City of Foster City

LEVEE PROTECTION PLANNING AND IMPROVEMENTS PROJECT (CIP 301-657)

Basis of Design Overview

October 2016

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Table of Contents

Tables

Figures

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1. Overview

Foster City's eight-mile levee system spans from the City of San Mateo boundary on the north to the O'Neill Slough Tide Gate at the San Mateo/Belmont boundary to the south. The main function of the levee system is to provide flood protection; however, the Bay Trail situated on top of or immediately adjacent to the levee also serves as a regional recreational amenity.

In 2007 the U.S. Federal Emergency Management Agency (FEMA) recertified the Foster City levee system, determining that the levees met the National Flood Insurance Program (NFIP) requirements for levee accreditation. In 2014 FEMA completed the Central and South San Francisco Bay Coastal Flood Hazard Studies associated with the California Coastal Analysis and Mapping Project (CCAMP) that include hazards associated with tides and waves in the San Francisco Bay. The CCAMP studies found that Foster City's levees do not meet the required freeboard elevation for accreditation per Title 44 of the Code of Federal Regulations Section 65.10 (44 CFR 65.10).[1] Therefore the Foster City levee system will not retain the current accredited status when FEMA remaps San Mateo County for coastal flood hazards. It is anticipated that the new maps will become effective sometime in 2017.

Foster City's levees must be improved to meet FEMA requirements for accreditation and protect the residents of Foster City and San Mateo from flooding. The basis of design builds on the analysis of the levee improvement alternatives in the 2015 Foster City Levee Protection Planning Study and provides preliminary design for improvements based on additional field reconnaissance, detailed wave run-up calculations, and preliminary geotechnical investigations undertaken since October 2015. Specifically, the basis of design report documents:

1. Designated sub-reaches based on existing conditions along the levee;
2. Levee elevation deficiencies within each sub-reach;
3. Preliminary geotechnical conditions within each sub-reach;
4. Design constraints within each sub-reach;
5. Design alternative analyses and recommended improvement type within each sub-reach;
6. Preliminary structural design considerations;
7. Sea level rise adaptation measures; and
8. Preliminary cost estimates for basic flood protection and Bay Trail restoration.

The Basis of Design document will be modified and enhanced throughout the course of design development to be suitable for inclusion with the Conditional Letter of Map Revision (CLOMR) documents that will be submitted to FEMA for their concurrence before levee improvement construction begins.

[1] *BakerAECOM, "A Central San Francisco Bay Coastal Flood Hazard Study (San Mateo County, California) Coastal Analysis Report," July 25, 2014; and BakerAECOM, "A South San Francisco Bay Coastal Flood Hazard Study (San Mateo County, California) Study Report," May 7, 2014.*

1.1. Foster City Flood Hazard Mapping Status

For Foster City to regain its previous Zone X (protected by levee) status – that is, to prevent all 9,000 parcels within Foster City and 8,000 parcels within San Mateo from being included in a Special Flood Hazard Area (SFHA) – improvements to the existing levee system must be made. Foster City has accepted levee seclusion mapping to be able to remain in the Zone X designation for an indefinite period of time while the levee improvements are being made.

The goal of this designation is to defer flood hazard remapping while the City raises funds, completes design, and starts construction on levee improvements without impacting the residents with mandatory flood insurance policy requirements. The area presently incorporated into the FEMA seclusion zone shown as "Zone X Protected by Levees" is depicted in Figure 1-1.

