# 3

# the shoreline

© Town of Corte Madera

The Shoreline neighborhoods of Corte Madera are home to valuable residential properties, critical infrastructure facilities, and vital portions of the Town's transportation network. The prominent areas include the eastern residential neighborhoods of Mariner Cove and Marina Village, the Paradise Drive corridor, the Corte Madera State Ecological Reserve and tidal marshlands, and the northwestern neighborhood along Lucky Drive adjacent to Corte Madera Creek. Some of these areas already experience periodic flooding from stormwater runoff and/or king tides, and all are at low elevations putting them at risk of flooding during prolonged storm events.

Mariner Cove and Marina Village are established bayside neighborhoods, which were built on filled baylands in the 1950's.[82] They have subsided as the bay mud and marsh soilds settle under the weight of the infrastructure.[83] The neighborhoods are subsiding at a rate of up to 1.4 inches per decade,[84] further exacerbating the risk of coastal flooding and the localized impacts of sea level rise. Many homes are situated directly on the bank of San Clemente Creek and are currently protected from storm surge by earthen levees; however, during king tides, backyards and driveways can be flooded (as seen in the image above).

Corte Madera's remaining tidal marsh and mudflats provide ecosystem services and have intrinsic value. The marsh and mudflats act as a first line of defense between the Bay and shoreline infrastructure, reducing wave heights and protecting inland areas from bay-side flooding. The tidal marshes also improve water quality by filtering out pollutants and trapping sediment, and they store carbon from the atmosphere. The Corte Madera Ecological Reserve, a large part of the marsh complex managed by the CA Department of Fish and Wildlife, is home to populations of rare and endangered species like the Ridgway's rail, San Pablo song sparrow, and California black rail.[85] The marshes of the Corte Madera Ecological Reserve provide valuable long-term habitat for these species and ecosystem services for the Town of Corte Madera. However, tidal marshes are vulnerable to the impacts of climate change, and future planning efforts must integrate adaptation planning for marsh ecosystems with planning for the built environment in order to preserve this valuable landscape, which is intrinsic to the character of Corte Madera and a critical stepping stone as one of the largest marshes in Southern Marin.

## BY THE NUMBERS

**257**
Total acres of marsh areas located in the Shoreline neighborhoods of Corte Madera.

**13**
Miles of road vulnerable to flooding at present during king tide (1 ft. above MHHW).

**1181**
Total number of buildings vulnerable to flooding at MHHW + 5.5 ft.

**36**
Percentage of buildings vulnerable to flooding at MHHW + 5.5 ft.

**25**
Miles of road vulnerable to flooding at MHHW +5.5 ft.

**368**
Number of total structures less than 1 ft. above MHHW.

**1,250,000,000**
Total value (in dollars) of structures in the FEMA flood zones(*).

* Value calculation assumes $1.3 million average/structure and includes all areas within the Town from Zillow.

## Sea Level Rise in Corte Madera

Sea level rise is often visualized using inundation maps that represent specific SLR scenarios (e.g. MHHW + 12" SLR) or extreme water levels (such as a 100-yr storm event). However, this adaptation plan focuses on three total water levels that represent a range of future water levels associated with extreme tides and SLR. Each of the scenarios approximates either permanent inundation likely to occur before 2100 or temporary flood conditions from specific combinations of SLR and extreme tides. Flooding can occur temporarily during a large flood or permanently due to incremental SLR. Flooding in inland areas can occur without water overtopping the bayfront shoreline if there is a "backdoor" pathway of flooding from a different source, such as Corte Madera Creek, stormwater runoff, or groundwater emergence.

**If no action is taken to further protect from and accommodate rising sea levels, the town will face extreme damage from flood waters.**

| Scenario | Threshold | SLR | "Event" |
|---|---|---|---|
| MHHW + 1 ft. | Episodic Flooding | 0 | King Tide |
| | | 1 ft. | Daily Tide |
| MHHW + 3 ft. | Levee Overtopping and Significant Flooding | 1 ft. | 5-yr |
| | | 3 ft. | Daily Tide |
| MHHW + 5.5 ft. | Chronic and Extensive Flooding | 2 ft. | 100-yr |
| | | 5.5 ft. | Daily Tide |

Figure 3.1 - This table describes the thresholds reached at each of the water level scenarios and different combinations of SLR and extreme water level events that can create each scenario.

### The Secondary Impacts of Flooding

Flooding can cause temporary or permanent business closures, decrease property values, close local and state roadways, and disrupt communications, utility and emergency response services.

Chronic flooding could jeopardize the homes and neighborhoods that contribute to the identity of Corte Madera. It can lower market values and leave houses undesirable or unsellable. Flood insurance for chronically inundated coastal properties could become increasingly expensive, or maybe not available at all. This could lead to a large number of coastal foreclosures and abandoned homes, lowering the value of homes in surrounding areas and force people to look to purchase/rent at higher elevations or in other municipalities. In addition, lower property values equate to less tax revenue that could lead to an increase in property taxes in order to pay for increasingly necessary improvements and fixes to existing infrastructure.[86]

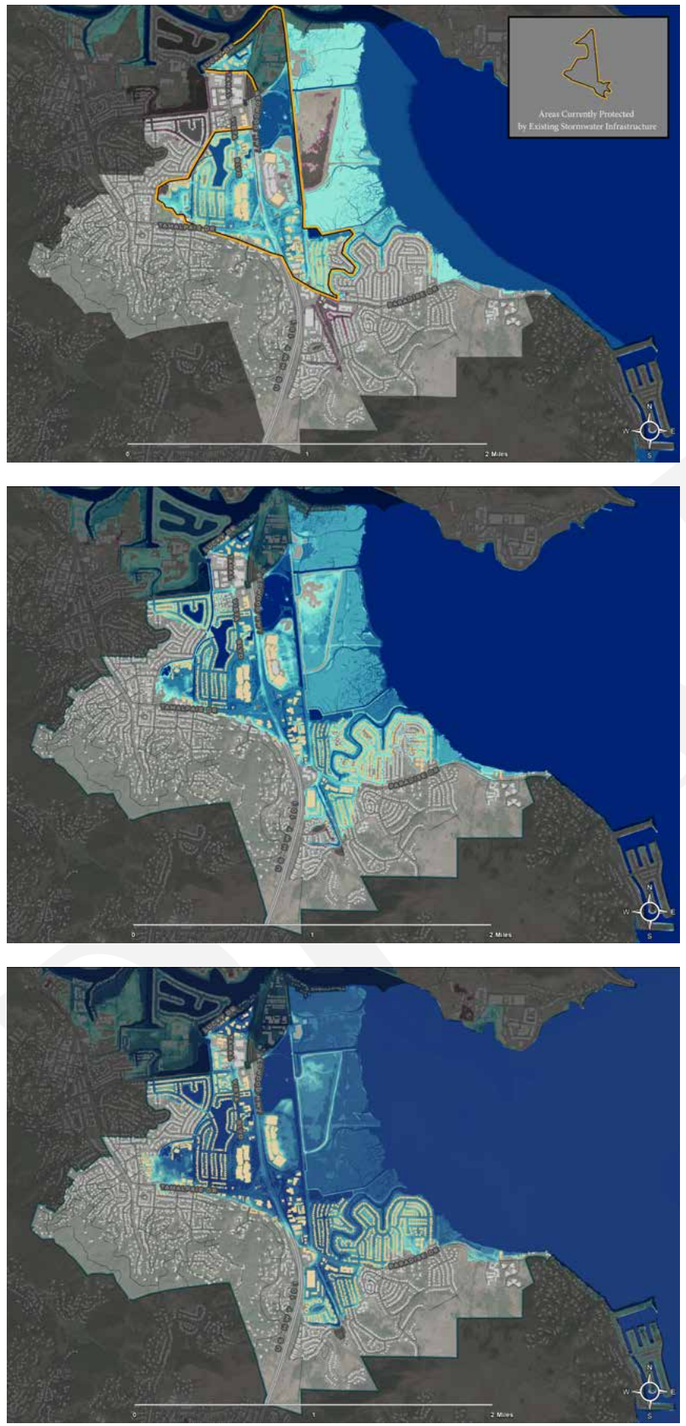


Figure 3.1. Maps depicting the MHHW + 1 (top), 3 (middle), and 5.5 ft. (bottom) inundation scenarios.

In Corte Madera during king tides, water levels frequently meet or exceed 1-foot above MHHW (top map). The center map shows inundation at 3 feet above today's MHHW. The bottom map shows inundation at 5.5 feet above today's MHHW. Note that the extent of flooding is similar between the 3 ft and 5.5 ft scenarios, but depths increase in the 5.5 ft scenario. The Town of Corte Madera does not experience the extent of flooding depicted on the 1-foot (top) scenario map during today's king tides. Currently, flood infrastructure protects much of the Town from 1-foot flood levels, even though the low-lying elevation of the land surface means much of the area would be inundated if no flood protection existed. Areas currently protected by infrastructure are depicted with a yellow border in the first map (MHHW +1 ft.). The flood inundation maps do not consider the duration of flooding from extreme tides or existing mechanisms for draining floodwaters from inundated areas (such as pump stations). While the map may overestimate the potential flood exposure during temporary flood events, the inundation maps and the overtopping assessment are still useful tools for evaluating the overall vulnerability of the Town to more permanent increases in water levels because they highlight how low the ground surface is relative to projected future water surface levels.

## Shoreline Adaptation in Practice

While episodic flooding is a current reality, the Town has time to plan for and proactively manage future flooding. Due to the range of impacts that can occur as a result of sea level rise, a combined suite of policies, programs, and projects are needed to protect critical infrastructure and residents, reduce vulnerability, and create a more resilient community. It is important to acknowledge that future conditions (environmental, financial, and social) are uncertain and can change rapidly, which may require adjusting plans and considering options that may not be among the current highest priority alternatives. In addition, these decisions impact people's lives, safety, property, and critical ecological and public resources, so planning inclusively and with contingencies is extremely important. Overall, part of becoming a more resilient community in the face of climate change is being flexible in the approach to adaptation.

Adapting to sea level rise and coastal flooding requires proactive planning and strategies that generally fall into three main categories: protect, accommodate, and retreat.[87]

- **Protection strategies** (*keep the water out*) utilize some kind of engineered structure, or other means, to defend a resource in its current location without changing the development itself.
- **Accommodation strategies** (*live with water*) require modification of existing developments, or design for new developments, to decrease flood risk, therefore increasing the resilience. Accommodation can happen at the individual parcel or structure scale (raising, floodproofing, retrofits, building material requirements) as well as at the community-scale (zoning ordinances, land use designations).
- **Retreat strategies** (*get out of the water's way*) focus on planning for long-term resilience and include actions that set the stage for relocation or removal of existing development out of hazard areas and/or limit the construction of new development in high risk areas.

No single category is considered "better" or "best", as different types of actions are appropriate for different areas and for different hazard management and resource protection goals, all of which can change over time. In many instances, a hybrid approach to adaptation that utilizes actions across multiple categories is necessary to reduce vulnerability. For each category, actions fall into three key groupings of projects, policies, and programs, each of which are described in more detail in the following pages. The effectiveness and implementability of many actions are contingent upon decisions made around other actions; therefore, these actions are meant to be grouped into larger strategies which can get implemented over space and time. An example of the complex relationship between actions is demonstrated with adaptation pathways on pages 84-85 (adaptation pathway for Mariner Cove and Marina Village and pages 94-95 (adaptation pathway for the Marsh and RR ROW).


Corte Madera's shoreline neighborhoods are home to many of the Town's residents, shopping malls critical to the town's economy, schools, and other services. Though these neighborhoods are vulnerable to coastal flooding, residents would prefer to stay in place as long as possible. Actions in the "Protect" category tend to be near- to mid- term actions that can, through a mix of green, grey, and hybrid approaches, provide flood protection and ecological enhancements to maintain current land uses through the middle of this century. Thus, construction and enhancement of engineered infrastructure and environmental restoration measures may be central to Corte Madera's efforts to combat sea level rise.

Earthen levees and riprap currently protect the Town and residences from high water levels and storm surge, yet, without intervention, these levees will eventually be overtopped by rising seas if not improved. The marsh serves as a natural buffer to sea level rise; however, marsh restoration and enhancement efforts are essential to improving the natural habitat and protecting the shoreline from rising seas and wave action.

While there are physical limits to the effectiveness of engineered protection measures in the long-term, these strategies can be critical to near- and medium-term resilience. It is important to regulate the construction of protective infrastructure to limit potential negative environmental impacts.[88] Well designed programs can help to inform the selection of appropriate actions, monitor environmental conditions, and assist residents and decision-makers in making optimal decisions.

## Fortify or elevate existing shoreline flood protection infrastructure (e.g. levee, flood barrier, or sheet pile wall) or construct new infrastructure to protect residents and critical resources.

**Project**
**Lead:** Corte Madera Department of Public Works

Levees currently protect much of coastal and central Corte Madera from high water levels, and as sea levels rise, it will be necessary to strengthen and elevate existing levees to protect areas behind them from even higher water. (*See Mariner Cove and Marina Village section on pages 78-85*).

## Require that future transportation infrastructure projects consider flood risk over the projected lifespan of the project.

Policy
Lead: Corte Madera Department of Public Works

Using future sea level rise and flood projections is essential for maintaining resilient roads and transportation infrastructure. While roads can still function with minimal flooding, understanding flood vulnerability over the lifespan of the project can help to reduce road closures, maintenance costs, and any disruption to essential travel.

## Develop a program to provide property protection assistance to qualified homeowners and improve compliance with hazard preparedness requirements on their property.

Project
Lead: TBD

Individual homeowners can reduce flood vulnerability and maintenance costs by adhering to flood-proofing and building requirements specific to flooding. The Town could assist homeowners and property owners in preparing permits related to resilient building and design projects, and reduce the amount of time and effort needed to fill out, review, and approve permits. The Town could also reduce fees associated with such processes with the intent to make the process more accessible for property owners seeking to comply with regulations.

## Establish a sea level rise monitoring program, and identify leading indicators and decision points/thresholds needed to protect infrastructure.

Program
Lead: TBD

Sea level rise science and projections are always improving; however, there will always be some level of uncertainty around the timing and rate of sea level rise. To combat this uncertainty and allow the Town to be flexible and adaptive in its response and action, developing a robust monitoring program and establishing thresholds for action is important. For example, the Town could work with others in the region to: 1) Identify thresholds for maximum flood depth or frequency of flooding after which roads will need to be elevated, relocated, temporarily closed, or abandoned (could include community survey to understand point at which flooding is perceived to be chronic and causing a problem); 2) Incorporate sea level rise inundation maps into the Town's GIS mapping system, and utilize GIS as a tool for tracking increased flooding and sea level rise.



## Case Study: Levee Improvements at Foster City (San Mateo County)

Foster City is a bayside development on former marsh and faces similar challenges to the neighborhoods of Mariner Cove and Marina Village in Corte Madera. A levee system surrounds most of the bayfront perimeter of Foster City, protecting the low-lying urban area from flooding. In 2014, the Federal Emergency Management Agency (FEMA) determined that the existing system does not meet minimum flood protection requirements. Given its location on the Bay, and lacking a significant fringing marsh, the levee needs to accommodate both storm surge and wave runup. The existing levee ranges from 12-13 feet NAVD in elevation, but to meet FEMA's current standards it must be raised to 16 feet NAVD in certain areas, and even higher to protect from future sea-level rise.[89] To do this, the crest elevation will be increased by adding a sheet pile wall to the existing levee. Due to impacts on views and geotechnical limitations, continuing to raise the sheet pile wall to protect from both storm surge and wave runup beyond 2050 may not be possible. A coarse beach has been proposed that would be placed in front of the levee to reduce wave runup and extend the life of the sheet pile wall. To reduce risk for their community and avoid designating Foster City as a flood zone (which would require expensive flood insurance for most homeowners), voters passed Measure P in 2018. This measure authorized the City to issue a $90 million general obligation bond to fund the levee improvement project. Measure P will cost property owners approximately $40 per $100,000 of assessed property value annually for levee improvements for 30 years, much less than the estimated cost of flood insurance.[90]

There are some key differences between Foster City and Corte Madera; today, much of Corte Madera lies within the FEMA floodplain, while Foster City (though very low-lying) has been exempt from flood insurance requirements due to the levee system. Because nearly all of Foster City is protected by the levee, fundraising by raising taxes for the whole city is easier than it might be in Corte Madera, where only a small portion of the city's population will directly benefit from new flood risk management infrastructure. In Foster City, homes are ringed by an external road, while homes in Corte Madera are directly adjacent to the Bay. Finally, Foster City also has an existing natural fringing beach along part of the shoreline, where Corte Madera does not (though it does have more extensive marshes). Both cities aim to protect residential neighborhoods constructed on Bay fill in former marshlands from the impacts of rising sea levels. More information about the Foster City project is available here.

# ACCOMMODATE

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One way to adapt to rising seas is to learn how to live with water. Creating space for more water in the landscape is a critical piece of the adaptation puzzle essential for Corte Madera. In many instances, accommodating rising sea levels by modifying existing structures and infrastructure can provide a cost effective way to help reduce current and future flood risk. Actions like elevating certain road segments or finished floor elevations can prevent further flood damage. To further reduce the community's vulnerability to flooding, the Town can take additional actions. Many of the recommended policies are flexible and can be adjusted as conditions or community needs change.

A large portion of the Town currently lies in the floodplain, which is considered a Special Flood Hazard Area (SFHA) and designated by FEMA. To accommodate flooding from Bay and creek sources in these areas, development must meet particular building requirements and adhere to specific regulations. In an effort to reduce flood insurance rates for residents, the Town participates in the FEMA/NFIP Community Rating System (CRS), which determines insurance discounts based on flood risk reduction and floodplain management efforts. The CRS credits community efforts to reduce flood risk by assigning points for different activities. Corte Madera is currently credited as a CRS Class 7, which translates to a 15% savings on all flood insurance rates.[91] For more information on the CRS classes and requirements, check out FEMA's resources. While the FEMA and CRS community participation requirements help reduce vulnerability to flooding, these requirements are based on historical flood data and do not account for future flood risk from extreme precipitation events or sea level rise.



## FEATURED ACTIONS: ACCOMMODATE

### Conduct a comprehensive, finished floor elevation inventory of buildings within current and future flood risk areas.

Project
Lead: Corte Madera Planning Department

This inventory can help the Town make the most informed decisions on where and when to most effectively invest resources by not relying solely on the bare-earth elevation data to determine at-risk structures or areas for future investments.

### Elevate portions of Lucky Drive and Paradise Drive at risk of flooding.

Project
Lead: Corte Madera Department of Public Works

Some portions of Lucky Drive already flood during high water events and king tides. These sections of road should be elevated to withstand sea level rise and storm surge for the lifespan of the roadway (*see Lucky Drive - page 76, - and Paradise Drive - page 77 - concept design sections*).

### Update real estate transaction disclosure requirements for homes in designated flood-risk zones to include hazards related to climate change including prior flood damage and current and future flood risk.

Policy
Lead: Corte Madera Planning Department

Work with real estate agencies and others to develop a disclosure ordinance that requires that sellers disclose past flood events and building elevation and location relative to Town defined flood zones. This will help buyers become aware of climate related risks.

### Require additional freeboard above base flood elevation.

Policy
Lead: Corte Madera Planning Department and Corte Madera Department of Public Works

Homes in the flood zone are currently required to be elevated one foot above the 100-year (1% annual chance) flood water elevation. Requiring additional freeboard (e.g. 3 feet above base flood elevation (BFE) for new structures can reduce vulnerability to flooding for homes in designated areas. For existing structures, these elevation requirements could be triggered at the time of "substantial improvement" or "significant damage" (threshold determined within municipal ordinance).

## Policy Consideration: Corte Madera Coastal Resilience Overlay Zone

Zoning is the most powerful tool that local governments can use to preemptively mitigate hazards by determining what is at risk, what is safe to build, and where it is safe to build. By analyzing vulnerabilities and planning for impacts, local governments can shape landowner expectations and build support for adaptation efforts. Through regulations, local governments can ensure that fewer people and less infrastructure is in harm's way as sea level rises and that developers site and construct new, more resilient buildings.[92]

**"An overlay zone is a land use planning area where additional zoning requirements 'overlay' the original requirements of the underlying zone."[93]**

The development of a coastal resilience overlay zone designation would serve a number of different purposes. Once in place, an overlay zone would provide landowners with the warning that they are currently, or will soon be, in the direct path of rising seas or chronic flooding. Over the longer term, phased implementation of restrictions and/or regulations can reduce or halt rebuilding in hazardous areas. Overlay zones can be designed to remain "transparent" and not impact the properties until a future triggering event (such as reaching an established king tide elevation) requires the prescribed changes. They can also be designed in a way that certain regulations are in place until a particular event occurs, decision is made, a defined threshold is reached, or other conditions change, which triggers those regulations to relax or change. These following strategies can be implemented at different times, depending on the Town's goals and needs, and some can occur simultaneously.

### Designate zones within the flood hazard area where regulations are tailored to specific conditions, characteristics, and adaptation goals.

How zone boundaries are drawn requires the Town to weigh the following policy considerations: community goals for particular areas; the area's vulnerability and the immediacy of adaptation needs; the extent and type of existing development (critical facilities, residential, commercial); how precautionary the town wants to be in regulating the different zones; and both the extent of existing protective measures and the feasibility and likelihood of future protective measures in the area.[94]

**Floodplain Frontline Zone:** This zone could consist of structures and habitat areas that are the most vulnerable to flooding from sea level rise and the hardest to cost-effectively protect from projected sea level rise (or maybe unfeasible to protect with hard infrastructure) in the near-term or long-term. This area could be drawn using existing data and observations or after specific regional or State sea level rise vulnerability maps were adopted for regulatory use for local governments. The following is a list of potential tools that could be employed in this zone.

- **Restrict rebuilding:** Limit or prohibit redevelopment of nonconforming structures, or upgrades to existing structures.
- **Implement development moratorium.** Prohibit the building of new structures for up to two years from implementation, or until certain conditions or protective measures are in place.
- **Downzone permitted use:** limit new development and redevelopment to low-density/low-intensity uses (such as recreational or open space).
- Increase setbacks: require that structures be setback on the lot as far landward or upward on a site as feasible ("maximum practicable setbacks").
- **Limit the size of structures:** permit only smaller structures that are built to be more easily relocated, will put fewer people at risk, and will minimize the economic consequences of floods.

**Floodplain Accommodation Zone:** This zone designation can allow for continued development and redevelopment while requiring that structures be sited and built in ways that are more resilient to flooding and reduce vulnerability to sea level rise. While regulations within this zone would be broadly applied with the goal of resilient growth and development, careful consideration should be taken for the individual siting of new development, especially critical facilities and utilities, that may need additional analysis.
The following tools could be employed in this zone:

- **Increase freeboard or structure elevation:** require additional freeboard consistent with estimates for projected SLR over the projected life of the structure (e.g. X feet of SLR over X years) or adding height to the BFE to accommodate sea level rise (e.g. increase to 3 feet above current BFE). Where freeboard is infeasible, the Town could require that structures be flood-proofed.
- **Require more resilient and adaptive building types:** require all new (and upgraded) commercial and residential developments be built using resilient materials and best practices.
- **Adjust building size/height and densities allowances:** consider adjusting building size and density allowances to reflect Town goals and housing requirements.
- **Streamline permitting process:** reduce the resources needed for property owners to acquire necessary permits to comply with flood regulations.

Most of the tools at the Town's disposal are not currently employed within the nine jurisdictions of Marin County, except freeboard elevation requirements and requirements for flood-resistant designs. Marin County requires structures to be built an additional foot above the FEMA-required base flood elevation. These requirements could be applied to the appropriate newly-designated zones. Some additional conditions or requirements may apply to some, or all, structures falling within a coastal resilience overlay zone (or specific zone).[95] Additional potential actions, conditions, or requirements can be found in Appendix X.

# RETREAT

Local governments and decision makers are increasingly having to discuss ways to best protect people, development, infrastructure, and coastal ecosystems from sea-level rise, coastal flooding, and subsequent land loss. Planning for strategically relocating people and infrastructure out of harm's way is synonymous with long-term planning for a safe and resilient future. While there are many actions a government can take to protect residents and infrastructure in the near- to mid-term, it's essential that discussion of the longer-term vision of the community occur in tandem, as these changes can require significant planning and analysis. There are actions that can be taken now to avoid significant damage from chronic flooding and reduce the financial burden on residents and the Town that are likely to occur if action is not taken. Planning for long-term resilience of shoreline homes can create new opportunities for homeowners to resettle in areas less vulnerable to coastal hazards before sea level rise is knocking on their front door.

**Managed retreat is the voluntary and planned movement and transition of people and infrastructure away from vulnerable coastal areas.**

Given the rates of sea level rise and subsidence in some of the Town's coastal neighborhoods, it is difficult to imagine a community that does not look radically different in 80 to 100 years. Preparing the community for potentially more than 6 feet of sea level rise by 2100 and additional flooding from groundwater rise means reenvisioning what coastal neighborhoods look like and how they function as part of the larger community. Over time, flooding from rising sea level will likely decrease the value of shoreline properties in Marin County and increase the cost of flood insurance, causing many homeowners to suffer financial losses. Similarly, the local government will also incur additional costs for infrastructure improvements and maintenance, health and human services, and emergency services.

Across the country and the world, most movement of people and infrastructure occurs post-disaster, such as after a hurricane, significant flood damage, or repetitive loss. However, many local governments are looking to proactively move people and property out of harm's way to avoid costly emergency actions and are exploring the feasibility of different programs and policies.

There is no "one size fits all" approach to managed retreat. Communities across the country and world are taking creative approaches to planning and implementing strategic retreat from the most vulnerable shoreline areas, using a mix of programmatic, regulatory, and educational strategies. While managed retreat as it is envisioned now may not be the answer for every coastal community, it is still essential to begin the difficult conversation with Corte Maderans. These discussions can help ensure that everyone affected by climate change has the opportunity to voice their concerns and consider all options. Given the long lead time associated with these types of policy decisions, it is important to have these discussions while discussing other more traditional protection and adaptation strategies.[96] Having the goal of planning early for long-term resilience can help the Town provide assistance to those at risk rather than leave people to do nothing or plan individual. Sea level rise is no longer an issue for future generations and holistic discussions of a variety of strategies, including retreat, should begin now.

## FEATURED ACTIONS: RETREAT

### Begin the community conversation around long-term impacts of sea level rise.

Program
Lead: TBD
Involving the community from the beginning of the planning discussion is essential for any potential future success of managed retreat programs. Educating residents on the future projections, impacts, and potential adaptation alternatives can help to bring the community along and garner support for future endeavors.

### Form a regional strategic retreat advisory board to investigate the potential and feasibility of managed retreat within Marin County and the surrounding region.

**Program**
**Lead:** TBD
Regional collaboration is essential for early planning and discussion around the feasibility of managed retreat in the region. Part of this should include the discussion on where displaced residents could be moved and how this program would work within the region.

### Assess the costs and benefits of investing in protective infrastructure vs. retreat.

Program
Lead: TBD
An analysis of the costs and benefits of constructing protective infrastructure versus investing in moving out of harm's way would be useful to determine the most appropriate use of Town funding.

### Retain the services of a financial analyst to explore the financial viability of an acquisition program.

Program
Lead: TBD
This is an essential early step to determining the feasibility of longer-term resilience options. A potential acquisition program could utilize a variety of funding sources, such as FEMA Building Resilient Infrastructures and Communities (BRIC), and tools to buy properties from willing sellers in established areas.

## Require flood risk status be disclosed to potential homebuyers of properties in highly vulnerable areas.

Program
Lead: TBD

Corte Madera does not currently require that potential homebuyers are informed of the current and future flood risk of the property of interest. By requiring this information be shared, it allows the potential purchaser to make a more informed decision. This can also be an opportunity to help people understand that the government cannot, and is not legally obligated to, ensure that property owners will not experience loss. It can help the market shift the future potential risk into pricing of homes. It can also serve as a means to explain that government funds (from taxpayers) are not required to pay for the costs of risks knowingly undertaken by property owners and purchasers.

## Restrict significant redevelopment or improvement of existing properties in highly vulnerable areas.

Policy
Lead: Corte Madera Planning Department

If combined with regulations that prevent new development in highly vulnerable areas, this can even further reduce the number of properties in areas of high current and future flood risk. However, this can result in the slow deterioration of properties and cause significant financial burden to homeowners in the near term.

## Initiate an outreach and education campaign focused on community awareness and involvement in long-term shoreline planning.

Project and Program
Lead: Corte Madera Planning Department

It is essential to involve the community in early planning discussions around a long-term vision for the community. This campaign can focus on educating residents and business owners on current and future flood risk, including sea level rise projections, feasibility of different adaptation strategies, and how different strategies and alternatives impact residents and the community as a whole.

### Case Study: Imperial Beach, California

The City of Imperial Beach proposed a plan to move residential structures away from the most vulnerable shoreline areas using two possible methods. The first option being proposed was through acquisition programs, where the local government purchases properties from homeowners and rents them back (called a lease/buyback program); renting these properties back out can allow for the City to recoup a portion of the buyout costs. The second option explored the feasibility of a Transfer of Development Rights (TDR) program that involves a transaction between the City and homeowner, where the City provides a housing option in a "receiving areas" (where residents would move) in exchange for the homeowner giving up development rights to their property in the "sending area." The decision to pursue and propose these programs to the community was not taken lightly. The City conducted a cost benefit analysis on multiple adaptation strategies, and found that transitioning residential housing away from the shoreline had the highest net benefit through the end of the century. Despite the City's research into the possible retreat strategies, the community was strongly opposed to these strategies. The latest Imperial Beach Local Coastal Program update does not consider managed retreat as an option.[97,98] Although this plan was not successful, there are many lessons to be learned from this city's approach to community engagement.

- **Engage the community early in the discussion and planning process.** If the community is well informed of the mechanisms of the proposed programs--what is and isn't involved--they are less likely to reject the idea due to misinformation or fear.
- **Invest in the time to educate the community on the impacts of sea level rise and the pros and cons of possible adaptation strategies.** The more educated the community is on the localized impacts of sea level rise, the better they will understand the need to plan for long-term resilience. If shown the possible solutions, and the costs and benefits for each, it is possible that the community will come to the determination on its own that managed retreat is necessary.

# NATURE-BASED ADAPTATION

Natural and nature-based measures are physical landscape features that are created and evolve over time through the actions of environmental processes, or features that mimic characteristics of natural features but are created by engineering and construction (in concert with natural processes) to provide coastal protection and other ecosystem services.[99] Nature-based adaptation measures are only appropriate in certain landscape settings. They can be used in combination with other appropriate nature-based measures, or in hybrid combinations that include both nature-based measures and conventional gray infrastructure measures. Two examples of suites of nature-based adaptation measures working in concert to provide flood protection and habitat benefits are shown in Figure 3.2 and 3.3. Examples of nature-based measures that are suitable in Corte Madera are tidal marshes, ecotone slopes, submerged aquatic vegetation, and coarse beaches, each of which are described in more detail below.

For more information about nature-based sea level rise adaptation strategies, please refer to the San Francisco Bay Shoreline Adaptation Atlas.

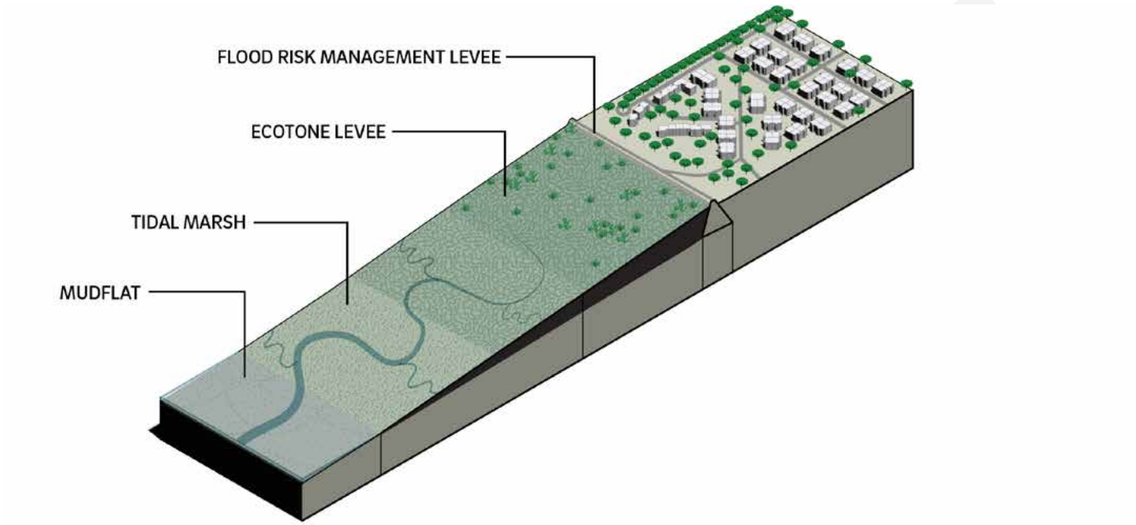



Figure 3.2. Example of multiple “gray” (traditional) and “green” (nature-based) adaptation actions working in concert to provide flood protection and habitat benefits. Illustration by Micaela Bazo, SFEI. Adapted from the SF Bay Adaptation Atlas (SFEI & SPUR 2019).

## Tidal Marshes

Protecting, maintaining, and restoring tidal marshes and their associated tidal flats is critical for sustaining their flood risk management services with a changing climate.[100]The topography of the marsh and its associated mudflat plays a significant role in wave refraction, shoaling, and breaking. Wide marshes at Corte Madera are an asset in wave attenuation. Stabilizing the outer edge of the marsh by placing coarse beaches can help maintain marsh width by reducing erosion. Specific actions include restoring tidal action to diked baylands to restore marshes, planting native species to accelerate colonization, placing sediment to raise subsided areas, and creating marsh mounds - higher areas within marshes to provide high-tide refuge.[101] In existing marshes this measure might also include sediment placement to help maintain marsh elevation with sea level rise.

## Ecotone Slopes

Ecotone slopes are ramps (with a length to height ratio of 10:1 or gentler) bayward of flood risk management levees and landward of a tidal marsh. They can provide wetland-upland transition zone habitat when properly vegetated with native clonal grasses, rushes, and sedges.[102] Ecotone slopes can attenuate waves before they reach the levee, provide high-tide refuge for marsh wildlife, and allow room for marshes to migrate upslope with sea level rise.[103] In Corte Madera, there is a unique opportunity to use on-site material (dredge spoils at the Golden Gate Bridge District parcel) to create an ecotone slope along the railroad embankment, connecting a future flood-risk management levee to the marsh.[104]

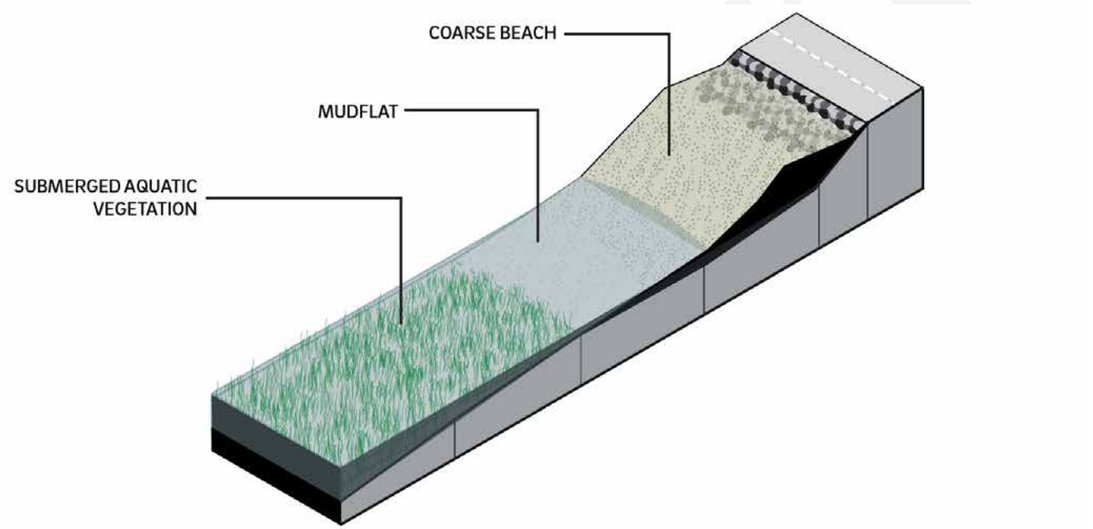



Figure 3.3 - Submerged aquatic vegetation, mudflats, and coarse beaches are natural features that can reduce the impact of wave action on the shoreline. Illustration by Micaela Bazo, SFEI. Adapted from SF Bay Shoreline Adaptation Atlas (SFEI & SPUR 2019).

## Submerged Aquatic Vegetation

Submerged aquatic vegetation refers to all underwater flowering plants, and contributes to trapping sediment and slowing shoreline erosion.[105] Eelgrass (*Zostera marina*) is the main species in the lower parts of the San Francisco Estuary, but other submerged vegetation species exist throughout the Bay as well. However, submerged aquatic vegetation cannot grow anywhere; salinity, light, and substrate are limiting factors for eelgrass beds, and they do best where current speeds and wave energy are not excessive. Potential exists to establish eelgrass beds at depths less than 2m in broad swaths along the shores of Corte Madera bayward of the tidal marsh.[106,107]

## Beaches

Coarse or composite estuarine beaches are dynamic features that can consist of a mixture of sand, shell, gravel, or cobble.[108] Coarse gravel and cobble beaches can dissipate wave energy over shorter distances than marshes and therefore may be more suitable within an urbanized estuary that has limited space.[109] Beaches can be placed in front of levees, roads or other infrastructure vulnerable to wave overtopping, or in front of marshes vulnerable to erosion. In addition, groins or other retention structures (large woody debris is one option) should be considered for beaches implemented along shorelines where the dominant waves tend to transport sediment down the shoreline.

# SHORELINE FOCUS AREAS

The previous pages have laid out numerous adaptation strategies that may be suitable for implementation in the Town of Corte Madera. In the following section, conceptual adaptation strategies are introduced for areas of the Town vulnerable to rising sea levels. Each of these strategies employs a range of measures (protect, accommodate, and retreat) based on the goals of the Town. Because nature-based measures may perform better than traditional engineered infrastructure while potentially costing less and providing more co-benefits,[110] they have been incorporated into the conceptual designs as much as possible. No single adaptation strategy will protect the Town from flooding indefinitely, so adaptation pathways are presented that demonstrate the approximate time period of protection that may be afforded by certain measures, and decision points that can be used to determine when to implement a new strategy.

The four shoreline focus areas range in land use types: critical road infrastructure for the Town of Corte Madera, single-family residential neighborhoods in Mariner Cove and Marina Village, and the tidal marshes of the Corte Madera Ecological Reserve. Each focus area faces near term vulnerabilities, which could be addressed by the conceptual adaptation strategies detailed on the following pages. Each of these areas are in different stages of the planning process. For some, alternatives and costs have been explored, and for all, further planning and discussion are needed with the variety of stakeholders and landowners critical to making tough planning decisions.



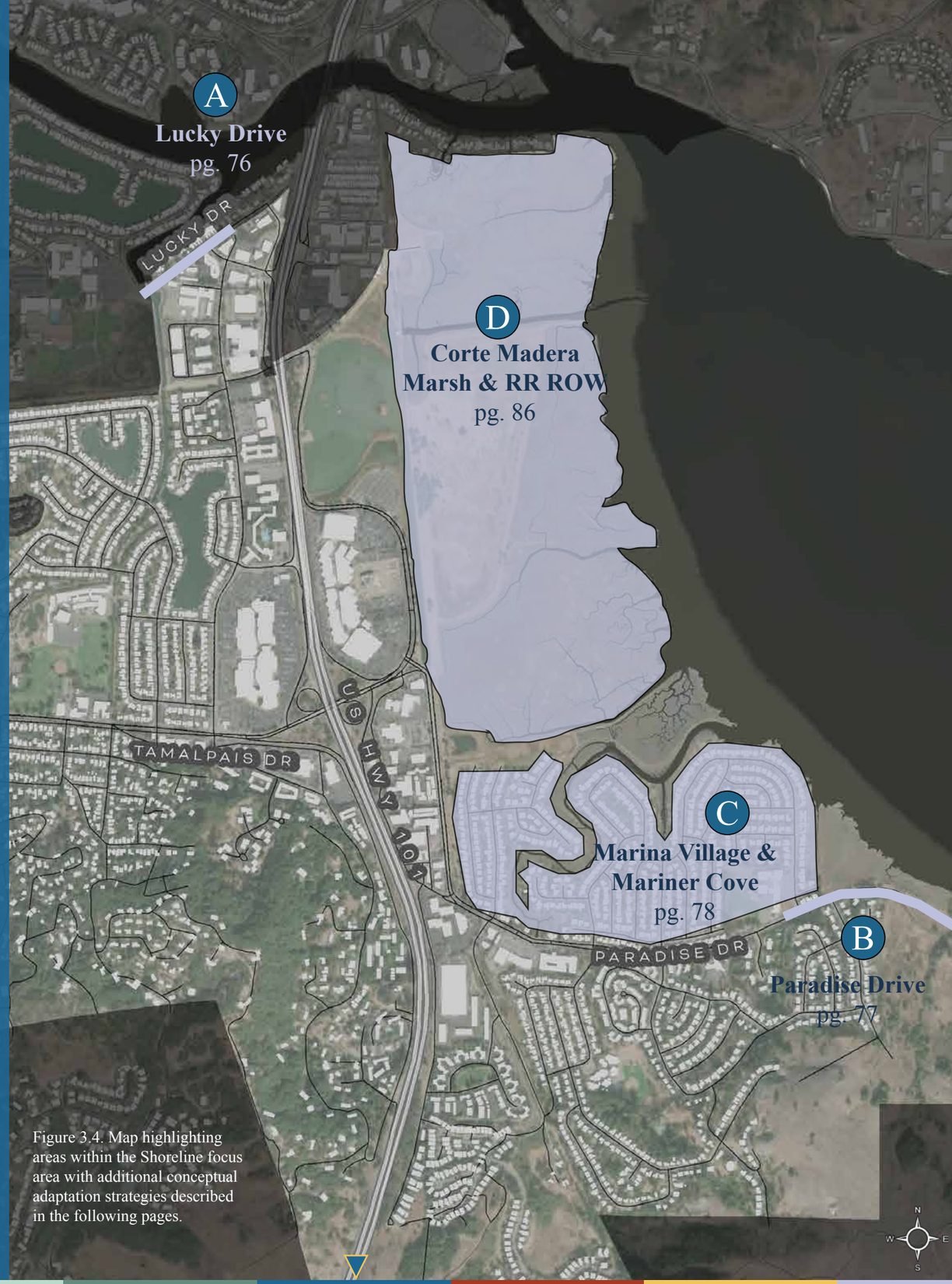




Figure 3.4. Map highlighting areas within the Shoreline focus area with additional conceptual adaptation strategies described in the following pages.

## A. Lucky Drive

Lucky Drive is a short-yet-essential stretch of roadway that connects Corte Madera and surrounding municipalities and US Highway 101. This stretch of road is a critical access point to US Highway 101 and the only way to get to many homes and commercial properties in the Town. Lucky Drive is susceptible to flooding from Corte Madera Creek during heavy precipitation events and vulnerable to sea level rise.

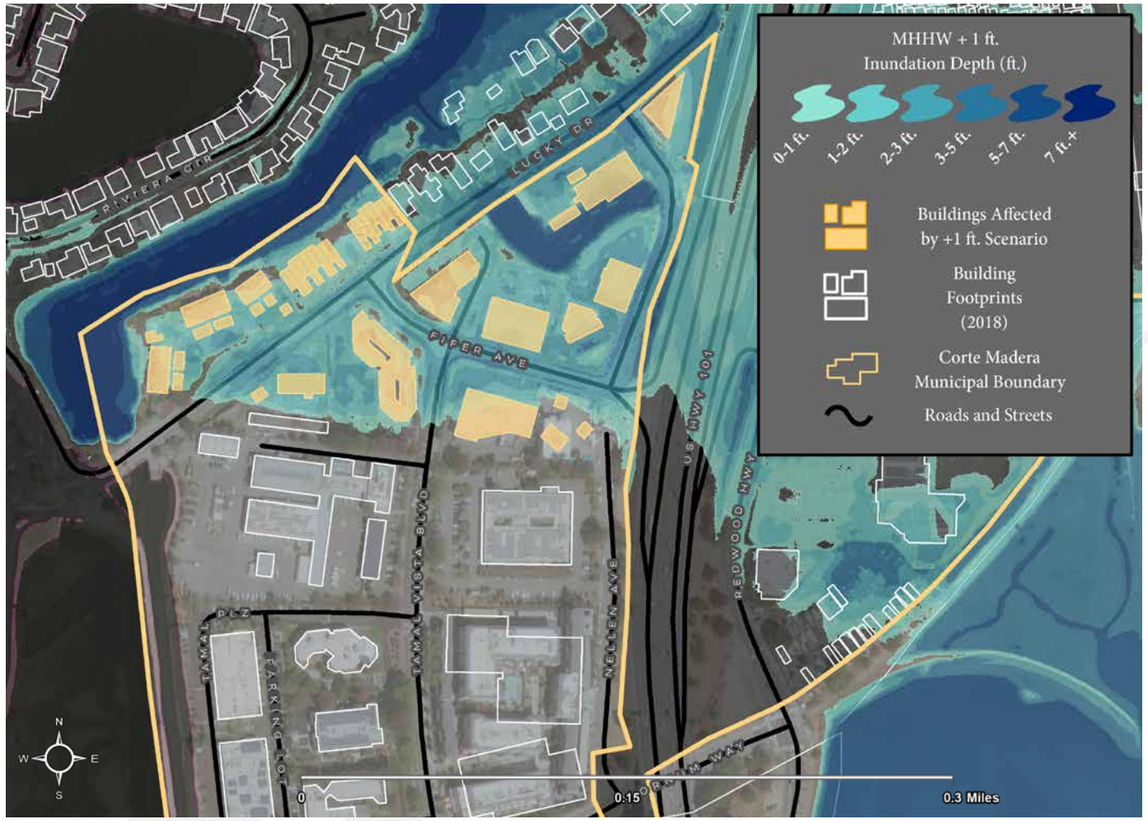



Figure 3.5. Section of Lucky Drive under a MHHW + 1 ft. scenario (approximately equivalent to a king tide). The area highlighted in yellow is currently protected from existing stormwater infrastructure, but coloring depicts water inundation levels without existing infrastructure in this protected area.

Despite being protected from temporary flooding by stormwater pumps, a section of Lucky Drive still floods during king tide events, especially when a king tide occurs during a period of high rainfall. To reduce the risk of flooding Lucky Drive, the roadway will need to be raised. The project team assessed the potential impacts of raising Lucky Drive from Doherty Drive to the northern Town border to a minimum elevation at the back-of-sidewalk of 10.7 ft (NAVD 88). The 10.7 ft NAVD88 elevation would move the roadway above the current 100-year flood and allow for an additional 13" of sea level rise over the lifespace of the roadway (~30 years). This would make the roadway above the 100-year flood event in the 2050s. These improvements should be made in conjunction with a proposed roadway reconfiguration to incorporate a two-way protected bikeway on the north side of the street.

The Town has already submitted a grant application to cover the majority of the costs for raising Lucky Drive and is looking to complete this project in the next three to five years. For more details on the conceptual design, elevations, and other considerations see Appendix X.



## B. Paradise Drive

Paradise Drive is another critical regional transportation corridor connecting Tiburon to the Town. It is designated as part of the Bay Trail and provides access to the Marin Montessori and Marin County Day schools and other residences. The Town has been looking into resurfacing the road, expanding bike lanes, and making other roadway improvements for a few years.


Figure 3.6. East Paradise Drive under a MHHW + 5.5 ft. scenario. Color shading depicts approximate depth of inundation.

To reduce the risk of flooding Paradise Drive, the roadway will need to be raised. The project team assessed the potential impacts of raising Paradise Drive from Westwood Drive to Robin Drive to 11.6 ft (NAVD 88), in conjunction with the proposed resurfacing and widening effort. The elevation of 11.6 ft (MHHW +5.5 ft) would take into account sea level rise and elevate the road above the 100-year flood event in the 2070s. The proposed roadway profile is required to be at a minimum elevation of 12 ft or higher, assuming a standard 2% roadway crown. With existing centerline elevations ranging from 7.0 ft to 11.5 ft along this segment of Paradise Drive, in some areas the roadway will need to be raised up to 5.0 ft to address the anticipated water level of MHHW + 5.5 ft. The primary potential impacts of raising Paradise Drive include disrupting connections to adjacent roadways and driveways, relocating utilities, raising the pedestrian overcrossing for the Marin County Day School, and navigating environmentally sensitive areas. The Town is considering elevating the road as part of an already identified roadway resurfacing project in the next five years. More information on the details and core considerations that would need to be addressed as part of this project are available in Appendix X.

## C. Mariner Cove & Marina Village

The Mariner Cove and Marina Village neighborhoods are a mix of residential development and critical marsh habitat. The neighborhoods were constructed in the 1950s and 1960s by placing fill material on top of tidal marsh and bay mud that in some places is more than 100 feet thick. Channels, culverts, pump stations, and the existing levee protecting Marina Village have largely curtailed flood impacts over the years, but yards, garages, and foundations along Golden Hind Passage in Mariner Cove flood during king tides, and sometimes pumping is required for drainage. Flood tides also overtop the banks on the west side of San Clemente Creek and flow to the storage pond at the Marina Village Pump Station.[111] Muzzi Marsh and Marta's Marsh to the north, and the Triangle Marsh to the east provide flood mitigation and valuable wildlife habitat for numerous species, including special-status species such as the Ridgway's rail (*Rallus obsoletus*).

The specific vulnerabilities in this area include marsh edge erosion, near-term flooding of back yards along Golden Hind Passage, wave exposure, and the threat of overtopping of the Marina Village levee. Additional threats include rising groundwater levels driven by rising sea levels, and flooding from storm runoff. Rising groundwater driven by sea level rise will mean managing stormwater landward of the levee is likely to be an increasing challenge.

The process of developing, exploring, and refining conceptual design alternatives for these areas of the shoreline involved a variety of conversations and a broad range of input. Guided by the Town Staff, particularly the public works and planning departments, the project team worked to create different coastal protection concepts that balance the need to protect important community residents, enhance or support important ecological areas, and are cost effective. Technical and scientific input was provided by Adaptation International, the San Francisco Estuary Institute, Marin Audubon, CA Fish and Wildlife, and Miller Pacific Engineering Group. The Resilience Advisory Committee (RAC) helped refine these concepts over as series of five meetings, and the community provided comments through two community workshops, three Flood Control Board meetings, and the review of preliminary and draft materials.

As a result of these meetings and inputs, two main alternatives were developed, guided by goals outlined by the RAC. The goals of these alternatives were: (1) to use nature based measures as much as possible; and (2) to maintain current land uses as long as possible, but to bear in mind the increasing vulnerability as the century progresses.

***A levee or sheet pile wall could be constructed to protect homes and residents from sea level rise and future storm and flooding events.*** Ideally, this would be a composite flood protection levee with integrated nature-based solutions such as a coarse beach on the bayward side of the levee to attenuate waves and reduce flood risk in Mariner Cove. Coarse beaches could also be designed to reduce marsh edge erosion at nearby Marta's and/or Triangle Marsh. Marsh mounds could provide high tide refuge for marsh wildlife as sea levels rise, and as the marshes downshift to low marsh and mudflat in the next several decades.When designing a levee, it is important to look at the low-risk tolerance sea level rise projections, consider the typical lifespan of the levee infrastructure, consider storms and provide freeboard. Putting those aspects together, the Town is considering a levee that would extend to 15ft NAVD88 (about 9 ft above current MHHW) that could be built in multiple phases to allow for settlement. Site constraints such as proximity to marsh and houses, lack of space, and poor ground conditions may limit the range of potential options. If a levee is constructed, a tide gate across San Clemente Creek would be required to complete the line of protection. It should be noted that as sea levels rise, this tide gate will need to be closed more often, resulting in loss of tidal marsh, reduced stormwater outflow, and potential water quality issues in the creek. Eventually this gate will need to be closed all the time. Tide gates and levees have finite life spans as they provide protection for a certain amount of sea level rise. However, they can be designed to be modified in the future and can reduce flood risk in the short- and medium-term while longer-term adaptation strategies are developed.

### Case Study: Marsh Restoration and Levee Improvements at Tiscornia Marsh (San Rafael)

Tiscornia Marsh is located at the mouth of the San Rafael canal and owned by the Marin Audubon Society. One of the last remnants of ancient marsh in the area that has remained unaltered by human development, Tiscornia Marsh has experienced considerable erosion over the past 30 years, with approximately 3 acres lost over that period.[112] This erosion has resulted in significant loss of habitat for the endangered Ridgway's rail and salt marsh harvest mouse, migratory shorebirds, and other important marsh wildlife. In addition, the levee behind the marsh is relatively low, exposing parts of San Rafael's canal neighborhood to flooding during an extreme coastal storm. Erosion and flood risk will be exacerbated by sea-level rise, and the proposed restoration design addresses both concerns.

The preliminary design for a habitat restoration and sea level rise adaptation project was created by Environmental Science Associates. The project design includes ecosystem enhancements (restoring an eroded section of the existing tidal marsh, opening the diked marsh to tidal action, providing transition zone habitat) and levee enhancements (improving a section of degraded levee and enhancing public access opportunities on the Bay Trail). The next phase of the Tiscornia project is funded by a Measure AA grant to the Marin Audubon Society.

This project pilots several elements relevant to adaptation designs for Corte Madera, including the use of coarse beaches for erosion reduction at the marsh edge, an integrated plan for marsh restoration and levee enhancements, inclusion of an ecotone slope connecting the marsh and levee, and the enhancement of public access to improve the site as an asset to the community. More information about the Tiscornia Marsh restoration project is available at http://www.tiscorniamarshp.org/

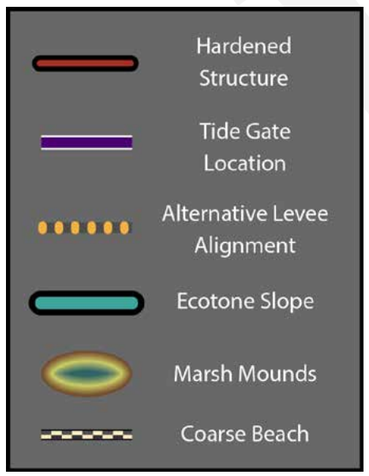
© Douglas Mundo, Multicultural Center of Marin. Courtesy of Marin Audubon Society

## Strategy: Levee/Sheet Pile Wall with Nature-Based Enhancements

Two possible alignments for a flood risk management levee/sheet pile wall and tide gate are shown in the maps to the right. There are a number of tradeoffs to consider between the inner and outer alignments. With the inner alignment, views and backyard space are impacted by the placement of the structure near more homes, while the outer alignment preserves the status quo for more properties. The tide gate location in the inner alignment disconnects less of San Clemente Creek from the Bay, with fewer corresponding ecological impacts. The location of the tide gate also determines the stormwater detention capacity of the area behind the gate, with the outer alignment offering more capacity. Because the inner alignment is constructed along the edge of the neighborhood itself, it is less likely to impact Marta's Marsh, while the outer alignment's location at the marsh edge likely means more impacts.


Figure 3.7. Graphic representing a potential inner levee alignment and tide gate designed to protect Mariner Cove and Marina Village.


Figure 3.8. Graphic representation of a potential outer alignment and tide gate designed to protect Mariner Cove and Marina Village.




## Conceptual Cross-Section for Outer Alignment at Marina Village

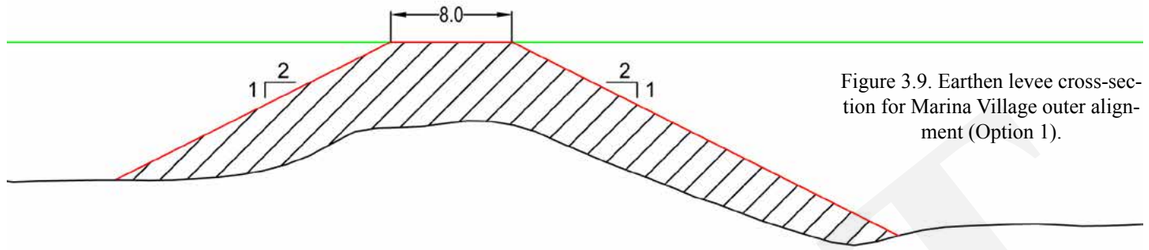



Figure 3.9. Earthen levee cross-section for Marina Village outer alignment (Option 1).

Option 1 is a traditional earthern or light weight fill levee built over the existing levee berm. The top crest width is reduced to a minimum of 8 ft. to provide access for construction and maintanence while limiting the overal size, weight, and extent of the levee. This portion of the marsh has extensive bay mud (in some places up to 110 ft. deep) that can cause significant settlement over decades and require the potential need to phase-in the initial design in order to maintain structrual integrity. The 15 ft. crest elevation would need to be raised over time to keep pace with sea level rise and settlement.

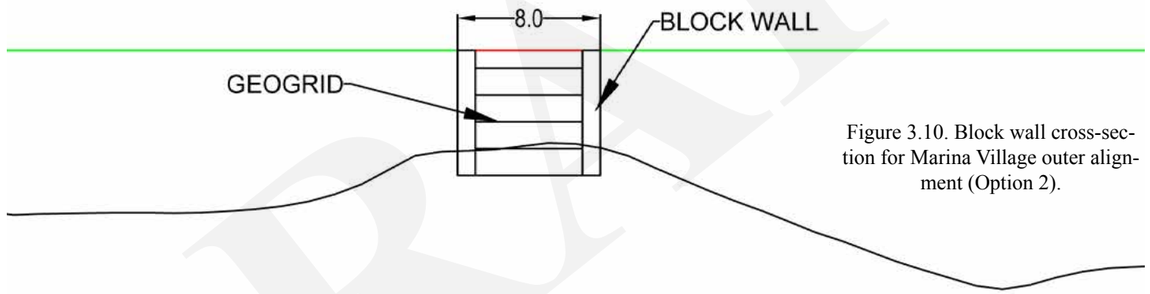



Figure 3.10. Block wall cross-section for Marina Village outer alignment (Option 2).

Option 2 is a block wall connected by a geogrid. This option would reduce additional weight on marsh, decrease settlement rates, and significantly reduce the width of the levee. The 8 ft. crest width would accommodate maintanence and potentially provide a pedestrian path. The block walls could be hidden with natural landscaping.

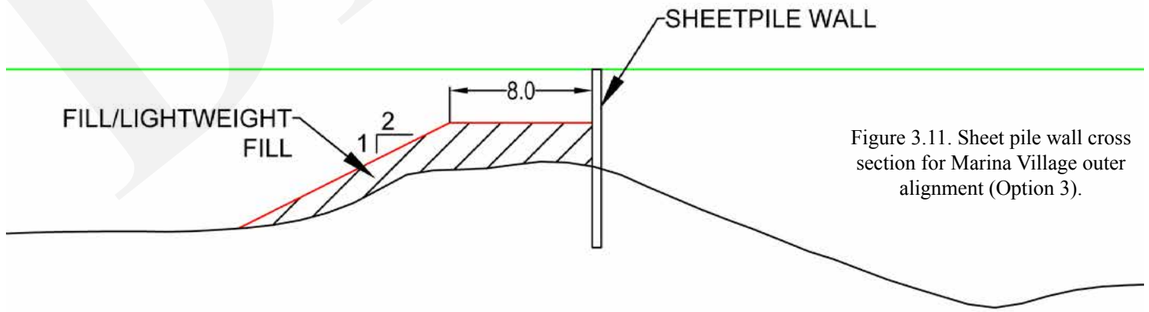



Figure 3.11. Sheet pile wall cross section for Marina Village outer alignment (Option 3).

Option 3 is a combination sheet pile wall with some additional earthen or lightweight fill for stabilization (on the Town-side of the wall). The sheetpile wall could be raised 3 feet above the top of the levee to decrease weight and associated settlement while still providing flood protection. The 8 ft. crest width is for maintance or pedestrian access.

## Conceptual Cross-Section for Inner Alignment and Mariner Cove

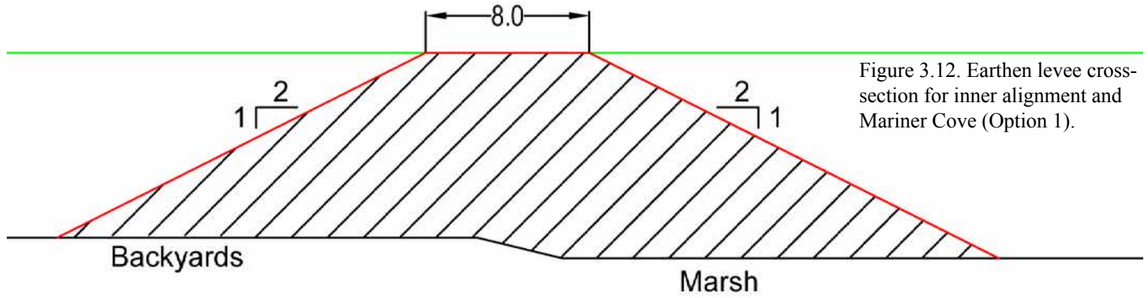



Figure 3.12. Earthen levee cross-section for inner alignment and Mariner Cove (Option 1).

Option 1 is a traditional earthern or light weight fill levee built in or near homeowners' backyards. While this is the least expensive option, it is likely infeasible due to space limitations, the net weight of the levee, and the associated settlement in areas built over bay mud.

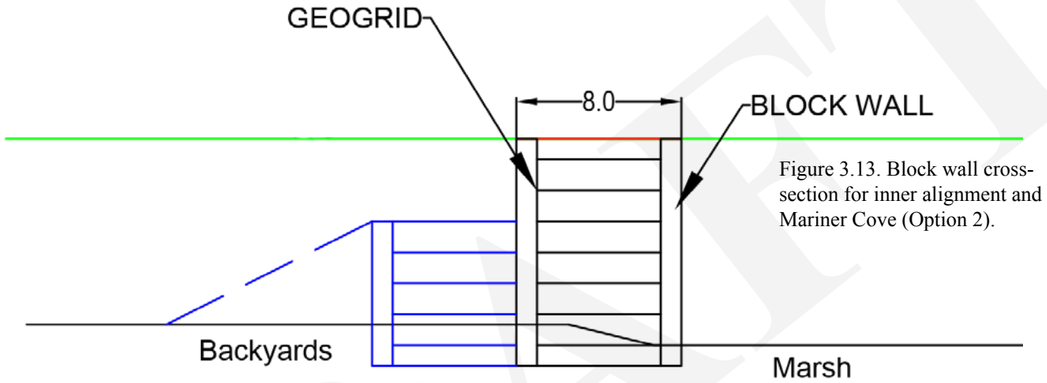



Figure 3.13. Block wall cross-section for inner alignment and Mariner Cove (Option 2).

Option 2 is a block wall connected by a geogrid. This option would reduce additional weight on marsh and significantly reduce the width of the levee; however, this option would reduce visibility of the Bay, as it would extend eight or nine feet above the current ground level to provide adequate flood protection through the middle of the century. The block walls could be modified on the inside to provide a set-up design (see blue lines in figure 3.13), be hidden by landscaping, or allow homeowners to build steps and decks connected to the wall.

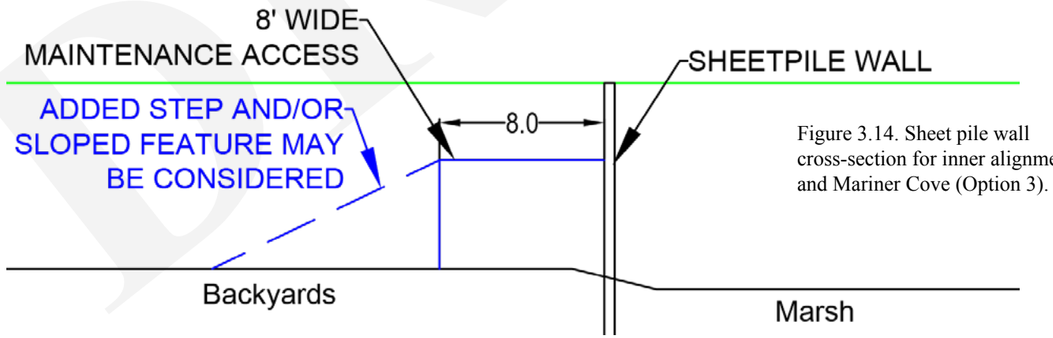



Figure 3.14. Sheet pile wall cross-section for inner alignment and Mariner Cove (Option 3).

Option 3 is a sheet pile wall. This is by far the narrowest and lightest weight option, reducing impacts to homeowners and reducing settlement. Potentially the least visually appealing, the inside of the wall could be designed with a step-up to limit visual disruption of the eight- to nine-foot tall wall, or homeowners could incorporate it into their landscaping. A coarse or composite beach (see page 73) could be placed on the bayside of the flood protection levee around Mariner Cove. The coarse beach can dissipate wave energy, help protect the vertical infrastructure, and reduce the design elevation for the wall helping to preserve views.



## Tide Gate and Pump Station

Existing tide gate and pump station at Shorebird Marsh. A tide gate across San Clemente Creek would likely look different.

In order make the levees effective as sea levels rise, a tide gate and pump station will have to be built across San Clemente Creek. Two potential locations for this tide gate are shown on figures 3.7 and 3.8 (dependent on the levee alignment). The tide gate would be designed to allow water to flow out of San Clemente creek when possible (depending on the tidal elevation) and the pump station would allow for pumping water out into the bay during high tides or storm events. While providing flood protection, the construction of a tide gate would eventually cut off the natural flow of water into and out of San Clemente Creek as sea levels rise, effectively turning the area into a stormwater detention basin. This has potential impacts on the ecology and habitat in the area.

## Initial Conceptual Design Costs

Initial costs for the different levee design alternatives were developed by Miller Pacific. The preliminary costs include fill needed for each of the levee designs, alternative costs based on the type of fill and the effort required to place that fill, and costs for materials, design, and construction of the block or sheetpile walls. Additional cost considerations include design, environmental assessment, permitting, mitigation, monitoring and contingency. These numbers are for initial cost comparison only and represent a wide range due to the different types of levees that could be built. A significant amount of additional engineering, evaluation, and design work will be required to further explore the feasibility of any individual alternative.

| Marina Village & Mariner Cove | |
|---|---|
| Preliminary Construction Costs | $21.5 million |
| Preliminary Engineering, Public Outreach, & Environmental Document | $1.5 million |
| Environmental Permitting & Mitigation | $4.0 million |
| Design *(15% of construction)* | $3.2 million |
| Construction Management *(15% of construction)* | $3.2 million |
| **Subtotal** | **$33.4 million** |
| Contingency *(20% of total)* | $6.6 million |
| Maintenance *(25 years)* | $4.0 million |
| **Total** | **$44 million** |

Figure 3.15. Preliminary project costs for flood protection levee and tide gate design, permitting, maintenance, and construction.

### Planning for the Future

Each of the flood protection options provide the opportunity to add additional height for future protection from additional sea level rise and storm surge. While initial cost calculations are based on flood protection through mid-century (crest elevation at 15 ft. NAVD88), it is possible to adjust these design elevations higher or lower as the concepts are further evaluated; however, consideration must be taken for settlement and structural stability. Earthen levees could be elevated by placing additional fill, block walls could be built straight up or tiered, sheetpile walls could be extended. Costs and timing of additional fill to account for settlement were not considered in the initial costs. It is important to consider flexibility, longer-term cost for maintenance and future flood protection when making a decisions on the final designs.

# ADAPTATION PATHWAY

## MARINER COVE & MARINA VILLAGE

This adaptation pathway diagram provides a visual depiction of the various decision points associated with adaptation planning for the neighborhoods, as well as a sense of how long various adaptation actions can be expected to provide protection. Continued coordination with stakeholders in the near term will help inform decisions regarding construction of a levee/sheet pile wall with a tide gate and nature-based infrastructure (coarse beach, ecotone levee) to protect the Mariner Cove and Marina Village neighborhoods. Stakeholders can also contribute to the development of the Town's stormwater master plan and the development of a shallow groundwater monitoring program. As environmental conditions reach predetermined thresholds, (e.g. sea levels nearing "freeboard" elevation, or the safety margin included as a buffer in the design of a levee) decisions must be made about next steps. For example, replenishing material on the coarse beach fronting a levee or sheet pile wall may reduce erosion for a certain amount of time, but eventually a decision needs to be made about raising the levee or moving toward a managed retreat strategy. This decision is likely to be dependent on the feasibility of continuing to manage stormwater and groundwater conditions on the landward side of the levee.

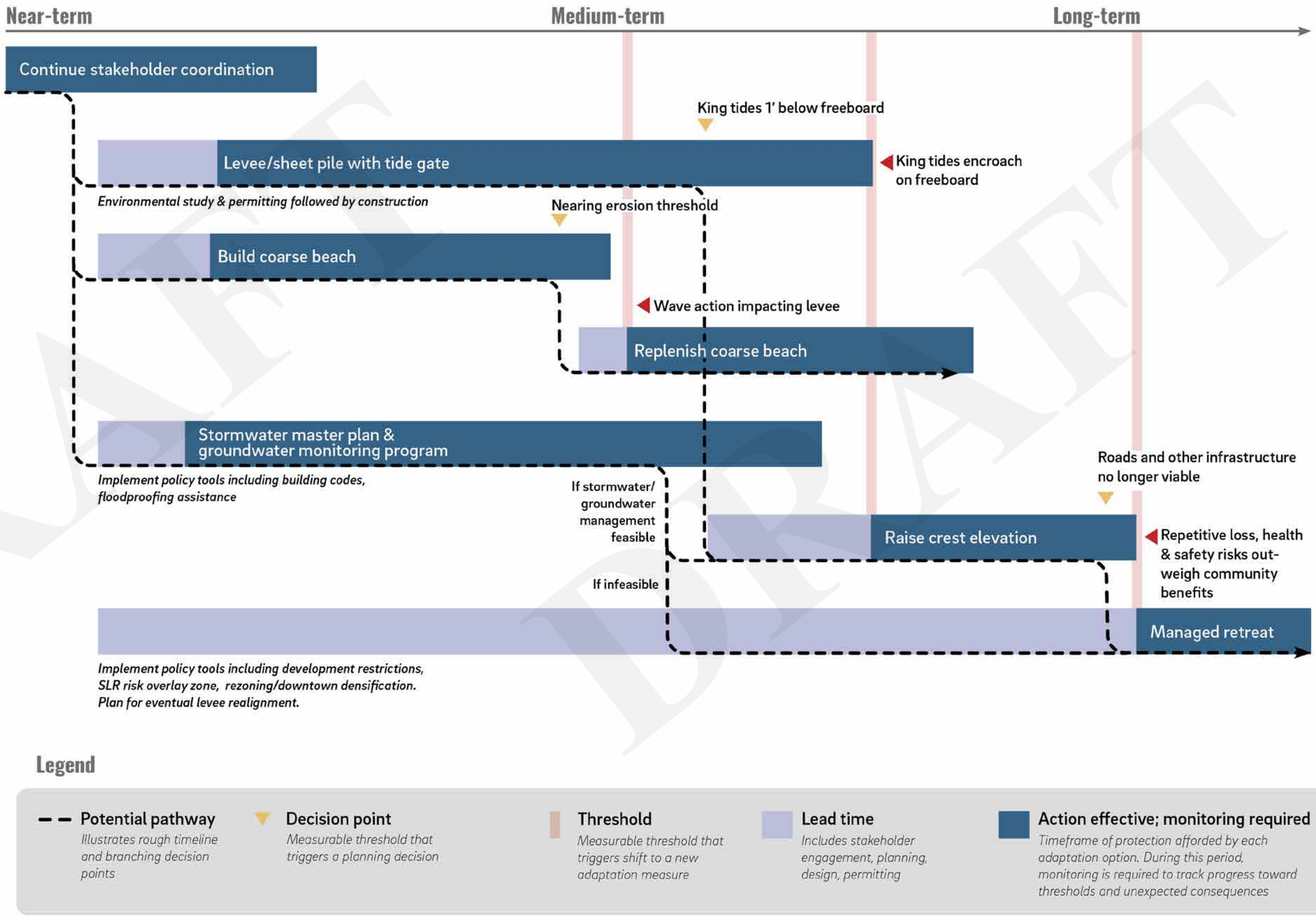



Figure 3.16. Adaptation pathway for Mariner Cove and Marina Village.

A king tide completely submerges Corte Madera Marsh in 2015. © Town of Corte Madera



## Corte Madera Marsh & Railroad Right of Way

Corte Madera Marsh is a unique and valuable community asset. When combined with the existing earthen levee along the current SMART right-of-way, the area provides both flood protection and critical coastal habitat for endangered species. The area is critical to the medium and long-term resilience of the community and provides an opportunity for a variety of partners to benefit from improved flood protection, enhanced habitat, and enhanced transit opportunities. Any actions to increase resilience in this area will require collaboration within and across jurisdictions.

Much of the Corte Madera baylands (including Muzzi Marsh and Marta's Marsh) were diked and filled for pastureland in the early 1900s, then later restored to tidal action. Heerdt Marsh is one of the few historical tidal marshes in the Bay that has never been cut off from tidal action by dikes.[113] Today, much of the marsh is managed by the California Department of Fish and Wildlife as the Corte Madera Ecological Reserve.

The Golden Gate Bridge and Highway Transportation District (Bridge District) parcel is separated from the Bay by berms. The Bridge District has received significant amounts of fill in the form of dredged material from Corte Madera Creek and much of it is above tidal marsh elevation today. Behind the Bridge District parcel, Shorebird Marsh acts as both a refuge for waterbirds and a detention basin for stormwater flows from the Town. A tide gate connects the Shorebird Marsh to the Bay, allowing for management of water level.

Sonoma-Marin Area Rail Transit (SMART) owns a railroad right of way along the old railroad berm at the back of the marsh. The railroad berm provides flood protection as well as public access — including biking, walking, and wildlife-viewing opportunities. In the future, SMART may extend their rail line south from Larkspur along this alignment, connecting San Rafael to The Village at Corte Madera shopping center.

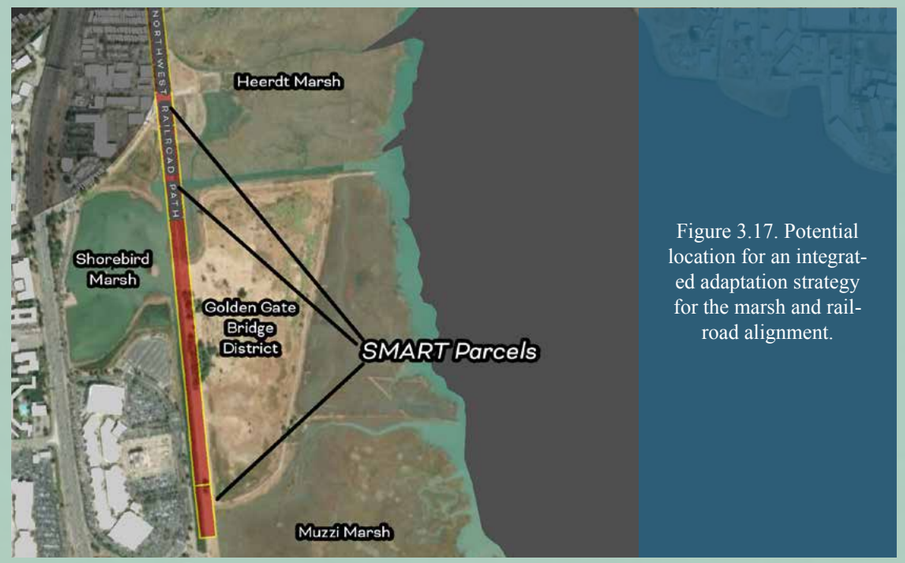



Figure 3.17. Potential location for an integrated adaptation strategy for the marsh and railroad alignment.

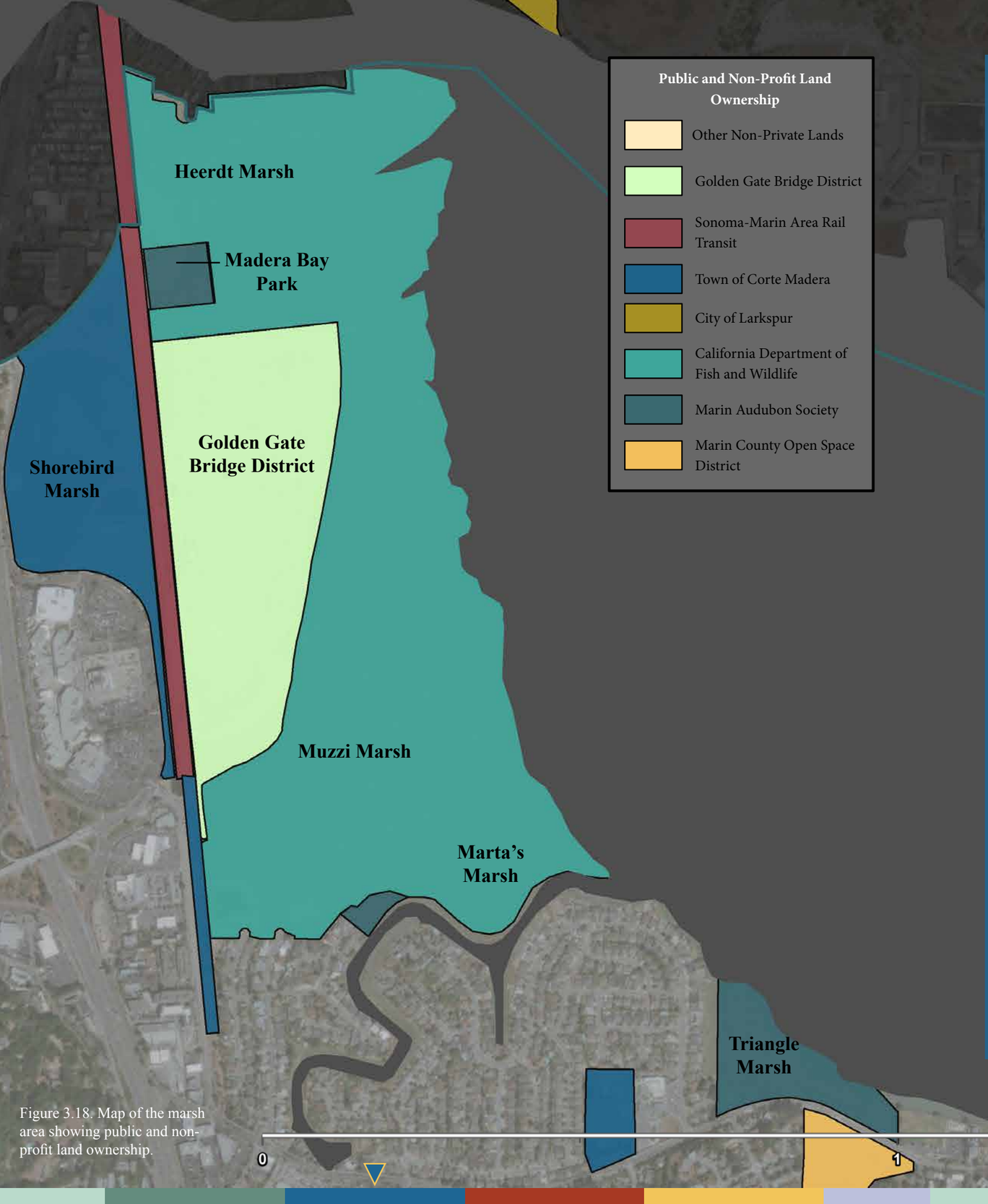



Figure 3.18. Map of the marsh area showing public and non-profit land ownership.

## Building Partnerships for Adaptation at Corte Madera Marsh

During April and May, 2020, the Town of Corte Madera and SFEI held a series of calls with interested partner organizations to discuss a vision for a resilient Corte Madera Marsh. All organizations were interested in participating in regional sea level rise and marsh restoration planning. Partners were also interested in providing general support to undertaking near term pilot adaptation projects while developing a long-term planning process. Such a process could include developing a regional shoreline master plan, similar to the Hayward Shoreline Master Plan. Critical partners included the following organizations:

- The **California Department of Fish and Wildlife (CDFW)** - CDFW manages most of the marsh and mudflats but has limited resources and no plans for any restoration or adaptation projects. Their focus is on managing and protecting the existing marshes, especially issues related to public access. CDFW responds to either an "immediate risk" or an "immediate need" and does not have the resources for the long-term management of new marsh restorations.
- The **San Francisco Regional Water Quality Control Board (RWQCB)** - RWQCB generally takes a long-term view on planning, looking for a net gain of ecological value. RWQCB would generally prefer the flood risk management levee encroach on the marsh as little as possible. RWQCB sees benefits in not delaying adaptation and developing a regional shoreline plan, although there was no reason some actions could not be piloted before the regional plan was complete. The RWQCB suggested that plans would benefit from an early review (10% design), by the Bay Restoration Regulatory Integration Team (BRRIT).
- The **County of Marin** - The County of Marin has interests in the Greenbrae Boardwalk and the underlying easement of the SMART alignment north of Madera Bay Park. The County is interested in helping facilitate a discussion among stakeholders about projects, such as discussions of any action in the Heerdt Marsh/Greenbrae boardwalk area, which would require a partnership among Corte Madera, Larkspur, and the County.
- The **Golden Gate Bridge, Highway, and Transportation District (GGBHTD)** - GGBHTD is focused on the restoration of a 4-acre marsh by the Shorebird Marsh channel, which is about to be constructed. Following that project, the GGBHTD is to prepare an environmental impact report (EIR) for the extension of the Larkspur Ferry Service, which will likely require the mitigation of marsh erosion due to ferry wakes.
- The **Marin Audubon Society** - The Audubon Society has recently completed the Madera Bay Park, where fill was removed to create tidal marsh habitat for the endangered Ridgway's rail and other marsh species. The Audubon Society believes there is potential to utilize some of the remaining upland fill from this project elsewhere but does not see many opportunities, however, north of the Madera Bay Park, including Heerdt Marsh.
- The **Bay Conservation and Development Commission (BCDC)** - BCDC recently passed the "Fill for Habitat Bay Plan Amendment" - which was written with Corte Madera in mind - to place fill adjacent to existing marshes. BCDC sees this amendment was part of an adaptive management approach. They also have a keen interest in public access along the shoreline.

**To enhance the resilience of the marsh and protect central Corte Madera from flooding, the Town is exploring a suite of adaptation actions that involve elevating the flood protection levee and investing in restoring the marsh.**

### Flood Protection Levee with Ecotone Slopes Along Some Segments

A raised flood risk management levee along the back of the marsh could take various forms depending on the north-south location along the existing corridor and desired design characteristics and can be combined with marsh restoration efforts. The segment of the railroad right-of-way included in this analysis is approximately 1.25 miles long and ranges from 90 to 150 feet wide. It runs between Paradise Drive and the Town border near its intersection with Industrial Way, parallel to San Clemente Drive and Redwood Hwy. At its southern end (Paradise and San Clemente Drive intersection), the right of way is 90 feet wide, nearly at grade with the surrounding land, and includes a paved bike path and a gravel walking path as part of the Bay Trail. The elevation increases towards the northern end of the corridor. North of the Clemente Drive and Redwood Highway intersection, the area is bordered on the west by a drainage channel and improved with a gravel path. Further north, the right of way widens to 150 feet, briefly interrupted by a flood control barrier with a pumping station.

The climate adaptation strategies under consideration for this corridor include new levees, improvements to existing berms, and improvements to multimodal transportation infrastructure, all of which would address sea level rise and increasing storm surge risk. As Corte Madera prepares to mitigate sea level rise near the marsh, the Town is considering flood protection alignments that follow the current alignment or are built on either side of that right-of-way. Each approach has trade offs including the optimal location, property status, required partnerships, cost, and the environmental impact of the intervention. In accordance with the 2016 Bicycle and Pedestrian plan, the Town also stands to enhance this area by considering amenities like a Class 1 bicycle facility which would offer a quieter and safer bike route parallel to the Bay Trail on Redwood Highway.

### Marsh Enhancements

Recent restorations, like Marin Audubon's Madera Bay Park restoration, have continued to reshape and enhance this area of shoreline. Marsh restorations help preserve essential habitat and provide flood protection and recreational benefits for the Town. Small-scale restoration is planned for part of the Bridge District parcel, which also presents opportunities for larger-scale restoration projects. For example, the dredge spoils on the site could be moved to create an ecotone slope and enhance flood protection along the railroad berm.[114] In the older, more pristine marshes, such as Heerdt Marsh and inner Muzzi Marsh, small marsh mounds to create high tide refuge may be a more appropriate adaptation strategy than ecotone levees, which require more fill to be placed on the marsh.

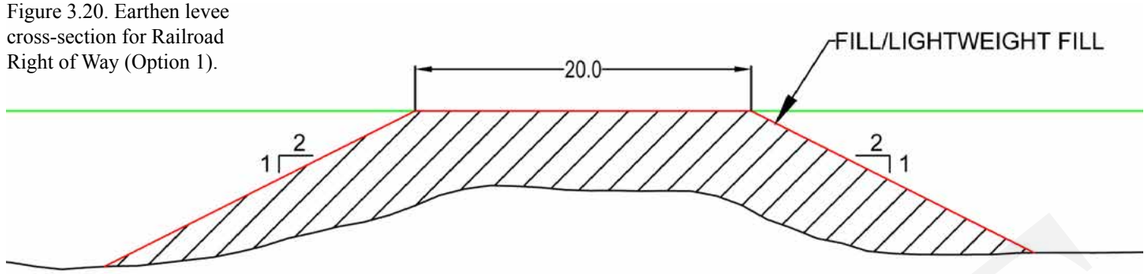
The edge of the Corte Madera marshes has eroded consistently over the last 25 years, with erosion rates averaging 0.5-2 m/yr.[115] On the outboard edge of the marsh, coarse beaches could be placed to reduce ongoing wave erosion. A recent conceptual design for a marsh-fringing coarse beach at Muzzi Marsh suggests using large woody debris to stabilize areas of cohesive marsh that are acting as "headlands" and placing beach sediments below the marsh scarp. Over time, waves would build the coarse material into a natural beach profile, slowing erosion of the marsh scarp.[116] This design also suggests the use of endangered plant, *Suaeda californica*, to create high tide refuge and trap sediment.


Figure 3.19. Conceptual design for potential restoration and adaptation options at Corte Madera Marsh and the railroad right-of-way.

A note about ecotone slopes: shown in teal on the map above, ecotone slopes are a way to soften the steep slope of a flood risk management levee, creating a gradient of vegetation and habitat types from tidal marsh to upland. This elevation gradient allows marsh species to seek high tide refuge above rising waters, and also provides a path (albeit a narrow one) for marshes to migrate as the seas rise. Ecotone slopes, given their gradual nature (10:1 to 20:1 slope), take up more space than a traditional 3:1 flood risk management levee. This can mean filling portions of current marsh to make way for future marsh as the climate continues to change. There is an inherent tension between conserving tidal marsh habitat for today and preserving it for tomorrow. To address this tension, we have suggested the placement of horizontal levees only in locations with degraded marsh, or on upland fill, and not in locations with high habitat value today. In this way, we can continue to pilot the concept of ecotone slopes for use as part of a flood risk management strategy without filling valuable marsh habitat. In more sensitive areas, marsh mounds can be used as an alternative strategy to attenuate some waves and provide high tide refuge.

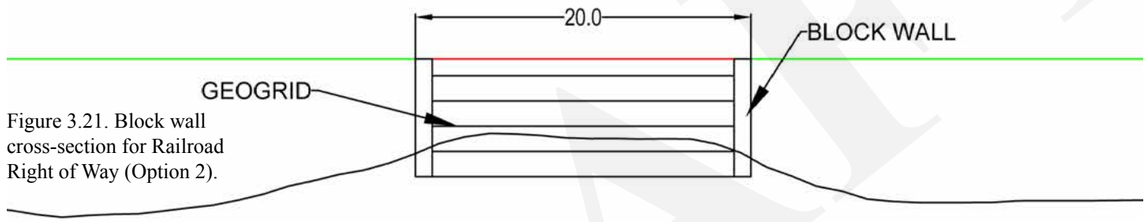
## Conceptual Cross-Section for Railroad Right of Way

Figure 3.20. Earthen levee cross-section for Railroad Right of Way (Option 1).




Option 1 is a traditional earthern levee built over the existing railroad berm. The 20 ft. wide crest at 15 ft. NAVD88 would protect the central portion of the town from a 100-year storm in the middle of the century and would provide 2 ft. of free board. It could also accommodate an enhanced bike and pedestrian path or a future rail expansion. The weight of the fill may cause differential settlement and require rasing over time. Replacing earthen fill with lightweight fill would reduce settling but be approximately three times more expensive.

Figure 3.21. Block wall cross-section for Railroad Right of Way (Option 2).




Option 2 is a block wall connected by a geogrid. This option would reduce additional weight on the marsh and reduce settlement rates. The 20 ft. wide crest could still accommodate additional bike and pedestrian facilities or a future rail expansion. The block walls could be hidden or made more visually appealing by adding natural landscaping.

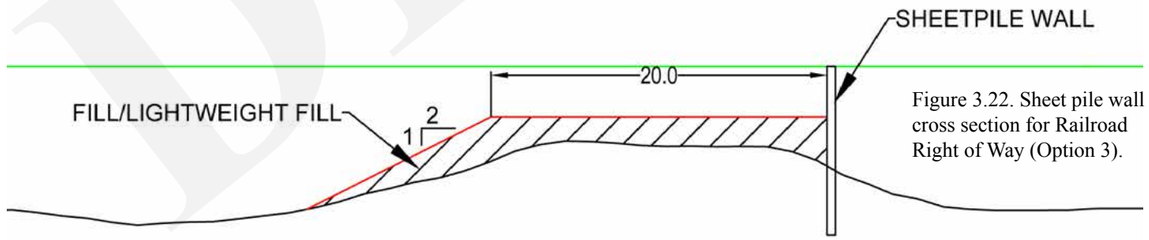



Figure 3.22. Sheet pile wall cross section for Railroad Right of Way (Option 3).

Option 3 is a combination sheet pile wall with some additional earthen or lightweight fill (on the Town side) for stabilization. The sheetpile wall could be raised 3 feet above the top of the levee to decrease weight, and significantly reduce settlement rates, while still providing flood protection. The 20 ft. wide levee crest could accommodate bike and pedestrian access or future rail.



## Initial Conceptual Design Costs

Initial costs for the different levee design alternatives were developed by Miller Pacific. The preliminary costs include fill needed for each of the levee designs, alternative costs based on the type of fill and the effort required to place that fill, and costs for materials, design, and construction of the block or sheetpile walls. Additional cost considerations include design, environmental assessment, permitting, mitigation, monitoring and contingency. These numbers are for initial cost comparison only and represent a wide range due to the different types of levees that could be built. A significant amount of additional engineering, evaluation, and design work will be required to further explore the feasibility of any individual alternative.

| Corte Madera Marsh & Railroad Right of Way | |
|---|---|
| Preliminary Construction Costs | $5.0 million |
| Preliminary Engineering, Public Outreach, & Environmental Document | $1.0 million |
| Environmental Permitting & Mitigation | $1.5 million |
| Design *(15% of construction)* | $0.8 million |
| Construction Management *(15% of construction)* | $0.8 million |
| **Subtotal** | **$9.1 million** |
| Contingency *(20% of total)* | $1.8 million |
| Maintenance *(25 years)* | $3.5 million |
| **Total** | **$14.4 million** |

Figure 3.23. Preliminary project costs for flood protection levee design, permitting, maintenance, and construction.

### Planning for the Future

Each of the flood protection options provide the opportunity to add additional height for future protection from additional sea level rise and storm surge. While initial cost calculations are based on flood protection through mid-century (crest elevation at 15 ft. NAVD88), it is possible to adjust these design elevations higher or lower as the concepts are further evaluated; however, consideration must be taken for settlement and structural stability. Earthen levees could be elevated by placing additional fill, block walls could be built straight up or tiered, sheetpile walls could be extended. Costs and timing of additional fill to account for settlement were not considered in the initial costs.  It is important to consider flexibility, longer-term cost for maintenance and future flood protection when making a decisions on the final designs.

# ADAPTATION PATHWAY

## CORTE MADERA MARSH & RAILROAD RIGHT-OF-WAY

This adaptation pathway diagram provides a visual depiction of the various decision points associated with adaptation planning for the marsh and railroad area, as well as a sense of how long various adaptation actions can be expected to provide protection. In the near term, a stakeholder group should be convened to coordinate planning actions between the various relevant actors (see pages 88-89). This group can oversee the coordinated development of adaptation designs for the railroad levee and marsh. Physical thresholds can be established in advance to guide the timing of key decisions and actions; for instance, marsh erosion and drowning thresholds which will be established by the Wetlands Regional Monitoring Program (WRMP) can be used to guide timing on decisions regarding the resilience of the marsh and needed interventions (e.g. replenishing coarse beach material, mudflat augmentation). Actions that enhance the resilience of the marsh will prolong the longevity of flood risk management infrastructure, but when king tides approach the freeboard elevation of the levee (the safety margin included as a buffer in levee design), a decision will need to be made to raise the levee or realign it.

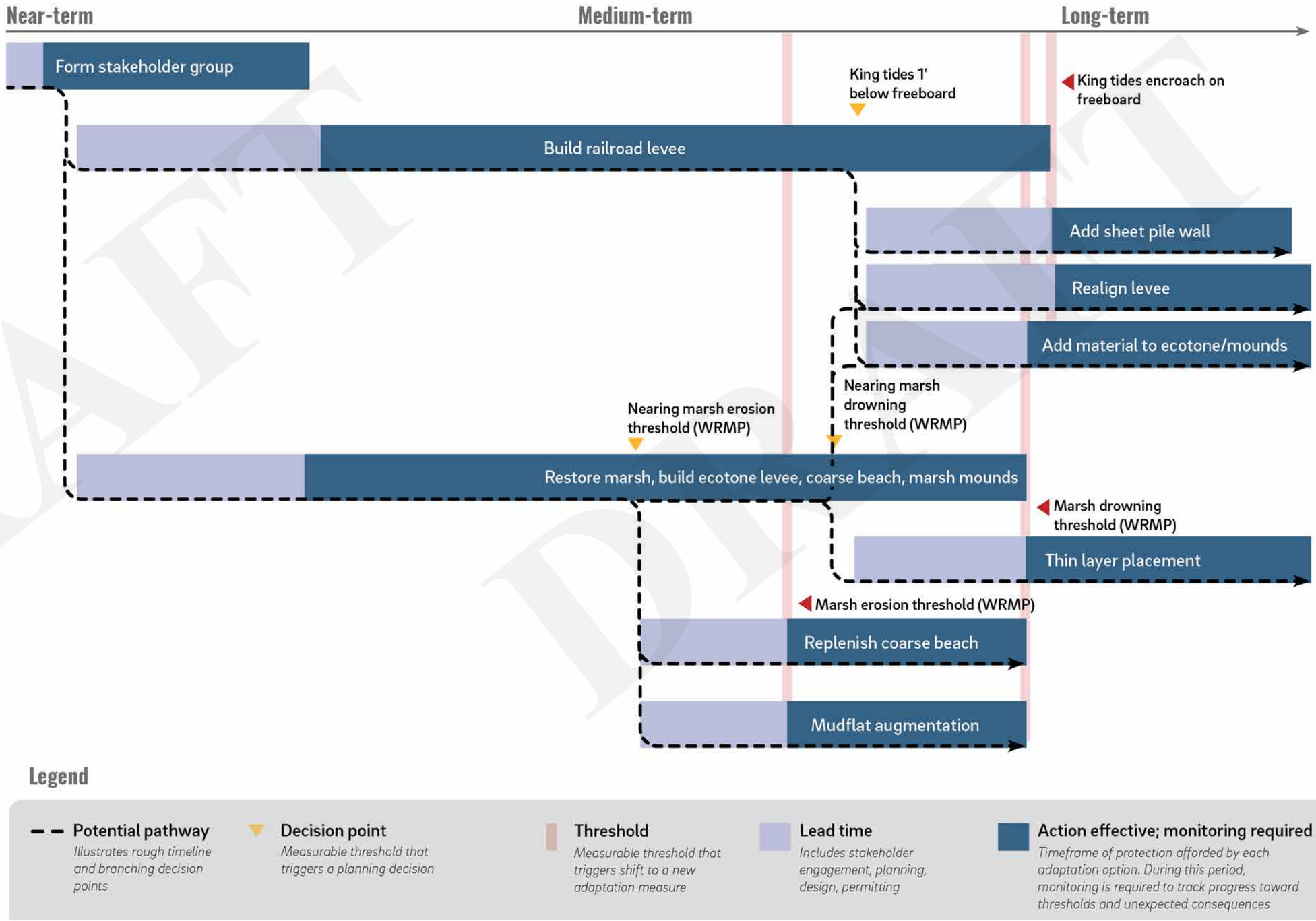



Figure 3.24. Adaptation pathway for the Corte Madera Marsh and Railroad Right-of-Way.