

EMBARCADERO SEAWALL MHRA OVERVIEW

SF Lifelines Council

3/11/2021



MHRA PRESENTATION

Objectives

- Provide overview of work
- High level key findings
- Discussion
- Next Steps



WATERFRONT RESILIENCE PROGRAM EFFORTS

Embarcadero Seawall MHRA Context



EMBARCADERO SEAWALL

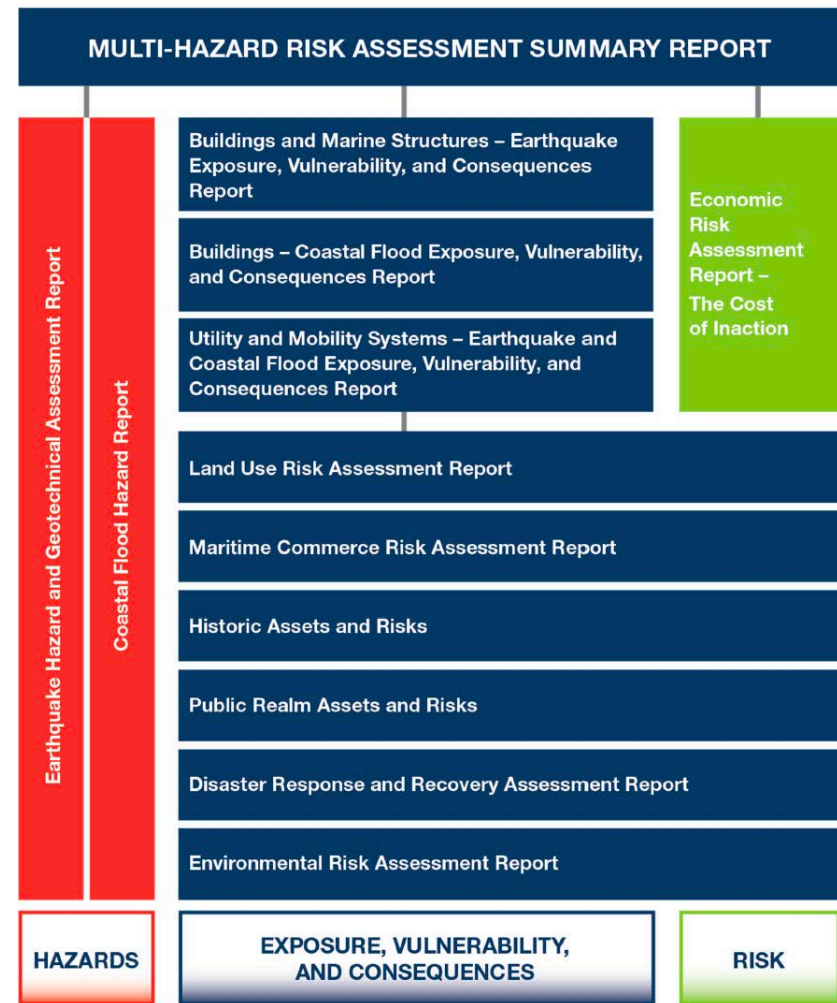
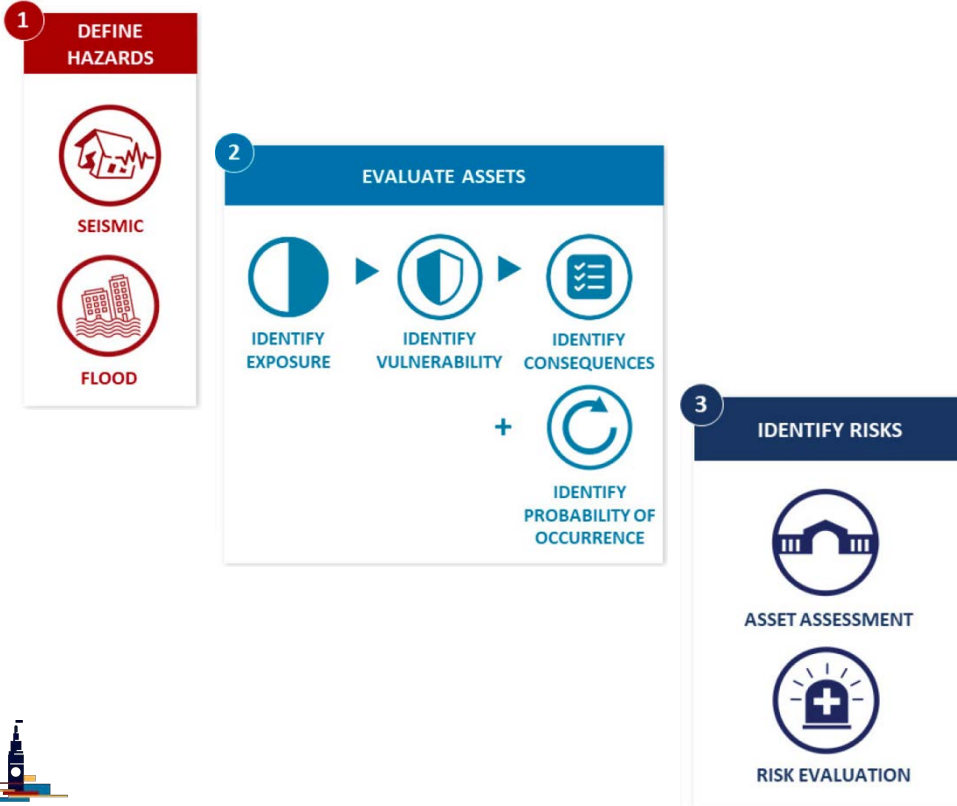
Critical Components of the Waterfront



