

NRCS……Natural Resources Conservation Service

OCOF……. Our Coast, Our Future

OES……Marin County Office of Emergency Services

OWTS……Onsite Wastewater Treatment Systems

PATCH……Plans for Adapting to Coastal Hazards

PBCS……Point Blue Conservation Science

PWA ……Phillip Williams Associates

SAC……..Stakeholder Advisory Committee

SBCWD……..Stinson Beach County Water District

SLR……..Sea level rise

STP……Surface Transportation Program

SCC……California State Coastal Conservancy

SWRCB……State Water Resources Control Board

TAC……Technical Advisory Committee

TAM……Transportation Authority of Marin

USGS……United States Geological Survey

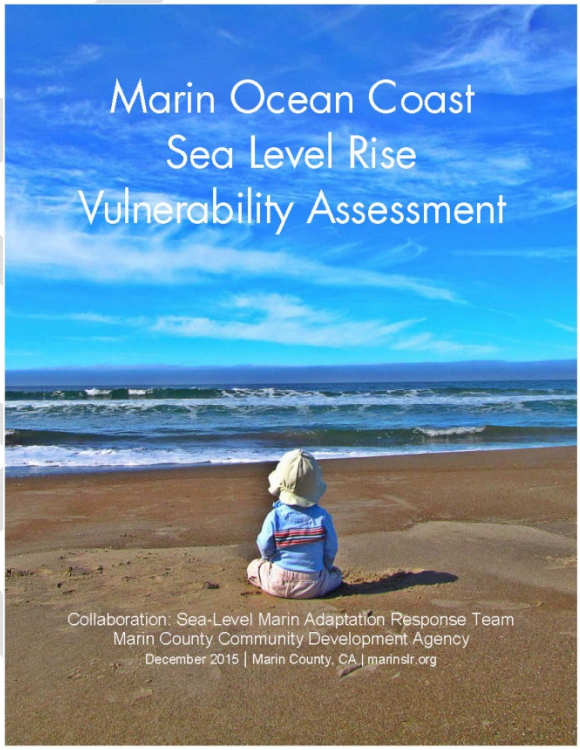
Executive Summary

Climate experts estimate that by 2100, sea level could rise by up to 70 inches and that the frequency, intensity and flood-effects of storms could increase. People in coastal areas should understand how sea level rise (SLR) may affect their homes, schools, roads, public facilities, natural resources and habitat areas, and how to prepare for these impacts. Marin County's "*Collaboration: Sea-level Marin Adaptation Response Team*" (C-SMART) is a multi-stakeholder, inter-governmental partnership that is working to develop this understanding of SLR and its potential impacts for Marin's ocean coast, so that together, we can prepare to meet the challenge of SLR.

C-SMART's Stakeholder Advisory Committee (SAC) is made up of representatives from each of the West Marin communities: Muir Beach, Stinson Beach, Bolinas, Point Reyes Station, Inverness, Marshall and Dillon Beach. The Technical Advisory Committee (TAC) is made up of resource managers, utility providers, conservation scientists and other local and regional experts. Members of the public joined the conversation through a series of community workshops and meetings with local stakeholder groups, providing valuable input to the study from July 2014 – April 2016.

Vulnerability Assessment

The *Marin Ocean Coast Sea Level Rise Vulnerability Assessment* identifies the vulnerability of parcels and buildings, transportation networks, utilities, working lands, natural resources, recreational activities, emergency services, and historic and archaeological resources; as well as community profiles outlining vulnerable assets for each of the West Marin communities. Information was gathered through mapping affected assets using the United States Geological Survey (USGS) SLR model available online at Our Coast, Our Future (OCOF). C-SMART Staff conducted interviews with asset managers to identify sensitivity, adaptive capacity and planned management actions. The Vulnerability Assessment serves as the foundation for the adaptation options of this report.



In the coastal zone, over 20 percent of buildings are vulnerable at the low end of the long-term scenario, which could occur around 2100. Vulnerable buildings are concentrated in the Calles and Patios neighborhoods of Stinson Beach, Downtown Bolinas, and the Tomales Bay shorelines in Inverness and East Shore. Nearly twenty miles of public and private roadways could be compromised by flooding and permanent inundation. Roadways exposed in the short-term include Shoreline Highway between Bolinas and Stinson Beach, Calle del Arroyo, all the Calles and Patios streets, Wharf

Road in Bolinas, and several creek crossings and bridges. In addition, other low-lying portions of Shoreline Highway, Sir Francis Drake Boulevard, and local roads are vulnerable in long-term. Coastal communities also rely on septic systems, water supply systems, and shared septic or sewage systems that could be vulnerable to SLR and storms. Certain roadways and utilities are critical lynch pin assets, such that their dysfunction or destruction will likely have negative consequences for nearly all other built assets.

Adaptation Report

This document, the *Marin Ocean Coast Sea Level Rise Adaptation Report,* presents potential actions to accommodate, protect against, or retreat from the threats of SLR and coastal hazards.

This report's objective is not to facilitate new development in hazardous areas, but rather present options for increasing resiliency in existing natural and built assets and systems in the face of increased sea level rise and coastal storms. Identifying adaptation solutions that will be most appropriate in each location will require further continued discussion with stakeholders and technical experts, as part of an ongoing adaptive management approach. A 2008 Governor's Executive Order states: "California must begin now to adapt and build our resiliency to coming climate changes through a thoughtful and sensible approach with local, regional, state and federal government using the best available science."[1] The C-SMART project represents the foundation of the County and State agencies' long-term commitment to plan for SLR and other climate change impacts.

For long-range adaptation planning and property risk disclosure, this report refers to the upper end of the National Research Council's 2012 SLR estimate for 2100 (66 inches), which is unlikely but could occur if thermal expansion of the oceans and melting ice caps continues to accelerate. For planning purposes related to environmental review and development projects, Marin County will refer to the "most likely" SLR projection of three feet by 2100.

Table 1. C-SMART Sea Level Rise & Storms Scenarios from CoSMoS

Sea Level Rise Scenario		Term
1	10 inches + Annual Storm	Near
2	10 inches + 20-year Storm	Near
3	20 inches + 20-year Storm	Medium
4	40 inches + 100-year Storm	Long
5	80 inches + 100-year Storm[2]	Long

A possible adaptation approach for West Marin is to protect existing homes, businesses and other assets through building elevation, floodproofing, and nature-based strategies with flood protection and habitat benefits in the near- to-medium term. Additionally community-wide solutions such as elevating/armoring roads and developing shared wastewater treatment systems are recommended for consideration. In the long term, a variety of solutions including

[1] California Governor's Executive Order #S-13-08. November 2008.

[2] The upper limit for 2100, scenario 5, was selected based on: *Rising sea levels of 1.8 meter in worst-case scenario, researchers calculate.* Science Daily Online News. University of Copenhagen. Oct. 14, 2014. http://www.sciencedaily.com/releases/2014/10/141014085902.htm Original published in the journal Environmental Research Letters. The article calculate 70 inches. In the scenario options, 80 inches (rounded up from 77 inches) is the closest option.

exploring retreat alternatives are suggested. Near-term refers to 2030, medium-term refers to 2050, and long-term refers to 2100. Moreover formalizing working relationships with CDA and other government agencies/stakeholder groups is a key recommendation as a means to continue discussions and implement solutions.

In the near-term, property owners can elevate or otherwise retrofit structures to be safe from temporary flooding during storms and high tides. The County can facilitate this process through updated Local Coastal Program (LCP) policies that build upon the existing regulatory framework for Flood Hazard Areas, and that encourage additional elevation for buildings threatened by SLR. Pending LCP certification, when existing structures are elevated by the minimum amount necessary, a resulting building height of up to 30 feet above grade could be deemed to comply with coastal hazard, public view, and community character provisions of the LCP, while structures over 30 feet tall could require an individual evaluation of conformance with the relevant LCP provisions. In the medium- to long-term, communities will need to consider the tradeoffs of various adaptation approaches, and decide whether remain in current location or consider relocating to safer areas. Flood insurance rates and coastal armoring mitigation requirements are anticipated to increase in the coming years, which may influence property owner decisions more than development regulations.

Stinson Beach homes at King Tide 2012.
Credit: J. Lamphier

Roads vulnerable to temporary flooding will be subject to increasing temporary closures, in some cases preventing emergency access. The Local Hazard Mitigation Plan identifies near-term approaches to maintaining safety during and after disasters. General approaches and relative costs of various adaptation options for transportation infrastructure have been prepared by the Marin County Department of Public Works (DPW), and will be used to guide evaluation of actions. Standards for road flooding closure need legal definition and should be publicized with signage to alert drivers as to what they should expect. Road repairs may be an opportunity to plan for higher water levels. Design standards and best practices can help guide Capital Improvement Projects and road repairs, to ensure that roads will be more resilient to SLR and other flood events related to climate change. Permitting remains a challenge as raising roadways typically requires expanding the roadway footprint and may impact existing natural areas.

Long term, specific stretches of roads identified as being highly vulnerable to floodwaters could be converted into recreational trails and possibly incorporated into the California Coastal Trail.

The cost of elevating, armoring or relocating exceeds the amount of funding currently available for road repairs, and will require ongoing collaboration between California Department of Transportation (Caltrans) and the County to identify opportunities for additional funding. A formalized working agreement such as an MOU could be developed with Caltrans, Marin Transportation Commission (MTC) and Transportation Authority of Marin (TAM) for Shoreline Highway planning support as part of the Regional Transportation Plan. Capital Improvement Projects and road repairs could account for SLR when cost-effective and funded to ensure that roads are more resilient to flooding. Over time, agencies may evaluate the feasibility of relocating critical access roads upland.

Shoreline Highway along Bolinas Lagoon
Credit: Bolinas PUD

As utility systems become increasingly compromised by temporary (and eventually permanent) flooding, the Community Development Agency will support ongoing efforts to elevate or otherwise protect electrical, fuel, sewage management and water systems from high tide levels. Adaptation strategies include retrofits to water meter connections to withstand salt water, and retrofitting septic systems to meet current regulations, or flip switches that can be shut off during flooding. The Community Development Agency can continue to work with utility districts to determine a trigger point after which communities would need to develop alternatives to compromised septic leachfields, such as shared public wastewater systems. New public capital improvement projects could consider 3 feet of SLR, and development policies should be consistent with adaptation strategies (e.g. consider eliminating requirements to bury utilities in areas vulnerable to SLR). As SLR progresses, the Community Development Agency could continue to work with local service providers to determine the point at which communities need to convert to community shared public wastewater system, and explore the feasibility of relocating wells and sewage lift stations. The County can connect with the PG&E task force and other service providers to move forward with long-term, coordinated approaches for utilities.

Working lands dedicated to agriculture and mariculture will be primarily impacted by loss of road access. The County should work with farmers whose lands are vulnerable to SLR to identify appropriate solutions.

Natural resources would need to be monitored over time to better understand the impacts of SLR to beaches, wetlands, and other habitat areas. The Greater Farallones National Marine Sanctuary (GFNMS) Climate-Smart AdaptationWorking Group developed a report (Appendix F) on potential strategic management actions which served as the basis for natural resource strategies identified in this report. The County and willing partners could continue to evaluate and pursue funding

opportunities for innovative living shorelines approaches to SLR protection, such as dune and wetland restoration, horizontal levees, oyster beds, eelgrass, and bluff vegetation. Another key strategy is to enhance SLR education programs through partnerships with educational organizations and citizen science initiatives. Shoreline erosion rates would need to be monitored on a seasonal basis and before/after major storms to better understand the impacts of SLR on natural resources. Funding remains a primary challenge under all scenarios as the available resources are inadequate to meet future requirements under most scenarios.

Western Snowy Plover *Credit: VanDerWal*

Water-based recreation is a key component of West Marin's economy including surfing, kayaking, fishing, birdwatching, and more. To ensure economic sustainability, other forms of recreation and tourism could be promoted including biking, hiking, and agritourism/farm trails.

Emergency access can be considered in road improvement projects, though raising roads can be problematic for emergency access as large vehicles may need a certain grade to navigate over the roads. Alternative evacuation routes need to be developed for communities (e.g., Bolinas) with one major road that may face more frequent future flooding. Water based emergency evacuation routes could be explored.

Adaptation planning should consider impacts on historic and archaeological resources. Continued discussions with the Federated Indians of Graton Rancheria should continue to ensure tribal concerns are addressed in adaptation planning processes. Marin County's 1981 Local Coastal Program Historic Study could be updated so the full extent of vulnerable properties can be assessed. Vulnerable historic structures could be documented before damaged by SLR or significantly altered by adaptation measures.

Community Specific Alternatives

All West Marin communities can benefit from strategies to improve resiliency to flood events and maintain safety in coastal hazard areas. SLR will cause areas that flood temporarily now to flood permanently at daily high tides in the future.

Homeowners can prepare by elevating or otherwise retrofitting buildings and utilities in the near-term, while considering community-wide protective measures such as living shorelines, elevation/armoring of critical assets, or managed retreat over time. Understanding the implications and tradeoffs of different approaches (protect, accommodate, or retreat) will require continued study and community dialogue around adaptation.

While not all adaptation solutions are permanent, public and private projects to address sea level rise in the near and medium term can still help with some level of protection and merit consideration. Cost estimates for

various strategies are included in this report, but come from a variety of sources, could be out of date or inconsistent with one another, and further analysis is necessary to fully assess specific costs considering implementation, environmental review, permitting, maintenance and more.

Muir Beach

The recently completed Redwood Creek restoration project is an example of a nature-based adaptation to SLR, which restored natural creek function in part by re-aligning vulnerable assets and infrastructure that impeded natural processes. This improved habitat function while simultaneously increasing resiliency to flooding and SLR. In the near-term, homeowners on bluffs vulnerable to erosion can improve stormwater drainage to stabilize bluffs. Revegetation and netting can also be used for bluff stabilization. It will be very difficult to obtain a permit for new shoreline armoring, although the Coastal Act allows for maintenance of existing structures under certain circumstances, and for new structures to protect existing development in danger of erosion when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Low-lying sections of Pacific Way and Shoreline Highway may be subject to closures during flood events, and may eventually need to be elevated or realigned. Resizing culverts and the Pacific Way Bridge would help to mitigate flooding as part of a suite of climate change resiliency best practices.

Stinson Beach

Accommodation of vulnerable structures, roads and utilities, primarily through elevation and retrofits, is a near- and medium-term priority for Stinson Beach. Elevation of homes would protect them from temporary flooding and permanent SLR, though road access would continue to be an issue. Many respondents of the 2015 West Marin Sea Level Rise Adaptation Poll supported "reasonable policies that allow property owners to develop in ways that protect against SLR." However, permits for structures in vulnerable areas may be conditioned to prove that the structure will be safe from coastal hazards.

Calle del Arroyo is the County road of most immediate concern, as it frequently floods and provides the only access to Seadrift, the Patios, and many of the Calles. If Calle del Arroyo were elevated, private roads would also need to be elevated, or at least sloped up to meet Calle del Arroyo. Elevating Shoreline Highway along Bolinas Lagoon will become a priority toward the middle of the century, as access to the community becomes impaired with increasing frequency.

If not yet retrofitted, Onsite Wastewater Treatment Systems (OWTS) can be updated to include shutoff valves, meet code, which will make them resilient to saltwater intrusion in the near-term. In the medium- to long-term, development code amendments allowing for mounded septic systems, or replacement of leachfields with holding tanks could be implemented. The Stinson Beach County Water District plans to continue retrofitting water meter connections in the near-term to withstand saltwater corrosion. Electric utilities located beneath buildings will also need to be elevated or retrofitted. The Water District office will likely need to be elevated or relocated in the near-term. Fire Station #2 is already elevated on a mound and the district has plans to relocate the facility before it is impacted by SLR in the medium-term.

A comparison of conceptual adaptation strategies for Stinson Beach is described in the Community Alternatives section and in Appendix D (ESA Adaptation Strategy Memo). A potential dune and beach protection strategy would involve placing sand on a cobble berm and adding sand at regular intervals and after major storm events, as a hybrid protection approach. The costs for these strategies is large and greatly exceeds available funding.

Brighton Beach in Bolinas *Credit: S. Hutto*

Bolinas

Accommodation of threatened structures and utilities through elevation and retrofitting could be priority action. Shoreline Highway and Wharf Road are of primary concern in the near-term, while Olema-Bolinas Road and the bridge at Pine Creek Gulch may need to be elevated or rerouted in the medium term. Bluff top homes may need to be removed once the bluff edge erodes to within a certain distance of the structure.

