TECHNICAL MEMO

COUNTY OF MARIN

DATE: October 14, 2016; Revised May 2017

BY: Roger Leventhal, P.E., Senior Engineer

RE: First Steps to Address Sea Level Rise in Marin County

TITLE: **Demonstration Projects on the Eastern Shoreline—Past, Present, and Future**

The purpose of this memo[1] is to describe existing and proposed demonstration projects that address adaptation approaches for sea level rise for the eastern shoreline of Marin County. Demonstration projects, also called pilot projects, are small-scale projects (relative to the length of shoreline to be affected by sea level rise in Marin County) intended to demonstrate the effectiveness and assess impacts and costs for these projects. Demonstration projects are constructed and monitored to provide essential information to engineers, scientists, builders, and the public that will inform and guide actions to be taken in Marin County and across the Bay in the near future to adapt to sea level rise and to develop the larger adaptation strategies required to be implemented on the full scale.

This memo includes completed, current, and potential projects that I believe will be useful as part of sea level rise adaptation planning and preparation. It is not an exhaustive list of all possible projects, as I've included only the projects I am aware of and I believe to be the most useful in the immediate or short-term future.

This memo covers:

- Past and present (ongoing) demonstration projects—completed or being implemented now
- Proposed demonstration projects—developed in concept and design and submitted for funding consideration in the short term
- Potential demonstration projects—yet-to-be-proposed concepts at early stages of development included here for discussion purposes.

The projects are grouped into three larger categories:

[1] This memo is also intended to fulfill the requirements of section 5.3 of the BayWAVE scope of work.

- Public education and outreach
- Streamlining and easing of permitting to facilitate project implementation
- Construction and monitoring of green sea level rise adaptation methods

The memo begins with an explanation of demonstration projects, what they are, and why they are useful and necessary for the future of the eastern shoreline of Marin County. It also gives examples for each of the three categories of projects.

What Are Demonstration Projects?

A demonstration project is a small-scale project constructed and monitored to evaluate the feasibility and effectiveness of a design concept or new restoration approach intended for implementation on a much larger scale. Demonstration projects serve important purposes in the design and implementation process, including enabling participants to:

- Monitor performance under actual conditions so that designers can assess the effectiveness of a proposed adaptation measure and recommend changes to the design
- Evaluate lessons learned and determine ways to improve the adaptation measure moving forward
- Evaluate construction means and methods to improve cost-effectiveness as the concepts scale up to full-size projects
- Build public awareness, knowledge, and support through ongoing engagement with the affected communities
- Disseminate findings and perform educational outreach to the communities involved in the implementation of full-scale projects, including elected officials, the general public, shoreline managers, professional design consultants, and the professional construction community.

Marin County is a leader in the implementation of demonstration-scale projects around San Francisco Bay. The eastern edge of Marin County contains a wide variety of shoreline types, from the flat alluvial slopes of the Novato Creek Baylands to the steep, rocky shorelines of southern Marin and therefore offers opportunities for testing of different shoreline adaptation approaches to shoreline communities throughout Marin and the Bay Area.

The Importance of Demonstration Projects

One of the more exciting areas of adaptation planning for sea level rise is the use of nature-based solutions. Nature-based projects, known by several names, including “living shorelines” or “green solutions,” seek to use adaptation approaches that mimic, in part or in whole, the way natural shorelines function and evolve. These types of projects have multiple benefits for habitat and water quality as well as flood protection. Permitting and fund-granting agencies focus on projects with multiple benefits and assign an advantage to such projects in the permitting and granting processes.

Interest in studying, designing, and building natural shorelines for sea level rise adaptation is relatively new. Demonstration projects provide experience in and knowledge of both how these systems function and how to construct them in a cost-effective way. There is a broad consensus among scientists, planners, and engineers of the need for more demonstration projects for nature-based adaptation approaches to sea level rise to demonstrate their effectiveness and to develop effective design and construction techniques.

For most natural-shoreline alternatives, not enough projects have been built and monitored to develop that knowledge base and provide the needed insight as to where these measures work or don't work and why. This lack of actual project experience means that we don't have empirically based (i.e., on-the-ground) results that inform future design techniques that make for successful projects. Therefore, because of unknown risks and consequent liability issues, professional consulting design companies and construction-trades contractors will not recommend these types of solutions. With increased knowledge of project requirements and familiarity with successful techniques, familiarity with design and building methods and cost effectiveness will follow.

Demonstration projects also need to evaluate improved methods and costs for engineers and contractors to construct. This is important since all major public construction projects must be awarded through the public bidding process with selection of lowest qualified bidder, therefore, finalizing design standards is critical to preparing successful bids. Another important benefit of demonstration scale projects is to promote community awareness through education to youth groups serve the community now and for succeeding generations. Marin County is already leading the way in several of these areas.

Why Marin County?

It is critically important to adaptation planning efforts that demonstration-scale projects are built and monitored across a range of living shoreline types (e.g., flat, alluvial-slope, steep, and rocky shorelines). The current design and permitting process can be onerous and expensive, thereby deterring the undertaking of demonstration projects for natural-shoreline alternatives. Planning and development agencies need to work with regulatory agencies to streamline the design and permitting process so that different approaches are allowed and designers and builders can test designs sufficiently.