- Filled land late 1800's to early 1900's
- Seawall retains filled soils containing Embarcadero corridor, connects piers to land, and provides water depth for maritime berthing.
- Seawall and Bulkhead Wharves provide Port and City flood and shoreline protection.

EMBARCADERO SEAWALL MHRA

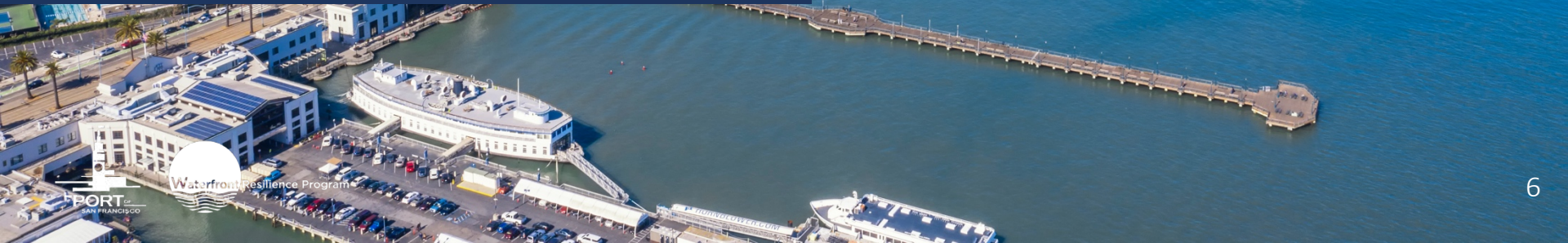
Report Overview & Report Organization





Defining the Hazards

Earthquake and Coastal Flooding with SLR



UNDERSTANDING THE SUBSURFACE

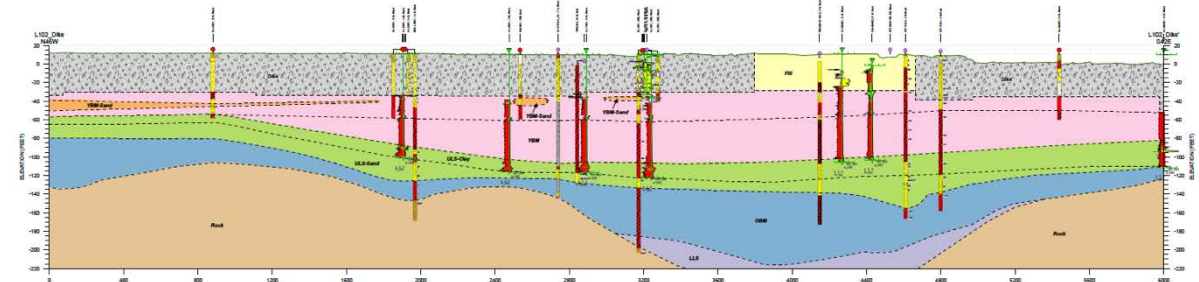
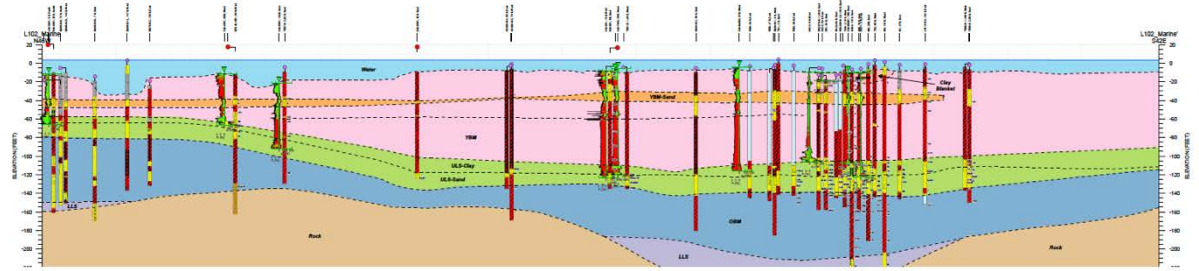
What is under the ground matters!

Compile existing data & determine gaps.

Pilot exploration program to test techniques.