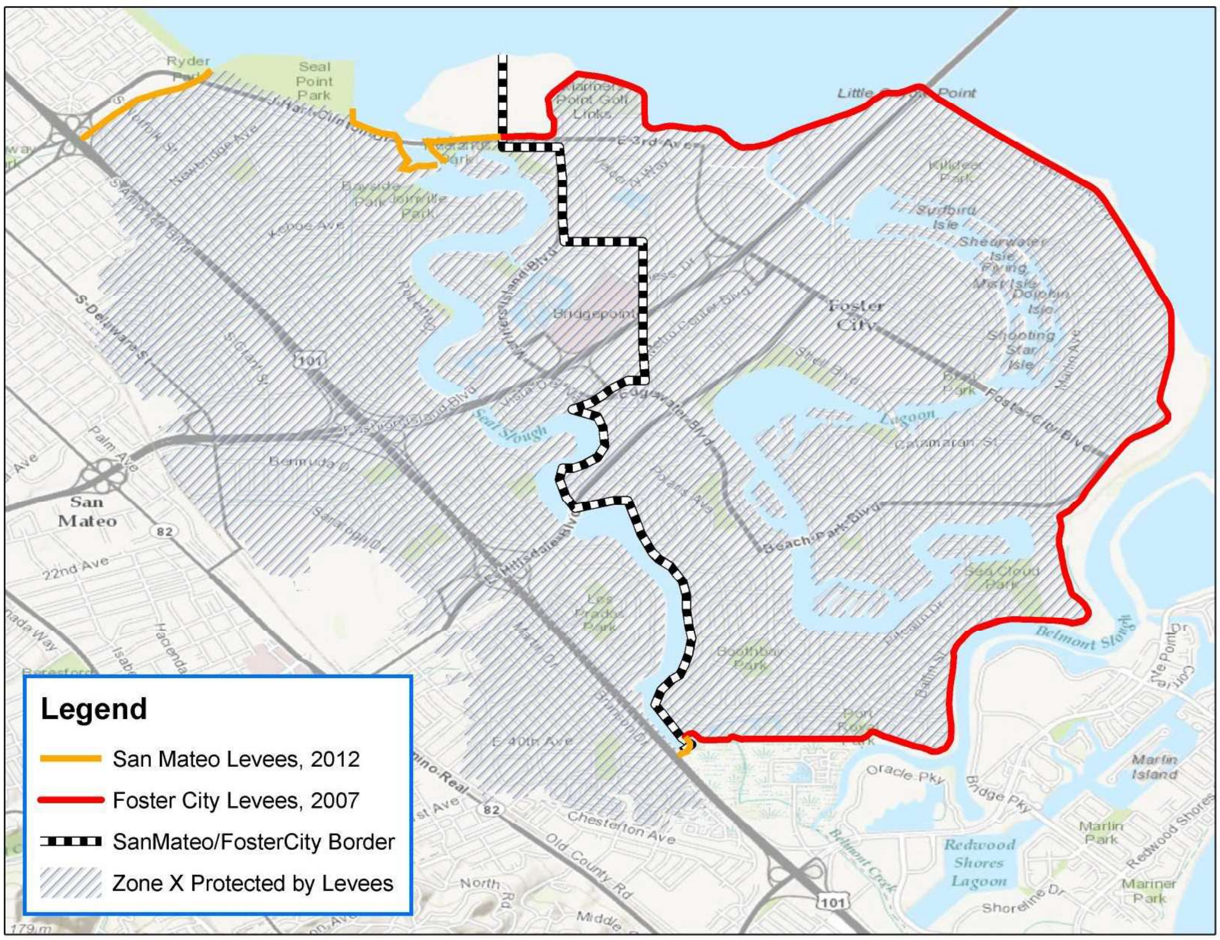

Figure 1-1: FEMA Seclusion Zone

In February 2015, Schaaf & Wheeler completed a Levee Protection Planning Study that analyzed the findings of FEMA's Coastal Flood Hazard Study. The planning study found that the Foster City Levees need to be raised up to four feet in some locations to meet FEMA requirements for freeboard.

Analyses in the CCAMP reports and FEMA's preliminary Flood Insurance Rate Map reflect changes in mean sea level that have occurred to date, but they do not account for potential future sea level rise (SLR). Since the levee improvement project is expected to function at least through to the 22nd Century, a flood protection facility that incorporates projections of future sea levels or is easily adaptable to those uncertain levels is desirable. To coincide with SLR projections for the Year 2100, an 80-year project life appears to be appropriate for consideration. Given the uncertainty inherent in future SLR predictions, levee improvements will be designed (at the least) to protect against likely Year 2050 SLR and could also be adaptable without substantial foundation rework to meet likely sea level projections for the Year 2100.

1.2. Design Assumptions

Initial cross sections from the 2015 Planning Study have been used to estimate the footprint of recommended levee improvements to meet FEMA requirements and to accommodate potential future sea level rise scenarios over an eighty year project life. The following assumptions are made for further planning and design to include additional freeboard above the top of levee elevation required for FEMA accreditation:

- Fill placement on the bayside should be limited due to permitting complexities.
- ENGEO will provide an estimate of the anticipated 30-year expected settlement. The anticipated settlement value will be added to the desired freeboard to determine the constructed levee elevation. Preliminary estimates of 30-year settlement are provided herein.
- Earthen levees shall be constructed at no steeper than a 2H to 1V bank slope.
- Levees will be designed to accommodate a 15 feet wide (minimum) pathway with a 10 feet wide paved section, although the minimum standard pathway width is 12 feet with an 8 feet wide paved section.

1.2.1. Sea Level Rise

To be consistent with current planning efforts underway by the Coastal Conservancy and County of San Mateo, sea level rise (SLR) scenarios are adopted from recent projections from the National Research Council (NRC).[2] Figure 1-2 provides the latest projected sea level rise curves from the NRC.