The Bolinas Public Community Utility District Sewage Treatment Facility will need to be protected, and other critical facilities and community resources like the grocery store, emergency shelter and library will need to be elevated or relocated in the medium-term. The Post Office and Bolinas-Stinson School will need to be elevated or relocated in the long-term. Nature-based protection measures such as an oyster reef and/or horizontal levee in Bolinas Lagoon may help protect Gospel Flats, which may eventually be conserved and returned to wetland. Wetland protection and enhancement efforts (currently underway as part of the Bolinas Lagoon Restoration Project) will also have flood protection benefits.

Old fishing boat in Inverness *Credit: R. Porrata*

Inverness

Homes and other structures currently near or over water could be further elevated, and portions of critical roadways like Sir Francis Drake and Shoreline Highway could also be raised to maintain access at higher water levels. In addition to protecting properties vulnerable in the near-term, converting affected segments of Sir Francis Drake Boulevard into a levee would protect the water pipeline beneath the road. Wetland restoration and oyster reefs in the near-term and a horizontal levee in the medium-term are potential nature-based solutions.

Restoring and enhancing living shorelines along Tomales Bay offers near- to medium-term protection against temporary flooding, storm surge, and wave impacts. Habitat restoration techniques can be used to manage the

shoreline, reduce coastal erosion, and maintain coastal processes.

East Shore

Homes and other structures currently over water could be raised higher, and portions of Shoreline Highway could also be raised to maintain access at higher water levels. Wetland restoration and oyster reefs in the near-term and potentially horizontal levee in the medium-term are potential nature-based solutions. Maintaining bulkheads under homes along the East Shore and Marshall is a high priority to protect Tomales Bay from sewage.

Raising houses along the Marshall waterfront is very difficult and expensive, and creative solutions from people familiar with Tomales Bay are needed. As water levels rise, the area under houses becomes less accessible for foundation work. There is a great deal of interest from residents in developing a community-wide solution by coordinating the elevation of multiple homes. This could help provide a better economy of scale for permitting, design work and construction. Such a pilot project could be modeled after the Marshall Community Wastewater System which was a coordinated effort to protect water quality and share costs between government agencies and property owners, though specific funding sources would need to be identified.

Point Reyes Station

Surrounding wetlands and marshes, including Giacomini Wetlands and Olema Marsh could be degraded by flooding, erosion, and increased salinity. Water district pipes traversing under the marsh and road could be damaged by higher groundwater and would benefit from elevation or other protection. Flooding is probable on portions of Shoreline Highway in the long-term scenarios, however Green Bridge is vulnerable in the near-term. Caltrans began the multi-year process of replacing Green Bridge in 2014, planning for SLR and identifying a set of alternatives for public review.

Dillon Beach

Priority actions for Dillon Beach are to support dune restoration efforts as a protective measure, research alternatives for managing flooding on Bay Drive, and implement policies to ensure that bluff top homes are safe from erosion. Plans for dune restoration and enhancement are being developed by Lawson's Landing owners. Planting native vegetation to augment existing beach grass may help encourage natural augmentation of the dunes. This is considered a cost-effective and environmental approach, compared to importing sand. A monitoring plan could be developed to contribute to the body of research on the efficacy of this measure at reducing coastal erosion and protecting Lawson's Landing recreational facilities from wave run up.

Implementation Phasing

Strategies were prioritized based on a set of criteria determined by Marin County, with input from the SAC and TAC. The criteria include projected onset of impacts (See Chapter 3), timing and duration of the strategy, co-benefits, and legal, political and community acceptability. General cost-benefit analysis was performed on various alternative scenarios using a published range of costs to provide a basis of evaluation of next steps. Priority for adaptation alternatives ready for action, further study, or long-term implementation were further refined through working sessions with DPW and Environmental Science (ESA).

See **Table 2** for a summary of priority strategies. Further detail is provided in the Asset-Based Strategies and Community Alternatives chapters.

Next Steps

This report summarizes adaptation options that have arisen through the C-SMART process to date. These options are not endorsed by the County of Marin or project partners, are not all necessarily feasible (economically, socially, environmentally, etc.), and in some cases may conflict with one another. However, the options presented in this report have been recognized as meriting further consideration. In conjunction with willing partners, C-SMART Staff can develop a work program to move strategy discussions forward. Option inclusion in this report does not imply financial commitment by Marin County, and completion of certain tasks is dependent on acquiring additional funding, which would require exploring various funding sources/types. Some potential next steps are listed below.

- Provide organizations recognized in the 'Potential Partners' column of the asset strategy options with a copy of this report for their consideration of implementation.
- Develop a subcommittee with representation from the Marin County Board of Supervisors, and representatives of the communities and local agencies to prioritize work going forward.
- Develop a process with relevant stakeholders to identify subarea boundaries for prioritization. Utilize support from willing partners and landowners and/or target areas based on timing, area of impact, costs, equity, environment, economy or some combination of the above. If there is stakeholder interest and funding secured, in conjunction with community members and asset managers, initiate Community Plans for Adapting To Coastal Hazards (Community PATCHs). Such efforts would build off C-SMART's Vulnerability Assessment and Adaptation Report. Vulnerabilities for assets of critical importance including flood timing, frequency and duration would be determined. Trigger points would be identified in conjunction with residents to understand the point at which flooding creates recurring significant problems. Planning timeframes would be developed around identified trigger points to plan for continued use of assets critical to the community. (see Page 123 for a proposed process of PATCH development)
- Develop an interagency SLR task force with representatives from various agencies who oversee West Marin assets (transportation, utilities, public lands, natural resources, etc.). This task force will meet regularly to discuss options outlined in this report and prioritize recommendations.
    - Among other topics, the task force could discuss existing state law, building codes, and Coastal Commission requirements that may need to be modified to reduce and ease approval requirements,

including costs. Task force recommendations could facilitate the efforts of homeowners and local public agencies to protect their properties in the face of sea level rise that actually threatens structures and utilities.

- Introduce *Homeowners Guide to Sea Level Rise* to local property owners for their consideration through public workshops, social media, etc.
- Consider options outlined in this Report during the next update of the Marin Countywide Plan, as a basis for developing Plan policies and programs that address SLR resiliency countywide.
- Utilizing ideas generated in the *Resilient Stinson Design Charrette,* develop performance design guidelines including alternatives to permanent static elevation that reduce or eliminate flood damage to structures which could include wet/dry floodproofing, flood gates, drainage improvements, amphibiation, etc.
- Formalize working relationships (e.g., Joint Powers Authority, MOUs, etc.) to oversee and carryout implementation of highest priority options. Establish sub-groups based on varying timeframes for different assets. Public infrastructure may be considered on a longer timeframe than private homes. Specifically MOUs or other formalized workshop agreements could be sought with:
    - Caltrans, MTC and TAM for Shoreline Highway planning support as part of the Regional Transportation Plan.
    - National Park Service (NPS)/Golden Gate National Recreation Area (GGNRA)/CA Department of Parks and Recreation (CSP)/Marin County Parks to share science and integrate planning/ management decisions for interlocking lands (e.g., Stinson Beach, Point Reyes National Seashore).
    - Marin County Office of Emergency Services (OES) to formalize working relationship with Local Hazard Mitigation Plan and SLR adaptation planning efforts.
    - PG&E and local service providers to discuss utility adaptation.
- Evaluate and accommodate for SLR in new capital improvement programs where cost effective, fully funded and permitted.
- Establish a citizens science monitoring program perhaps in coordination with GFNMS existing program.
- Continue to pursue funding and partnerships to formalize a SLR public education program
- Coordinate with other entities planning for SLR to share investigation and evaluation of specific adaptation techniques. This can be done through existing networks such as the California Coastal Adaptation Network.

- Continue to work with GFNMS to support strategies recently approved by the GFNMS Advisory Council, and conduct sediment management planning.

- Continue to work with the Sonoma/Marin County Sediment Management Working Group to assist with the development of a Regional Sediment Management Plan for Marin and Sonoma's outer coastline. The Plan intends to develop consensus-driven approaches to regional sediment management throughout the region; encourage beneficial reuse of available, non-polluted sediment resources; restore and maintain coastal beaches and other critical areas with too much or too little sediment; reduce shoreline erosion and coastal storm damages; reduce the proliferation of protective shoreline structures; sustain recreation and tourism, and; enhance public safety and access to the coast. The plan is being developed by the Greater Farallones National Marine Sanctuary in partnership with the Greater Farallones Association and funded by the California Natural Resources Agency. A possible Working Group topic could be the feasibility of acquiring sand from the San Andreas Graben that could possibly support Marin County beach nourishment. If sand is available, initiate discussions with land managers and other willing partners to move renourishment efforts forward.

The tables that follow are a list of near-term, medium-term, and long-term potential management actions to protect the vulnerable assets along coastal Marin County and a guide to find more detailed information in the document by page number.

Table 2. Priority Sea Level Rise Adaptation Strategies

		Potential Management Action	Potential Partners	Resources	Page
		All Assets			
Near/ Ongoing	A-1	Explore the feasibility of experimental and innovative coastal protection options, and where possible implement demonstration projects, including constructed wetlands/horizontal levees, offshore reefs/oyster beds, and dune restoration/beach nourishment. Evaluate the effectiveness of such projects to inform future efforts across the region.	CDA, GFNMS, NPS, DFW, Universities, CCC, SCC, COS, Property Owners	Staff, partners, financial resources, agency coordination	58, 76, 76, 76, 82, 146, 148, 150, 158, 162, 178, 178, 179, 188, 189, 189, 192, 200, 200, 200, 209, 209, 215, 217
	A-2	Participate and support existing local community programs, including but not limited to education, outreach, and emergency preparedness, that promote community resilience.	CDA, Community Groups	Staff, community groups	72, 82, 178, 179, 217
		PARCELS & BUILDINGS			
Near/Ongoing	B-1	Through LCP Environmental Hazards policies including EH-1, EH-2, EH-3, EH-5, EH-8, EH-9, and EH-11 (Appendix B), ensure new development is safe and limit development in hazardous areas. Require property owners to assume and disclose risks from coastal hazards, including impacts from 3 feet of SLR.	CDA, CCC, Property owners	Staff, private time/financial resources	73, 86, 86, 164 86

	Potential Management Action	Potential Partners	Resources	Page
B-2	Require three feet additional elevation of structures in Special Flood Hazard Areas (in addition to Federal Emergency Management Agency (FEMA) Base Flood Elevation) to accommodate three of SLR. In areas outside FEMA Special Flood Hazard Areas that are nevertheless exposed to SLR, the 3 foot building elevation would also be required. The policy would apply when a new or remodeled building requires a Coastal Permit, based on actual conditions of the site. FEMA grant funding for structural elevation could be sought, possibly including the Marin County Structure Elevation program, a FEMA Hazard Mitigation Grant Program.	CDA, CCC, FEMA, Property owners	Staff, Public and/or private funding	74, 86, 86, 164
B-3	Pursuant to Local Coastal Program C-EH-22.a(7): Support efforts to develop and implement innovative design alternatives to elevating structures that would reduce or eliminate flood damage. Measures would need to be adopted by FEMA to qualify as acceptable alternatives to elevation under the National Flood Insurance Program (NFIP). Such alternatives could include wet/dry floodproofing, flood gates, drainage improvements, amphibiation, etc. Encourage homeowners to implement voluntary flood-proofing measures.	CDA, CCC, FEMA, Property owners	Staff, Agency Coordination	76, 86, 87, 94, 95,
B-4	Develop a "Homeowner's Guide to Preparing for Sea Level Rise" to help homeowners navigate regulatory system and funding opportunities to elevate or otherwise retrofit homes to accommodate SLR and storms. Topics could cover: • County permitting process. • Coastal Permit Development Requirements (Figure 6) • Agency Compliance (FEMA, California Coastal Commission (CCC), etc.)	CDA, FEMA, CCC, Property Owners	Staff, Public outreach materials	87

		Potential Management Action	Potential Partners	Resources	Page
		• Potential estimated building elevation increase			
	B-5	Use Marin Map as a platform to show regulatory boundaries (e.g., FEMA, CCC jurisdiction, Categorical Exclusion), County-developed "Potential Sea Level Rise Maps", and other existing coastal hazard boundaries.	CDA, CCC, FEMA	Staff., agency coordination, Marin Map	87
	B-6	Conduct a comprehensive finished floor elevation inventory to fully assess West Marin building vulnerabilities.	CDA, DPW	Staff, intern or volunteer time	87
Long	B-7	Explore the feasibility of programs (incentives, TDRs, Acquisition/Buyout) and potential receiving sites to relocate existing vulnerable development.	CDA, NPS, CA CSP, MALT	Staff, Legal coordination, Precedents, Upland property	59, 67, 88, , 148, 170, 180, 191, 203, 209, 216
		TRANSPORTATION			
Near/Ongoing	T-1	Consider planning for Shoreline Highway and county-maintained roads as part of the Regional Transportation Program	Caltrans, MTC and TAM, DPW, community members	Staff, agency coordination	76, 77, 112, 113, 147, 157, 167, 177, 190, 190, 201, 201, 203, 209, 209, 210,
	T-2	Further investigate Shoreline Highway vulnerability along Tomales Bay in the Eastshore Area. Determine if bulkheads below homes help protect highway. If so examine long term adaptation strategies for continued protection in collaboration with homeowners.	Caltrans, property owners	Staff, agency coordination, homeowner participation	113, 199
	T-3	Evaluate new capital improvement projects to account for 3 feet of SLR.	CDA, DPW, Caltrans	Staff, agency coordination	74, 77, 111, 113, 118,

		Potential Management Action	Potential Partners	Resources	Page
	T-4	Identify triggers for maximum flood depth or frequency as thresholds at which roads will need to be elevated, relocated, seasonally closed, or abandoned. This could include community surveys to understand the point at which flooding is perceived as causing public inconvenience.	CDA, Caltrans, DPW, Other technical Experts	Staff, Agency coordination, Technical assistance	67, 113, 147, 167, 180, 201, 209, 216
	T-5	Support post-disaster repairs as an opportunity to plan for higher water levels.	CDA, DPW, Caltrans	Agency coordination, Staff	111, 113
	T-6	Standards for road flooding closure need legal definition and should be publicized with signage to alert drivers as to what they should expect.	*CDA, DPW, Caltrans*	Agency coordination, Staff, Legal Counsel, Signage	
Medium	T-7	Explore the feasibility of realigning vulnerable roads landward. Utilize Marin County DPW table on *Potential Adaptation Options - General Strengths and Weaknesses* to guide evaluation of transportation adaptation alternatives.	CDA, DPW, Caltrans	Agency coordination, Staff	76, 67, 113, 116, 125, 167, 180, 180, 191, 201, 203, 210,
		UTILITIES			
Near/Ongoing	U-1	Continue efforts to elevate or otherwise protect electrical, fuel, sewage management and water systems from high tide levels.	CDA, Utilities, Homeowners Associations, Property owners	Staff, Public/ private funding	64, 79, 73, 104, 118, 156, 157, 177, 180, 190, 190, 201,
	U-2	Consistent with proposed LCP home elevation requirements, consider new capital improvement projects to evaluate impacts and costs for 3 feet of SLR.	CDA, DPW, Marin County Parks, other agencies as necessary	Staff, Public funding	74, 77, 73, 111, 113, 118

		Potential Management Action	Potential Partners	Resources	Page
	U-3	Ensure that development policies are consistent with strategies for accommodating SLR (e.g., consider eliminating requirements to bury utilities in areas vulnerable to SLR).	CDA, CCC	Staff	64, 118
	U-4	Work with Stinson Beach County Water District (SBCWD) and EHS to determine if SLR will raise groundwater levels to impair OWTS.	CDA, SBCWD, EHS	Staff, agency coordination	119
Medium	U-5	Work with local service providers to determine the point at which communities would need to convert to shared public wastewater system alternatives to accommodate for SLR.	CDA, Local service providers	Staff, agency coordination	118, 148, 169, 190,
	U-6	Identify potential upland areas to retreat/relocate utility systems, including wells and wastewater infrastructure which may include sewage pumps, lift stations and septic leach fields. National Park lands could be considered, in close coordination with NPS.	CDA, Local service providers, NPS, CSP, MALT	Staff, spatial data, GIS	118, 120, 148
Long	U-7	Establish community shared public wastewater systems in relevant areas.	CDA, Landowners, Local service providers, Local assessment district	Staff, upland property, private and/or public financial resources	119, 148, 169, 190,
		WORKING LANDS			
Near/Ongoing	W-1	Maintain and adapt coastal armoring.	CDA, Property Owners, CCC	Staff, Private financial resources	74, 68, 121, 157, 177
	W-2	Work with agricultural interests to respond to SLR.			
Medium	W-3	Work with agricultural operators and funding organizations to secure rights to allow wetlands to expand inland with SLR.	CDA, Property owners, CCC	MALT, SCC, DFW	121