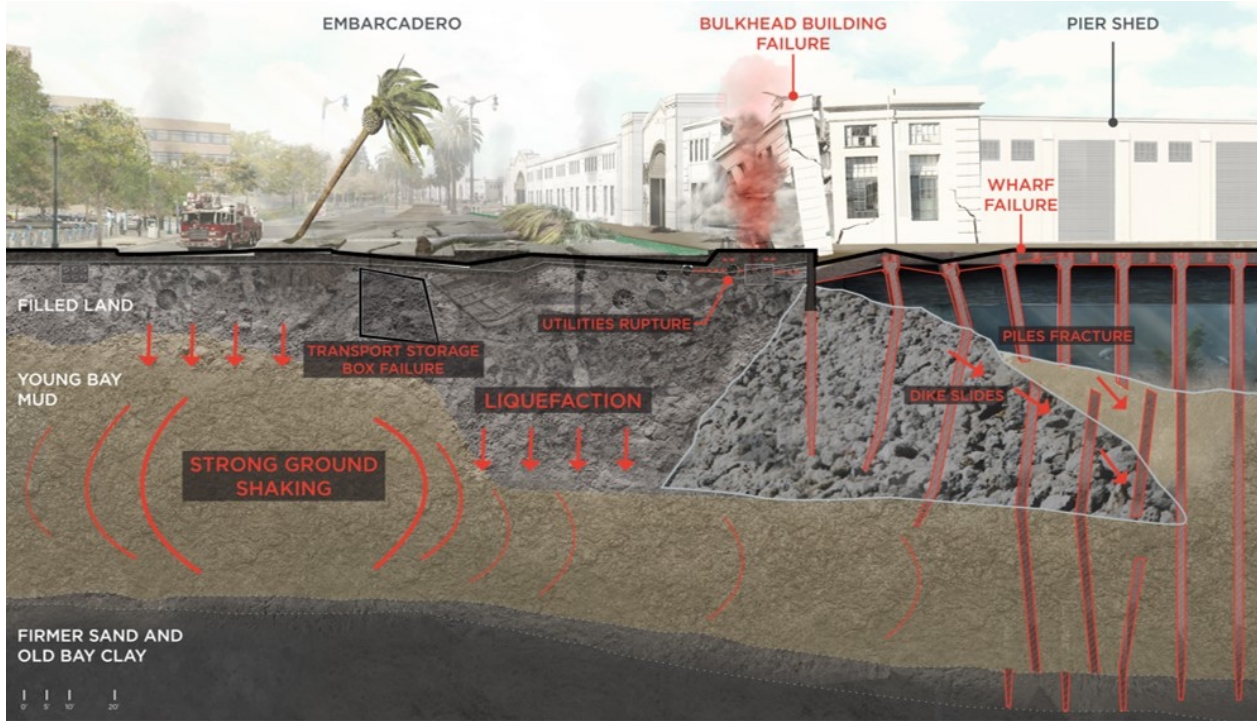
Final exploration program, 92 new borings & CPT's, high quality laboratory data.

Final product, subsurface characterization and engineering data for 3 miles of waterfront.



DEFINING THE EARTHQUAKE HAZARD

Shaking, Liquefaction, Lateral Spreading



Liquefaction induced lateral spreading at Port de Port-au-Prince



Lateral spreading cause by 1906 earthquake in San Francisco

EARTHQUAKE HAZARD

Probabilistic EQ Hazard Scenarios

Table 3-1. Earthquake Scenarios Evaluated in the Multi-hazard Risk Assessment

Likelihood	Earthquake Scenario Return Period and Probability	Historical Context
Frequent	43-year (70% probability in 50 years)	Similar to shaking in San Francisco from 1989 Loma Prieta earthquake (M7+/-)
Occasional	100-year (40% probability in 50 years)	Similar to Loma Prieta earthquake (M7+/-), but with an epicenter located within 10 miles instead of 60 miles away
Rare	225-year (20% probability in 50 years)	Similar, but slightly larger than the 1906 Great San Francisco earthquake, (M7.5+/-) located nearby
Very Rare	975-year (5% probability in 50 years)	M8+ earthquake, larger than 1906 Great San Francisco earthquake, located nearby