Table 1-1 summarizes sea level rise projections from the 2012 NRC Report, which have been adopted by the City and County of San Francisco and other Bay Area organizations for infrastructure planning and are used herein as the basis of design analysis for adaptive sea level rise measures. The projections (for example, 36 ± 10 inches in 2100) represent likely sea level rise values based on a moderate level of greenhouse gas emissions and extrapolation of continued accelerating land ice melt patterns, plus or minus one standard deviation. The extreme limits of the ranges (17 and 66 inches for 2100) represent unlikely but possible levels of sea level rise using both very low and very high emissions scenarios and, at the high end, including significant land ice melt that is currently not anticipated, but could occur.

[2] *National Research Council, Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past Present, and Future, National Academies Press, Washington, 2012.*

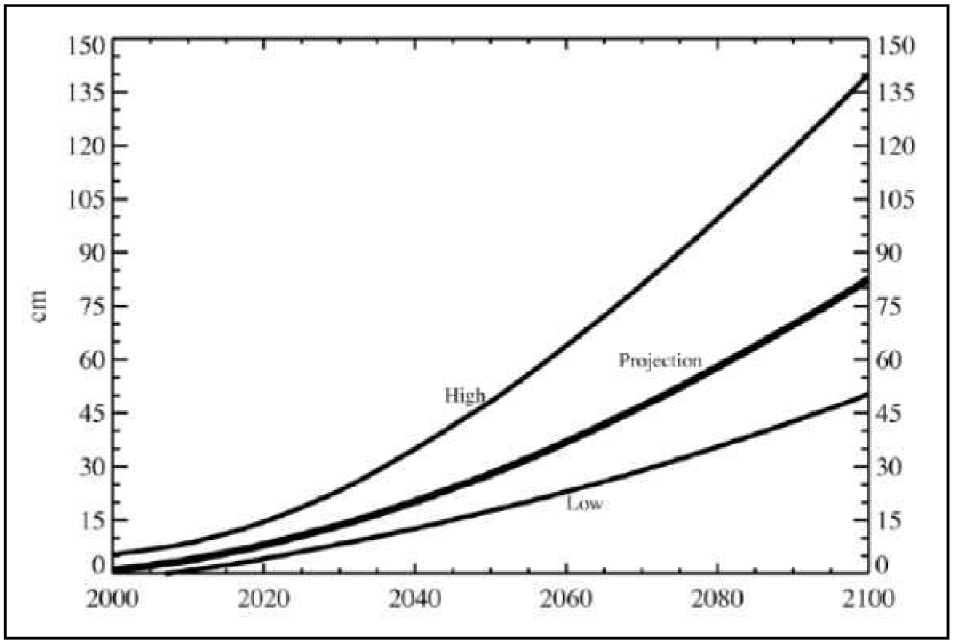

Figure 1-2: Sea Level Rise Projections

Table 1-1: Locally Adopted Sea Level Rise Estimates

Time Period	Projection (inches)	Range (inches)	Adopted for Planning and Design in Foster City
2000 – 2030	6 ± 2	2 to 12	8 inches
2000 – 2050	11 ± 4	5 to 24	15 inches
2000 – 2100	36 ± 10	17 to 66	46 inches

Creditable sources generally do not provide estimates of future sea level rise beyond 2100. Assuming the completion of levee improvements in 2020, any system designed to ultimately accommodate predicted SLR in 2100 would be said to have an 80-year design life. (This basis of design assumes that NFIP and FEMA standards for levee accreditation will remain unchanged over those 80 years.) At a minimum, it assumed that the design life without modification of this project is 30 years. Both options are investigated in terms of the protection afforded against predicted future sea level rise scenarios. Further environmental and economic analyses are needed to determine the option that best suits Foster City's needs. The basis of design report is one tool that can be used to help cultivate these analyses.

1.2.2. Levee Accreditation Standards for Design

Title 44 of the Code of Federal Regulations Section 65.10 (44 CFR 65.10) provides the minimum design, operation, and maintenance standards levee systems must meet and continue to meet to be recognized as providing protection from the base flood on a Flood Insurance Rate Map as part of the National Flood Insurance Program (NFIP). For levees to be accredited by FEMA, evidence that adequate design and operation and maintenance systems are in place to provide reasonable assurance that protection from the base flood exists must be provided.

For coastal levees such as those that provide protection against the San Francisco Bay, freeboard (a measure of safety above the top of the levee system) must be established at one foot above the height of the one percent wave or the maximum wave run-up (whichever is greater) associated with the 100-year surge elevation at the site. In Foster City the criterion for one foot of freeboard above the maximum wave run-up elevation generally controls the levee elevation requirements for those levee segments exposed to wind-waves from San Francisco Bay. Regardless of wave run-up, freeboard of less than two feet above the 100-year surge elevation will not be accepted for an accredited levee by FEMA. Two freeboard options are investigated for initial levee improvement design and construction:

- **FEMA + 2050 SLR.** This freeboard option would raise levees to FEMA requirements (including freeboard) plus additional freeboard to maintain the design level of protection after 30 years of settlement. The finished post-construction elevation would account for predicted settlement and provide protection against increased one-percent stillwater elevations and wave run-up due to 15 inches of future sea level rise.

