MEMORANDUM

April 8, 2022

TO: MEMBERS, PORT COMMISSION
Hon. Willie Adams, President
Hon. Doreen Woo Ho, Vice President
Hon. Kimberly Brandon
Hon. John Burton
Hon. Gail Gilman

FROM: Elaine Forbes
Executive Director

SUBJECT: Informational presentation regarding the San Francisco Living Seawall Pilot Project

DIRECTOR'S RECOMMENDATION: Information Only – No Action Required

EXECUTIVE SUMMARY

In 2018, the San Francisco Board of Supervisors proposed Proposition A Seawall Earthquake Safety Bonds. San Francisco voters approved this bond with a margin of 83-17% at the November 6, 2018 election. At the time, the Port and the City acknowledged that Proposition A was a vital down payment to address much more costly seismic and flood risks along the waterfront.

Since the passage of Proposition A, the Port has engaged in in-depth study and analysis of the waterfront earthquake risks to life safety and emergency response. The Port has also developed a greater understanding of the engineering challenges and risks of rising sea levels through its work with the U.S. Army Corps of Engineers ("USACE") on the San Francisco Waterfront Coastal Flood Study ("Flood Study"). Exhibit A to this report contains links to Port Commission staff reports that describe development of Waterfront Resilience Program ("Program").

Through the development of adaptation strategies and the identification of flood risk mitigation plans, the Port and the USACE will consider the application of natural and nature-based features and incorporation of "engineering with nature" in all adaptation

strategies and Port resilience projects. Application of nature-based features as a means of climate adaptation has steadily grown over the past 20 years and technical advances are being implemented and monitored. This staff report describes a key strategy the Waterfront Resilience Program is commencing to examine how we can incorporate nature-based features along segments of the shoreline that require a highly engineered shoreline solution to reduce future flood risks – the San Francisco Living Seawall Pilot ("Living Seawall Pilot").

STRATEGIC OBJECTIVES

The Port's Waterfront Resilience Program supports the goals of the Port's Strategic Plan as follows:

Engagement
The Port will lead an inclusive stakeholder process to develop a shared vision, principles and goals for the Waterfront Resilience Program and Flood Study. Data from this pilot study will be publicly available to benefit all future projects proposed within SF Bay.

Resiliency
The Port will lead the City's efforts to address threats from earthquakes and flood risk through research and infrastructure improvements to the Embarcadero Seawall and adjoining buildings and other infrastructure, and to the 7½ miles of Port shoreline property. Data from this pilot study will allow engineering with nature principles to be incorporated into future projects within SF Bay.

Sustainability
The Port will incorporate engineering with nature principles to provide opportunities to enhance the ecosystem with habitat improvements as well as sustainable design and construction best management practices. This pilot study will explore the living shoreline aspect of natural infrastructure alternatives (e.g. wetlands, horizontal levees, and "living shorelines") for future shoreline stabilization and improvement projects. This pilot study will provide data to help implement City Biodiversity Goals and best sustainable practices in all in SF Bay projects.

Stability
This pilot study will produce valuable data and findings that will have long term benefit for the Port, the City, and the region.

BACKGROUND

In 2021 the USACE published International Guidelines on Natural and Nature-Based Features for Flood Risk Management[1], the product of an international collaboration to help flood risk management practitioners develop innovative solutions to current and future flood risk management challenges.

[1] USACE International Guidelines on Natural and Nature-Based Features for Flood Risk Management: https://ewn.erdc.dren.mil/?page_id=4351

The San Francisco Bay Restoration Authority[2] ("Restoration Authority") is funding thoughtful and programmatic design planning and permitting for intertidal and subtidal habitat restoration projects in the Baylands, which includes a mix of urbanized and natural shorelines and extends down into the submerged aquatic habitats of the Bay. The Restoration Authority also recently announced funding for an effort called the Regionally Advancing Living Shorelines Project, which is a unique opportunity spearheaded by San Francisco Estuary Institute in collaboration with the California Coastal Conservancy to examine living shorelines and subtidal habitat around San Francisco – including the Port of San Francisco's waterfront – and develop strategies drawing inspiration from around San Francisco Bay and other urban and port areas.

Other groups are also advancing nature-based solutions that reduce flood risks and hybrid strategies that can potentially extend the design life of more traditionally engineered flood defenses in San Francisco Bay, nationally, and internationally.

