Exhibit 5

OAAC ADAPT: Oakland Alameda Adaptation Committee Projects

Oakland Alameda Multi-Hazard Adaptation and Community Benefits Project

Technical Report for BRIC 2023

December 2023

Prepared For

Oakland Alameda Adaptation Committee (OAAC)

Prepared By

Pathways Climate Institute

PRIMARY AUTHORS

Kris May, PhD PE

Lindsay Luchinsky, MSc

Nick Wrubel

Meagan Brown, MSc

Michael Mak, PE

Acknowledgements

With support from CMG Landscape Architecture, Moffatt & Nichol, Schaaf and Wheeler, Environmental Science Associates, NHA Advisors, and the City of Alameda, City of Oakland, Port of Oakland, East Bay Regional Park District, California Department of Transportation and Community Partners: Hood Planner, Community Action for a Sustainable Alameda, and Greenbelt Alliance.

Disclaimer

Suggested Citation

May, CL, Luchinsky, L, Brown, M, Mak, M (2023). Oakland Alameda Multi-Hazard Adaptation and Community Benefits Project: Technical Report for BRIC. Prepared for the City of Alameda, CA.

Table of Contents

Tables

Figures

Photos

Acronyms / Abbreviations

Acronym	Signification
Airport	Oakland International Airport
BRIC	Building Resilient Infrastructure and Communities
Caltrans	California Department of Transportation
CDRZ	Community Disaster Resilience Zone
EBRPD	East Bay Regional Park District
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
MHHW	mean higher high water
MLK Jr	Martin Luther King Junior
OAAC	Oakland Alameda Adaptation Committee
Port	Port of Oakland
SF Bay	San Francisco Bay
SFHA	Special Flood Hazard Area
SLR	sea level rise
SR	State Route
SWL	stillwater level
TWL	total water level
USACE	United States Army Corps of Engineers

1 Introduction

The Oakland Alameda Multi-Hazard Adaptation and Community Benefits Project will reduce existing and future flood risk (up to two feet of future sea level rise) within the Oakland International Airport (the Airport) Community Disaster Resilience Zone (CDRZ) and will address existing and future flood risks along San Leandro Creek within east Oakland underserved communities. The project includes flood mitigation elements that will remove the Airport, and communities within the Cities of Oakland and Alameda from the Federal Emergency Management Agency (FEMA) Special Flood Hazard Area (SFHA) while also protecting important transportation corridors, enhancing access to the San Leandro Bay shoreline, and providing adaptive capacity and resilience for future sea level rise.

This project requires collaboration across multiple jurisdictions due to the connected nature of coastal flooding that occurs when coastal waters overtop multiple locations along the shoreline. Projects implemented within a single jurisdiction would be insufficient to remove the project area from the FEMA SFHA. A multi-hazard, multi-jurisdictional adaptation project is required to address the complex, compounding, and co-mingled existing and future flood hazards across the Cities of Alameda and Oakland and the Airport and within the CDRZ.

2 Project Area

San Leandro Bay is located on the western shoreline of San Francisco Bay in the County of Alameda (Figure 1), nestled between the Cities of Alameda and Oakland and the Airport where San Leandro Creek enters the bay (Figure 2). San Leandro Bay is a sheltered estuary with high-quality marsh habitat for the endangered Ridgway's rail (*Rallus obsoletus obsoletus*) and the salt marsh harvest mouse (*Reithrodontomys raviventris*). San Leandro Bay is surrounded by a mix of marsh habitat, the Airport, industrial areas, transportation corridors, and residential areas.

A portion of the City of Oakland, including the Airport, is located within a CDRZ, a geographic area that FEMA identified as most at-risk and most in-need from natural disasters and climate change (FEMA 2023a). The CDRZ is listed as disadvantaged by the White House Council on Environmental Quality Climate and Economic Justice Screening Tool. The Airport, and much of the surrounding area, is also over the 99th percentile for FEMA's National Risk Index (NRI), highlighting its very high risk to natural hazards (FEMA 2023b).

The **Airport** opened in 1927 with the world's longest runway and it continues to serve as one of the three international airports serving the larger San Francisco Bay Area. The Airport has 14 airlines operating out of its two terminals and nine rental car agencies as well as supporting businesses in the Airport CDRZ. The Airport saw 13.3 million passengers pass through its terminals in 2019 and is expected to grow beyond 20 million over the next decade (Port of Oakland 2021). Airport employees mainly live in the adjacent cities of Oakland (435,000 population) and Alameda (76,000 population), with east Oakland (95,000 population) having the highest concentration of Airport workers, along with other areas in the far East Bay, which often have a high National Risk Index, also benefitting from Airport employment.

Figure 1. San Francisco Bay and San Leandro Bay

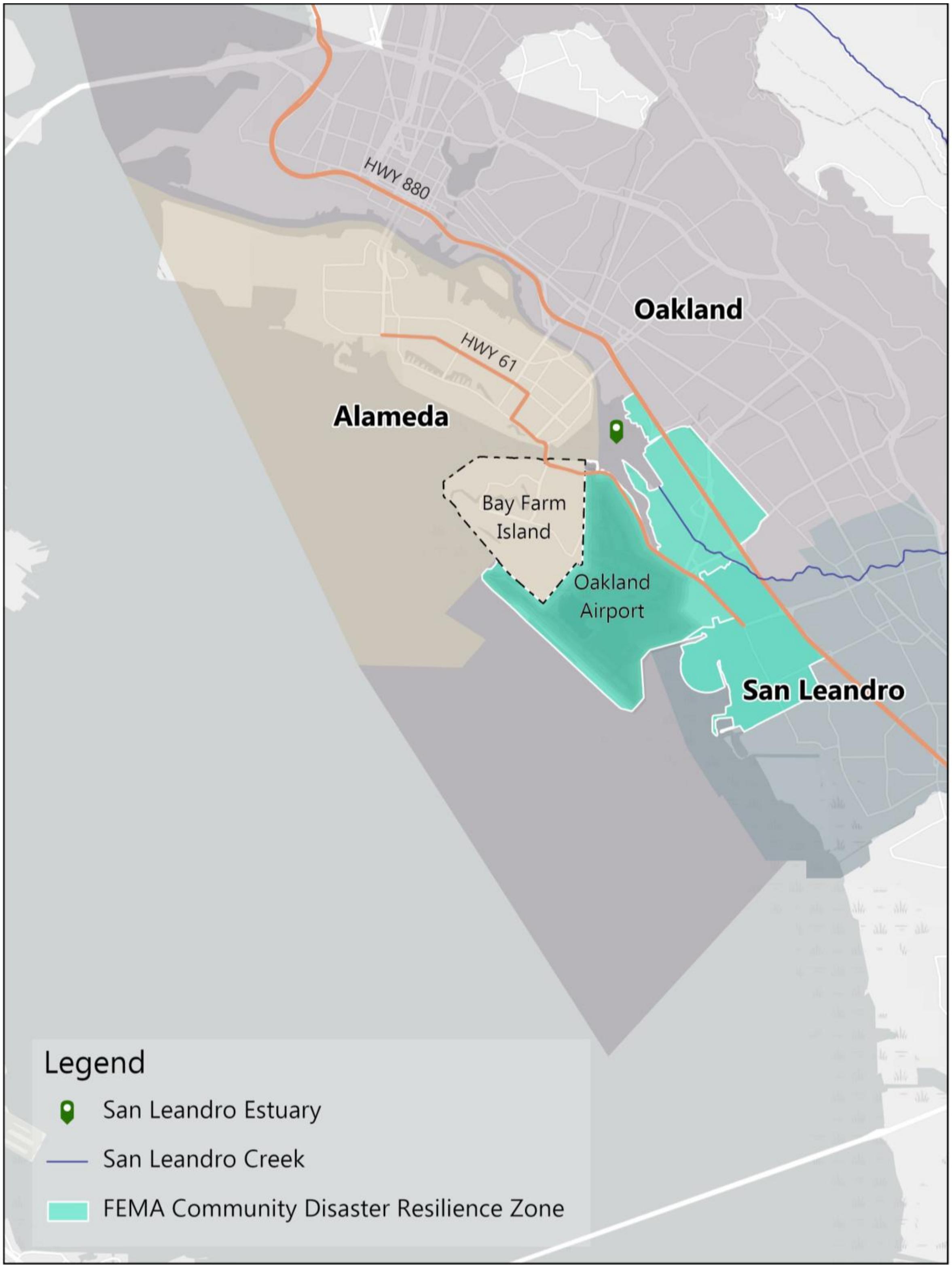


Figure 2 Project Area and FEMA Community Disaster Resilience Zone

State Route 61 /Doolittle Drive is located between the Airport and San Leandro Bay and is the primary throroughfare for accessing the Airport service industries. The Average Annual Daily Traffic from 2021 is 22,300 for this section of State Route 61 (SR 61)/Doolittle Drive. SR 61/Doolittle Drive is a critical evacuation route for residents on Bay Farm Island in the event of a tsunami, severe flood, or other disaster. Owned and operated by the California Department of Transportation (Caltrans), SR 61/Doolittle Drive is a busy and low-lying roadway that experiences coastal overtopping during extreme high tides and coastal storm surge events. A gap in the San Francisco Bay Trail, which is a 500 mile trail around the San Francisco Bay, exists along SR 61/Doolittle Drive to the north of the Martin Luther King Junior (MLK Jr) Shoreline Center totaling about 3,000 feet (EBRPD 2021), which results in people walking and bicycling on the shoulder directly adjacent to the roadway (Photo 1).