EARTHQUAKE HAZARD

MHRA Findings

← *Liquefaction of Embarcadero fill – High hazard throughout* →

Seawall Hazard
Moderate to Low
firmer soils

Seawall Hazard
High to Very High
due to deep
Young Bay Mud

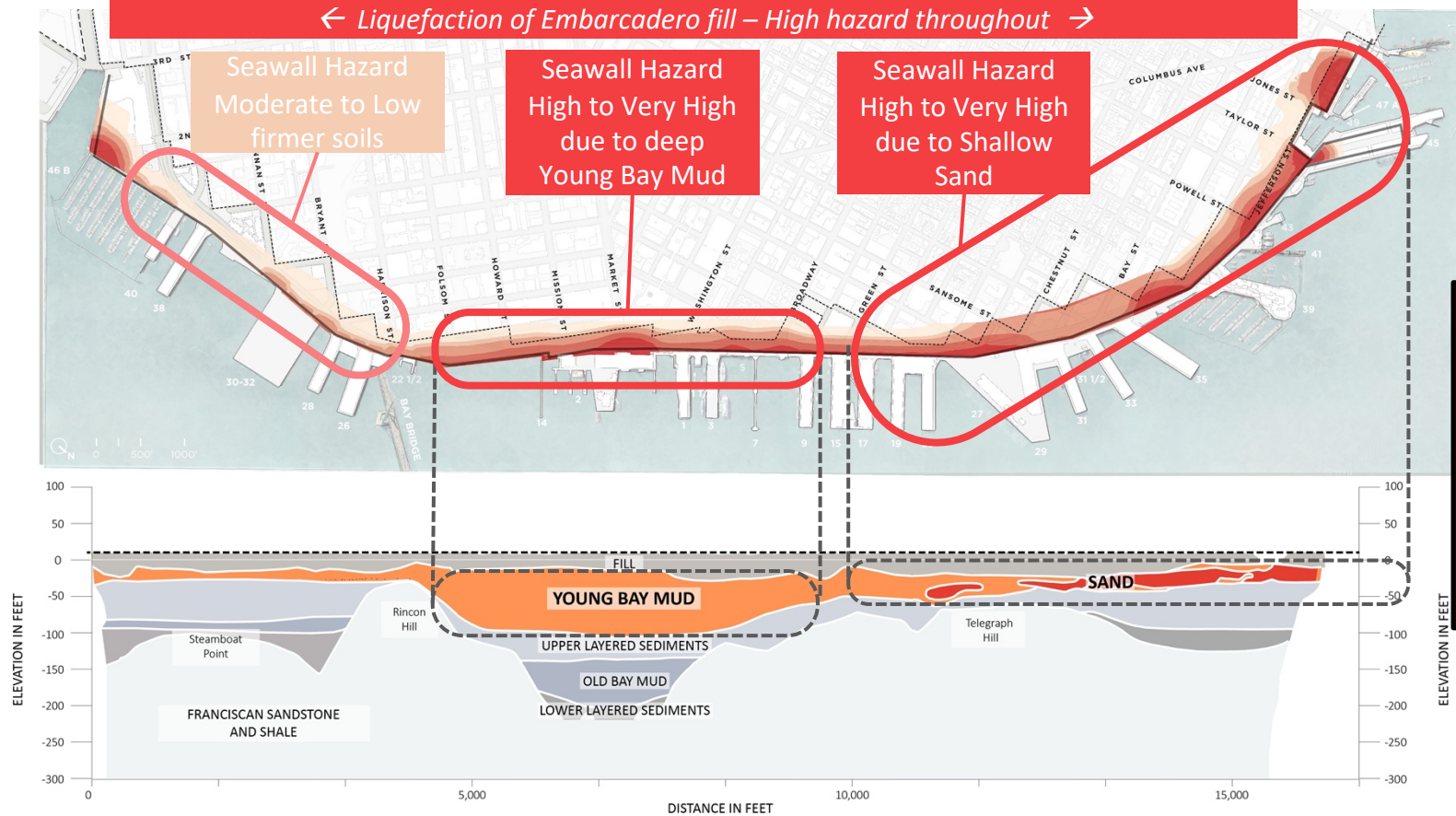
Seawall Hazard
High to Very High
due to Shallow
Sand

LEGEND

- Seawall
- SF Port Boundary
- SEAWALL EARTHQUAKE HAZARD ZONE
- Very Low
- Low
- Moderate
- High
- Very High