Through the development of adaptation strategies and the identification of flood risk mitigation plans, the Port and the USACE will consider the application of natural and nature-based features and incorporation of "engineering with nature" in all adaptation strategies and Port resilience projects. As part of this effort, USACE is pulling in the expertise of the San Francisco District's Environmental Planning Section Chief Julie Beagle to support this effort. Ms. Beagle has extensive experience with Engineering with Nature in San Francisco Bay.

SAN FRANCISCO LIVING SEAWALL PILOT

The Living Seawall Pilot is the first of its kind on San Francisco Bay and the findings from the pilot project could potentially support combining habitat creation and native-species benefits with projects designed to increase the seismic safety of the Embarcadero Seawall and the San Francisco Waterfront as well as potential flood defense projects. The pilot project is a collaboration between Port staff and Smithsonian Environmental Research Center ("SERC") scientists. This study can help define best practices for embedding natural elements within and along engineered structures for other San Francisco Bay area coastal communities.

The Living Seawall Pilot is designed to better understand how the Port can create viable habitats along the waterfront that provide benefits to the larger San Francisco Bay ecosystem.

The pilot study includes attaching a series of concrete panels to the seawall or breakwaters made with materials developed to benefit the ecosystem and potentially promote the establishment and success of native species. The panels will include flat and textured designs to assess surface texture's effect on promoting beneficial marine growth. The pilot study will also assess the number of species established and the quality of the habitat provided across the full tidal range, from the high intertidal zone to the subtidal zone, along with differences in wave exposure and salinity gradients, and

[2] San Francisco Bay Restoration Authority website: https://www.sfbayrestore.org/

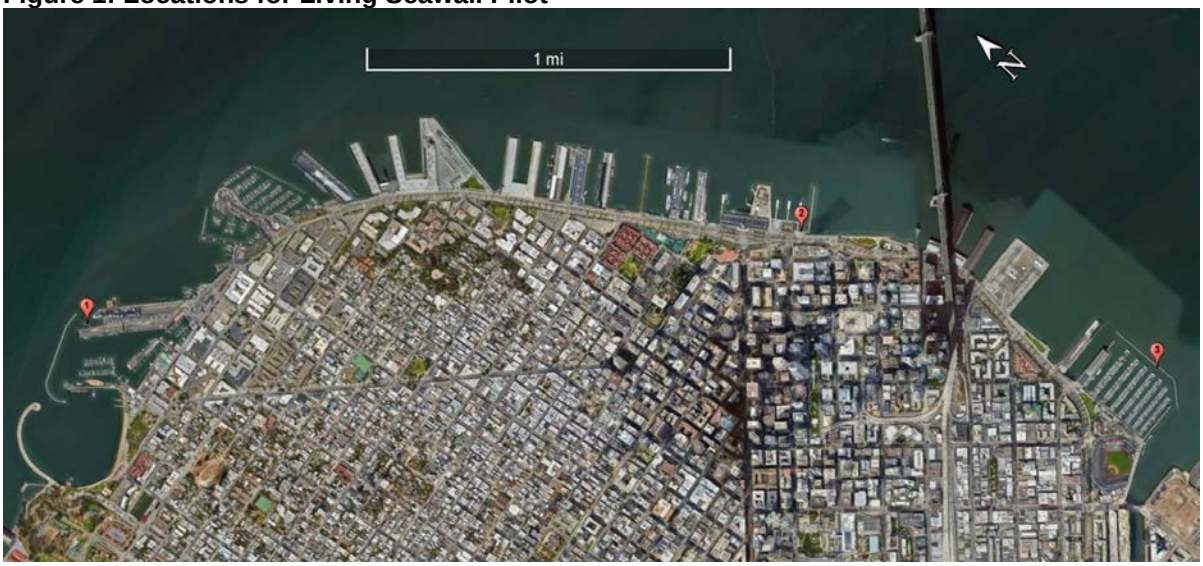
the ability to scale the project up to larger expanses of the seawall that could provide greater benefits for native species.

The experimental design includes the fabrication of steel frames that will be mounted along the seawall or breakwaters. The custom frames will hold the concrete panels in place and provide handholds and access points for the scientists to monitor the recruitment of species over the 2+ year monitoring period. Experimental success could result in increases in native species richness (number of species), differences in community composition (which species are present) and increases in total abundance and distribution of native species.