Underserved east Oakland communities are located east of SR 61/Doolittle Drive and along San Leandro Creek within the Airport CDRZ. Migrations from the American south starting in 1914 and from the adjacent I-580 freeway construction in 1947 caused east Oakland to become a predominately Black and now Latinx community due to the federal policy of redlining, which was enacted in 1934, adjacent industrial jobs, and restrictive covenants in other neighborhoods. Currently, east Oakland residents experience a lower life expectancy at 72 years, higher rates of obesity at 32 percent and 48 percent for children, and lack of access to healthy food and affordable housing. The adjacent I-880 freeway - built in 1958 - exposes the community to higher-than-average rates of air pollution, which contributes to higher rates of asthma in these communities. Consequently, East Oakland is recognized as a Justice40 community and currently has a median household income of about $40,000 with a disproportionately Black (37%) and Other/Latino (32%) population.

Photo Credit: Sergio Ruiz, Flickr 2019

Photo 1. Low-lying State Route 61/Doolittle Drive adjacent to San Leandro Bay

Bay Farm Island is located within the City of Alameda, directly adjacent to the Airport. Bay Farm Island includes the Chuck Corica Golf Complex, office and retail complexes, and approximately 14,600 residents. A portion of the San Francisco Bay Trail wraps around the bay-edge of Bay Farm Island, and along Doolittle Drive, providing public access to the bay and recreation. The San Francisco Bay Trail within Alameda County is managed by the East Bay Regional Park District (EBRPD) and the City of Alameda.

3 Flood Hazards

San Francisco Bay (SF Bay) is the largest estuary in the western U.S., with a contributing watershed that includes nearly 40% of California, and substantial freshwater flows entering through the Sacramento River. The 300-foot-deep Golden Gate inlet connects the SF Bay with the Pacific Ocean, and the tides, ocean-driven swells, and extreme ocean water levels all enter the SF Bay through this single inlet. The large expanse of the SF Bay and the complex topography surrounding the SF Bay can transform storm-driven winds in a multitude of directions depending on the primary driver of the onshore or offshore winds or the track of the large storm system descending on the SF Bay Area. The water levels and wave heights of the SF Bay exhibit a high degree of variability driven by many factors, including the bathymetry, astronomical and oceanic cycles, windspeeds and direction, and atmospheric events (May et al. 2016b). In the SF Bay, no single storm event produces the highest water level and highest wave hazard along the entire shoreline (May et al. 2016a).

Although large wave hazards (e.g., up to 5 feet) can occur on the SF Bay side of the Airport, San Leandro Bay is protected from large waves due to its sheltered location and much smaller size. FEMA analyzed coastal water levels and wave hazards for the entire SF Bay shoreline, resulting in updated Flood Insurance Rate Maps (FIRMs) for the nine Bay Area counties, including the County of Alameda (DHI 2011; FEMA 2018). Figure 3 shows FEMA SFHA within the project area. The Airport's levee along SF Bay is accredited, allowing a portion of the Airport to be removed from the SFHA as an area with reduced risk protected by a levee (see the hatched area on Figure 3).

This project seeks to mitigate the flood risks within the Airport CDRZ, which includes flood risk mitigation for the Airport, Bay Farm Island, and East Oakland's Columbian Gardens neighborhood. Additional mitigation on Bay Farm Island will enhance the effectiveness and long-term resilience of the project.

3.1 The Airport and Bay Farm Island

The Airport's North Field and supporting industries remain within the FEMA SFHA. Removing this area from the FEMA SFHA will require addressing multiple areas where coastal floodwaters can overtop the shoreline (Figure 4):

- SR 61/Doolittle Drive: SR 61/Doolittle Drive is low-lying along its entire length adjacent to the Airport's North Field and supporting industries. Overtopping can occur at multiple locations along SR 61/Doolittle Drive. Fringing marsh is located on the bayside of SR 61/Doolittle Drive for much of its length within the project area, although a portion is armored with rock revetment. The MLK Jr Shoreline Park, with parking, a kayak/boat launch, and open space is located along SR 61/Doolittle Drive between Langley and Grumman Streets. Mitigation along SR 61/Doolittle Drive to address flooding will require coordination between the Airport, Caltrans, EBRPD and the cities of Oakland and Alameda.

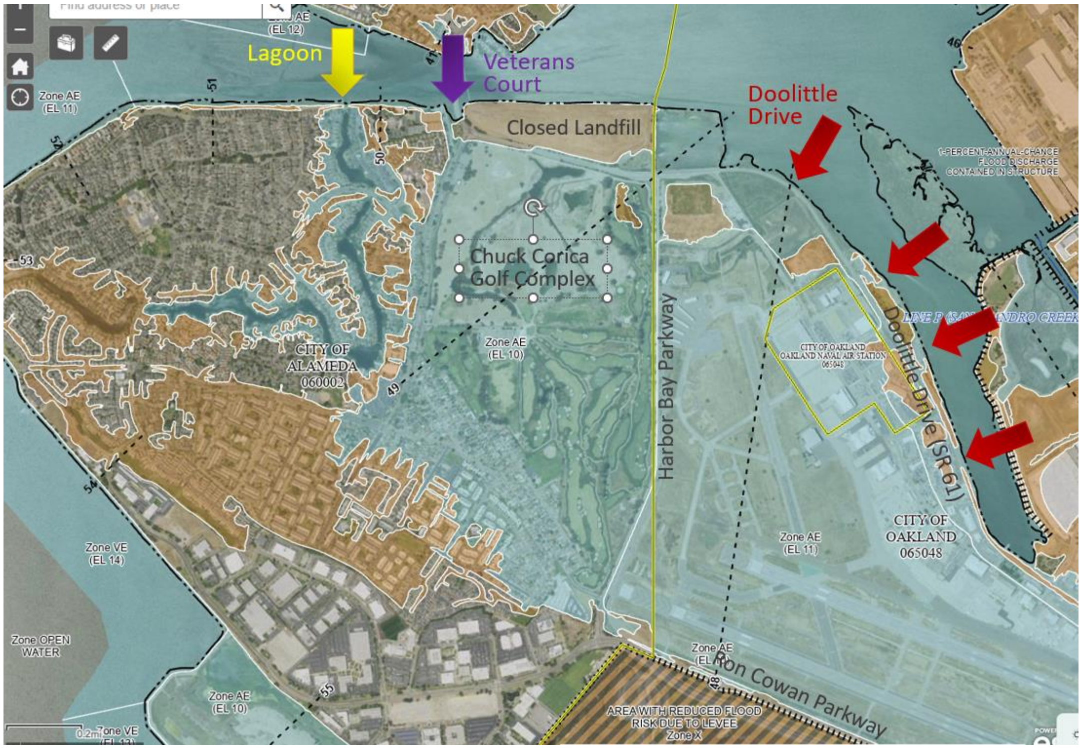
- Lagoon Northern Shoreline: At the northern end of the Lagoon on Bay Farm Island within the City of Alameda is where the shoreline and tide gate structure are low spots along the existing shoreline.
- Veterans Court: Floodwaters can overtop the shoreline near the touchdown of the Bay Farm Bridge (SR 61), between the closed Alameda landfill and Veterans Court, within the City of Alameda. The shoreline includes an aging seawall, rock riprap, and fringing marsh habitat.