- **FEMA + 2100 SLR.** This freeboard option would raise levees to FEMA requirements (including freeboard) plus additional freeboard to maintain the design level of protection after long-term settlement has occurred, which is anticipated to be largely completed within 30 years of construction, similar to the FEMA + 2050 SLR scenario. The finished post-construction elevation would account for predicted settlement and provide protection against increased one-percent stillwater elevations and wave run-up due to 46 inches of future sea level rise, which is projected as the "likely" 2100 global mean sea level rise. Some state agencies, based on NRC predictions, have advised providing protection for up to 66 inches of sea level rise by Year 2100.

In addition to required freeboard, levee systems must be evaluated for their ability to resist the various structural loads placed on them, and with earthen levee systems, meeting geotechnical performance standards is paramount. These standards are also explicitly stated in 44 CFR 65.10:

- **Embankment protection.** Engineering analyses must be submitted that demonstrate that no appreciable erosion of the levee embankment can be expected during the base flood, as a result of either currents or waves.
- **Embankment and foundation stability**. Engineering analyses demonstrating levee embankment stability must be submitted. The analyses shall evaluate expected seepage during loading conditions associated with the base flood and shall demonstrate that seepage into or through the levee foundation and embankment will not jeopardize embankment or foundation stability.
- **Settlement**. Engineering analyses must be submitted that assess the potential and magnitude of future losses of freeboard as a result of levee settlement and demonstrate that freeboard will be maintained within the minimum standards.

Other NFIP levee standards for accreditation for design include:

- **Closures**. All openings must be provided with closure devices that are structural parts of the system during operation and design according to sound engineering practice.
- **Interior drainage**. An analysis must be submitted that identifies the source(s) of such flooding, the extent of the flooded area, and, if the average depth is greater than one foot, the water-surface elevation(s) of the base flood. This analysis was completed by Schaaf & Wheeler in 2014, which FEMA used to map the base flood elevation of the Foster City Central Lagoon.

1.3. Levee Improvement Types

Foster City Council has directed the Public Works Department to plan, design and construct a barrier system that protects Foster City from San Francisco Bay flooding hazards while meeting FEMA criteria for accreditation. The "no project" alternative is an option, but not considered herein, as this option would mean Foster City and portions of San Mateo are placed within a Special Flood Hazard Area, which does not meet the basic project objective.

1.3.1. Earthen Levee

The earthen levee improvement type is shown as Figure 1-3. The base of the improved earthen levee would be sufficient to support additional fill (shown dashed) that may be placed in future years to restore levee elevations lost to long-term settlement or to provide protection against future sea level rise for the life of the project. Earthen levees are a preferred alternative for maintaining views along the trail, providing access to the shoreline, and providing escape routes for wildlife during flood events.

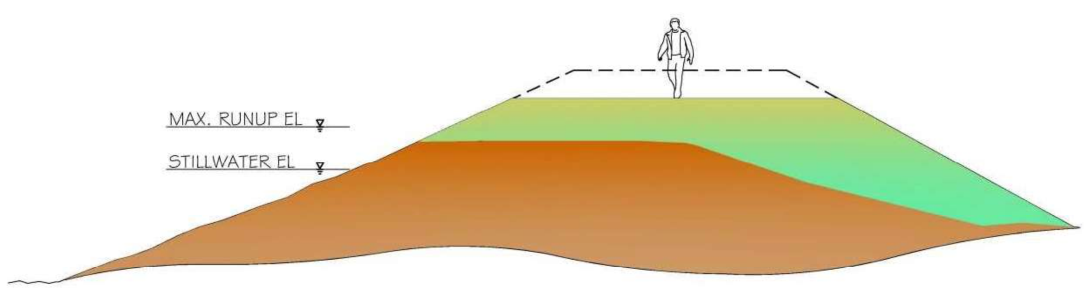

Figure 1-3: Typical Earthen Levee Improvement Type

1.3.2. Conventional Structural Floodwall

Structural floodwall sections are advantageous where there is not enough right-of-way to accommodate increased elevations and widening for an earthen levee. If seepage is an issue in the levee section below the floodwall, a slurry or sheet pile barrier also needs to be installed. Additional earthen fill (shown as green shading in Figure 1-4) can be added to increase the height of the trail and decrease the relative height of the wall so that the wall is no higher than 3.5 feet adjacent to the Bay Trail after long-term settlement. Assuming the base of the floodwall structure is designed to accommodate loads from future wall height increases (shown dashed), a structural flood wall is relatively easy to modify and adapt to future sea level rise.