		Potential Management Action	Potential Partners	Resources	Page
		NATURAL RESOURCES			
Near/Ongoing	N-1	Enhance SLR education programs through partnerships with educational organizations and other public entities, including: • Partnerships with environmental education organizations, schools and other public entities • Social media and other communication strategies, such as SLR visualizations and crowdsourcing king tides photos • Interpretive signage • Expansion of Marin County's existing Youth-Exploring Sea Level Rise Science (YESS) program. • Marsh and tidepool education and interpretation programs through training and guidance to communicate implications of climate change • Establish a volunteer docent program, for highly visited areas. This could augment existing programs (e.g., Duxbury Marin Reserves). Docents training could include climate change impacts on intertidal habitats, as well as tidepool etiquette and safety.	CDA, GFNMS, CA Academy of Sciences, NPS, CSP, County Parks, Other educational organizations	Financial resources, staff, volunteers, curricula trainings, classrooms	71, 122, 146
Medium	N-2	Stabilize cliffs through revegetation (with native, climate appropriate species) and natural netting (e.g. jute, not chain-link fence). Design any hardening methods to take into account ecosystem needs (e.g. seabird nesting). Consider the listed Showy Rancheria Clover (*Trifolium amoenum)*, including assisted migration to locations further upslope. Avoid armoring and encourage relocation of infrastructure to allow for managed retreat. Minimize non climate stressors including human and livestock access.	CA Conservation Corps, CA Native Plant Society, Caltrans, landowners/managers (public and private)	Financial resources, staff, permits, engineering studies	85, 123, 146, 16

		Potential Management Action	Potential Partners	Resources	Page
	N-3	Consider nature-based adaptation options for eelgrass habitat. • In the near-term map potential landward transgressional areas and protect potential transition habitat. • As water rises, monitor trends in eelgrass extent; possibly plant in shallower water to kick-start colonization of areas available for landward transgression. • Minimize non-climate stressors including restoration of areas lost from moorings, minimizing disturbance to existing beds and monitoring changes in turbidity.	CDA, GFNMS, DFW, Community Members, Business owners, SF Bay Living Shorelines Projects (case study)	Financial resources, staff, local community involvement, mapping/monitoring equipment and software, plant propagules, possible land acquisition/easements etc. for habitat restoration, volunteer/citizen scientist monitors	123, 178, 189, 192, 200

		Potential Management Action	Potential Partners	Resources	Page
	N-4	Consider nature-based adaptation options for Tidal Marsh habitat. • In the near-term consider accommodation strategies including o Mapping potential landward transgressional areas and protecting potential transition habitat and allowing for habitat transition o Consider removing potential barriers to landward migration (e.g, Highway 1 bridge in the Walker Creek Delta, Sir Francis Drake Blvd. between Inverness Park and Reyes Station, Bear Valley Road and Highway 1, Shoreline Highway in Marshall, Shoreline Highway in Bolinas Lagoon) o Identifying ownership of and acquiring potential transition zones upstream of current marsh footprint. • If high value resources/functions are present, consider augmenting sediment in the long-term to allow for accretion of marsh within existing footprint (e.g., Walker Creek Delta, Giacomini Wetland Restoration Footprint). • Non-Climate stressors such as invasive species should be minimized. • Allow for loss of marshes in cases that they have less high value resources (could include Tomales Bay area in Inverness). Instead, prioritizing action on more significant areas of intact marshes nearby (e.g., Pt. Reyes Station/Lagunitas Creek Delta). • Engage with ongoing efforts (e.g., Bolinas Lagoon Restoration Project) to ensure planning includes future SLR. • Engineer marshlands to enhance water flow and balance sediment transport by including design elements such as sinuous channelization.	CDA, Marin County Parks and open Space, Point Reyes National Seashore GFNMS,GGNRA, Community Members, Business owners, DFW	Financial resources, staff, local community involvement, mapping/monitoring equipment and software, plant propagules, possible land acquisition/easements etc. for habitat restoration, volunteer/citizen scientist monitors, engineering studies, permits/environmental reviews	58, 76, 76, 76, 82, 122, 146, 148, 150, 158, 162, 178, 178, 179, 188, 189, 189, 192, 200, 200, 200, 209, 209, 215, 217

	Potential Management Action	Potential Partners	Resources	Page
	NATURAL RESOURCES (cont.)			
N-5	Consider nature-based adaptation options for beach/dune habitat. • Determine if topography and land use/infrastructure allows for inland movement of beach/dune habitat. Where feasible, remove/relocate shoreward constraints to dune movement and evolution. • Restore/Construct/augment coastal dunes. This could include placement of sand, graded and planted to form back beach dunes or placement of cobble. Drought tolerant and heat resistant species or strains should be used. In cases where dredge materials are used, make sure materials are screened for contaminant exposure. • Where applicable, minimize human and pet access through dunes to protect stability and disturbance, which could include fencing, creating walkways, and informational signage. Beach grooming should be ceased as well as any activity that adversely affects the sediment supply of dunes. • Identify potential sources of compatible sediment (considering appropriate grain size and structure) for vulnerable beaches in order to enable potential nourishment.	NPS, Landowners	Sand, Financial Resources, Staff, Permits/Environmental Review	58, 76, 82, 146, 158, 178, 215, 217
N-6	In cases that coastal armoring is exacerbating erosion, explore natural alternatives that create sloped, transitional habitat (e.g., artificial reef, horizontal levee or dune). If armoring can't be removed, implement living shoreline techniques in conjunction with new construction/repairs.	GFNMS, NPS, DFW, Universities, SCC	Financial Resources, Staff, Permits/Environmental Review, Public Outreach	124

		Potential Management Action	Potential Partners	Resources	Page
	N-7	In cases in which roads need to be realigned/relocated due to 'trigger points' being reached (e.g., causing public inconvenience), siting and design should allow for natural expansion of habitats. Areas should be identified that are critical for estuary expansion and roads could be realigned accordingly.	Caltrans, GFNMS, US Army Corps of Engineers, Regional Water Quality Control Board, Landowners	Agency Coordination, Financial resources, Staff, Permits/Environmental Review	125
	N-8	Establish a monitoring program to detect impacts of climate change and management actions on natural resources including the following steps: • Postulate hypotheses of habitat change, based on scenarios and literature, of how habitats will evolve in response to climate change. • Design the monitoring programs to measure hypothesized changes • Identify indicator species for selected habitats, and set tentative population parameter goals based on current status and knowledge of the species. • Design the monitoring program to estimate the population parameter, and determine the extent and intensity of sampling required to achieve the monitoring goals, including sources of data, precision in parameter estimation, and costs • Review costs vs expected probability of monitoring goals to choose final indicator species, monitoring targets, data sources, survey effort, and costs	CDA, Scientific Partners, local community members, environmental non-profits	Financial resources, staff, mapping/monitoring equipment and software, volunteer/citizen scientist monitors	126
		RECREATION			
Near/Ongoing	R-1	Increase awareness of seasonal flooding on public lands/trails through signage and social media.	National, State and County Parks	Staff, projections, Impacts to local businesses	133

		Potential Management Action	Potential Partners	Resources	Page
Long	R-3	Retrofit or relocate recreation and visitor-serving facilities, including trails and access points, considering SLR projections. Acquire new parklands as existing parks become unusable from flooding, inundation, erosion, etc.	CDA, Property/ business owners, CCC, CSP, NPS, County Parks	Public/ private funding, Permits, Receiving sites, Materials	77, 133, 134, 191, 201, 203, 53
		EMERGENCY SERVICES			
Near/Ongoing	E-1	Partner with Local Hazard Mitigation Plan efforts to coordinate near term disaster preparedness with long-term community resilience.	CDA, Marin County OES, State OES, Local Emergency Response Teams	Staff, Agency coordination, Outreach materials	136,
Medium	E-2	Adapt or relocate vulnerable emergency facilities (e.g., fire stations, emergency generators).	CDA, OES, Stinson Beach Fire Department	Staff, property, financial resources	72, 136, 157, 177,
Long	E-3	Develop additional emergency response teams and resources required for disaster response, recovery and mitigation, as well as temporary housing and other sustainability needs.	CDA, Marin County OES, Local Emergency Response Teams	Staff, Coordination, Financial resources, Housing	71, 136
	E-4	Build redundancy into the system by providing alternate evacuation routes where feasible. This is particularly critical for communities such as Bolinas with one primary access road in and out that could be inoperable from flooding.	Stinson Beach, Bolinas, Inverness, Point Reyes Station, East Shore, Dillon Beach	Staff, Funding, Upland property, Permits, Environmental reviews	76, 64, 111, 117, 136, 147, 190
		HISTORIC & ARCHAEOLOGICAL RESOURCES			
Near/Ongoing	H-1	Adaptation planning/implementation efforts should consider the impacts on historic structures and archaeological sites consistent with applicable state/federal regulations as well as local community input. In cases where projects could have adverse effects, efforts should be made to avoid, minimize or mitigate the impacts consistent with relevant statutes (CEQA, Section 106, etc.).	CDA, Office of Historic Preservation, Tribal Historic Preservation Officers	Staff	77, 138, 180

		Potential Management Action	Potential Partners	Resources	Page
	H-2	Continue discussions with the Federated Indians of Graton Rancheria for consideration of archaeological sites in future vulnerability assessments, adaptation plans, and adaptation strategy implementation.	Federated Indians of Graton Rancheria	Staff and agency coordination	77, 138
	H-3	Update the 1981 Marin County Local Coastal Program Historic Study. This could include inventorying historic sites with lists, photographs and descriptions, and revising and expanding historic district boundaries. An updated study could: • Inform future SLR/climate change vulnerability assessments to more fully understand the extent of West Marin's threatened historical resources • Inform future adaptation planning for historic resources. • Document the resources in case coastal hazards damage or destroy the structures.	CDA, CCC	Staff, consultant assistance, financial resources	77, 138
Medium	H-4	Recognize and consider projects which protect/mitigate historic and cultural resources in Marin County's Local Hazard Mitigation Plan. Use FEMA's How-to-Guide "Integrating Historic Property and Cultural Resource Considerations Into Hazard Mitigation Planning". Upon FEMA approval, such projects may be eligible for Federal Funding.	CDA, OES, DPW, FEMA	Staff, agency coordination, FEMA grant funding	77, 138
	H-5	Work with the State Office of Historic Preservation's disaster task force to assess damages to historic and archaeological sites that may occur from storm events or other disasters.	CDA, State Office of Historic Preservation, Private Property Owners, Federated Indians of Graton Rancheria	Staff, agency coordination	77, 139

1) Introduction

In this section you will find:

- A statement of the intention and goal of the project;
- A list of the project partners;
- The planning areas covered in the report;
- The principles that guide the planners in their efforts;
- A summary of the Vulnerability Assessment report that was published in December 2015.

1.1) Project Intent and Goals

Global SLR has opened questions about the wisdom of rebuilding or protecting vulnerable assets, versus relocating or abandoning them as part of a managed retreat program. With over one-quarter of properties in the Coastal Zone and hundreds of natural and community assets threatened by SLR, Marin County is engaged in the critical task of planning how to prepare for and adapt to, changing seas. SLR is a pressing global issue that locally will increase the potential for erosion, increase the extent of chronic inundation in low lying areas and result in more severe storm flooding.

The *Marin Ocean Coast Vulnerability Assessment* and this document, the *Marin Ocean Coast Adaptation Report*, lay the groundwork for an adaptive management approach to addressing SLR in Marin County. The Adaptation Report presents near, medium, and long-term options to accommodate, protect against, or relocate/ retreat from the threats of SLR and extreme events. There is no silver bullet for adapting to the changes coming to our coastline, and adaptation measures will have varying economic, environmental, and social costs and effects. The goals of adaptation planning are to help protect human life, health and property, ensure the safety of new development, maintain public access and recreational opportunities, and protect beaches, wetlands and other natural resources on Marin's ocean coast.

This document is intended to inform the Marin County Local Coastal Program, coastal permitting and other County goals related to SLR preparation. This document would also be considered by the Local Hazard Mitigation Plan (LHMP), the Marin Countywide Plan (CWP), and Design Review process for proposed development. The adaptation options provided in this Report are intended to be useful in developing strategies throughout County operations, including securing funding and establishing ongoing programming. This Report serves as a tool for Marin County governmental departments, individual property owners, state and federal parks, state transportation agencies, asset managers, and coastal residents. Marin County's adaptation planning process may also serve as an example for other communities.

1.2) Project Partners

Led by the Marin County Community Development Agency (CDA), "Collaboration: Sea-level Marin Adaptation Response Team (C-SMART)" began in July 2014 with financial support from the California Ocean Protection Council (OPC) and the CCC.

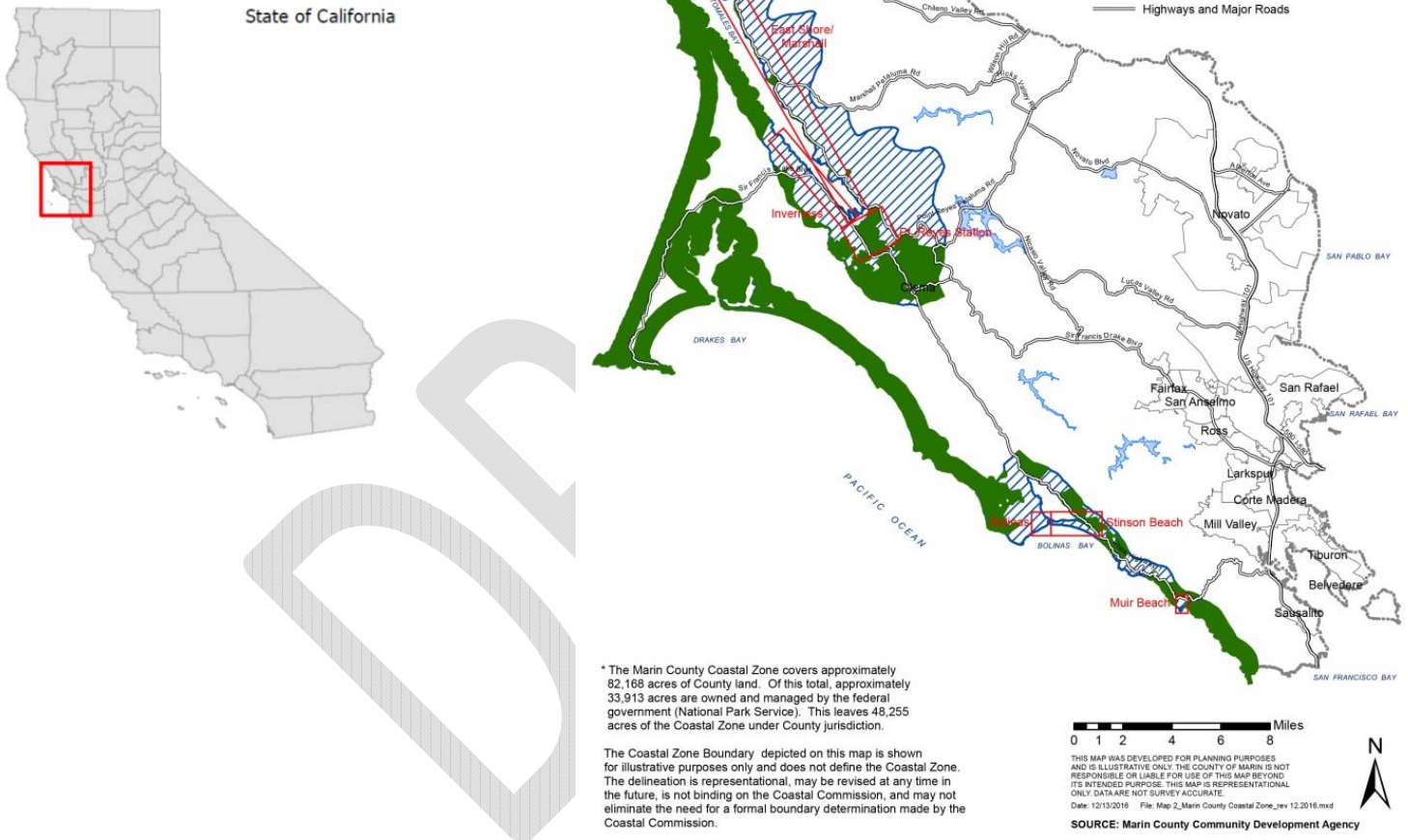
Project partners include GFNMS, USGS, Point Blue Conservation Science (PBCS), Coravai, Center for Ocean Solutions (COS), and DPW. The technical advisory committee includes staff from FEMA, Caltrans, National Oceanic and Atmospheric Administration (NOAA), California CSP, and the NPS, while the stakeholder

advisory committee includes representatives from Marin's coastal communities of Muir Beach, Stinson Beach, Bolinas, Inverness, Point Reyes Station, the East Shore (including Marshall), Dillon Beach, and further north to the Sonoma County border.

1.3) Planning Area

The planning area (Map 1) is Marin County's Coastal Zone (in some cases stream impacts extend beyond the eastern boundary). The Marin County Coastal Zone covers approximately 82,168 acres. Of this, approximately 33,913 acres are owned and managed by the NPS, leaving 48,255 acres of the Coastal Zone under County jurisdiction [Pursuant to the Federal Coastal Zone Management Act of 1972 (16 U.S.C. 1451, et seq.)].

Map 1. Planning Area. Areas indicated in red are relative locations of Community Alternative sections



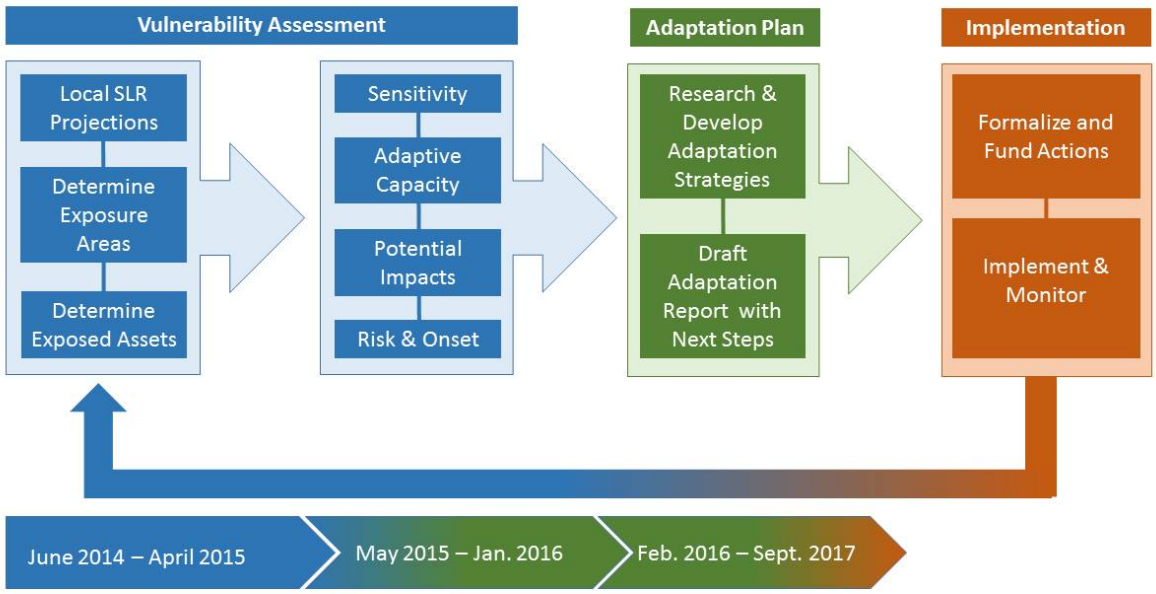
1.4) The C-SMART Process

The C-SMART process is in the Adaptation Plan Phase as shown in Figure 1. This document incorporates findings from the *Marin Coast Sea Level Rise Vulnerability Assessment* (Assessment). The Assessment provides data and the best available science for SLR and how it could impact coastal Marin. Ideas for adaptation strategies came from a wide variety of sources. C-SMART C-SMART Staff has done extensive literature review to identify potential strategies for West Marin based on comparable case studies. Insights and additional ideas were generated in engaging coastal residents in several community workshops addressing SLR vulnerability and adaptation. C-SMART's TAC and SAC provided ideas on adaptation strategies through advisory committee meetings. Finally, this Plan utilizes the expertise of several partner organizations including ESA, the COS (Stanford University), and GFNMS, among many others. Methodologies from stakeholder, technical expert and C-SMART partner processes are described in greater detail below.

The options were gathered from the community, technical experts, and literature and case study research and vetted to answer the following questions:

1. Does the strategy:
    a. Protect?
    b. Retreat?
    c. Accommodate?
    d. Preserve? (natural resources)
2. Is the strategy suited for:
    a. Infrastructure?
    b. Developed properties?
    c. Vacant properties
3. Is the strategy useful in the:
    a. Short-term?
    b. Medium-term?
    c. Long-term?
4. Does the strategy have positive, neutral, or negative impacts on:
    a. Economy?
    b. Environment?
    c. Social equity?
    d. Administrative?
    e. Legal?
5. Is the strategy suited for:
    a. Coastal shoreline/blufftop?
    b. Bay / estuarine environments?
    c. Riverine environments?
6. The strategy reduce impacts of:
    a. Temporary Flooding?
    b. Inundation?
    c. Erosion?
    d. Wave Surge?
    e. High Wind
7. Where has this strategy been implemented?
8. What are the estimated costs (administrative, capital, construction, maintenance)?

Figure 1. C-SMART Process



1.5) Guiding Principles

Principles were developed to guide the adaption planning process and outcomes, and vetted with stakeholders through the C-SMART process. These include:

1.5.1 General Approach

- Recognize that West Marin is affected by the world around it.[3]
- Recognize that SLR is one of several climate change and other potential coastal hazards (earthquakes, fires, sandy soils, creek and river flooding, storm winds and waves, and fluctuating tides) current and future residents will likely face. Interrelationships between these factors will impact the coast and can be monitored moving forward.
- Facilitate adaptation of existing development to reduce vulnerability to SLR impacts over time.[4]
- Prioritize SLR adaptation strategies that have co-benefits for other climate risks.[5] Adaptation measures should minimize adverse impacts while encouraging common benefits.[6]
- Design adaptation to fit into existing programs and mechanisms where possible, so as to not create additional layers of bureaucracy
- Adaptation planning, and initial plan implementation, must begin now, and can be refined as more information becomes available.[7]
- Due to the high degree of uncertainty, use an adaptive management approach, with indicators and established monitoring. Adaptation policies need to be flexible enough for circumstances that may not yet be fully predictable. Avoid unnecessarily prescriptive adaptation actions. Encourage decisions at the local level.[8]
- Acknowledge that there will be losses, and rationally assign budgets and efforts to those assets that have the highest value and the best chances of survival. Discuss value of adding some life to certain assets while forgoing long-term preservation, rather than complete preservation. Strike a balance between protection of homes, infrastructure and conservation of natural resources. [9]
- Utilize a precautionary approach to minimize risk borne by local communities.[10]
- Avoid, and where unavoidable, minimize, significant coastal hazard risks to new development and redevelopment over the life of authorized structures.[11]
- Warn property owners that they need to understand and assume the risk of development in hazardous areas.[12]

3 National Adaptation Forum. *Adaptation Pledge.* www.nationaladaptationforum.org/about/adaptation-pledge

4 ICLEI-Local Governments for Sustainability. *Sea Level Rise Adaptation Strategy for San Diego Bay.* January 2012.

5 Ibid. "Co-benefits" are the other benefits (in addition to flood and sea level rise protection) that a community may experience if an adaptation strategy is implemented. These can include greenhouse gas reduction, habitat protection/creation, economic improvement, and many other potential community goals.

6 National Adaptation Forum. *Adaptation Pledge.*

7 Delaware Coastal Programs. *Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware.* September 2013.

8 ibid

9 ibid

10 ICLEI-Local Governments for Sustainability. *Sea Level Rise Adaptation Strategy for San Diego Bay.* January 2012.

11 California Coastal Commission. *Sea Level Rise Policy Guidance*. August 2015.

12 ibid

- Encourage priority for coastal-dependent and coastal-related development over other development.[13]
- Recognize public trust boundary changes resulting from SLR.
- Avoid "maladaptation" by avoiding actions that, relative to alternatives: increase emissions of greenhouse gases, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt, and set paths that limit the choices available to future generations.[14]

1.5.2 Available Science

- Use available science and knowledge to consider present, past, and foreseeable future conditions[15], and use best available technology for decision-making and adaptation strategies and actions. Take account of locally-relevant and context-specific SLR projections in planning, project design, and permitting reviews.[16]
- Stay abreast of the responses of threatened areas around the globe to learn of sensible and effective strategies.[17]
- Consider the cumulative impacts and regional contexts of planning and permitting decisions. [18]

West Marin coastal marsh. *Credit: Sevin*

1.5.3 Equity

- Promote a diversity of partners and stakeholders in conversations and decisions. [19]
- Work to ensure the equitable sharing of the benefits and costs of SLR. Consider equity in selection and funding of adaptation measures. Safeguard integrity: Encourage transparency, accountability & follow-through.[20]
- Adaptation measures should consider the distinct vulnerabilities of potentially affected subpopulations.[21]

1.5.4 Engagement

- Engage broad public participation in adaptation decisions.[22] Foster collaborative problem solving, involve relevant stakeholders in considering the adaptation strategy. [23]

13 ibid
14 Global Environmental Change. *Maladaptation Editorial.* www.elsevier.com/locate/gloenvcha. 2010.
15 National Adaptation Forum. *Adaptation Pledge.* www.nationaladaptationforum.org/about/adaptation-pledge
16 California Coastal Commission. *Sea Level Rise Policy Guidance.* August 2015.
17 C. Harrington
18 California Coastal Commission. *Sea Level Rise Policy Guidance.* August 2015.
19 California Natural Resources Agency. *Safeguarding California: Reducing Climate Risk.* July 2014.
20 Natural Adaptation Forum http://www.nationaladaptationforum.org/program/good-adaptation-pledge
21 California Climate Change Center.
22 California Coastal Commission. *Sea Level Rise Policy Guidance.* August 2015.
23 Environmental Protection Agency (EPA) *National Estuary Program.* 2015.

- Strive to establish and maintain partnerships between government, tribes, businesses, landowners, and non-governmental organizations (NGOs) in the development and implementation of adaptation strategy recommendations. [24] Support each other in research and monitoring efforts.[25]
- Coordinate and consider consequences of adaptation among jurisdictions and resource types. [26]
- Communicate within and between the coastal communities to share information, successes, failures and funding resources. Maintain an ongoing public outreach program.

1.5.5 Environment

- Maximize natural shoreline values and minimize shoreline armoring.[27]
- Protect ocean and coastal ecosystems. Protect public access to coastal areas and beaches, natural shoreline, and park and recreational resources. [28]
- Address potential coastal resource impacts (wetlands, habitat, agriculture, scenic, *etc.*) and recognize the desirability of measures to protect coastal resources in all coastal planning and regulatory decisions.[29]

1.5.6 Economy

- Adaptation planning should identify and address potential impacts to the local and regional economy from SLR.
- Adaptation efforts that preserve and enhance habitat contribute to healthy working and living conditions, provide a continuing draw for tourism and recreational industries, and stimulates related economic opportunities.
- Appropriate and timely adaptation measures can benefit the economy by maintaining a diverse and sustainable local economy, and providing for the safe and efficient movement of people and goods.[30]

Sunrise at Nick's Cove. *Credit: Klingel*

24 ICLEI-Local Governments for Sustainability. *Sea Level Rise Adaptation Strategy for San Diego Bay.* 2012.
25 California Coastal Commission. *Sea Level Rise Policy Guidance.* August 2015
26 Delaware Coastal Programs. *Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware.* September 2013.
27 ibid
28 ICLEI-Local Governments for Sustainability. *Sea Level Rise Adaptation Strategy for San Diego Bay.* January 2012.
29 California Coastal Commission. Sea Level Rise Policy Guidance. August 2015.

30 Marin Countywide Plan. Prepared by the Marin Community Development Agency. November 6, 2007.

1.6) Vulnerability Assessment

The *Marin Coast Sea Level Rise Vulnerability Assessment*, published in December 2015, presents asset profiles of community assets describing their vulnerability. These assets are: parcels and buildings, transportation networks, utilities, working lands, natural resources, recreational activities, emergency services, and historic and archaeological resources. It also includes community profiles highlighting the vulnerable assets in Muir Beach, Stinson Beach, Bolinas, Inverness, Point Reyes Station, East Shore, and Dillon Beach (which includes north of Dillon Beach to the county line).

Each profile details key issues, geographic locations, existing policies, and other economic, environmental, equity, and management considerations related to SLR vulnerability. Each profile can be used independently of the others to enable asset managers to focus on their professional area, and community members, elected officials, and others to read the results by community.

Vulnerability is based on an asset's exposure, sensitivity, and adaptive capacity to rising waters and storm threats. If an exposed asset is sensitive to SLR impacts, with low to no adaptive capacity, the asset is considered vulnerable. The project team interviewed asset managers using the "Asset Vulnerability Assessment Tool", which was developed by County staff with questions for asset managers aimed to quantify assets' sensitivities and adaptive capacities to flooding (permanent and temporary), erosion and other impacts. The interview results were combined with geographic data and citizen input gathered during public workshops to develop the Vulnerability Assessment.

Table 3 shows the range of SLR projections for California adopted by the National Research Council (NRC) in 2012.

Table 3. Sea Level Rise Projections for San Francisco, CA Region

Time Period	Projected Range
by 2030	1.6 – 11.8 inches
by 2050	4.7 – 24 inches
by 2100	16.6 – 65.8 inches

Source: NRC 2012

Given the uncertainty in the magnitude and timing of future SLR, Marin County used a scenario-based approach to assess a range of potential SLR impacts. The five scenarios selected were derived from the USGS Coastal Storm Modeling System (CoSMoS) which identified areas that may flood at 10 different sea levels (ranging from 0 to 500 centimeters) and four storm severities (none, annual, 20-year storm, 100-year storm). All of these scenarios are available on the Our Coast, Our Future (OCOF) online Flood Map.

The key findings of the Vulnerability Assessment are based on the five sea level and storm combinations, given below in Table 4, representing near-term, medium-term, and long-term futures.

Scenarios 1 and 2 represent the near-term, and correspond to the 2030 NRC projected sea level range.

Scenario 3 is considered medium-term and is within the 2050 NRC range.

Scenarios 4 and 5 represent the long-term. Scenario 4 corresponds to the 2100 NRC range.

Scenario 5 represents levels based on additional research theorizing the worst case: that by 2100

sea level rise is nearing 70 inches globally. The CoSMoS option that most closely reflects that is a rise of 200 centimeters, or 77 inches, and is referenced as 80 inches in this assessment.

The five scenarios selected for the C-SMART analysis are shown in Table 4.

Table 4. C-SMART Sea Level Rise & Storms Scenarios from CoSMoS (OCOF)

Sea Level Rise Scenario		Term
1	10 inches + Annual Storm	Near
2	10 inches + 20-year Storm	Near
3	20 inches + 20-year Storm	Medium
4	40 inches + 100-year Storm	Long
5	80 inches + 100-year Storm[31]	Long

The scenarios include SLR, tides, storm surge, El Niño effects, wave set up, and wave run up. CoSMoS scales down global and regional climate and wave models to produce local hazard projections.[32] High quality elevation data incorporated in the Digital Elevation Model (DEM) is used to create maps of mean higher high water (MHHW) tidal elevation plus SLR heights and provides the option to add storm impacts. Mean higher high water is the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.[33,34] Because the analysis uses high tide, properties nearest the limit of the exposure area exposed to MHHW could be dry at lower tides, while inundation could be deeper for the period of the cycle where water levels are above MHHW. Note that the CoSMos model only accounts for ocean levels and does not incorporate impacts from creek flooding during storms or changes in the coast line (geomorphology) as erosion continues.