Coastal overtopping along SR 61/Doolittle Drive, and at the Lagoon Shoreline and Veterans Court must all be addressed to mitigate flood risks along SR 61/Doolittle Drive and the Airport. The Port of Oakland, which owns the Airport, completed a two-dimensional hydrodynamic modeling study to better assess stormwater and coastal flood risks and mitigation strategies. The Port determined that, in addition to mitigation elements along SR 61/Doolittle Drive, the Airport would either have to construct a floodwall along much of Harbor Bay Parkway, from Doolittle Drive to Ron Cowan Parkway to address the flood hazards coming from the City of Alameda into the Airport property, or collaborate with the City of Alameda to mitigate the coastal overtopping occurring at the Lagoon Shoreline and Veterans Court (Port of Oakland 2023). An earlier study completed by the San Francisco Bay Conservation and Development Commission (BCDC) as part of the Adapting to Rising Tides program agrees with this finding (AECOM 2014).

The converse of this equation is also true. The City of Alameda can mitigate the flood risks at the Lagoon and Veterans Court low points, but they cannot remove the Bay Farm Island residents who live along the Bay Farm Lagoon from the FEMA SFHA until the flooding along SR 61/Doolittle Drive, which is outside of their jurisdiction, is also mitigated (AECOM 2014). The most cost-effective solution to mitigate flood risks within these areas requires coordination between all entities (Port of Oakland 2023). This coordination is occurring through the Oakland Alameda Adaptation Committee.

Source: (FEMA 2023c)

Figure 3. Project Areas in FEMA Effective Flood Insurance Rate Map

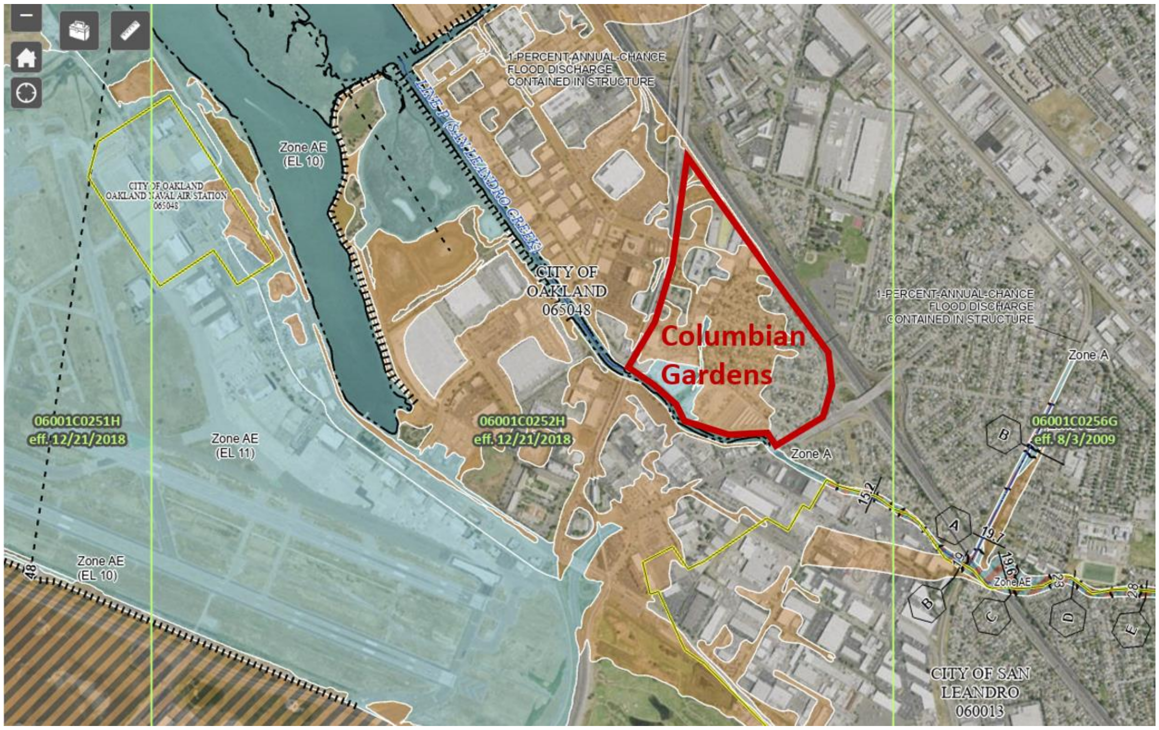


Source: (FEMA 2023c)

Figure 4. Shoreline Overtopping Locations

3.2 East Oakland (Columbian Gardens)

In addition to the Airport and Bay Farm Island, the Columbian Gardens neighborhood is mapped within FEMA's SFHA (Figure 5). This area experiences regular flooding during heavy rainfall events, due to overtopping along a drainage channel adjacent to the neighborhood, and flooding during extreme bay (coastal) water levels due to overtopping along San Leandro Creek (Figure 6). This neighborhood is low-income and recognized as a Justice40 community with a median annual household income of about $40,000 and is disproportionately Black (37%) and Other/Latino (32%). Removing this community from FEMA's SFHA requires addressing both sources of flooding (City of Oakland 2022).



Source: (FEMA 2023c)

Figure 5. East Oakland's Columbian Gardens in FEMA's Flood Insurance Rate Map

Source: Google Earth Aerial Imagery

Figure 6. Columbian Gardens Overtopping Locations

3.3 Additional Bay Farm Island Flood Risks

3.3.1 Lagoon Stormwater Flood Risk Mitigation

A system of lagoons is used to manage stormwater and reduce rainfall-driven flood risks on Bay Farm Island. Bay waters are pumped into the Bay Farm lagoon on the San Francisco Bay edge, and water flows via gravity through the lagoon and out a tide gate at the Lagoon overtopping point shown on Figure 4. The lagoons provide open space, wildlife habitat, public access and recreation benefits, with a network of trails and playgrounds along the lagoon shoreline. Prior to significant rainfall events, the lagoons are drawn down (i.e., the water level of the lagoon is lowered) using gravity flows by opening the tide gate when Bay water levels are low (Photo 2). Drawing down the lagoon provides stormwater flood storage capacity, and Bay Farm Island's stormwater network largely drains to the lagoon system. Raising the shoreline elevation of the lagoon overtopping low point will require enhancements to the lagoon operations to maintain the stormwater flood risk reduction capacity of the system.

Photo Credit: Kris May

Photo 2. Bay Farm Lagoon Tide Gate

3.3.2 Northern Bay Farm Island Shoreline Mitigations

The San Francisco Bay Trail wraps around Bay Farm Island, providing recreation and public access to the bay totaling 500 miles (Photo 3). However, portions of the shoreline are experiencing wave- and storm-driven erosion, threatening the trail, and reducing the flood risk reduction capacity of the northern shoreline. In some areas, the shoreline has eroded by up to 30 feet, placing former public benches and irrigation lines in areas of open bay water (Photo 4). Addressing this ongoing hazard will improve the overall resilience of the flood risk mitigation actions on Bay Farm Island.

Photo Credit: Maurice Ramirez

Photo 3. Bay Farm Island's San Francisco Bay Trail

Photo Credit: Kris May

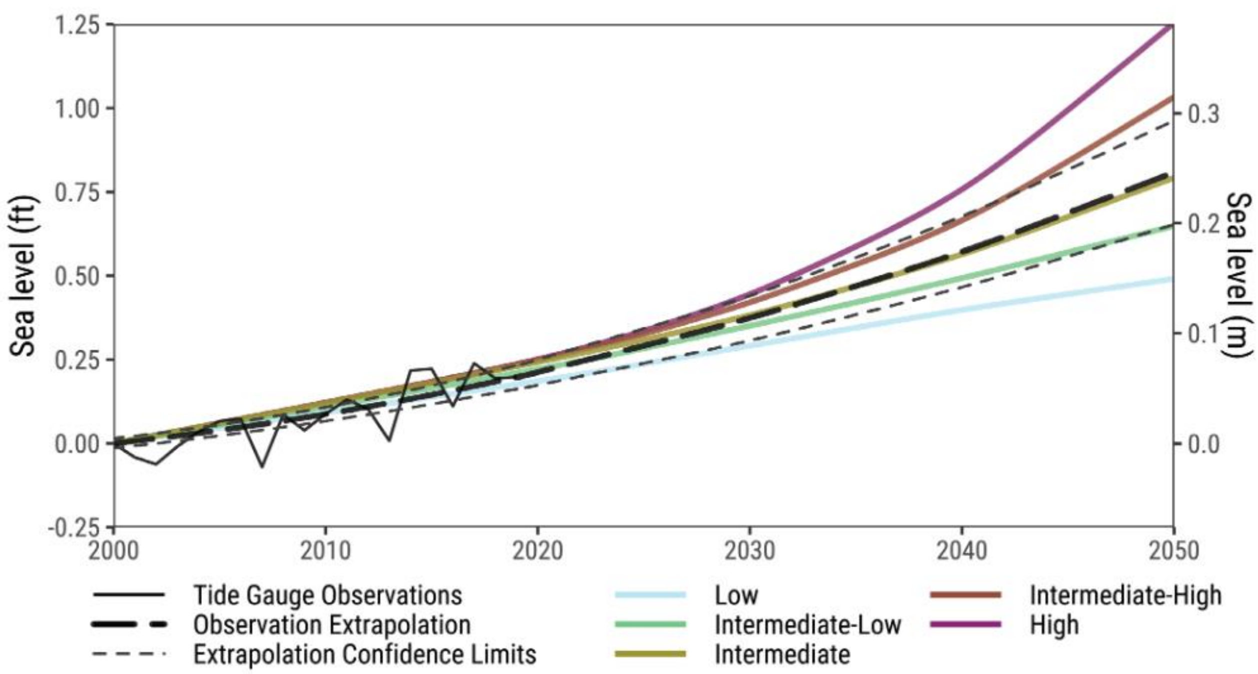
Photo 4. Bay Farm Island's San Francisco Bay Trail Erosion