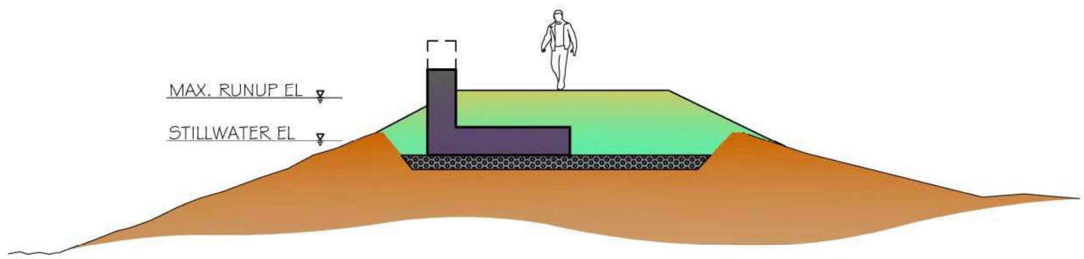

Figure 1-4: Typical Conventional Floodwall Improvement Type

1.3.3. Hybrid Sheet Pile Floodwall

During construction of a conventional structural floodwall (Figure 1-4), levee excavation is required to build the wall foundation. This could compromise the level of flood protection provided during construction, so a temporary sheet pile on the water side would be necessary. Rather than first install and later pull the sheet pile after conventional flood wall construction, this alternative uses sheet pile floodwall sections as the permanent flood protection facility, particularly where there is insufficient right-of-way for an earthen levee. Similar to the conventional floodwall improvement type, the trail could be raised with additional fill in locations where the finished floodwall elevation is higher than 3.5 feet above the trail. Fill placement is shown as green shading in Figure 1-5.

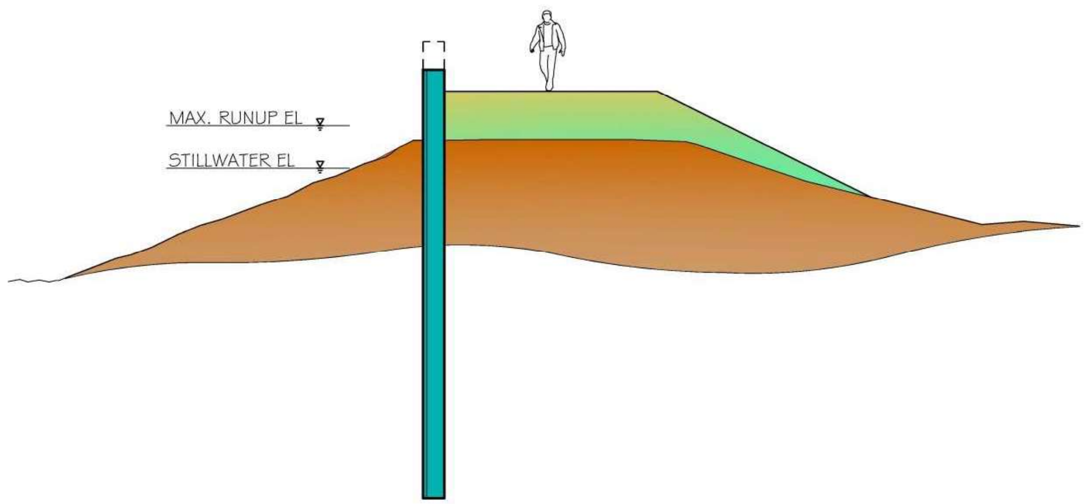

Figure 1-5: Typical Sheet Pile Floodwall Improvement Type

1.4. Public Safety and Appearance

Levee improvements need to be designed with considerations for both aesthetics and public safety. The preferred paved width of the reconstituted Bay Trail is 10 feet, with a minimum allowable paved width of 8 feet. It is essential that all improvements comply with the American with Disabilities Act (ADA) and fall protection must be provided in all areas where levee improvements create a potentially unsafe drop on the bay side of a vertical wall. The maximum allowable longitudinal grade along the trail is 5 percent.

Beyond the improvements needed for FEMA accreditation, the Foster City levee system is an important public amenity and as such must be palatable to the public to the maximum extent practicable.

1.4.1. Public Access to Bay Trail

Public access from surrounding streets must be maintained to the Bay Trail and suitable public access points to the Bay shoreline from the Bay Trail need to be maintained. There are numerous unauthorized access points along the trail that may be purposefully eliminated; and additional access points could be added to the design. The design will reflect feedback obtained during public outreach efforts as well as Bay Conservation and Development Commission (BCDC) requirements and input. Vehicular access to the trail for maintenance, firefighting, rescue operations, public safety and crime prevention is also important.

1.5. General Geotechnical Hazards

The Foster City levee system was constructed on reclaimed marsh land by placing fill over highly compressible clayey deposits, locally known as Bay Mud. The thickness and composition of manmade fill varies along the 8-mile levee system. Based on regional mapping and existing subsurface information, Bay Mud deposits along the 8-mile levee system vary between 40 to 90 feet thick. Bay Mud deposits are generally underlain by older alluvial deposits and bedrock, which is mapped by California Division of Mines and Geology (CDMG, 1969) to be as much as or greater than 180 feet below the ground surface.

The major geotechnical hazards related to levee improvements include:

- Global levee stability (under static and seismic conditions)
- Long-term settlement (settlement 30 years after construction is complete)
- Liquefaction
- Seepage

The impact of the above geotechnical hazards is dependent on the type of levee improvements (earthen fill, conventional floodwall or sheet pile hybrid solution) and the design levee height to achieve the desired flood protection goal. In general, long-term load induced settlement is anticipated due to placement of new levee fill along the majority of the 8-mile levee system.

1.6. Alternative Design Levee Elevations

Preliminary design focuses on providing the required top of levee (or floodwall) elevations to meet current NFIP/FEMA levee accreditation criteria for freeboard under the following scenarios:

1. CCAMP projections for the maximum wave runup associated with 100-year tide – “FEMA”
2. Projected 2050 Sea Level Rise (plus one standard deviation) – “2050 SLR”
3. Projected 2100 Sea Level Rise (plus one standard deviation) – “2100 SLR”

1.7. Environmental Considerations

The CEQA process includes the completion of an Environmental Impact Report and Notice of Determination. Required State environmental regulatory authorizations must be obtained from the San Francisco Regional Water Quality Control Board, San Francisco Bay Conservation and Development Commission, California Department of Fish and Wildlife, and State Lands Commission.

Project authorization cannot be obtained without:

- A determination from the lead agency that the project complies with CEQA
- Allowing for adequate public access
- Selecting the Least Environmentally Damaging Practicable Alternative
- Providing adequate mitigation for unavoidable impacts

Required Federal environmental regulatory authorization includes the US Army Corps of Engineers. Project authorization cannot be obtained without:

- Selecting the Least Environmentally Damaging Practicable Alternative
- Providing adequate mitigation for unavoidable impacts
- 401 Water Quality Certification from RWQCB
- Compliance with the Coastal Zone Management Act (BCDC)
- Endangered Species Act Section 7 Biological Opinion from the US Fish and Wildlife Service
- Endangered Species Act Section 7 Biological Opinion from NOAA Fisheries
- Compliance with Magnuson-Steven Fisheries Management and Conservation Act
- Compliance with Section 106 of the National Historic Preservation Act (SHPO)

1.8. Initial Screening of Levee Improvement Alternatives

A number of levee improvement alternatives combining the three levee improvement types have been evaluated for initial screening based on capital cost, environmental impact and aesthetics. The use of what is known as a “horizontal levee” or “ecotone slope” for the open water portion of the levee system outside of Belmont Slough has also been evaluated. Figure 1-6 presents the estimated initial construction cost of the following alternative levee improvement concepts:

1. Hybrid Construction for FEMA Accreditation
2. Hybrid Construction for 2050 SLR (30-year design life)
3. Hybrid Construction for 2100 SLR (80-year design life)
4. Hybrid Construction for Unlikely High Range 2100 SLR (80-year design life)
5. Foundation for 2100 SLR - Top of Levee Set for 2050 SLR (80-year design life)
6. Hybrid Construction for 2050 SLR/Adaptable to 2100 SLR (80-year design life)
7. Ecotone Slope for 2100 SLR (80-year design)

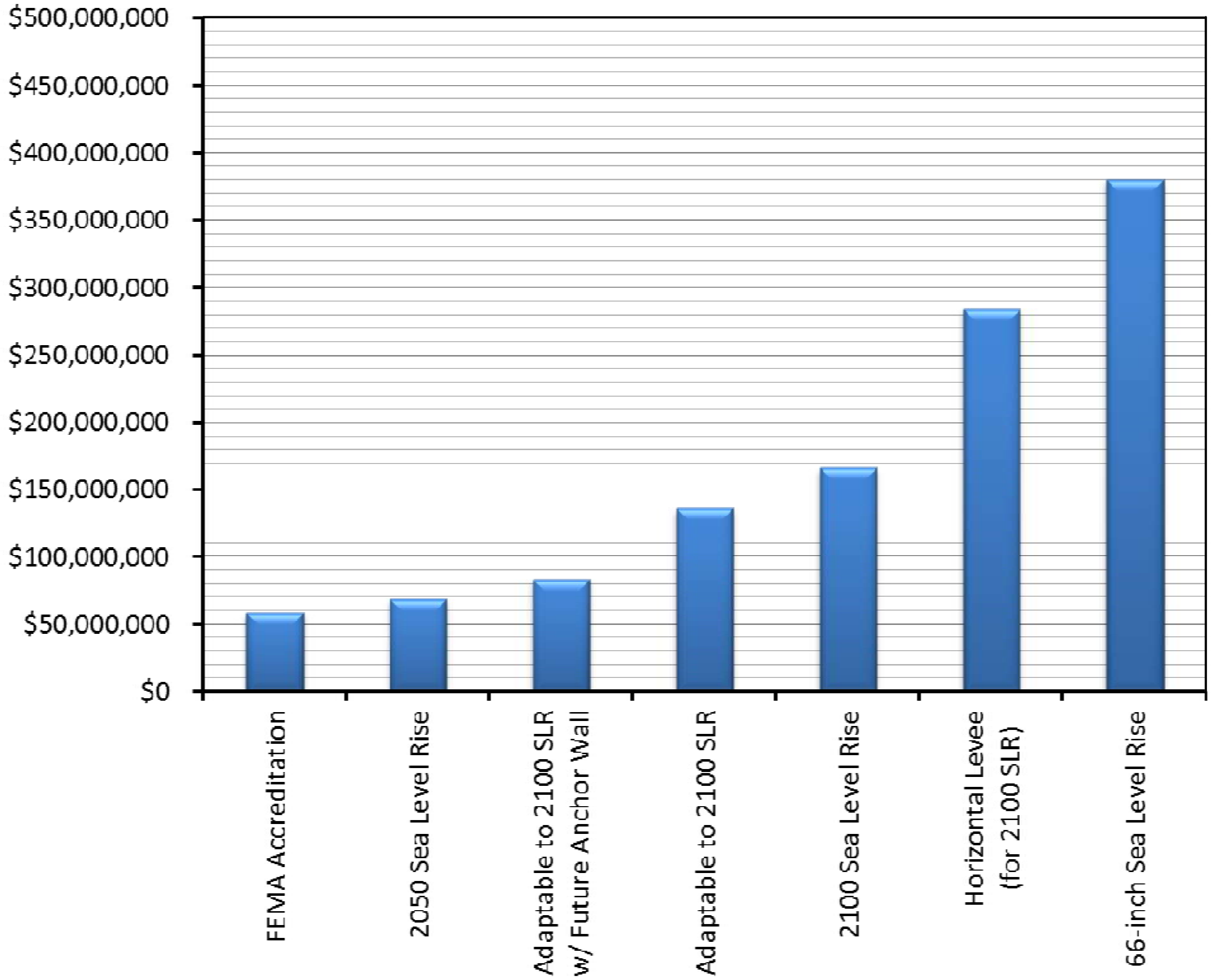

Figure 1-6: Comparison of Alternative Levee Improvement Costs

1.9. Levee Improvement Program

Based on the project constraints listed herein and as understood at this time, the most economic means to meet FEMA requirements for accreditation with an adaptive strategy for sea level rise is to construct a mix of hybrid levee improvement types as shown by Figure 1-7. Table 1-2 provides the percentage of each levee improvement type within the total system.

Table 1-2: Levee Improvement Type Summary

Improvement Type	Total Length (feet)	Percentage of Project
Hybrid Sheet Pile Floodwall	31,400	73%
Raise Earthen Levee	5,100	12%
No Improvements at High Ground	3,400	8%
Conventional Floodwall	2,900	7%
	42,800	100%

Figure 1-7: Recommended Levee Improvement Project

1.10. Summary

Through the initial filter of gross affordability, levee improvement options that can likely be built for $100 million or less in initial capital outlay are:

1. Hybrid Construction to Regain FEMA Accreditation ($60,000,000)
2. Hybrid Construction for 2050 SLR ($70,000,000)
3. Hybrid Construction for 2050 SLR/Adaptable to 2100 SLR ($90,000,000)

Most of the additional cost for an adaptable system involves the need for additional steel thickness in the sheet pile walls as the longer design life will result in a loss of additional material due to corrosion. City Council, however, may find that additional initial costs are justified to design a levee system that is more resilient to climate change. Selecting the levee elevations and system configurations for detailed design development is a two-step process:

1. Establish the levee elevation criterion for initial construction.
2. If an adaptable levee system is chosen; select the method of adaptation.

The levee elevation criterion will be based on the immediate environmental impact, particularly the increase in levee elevation relative to existing conditions, in context with the uncertainty of future sea level rise estimates when compared to the design life of the improvements. If an adaptable levee system is desired, the method of adaptation must consider the cost-effectiveness of initial and ultimate construction given that some capital expenditures may be deferred to a date uncertain.

Table 1-3 presents a decision matrix for selecting the levee elevation criterion for initial construction. Capital costs must be weighed against the design life and risk associated with a shortened design life due to higher than anticipated sea level rise. Surrogates for this risk assessment are the predicted years when FEMA freeboard (and therefore accreditation) would be lost, or when physical overtopping in a one-percent storm event would occur based on the NRC "unlikely but possible" sea level rise projections through 2100.