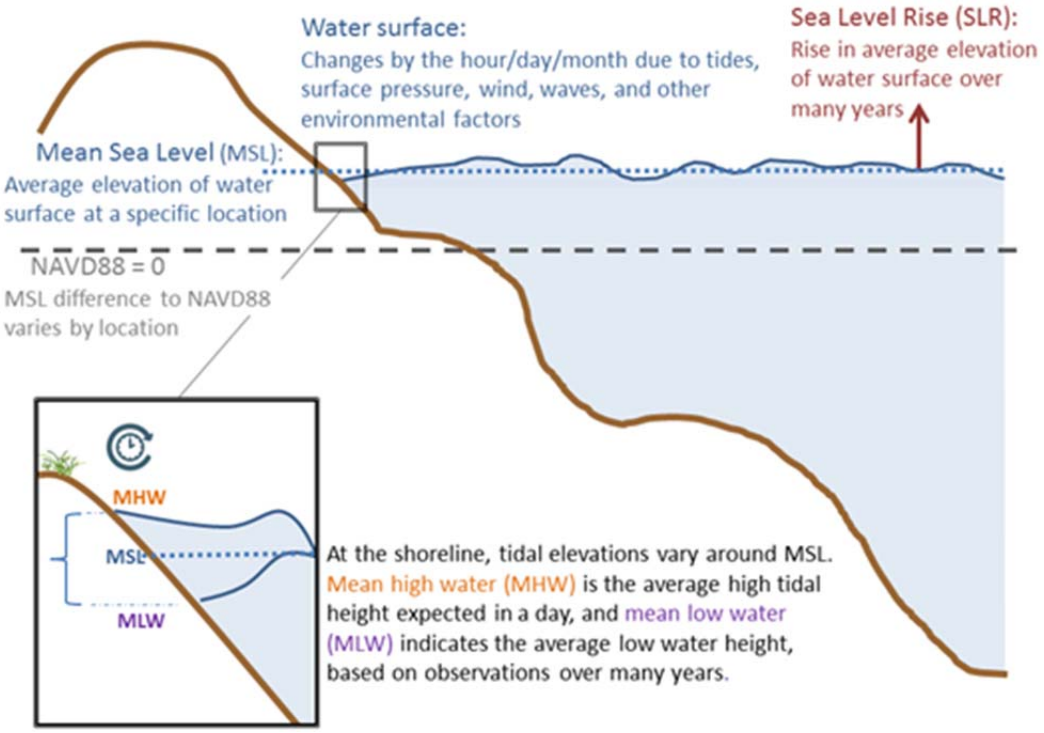
[31] The upper limit for 2100, scenario 5, was selected based on: *Rising sea levels of 1.8 meter in worst-case scenario, researchers calculate.* Science Daily Online News. University of Copenhagen. Oct. 14, 2014. http://www.sciencedaily.com/releases/2014/10/141014085902.htm Original published in the journal Environmental Research Letters. The article calculates 70 inches. In the scenario options, 80 inches (rounded up from 77 inches) is the closest option.

[32] Ballard, G., Barnard, P.L., Erikson, L., Fitzgibbon, M., Higgason, K., Psaros, M., Veloz, S., Wood, J. 2014. Our Coast Our Future (OCOF). [web application]. Petaluma, California. www.pointblue.org/ocof. (Accessed: Date August 2014]).

[33] National Tidal Datum Epoch is the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal data.

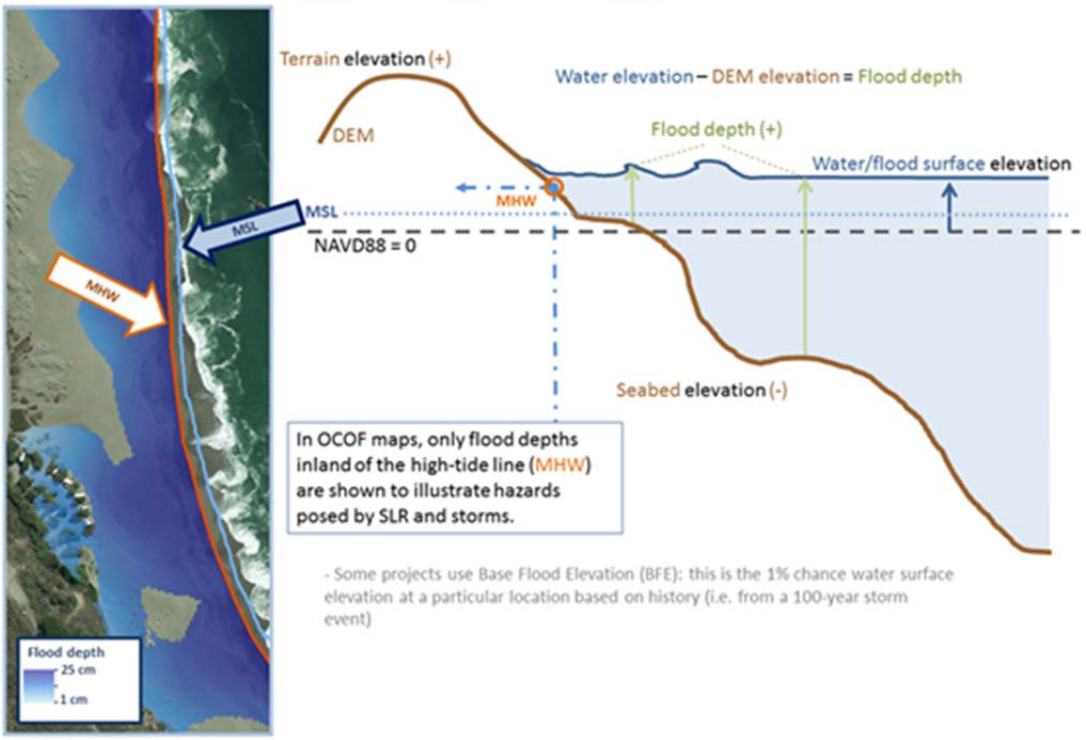
[34] NOAA / National Ocean Service. *Tidal Datums*. Access Oct. 19, 2015. Last updated: 10/15/2013 . Center for Operational Oceanographic Products and Services. https://tidesandcurrents.noaa.gov/datum_options.html.

Figure 2. Water Surface Diagram (OCOF 2016)



Note: While Figure 2 depicts MHW, the COSMOS model which informs OCOF maps uses MHHW including those used for this report and denotes more landward flooding than MHW.

Figure 3. Flood Depth Diagram (OCOF 2016)



Using the CoSMoS data for sea level rise and its extent into the coastal areas, the Vulnerability Assessment determined the exposure of the eight assets. **Table 4** lists the number and percentage of Parcels and Buildings in the coastal zone exposed in each of the 5 Scenarios.

Table 4. Number of Exposed Parcels & Buildings

	Parcels		Buildings	
	#	%	#	%
Scenario 1	824	16%	372	8%
Scenario 2	1,046	20%	588	10%
Scenario 3	1,085	21%	680	11%
Scenario 4	1,150	21%	853	14%
Scenario 5	1,298	25%	1,076	18%

Source: Marin Map, OCOF

In the coastal zone, over 20 percent of buildings are exposed at the low end of the long-term scenario (scenario 4), and 25 percent at the high end of the long-term scenario (scenario 5).

These buildings are concentrated in the Calles and Patios neighborhoods in Stinson Beach, downtown Bolinas, and the Tomales Bay shorelines in Inverness and East Shore (Marshall).

The VA also finds that on the East Shore, 90 to 100 percent of commercial, and 78 to 84 percent of residential parcels are exposed in the medium-term and high-end of the long-term respectively, representing the majority of buildings along the eastern shore of Tomales Bay. In Bolinas, 27 to 87 percent of commercial properties are exposed in the medium-term and high end of the long-term respectively, including both resident and visitor services. In Stinson Beach, nearly 70 percent of residential parcels are exposed in medium-term and onward.

Nearly twenty miles of public and private roadways could be compromised. Roadways exposed in the short-term include Shoreline Highway between Bolinas and Stinson Beach, which accounts for 20 percent of road length in the Coastal Zone and represents the only roadway between the two communities, not to mention the primary accessway wihin the coastal Zone. In Stinson Beach, Calle del Arroyo and the other Calles and Patios are compromised. In Bolinas, Wharf Road as well as several creek crossings and bridges are compromised. Other low-lying portions of Shoreline Highway, several local roads, and Sir Francis Drake Blvd. (17 percent) are vulnerable in the long-term.

Coastal communities also rely on septic systems, water supply systems, and shared septic or sewerage systems that could be exposed to SLR and storms. Roadways and utilities are lynch pin assets, such that their dysfunction or destruction will have negative consequences for nearly all other built assets.

1.7) Prioritize Adaptive Needs

Prioritization is based on potential impacts, existing adaptive capacity, and the risk and onset identified by the Vulnerability Assessment. For example, higher priority is assigned to strategies addressing impacts with greater potential severity or longer ramp-up times. Impacts that are predicted to arise further in the future, offering more time to mobilize a response based on ongoing monitoring, would rank with relatively lower priority.

Based on the findings of the Vulnerability Assessment, overall the most vulnerable assets (in order of timing and flood depth) of coastal Marin are listed below. The full list of exposed assets with flooding depths by scenario can be found in **Table 5**:

Near-term

- Beaches, underground OWTS, buildings, and streets in Stinson Beach (west of Shoreline Highway),
- Shoreline Highway between Stinson Beach Bolinas, at Green Bridge in Point Reyes Station, the Walker Creek crossing in Marshall, and bridges on Middle Road and Valley Ford Lincoln School Road in the near-term.
- Beaches, beach front and downtown buildings and streets in Bolinas.
- Septic systems, beaches, marshes, and buildings along the eastern and western shores of Tomales bay on the East Shore and in Inverness.
- Water distribution pipe extending underneath Shoreline Highway and Sir Francis Drake serving Inverness residents.
- Intertidal rocky lands in Muir Beach, Agate Beach (Duxbury Reef).
- Fire Service facilities and tsunami routes in Stinson Beach.
- Recreational facilities at Dillon Beach Resort and Lawson's Landing.

Medium-term

- Olema-Bolinas Road, the primary access road to Bolinas.
- Further north into downtown Bolinas, including the historic district.
- Bolinas Public Utilities District lift station.
- Shoreline Highway in Pt. Reyes Station Sir Francis Drake Blvd. in Inverness.

Long-term

- Shoreline Highway along the Eastshore in the medium and long-terms.
- Buildings in Inverness west of Sir Francis Drake Blvd.
- Downtown Bolinas up to Bridgton Road along Olema-Bolinas Road, including the market, library, community center, gas station, museum, and several other valued places.

Several of these vulnerabilities will impact both human and wildlife communities. In several cases not only is the asset vulnerable, but so are the means for accessing the asset, whether it is a building at the end of a flooded road, or an access point to reach a beach or trail.

Underground resources will likely be impacted before the assets above will be (buildings, roads). Road segments were measured at a high and low depth point along the vulnerable segment described.

Community members and decision-makers will need to decide whether to adapt by protecting, accommodating, retreating, or combining strategies in the face of SLR and increased threats from extreme events. For each of these choices, several other strategies, programs, and policies will need to be established to carry out these efforts using the most equitable, environmentally friendly, and economically efficient methods possible.

Table 5 shows the ranking of assets, first by chronological order of onset and, secondarily, by the highest flood depth measured.

1.8 Programs and Documents Referenced in the Report

C-SMART

C-SMART is an effort led by the Marin County Community Development Agency to understand the potential impacts of SLR and work together with communities to prepare for a resilient future. Through developing a sound scientific and technical basis for assessing vulnerabilities, C-SMART has identified possible response and resiliency strategies, coordinated with partner agencies and local communities, and informed Marin's Local Coastal Program.

Vulnerability Assessment

As the first step in planning for sea level rise impacts, the C-SMART Vulnerability Assessment identifies West Marin assets and areas that could be impacted over five sea level rise scenarios from near to long term. The report includes asset profiles describing the vulnerability of parcels and buildings, transportation networks, utilities, working lands, natural resources, recreational assets, emergency services, and historic and archaeological resources; and community profiles highlighting vulnerabilities of Muir Beach, Stinson Beach, Bolinas, Inverness, Pt. Reyes Station, East Shore, and Dillon Beach.

Adaptation Report (this report)

This report presents potential actions to accommodate, protect against, or retreat from the threats of SLR and coastal hazards that can be considered by communities, homeowners, and asset managers. Possible adaptation options are broken down by the asset and community profiles categories used in the Vulnerability Assessment. Possible next steps are discussed including further planning and implementation.

BayWAVE

The Marin Bay Waterfront Adaptation Vulnerability Evaluation (BayWAVE) is the parallel program for assessing Main's bayside shoreline vulnerabilities through 2100 with asset and community profiles.

Local Coastal Program

Informed by C-SMART, Marin's Local Coastal Program Environmental Hazards chapter is currently being revised. In accordance with the California Coastal Act, policies guide development in West Marin communities with the recognition of sea level rise and other coastal hazards.

1.8 Programs and Documents Referenced in the Report (cont.)

Marin County's Multi-Jurisdictional Local Hazard Mitigation Plan (MCMLHMP)

With a five year planning cycle, Marin County's Multi-Jurisdictional Local Hazard Mitigation Plan (MCMLHMP), is part of an ongoing planning process facilitated by the OES to meet the requirements of the Disaster Mitigation Act of 2000 to maintain continued eligibility for certain FEMA Hazard Mitigation programs. The LHMP is intended to improve the ability to recover after a variety of disasters: earthquakes, fires, floods, tsunamis, and landslides. Once approved by FEMA, LHMP projects are positioned to receive Federal Funding. . LHMP's focus is on near term strategies to protect people from current threats, while C-SMART focuses on strategies to protect people from future risks.

Marin Countywide Plan

The Marin Countywide Plan (CWP), last updated in 2007, is the comprehensive long-range general plan that guides land use and development in the unincorporated areas of Marin County. With the overarching theme of "planning sustainable communities", the CWP promotes leading edge strategies started in 1974 when Marin County initiated policies to constrain development and protect open space. Sustainability is emphasized as the CWP calls for environmentally friendly building techniques and energy-efficiency standards.

Table 5. Vulnerability Ranking of Exposed Assets by Scenario

Community	Asset	High Tide & Extreme Event Flooding Depth Estimates (Underlined values indicate tidal flooding at mean higher high water (MHHW) based on one geographic point located at the landward limit of the first scenario overlapping the asset. Other values represent extreme event flooding. Roads received a high, used for ranking, and low value along the line segment.)					Vulnerability TF: Temp. Flooding during extreme events; I: Inundated at mean highest high tide; E: Erosion; WT: Water Table; SI: Saltwater Intrusion; WS: Wave Surge; HW: High Wind, HS: Habitat Shift
		Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	
Stinson Beach	Septic Systems west of Shoreline Highway	underground resource			6'4"	9'7"	I, WT, WS, TF
Stinson Beach	Water Distribution Lines	underground resource			6'4"	9'7"	E, WS, TF, I, SI, ES
Inverness	NMWD Pipeline	underground resource (see Shoreline Highway Point Reyes Station to Inverness for depths)					WT, SI, E
Pt. Reyes Station	NMWD Pipeline	underground resource (see Shoreline Highway Point Reyes Station to Inverness for depths)					I, SI
Stinson Beach	Calle del Arroyo	7" - 6'11"	3" - 6'8"	8" - 9'6"	2'5" - 12'2"	5'11" - 13'9"	I, TF
Stinson Beach	Upton Beach	4'7"	6'2"	7'5"	9'8"	14'9"	I, E
Stinson Beach	Seadrift, Patios, and Calles Buildings	≤1.5' - 4.5'	≤1.5' - 7.5'	≤1.5' - 9'	≤1.5' - 10.5'	≤1.5' - 13.5'	I, WT, WS, TF
Bolinas	Bolinas Buildings	≤1.5' - 4.5'	≤1.5' - 4.5'	≤1.5' - 6'	≤1.5' - 7.5'	≤1.5' - 10.5'	I, WT, WS, TF
Inverness	Inverness Buildings	≤1.5' - 4.5'	≤1.5' - 4.5'	≤1.5' - 6'	≤1.5' - 7.5'	≤1.5' - 10.5'	I, WT, WS, TF
Eastshore	Eastshore Buildings	≤1.5' - 3'	≤1.5' - 4.5'	≤1.5' - 6'	≤1.5' - 7.5'	≤1.5' - 10.5'	I, WT, WS, TF
Inverness	Inverness Yacht Club	3'2"	4'1"	4'11"	6'10"	10'1"	I, WS, HW
Inverness	Brock Schreiber Boathouse	2'7"	3'6"	4'	5'10"	9'2"	I, E
Eastshore	Walker Creek Access Point	2'4"	3'3"	4'2"	6'1"	9'3"	I
Bolinas	Tsunami Evacuation Route	2'4"	1'8"	2'5"	4'2"	7'9"	TF, I, WS, E
Eastshore	Brighton Beach	2'2"	3'5"	4'11"	6'	9'11"	E, WS

Table 5. Vulnerability Ranking of Exposed Assets by Scenario

Community	Asset	High Tide & Extreme Event Flooding Depth Estimates (Underlined values indicate tidal flooding at mean higher high water (MHHW) based on one geographic point located at the landward limit of the first scenario overlapping the asset. Other values represent extreme event flooding. Roads received a high, used for ranking, and low value along the line segment.)					Vulnerability TF: Temp. Flooding during extreme events; I: Inundated at mean highest high tide; E: Erosion; WT: Water Table; SI: Saltwater Intrusion; WS: Wave Surge; HW: High Wind, HS: Habitat Shift
		Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	
Eastshore	Livermore Marsh Cypress Grove	2'1"	3'1"	3'11"	5'10"	9'2"	I
Eastshore	Hog Island Oyster	2'1"	2'1"	2'10"	4'10"	8'1"	I
Inverness	Martinelli Park	1'1"	2'	2'2"	4'1"	7'3"	I, E
Bolinas	Wharf Road	6" - 2'1"	3" - 2'4"	2" - 2'9"	1" - 5'4"	10" - 7'4"	I, TF
Eastshore	Shoreline Hwy	3" - 1'7"	3" - 2'4"	3" - 3'	2' - 4'6"	6" - 8'1"	I, TF
Bolinas	Agate Beach	2'1"	1'11"	2'8"	4'8"	9'3"	I
Stinson Beach to Bolinas	Shoreline Hwy.	0"- 1'8"	0" - 2'3"	0" - 3'1"	0.4" - 4'10"	0.4" - 8'6"	I, TF
Eastshore	Marconi Boat Launch	1'1"	2'	2'11"	4'10"	8'2"	I
Inverness	Tomales Bay State Park	10"	1'10"	2'8"	4'7"	7'10"	I, HS
Eastshore	Tony's Restaurant	8"	1'8"	2'6"	4'5"	7'9"	I
Eastshore	Tomales Bay Oyster Company	8"	1'5"	2'3"	4'1"	7'5"	I, TF
Stinson Beach	Water Dist. Office	7"	3'3"	4'8"	6'6"	8'8"	TF, I
Stinson Beach	Walla Vista Wkwy.	3"	1'8"	2'	4'4"	10'4"	I, E
Dillon Beach	Lawson's Landing Facilities	2"	1'1"	2'11"	3'10"	7'3"	I, E, WS, HW, HS
Pt. Reyes Station	Green Bridge	No depth data	No depth data	2"	2'	9'10"	I, TF
Bolinas	Historic District		3'10"	4'8"	6'4"	10'	I, E
Stinson Beach	Stinson Fire Department #2		3'6''	5'3"	6'10"	9'1"	I, TF, WT

Table 5. Vulnerability Ranking of Exposed Assets by Scenario

Community	Asset	High Tide & Extreme Event Flooding Depth Estimates (Underlined values indicate tidal flooding at mean higher high water (MHHW) based on one geographic point located at the landward limit of the first scenario overlapping the asset. Other values represent extreme event flooding. Roads received a high, used for ranking, and low value along the line segment.)					Vulnerability TF: Temp. Flooding during extreme events; I: Inundated at mean highest high tide; E: Erosion; WT: Water Table; SI: Saltwater Intrusion; WS: Wave Surge; HW: High Wind, HS: Habitat Shift
		Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	
Eastshore	Inn on Tomales Bay		2”	11”	2’10”	5’5”	I
Inverness	Sir Francis Drake Blvd.			1" - 3'6"	1" - 4'6"	1" - 7'10"	I, TF, WS
Bolinas	Sewage Lift Station			3’3”	5’	8’7”	TF, I
Bolinas	Olema-Bolinas Rd.			2’8”	4” - 4’4”	2” - 7’11”	I, TF
Pt. Reyes Station	White House Pool/Trail			2’5”	2’3”	5’11”	I
Inverness	Inverness Store			2’5	4’4”	7’6”	TF, I, WT
Bolinas	Bolinas Super Market			8”	2’6”	6’1”	I, E, SI
Pt. Reyes Station to Inverness	Shoreline Hwy.			6"	3" - 1'5"	1'9" - 9'7"	I, TF
Inverness	Dana Marsh & Beach Access				3’	6’2”	I, E, SI, HS
Inverness	Motel Inverness				2’9”	5’10”	I, WS, HW
Eastshore	Nick's Cove				2’6”	5’10”	
Eastshore	Millerton Point				2’5”	5’8”	I, E
Eastshore	Historic District				2’5”	4’5”	I
Inverness	Historic District				2’1”	5’1”	TF
Bolinas	Bolinas Library				1’8”	5’3”	I, TF
Bolinas	Bo-Gas Station				1’7”	5’3”	I
Bolinas	Gospel Flats				1’7”	5’3”	I, WT, SI, TF
Bolinas	Community Center Emergency Shelter				1’7”	5’2”	I, E
Bolinas	Community Land Trust				1’2”	4’10”	I

Table 5. Vulnerability Ranking of Exposed Assets by Scenario

Community	Asset	High Tide & Extreme Event Flooding Depth Estimates (Underlined values indicate tidal flooding at mean higher high water (MHHW) based on one geographic point located at the landward limit of the first scenario overlapping the asset. Other values represent extreme event flooding. Roads received a high, used for ranking, and low value along the line segment.)					Vulnerability TF: Temp. Flooding during extreme events; I: Inundated at mean highest high tide; E: Erosion; WT: Water Table; SI: Saltwater Intrusion; WS: Wave Surge; HW: High Wind, HS: Habitat Shift
		Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	
	Housing						
Inverness	Shell Beach Tomales Bay SP				5”	3’4”	TF, I, WT
Stinson Beach	CA Coastal Trail				0.4”	1’3	TF, E
Bolinas	Calvary Church					5’10”	I, TF
Bolinas	Bob Stewart Trail					4’8”	I, TF
Inverness	Tomales Bay Resort					4’	TF
Inverness	Inverness Post Office					3’7”	TF, I, WS, E
Eastshore	Shoreline Hwy.					3’5”	I, E
Stinson Beach	Stinson Picnic Area					3’3”	TF
Bolinas	Bolinas People's Store					3’	I, TF
Bolinas	Bolinas Post Office					2’9	TF, I
Point Reyes Station	Olema Marsh Trail					2’9”	I
Bolinas	Bolinas Stinson School					2’2”	I, TF, E, WS
Dillon Beach	Dillon Beach Resort Parking Lot					1’6”	I
Pt. Reyes Station	Gallagher Well					underground resource	SI
Dillon Beach (north)	Stemple Creek Recreation Area	X	X	X	X	X	HS
Stinson Beach / Bolinas	Bolinas Lagoon	water resource					HS
Inverness /	Tomales Bay &	water resource					HS

Table 5. Vulnerability Ranking of Exposed Assets by Scenario

Community	Asset	High Tide & Extreme Event Flooding Depth Estimates (Underlined values indicate tidal flooding at mean higher high water (MHHW) based on one geographic point located at the landward limit of the first scenario overlapping the asset. Other values represent extreme event flooding. Roads received a high, used for ranking, and low value along the line segment.)					Vulnerability TF: Temp. Flooding during extreme events; I: Inundated at mean highest high tide; E: Erosion; WT: Water Table; SI: Saltwater Intrusion; WS: Wave Surge; HW: High Wind, HS: Habitat Shift
		Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	
Eastshore	Marshes						
North of Dillon Beach	Estero Americano	water resource					HS
Dillon Beach	Sewage Pump Station	bluff top asset					E

Source: Marin Map, OCOF, Asset Manager Interviews conducted by CDA

2) C-SMART Participants

2.1) Community Workshops

To date, C-SMART Staff has hosted four sets of public workshops throughout West Marin with various objectives to further engage local stakeholders in C-SMART and educate residents about SLR impacts and future adaptation options. Workshops were promoted extensively through both traditional outreach (fliers, posters, postcards, press releases etc.) and internet/social media (website, email lists, Facebook, Nextdoor, etc.). Workshop participation ranged from around 20 to 170 attendees. More details including methods, materials, presentations, and summary reports can be found at **marinSLR.org**.

Workshop 1 – Kickoff

July 10, 2014 –Point Reyes National Seashore

This evening meeting commenced the C-SMART public engagement process. Items included an introduction on the C-SMART timeline and scope by C-SMART Staff, plus presentations from USGS staff on the OCOF modeling methods and website tools available to the public. Participants were also invited to apply for the SAC.

Workshops 2 – Vulnerability Assessment

October 28, 29 and 30, 2014 – Inverness, Stinson Beach and Tomales

These evening meetings introduced the Vulnerability Assessment process with several participatory activities. On large poster boards, attendees were asked to identify what they love about West Marin as a means to spotlight local values. Next, participants were invited to mark up the draft community asset exposure maps compiled by C-SMART Staff. This crowdsourcing activity identified over 70 additional assets for consideration in the C-SMART vulnerability assessment. Finally, facilitated small group discussions asked questions on residents' current observations of climactic impacts, future concerns, and potential strategies to address these concerns.

Workshops 3 – Game of Floods and Adaptation

May 30 and June 6, 2015 – Point Reyes Station and Stinson Beach

These Saturday workshops educated stakeholders on adaptation strategies through "The Game of Floods", a small group participatory activity spotlighting a wide array of strategies including traditional/hard engineering (seawalls, levees, etc.), green infrastructure (horizontal levees, wetlands, beach nourishment, etc.), managed retreat, and accommodation (retrofitting buildings, realigning roads, etc.). Centered around a game board with a map of the fictitious Marin Island, players were asked to protect an asset they valued through applying a suite of the aforementioned strategies. Information on environmental impacts, costs, effectiveness, and more were provided to inform the decision making process.

Once the game was completed, attendees were given individual workbooks with a map of the attendee's community identifying exposed assets. Participants were asked to suggest adaptation strategies for consideration to protect the vulnerable assets that they valued. Workbooks were anonymous and handed to C-SMART Staff once complete.

Workshop 4 – Adaptation Polling

November 14, 2015 – Stinson Beach

This Saturday workshop included presentations from a variety of technical experts (including staff of FEMA, the CCC, Arcadis, ESA, and

Game of Floods in Point Reyes Station. May 2015. Credit: Marin County CDA

DPW) on adaptation strategy case studies throughout California highlighting pros, cons, and lessons learned from other areas. With this plethora of information, participants were given a poll to inquire about conceptual adaptation strategies that could be applied to their community. Included were questions on local coastal program policy amendments which could guide new and existing development to accommodate for changing conditions likely to result from SLR and other climactic impacts. Poll results have informed C-SMART Staff on the general community interests and concerns for continued adaptation planning, including the Community Acceptability column in Table 6.

Marin County planners also presented updates on the C-SMART study in Spring 2016 at meetings with the East Shore Planning Group, Stinson Beach Village Association, Muir Beach Community Service District and residents, and Point Reyes Village Association.

Resilient Stinson Design Charrette

February 3, 2016 – Stinson Beach

In partnership with Gensler, Marin County CDA hosted the Resilient Stinson Design Charrette. The charrette goals were to define community character in residents' and design professionals' words, and to collect aesthetic feedback on potential flood response options. This information was used to inform both practical and aesthetic considerations of the design principles. Around 40 attendees including local residents, architects, planners, engineers and other professionals were convened.

The event began with an introduction of the challenge of SLR and Stinson Beach. Staff shared maps of flood depths in the Calles and Patios neighborhood at 2.5 feet SLR which is in the midrange of 2070 projections. Recently released FEMA Flood Insurance Rate Maps (FIRM) maps were also shared to indicate locations subject to more near term flooding and FEMA compliance requirements. A variety of home retrofitting strategies were presented, including the innovative concept of amphibiation, in which buoyant foundations are installed, enabling homes to float when floodwaters hit.

Next local homeowners led guided walking tours of properties vulnerable to flooding (both coastal and riverine). This exposed participants to the variety of architectural styles, building heights, materials, existing retrofitting approaches, etc.

Over lunch, shared initial impressions on community character were discussed in small groups including intangible 'look and feel' to guide building elevation so it does not compromise sense of place. In advance of the workshop, Image cards had been developed with a variety of images intended to characterize Stinson Beach as a place, including different architectural styles, its relationship to nature, water, etc.

Resilient Stinson Design Charrette. February 2016. Credit: Gensler

Images that defined character elements which were more widely preferred were placed near the center of the bullseye, while elements that were not preferred were placed further out. Each group then reported back to the large group to discuss commonalities.

The main exercise was an evaluation of different retrofitting options to accommodate homes to increased water levels including:

- Structure Elevation: Piers & Columns
- Semi-Enclosed Ground Level
- Landscaped Ground Level
- Bunker Houses
- Structure Elevation: Communal
- Breakaway Walls
- Waterproof Construction
- Amphibious Architecture
- Floating Development
- Floodable Development
- Moveable Walls
- Others?

In small groups, participants filled out pros/cons matrices of each option from an aesthetic perspective. Included in the matrices were 'maximize the pro' and 'mitigate the con'. After a couple hours of small group discussions, summary points were shared with the large group.

This event helped articulate community character from the design perspective, which helped C-SMART Staff craft urban design principles (page 81). Additionally it helped staff understand aesthetic considerations of the various home retrofitting options that could be applied for flood/SLR protection (pages 89-104)

Workshops Summary

In summary, public workshops were an effective means to educate residents on SLR impacts and possible responses, as well as the C-SMART process. Additionally, these workshops, particularly workshops 2, 3, and 4 provided a means for C-SMART Staff to better understand potential adaptation solutions from the public perspective. Such adaptation strategies have been incorporated into this report for consideration.

2.2) Stakeholder and Technical Advisory Committees

C-SMART SAC and TAC were developed to guide C-SMART through providing input from community and technical organization representatives. A roster of both committees can be found in the acknowledgements section of this report. Both committees met periodically throughout the process to advise C-SMART Staff on topics including public outreach activities, vulnerability assessment processes, C-SMART deliverables, and more. To further obtain input on adaptation options, a joint meeting of the SAC, TAC, and partners was held on February 10, 2016 in Point Reyes Station. Meeting products were intended to mirror the deliverables produced by the Climate-Smart Adaptation Working Group convened by NOAA

staff to inform the Gulf of the Farallones National Marine Sanctuary. See more details below on the working group's process and products, which serve as the basis for this report's natural resources section.

At the joint TAC/SAC/partner meeting, participants were presented with spreadsheets of adaptation options spanning seven of the eight asset categories spotlighted in this report (parcels & buildings, transportation, utilities, working lands, recreation, emergency services, and historic and archaeological resources). Natural resources were not discussed at this meeting, due to the aforementioned GFNMS Working Group's efforts. Draft spreadsheets had been compiled by C-SMART Staff with adaptation options from staff's literature reviews, consultant deliverables, the public workshops and adaptation poll. Spreadsheet columns included the approach, strategic management action, spatial or site specific details, timeframe, impacts addressed, key partners, required resources, and other asset categories.

Strategic management actions included the spectrum of adaptation strategies (retreat, defend, accommodate, etc.), plus other activities that could be undertaken in West Marin to help minimize, avoid, mitigate SLR/storm impacts included public outreach/education, surveying/documentation, policy development and more. These ideas are not staff recommendations or in any way endorsed by Marin County or project partners, but simply a compilation of options suggested through the C-SMART process that merit further consideration. The options were not intended to be collectively viewed as a plan, are not all currently feasible, and in some cases may conflict with one another.