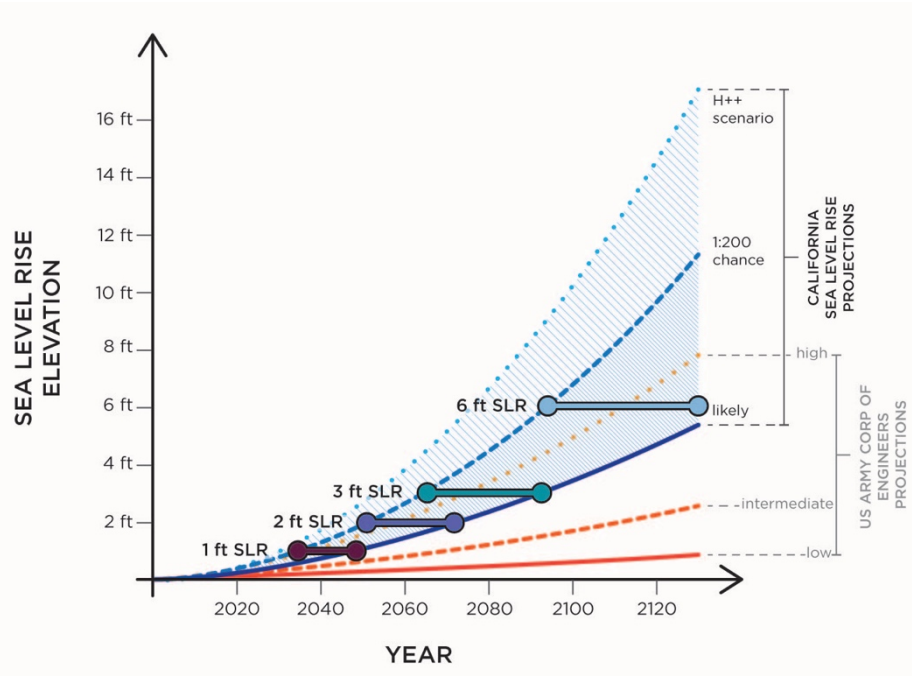
EQ HAZARDS

- GROUND SHAKING - AMPLIFIED
- LIQUEFACTION
- LATERAL SPREADING (SEAWALL HAZARD)

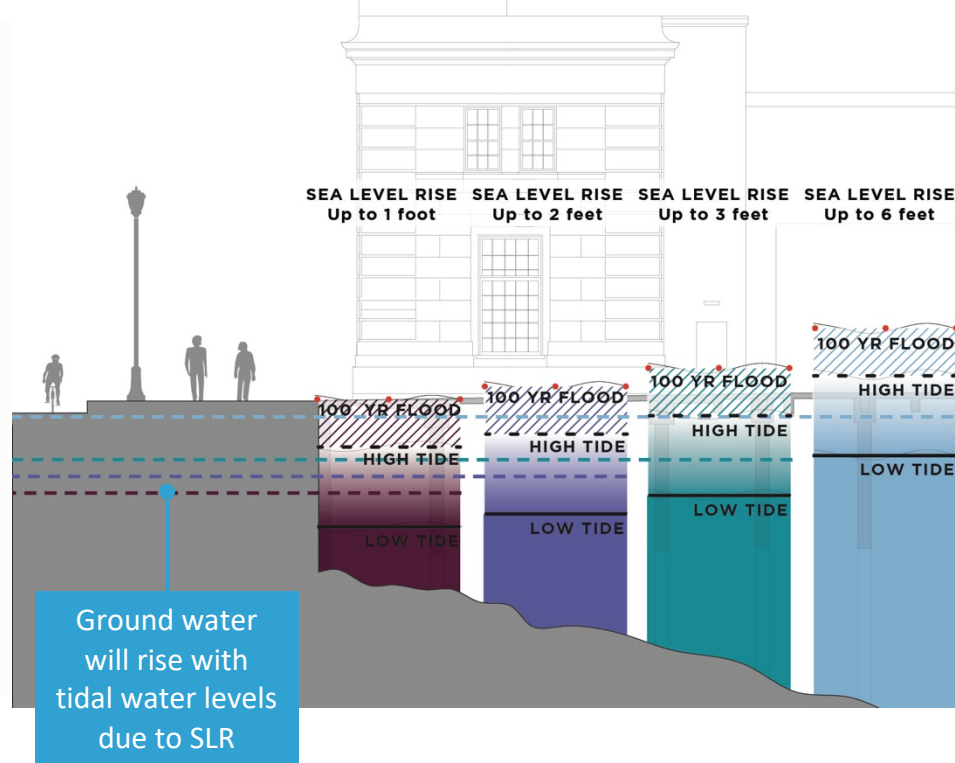


DEFINING FLOOD HAZARD

- Flood Mapping includes waves & water depths
- Tidal frequency from daily to 500 yr tide (extreme)
- Current CCSF & USACE Sea Level Rise Scenarios



State of CA – Updated 2018; USACE – Updated 2013

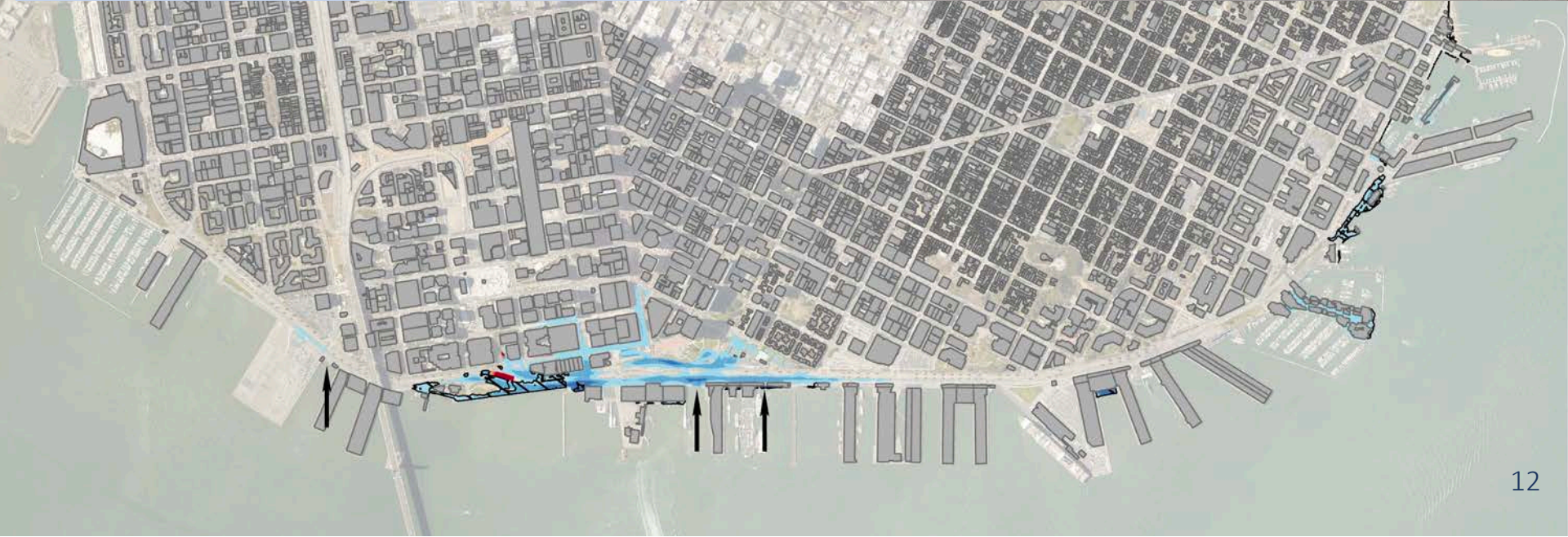


Ground water will rise with tidal water levels due to SLR

FLOOD HAZARD

1 FT OF SEA LEVEL RISE (2035 – 2055; 15 to 35 yrs)

- 100yr Coastal Flood Extents Shown
- Daily high tides: similar to King Tides today
- Ground water rise 1 ft to 6 ft below surface, impacts some utilities



FLOOD HAZARD

2 FT OF SEA LEVEL RISE (2050 – 2070; 30 to 50 yrs)

- 100yr Coastal Flood Extents Shown
- Daily high tides: waves overtop Pier 5 to Rincon Park & impact northbound Embarcadero
- Ground water rise by 2 ft to 5ft below surface, impacts utilities and roadway/LRT subgrade



FLOOD HAZARD

3 FT OF SEA LEVEL RISE (2065 – 2100; 45 to 80 yrs)

- 100yr Coastal Flood Extents Shown
- Daily high tides: inundate northbound Embarcadero
- Ground water rises 3 ft to 4ft below surface, impacts utilities and roadway/LRT subgrade





Evaluating Assets & Functions

Exposure, Likely Damages & Consequences



METHODOLOGY

Earthquake Damage & Loss Predictions for Assets

Define Exposure: site specific *shaking & ground movement intensity* from liquefaction and lateral spreading at each probabilistic earthquake level.

Estimate Damage, Repair Costs, & Repair Durations by developing asset specific methodology.

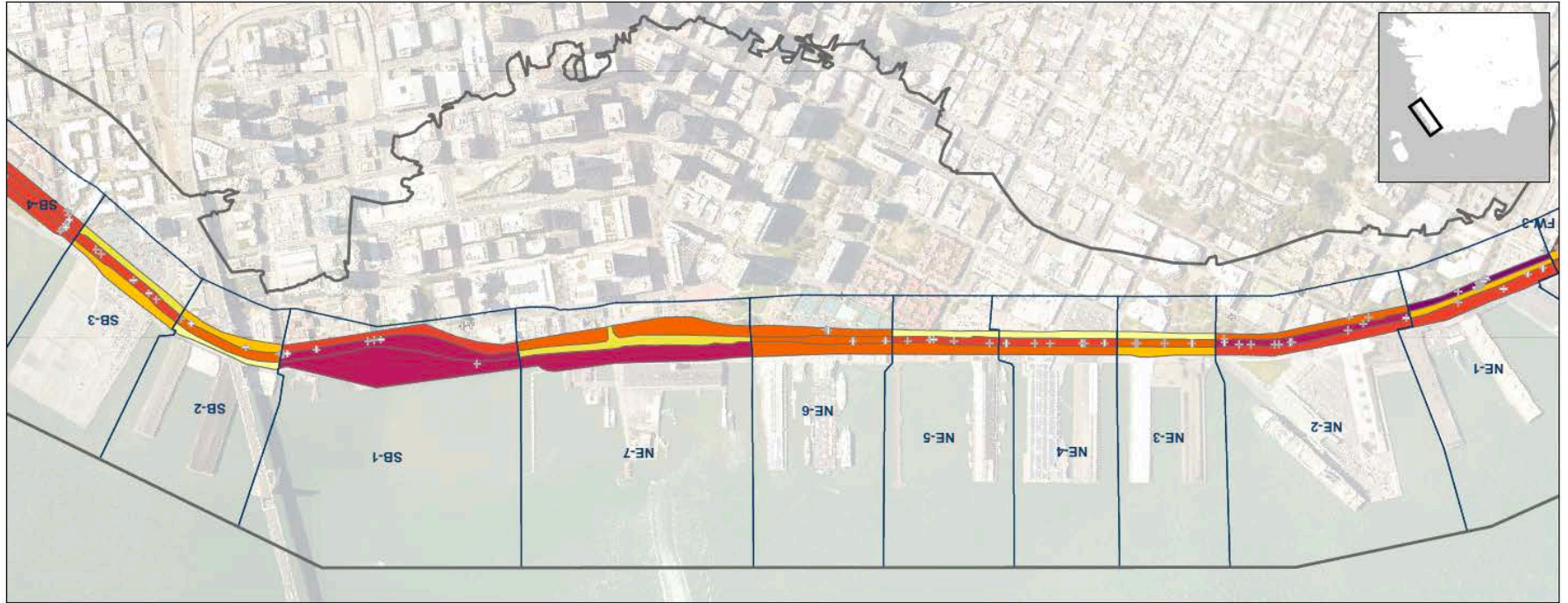
- *Buildings & Marine Structures:* Custom built functions for marine structures.
- *Utilities, Roadways, and LRT:* Consulted with Lifelines experts Professor Tom O'Rourke and Craig Davis to modify established functions to reflect unique site conditions. Limitation - No established methodology to consider interdependence.

Flood Damage & Loss Predictions

Define Exposure: site specific water depth, likelihood, and changes due to sea level rise

Estimate Damages: USACE specific depth/damage functions, Buildings Only

EARTHQUAKE DAMAGE ESTIMATE, Utilities (225-yr level)



LEGEND

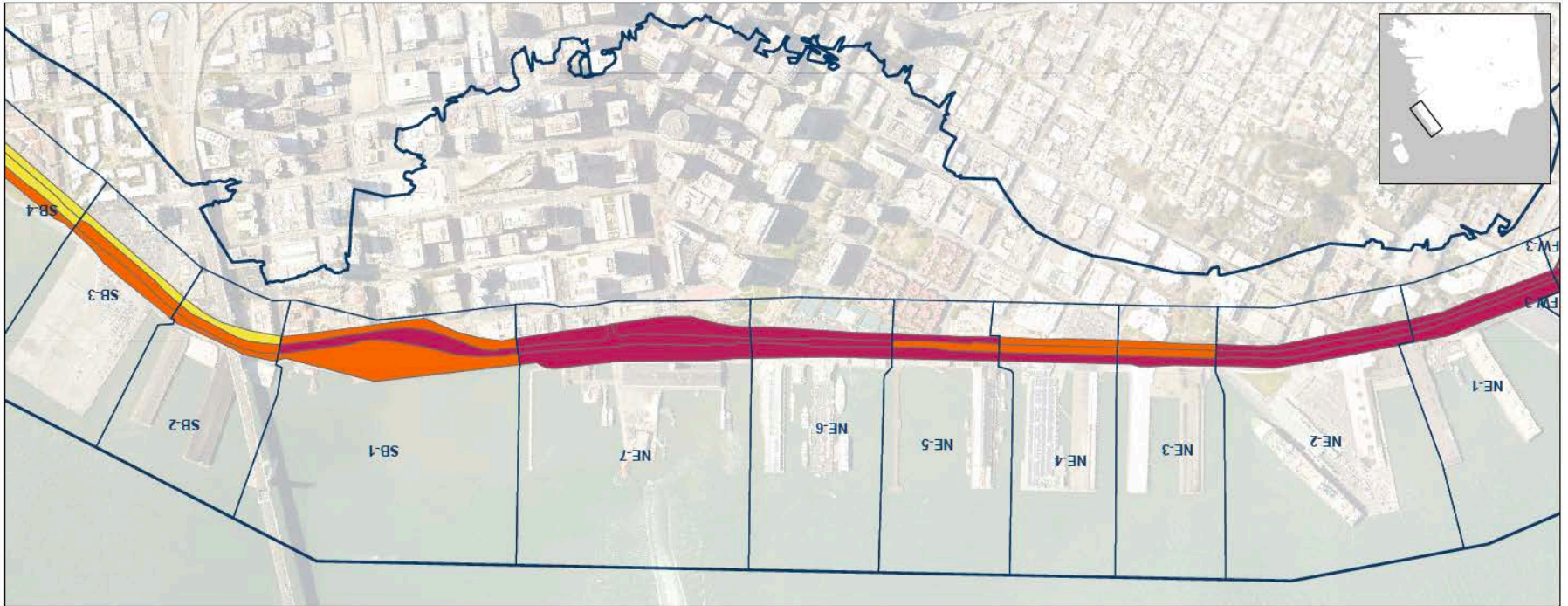
- Seawall Program Boundary
- Seismic Modified Reaches
- Wastewater Crossings