4 Sea Level Rise

Climate change, including sea level rise, is increasing the severity of flood hazards. Updated sea level rise projections produced by the Federal Interagency Sea Level Rise Task Force suggest that California sea level rise is following the Intermediate curve (Collini et al. 2022; Sweet et al. 2022). Figure 7 shows the sea level rise scenarios, along with an observation-based extrapolation of tide gage and satellite observations. This extrapolation is not extended past 2050, as the observed rate of sea level rise is based on past conditions, and with continued greenhouse gas emissions, the rate of sea level rise is likely to continue increasing. By 2050, California is likely to observe 9 to 12 inches of sea level rise. By 2100, if California sea level rise continues to trend along the Intermediate scenario, up to 4 feet of sea level rise is possible (Figure 8).

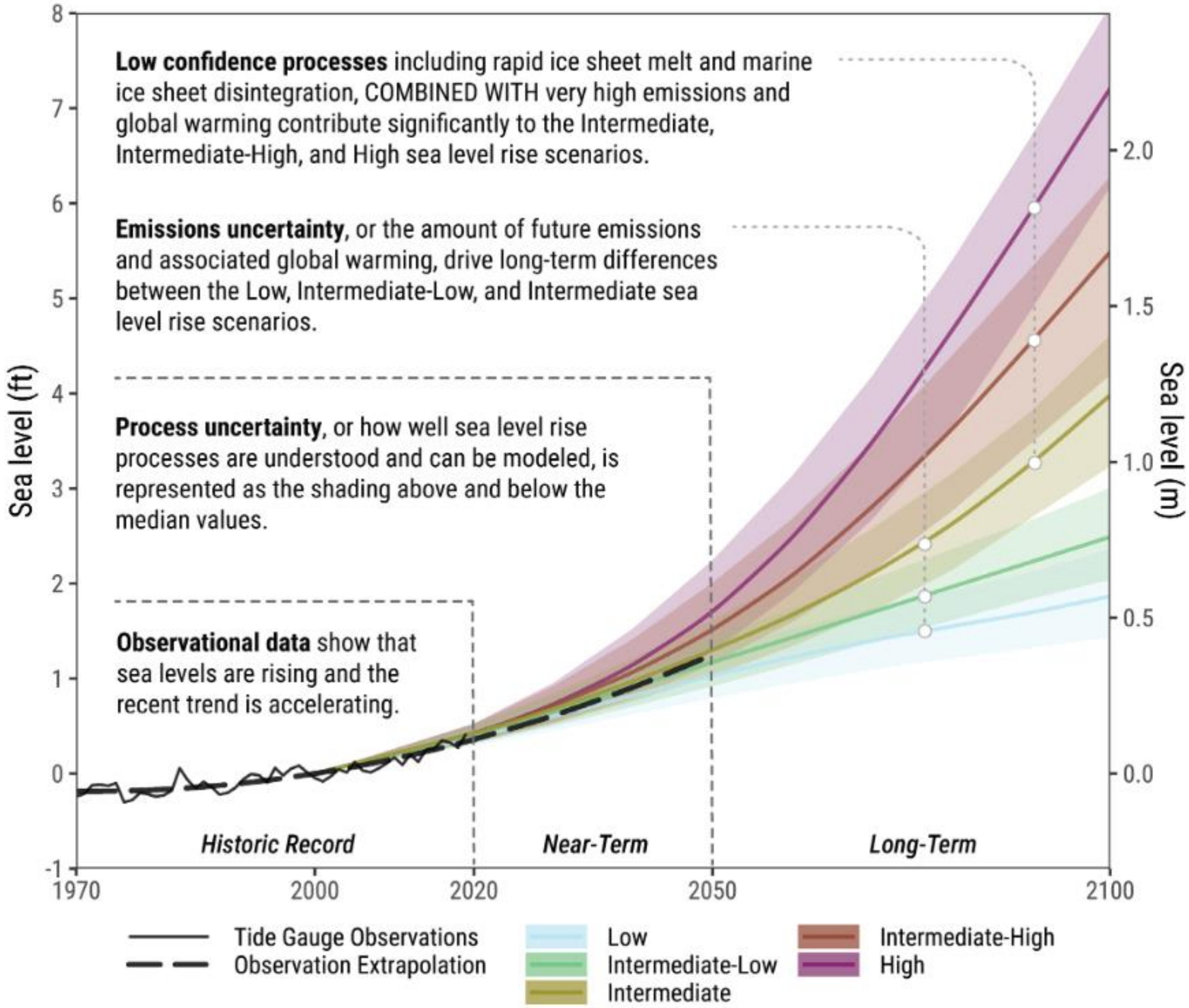
Higher rates of sea level rise could occur if greenhouse gas emissions continue to follow a very high emission scenario, coupled with rapid ice sheet melt and ice sheet disintegration (Collini et al. 2022; Sweet et al. 2022). The Federal Interagency Sea Level Rise Task Force will update the observation-based trajectories every five years, or as advancements in climate science occur. These updates will provide communities with information on future rates of sea level rise that will help guide climate adaptation decisions and the timing of future flood risk mitigation needs.

This BRIC 2023 project includes two feet of future sea level rise, in addition to the Title 44 Code of Federal Regulations Section 65.10 requirements for flood protection systems. The project is also considering future adaptability for higher rates of sea level rise. Therefore, a future implementation phase, likely near the end of the assumed 50-year project lifespan, may be required.



Source: (Collini et al. 2022)

Figure 7. Regional Sea Level Rise Scenarios and Observation-based Extrapolations for California



Source: (Collini et al. 2022)

Figure 8. Sea Level Rise Scenarios for the contiguous United States relative to the year 2000

5 Project Benefiting Area

The project benefiting area includes the Airport CDRZ, and the area around the Bay Farm Island Lagoon that would be removed from the FEMA SFHA (Figure 9). Although the Chuck Corica Golf Course is within the FEMA SFHA, this area is not included within the project benefitting area because the grades have been raised above elevation 10 feet NAVD88 to mitigate potential flood hazards (Figure 10). These activities occurred after 2018 FIRMs became effective. The residential homes in the vicinity of Maitland Drive are also not included within the project benefiting area. This area is low lying, with ground elevations that are 5 to 10 feet below the surrounding areas (at about mean sea level or below). This area would still experience stormwater driven flood risks after implementation of this project.