Three project sites were chosen along the northern waterfront, as shown in Figure 1 below: Site 1) Pier 45 Breakwater, Site 2) Agriculture Building Seawall, and Site 3) South Beach Harbor East Breakwater. The locations were chosen based on the ability of the scientists to safely monitor the panels over time, tidal extent from the high intertidal zone to the shallow subtidal zone, and to represent differences in wave exposure and salinity.

The panels will be monitored for a minimum of 2 years. Depending on funding availability, the Living Seawall Pilot study could be extended for an additional year, or additional design variations could be added to further characterize and refine features to enhance species recruitment. The best-performing design elements will be considered for incorporation into a restored or new seawall and other flood defense features for the entire waterfront.

Figure 1: Locations for Living Seawall Pilot



Matthew Bell, Waterfront Resilience Program engineer, designed the steel frames in close collaboration with Tim Felton and Luis Vallejos from the Port's Maintenance Division and SERC's scientists. The collaborative design process included the fabrication of a prototype frame and hands-on testing by the SERC scientists as shown in Figure 2. The Port Maintenance Division will purchase the materials and fabricate the frames at their Pier 50 facilities. The Port Maintenance Division will also install the

experimental frames at the three selected sites and provide boat services to the SERC scientists for periodic monitoring of the panels during the 2-year (or longer) monitoring period. Port Maintenance will remove the steel frames and panels from three sites upon completion of the pilot project.

Figure 2: Prototype Frame Testing at Pier 50

SERC scientists will provide regular progress updates during the monitoring period and provide a final report describing their findings and results, including recommendations for elements that that could be incorporated within Waterfront Resilience Program projects. The final report will summarize the potential benefits to the Bay, including to native species, of incorporating admixture and textural elements within the seawall design and recommendations for additional pilot studies or design variations that could further benefit and improve habitat and ecosystem conditions. In addition to using data and information learned from this pilot study for Port projects, the information will be circulated to other agencies pursuing engineering with nature approaches along engineered shorelines in San Francisco Bay.

Living Seawall Pilot Problem Statement, Goals, and Anticipated Outcomes

Traditional modern seawalls tend to be smooth vertical structures that have no real analog in nature (Figure 3). While many species inhabit natural rocky shorelines, research from around the world indicates that only a subset of native rocky-shore species are able to inhabit seawalls. Even within this group, some species do not do as well as their counterparts on natural shores, with smaller body sizes, lower rates of reproduction, and lower genetic diversity. Notably, many invasive marine species – which tend to be “weedier” – can thrive on seawalls and other artificial structures. San

Francisco Bay is one of the most heavily invaded bays in the world, with many common non-native species. In the region, there is a strong desire to protect and enhance marine habitat, especially for native species. The overarching goal of this project to is enhance the habitat value of the seawall that the Port of San Francisco will be rebuilding over the coming years for existing native species in the Bay.

Figure 3: Example of Smooth Vertical Seawall Surface North of Pier 38

This project will provide key scientific information in support of that goal, with two main study objectives: 1) to experimentally determine whether the addition of three-dimensional structure and/or an admixture created to increase marine growth increase overall and native species richness and/or abundance, and 2) determine whether the effects of these modifications vary with tidal elevation, a gradient of wave exposure and salinity, or with scale of treatment (large vs. small panels).

The project is designed to generate San Francisco Bay-specific information, which is currently lacking, and to fill critical data gaps in the larger body of research on ecological enhancements to seawalls. As such, the Program team expects the project to be able to provide specific design guidance for the Embarcadero Seawall improvements. For example, the team may find that enhancements promote overall and/or native species richness at more ocean-influenced sites, closer to the Golden Gate, but don't have the same effects on the southern waterfront. In this instance, Port leadership could then decide to save costs by including these ecological enhancements only on a portion of the waterfront.

The Program team has identified three target native species that may particularly benefit from ecological enhancements of the seawall, all of which are of interest to local resource management agencies:

- the Olympia oyster, *Ostrea lurida,*
- the common rockweed, *Fucus distichus,* and
- the Pacific herring, *Clupea pacifica*.

Olympia oysters, the only oyster native to the West Coast, are the focus of restoration efforts in San Francisco Bay, and along the West Coast of North America more broadly (https://olympiaoysternet.ucdavis.edu/). The brown alga *Fucus distichus* is a foundation species (providing food and habitat for many other organisms) and has been the focus of mitigation efforts such as those following the Cosco Busan oil spill, which damaged *Fucus* and other intertidal species in 2007. The Pacific herring supports Bay food webs and an important commercial fishery and is a state-managed species.

Oysters and *Fucus* both live attached to hard substrate in the intertidal zone (the portion of the shoreline between high and low tides) in San Francisco Bay, so an enhanced seawall could support them directly by providing appropriate habitat. The herring uses many types of substrates along the San Francisco waterfront for seasonal spawning, but herring eggs develop best on macroalgae, such as *Fucus.* While the Program team highlights these three species, we anticipate that an enhanced seawall could support many other species, including a number of other native seaweeds, which provide food and habitat for many species at the base of the food web. These include a host of marine invertebrates and small fish, which are in turn, important food for larger fish and birds.

Globally, the body of research on approaches to "greener" seawalls and other hard shoreline protection and maritime structures is increasing. Much of this research has been conducted on a small scale with experimental manipulations, such as the addition of textured panels/tiles or small artificial tide pools.

Two examples of larger-scale projects are in Sydney, Australia[3], where panels/tiles mimicking mangrove prop roots have been added to existing seawalls, and the Elliott Bay Seawall[4] in Seattle, an effort focused on creating well-lit shallow water habitat for use by juvenile salmon. While the effects of enhancements vary depending on target species, location, and enhancement type, as a general principle, the research indicates that increased surface complexity – making structures that mimic some of the elements of natural shorelines – increases the number of species that can inhabit it. While these results are encouraging for jurisdictions looking for ways to build greener, some significant data gaps remain.

For example, most of the work to date has focused on the effects of the addition of three-dimensional structure in the intertidal zone, the area of the shoreline that is

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[3] Sydney, Australia Living Seawalls Website: https://www.livingseawalls.com.au/

[4] Seattle, WA Elliot Bay Seawall Website: https://waterfrontseattle.org/waterfront-projects/seawall

exposed during low tides. Three-dimensional structures may be particularly important in providing shade and retaining moisture for marine animals and seaweed that are exposed to hotter, drier conditions during low tides. This may allow more species to survive that periodic exposure to air.

Much less is known about the effects of surface complexity below the low tide mark, and whether it similarly benefits subtidal species. This is important because many more Bay species live below the low tide mark, and because as sea level rises, today's low intertidal zone will become tomorrow's subtidal zone. Another key data gap that is particularly important in an estuary like San Francisco Bay, which has many invasive species, is whether structural enhancements also might benefit or even favor non-native species over natives. Most research to date has either focused just on a small set of target taxa, or has not distinguished between native and non-native species in evaluating the response of ecological communities to enhancements.

The Living Seawall Pilot aims to close some of these data gaps by investigating the effects of the addition of texture and the use of a growth-promoting concrete admixture. Scientists will determine whether such effects are important at three tidal elevations, at three sites with different environmental conditions, and at two spatial scales (large and small panels/tiles). Scientists also intend to compare native vs non-native species use of the ecological enhancements. SERC has strong taxonomic expertise gained from decades of studying invasive species in San Francisco Bay. Port staff know of no other study that has attempted to answer all of these questions simultaneously and are excited to engage in a project that will not only provide design guidance for a "greener" seawall in San Francisco, but that will make a major contribution to research on the world stage.

Design guidance for ecological enhancements to seawalls is particularly needed at this time, as more coastal defense structures are built in response to sea-level rise. Options for shoreline protection range along a continuum from green (all nature-based, soft elements, such as marsh restoration) to gray (all artificial, hard substrates, such as seawalls and revetments), and approach is dependent on both shoreline conditions and human uses. Within San Francisco Bay, numerous agencies are working on shoreline solutions along this continuum, from revegetating marsh edges, to mixed hard and soft living shorelines projects (such as the San Francisco Living Shorelines Project http://www.sfbaylivingshorelines.org/sf_shorelines_about.html), but seawall modifications for habitat benefits have not yet been tried.

The San Francisco Estuary Institute will utilize recently awarded funding to convene agencies working on nature-based designs, to refine and develop best practices along the green-to-grey continuum. Data generated by this study will help inform these practices, which can then be used by other ports, cities, private landowners and others who are looking for ways to protect people and property while providing habitat for more diverse marine ecological communities and more native species.

Similar Projects in San Francisco

Heron's Head Park is a 21-acre park, originally constructed as part of a never-completed cargo terminal, "Pier 98," and officially zoned as an industrial area. The park is now home to native plants, more than 100 bird species, and one of the few wetlands on San Francisco's shoreline. The EcoCenter at Heron's Head Park is the first LEED Platinum, Zero Net Energy Building in San Francisco, using sustainable on-site power and wastewater systems. The educational community center at the EcoCenter as well as the park walking paths, bird watching, and ecosystem restoration activities are part of a commitment to create a sustainable waterfront.

Heron's Head Park is a low-lying part of Port property. Sea level rise and erosion threaten the habitat and recreational value of the park. In response, Port staff have developed and are implementing plans for the Heron's Head Park Living Shoreline project[5] to achieve the following objectives:

1. Stabilize the southern shoreline and protect it from continued erosion and subsidence;

2. Restore native plant vegetation to enhance biodiversity and ecological function;

3. Create a resilient shoreline that can adapt to a moderate amount of sea level rise through 2050; and

4. Create youth employment and community engagement opportunities through hands-on involvement in park restoration activities.

The Pier 94 wetlands formed along the Bay shoreline at the end of Pier 94 after a portion of the Pier's fill material subsided and became inundated by the Bay tides. Although small, these wetlands are now home to over 168 species of birds, including migratory birds, and provide a rare and valuable salt marsh habitat for a variety of plant and animal species. The Port, in collaboration with the Golden Gate Audubon Society, improved the physical, hydrologic, and aesthetic features of the wetland to strengthen its ecosystem. The Audubon Society also removed invasive species and added a transition zone that increased the size and habitat value of the wetland and is pursuing funding for a living shoreline project that would provide oyster habitat while protecting the marsh from erosion.

Crane Cove Park is a major new open space along a formerly inaccessible stretch of industrial shoreline. The design of the park accommodates coastal flooding and sea level rise. The park includes native landscaping and tidepool features to provide potential urban habitat, but the park is surrounded by urban uses, so no bird nesting or

[5] Port Commission Staff Report: https://sfport.com/sites/default/files/Commission/Documents/Item%2010A%20Heron%27s%20Head%20Park%20Shoreline%20Stabilization_final.pdf

roosting locations occur within the site, and no substantive aquatic habitats are known to have developed to date.

Other projects include:

- Mission Rock's China Basin Park was designed with habitat and biodiversity-supporting landscaping, and tidal shelves[6]; and

- The India Basin Waterfront Park[7] is intended to enhance shoreline habitat just south of Heron's Head Park.

Project Phasing, Schedule, and Cost

The total cost estimate to construct the Living Seawall Pilot, monitor for two years, report findings, and remove the frames is approximately $901,000, with a total project budget of $1.04 million after the inclusion of a 15% project contingency. A 15% contingency was applied considering current inflation pressure on the cost of construction materials and the inherent uncertainty of experimental scientific work.

The pilot is bond-eligible in support of the Waterfront Resilience Program, including projects that could be funded with Proposition A. We know our goal is to maximize the hard costs that the bonds pay for so, the Program team is continuing to seek grant funding to support this work and thus allow Proposition A funding to be used for other construction projects.

Proposition A will fund all current planned scope, with a significant proportion of construction funding for Port Maintenance Staff support. The team will continue to seek grant funding for the monitoring program, including potential extensions to the monitoring. Table 1 includes a budget for the Living Seawall Pilot.

[6] BCDC Staff Memorandum to the Design Review Board related to China Basin Park: https://www.bcdc.ca.gov/drb/2020/06-08-Mission-Rock-China-Basin-Park.pdf

[7] https://ibwaterfrontparks.com/

Table 1: Living Seawall Pilot Budget

Scope	Schedule	Estimated Cost	Status
Pre-Design - Phase 1: Includes initial project conception through completion of pre-design	2021	$23,000	Completed Dec. 2021
Detailed Design, Construction, & Baseline Survey - Phase 2: Completion of installation design and permitting. Fabrication of frames, panels, and installation at three sites. Baseline survey coordinated with installation.	Jan. 2022 – Sept. 2022	$400,000	Current Phase. Design complete, permits in progress. Funding released to start frame fabrication.
Monitoring - Phase 3: Three field surveys per year, six total, lab work, report interim scientific findings.	2 years	$385,000	Planned
Interpretation of Results and Frame Removal - Phase 4: Final scientific report on experiment results and findings. Remove frames and patch anchor holes at conclusion of monitoring.	3 months	$93,000	Planned
Subtotal Estimated Cost		$901,000	-
Total Living Seawall Pilot Cost (+15% or +$135k)		**$1.04 million**	-

Environmental and Regulatory Requirements

The Living Seawall Pilot will follow all required permitting and review processes for in-water work in San Francisco Bay:

- The project has been reviewed by the Port's Interdivisional Project Review and will receive a Port permit for installation and monitoring;
- The project has been reviewed for compliance with the California Environmental Quality Act by the San Francisco Planning Department and determined to be categorically exempt;
- The Port has applied for review of the project or provided notification of the project to USACE, the Bay Conservation and Development Commission, and the San Francisco Bay Regional Water Quality Control Board; and
- The project has been presented to the Program's Resource Agency Working Group.

Next Steps

The project is currently in Phase 2. The design of the installation is complete and has been submitted to all applicable agencies for approval. Procurement of materials is ongoing, and the construction portion of Phase 2 will soon commence with the

fabrication of steel frames and platforms by the Maintenance Division at their Pier 50 shops. The pilot installation is scheduled to be completed by the end of Q3 2022. After installation, the project will proceed to the monitoring phase, Phase 3, and then the final reporting and removal phase, Phase 4.

Data from the Living Seawall Pilot will be used for the development and design of projects proposed with in-Bay components. The data will allow proposed projects within the Bay to incorporate engineering with nature principles and provide for design features to improve habitat conditions within the Bay for the entire San Francisco waterfront and will contribute to the base of knowledge available for inclusion in Bay shoreline projects outside of San Francisco.

Port staff will provide periodic updates to the Port Commission regarding the Living Seawall Pilot and other Program efforts to implement engineering with nature or nature-based adaptation.

Prepared by: Kelley Capone, Project Manager
Mathew Bell, Project Engineer

Prepared for: Brad Benson, Waterfront Resilience Director
Tim Felton, Deputy Director of Port Maintenance

Exhibit A: Port Commission Staff Reports Describing the Development of the Waterfront Resilience Program

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Table 1 below includes a description of and links to Port Commission staff reports which describe development of the Waterfront Resilience Program.

Table 1: Relevant Port Commission Staff Reports

Meeting Date	Item Description	Hyperlink
May 12, 2020	United States Army Corps of Engineers San Francisco Waterfront Flood Resiliency Study	https://sfport.com/sites/default/files/Commission/Documents/Item%2010A%20Info%20USACE%20Flood%20Study%20Update%20and%20Amendment%20to%20Feasibility%20Cost%20Sharing%20Agreement%20%28S%29_0.pdf
November 10, 2020	Proposed Program decision framework, including a Program goal, principles, draft evaluation criteria, draft flood and seismic standards, and draft Proposition A funding guidelines	https://sfport.com/sites/default/files/Commission/Documents/Item%2012A%20Waterfront%20Resilience%20Program%20Strategy%20and%20Decision%20Framework.pdf
November 9, 2021	Framework for Waterfront Resilience Program Early Projects	https://sfport.com/files/2021-11/11092021_Item%2010A%20Waterfront%20Resilience%20Program%20Update_final_0.pdf
December 14, 2021	Embarcadero Early Projects to address life safety and disaster response	https://sfport.com/files/2021-12/12142021_Item%2012A%20Waterfront%20Resilience%20Program%20Early%20Projects_final.pdf
December 14, 2021	Amendment to the Feasibility Cost Sharing Agreement with the United States Army Corps of Engineers for the San Francisco Coastal Flood Study	https://sfport.com/files/2021-12/12142021_Item%2010E%20USACE%20Feasibility%20Cost%20Sharing%20Agreement_final.pdf