Marin County has a culture with a strong green ethic, active progressive communities, and political leadership interested in nature-based measures and in continuing to lead the Bay Area in green adaptation alternatives to sea level rise adaptation. With this broad foundation of support for a green approach and a willingness to lead, there is much that can be done here in Marin County to further our efforts at building a reliable, tested knowledge base of sea level rise adaptation methods. Education and community outreach are both very strong in Marin County.

Marin County Demonstration Projects

In Marin County, we have divided the demonstration projects into three categories with the following objectives:

- Public education and outreach, e.g., The Game of Floods
- Streamlining and easing of permitting to facilitate project implementation, e.g., cost-effective reuse of sediment from dredging waterways
- Construction and monitoring of natural “living” shoreline sea level rise adaptation approaches, e.g., tidal marshes, beaches, and oyster reefs providing design data

In this review of the demonstration projects in Marin County, note that some projects are still in development and that the information given here is based on the current status and condition of those projects. Some information may change as these projects continue to be monitored and evaluated.

Projects described as proposed or potential are project concepts at this point and may or may not ever be implemented. These projects still have to go through the public outreach and permitting process and find funding for implementation. This list will be ever evolving and development and selection of future demonstration projects will occur under future phases of the BayWAVE project or by others working in Marin County.

Demonstration Project Category #1: Public Education and Outreach

1. The Game of Floods—An Ongoing Demonstration Project

Marin County is in the forefront of public education with respect to the risks associated with sea level rise and the range of possible adaptation methods. The county Community Development Agency (CDA), the county Department of Public Works (DPW), and the BayWAVE process are leading outreach efforts with innovative methods and growing community engagement.

One such innovative approach to education and engagement is the county-developed board game The Game of Floods, which takes place on an island with fictitious communities that have the same real-world sea level rise issues as those in Marin County. The Game of Floods engages community members in learning about applicable sea level rise adaptation techniques they then place around the board. This exercise raises awareness of the different techniques available to Marin County and their accompanying pros, cons, costs, and benefits.

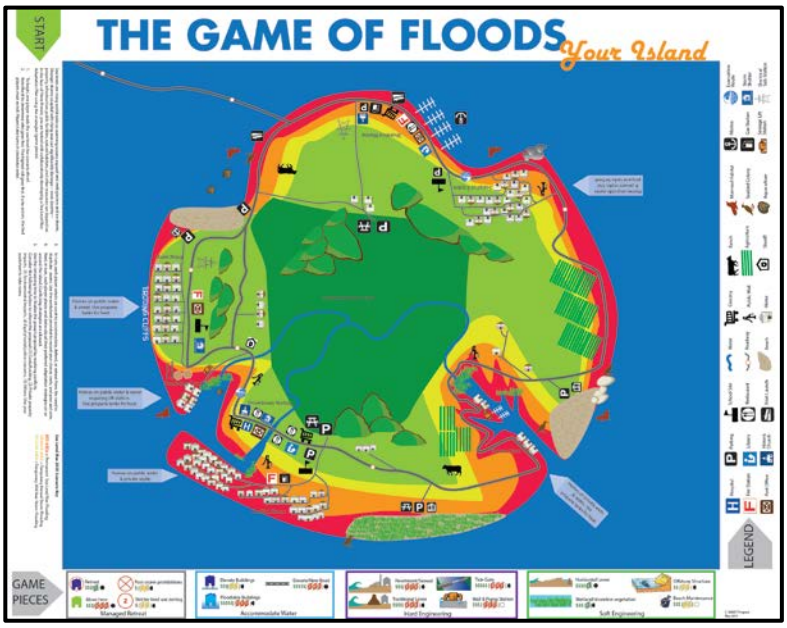

Figure 1: The Game of Floods game board

How the Game Is Played

Players break into smaller groups of three to six people. County staff facilitates a discussion of various adaptation alternatives around the island. The purpose of the discussion is to create awareness of the impacts and trade-offs associated with each alternative in adapting to sea level rise. For playing the game, each alternative is represented by a token that has a pre-assigned unit cost. Each group receives a number of tokens and proceeds to place them around the board to address a specific sea level rise scenario in each community. The game continues for approximately 90 minutes. The groups then tally the cost of their chosen alternatives and report the

total cost of their selected alternatives and their reasons for choosing them to the larger group. Other group members can comment and a general discussion follows. This general discussion is the primary goal of The Game of Floods.

County staff has played the game with local and regional groups and, through the Youth Exploring Sea Level Rise Science (YESS) program, works with high school students to engage them on sea level rise issues and adaptation alternatives.

In 2016, Marin County's The Game of Floods won the Best Outreach Tool Award from the American Institute of Planning (AIP). County staff continues to refine and play the game with a number of nongovernmental organizations and school groups.

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2. The Game of Floods Extended Version—A Potential Demonstration Project

As implemented to date, The Game of Floods is usually played in a two- to three-hour meeting with upfront lecture time and a short-session playing time of sixty to ninety minutes. This format has been very useful as a general education tool in raising awareness of the sea level rise issues around Marin County.

However, the short-session format can be misleading, as solutions seem easy and readily achievable, which in most cases is a false expectation. To truly engage in community-based planning, longer sessions must be held that include detailed discussions of the group-chosen alternatives and the serious business of weighing the trade-offs inherent in all the alternatives. However, there is much value still to be gleaned from the use of The Game of Floods. The long-term, primary goal of using the game as an educational and engagement tool is to genuinely involve community members in the details and decisions that will impact Marin County communities in the very near future.

This potential demonstration project would involve using the game to develop community-based adaptation plans for one or two selected reaches of the eastern shoreline. The goal is to gain an informed, realistic understanding of the real impacts and trade-offs required to adapt to sea level rise. The original intent of the game's creators is to use it as a scenario-based planning tool, envisioning it being played at a deeper and sustained level over several months with the goal of developing actual site-specific, community-generated adaptation plans.[2]

Playing the game in this way inverts the typical planning approach, one that is commonly top down from county staff and consultants to the communities. This inverted approach would empower community members to develop their own plans from the bottom up as they grapple with the difficult issues and trade-offs firsthand.

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[2] "The Game of Floods: Community Driven Adaptation Planning for Sea Level Rise Along the Inner Richardson Bay Shoreline," Roger Leventhal, P.E., Feb. 28, 2014.

This unique type of planning is appropriate to sea level rise adaptation, a slow and expensive process requiring that options be envisioned that are both large and small and that take place over relatively long periods of time and in differing locations. Community-based plans will need to have multiple pathways to the desired objectives due to much uncertainty as to how sea level rise will play out over time.

These pathways will be based on different scenarios that then trigger different techniques. This technical approach is known as "*decision-making under deep uncertainty*." This approach to planning has its own unique tools and techniques. Recent advances in this type of planning take the approach of creating decision trees based on multiple scenarios. These decision trees are developed early in the process with multiple plans and critical pathways to achieving objectives that are then tracked and updated frequently. Uncertainties are tracked and figured into costs, actions that can be taken are identified and moved forward, next steps are built into the tree, and elements that are too uncertain are delayed until the need for them is apparent. This type of planning requires more technical support by staff serving as consultants for the planning process of the community planning teams.

Community teams would, by design, include a broad spectrum of community members so that different interests are reflected in the issues raised and the selected alternatives. The teams' standing would be more akin to the grand jury process, in which members are engaged over a period of time receiving, understanding, and evaluating the alternatives for a given location or community. The district supervisor would appoint members, who would deliver a nonbinding white paper of their findings at the end of the planning term.

The goal of this potential demonstration project is to produce plans for two locations along the eastern edge shoreline within one year. The locations are:

- Canal Area of San Rafael, a designated disadvantaged community (DAC)
- Richardson Bay shoreline—a reach of shoreline with the most assets currently impacted by tidal flooding.

A schedule will be developed to hold focused meetings, and staff envisions the game being played over a series of Saturdays (or another day suitable to the community team) with clearly identified milestones. County staff, acting as consultants to the game players, will use the time between meetings to review team progress, evaluate results, answer questions, and bring forth issues for evaluation. Members of the task force will be supported and guided throughout the process and not allowed to founder due to the complexity of the issues involved. These issues include but are not limited to the following:

- Evaluation of public and private-property rights—how would private-property rights be handled when more than the private property is threatened?
- Phasing of sea level rise adaptation—what will be done when the limited ability of wetlands to provide flood control is exceeded?
- Shall redevelopment of large areas into "floodable" developments be allowed?

- How would this look?
- What is the process to do so?
- Should private-property owners be compensated after development occurs?
- Should private funds be permitted if public funds are scarce?
- How would real costs for impacts to wetlands, mitigation costs, and site-specific engineering design costs be tracked and future cost projections adjusted accordingly? (Real costs will surely differ from the average costs assigned to game tokens.)
- Will trade-off mitigation be possible (e.g., restoration of parks in one location in trade for impacts due to tide gates being installed in a different location)?
- When does “hardening” the shoreline become ineffective, and how will planning for retreat occur?
- Will property owners be compensated if retreat is necessary?

Because these issues are and will be complex and controversial, the importance of having a diversity of opinions, allowing for dissent, and creating minority reports to track the dissenting voices for continuing discussion cannot be overstated. Unanimity isn’t the goal. The goal is to recognize the options and potential issues and develop scenarios for dealing with them collectively, including putting off some decisions and actions into the future. With experience and knowledge gained in this demonstration project, realistic planning time frames will be developed, triggers for actions will be identified, and the game will transform from applying solutions on a fictitious island to actual implementation at real locations with real outcomes.

Demonstration Project Category #2: Streamlining and Easing Permitting Restrictions

At present, many important regulatory and permitting requirements inhibit, even prevent, the ability to design and build projects to adapt to sea level rise. Important environmental laws such as the Endangered Species Act and the California Environmental Quality Act (CEQA) prevent damaging projects from being built, thereby protecting and preserving endangered species and fragile habitats. However, these same laws that have been beneficial to the environment now present possible serious impediments to efforts to reduce damages from flooding due to sea level rise, creek capacities, and outdated, underperforming storm-drainage systems. These laws may, ironically, inhibit our ability to protect human life and provide effective public safety.

Demonstration projects in category #2 are intended to streamline and reduce the burdens of the permitting process. They look to rebalance the permitting process such that the DPW and other public-safety agencies are allowed to prepare for the impacts of sea level rise.

1. Novato Basin Dredging Sediment Beneficial Reuse—An Ongoing Demonstration Project

Novato Creek is presently dredged on a four-year cycle to maintain the flow capacity of the creek to prevent flooding. The adjacent Deer Island basin is a historic tidal-marsh area in which full tidal ebb and flow conditions have been impacted by development. Restoring the marshes to full tidal conditions, a beneficial and protective condition, requires that sea level rise levees be constructed to protect surrounding properties. Building these levees is best done in stages over time rather than building them to full height over one or two seasons. The amount of fill, or earth, required to build them is very large with respect to both volume and cost. Therefore, staging the construction over time is practical, given the limiting quality of government budgets and the uncertainty in any given year of the volume of usable fill from a dredging project.

There are compelling reasons for focusing efforts on lowering the permitting hurdles for reusing dredge sediment. They are:

- Cost effectiveness: Moving large volumes of soil or sediment into position is very often the costliest component of large-scale landscape projects. Obtaining and reusing dredged sediment, particularly from nearby dredge projects, is key to cost-effective adaptation to sea level rise.
- Smart use of existing government funds: Marin County Flood Control Zones regularly spend funds to dredge creeks and channels. Reuse of the dredged sediment amounts to a dual benefit, providing for the reduction of flood risk while reducing costs for dredging through reducing or eliminating hauling and disposal costs. Flood Control Zones, in this case, serve as a partial funding source for the sea level rise action, thereby reducing reliance on grant funding for the sea level rise projects, which is difficult to obtain and usually comes with strings attached.

- Multi-benefit projects: Grant-funding agencies require that projects have multiple benefits beyond the primary purpose of the project. Concurrent construction of habitat improvements, water-quality improvements, and other benefits are required to attract grant funding.

In 2016, Marin County Flood Control and Water Conservation District staff took the initiative and proposed the beneficial reuse of dredging sediment from Novato Creek. The proposal requested that the regulatory and permitting agencies allow placement of the dredged sediment from the Novato Creek watershed at the edge of the former Deer Basin marshlands for use in the construction of future sea level rise levees. Additionally, they requested that they *not* be required to mitigate for the impacts of this placement.

In January 2016, District staff gave an on-site presentation and briefing to regulatory agency personnel followed by a walking tour of the proposed site. The briefing was followed by a series of meetings and discussions with regulatory agency personnel to analyze the proposal and consider permitting the proposed process. This unique permit request had no precedent, so obtaining permits for the proposed project has been a long process of district staff working with regulatory agency staff.

The results of this effort are mixed but very useful to the county. The permitting agencies did allow for placement of dredged sediments along the requested alignment, but to a lower height of fill than requested. Instead of the requested four feet of fill, they permitted two feet. In doing so, the Regional Water Quality Control Board (RWQCB) was able to designate the fill as having “temporary impact” and therefore not requiring the extensive, costly mitigation that four feet of fill, designated as having “permanent conversion” impact, would require.

Even so, this permitting compromise was a successful outcome for the district, which was able to reuse the dredged sediment in a beneficial manner in the desired location. The compromise also allayed concerns over potential geotechnical impacts from a higher, heavier levee. In the end, the height of the fill was optimum. However, the overall goal still stands—to allow public agencies, which are responsible for ensuring public safety by flood control, to prepare for sea level rise without an undue burden of expensive mitigation. This effort on the part of district staff served to move the regulatory and permitting paradigm, bringing a fresh awareness to the regulatory and permitting agencies of the issues, responsibilities, and limitations in the current permitting process with respect to sea level rise adaptation.

Future demonstration projects can build on the approach taken here of there being no requirement of mitigation when using dredged sediment for flood protection levees and structures and for building nature-based solutions to protect property and the public safety from the impacts of sea level rise. District staff continue to work with regional associations like the Bay Area Flood Protection Agencies Association (BAFPAA), the San Francisco Bay Regional Coastal Hazards Adaptation Resiliency Group (CHARG), the San Francisco Bay Conservation and Development Commission (BCDC), and the County Engineers Association of California (CEAC) to suggest and evaluate changes to planning policies and bring a raised awareness to regulatory agency staff of the challenges to sea level rise adaptation imposed by permitting requirements on efforts to adapt to sea level rise.

2. Participation in BCDC Initiative to Update Permitting Regulations—An Ongoing Project

Marin County Flood Control and Water Conservation District staff are participating with the BCDC in a regional effort to determine whether BCDC regulations must be modified to allow for adaptation to sea level rise. Working with a BCDC policy subgroup for fill policy, district staff developed a project to install a tide gate on Coyote Creek in southern Marin County as a way evaluate the impacts of using tide gates as an alternative for sea level rise adaptation. The BCDC policy subgroup prepared a report highlighting concerns about cost and regulations and proposed changes. District staff will continue to participate in this ongoing, long-term regional initiative.

Demonstration Project Category #3: Building and Monitoring Natural Shoreline-Adaptation Projects

Below are seven demonstration projects or studies at different stages of development. Two are completed and being monitored, while five are in varying stages of study, design, funding, and implementation. Two of these projects are aimed at developing techniques to construct natural-shoreline projects and will provide valuable information to engineers, scientists, and contractors; two are proposed demonstration projects; and three are feasibility studies.

1. Aramburu Island Constructed Beach as Part of the Ecological Enhancement Projects—A Constructed and Monitored Demonstration Project

The Aramburu Island Ecological Enhancement Project contained a constructed bay beach as a design element and was the first demonstration project constructed in San Francisco Bay for adaptation to sea level rise. Constructed in 2011–2012 in outer Richardson Bay, this adaptation method uses a coarse-grained, engineered bay-beach system as a natural approach to mitigate shoreline erosion. The Island is owned by Marin County Parks and Open Space and is operated by the Richardson Bay Audubon Society.

Visual observations and site surveys show that the project has been successful in halting extensive shoreline erosion and is self-adjusting its elevation. Surveys of the constructed beach before and after storms are documenting changes to the bay beach so that the usefulness of constructed coarse-grained beaches as an approach to sea level rise adaptation and habitat benefits can be evaluated and promoted.

Figure 2: Placing gravel along Aramburu Island shoreline.

This constructed habitat has also been successful in supporting bird populations, including several threatened and endangered species such as the snowy plover. The Richardson Bay Audubon Society monitors the site in Richardson Bay for bird usage and reports that results of the beach monitoring show overall success in attracting birds. Overall, the results are positive for using this approach to reduce shoreline erosion, with the added benefit of creating and/or enhancing wildlife habitat.

Some lessons learned from the project follow:

- The northern end of Aramburu Island was projected to have the lowest wave energy, and the shallow nature of Richardson Bay to the north of the island was expected to reduce the combined wind and wave energy. For these reasons, less erosion was expected at this end of the island. But observations reveal that there is greater erosion and a higher sediment transport power, resulting in more movement of sand to the northern end of the island. To mitigate this, a slightly larger rock would have been a better choice in north cell beach construction.
- The microgroins installed to control sand movement worked well. (Microgroins are tidally submerged wood and rock structures designed to retain sand from migrating along the direction of the wind-wave transport). However, additional smaller wood pieces placed along the shoreline alignment would enhance the ability of the engineered shoreline system to reduce sediment transport. There has been some movement of sand around the microgroins due to the highly oblique angle of wind-waves to the shoreline. Longer microgroins would have increased the retention of sand moved by longshore transport.

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2. Coyote Creek to Bothin Marsh Dredge Sediment Reuse Feasibility Study—A Potential Demonstration Project

The Marin County Flood Control District was awarded a $25,000 grant by the North Bay Watershed Association (NBWA) to conduct a feasibility study of the costs, impacts, and effectiveness of reusing dredge sediments from Coyote Creek in Tamalpais Valley to enhance habitat in the adjacent Bothin Marsh and prepare the marsh area to assist with sea level rise adaptation. Coyote Creek is owned by Marin County Flood Control District and Bothin Marsh is primarily owned by Marin County Open Space with some lands belonging to CalTrans. The proposed project is a joint effort between these two County agencies to prepare the marsh for the impacts of SLR and to assess the costs and effectiveness of this type of approach for adapting the marsh to sea level rise and providing flood protection benefits. The study developed a conceptual plan to evaluate the opportunities and potential impacts of placing fine-grained dredged sediment in thin lifts in the marsh as well as construct a coarse-grained “beach” edge to reduce shoreline erosion.

The Coyote Creek–Bothin Marsh project presents ideal conditions for a demonstration study. The volume of sediment from dredging Coyote Creek is relatively low—4,000 to 6,000 cubic yards—and

the benefits to marsh enhancement and flood attenuation are easy to monitor. During high astronomical tides, the roads and utilities in this area experience regular flooding, making this a very visible location to observe results and the viability of this approach. This study was completed on January 30, 2017.

Elements of the feasibility study included:

- Evaluation and mapping of site ecology and habitat types
- Determination of placement locations of the dredged sediment to
    - Maximize habitat value (i.e., heights of placement and placement type)
    - Provide flood protection of infrastructure now and for future sea level rise along the back edge of the marsh
- Evaluation of beneficial opportunities for using both fine-grained and coarse-grained sediment sizes, both of which are found in the Coyote Creek channel
- Evaluation of engineering methods (hydraulic, mechanical) for placing dredged sediment to meet ecological and flood-reduction goals
- Preparation of conceptual plans to meet project goals while protecting existing site resources
- Development of concept-level cost estimates
- Preparation and dissemination of a final report for use by other agencies and organizations when assessing the feasibility of projects designed for the beneficial reuse of dredged sediment
- Development of next steps to prepare a shovel-ready demonstration project.

The feasibility study determined it is technically feasible to conduct the demonstration study. However, there are still significant hurdles before any demonstration project can be implemented including development of a public process for receiving and addressing stakeholder and public input on the proposed project, permitting of the project on a site with endangered species as well as securing costs for implementation. The next step in the project would be to secure funds to prepare a preliminary design study and begin the community outreach and permitting process. No additional work on this pilot project is currently funded.

3. Constructability Testing of Methods for Hydraulic Placement of Truck Transported Dredged Sediments—An Ongoing Demonstration Project

An important part of the Novato Basin Dredging Sediment Beneficial Reuse Demonstration Project, presented above under category #2, was to focus on the method of placing the sediment in the Deer Island Basin. The goal is to identify the most suitable construction method for creating ecotone levees, or those that serve as a transition zone between two biological communities (e.g., high marsh to upland vegetation).

The goal of this pilot demonstration project was to test different methods of mechanically mixing the sediment into a slurry and pumping it into place in a manner that mimics the natural flow of sediment that might occur during a flood event or other natural high-flow events. Novato Creek is dredged with long-reach excavation equipment, and the sediment is transported away from the creek in trucks after it dries. Therefore, dredged sediment cannot be directly pumped from the creek and placed directly into the marsh, as is the case in some creeks around San Francisco Bay.

Marin County Flood Control and Water Conservation District staff had the contractor experiment with placement of sediment using three methods:

- Placement using a slurrying mixing tank and pumping system—The contractor placed dry sediment into a concrete slurry mix tank, added water to create the slurry, and pumped the slurried sediment through a pipe into the ecotone levee area.
- Placement by constructing sediment slurry ponds—The contractor created three sediment slurry ponds using the dry sediment to create earthen berms around the ponds. Within each pond, they placed hundreds of cubic yards of dry sediment, added a large volume of water, and mixed the sediment and water using a bulldozer that drove back and forth inside each ponded area. When the sediment reach optimum conditions for flow, approximately 90 percent water to 10 percent solids, the earthen berm was breached, allowing the 90/10 slurry to flow into the ecotone levee area. Using a long-reach excavator and a bulldozer blade, the sediment was pushed into the ecotone levee location and shaped.
- Placement by using the long-reach excavator to place the slurry mixture into the ecotone area. In this method, the contractor used a smaller long-reach excavator to directly place and “throw” buckets of the slurry into the ecotone levee area.

A contractor was hired to monitor these three methods and gather data that included:

- A description of the placement methodologies
- A list of placement equipment and personnel
- A placement-plan layout
- Daily averages of the volume (cubic yards and number of bins mixed) of dredged sediment placed
- Locations (stations) and approximate depths of material
- A photo log, including photos taken by aerial drones.

4. McInnis Marsh Restoration with Sea Level Rise Levees—An Ongoing Demonstration Project

McInnis Marsh is a 180-acre diked wetland east of McInnis Park between Miller and Gallinas Creeks. Historically, these creeks were connected through a system of channels. This connectivity was lost in the early 1900s with the construction of levees designed to make the marsh suitable for agricultural use. Marin County Parks & Open Space, in partnership with the Las Gallinas Valley Sanitary District and the Marin County Flood Control and Water Conservation District, is proposing to restore the historic tidelands. A preliminary feasibility study was released in March 2017 and is available on the Marin Parks webpage.

The project will restore intertidal wetland habitat, protect habitat for threatened and endangered species, improve flood control protection, reduce maintenance-dredging requirements on Miller Creek, and reduce the likelihood of flooding at a wastewater-treatment plant and its resultant environmental degradation.

The partners propose to construct a horizontal levee, which is shaped like a gently sloping ramp that gradually transitions from salt-marsh habitat to wet, marshy meadow. The elongated, marshy toe of the levee slows wave action and prevents overtopping in a flood or storm surge. Horizontal levees are designed to collect sediment and increase in height over time, providing incrementally increased protection from sea level rise. In addition to the horizontal levee, the project includes improved brackish and freshwater habitats and improved fish passage for salmon into Miller Creek. The new levee will include a public-access trail, interpretive signs, and viewing areas. The current plan calls for placement of dredged sediments form Gallinas creek to be placed in the marsh as part of restoration activities.

In late 2016, Marin County Parks & Open Space was awarded a substantial grant from the California Department of Fish and Wildlife to continue with the design and planning for the project. This grant, along with contributions from Marin County Parks & Open Space and the Las Gallinas Valley Sanitary District, will allow the county to complete the design and environmental review for the project.

5. Subtidal Oyster Reef Construction for Habitat and Sea Level Rise—An Ongoing Demonstration Project

This project is part of the San Francisco Bay Living Shorelines Project. These projects use a suite of bank-stabilization and habitat-restoration techniques to reinforce the shoreline, minimize coastal erosion, and maintain coastal processes while protecting, restoring, enhancing, and creating natural habitat for fish and aquatic plants and wildlife.[3]

The California State Coastal Conservancy and San Francisco State University, along with other partners, are participating in a living-shoreline project off the Marin shoreline at San Rafael to evaluate the effectiveness of using subtidal oyster reefs for habitat and water-quality improvements and as a method to dissipate wind-wave energy that leads to erosion. The project is meant to provide an opportunity to learn more about the best locations and techniques for restoring native oyster and eelgrass; gather information about fish, invertebrate, and bird use of the reefs as habitat; and assess whether the reefs can provide benefits such as reducing wave action and protecting adjacent shorelines.

Oyster and eelgrass reefs were constructed at two sites in San Francisco Bay in July and August 2012. A large experiment and a small one were constructed near Jean & John Starkweather Shoreline Park in San Rafael and a small experiment was constructed at Hayward near the Eden Landing Ecological Reserve. More information can be found on the project website, www.sfbaylivingshorelines.org/sf_shorelines_about.html.

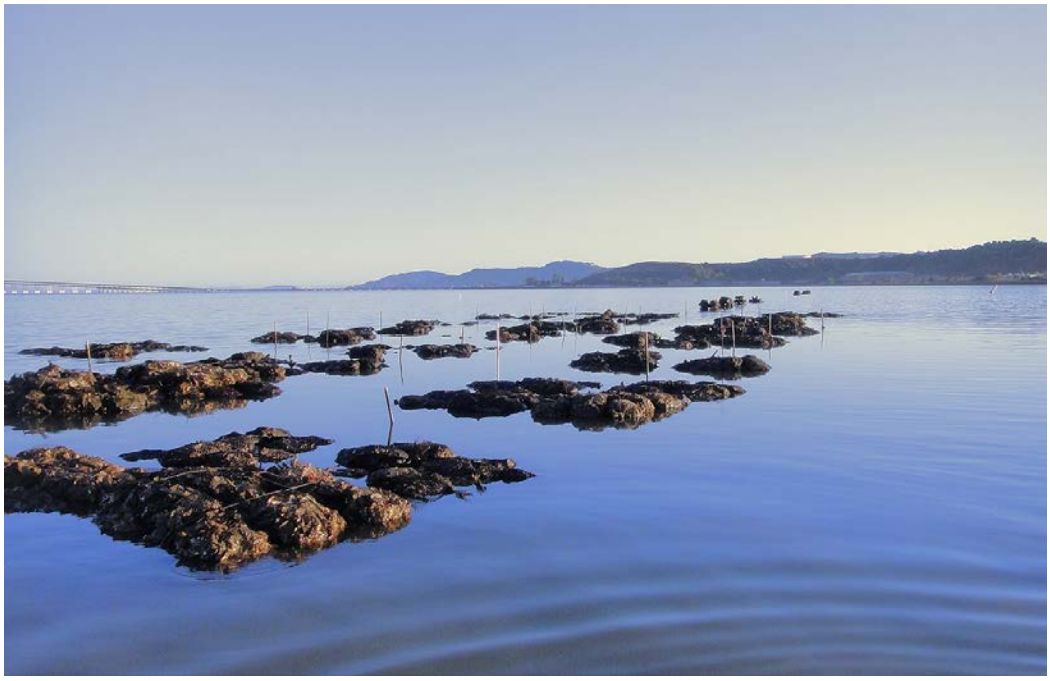

Figure 3: Living Shorelines oyster-reef test plots off the San Rafael shoreline.

[3] San Francisco Bay Living Shorelines Project, www.sfbaylivingshorelines.org.

6. Engineered Bay-Beach Shoreline Demonstration Projects—A Potential Demonstration Project

Much of the eastern Marin shoreline is actively eroding. The tidal marshes that form much of the shoreline and that provide wave attenuation as well as habitat are under the threat of severe erosion. The Corte Madera marsh complex has experienced dozens of feet of significant shoreline erosion over the past decades, and there is active edge erosion at other marshes along the shoreline.

This proposed project will evaluate the effectiveness of constructing coarse-grained beach edges at a number of locations in the Richardson Bay and Corte Madera Creek watersheds. Sites with various wind-wave characteristics have been selected to allow for evaluation of this method of erosion control under diverse conditions. This will provide an understanding of the limits of this natural-shoreline approach.

The geography of the eastern Marin shoreline, with its steep bluffs and historic beaches and ease of construction access provides an ideal location for construction and monitoring for these types of projects.

Potential locations for engineered shorelines potentially include:

- Bothin Marsh, Mill Valley; Mill Valley–Sausalito Multiuse Pathway
- Mill Valley city shoreline
- Corte Madera Marsh Ecological Preserve
- Marsh near Blackie's Pasture, Tiburon
- Lower Novato Creek Baylands levees

Currently, there is no approval or funding for design or implementation at any of these sites except for Corte Madera Ecological Preserve and Blackies Pasture where conceptual design only has been funded and will begin in 2017. Permission from property owners would be required to move any of the other sites into design and implementation has not been funded at any of these sites. In any final demonstration project programs, each of several selected sites will be designed to address specific research questions that will be developed in any planning phase. Once implemented, the projects will be monitored to assess performance with respect to the research questions. Particular emphasis on constructability will be part of the design and monitoring program for each of the demonstration projects. Currently there is no funding or agreement to move forward at any of these sites except as noted above which would require potential significant permitting approvals.

7. Novato Creek Baylands Sea Level Rise Adaptation Projects—A Proposed Demonstration Project

The Marin County Department of Public Works (DPW) has been working on flood control and sea level rise adaptation planning in the lower Novato Creek watershed for several years. The Novato Creek Baylands contain large areas of diked, subsided baylands that could be restored to historic tidal-marsh habitat. This will create wetlands that provide for attenuation of wave energy, thereby buffering the impacts of sea level rise on the shoreline, and will provide habitat for several threatened and endangered species.

In 2012, the Novato Creek Baylands project was selected as one of three demonstration projects included in a large flood control and sea level rise adaptation program funded by the US Environmental Protection Agency (EPA). This program is led by the San Francisco Bay Joint Venture (SFBJV) and the San Francisco Estuary Institute (SFEI) and is meant to assist flood control agencies in the design and operation of their flood control channels through a project called Flood Control 2.0. This innovative regional project by SFEI, which seeks to integrate habitat improvement and flood-risk management at the bay interface, focuses on helping flood control agencies and their partners create landscape designs that promote improved sediment transport through flood control channels, improved flood conveyance, and restoration and creation of resilient bayland habitats.

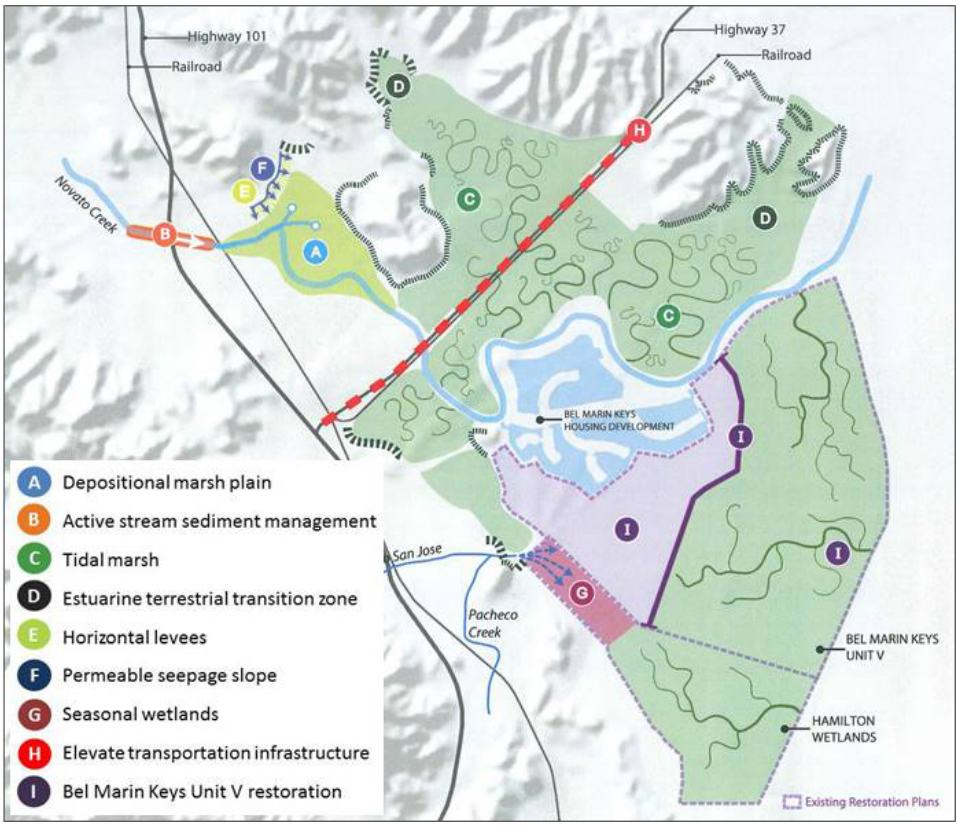

Figure 4: Map of Novato Creek SFEI Year 2100 and Beyond Vision Plan

Flood Control 2.0 provided design guidance to Marin County's DPW along with a long-term vision plan for the Novato Creek Baylands. SFEI's *Year 2100 and Beyond Vision Plan* for this area requires reworking of large-scale infrastructure such as Highway 37. It has also prepared an economic evaluation of the costs and benefits of alternate approaches to flood protection under rising sea levels.

In lieu of the implementation of the SFEI'S long-term vision plan, Marin County, through its watershed program, has developed a modified version of the plan called the Novato Baylands Restoration Initiative. This initiative calls for the breaching of dikes and full tidal-marsh restoration of several basins that will increase tidal prism (the extent of daily tidal flows). These actions will improve channel scour to remove accumulated sediment without dredging and provide important habitat to several threatened and endangered species of concern and will be carried out within current property-ownership boundaries. Adaptation to sea level rise is an important focus of the baylands restoration initiative involving sloped ecotone levees.

Two projects from the Novato Baylands Restoration Initiative were selected for funding as part of a special shoreline-resiliency subgroup as one of eight project locations in the San Francisco Bay Area. The projects were included in a submitted funding request in 2015 to the California Department of Water Resources under its Integrated Regional Water Management (IRWM) program submittal. The grant was awarded to Marin County in 2016, and these two projects will be constructed by 2019.

The remainder of the initiative will require passage of a local tax measure for funding. Passage of such a measure, one of which is tentatively scheduled for inclusion on a ballot in 2018, would allow for implementation of additional projects from the SFEI long-term vision plan.