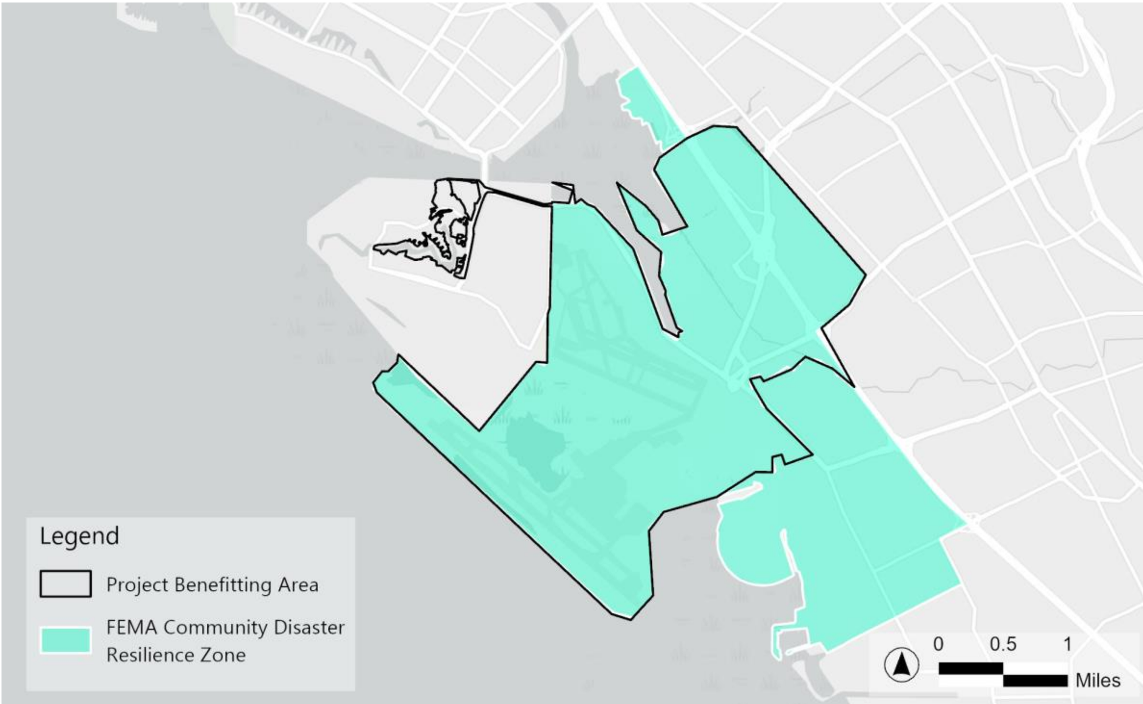


Figure 9. Project Benefiting Area

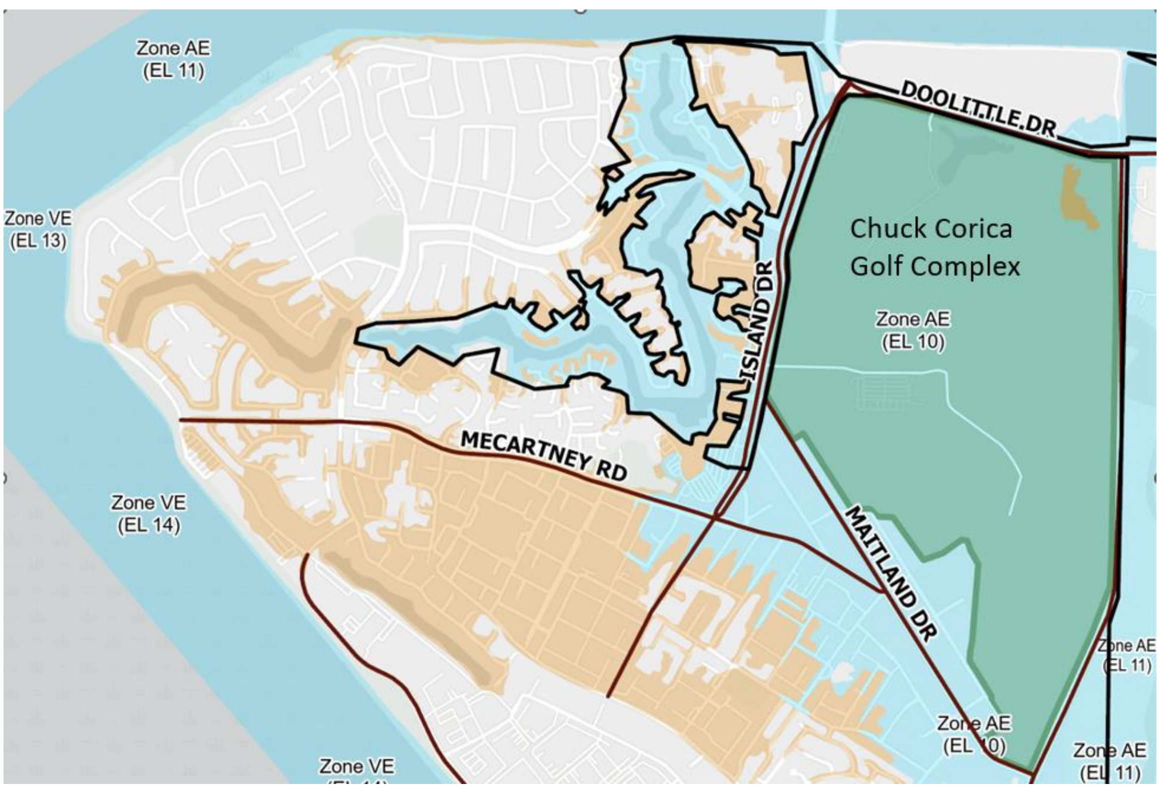


Figure 10. Project Benefitting Area on Bay Farm Island, City of Alameda

6 Mitigation Actions

Addressing existing and future flood risks requires a coordinated, multi-jurisdictional effort between the Cities of Oakland and Alameda, the Port of Oakland, Caltrans, EBRPD, community-based organizations (CBOs) including Tribal partners, and other local and state agencies. Together, these entities are collaborating to reduce existing and future flood risks with hybrid nature-based solutions and habitat enhancements along both estuarine and riverine shorelines. Led by the City of Alameda, the group is called the Oakland Alameda Adaptation Committee (OAAC). OAAC is paying CBOs as Community Partners to bring much-needed benefits to, and build capability and capacity in, underserved and marginalized communities within the project area.

This BRIC 2023 project includes mitigation actions that were developed through separate planning processes by the Cities of Alameda and Oakland, the Port of Oakland, and the EBRPD. The OAAC has brought these mitigation actions together as one cohesive solution to mitigate existing flood risks within the Airport CDRZ, as well as two feet of future sea level rise to provide future climate change resilience. Combining these projects together reduces project costs, provides opportunities to enhance project benefits, and maximizes the likelihood of achieving a comprehensive flood risk reduction solution.

The following sections describe the mitigation actions included within the overall project:

1. State Route 61/Doolittle Drive
2. Lagoon and Northern Bay Farm Island Shoreline
3. Veterans Court
4. Columbian Gardens
5. Lagoon System
6. Wetland Enhancements to Maintain and Reduce Flood Risks as Sea Levels Rise

Source: Google Earth Aerial Imagery

Figure 11 Flood Risk Mitigation Actions

6.1 The Airport and Bay Farm Island

6.1.1 State Route 61/Doolittle Drive

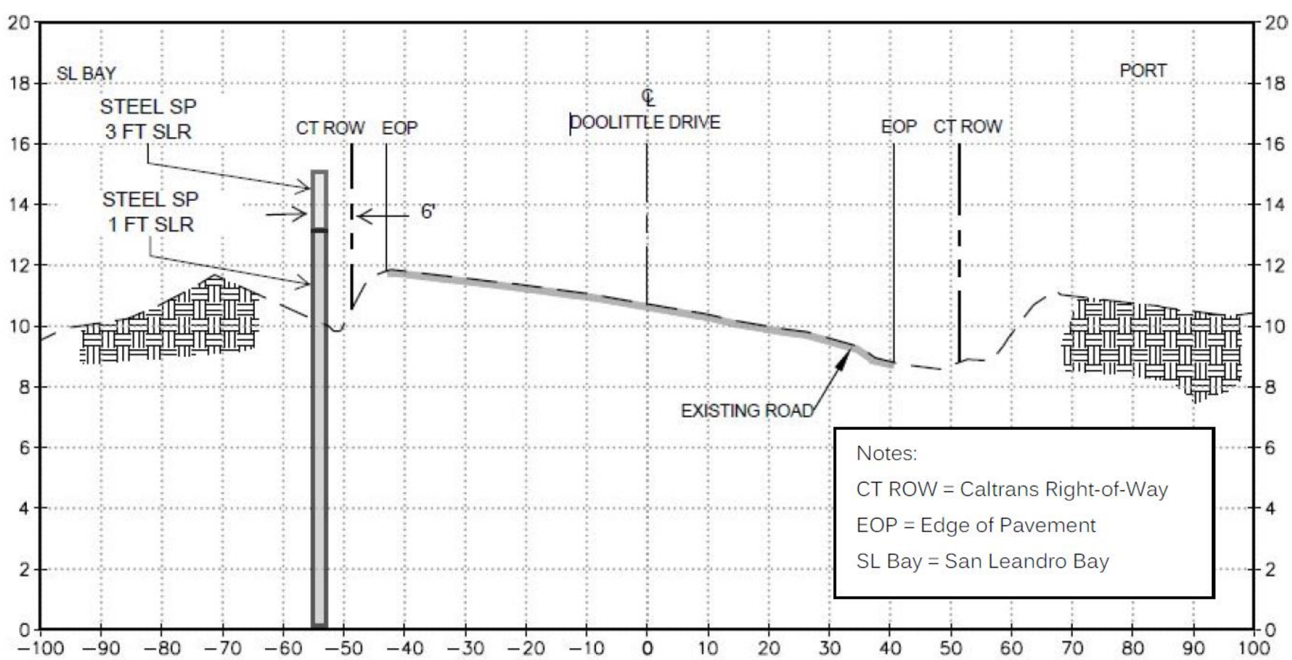
The Port of Oakland analyzed four project alignments to mitigate coastal overtopping along SR 61/Doolittle Drive (Item 1, Figure 11), as well as three potential flood risk reduction measures (i.e., sheet pile floodwall, earthen levee, and a concrete floodwall). The concrete floodwall was about twice the total costs of the sheet pile floodwall and earthen levee measures, respectively. The sheet pile floodwall and earthen levee have comparable total costs; however, the earthen levee requires a much larger project footprint. Constructing an earthen levee along SR 61/Doolittle Drive would either impact the highway, requiring roadway re-alignments to maintain traffic flow, or the earthen levee would require bay fill within San Leandro Bay, including filling the fringing marsh habitat which serves two endangered species, including the Salt Marsh Harvest Mouse and Ridgway's Rail (formerly California Clapper Rail).The sheet pile floodwall is a cost-effective solution and requires a minimal project footprint (i.e., horizontal cross section). The sheet pile floodwall would be constructed between SR 61/Doolittle Drive and San Leandro Bay. This project would close a half-mile gap in the San Francisco Bay Trail, providing an opportunity to increase safety for people walking and bicycling by eliminating the need to use the shoulder of SR 61/Doolittle Drive. The San Francisco Bay Trail is a planned 500-mile walking and cycling path around the entire San Francisco Bay, and this gap closure would create 17 miles of continuous trail. The flood walls' aesthetics would be enhanced with the use of a concrete cap. This solution is similar to that used by Foster City, California, on the eastern shore of San Francisco Bay to mitigate flood risks (Photo 5 and Photo 6). The Foster City project also provides recent, comparable construction costs (Foster City 2016, 2020a, b).