Table 1-3: Levee Elevation Design Criterion Decision Matrix

Set Levee Elevation for	Project Cost	Increase in Levee Height (feet)	Year Accreditation Lost based on High Range SLR	Year of First Overtopping based on High Range SLR
FEMA Accreditation	$60,000,000	0 - 4	Next FEMA Study?	2040
2050 SLR (15 inches)	$70,000,000	2 - 7	2040	2060
2100 SLR (46 inches)	$170,000,000	5 - 10	2075	2090

Table 1-4 presents a similar decision matrix for assessing the economics of providing adaptive resilience to sea level rise. Two methods for achieving this resilience have been evaluated:

1. Initially embed sheet pile wall sections for the projected Year 2100 loading with an 80-year design life. Add to the wall height in the future.

2. Initially embed sheet pile wall sections for 2050 SLR load and with an 80-year design life. Add to the wall height in the future and construct a secondary anchor wall to accommodate transferred loads from the floodwall. (Figure 1-8) Since some state agencies advise providing protection for up to 66 inches of sea level rise by Year 2100 and the cost of achieving this with the initial embedment of sheet piling is exorbitant (nearly $400 million), the initial cost of a deferred anchorage system for this scenario has been estimated.

Table 1-4: Adaptive Design Measures Decision Matrix

Method of Adaptation	Initial Project Cost	Future Cost	Total Present Worth
Deeper Initial Embedment	$140,000,000	$40,000,000	$180,000,000
Deferred Secondary Anchorage (projected 2100 SLR)	$90,000,000	$110,000,000	$200,000,000
Deferred Secondary Anchorage (unlikely but possible 2100 SLR)	$140,000,000	$200,000,000	$340,000,000

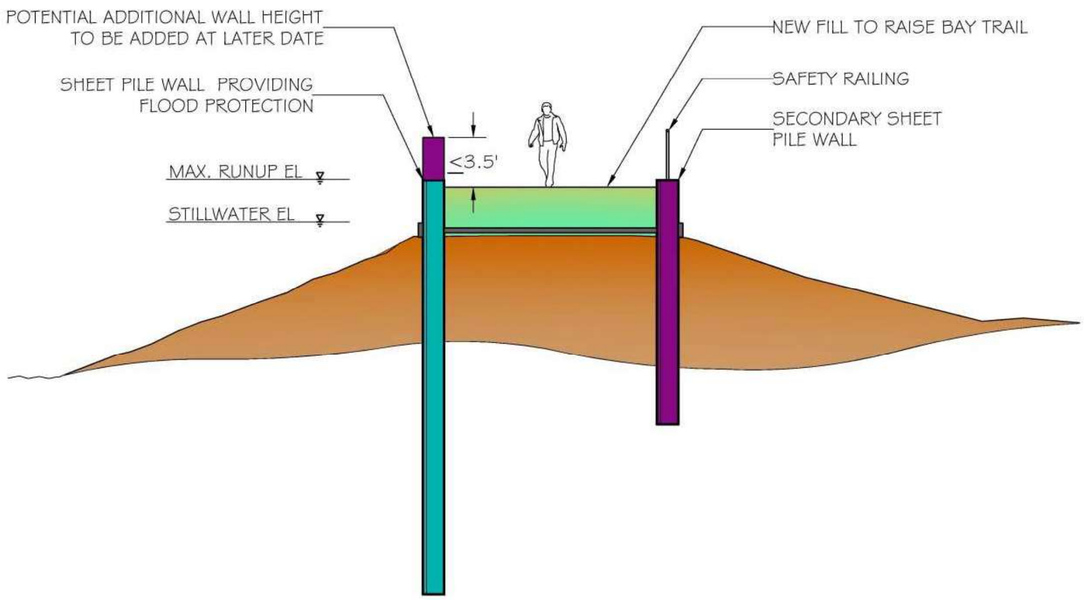

Figure 1-8: Concept for Levee Adaptation to Sea Level Rise

The "penalty" for deferring the construction of additional levee elevation to combat potential future increases in sea level is not particularly steep, representing about ten percent of the present value for construction.

Analysis does show that with slightly deeper sheet pile embedment at some locations, by initially embedding the sheet pile wall sections for the projected Year 2100 loading, protection against the unlikely but possible 66 inches of sea level rise could be afforded by building a secondary anchor wall. Also, with such extended levee heights using a second anchored wall is more cost-efficient than a single wall. The decision is whether the enhanced future design flexibility and resiliency justifies an additional initial capital outlay of $50 million, which increases the project cost and funding requirements by nearly 60 percent.

Perhaps future sea level rise will be worse or far worse than predicted, so capital expenditures made at this time in anticipation of the future are sufficiently uncertain as to be at risk. That is, the levee system would need to be completely rebuilt sooner than the end of the design life regardless of the decisions made now. At some point a regional solution may be the only viable alternative for protection against rising sea levels.

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