Waterfront Total Repairs

- 0
- 0-1
- 1-2
- 2-4
- 4-8
- 8-12
- 12-16
- 16-20

Number of Total Utility Repairs due to break or leak per Seawall Reach (Northbound, LRT/Median, Southbound)

EARTHQUAKE DAMAGE ESTIMATE, Transit (225-yr level)



LEGEND

- Seawall Program Boundary
- Seismic Modified Reaches

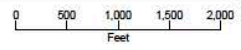
- Transit Damage State
- None
 - Slight
 - Moderate
 - Extensive/Complete

Transit Damage State: None, Slight, Moderate, Extensive
per Seawall Reach (Northbound, LRT/Median, Southbound)

COASTAL FLOODING, Electrical System Exposure

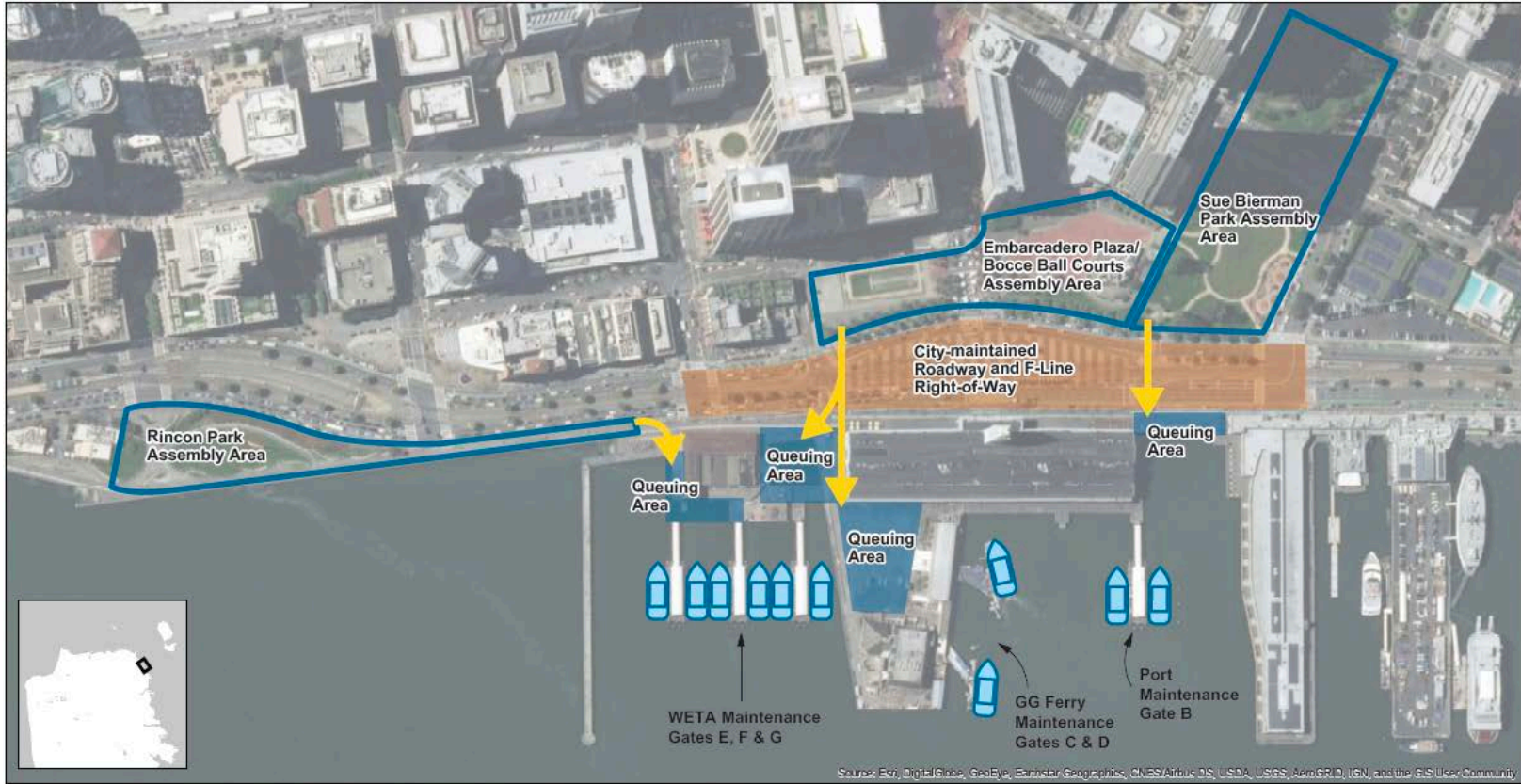


- Seawall Program Boundary
- Embarcadero Substation
- Shoreside Power Facility
- Photovoltaic Generator
- Backup Generator
- Streetlights
- Embarcadero Substation Service Area Extent
- 230kV Transmission Lines (PG&E)
- Flood Extent at 10.7 NAVD88 Stillwater Level
- