Memorandum

To:	Capital Planning Committee
From:	Elaine Forbes, Executive Director, Port of San Francisco Brad Benson, Waterfront Resilience Director, Port of San Francisco
Date:	September 12, 2022
Subject:	Draft Port of San Francisco Recommendations for City Coastal Flood Risk Reduction

Overview

The existing Capital Planning Committee ("CPC") sea level rise guidance is focused on analyzing flood risk and risk mitigation strategies for individual assets. City staff is now evaluating flood risk reduction strategies for the entire Bay shoreline under the jurisdiction of the Port of San Francisco ("Port"). For coastal areas outside of the Port's jurisdiction, other City agencies are developing projects to mitigate current and future coastal flood risk.

The systematic approach to managing flood risk along the entire shoreline is a fundamental shift to how sea level rise related flood risk is mitigated and funded, removing or reducing the burden of flood risk management from individual assets. However, this strategy requires a dedicated, coordinated, holistic approach to manage flood risk on a larger geographic scale. Port staff welcomes the input of the CPC as it further refines this approach to the broader challenge of making the Bay shoreline more resilient, including but not limited to the policy questions set forth in the final section of this memorandum.

Attached to this memorandum are draft Port Recommendations for City Coastal Flood Risk Reduction ("Draft City Flood Guidance"). The Draft City Flood Guidance are planning-level guidelines to inform the development of long-range adaptation strategies to mitigate coastal flooding from storms and sea level rise.

Draft Waterfront Adaptation Strategies

Reaching consensus on the Draft City Flood Guidance is a key task in supporting the broader planning effort of the Port's Waterfront Resilience Program. Based on public feedback and values gained through public engagement since 2018, the Port is now working with the U.S. Army Corps of Engineers ("USACE") and partner agencies including the San Francisco Municipal Transportation Agency, the San Francisco Planning Department, San Francisco Public Works, Office of Resilience and Capital Planning, and the San Francisco Public Utilities Commission to develop a range of draft coastal flood defense adaptation strategies (Draft Strategies) for the Port's entire 7½ mile jurisdiction, with a goal of selecting a preferred plan for coastal flood defenses informed by public preferences by mid-2023.

The Draft Strategies will develop options to reduce flood and seismic risk along the Port's entire waterfront jurisdiction, from Heron's Head Park to Fisherman's Wharf, through a combination of phased large and small projects and new policies. The Draft Strategies will include:

- The approximate location and height of the proposed coastal flood defense system
- Measures that the flood defense would be built out of, such as a seawall, levee, or nature-based feature
- The approximate area needed to gain elevation to reach the top of the coastal flood defense system, and implications on adjacent infrastructure, such as roadways, rail lines, utilities, and adjacent buildings
- Asset-specific strategies such as floodproofing or elevating buildings or infrastructure
- Policies such as new or updated emergency plans and warning systems, flood-resilient code updates, as well as land use and zoning changes.

The Port and USACE are working towards developing a draft preferred strategy ("Tentatively Selected Plan" or "TSP") by Summer 2023. The TSP will subsequently be developed to a greater level of design and engineering detail and will undergo environmental review (NEPA/CEQA), USACE review and approvals before Flood Study completion in 2025. The Final Project will be presented to U.S. Congress for potential federal funding of up to 65% of the total project cost.

Figure 1: Draft Waterfront Adaptation Strategies Development Schedule

Published Draft City Flood Guidance such as this may have implications for what USACE considers an acceptable plan, thereby strengthening the City's position when determining the basis for a construction cost sharing agreement.

Staff expects that after a preferred plan is identified and endorsed by the Mayor and the Board of Supervisors, it will take another decade or more to design, conduct environmental analysis, fund and construct future coastal flood defenses, meaning that construction of long-term flood defenses is not expected to occur until after 2030.

Managing coastal flood risk at a geographic scale requires a number of considerations that do not apply at the asset scale, including reliance of private property owners and public infrastructure systems on the effectiveness and useful life of coastal flood defenses. Thus, staff is recommending new Draft City Flood Guidance as a key tool to guide the planning work underway.

There are many considerations involved in developing coastal flood defenses, including the elevation (height), location, type, and future adaptability of such defenses. The Draft City Flood Guidance attempts to answer only one of these major considerations: the formula to determine the minimum elevation a project constructed as part of the long-term coastal flood defense system, which is based upon a combination of risk tolerance, functional life, and projections of future sea level rise.

Draft City Flood Guidance

Projections of future sea level rise are uncertain. The State of California's Ocean Protection Council ("OPC") (2018) and USACE (2013) have each published projections of future sea level rise, often referred to as sea level rise "curves", based on evolving understanding of climate change and its impacts on the temperature of the oceans and melting of ice sheets.

The Draft City Flood Guidance examines:

- Relevant criteria and guidance documents from other jurisdictions, including the Federal Emergency Management Agency ("FEMA") and the San Francisco Bay Conservation and Development Commission
- Updated sea level rise science from the 2022 Federal Sea Level Rise Task Force Report
- Recommended coastal flood risk reduction criteria to support program wide planning
- Overview of initial elevation studies to assess the feasibility of the recommendations
- Consideration of near-term flood risk reduction projects that may be built to a lower level of coastal flood risk reduction (i.e., allowing for early implementation of Prop A projects in advance of long-term adaptation planning)
- Consideration of Port and maritime assets that may have a higher flood risk tolerance (i.e., providing flexibility for maritime terminals and overwater piers)
- Consideration of critical infrastructure assets that may have a lower flood risk tolerance (such as the Embarcadero MUNI Tunnel)

The attached Draft City Flood Guidance was reviewed by the City's Sea Level Rise and Flood Hazard Coordinating Committee and all of their technical comments were addressed.

Flood Risk Management for the City, including Areas Inland of Port Property

While Port infrastructure including the Embarcadero Seawall and wharves play a significant role in defending San Francisco from coastal flooding today, the relevant sections of the City Charter governing the Port do not expressly contemplate a Port role in providing flood defenses to the City. Accordingly, Port staff is using this dialogue and the Draft City Flood Guidance to create a better working understanding of the Port's work within the context of the broader City flood risk management strategy.

Under the San Francisco Administrative Code, the City Administrator is the administrator of the San Francisco Floodplain Management Ordinance, which governs new construction and substantial improvements to properties located in high hazard flood zones designated by FEMA on its Flood Insurance Rate Maps for San Francisco. Properties located in these areas inland of Port property (primarily around Mission Creek and Islais Creek) are required to purchase flood insurance and to perform designated flood improvements for new construction or when making substantial improvements to existing structures.

Future coastal flood defenses, designed to meet standards for FEMA accreditation, could serve the purpose of 1) eliminating current high hazard flood designations on FEMA maps, and 2) avoiding mapping substantially larger areas of San Francisco as high hazard flood zones with future sea level rise.

Application of Draft City Flood Guidance

The calculation below depicts the effect of the Draft City Flood Guidance. The elevation of San Francisco's Bay shoreline is fairly constant along Port property, but there are variations. Elevations are measured relative to the North American Vertical Datum ("NAVD88").

Current mean high tide (excluding waves) along the Port's waterfront is just over 6' NAVD88. Shoreline elevations along most of the Port's waterfront range between 8.5-13' NAVD88. Extreme high tides (excluding waves) can exceed 9' NAVD88, which leads to periodic flooding of the Embarcadero Roadway and other areas of the Port, including areas around Islais Creek and Piers 94-96.

Future coastal flood defenses will need to manage extreme tides, waves and sea level rise. The Draft City Flood Guidance recommends taking into account the following water elevations to determine recommended elevations for projects that will be part of a long-term coastal flood defense system:

~6.2' Current average high tide (at Ferry Building)
\+ ~3.4' 1% annual chance extreme tide
\+ ~2' freeboard (minimum safety margin, required by FEMA)
\+ minimum 3.5' of sea level rise by 2100 (California OPC "Likely" curve)[1]

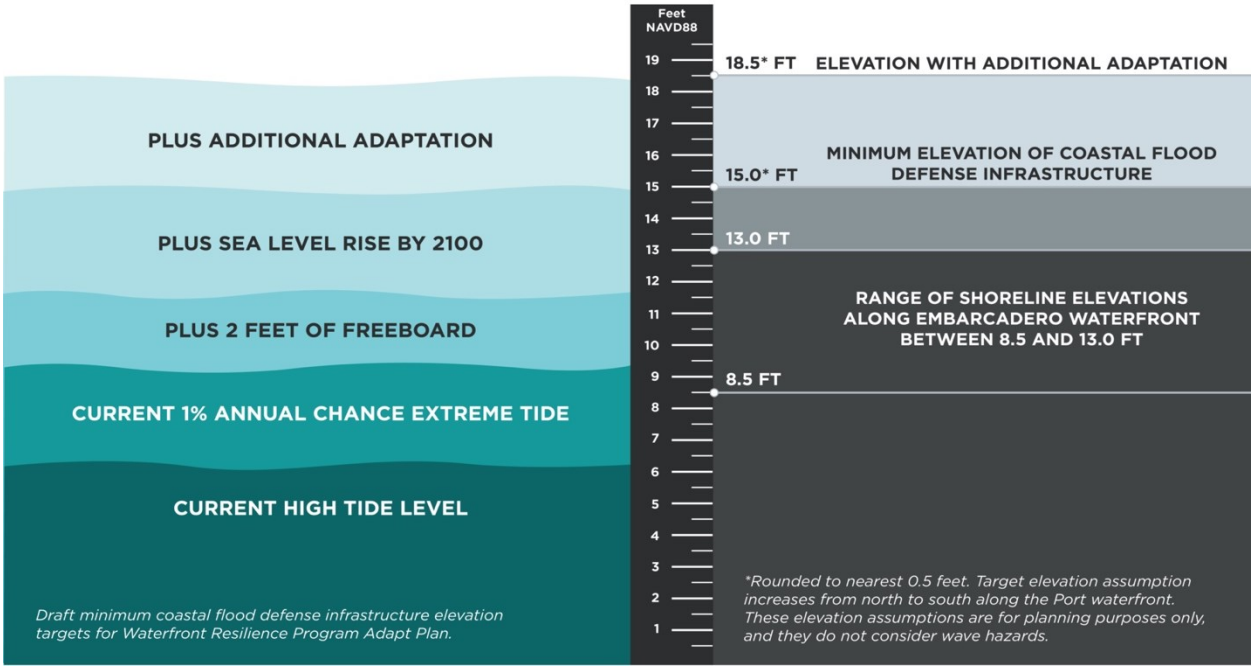
= ~15.1' elevation of future flood defense at Ferry Building (varies slightly across shoreline)

The Draft City Flood Guidance also recommends that flood defenses should be adaptable to manage water elevations under a low probability but high consequence scenario where sea levels rise up to 7' by 2100.

As shown in Figure 1 below, this calculation yields a flood defense system with an elevation of ~15' NAVD88 that is adaptable to ~18.5' NAVD88. For the elements of this system that are constructed along today's shoreline, this would mean elevating the shoreline by 2' to 5' on average and as much as 7' (e.g., the area just south of the Ferry Building), or more at specific low points.

[1] The Draft City Flood Guidance recommends selecting a higher sea level rise projection for future coastal flood defenses that are less adaptable to higher water levels, are designed to have a longer lifespan than 50 years or are designed to defend very critical assets and infrastructure.

FIGURE 1:
UNDERSTANDING COASTAL FLOOD DEFENSE INFRASTRUCTURE ELEVATION TARGETS ALONG THE EMBARCADERO WATERFRONT



The Draft City Flood Guidance is planning-level guidance to inform planning work currently underway at a geographic scale.

As the Port and USACE move closer to designing future coastal flood defenses, staff recommends revisiting the guidance to examine changes in understanding about rates of sea level rise and in the regulatory permitting regime to make sure that staff is designing coastal flood defense infrastructure that:

- provides the level of flood risk management that the City desires;
- can be permitted; and
- has a lifespan commensurate with the level of investment required to plan, design and build coastal flood defenses.

Design of coastal flood defense infrastructure will also be informed by coastal conditions at specific locations along the waterfront (e.g., where wave heights or wave runup are higher), which means that elevations will vary along the shoreline as projects are implemented over an extended timeline.

Policy Considerations for CPC

The Draft City Flood Guidance ties directly to a few high-level policy considerations related to risk tolerance, longevity of investment, and adherence to the Federal Flood Risk Management Standard as explored with policy consideration questions below:

- Water levels range from daily high tide to the 10-year, 50-year, 100-year storm and beyond. The Draft City Flood Guidance is to construct the coastal flood defense

infrastructure to protect against the 100-year coastal storm. This event has a 1% chance of occuring any given year or a 39% chance of occuring over a 50 year time period. This aligns with floodplain mapped through the National Flood Insurance Program.

- Should the City consider a smaller or bigger event as the baseline?
- Are there individual assets or areas of the City that require a higher level of protection?

- Uncertainty around sea level rise complicates planning and design for long life infrastructure, where balance needs to be struck between scale of change, longevity of investment, impacts during construction, and benefits provided. To address sea level rise uncertainty, an adaptive approach can be utilized to address risk in a stepwise manner, however, assumptions need to be made related to the minimum amount of time between steps.
    - Is a 50-year minimum functional life, before adaptation, sufficient for new coastal flood defense infrastructure?
    - Would a shorter functional life be acceptable if investment to reduce risk today provides the City with enough time to plan, design, fund and build longer-term coastal flood defenses?

- FEMA accreditation of the coastal flood defense allows for areas of the City to be removed from the floodplain when Flood Insurance Rate Maps are updated at an unknown point in the future.
    - Does the City want FEMA accreditation of the coastal flood defense system?
    - By what point in time does the City want to have an accredited system built?

The Draft City Flood Guidance is currently drafted for the bayside shoreline segments within in the Port's jurisdiction, however other area of the ocean and bayside shoreline face risks from sea level rise as outlined in the Sea Level Rise Vulnerability and Consequence Assessment completed in 2020.

- Should this Draft City Flood Guidance become a city-wide standard that is applied to all City coastal flood defense projects, regardless of agency ownership?
- If so, how should the guidance be enshrined in City policy or code?

Coastal Flood Risk Reduction Infrastructure will provide benefits and opportunity to several City Departments and will require substantial capital and on-going investment for operations and maintenance. The following are <u>long-range policy considerations</u> which the CPC members should begin deliberating and discussing:

- Which department(s) should serve as the owner and operator of this infrastructure, with responsibility for maintenance and liability?

- What sources are available for funding of ongoing maintenance and capital improvements for this infrastructure?

MEMORANDUM

Draft Port of San Francisco Recommendations for City Coastal Flood Risk Reduction

PREPARED FOR:	Sea Level Rise and Flood Hazards Coordinating Committee
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PROJECT NUMBER:	1.05.02.09

1 Introduction

The Port of San Francisco (Port) manages 7.5 miles of shoreline that includes a wide variety structures and infrastructure, including over water piers and wharves, buildings, bulkheads, marine terminals, roads, utilities, open space and parks, and historic resources. The Port's aging shoreline infrastructure has been very effective in preventing shoreline erosion and keeping San Francisco Bay (Bay) tides and storms from flooding Port and City and County of San Francisco (City) lands for more than a century. Over time, sea level rise and subsidence have reduced the level of coastal flood protection provided by the shoreline infrastructure. Without significant investment, coastal floodwaters will overtop the shoreline more and more frequently in the coming decades, flooding both Port and City land and causing damage and disruption.

The Port Waterfront Resilient Program is developing phased resilience actions to address both seismic and coastal flood risks along the Port-managed waterfront. The long-term goal of the program is to adapt the waterfront under the Port's jurisdiction, coordinated with regional and City-owned assets along the waterfront, to create a waterfront that is more resilient in the face of earthquakes and to reduce inland coastal flood risks that consider future sea level rise. A foundational assumption required for program planning is the level of coastal flood risk reduction that should be provided for the inland areas of the City of San Francisco (e.g., the level of flood protection provided for residents and businesses within areas that could be flooded as sea level rises in the absence of a project). Using a consistent assumption for the long-term level of coastal flood risk reduction will help the city achieve consistency along the shoreline.

The Port recommends that long-term coastal flood risk reduction projects meet or exceed existing Federal Emergency Management Agency (FEMA) requirements for accredited coastal flood risk reduction structures, while also complying with local and state guidance for sea level rise. The Port is seeking concurrence from other City departments regarding the flood risk reduction guidance recommendations. Once agreement is reached, a series of conversations will begin regarding the long-term financial commitments and responsibility needed to properly build, maintain, and adapt this infrastructure in the future as sea levels continue to rise.

To support the recommendations, this document presents:

- Relevant criteria and guidance documents that informed the recommendations

- Updated sea level rise science from the 2022 Federal Sea Level Rise Task Force Report: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines.
- Recommended coastal flood risk reduction criteria to support program wide planning, and recommended criteria for individual projects as they are phased over time[1]
- Overview of initial elevation studies to assess the feasibility of the recommendations
- Consideration of Near-Term Flood Risk Reduction Projects that may be built to a lower level of coastal flood risk reduction
- Consideration of Port and maritime assets that may have a higher flood risk tolerance
- Consideration of critical infrastructure assets that may have a lower flood risk tolerance

It is important to note that this document does not recommend a specific alignment for coastal flood defenses, nor does it recommend specific flood resilience structures or strategies. The alignment and range of strategies may include nature-based features, targeted retreat, and a wide-array of flood proofing measures. However, this guidance document is specific to the level of flood risk reduction to be provided. The alignment and the appropriate range of strategies will be selected and refined through a collaborative process with other city departments, stakeholders, and the public.

To promote cohesion across the city's shoreline, the Port recommends that coastal flood risk reduction projects implemented outside of the Port's jurisdiction adopt a similar approach as a best practice to provide a consistent level of coastal flood risk reduction for all San Francisco residents and businesses.[2]

2 Relevant Criteria and Guidance Documents

The Port recommends that coastal flood risk reduction projects meet or exceed the following federal criteria and state and local guidance. Note that these criteria and guidance documents are not necessarily additive.

- Federal Emergency Management Agency (FEMA) requirements for accredited coastal flood risk reduction structures. Flood resilience structures that are accredited by FEMA can remove protected areas from the special flood hazard areas on the FEMA Flood Insurance Rate Maps, thereby removing the mandatory requirement to purchase flood insurance. This requirement includes the greater of:

[1] Full implementation of coastal flood risk reduction projects along 7.5 miles of the shoreline are likely to take several decades, with projects implemented in phases. Although each individual project will not provide citywide coastal flood risk reduction on its own, each project will be a building block toward achieving citywide flood risk reduction. It is therefore important that each building block uses a consistent approach when selecting flood risk reduction and sea level rise criteria – or be able to adapt to meet or exceed the criteria to reduce the likelihood of gaps in the coastal flood risk reduction system.

[2] This recommendation is not intended to apply to the San Francisco International Airport, which has developed its own flood risk reduction and sea level rise design criteria and is hydrologically and geographically separated from the Port of San Francisco property. This recommendation is also not intended to apply to the open Pacific Coast side of the city, which has a lesser coastal overtopping -related flood risk based on the findings in the Citywide Sea Level Rise Vulnerability and Consequence Assessment.

  - The 1-percent annual chance coastal stillwater elevation[3] + 2 feet of freeboard
  - The 1-percent annual chance total water level[4] (including wave runup) + 1 foot of freeboard

- The Federal Flood Risk Management Standard (Executive Order 13690) was adopted in 2015 to improve the resilience to current and future flood risk across the United States by creating a new (higher) flood risk reduction standard for federally funded projects. The executive order provided options for compliance with the executive order, such as adding an additional foot of freeboard to the FEMA criteria to account for climate change, including increasing storm intensity (that is, the 1-percent annual chance event based on the historical record may underestimate future storm events), and accelerated sea level rise. This executive order was revoked in 2017 by Executive Order 13807, and re-instated in 2021 by Executive Order 14030 (Climate Related Financial Risk).

- California State Agencies co-developed six "Principles for Aligned State Action," where they were adopted as a goal by the San Francisco Bay Conservation and Development Commission. The principals recommend a planning assumption of 3.5 feet of sea level rise for all projects constructed prior to 2050, and a planning assumption of 7.0 feet of sea level rise by 2100 for roads, rail, ports, power plants, water and wastewater systems, and other critical infrastructure (California State Agencies 2020).

- California Ocean Protection Council (OPC) guidance, which recommends that projects consider a range of sea level rise values, including 3.4 feet (a likely value by 2100) and 6.9 feet (a lower-likelihood but plausible, high-impact value for 2100 that cannot be ruled out), and 10.2 feet (extreme sea level rise for 2100 resulting from loss of the West Antarctic ice sheet) along the sea level rise projection associated with the highest greenhouse gas emission scenario (Section 3) evaluated by IPCC in 2014 (OPC and CNRA 2018; Griggs et al. 2017; IPCC 2014). OPC guidance recommends consideration of the plausible, high-impact, and extreme sea level rise scenarios when adapting interrelated critical infrastructure, and for long-lasting projects with less adaptive capacity that would result in threats to public health and safety, natural resources, and critical infrastructure should sea level rise be underestimated. OPC guidance acknowledges the unique characteristics, constraints, and values of existing water-dependent infrastructure, ports, and Public Trust uses, particularly in densely developed coastal areas where managed retreat, nature-based solutions, and other strategies may not be feasible due to space or other constraints (OPC and CNRA 2018).

- Capital Planning Committee (CPC) guidance adopted in 2014 and updated in 2020, "Guidance for Incorporating Sea Level Rise into Capital Planning," which recommends that projects consider the functional life[5] of the structure when selecting the appropriate amount of sea level rise for planning and adaptation (CPC 2020).

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[3] The 1-percent annual chance coastal stillwater elevation is the extreme water level in the Bay, in the absence of waves, that has a 1-percent of occurring in any given year

[4] The 1-percent annual chance total water level elevation is the extreme water level in the Bay, in the presence of waves and wave runup along the shoreline, that has a 1-percent of occurring in any given year.

[5] Functional lifespan represents how long (in years) a project will continue to function as designed, including regular repair and maintenance.

3 Sea Level Rise Science

Climate change and sea level projections are regularly updated by the Intergovernmental Panel on Climate Change (IPCC), refined for use along U.S. coastal by the federal government, with recommendations and guidance provided at the state and local level for sea level rise adaptation and flood risk reduction projects. The IPCC released updated climate projections in August 2021 (IPCC 2021), and the Federal Sea Level Rise Task Force released updated sea level rise projections for the U.S. in February 2022 (Sweet et al. 2022). Although California state agencies have not yet released updated recommendation and guidance, the Port recommends the use of the latest science to guide program planning.

One scientific contribution of Sweet et al. (2022) is the exclusion of the Extreme (i.e., H++ in California state guidance) scenario. The uncertain physical processes such as ice-sheet loss that could lead to much higher sea level rise increases, such as 10.2 feet (H++) by 2100, are considered less plausible in the coming decades. However, the High scenario could reach this threshold in the decades following 2100 (and continue rising).

A second significant scientific contribution of Sweet et al. (2022) is the extrapolation of tide gage and satellite observations from 2020 to 2050, which provide enhanced insight on regional sea level rise trends (Figure 1). This extrapolation is made possible due to the increased number and length of available tide gauge and satellite altimetry records. Figure 1 presents the trajectory of mean sea level for the Southwest region of the U.S. (California, Arizona, and Nevada), which highlights that the current trajectory of sea levels along the California coast is currently aligned with the Intermediate scenario. Extrapolations beyond 2050 were not developed, as it is assumed that processes not fully represented in the observations from 1970 – 2020 could become dominant, thus altering the projections (Sweet et al. 2022).

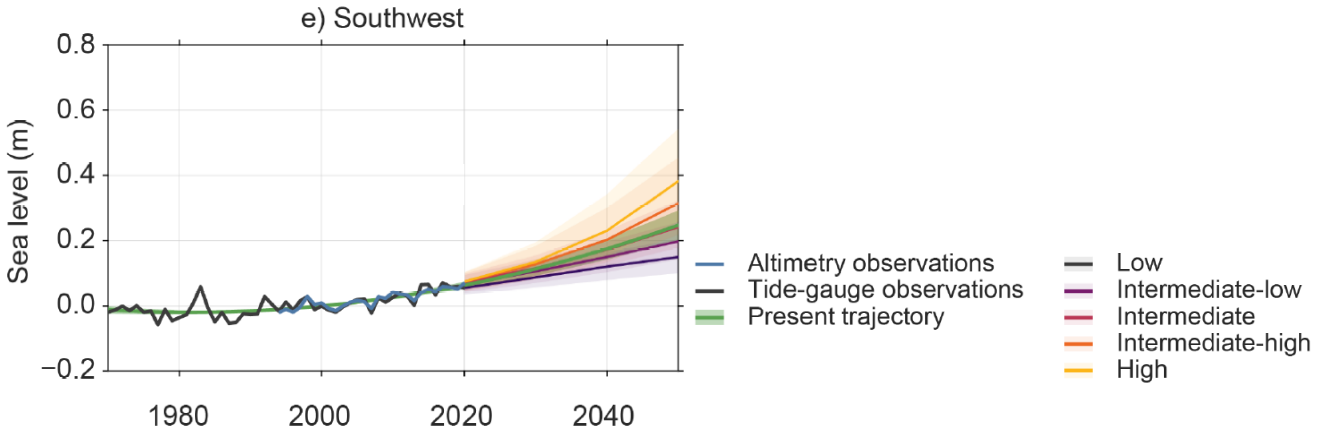

Figure 1. Observation-based extrapolations and five regionalized global mean sea level scenario projections [a], in meters, of relative sea level rise from 2020 to 2050, relative to 2000 baseline elevations.

[a] For reference, USACE low curve = Global low projection, USACE intermediate curve = Global Intermediate-low projection, and USACE high curve = Global Intermediate-high projections. CA OPC likely projection = Global intermediate scenario, and CA OPC 1:200 (plausible, high impact) = Global high scenario.

Although sea level rise trends after 2050 may not continue to trend with the Intermediate scenario, as shown in Figure 1, it is reasonable to assume that sea level rise is likely to continue along this trajectory or accelerate and trend along a higher scenario. Therefore, it is recommended that the low and intermediate-low scenarios are not utilized when planning flood risk reduction projects for San Francisco.

Table 1 presents current local and state projections for 2100 (based on IPCC (2014)) and the latest IPCC (2021) global projections, expressed as the "likely" and "plausible, high-impact" scenarios for consistency with existing local guidance. The numbers in Table 1 are associated with the highest modeled global emission scenario, RCP8.5 for IPCC (2014) or SSP5-8.5 for IPCC (2021). RCP8.5 and SSP5-8.5 are represented by a suite of global climate model simulations, often represented with a median value (50th percentile) and an uncertainty bound (5th to 95th or 0.5th to 99.5th percentile) of what is plausible, as shown in Figure 1. Within the California OPC Guidance, the likely scenario is defined as the upper end of the likely range (~83rd percentile) of model projections, and the plausible, high impact scenario is at the upper end of the uncertainty bound (~99.5th percentile) of what could occur along this same emissions trajectory based on the model simulations.

To date, the Port has used sea level rise projections shown in Table 1 as they all show excellent agreement. For simplicity, and to avoid implying a level of precision that is not warranted at the programmatic planning scale, the Port selected 3.5 feet of sea level rise for project planning, with future adaptative capacity capable of addressing 7 feet of sea level rise. If a project cannot easily be adapted in the future, a higher rate of sea level rise is used to inform project planning.

Table 2 presents the updated sea level rise projections from Sweet et al. (2022) relative to the five regionalized scenarios for California for 2100 and 2150. Using the updated projections, the Port's recommendations track closely with the Intermediate scenario, with flood risk resilience to 3.3 feet of sea level rise and adaptability to greater than 6.2 feet of sea level rise. If global climate change tracks along the High scenario, future adaptation would need to occur sooner than recommended herein (i.e., before 2100).

Table 1. Sea Level Rise Comparisons by Source for 2100

Source	2100 Likely	2100 Plausible, High-impact
City and County of San Francisco (local) (CPC 2020)	3.4 feet	6.9 feet
State of California (regional) (OPC and CNRA 2018)	3.4 feet	6.9 feet to 10.2 feet
Stage Agencies (regional)[a] (California State Agencies 2020)	3.5 feet	7.0 feet
Intergovernmental Panel on Climate Change (global) (IPCC 2021)[b]	3.3 feet	6.2 feet

[a] Recommended for use to support this Coastal Flood Risk Reduction Guidance

Table 2. Sea Level Rise Comparisons for California for 2100 and 2150

Sea Level Rise Scenario	2100	2150
Low (USACE Low)	1.0 feet	1.3 feet
Intermediate-low (USACE Intermediate)	1.6 feet	2.6 feet
Intermediate (~CA OPC likely)	3.3 feet	6.2 feet
Intermediate-high (USACE High)	4.9 feet	8.5 feet
High (~CA OPC 1:200; plausible, high impact)	6.6 feet	12.1 feet

Source: Sweet et al. 2022

4 Recommended Flood Risk Reduction Guidance

4.1 Program wide planning

The Port recommends using the following criteria for program wide planning. The program wide planning assumptions will allow the City to evaluate a range of adaptation strategies along the shoreline and develop a reasonable range of alternatives for completing the National Environmental Protection Agency and California Environmental Quality Act processes.

- Recommended planning horizon for programmatic planning
  - 2100 planning horizon. Although it is recognized that the flood risk reduction structures may have a functional lifespan beyond 2100, particularly as the structures will be implemented in phases over several decades, the use of 2100 as a planning horizon will allow the Port and the City to evaluate a broad range of potential structures along the complex San Francisco waterfront and shoreline. As individual long-term flood risk reduction projects are designed, the functional lifespan of each project will be considered (see Section 4.2).
- Recommended as the *minimum* criteria for coastal flood resilience projects
  - FEMA criteria (the greater of the two criteria for the 1-percent annual chance stillwater and 1-percent annual chance stillwater total water levels, plus the respective freeboard) + 3.5 feet of sea level rise (2100 likely scenario)
  - If the structure(s) are not readily adaptable to 7.0 feet of sea level rise (plausible/high-impact scenario), consider a sea level rise value greater than 3.5 feet
- Recommended adaptation criteria for coastal flood resilience projects
  - FEMA criteria (for 1 percent annual chance stillwater and total water levels, including wave runup) + 7.0 feet of sea level rise (2100 plausible/high-impact scenario, ~2150 likely scenario)

4.2 Individual Phased Long-Term Flood Risk Reduction Projects

The Port recommends using the same flood risk reduction guidance criteria for the design of each long-term coastal flood resilience project. However, the planning horizon should be set based on the planned construction completion year and functional lifespan of structure, considering engineering best practices and judgement in

assessing the structures functional lifespan, consistent with the CPC (2020) guidance for asset- and facility-based sea level rise adaptation. For example, if a project will be completed in 2050 with a functional lifespan of 80 years, the planning horizon would be 2130. Using best available sea level rise science *at the time of project planning*, sea level rise projections for 2130 would be selected and additive to the freeboard requirements for FEMA accreditation for the 1-percent annual chance water levels.

As each future phase is planned, designed, and implemented, the latest climate science, sea level rise projections, policies, permit requirements, and regulations should be reviewed to guide the selection of the appropriate sea level rise values and design criteria. Additional factors should also be considered when selecting design and future adaptation criteria, including historic preservation, public and water-based access, maritime use, public support, settlement, subsidence, geotechnical conditions, continuity with adjacent structures, and other objectives and drivers that are likely to arise during project planning, design, and implementation.

Figure 1 presents the process for translating the information into a flood resilience project elevation, assuming a planning horizon of 2100. The designed height of the structures may exceed this elevation.

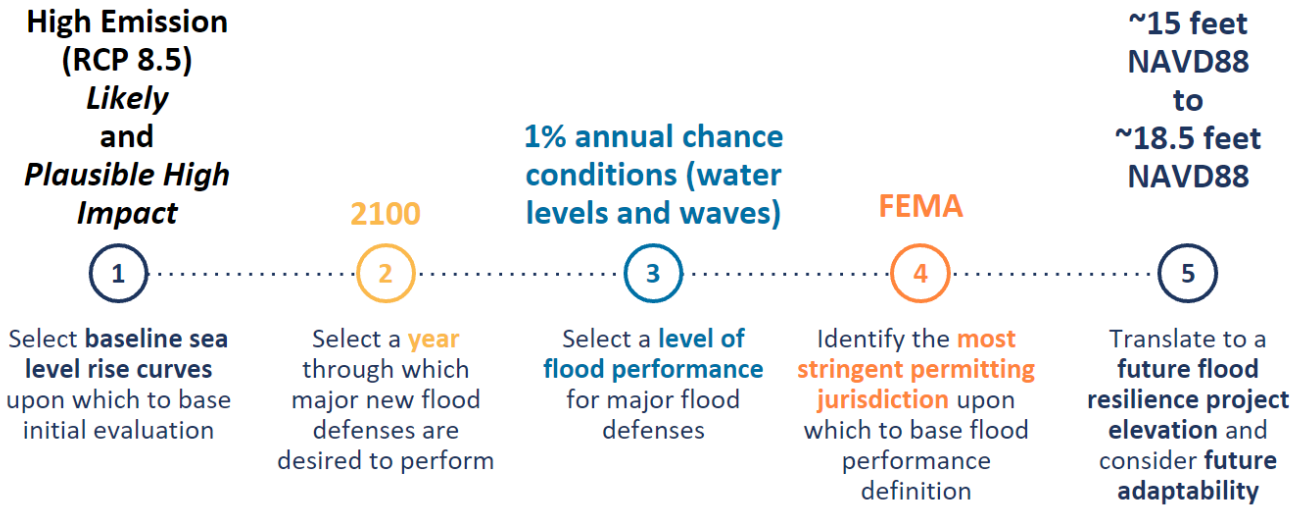

Figure 1. Example Process Diagram for Defining Flood Risk Reduction Elevation Criteria for each Coastal Flood Resilience Project

5 Initial Elevation Studies

The Port evaluated achieving FEMA criteria plus the recommended sea level rise value (3.5 ft) at 20 locations along the shoreline (Figure 2). The locations were chosen based on their complexity relative to the wave climate, roadway design (for example, grades, intersections, and bike paths), historic structures, and major utilities (for example, San Francisco Public Utility Commission wastewater infrastructure). Each location was also assessed against standard public realm assumptions (for example, maintaining Bay views and relationship to the water, sufficient promenade widths, and universal access in compliance with the Americans with Disabilities Act). Along much of the shoreline, a floodwall could potentially achieve the level of flood risk reduction desired, but a floodwall may not provide an enriching Bay connection or maintain the desired quality of public realm and water

views. A continuous floodwall along the shoreline is also extremely unlikely to garner public and political acceptance or support. Public realm considerations were a major factor in this assessment; therefore, strategies other than floodwalls were considered in the assessment although floodwalls may be considered in some locations as part of the adaptation strategies process.

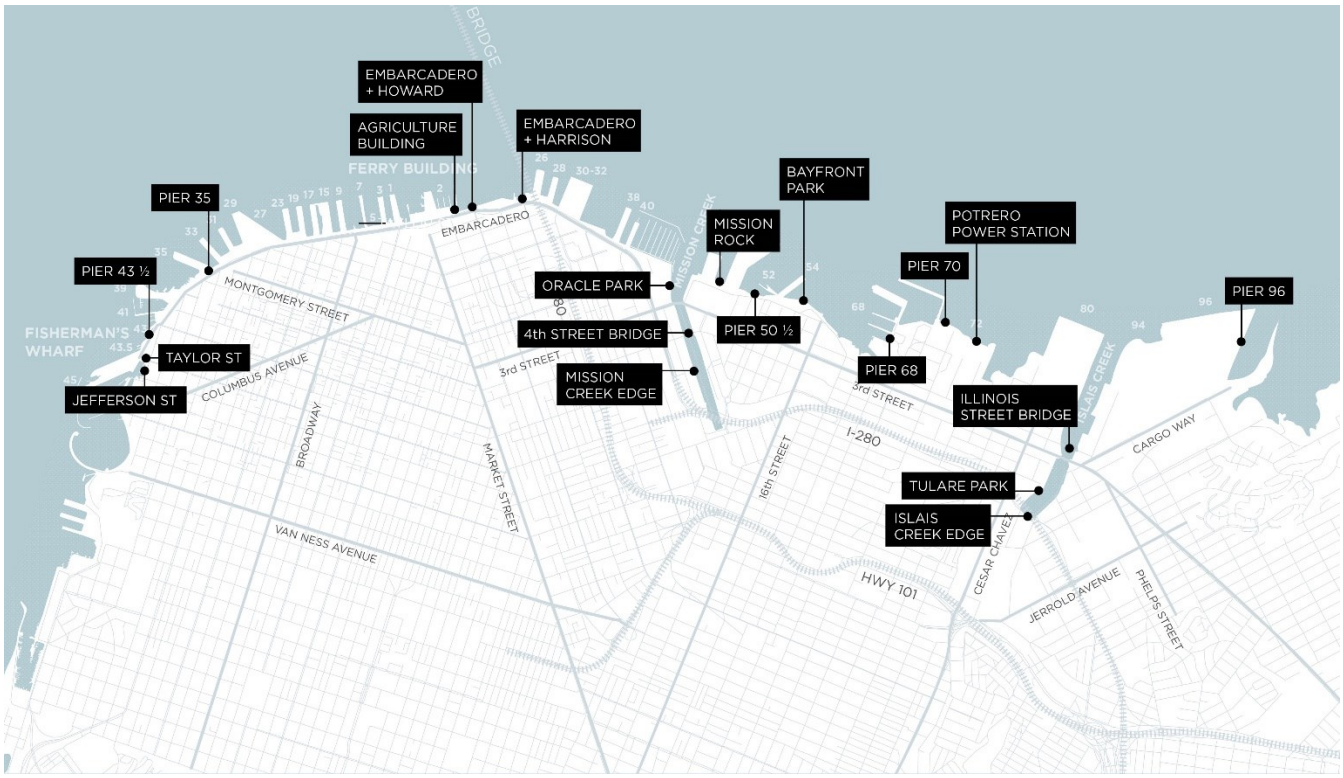

Figure 2. Locations Along the Shoreline Evaluated Relative to the Draft Flood Risk Reduction Guidance

This initial assessment was not intended to uncover every possible complication that could arise as the City attempts to adapt the shoreline to accommodate sea level rise and coastal flooding. Rather, the assessment was intended to assess the general feasibility from an urban realm perspective of raising the shoreline, and the extent of the "adaptation zone" that may be required if the City chooses to maintain the shoreline at its current location. The adaptation zone is the geographic area that would likely require modifications to accommodate the increase in shoreline height, but it may not capture the full area that would be disrupted during construction, or the full area that may require modifications such as maintaining or relocating utilities or utility connections, or maintaining grade connections with adjacent streets, sidewalks, or railways.

The assessment shows that the City can achieve existing FEMA criteria + 3.5 feet of sea level rise. This could be accomplished with a combination of floodwalls (with a maximum height of 3.5 feet to minimize public realm impact), elevating portions of adjacent roadway lanes, and extending the shoreline into the Bay (adding Bay fill) in some locations to minimize the potential of impacting the MUNI tracks along the Embarcadero roadway. The bridges and rail tracks across Islais Creek and Mission Creek, as well as the shoreline between Piers 54 and 48 in Mission Bay, will require additional detailed evaluation.

Achieving the FEMA criteria + 7.0 feet of sea level rise would require more extensive modifications to the Embarcadero roadway and other transportation infrastructure. Alternatively, these modifications could be minimized by extending the shoreline farther into the Bay (farther than needed for the 3.5 feet of sea level rise scenario outlined above), or through the addition of floodwalls with heights greater than 3.5 feet. The 20 selected locations served as a proxy for different conditions along the entire waterfront, thus it is understood that the cumulative impacts of filling the Bay, modifying roadway and rail alignments, and modifying or relocating utilities along the entire 7.5 miles of waterfront would be significantly greater under this option. This would also require significant cross-department coordination across the entire shoreline (such as with San Francisco Municipal Transportation Agency, San Francisco Public Utilities Commission, and San Francisco Public Works).

In general, this initial assessment noted that shoreline could be modified and adapted to meet FEMA criteria + 3.5 feet of sea level rise without the need for extensive Bay fill. Therefore, this is recommended as the minimum criteria for coastal flood risk reduction. Achieving FEMA criteria + 7.0 feet of sea level rise would be more challenging and would likely require either significant amounts of Bay fill or significant modifications to the complex interrelated critical infrastructure along the shoreline (such as major roadways and lifeline routes, rail tracks, wastewater transport storage boxes, and disaster response infrastructure). However, although 7.0 feet of sea level rise may not happen by 2100, it is very likely to happen before 2150. The tradeoffs between achieving 3.5 feet and 7.0 feet of sea level rise should be closely evaluated as the alternatives are evaluated.

Although the general approaches to meet the FEMA criteria + 3.5 or 7.0 feet of sea level rise were considered feasible, this is not intended to imply that either approach would lead to a publicly and politically acceptable outcome. To avoid the perception that this initial analysis produced viable coastal flood resilience alignments or strategies, the specific details of the concept evaluated are not presented in this document. Robust City collaboration and public engagement will be required to develop publicly and politically acceptable outcomes.

6 Considerations for Early Projects (Near-term Flood Risk Reduction)

The design and implementation of the waterfront resilience program long-term flood risk reduction projects along the full 7.5 miles of shoreline will likely span several decades. However, flood risk exists along low points of the shoreline today and will continue to increase as the longer-term flood risk reduction projects are developed. To address this near-term risk, early projects for coastal flood risk reduction are currently under development. These near-term flood risk reduction projects may not achieve the level of flood risk reduction recommended in this document due to financial, schedule or other constraints, but still serve an important role in reducing coastal flood risk for the next decade or more. The recommendations provided in this document are not intended to constrain the implementation of near-term actions that reduce current risk.

7 Consideration of Port and Maritime Assets

The Port-owned over water piers and wharves, buildings, bulkheads, marine terminals, and maritime lands may have a higher flood risk tolerance than the inland city, its business and residents, and the city's critical

infrastructure and lifelines. Therefore, the city's flood risk reduction alignment may, at times, be located inland of some Port assets or inland of the Port jurisdiction. In areas where Port lands are outside (that is, on the Bayside) of the city's flood risk reduction alignment, the Port will develop and maintain its own flood risk reduction policies and measures. The Port policies and measures will not reduce or impact the ability of the city's flood risk reduction structures from serving their intended purpose to reduce the likelihood of flood related damages, disruption, and loss of life. Alignment of the flood risk reduction infrastructure is not part of this recommendation and will be explored through robust City collaboration and public engagement.

8 Consideration of Critical City Infrastructure Assets

Some critical infrastructure assets may have a lower flood risk tolerance than the recommendations presented within this document. For example, the entrances to the underground MUNI/BART system may warrant flood risk reduction from a 0.2 percent annual chance flood event (500-year event) that considers both coastal and precipitation-based urban flooding. Other assets, such as electrical substations, wastewater pumpstation, hospitals, and fire stations may also require additional strategies, such as flood proofing and deployable flood barriers, to reduce the likelihood of significant consequences in the event flooding occurs. The recommendations presented in this document do not negate the need for a thorough evaluation of flood risk tolerance for individual critical infrastructure assets.

9 References

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