At a February 2016 meeting, TAC/SAC/Project Partners were asked to further elaborate on existing options or suggest new options for incorporation. After the meeting C-SMART Staff synthesized the options to finalize the spreadsheets found in section 4.3. See section 4.3 for more information on general format and content of the spreadsheet.

2.3) Center for Ocean Solutions

To support decision-makers in their efforts to manage coastal resources in a changing climate, the COS engaged with C-SMART Staff by mapping and assessing the presence and relative importance of coastal habitats along Marin County's Pacific coast. In addition, the effects of coastal adaptation strategies on services provided by coastal habitats were evaluated. The role of natural habitat in providing the ecosystem service of coastal protection was assessed using the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) decision support tool, a suite of tools to map and value the goods and services from nature. The InVEST Coastal Vulnerability model was specifically utilized for this assessment.

InVEST is a free and open-source suite of software models created by the Natural Capital Project at Stanford University. The InVEST Coastal Vulnerability (CV) model incorporates a scenario-based approach to evaluate the role of natural habitats in reducing exposure to coastal erosion and inundation during storms. The InVEST CV model produces a qualitative estimate of coastal exposure. The Exposure Index differentiates areas with relatively high or low exposure to erosion and inundation during storms.

Spatial data inputs include: 1) Geomorphology: 2) Coastal habitat: 3) Wind and wave exposure: 4) Surge potential 5) Relief: A DEM representing the topography and (optionally) the bathymetry of the coastal area 6) Sea-level rise: Rates of (projected) net sea-level change derived from the National Research Council 2012 report; 7) Hard Armoring: Data set inventory of man-made structures and natural coastal barriers that have the potential to retain sandy beach area in California.

Results can help evaluate tradeoffs between climate adaptation strategy approaches. In this assessment, COS compared the InVEST Exposure Index results both with and without the protective services provided by natural habitats. This approach (computing the difference between exposure indices) provides a priority index for locations in which coastal habitats play the largest relative role in reducing exposure to erosion and inundation. These locations are then further investigated for nature-based strategies to reduce vulnerability.

The ecosystem service and adaptation policy research focuses on three specific areas of interest: Muir Beach, Dillon Beach, and Bolinas Lagoon (including Bolinas and Stinson Beach). For each location, COS mapped and assessed the natural habitats, the role of those habitats in reducing exposure to storm impacts, the potential adaptation options to address these impacts, and the policy considerations relevant for each strategy. In addition, COS identified general considerations for pursuing land-use policy approaches as well as a summary of our analysis methodology.

This assessment involved a combination of ecosystem services modeling as well as adaptation policy research to identify priority locations for nature-based strategies that reduce vulnerability of critical assets using feasible land use policy methods.

2.4) Greater Farallones National Marine Sanctuary

The GFNMS Advisory Council served as a key partner in the development of climate change adaptation options for natural resources (beaches and dunes, rocky intertidal, cliffs and wetlands/estuaries). Building on Phase 1 of the GFNMS Climate-Smart Adaptation Project that assessed vulnerability to climate and non-climate stressors for select species, habitats, and ecosystem services, a Working Group of the Advisory Council undertook a yearlong multi-agency process to develop climate-smart adaptation strategies for the Study Area, which included GFNMS, Cordell Bank National Marine Sanctuary and part of Monterey Bay National Marine Sanctuary. C-SMART Staff participated as Working Group members, alongside representatives from a variety of other local, state and federal agencies; non-profit organizations, and academic institutions. The working group was staffed and advised by sanctuary representatives, as well as members of the scientific and conservation community. Five meetings, numerous conference calls, and online discussions were held to develop the recommendations. Meetings included group brainstorming exercises to generate ideas, focused discussions to further flesh out options, and an exercise to prioritize options based upon criteria including co-benefits, and legal/economic/institutional feasibility. More details on the process can be found in the final report (Appendix G).

In early 2016, final recommendations were presented to the GFNMS Advisory Council, who

approved 78 strategies total, spanning several categories:

- Alleviate Climate Impacts
- Manage Dynamic Conditions
- Promote Education
- Protect and Restore Habitat
- Limit Human Disturbance
- Address Invasive Species
- Promote Landward Migration
- Invest in Science Needs
- Protect Species
- Manage Water Quality

Recommendations relevant to C-SMART (e.g., within the study area and addressing SLR) serve as the basis of the natural resources section of this report, along with findings from COS and PBCS. Strategies with additional co-benefits, (e.g., protection of economic, social, infrastructure assets) were prioritized.

2.5) Environmental Science Associates

ESA served as project consultants with contributions including advice on trigger points and analysis of adaptation options. ESA's final deliverable is appendix C of this Report, and portions of their work have been incorporated throughout relevant sections of this report.

Trigger Points

In order to shape a tiered approach to adaptation, ESA advised on the setting of 'triggers' for inundation and temporary flooding. Such an understanding can help inform plan and policy development while considering the range of near to far term impacts. Specifically ESA characterized triggers for roads and buildings answering questions such as: What flooding frequency or depth triggers the need to elevate or relocate homes or roads?

Broad Analysis of Adaptation Options

ESA broadly reviewed alternative options to better understand costs, considerations and implications as follows:

- Muir Beach (Bluff top development)
  - Protect
    - Dune restoration
    - Armoring
  - Retreat
- Bolinas
  - Armoring
  - Nature based (beach nourishment and horizontal levee)
  - Accommodate
    - Elevation of homes and Wharf Road
    - Culverts at streams vs causeway at sections (Shoreline Hwy Bolinas Lagoon)
- Dillon Beach
  - Dune restoration
  - Retreat (wells and road)

Detailed Analysis of Adaptation Options

Additionally, ESA provided detailed analysis of specific adaptation options including economic implications, specific costs, environmental impacts and other considerations for:

- Stinson Beach/Seadrift
  - Armoring approach - how do you protect homes?
  - Extending Seadrift's sand covered revetment
  - Elevating homes
  - Reroute Easkoot Creek and Calle del Arroyo (from Marin County DPW's existing Flood Study)
- East Shore/Tomales Bay
  - Elevating Homes

- Raise/relocate road
- Oyster reefs for Tomales Bay

3) Adaptation Framework

3.1) Adaptation Options

Adaptation strategy options were gathered from a variety of sources including project consultants ESA, several existing adaptation plans from other jurisdictions, and several guidance and research publications, such as the *California Coastal Commission's Sea Level Rise Policy Guidance*. Adaptation strategies generally fall into three main categories: protect, accommodate, and retreat. An approach of "no action" may be considered an option, but will likely result in greater safety hazards, economic costs, and environmental impacts in the long-run.

Protect

Protection strategies refer to those strategies that employ some sort of engineered structure or other measure to defend development (or other resources) in its current location without changes to the development itself. Protection strategies can be further divided into "hard" and "soft" defensive measures or armoring. "Hard" armoring refers to engineered structures such as seawalls, revetments and bulkheads to defend against coastal hazards like wave impacts, erosion, and flooding. Such armoring is a fairly common response to coastal hazards, but it can result in serious negative impacts to coastal resources, particularly as sea level rises. Most significant, hard structures form barriers that impede the ability of natural beaches and habitats to migrate inland over time. If they are unable to move inland, public recreational beaches, wetlands, and other habitats will be lost as sea level continues to rise.

Not all of these measures are favored by regulatory agencies and stakeholders that are primarily concerned with natural assets such as beaches and wetlands. Implementing these strategies will likely follow a relatively traditional permitting process involving the local permitting agencies, CCC, California State Lands Commission, and for those located below Mean High Water (MHW) GFNMS and the U.S. Army Corps of Engineers (USACE)(ESA 2015).

Soft armoring include nature based solutions such as horizontal levees, wetland restoration, and dune restoration. As such approaches are relatively new concepts, their effectiveness has not yet been fully demonstrated. However such alternatives are favored by many over hard engineering due to potential public benefits including habitat, recreation, aesthetic, and more. For example, dune habitat in Stinson Beach and wetlands in Bolinas Lagoon help absorb energy from storms and protect against shoreline erosion.[35]

Accommodate

Accommodation strategies employ methods that modify existing developments or design new developments to decrease hazard risks and thus increase the resiliency of development to the impacts of SLR. On an individual project scale, these accommodation strategies include actions such as elevating structures, retrofits and/or the use of materials meant to increase the strength of development, building structures that can easily be moved and relocated, or requiring adequate setbacks from eroding blufftops and shorelines. On a community-scale, accommodation strategies include any of the land use designations, zoning ordinances, or other measures that require the above types of actions, as well as strategies

[35] Center for Ocean Solutions. Natural Capital Project. 2016 Coastal Adaptation Policy Assessment: Marin County.

such as locating development in less vulnerable areas or requiring mitigation actions to provide for protection of natural areas even as development is protected (CCC 2015).

Structural adaptation is the modification of the design, construction and placement of structures sited in or near coastal hazardous areas to improve their durability and/or facilitate their eventual removal. This is often done through the elevation of structures or specific site placement. Structural modification entails reconfiguring development to withstand progressively increasing coastal hazards. Examples are pile foundations that allow wave run-up and erosion to progress without damage to structures, and waterproofing or reinforcing for severe events. Structural adaptation can be applied to any parcel or infrastructure although the cost and technical feasibility of an effective modification would be required. Cost may be high depending on the density of development on the coast (ESA 2015).

Relocate/Managed Retreat

Managed retreat allows the shoreline to advance inward unimpeded. As the shore erodes, buildings and other infrastructure are either demolished or relocated inland. It can also involve setting back a line of actively maintained defenses to a new line inland of the original and promoting the creation of intertidal habitat between the old and new defenses. This can either be a complete removal or a breach of the defense (seawall, revetment, etc.).

A managed retreat approach typically involves establishing thresholds to trigger demolition or relocation of structures threatened by erosion. Therefore, this approach is frequently coupled with several other planning and regulatory techniques including: shoreline planning to identify high-risk areas where this type of policy would be the only cost-effective, long-term solution; regulating the type of structure allowed near the shore to ensure that buildings are constructed in a way to facilitate relocation when needed; and instituting relocation assistance and/or buy-back programs to help with relocation costs or compensate property owners when their property becomes unusable.[36] More detail about potential mechanisms for managed retreat is provided in Appendix B.

Some challenges to implementing managed retreat programs, particularly in areas with existing development, include uncertainty over who pays and who benefits, and quantification of benefits. Another challenge is identifying sufficient space or land for the structure to be relocated. The costs for retreat in areas consisting of private property could be estimated by assessing the value of the property and identifying the compensation mechanism (e.g. purchase, easement, etc.). Managed retreat requires ongoing and long-term commitment from government agencies and citizens.

In California, managed retreat has typically been used by government agencies on public properties such as beach parks. Erosion has been a consistent problem at Surfer's Point, a popular surfing spot in Ventura, California, for more than 20 years. Multiple options were explored by the city and non-governmental groups, including the Surfrider Foundation. Surfrider played a critical role in the approval of

[36] Columbia Center for Climate Change Law. *Managed Coastal Retreat: A Legal Handbook on Shifting Development Away from Vulnerable Areas.* October 2013.

a managed retreat strategy, which included relocation of a bike path and parking lot, beach renourishment, habitat restoration, and riprap removal.

Pacifica State Beach is another example of managed retreat. Despite the use of stabilizing structures, flooding of San Pedro Creek and coastal erosion at Pacifica/Linda Mar State Beach has been a recurring problem for the City of Pacifica. In the early 1990s, the city partnered with state and federal agencies, scientists, engineers, and non-profit organizations to work toward a managed retreat strategy for Pacifica State Beach as well as restore wetlands and banks along San Pedro Creek. These actions reduced flooding and erosion threats and restored habitat, which is likely to buffer the system against future climate-related changes such as SLR.[37]

Hybrid Strategies

Hybrid strategies involve phased approaches combining accommodation, protection and/or relocation. Local government can update land use designations and zoning ordinances, and enact redevelopment restrictions and permit conditions to discourage the rebuilding of existing development or siting of new development in hazard areas. Recent experience indicates that hybrid approaches that include a mix of adaptation measures may be the most practical in some situations. The mix of measures in a hybrid solution varies depending upon the conditions at that location. For example, the Ocean Beach Master Plan includes a hybrid approach in south Ocean Beach where prior development and erosion have resulted in an acute hazard to both built and natural assets. At this location, a low-height seawall is proposed but at a location established as far landward as possible which requires removal of roadway and parking within a managed retreat framework [3,6]. The plan also includes beach nourishment and dune construction, and includes adaptive management with revisions anticipated for higher sea level rises after 2050.

[37] Climate Adaptation Knowledge Exchange. *Restoration and Management of Pacifica State Beach.* www.cakex.org. December 2010.

3.2) Prioritization Criteria

Broad strategies have been characterized in Table 6 based on the projected onset of impacts; cost estimates (both initial and ongoing); calculated effectiveness; timing and duration of the strategy; full spectrum of environmental, recreational, and habitat benefits; and legal, political, and community acceptability. Cost estimates were developed by Marin County staff and should only be used generally to understand relative costs from one strategy to another. Legal acceptability is based off of project's staff interpretation of the California Coastal Act and the *California Coastal Commission's Sea Level Rise Policy Guidance*. Political acceptability was based off August 2017 Board of Supervisors workshop. Community acceptability is based on responses to the West Marin Sea Level Rise Adaptation Poll (See Appendix G) and feedback received from community members.

Table 6. Adaptation Strategy Characteristics

Category	Strategy	Public Benefits	Environmental Impacts (+ = positive, 0 = neutral/varied, - = negative)	Cost		Flood Protection	Acceptability: H=High, M=Medium, L=Low		
				Unit	Cost ($)		Legal	Political	Community
Hard Protection	Seawall/Revetment	Public Safety	-	Km	3,7000,000	M	L		M
	Elevate Bulkheads	Public Safety, Recreation/ tourism	-	Km	590,000	M	L		M
	Breakwaters, Artificial Reefs and Groins	Public Safety, Recreation/ tourism	0	Km	44,000,000	M	L		M
	Traditional Levee	Public Safety, Recreation/tourism	-	Km	5,500,000	M	L		M
	Pump Station	Public Safety	-	Ea	500,000-several million	L	L		N/A
	Tidal Gate	Public Safety, Recreation/ tourism	-	Ea	200,000,000	M	L		N/A
Nautre- based	Beach Nourishment	Recreation/ tourism/ aesthetic	0	Ac	500,000-830,000+	M	M		M
	Dune Restoration/ Nourishment	Recreation/ tourism/ aesthetic	+		200,000	M	M		M
	Offshore structures	Public health, Recreation/ tourism, aesthetic, Carbon sequestration, Air quality, Water quality	+	Ac	2 million	M	M		M
	Wetland Enhancement	Public health, Recreation/ tourism/ aesthetic, Carbon sequestration, Air quality, Water quality, stormwater mgmt.	+	Ac	20,000	M	H		H
	Horizontal Levee	Public health, Public safety, Recreation/ tourism/ aesthetic, Carbon sequestration, Air and water quality,	+	Lf	1.500	H	M		L

		Stormwater mgmt.							
Accommodate	Elevate Buildings	Public safety, Seismic safety, Recreation/ tourism/ aesthetic, Stormwater mgmt.	0	sf	140	M	M		M
	Raise Grades	Public safety, Seismic safety	-	High cost - varies		M	M		M
	Waterproof Buildings	Public health, Public safety, Recreation/ tourism/ aesthetic	0	Varies		L	H		M
	Floodable and Floatable Development	Public safety, Recreation/ tourism/ aesthetic, Stormwater mgmt.	0	Ea	2,400,000	M	M		M
Retreat	Managed Retreat/Relocation	Public safety, Recreation/ tourism, aesthetic, Stormwater mgmt.	+	+	Varies	H	L		L
	Zoning and overlay zones	Public health, public safety, recreation/tourism, aesthetic	+	+	Varies	H	L		L
	Setbacks for development	Public safety, recreation/tourism, aesthetic	+	+	Varies	H	L		L
	Siting and design requirements	Public safety, recreation/tourism, aesthetic	+	+	Varies	H	L		L
	Capital improvement programs	Public safety, seismic safety, recreation/tourism, aesthetic	+	+	varies	H	L		L
	Acquisition/buy-out	Public health, public safety, seismic safety, recreation/tourism, aesthetic	+	+	Varies	H	L		L
	Conservation easements	Public health, public safety, seismic safety, recreation/tourism, aesthetic	+	+	Varies	H	H		M
	Rolling easements	Public health, public safety, seismic safety, recreation/tourism, aesthetic	+	+	Varies	H	H		M
	Transfer of development credit/rights	Public health, public safety, seismic safety, recreation/tourism, aesthetic	+	+	varies	H	H		M

3.3) Trigger Points for Adaptive Management

In addition to amplifying erosion hazards, SLR will increase the extent of frequent (chronic) inundation in low lying areas and result in more severe storm (event) flooding. Adaptation measures can be tailored to the governing flood hazard mechanism (chronic or event), and will be initiated at determined "trigger points."

The concept of "trigger points" means that adaptation strategies would be initiated when projected hazards surpass a certain level of risk, either in frequency or severity. ESA described various erosion and flooding mechanisms to inform the County and its residents about potential trigger options to consider while deciding when to implement adaptation measures, such as: nourish beaches and raise or relocate homes, roads and other infrastructure.

The trigger type depends on the level of service the infrastructure provides (e.g. critical roadway versus park driveway) and what consequence (how deep/ far) and frequency of erosion or flooding impact is acceptable. The science behind both erosion and flooding triggers are summarized below. The information about potential triggers in this report is advisory only, and subject to revision based on additional information and further analysis.

Flooding

Triggers based on water level could be based on tide data from the Point Reyes tide gauge:

- **Mean High Water (MHW)** - Average of all high tides over the National Tidal Datum Epoch of 19 years. MHW is 5.1 feet NAVD, and occurs 1-2 times per day for a few minutes to a few hours.
- **Extreme Monthly High Water (EMHW)** Highest high water level that is reached once in a month. EMHW is approximately 6.9 feet NAVD.
- **1-year Water Level** – Water level exceeded on average once every year, or has a 99 percent chance of being exceeded in any year from a storm event. The 1-year water level is about 7.1 feet.

Acceptable flood levels will vary by asset. For example, a road that is only used to access a beach park can tolerate flooding once a month, but flooding every other day would limit access, so the EMHW could be chosen as a trigger for raising the road. On the other hand, a critical road such as Calle del Arroyo in Stinson Beach that is the only access route to residences should have a higher level of acceptable impact so that it is operable for emergency situations. In this case, a more frequent flood level could be used to set a trigger to initiate adaptation measures.

For underground utilities such as gas and septic leach fields that could be affected by high groundwater, reaseach could be conducted to identify how MHW level could affect groundwater levels. Additional factors could play into the trigger selection, such as infrastructure materials (pavement that degrades quicker under prolonged flooding versus a building that is floodable up to a certain depth).

Erosion

Erosion rates and storm erosion impact distances indicate the vulnerability of beaches and waterfront property, and are used below to suggest potential triggers for adaptation measures. Erosion indicators are:

Toe elevation – Where the beach meets the back beach dune, cliff, or armoring structure. Toe elevation is compared to total water levels and used as an indicator of the amount of wave energy that could reach the back beach and cause erosion and overtopping. This elevation varies as the beach erodes in the winter/spring and accretes in the summer/fall. Extreme low values are an indication of erosion during heavy winter storms.

Dry beach and dune width – Dry beach width buffers the backshore from waves. Dry beach is defined as beach width above the shoreline (see below for definition of shoreline). Narrow beaches offer little protection, as more wave energy reaches the backshore which results in greater run-up, erosion of dunes and bluffs and impacts to coastal armoring structures.

Shoreline position – The shoreline location is used to track shore changes and estimate the volume of sand in the beach. In combination with the back shore location, a dry beach width can be calculated. The shoreline is typically defined as the elevation of Mean High Water (MHW), Mean Higher High Water (MHHW) or similar.

Toe elevation, beach width and shoreline position are influenced by wave exposure and littoral processes. In the case of an armored backshore (e.g. Seadrift) the beach elevation at the toe of structures indicates the exposure of the structure to wave action. As sea level rises and storm intensity increases, beach elevation drops and the structure experiences more scour from deeper and faster-moving wave run-up and reflection of wave energy by the structure. Reduced beach elevation results in more wave overtopping and degradation of the structure. To guide long-term and emergency management activities, the following vulnerability triggers and potential actions are proposed:

Toe Elevation Triggers

Long-term "maintenance" trigger = Elevation of the beach berm (break in slope) that typically occurs several feet above high tide, depending on wave exposure, at a particular location.

- Action: Increase monitoring frequency, evaluate resources at risk, consider actions (nourishment, notify residents, etc).

Critical condition trigger = Mean tide or sea level.

- Action: Emergency nourishment, evaluate resources at risk, consider other actions.

Beach Width Triggers

Long-term "maintenance" trigger = Beach width equal to or greater than the typical summer-winter change plus an allowance for an extreme erosion event. Provisionally, this distance is about 85 feet at Stinson Beach/Seadrift beaches, based on available estimates of storm erosion (ESA, 2015a). In some areas the beach is already very narrow and a smaller distance of 50 feet may be applicable. Information on past seasonal beach width fluctuations along with future monitoring would further refine the selected trigger distance.

- Action: Increase monitoring frequency, including the use of inexpensive aerial photography to track beach width, evaluate resources at risk, consider other actions (nourish, notify residents, etc).

Critical condition trigger = When beach widths in the summer/fall are less than typical seasonal recession due to winter conditions, it is possible that the beach will narrow to the point of providing nearly no protection to the backshore if a severe storm or swell occurs. Monitoring surveys would inform this seasonal fluctuation distance along the beach (for example, 25 feet).

- Action – Sand placement in a berm or embankment shape to temporarily raise the backshore elevation and limit wave runup, absorb wave power as the sand erodes, and provide sand to the beach during erosion events. Consider other actions such as sand bags, blocking low areas that might be used for access but also provide a pathway for wave runup, and contingency preparation for evacuation and utility shutdown.

Timing of Adaptation Triggers

The timing of implementation for an adaptation measure depends on the lead time required to effectively plan, permit, design and construct that particular measure. Caltrans (2011) has published guidance on planning and development of project initiation documents. A previous study by GHD, ESA, (former Phil Williams Associates (PWA)) and Trinity Associates (GHD 2014) identified and evaluated a range of adaptation options to address SLR vulnerabilities at four example locations in Northern California. For the GHD study, designs were developed to provide protection against a king tide (1-year tide) plus 1 foot, but were not specific about the initiation selection. Marin County could consider adopting an evolving assessment methodology that incorporates the latest SLR and climate change science.

Figure 4. Timing of Adaptation Triggers – Suggested Methodology

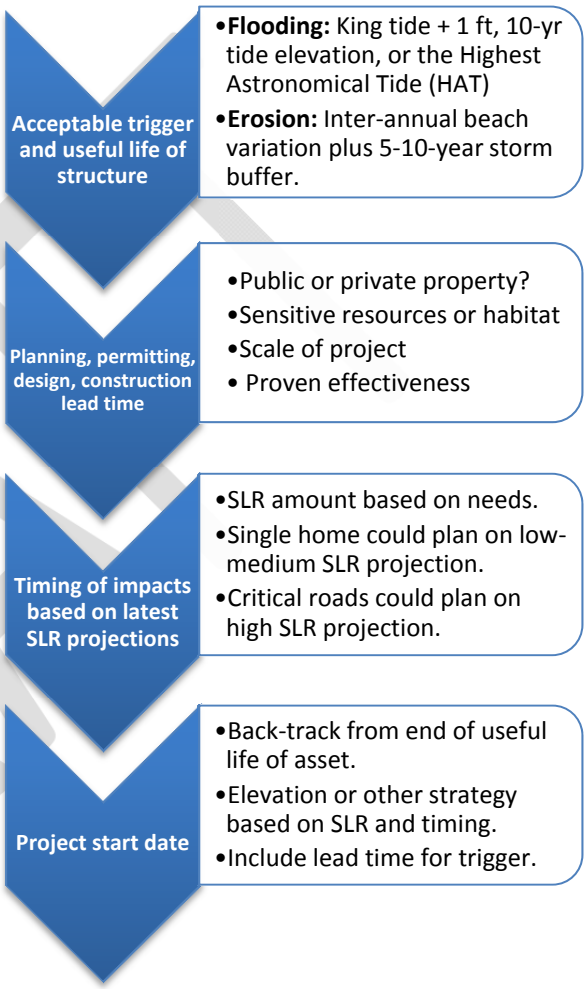


Figure 5. Example Adaptation Trigger Timeline for Road

While uncertainty may be high for future water level predictions, a sufficient level of elevation could be chosen to limit the risk of planning for too little SLR. This trigger-timing process could

also be applied to shrinking beaches and backshore adaptation strategies with sea-level rise or stream bridge and culvert crossings with climate driven precipitation changes.

Shoreline Monitoring

Due to the uncertainty of future rates of SLR and thus anticipated shoreline response, it is important to monitor the shore into the future to properly assess vulnerability to coastal hazards. A shoreline monitoring program could include periodic transect surveys along reaches of concern to track the following beach attributes: shoreline position, toe elevation at the backshore, and dry beach width or dune width.

In the case of an armored backshore (e.g. Seadrift) monitoring the beach elevation at the toe of structures will indicate the exposure of the structure to wave action. Residents in the FEMA V-Zone (with or without fronting armor structure) may consider actions to protect their home if the long-term triggers for dry beach width (or toe elevation) are reached. Homes closest to the ocean are most vulnerable to wave loads, and would benefit the most from structural modification measures such as elevation. However, the homes farther inland may be lower due to the pre-existing grades, and may be more subject to deeper flooding that may persist after a wave overtopping event. While Easkoot Creek is also a hazard source, it was not addressed in this study due to lack of models that integrate riverine and coastal sea level rise. However, Easkoot Creek hazards were considered in the Stinson Beach Flood Control Alternatives Study (Marin County DPW, 2014).

A complete shoreline monitoring program could be developed by a coastal engineer, and data could eventually be collected by County staff or other entities. In example projects by ESA in South Ocean Beach and Surfer's Point, a survey team of at least two people is dispatched to collect topographic data at evenly spaced intervals twice a year (late summer/early fall and late winter/early spring) to capture seasonal shore changes, as well as before and after a significant coastal storm event. Approximate storm retreat amounts, scour depth, and other impacts are quantified and applied to subsequent erosion control measure implementations. Erosion control measures such as sandbag structures and sand placements are also monitored.

The Ocean Beach project establishes a framework for evaluating shoreline conditions, will inform the need for immediate interventions, and sets forth a methodology for tracking and reporting shoreline changes over the next 5 years. Environmental data including waves, tides and weather are archived annually for each monitoring period to improve the understanding of the shore response to storm events and seasonal changes over the course of a year. Additionally, aerial surveys could be conducted to generate a continuous DEM and aerial imagery for desktop analysis of structures and shoreline position.

Relocate/Managed Retreat

In the absence of human development, coastal ecosystems would likely adapt to SLR by migrating inland, with sediment transport and replenishment from erosion providing some stability during these migrations. Due to human development, migration is impossible and sediment transport is inhibited in many areas. On coastlines around the world, and especially in California, there is a delicate balance between protecting private property rights by allowing homeowners to defend their properties against rising waters, while

protecting natural resources and public access to the coast.

Marin County does not promote mandatory retreat as a near-term solution to SLR. However, adaptation strategies should be developed with long-term consequences in mind, and in some areas homeowners, communities and asset managers will need to take adaptive management actions that may involve relocation or abandonment of vulnerable assets over time. The County can help facilitate an orderly and voluntary managed retreat program as a long-term strategy.

Managed retreat programs involve the purchase or abandonment of properties vulnerable to coastal hazards. Structures are typically demolished or relocated. Properties can be restored to a natural state and used for open space or recreation. As part of a land exchange or Transfer of Development Rights program, lands of lesser habitat value and hazard vulnerability could be rezoned or made available in exchange for properties in hazard areas, along with equitable financing arrangements. Managed retreat can be incorporated into other adaptation measures; for example, a road realigned inland could be protected by a horizontal levee, which requires a large right of way.

The costs for retreat in areas consisting of private property are not well known, but could be approximately estimated by assessing the value of the property, and the compensation mechanism (e.g. purchase, easement, etc.) if appropriate 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 shore armoring. Case studies of managed retreat projects in Ventura and Pacifica, among others, are available on the Climate Adaptation Knowledge Exchange website www.cakex.org.

Although managed retreat may be the most straightforward method for protecting development that is under imminent or long-term threat of being damaged or destroyed, 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, and the property owner is often responsible for the full cost of the relocation. Accordingly, this approach has been most typically used for public property and by government agencies such as the CSP in this region (ESA 2015).

Removal and/or relocation of development in vulnerable coastal areas would provide important habitat and public recreation benefits, as beaches and wetlands will have space to migrate inland. Coastal armoring prevents ecosystems from migrating inland and cuts off sand supply by preventing natural erosion processes, causing beaches to narrow and eventually disappear. Statewide policies are evolving in response to concerns about the impacts of coastal armoring, essentially moving away from allowing armoring and toward natural infrastructure or managed retreat as a response to SLR. The California Coastal Armoring Report[38] identifies a conflict between the language in Section 30235 of the California

[38] Melius and Caldwell. Environment and Natural Resources Law & Policy Program, Stanford Law School. 2015. California Coastal Armoring Report: Managing Coastal Armoring and Climate Change Adaptation in the 21st Century.

Coastal Act, which states that the CCC "shall" allow armoring to protect existing structures in danger of erosion; and the overarching goals and objectives of Chapter 3 of the Coastal Act, which call for protection of beach access, coastal resources, and scenic views. The need to avoid "maladaptive" protection measures is important to California's natural resources and public access to the coastline. However, policies must be formulated in a way that reasonably protects private property rights and is legally defensible.

The idea of managed retreat received very little support from Marin County's Adaptation Poll respondents, and many residents felt strongly that retreat should be voluntary. There are few examples of managed retreat in developed residential areas. A major challenge is that there is very limited space to retreat to in the coastal areas, as most land is protected or unsuitable for development.

The County could identify regulatory constraints that may conflict with SLR adaptation, potential "receiving areas" for a managed retreat program, to prepare for future implementation of this strategy (most likely after storms damage vulnerable development). The County could work with land trust organizations to convert at risk areas to open space, establish transfer of development rights programs, and work with these organizations to conduct ongoing monitoring activities. Similarly, existing open areas can be designated as conservation zones to protect and provide upland areas for wetland and habitat migration or for additional agricultural land.

3.4) Recent, Ongoing and Anticipated Adaptations

Because the coast is a dynamic place and changing conditions are already having impacts on coastal assets, several areas are already making improvements to reduce their vulnerability.

Most recently, homes and businesses along the East Shore have relocated and consolidated their OWTSs in a community system leach field landward, east of Shoreline Highway to maintain functioning systems and to prevent polluting Tomales Bay with wastewater.

In the low-lying areas of Stinson Beach, the Stinson Beach County Water District has and continues to work with property owners to update underground gravity fed OWTS to include an off switch that triggers during high water events. This will provide short-term improvements; however, when the water is high enough often enough, these systems will become inoperable more frequently, likely prompting a second phase of OWTS adaptation.

Stinson Beach Fire Station No. 2, which will become vulnerable, will likely relocate landward regardless of SLR because larger fire trucks require larger facilities than Fire Station No. 2 can provide.

In June 2014, the Marin County Parks and Open Space (County Parks) began developing a feasibility study and conceptual design plans for a restoration project located at the north end of Bolinas Lagoon that was recommended in the *Bolinas Lagoon Ecosystem Restoration Project, Recommendations for Restoration and Management* (2008), and by a scientific design review group. The project objectives are to alleviate chronic flooding of county and state roadways at the Bolinas Wye, improve the function of Lewis and Wilkins Creeks, enhance riparian and wetland habitats, and allow for future expansion of Bolinas Lagoon as sea level rises. The scope of services was developed in collaboration with the DPW, Gulf of the Farallones National Marine Sanctuary, Point Reyes National Seashore, and the GGNRA. Given the status of Bolinas Lagoon as a Wetland of International Importance, strong community interest in the lagoon, and the project's potential to affect the road into Bolinas, C-SMART staff will refine a community outreach plan at the time of project initiation.

In March 2015 County Parks made an agreement with the NOAA for the management, operation, maintenance, and repair of a tide gauge at Bolinas Lagoon.