Photo Credit: San Mateo Daily Journal

Photo 5. Foster City San Francisco Bay Trail Before Project

Photo Credit: Riex, Flickr User

Photo 6. Foster City San Francisco Bay Trail After Flood Risk Mitigation Project



Source: (Port of Oakland 2023)

Figure 12. Sheet Pile Floodwall (Outboard of Doolittle Drive) Example Cross Section

Table 1. Doolittle Drive (State Highway 61) Construction Costs

Item	Length (feet)	Cost	Unit	Construction Cost
Sheet Pile Floodwall	5,000	$1,095	LF	$5,475,000
Concrete Cap	5,000	$300	LF	$1,500,000
Flood Break Structure (1)	60	$12,000	LF	$720,000
Class 1 Bike Lane / Roadway Improvements	3,000	$1,736	LF	5,208,456
Subtotal				$12,605,929
40% Soft Costs				$5,042,372
Total Construction Costs				**$17,648,300**
Maintenance (50 years)				**$3,781,799**

Source: (Foster City 2020a; Port of Oakland 2023)

6.1.2 Lagoon and Northern Shoreline

The northern Bay Farm Island shoreline, from Veterans Court to the northwest corner, would be improved by raising the shoreline elevation and the associated SF Bay Trail with an 18-foot-wide earthen levee (Item 3, Figure 11). In areas where erosion is occurring, existing rock riprap will be re-used on site, and ecological armoring will be used to augment the existing rock slop protection. The use of engineering with nature to mimic natural processes and increase the resilience of flood protection infrastructure is a growing practice within FEMA and USACE (Bridges et al. 2021; Holmes et al. 2022; FEMA 2023d). The Port of San Diego used bio-enhanced concrete to construct ecological enhancements of riprap areas protecting the shoreline adjacent to the San Diego International Airport (Krasna and Rella 2023). In addition to erosion and slope protection, the project provided a solution that mimicked natural rock pools and provided habitat that increased shoreline biodiversity (Krasna and Rella 2023). The Port of San Francisco is currently conducting a living seawall pilot study, with a goal of enhancing biodiversity along coastal and marine infrastructure (USACE 2024). (Bridges et al. 2021; Holmes et al. 2022; FEMA 2023d)

Table 2. Lagoon and Northern Shoreline Construction Costs

Item	Length (feet)	Cost	Unit	Construction Cost
Earthen Levee	4,500	$990	LF	$4,455,000
Ecological Armoring	2,000	$400	LF	$800,000
Subtotal				$5,255,000

Item	Length (feet)	Cost	Unit	Construction Cost
40% Soft Costs				$2,102,000
Total Construction Costs				$7,357,000
Maintenance (50 years)				$1,576,500

Source: Moffatt & Nichol 2023

6.1.3 Veterans Court

At Veterans Court (Item 2, Figure 11), the existing cul-de-sac will be moved about 250 feet to the south, providing space to expand the wetland area in the relatively sheltered cove surrounding the Bay Farm Island Bridge (SR 61) touchdown on Bay Farm Island (Figure 13). An earthen levee with 18-foot-wide Bay Trail would be constructed along the existing SF Bay Trail alignment, between the Harbor Bay Club tennis course and San Leandro Bay.

Caption: the levee and wetlands would cross under the Bay Farm Bridge (SR 61). The above graphic is for illustrative purposes only.

Figure 13. Veterans Court Shoreline Realignment and Flood Risk Mitigation Actions

Table 3. Veterans Court Construction Costs

Item	Length (feet)	Cost	Unit	Construction Cost
Earthen Levee	800	$1,100	LF	$880,000
Ecological Armoring	400	$400	LF	$396,000
Wetland Expansion	0.5 (acre)	$1,000,000	acre	$500,000
Subtotal				$1,776,000
40% Soft Costs				$710,400
Total Construction Costs				$2,486,400
Maintenance (50 years)				$532,800

6.2 East Oakland (Columbian Gardens)

The mitigation actions described below in Section 6.2.1 and Section 6.2.2 are recommended for stormwater flood risk reduction and air quality benefits as part of the BRIC 2023 grant. Mitigation actions to address potential overtopping along San Leandro Creek during large storm events are not part of this BRIC 2023 grant. This flood risk should be evaluated separately by the City of Oakland.

6.2.1 Stormwater Flooding

The City of Oakland evaluated a range of alternatives to mitigate the stormwater flooding in the Columbian Gardens neighborhood (City of Oakland 2022). This area was found to have maintenance deficiencies related to debris collection, sediment deposition, and vegetation overgrowth. Nevertheless, even with improved maintenance, the conveyance capacity of the stormwater pipes and drainage channel was determined to be insufficient and a major source of flood risk. The City of Oakland performed detailed hydrologic and hydraulic modeling to develop and evaluate alternatives (City of Oakland 2022).

The preferred alternative includes constructing a bypass dual 18” storm drainpipe system along Cairo Road that will work with the existing storm drain system and drive flows into the channel. The drainage channel would be deepened to increase its capacity, and sheet pile walls would be constructed on either side of the channel to maintain the channel banks and reduce the likelihood of channel overtopping during extreme rainfall events (City of Oakland 2022). The channel would be deepened enough to allow unmaintained channel bottom overgrowth and vegetation, while still maintaining the required capacity for flood risk reduction. Allowing vegetation to remain within the channel is preferred over maintaining a clear, earthen channel bottom. Although this preferred option has a higher initial capital cost, the longer-term maintenance for vegetation overgrowth would be reduced; and there would be a higher likelihood that the channel would provide sufficient flood risk reduction during heavy rainfall events for the adjacent underserved community.

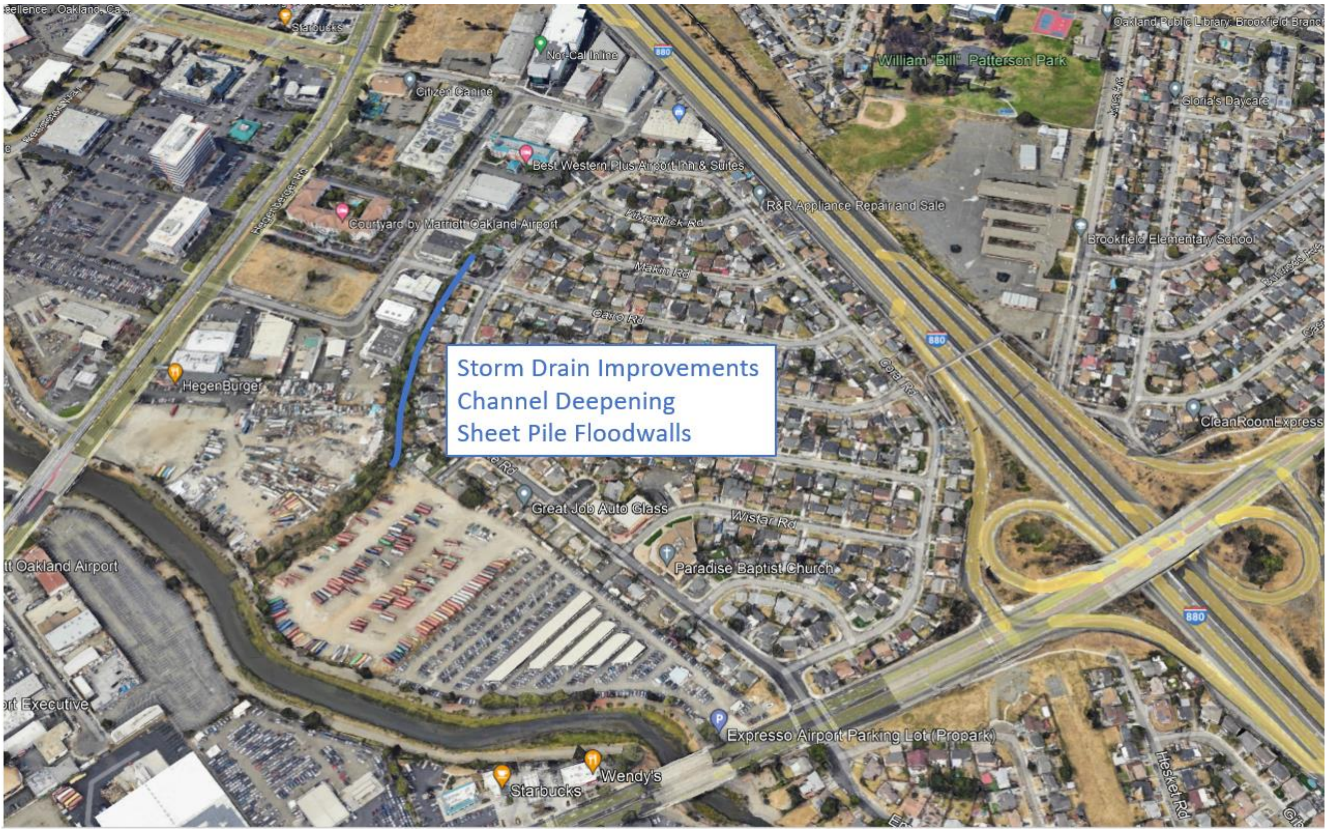


Figure 14. Columbian Gardens Flood Risk Mitigation

Table 4. Columbian Gardens Stormwater Flood Risk Reduction Construction Costs

Item	Length (feet)	Cost	Unit	Construction Cost
Dual 18" RCPs	475	$1,460	LF	$693,500
Channel Deepening	700	$1,000	LF	$700,000
Sheet Pile Flood Walls	1,400	$1,995	LF	$2,793,000
Subtotal				$4,186,500
40% Soft Costs				$1,674,600
Total Construction Costs				$5,861,100
Maintenance (50 years)				$1,255,950

6.2.2 Green Infrastructure

Columbian Gardens would also benefit from flow-thru bioretention areas (about 6 feet by 35 feet) to provide water quality treatment and stormwater retention (Figure 15 and Figure 16) (City of Oakland 2021; EONI 2021). The bioretention areas can include tree plantings to improve air quality and reduce the heat island effect during high heat days. The neighborhood is directly adjacent to Interstate 880 and is within a corridor of known poor air quality (EDF 2020, 2023). Truck traffic is banned on Interstate 580, which runs parallel to Interstate 880 but more inland near the Oakland hills. Interstate 880 carries the greatest volume of truck traffic in the Bay Area region and among any highway in California. The stretch of Interstate 880 near Columbian Gardens sees on average 200,000 vehicle trips per day.

Figure 15. Columbian Gardens Green Infrastructure Plan

Table 5. Columbian Gardens Green Infrastructure Construction Costs

Item	Number	Cost	Unit	Construction Cost
Bioretention Areas	60	$17,900	--	$1,074,000
Tree Plantings	104	$1,000	each	$380000
Subtotal				$581,600
40% Soft Costs				$1,674,600
Total Construction Costs				$2,035,600
Maintenance (50 years)				$436,200

Figure 16. Columbian Garden Bioretention Planters Example

6.3 Additional Bay Farm Island Flood Risk Reduction

6.3.1 Lagoon Stormwater Flood Risk Mitigation

Raising the low point along the shoreline at the lagoon tide gate and outfall will prevent coastal floodwater from overtopping the shoreline and causing inland coastal flooding (Section 3.1 and 6.1). However, additional mitigation actions of the lagoon operations are required to remove the inland properties along the lagoon shoreline from the FEMA SFHA. The mitigation actions include installing a pump station at the lagoon outfall to facilitate drawing down the lagoon at all stages of the tidal cycle, improving the tide gate structure, and installing emergency back-up power and controls for automatic operation during extreme events.

Table 6. Lagoon Stormwater Construction Costs

Item	Length (feet)	Cost	Unit	Construction Cost
Pump Station	--	$2,520,000	unit	$2,520,000
Tide Gate and Trash Rack	--	$364,000	unit	$364,000
Retaining Wall	50	$3,400	LF	$170,000
Emergency Power and Controls	--	$240,000	unit	$240,000
Subtotal				$3,294,000
40% Soft Costs				$1,317,600
Total Construction Costs				$4,611,600
Maintenance (50 years)				$988,200

Source: S&W 2015, project costs escalated to 2023 dollars

6.3.2 Northern Bay Farm Island Shoreline

Mitigation actions along the eroding areas of the northern Bay Farm Island shoreline are included within the construction costs for the Lagoon and Northern Shoreline (Section 6.1.2). Economies of scale can be achieved by completing this stretch of shoreline mitigation at the same time, and addressing the shoreline erosion will increase the overall resilience of the Bay Farm Island mitigation actions.

6.4 Wetland Enhancement for Flood Risk Reduction

In addition to the 0.5 acres of wetland enhancement and expansion at Veterans Court (Section 6.1.3 and Figure 13), additional wetland enhancement is required to maintain flood risk reduction. The Port of Oakland conducts routine dredging to maintain the channel and turning basins adjacent to the Port of Oakland in the Oakland Alameda Estuary, which is outside of the project area. USACE currently dredges the Port of Oakland navigation channel to maintain water depths for container ships. This sediment has been beneficially used for upland placement, deposited in inland landfills, deposited in SF Bay, or deposited outside of SF Bay at a deep ocean disposal site. This sediment has also been reused to support wetland restoration along the SF Bay shoreline (i.e., beneficial reuse), most notably in the conversion of the Hamilton Air Field in Marin County to the Hamilton wetlands, which used about 7 million cubic yards of beneficially reused dredge material (Photo 7). Thin-layer sediment placement is a recognized strategy to enhance tidal marsh resilience to sea level rise (Raposa et al. 2020; Mohan et al. 2021).

USACE is completing an Integrated Feasibility Study and Environmental Assessment for widening the turning basins, which will produce additional dredged sediment for potential beneficial reuse (USACE 2023). The SF Bay Area has lost 85% of its tidal marsh to development and filling of former marshes and Baylands over the past 150 years, and protecting and enhancing these vital ecosystems is important for long-term resilience in the Bay Area (CSCCC and OPC 2010; Goals Project 2015; SFEI & SPUR 2019; SFEI 2021). Save the Bay, a non-profit foundation, has a goal of restoring 100,000 acres of tidal marsh in the Bay.

Photo Credit: USACE

Photo 7. Hamilton Airfield Wetland Restoration, Novato, California

MLK Jr Regional Shoreline Park and San Leandro Bay provide vital tidal marsh and open water habitat to thousands of birds. Until 1938, San Leandro Bay and its 1,800 acres of tidal marsh were a wildlife paradise, protected as a state wildlife reserve. However, the construction of the Oakland Coliseum Complex, Interstate 880, and the Airport left only 76 acres of tidal marsh remaining by 1986. The Port of Oakland deeded the remaining wetlands, as well as additional 72 acres of restored wetlands, to

EBRPD to complete the MLK Jr Regional Shoreline Park. The park offers magnificent views of the wetlands as well as hiking and biking trails. The park is visited by about 300,000 people per year, including by community members from the nearby underserved neighborhoods.

Arrowhead Marsh dissipates wave energy when the wind fetch is aligned with the San Leandro Airport Channel, and the entire marsh complex also improves water quality in this highly industrialized area. Fringing wetlands enhance the lifespan of shoreline flood protection infrastructure while providing a host of other beneficial amenities (Bridges et al. 2021). Augmenting the marsh elevations with the beneficial reuse of sediment would protect shorelines, inland infrastructure, and communities from future sea level rise driven flooding. Increasing the marsh elevations would also preserve tidal marsh habitat under threat from sea level rise, supporting critical habitat for the endangered Ridgway's rail and salt marsh harvest mouse.

EBRPD, with local partners, recently repurposed the right-of-way along a portion of SR 61/Doolittle Drive and created a 2,300-foot multi-model paved and protected trail. To offset the impacts of this project, EBRPD restored one acre of salt marsh habitat at New Marsh. The construction associated with the flood risk reduction projects proposed by this Oakland Alameda Multi-Hazard Adaptation and Community Benefits Project will require more significant offsets. However, San Leandro Bay offers ample opportunities to offset the impacts within the project area, while also enhancing the flood risk benefits of the projects.

Figure 17 identifies wetland areas where thin sediment placement can provide habitat as well as flood reduction benefits. The Model Marsh Opportunity Area is an enclosed area with open water adjacent to the closed landfill and could be filled with dredged sediment to create additional salt marsh habitat, similar to New Marsh. provides approximate cost estimates for placing a thin layer (3 to 5 inches) of sediment on top of the existing marsh surface. Table 7 does not include costs to create salt marsh habitat in the Model Marsh Opportunity Area. For the benefit cost assessment, the higher end of the range shown in Table 7 was used.

The estimates include all costs associated with sediment placement but do not include the cost of dredging or transport of the material from the dredge location. Transport of the material to the project area could result in a significant cost savings to USACE due to the proximity of the project area to the Port of Oakland navigation channel, as opposed to transporting and depositing dredged sediment at the deep ocean disposal site. The Long-Term Management Strategy for the placement of dredged material in SF Bay has a goal of at least 40% of dredged sediment being beneficially reused (DMMO 2022).

Figure 17. Wetland Enhancement and Flood Risk Reduction Locations

Table 7. San Leandro Bay Wetland Area and Thin Sediment Placement Cost Estimate

Wetland Area	Acreage[1]	CY Sediment	Cost/CY	Sediment Place Cost
Arrowhead Marsh	45	18,000 – 30,050	$20	$363,000 – $605,000
New Marsh	35	14,000 – 23,500	$20	$282,000 – $470,000
North Fringing Marsh	5	2,000 – 3,500	$20	$40,000 – $67,000
South Fringing Marsh	4	16,00 – 2,700	$20	$32,000 – $54,000
Model Marsh[2]	16			
Subtotal				$718,000 – $1,200,000
40% Soft Costs				$287,000 – $478,000
Total Cost				$1,000,000 – $1,700,000
Maintenance (50 years)[3]				215,000 – 360,000

[1] Wetland acreage was estimated using ArcGIS and may not reflect EBRPD reported acreage.

[2] Model Marsh includes the creation of a new marsh in an enclosed area of open water. The cost of creating this marsh is not comparable with thin layer sediment and may be more comparable with the cost of restoring New Marsh. This cost is not included.

[3] Maintenance costs may include monitoring.

7 Literature Cited

AECOM (2014) Bay Farm Island Focus Area. Prepared by AECOM for the San Francisco Bay Conservation and Development Commission and the Alameda County Flood Control and Water Conservation District

Bridges TS, King J, Simm J, et al (2021) International Guidelines on Natural and Nature-Based Features for Flood Risk Management. Engineer Research and Development Center (U.S.)

City of Oakland (2022) City of Oakland Drainage Study: Empire Road and Bernhardt Drive Drainage Areas. Prepared by Wood Rogers for the City of Oakland

City of Oakland (2021) East Oakland Mobility Action Plan. Prepared by the East Oakland Collective, TransForm, and Just Cities for the City of Oakland

Collini R, Carter J, Auermuller L, et al (2022) Application Guide for the 2022 Sea Level Rise Technical Report. National Oceanic and Atmospheric Administration Office for Coastal Management, Mississippi–Alabama Sea Grant Consortium (MASGP-22-028), and Florida Sea Grant (SGEB 88)

CSCCC, OPC (2010) San Francisco Bay subtidal habitat goals report: conservation planning for the submerged areas of the bay. California State Coastal Conservancy and Ocean Protection Council 147–161

DHI (2011) Regional Coastal Hazard Modeling Study for North and Central San Francisco Bay. Prepared for the Federal Emergency Management Agency Region IX in support of the San Francisco Bay Area Coastal Study

DMMO (2022) 2021 Dredged Material Management Office Annual Report: Dredging and Placement of Dredged Material in San Francisco Bay: January - December 2021 Report. Prepared by the Dredged Material Management Office

EBRPD (2021) San Francisco Bay Trail Risk Assessment and Adaptation Prioritization. Prepared by WRT, ESA, Arup, San Francisco Estuary Institute, and OnClimate

EDF (2020) A Tale of Two Freeways. Prepared by the Environmental Defense Fund

EDF (2023) Air pollution and health in East Oakland. Prepared by the Environmental Defense Fund

EONI (2021) Better Neighborhoods, Same Neighborhoods, EONI Community Plan. Prepared by the East Oakland Neighborhoods Initiative

FEMA (2023a) Community Disaster Resilience Zones

FEMA (2023b) National Risk Index: Technical Documentation. Federal Emergency Management Agency

FEMA (2018) Alameda County Flood Insurance Study. Federal Emergency Management Agency

FEMA (2023c) National Flood Hazard Layer Viewer

FEMA (2023d) Engineering with Nature: Alternative Techniques to Riprap Bank Stabilization. In: Federal Emergency Management Agency. https://www.fema.gov/pdf/about/regions/regionx/Engineering_With_Nature_Web.pdf

Foster City (2016) Foster City Levee Protection Planning and Improvements Project: Draft Environmental Impact Report. Capital Improvement Project No. 301-657, State Clearinghouse No. 2016012012

Foster City (2020a) Foster City Levee Improvements Project Bid Tabulation Spreadsheet

Foster City (2020b) Foster City Levee Improvements Project Final Plans

Goals Project (2015) The Baylands and Climate Change: What Can We Do. Baylands Ecosystem Habitat Goals Science Update 2015. prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA

Holmes R, Burkholder S, Holzman J, et al (2022) Integrating Engineering With Nature® strategies and landscape architecture techniques into the Sabine-to-Galveston Coastal Storm Risk Management Project. Integr Envir Assess & Manag 18:63–73. https://doi.org/10.1002/ieam.4434

Krasna R, Rella A (2023) Nature-inclusive shoreline protection installed in San Diego. ASCE From the Field

May CL, Mak M, Harris E, et al (2016a) Extreme Storms in San Francisco Bay – Past to Present. Federal Emergency Management Agency

May CL, Mak, M, Harris, E, et al (2016b) San Francisco Bay Tidal Datums and Extreme Tides Study. Prepared by AECOM for the Federal Emergency Management Agency Region IX and the San Francisco Bay Conservation and Development Commission

Mohan R, Piercy C, Welp T (2021) Thin layer placement for marsh enhancement: Planning, design, construction, and monitoring considerations. Shore & Beach 4–12. https://doi.org/10.34237/1008941

Port of Oakland (2021) The Economic Impact of the Port of Oakland. Prepared by Martin Associates for the Port of Oakland

Port of Oakland (2023) Stormwater Management and Tidal Flooding Vulnerability Assessment at North Field Oakland International Airport: Tidal Flooding Vulnerability Assessment. Prepared by Wood Rogers for the Port of Oakland

Raposa K, Wasson K, Nelson J, et al (2020) Guidance for thin-layer sediment placement is a recognized strategy to enhance tidal marsh resilience to sea level rise. Published in collaboration with the National Estuarine Research Reserve System Science Collaboratives

SFEI (2021) Ecotone Levees and Wildlife Connectivity: A Technical Update to the Adaptation Atlas. Publication #1037

SFEI & SPUR (2019) San Francisco Bay Shoreline Adaptation Atlas: Working with Nature to Plan for Sea Level Rise - Using Operational Landscape Units

S&W (2015) Bay Farm Island Lagoon Operations. Memorandum prepared by Schaaf & Wheeler for the City of Alameda, July 20, 2015

Sweet WV, Hamlington BD, Kopp RE, et al (2022) Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01, Silver Spring, Maryland

USACE (2024) Appendix J. Engineering with Nature. San Francisco Coastal Study Draft Integrated Feasibility Report and Environmental Assessment. Prepared by the US Army Corps of Engineers and the Port of San Francisco

USACE (2023) Oakland Harbor Turning Basins Widening: Draft Integrated Feasibility Report and Environmental Assessment. Prepared by the US Army Corps of Engineers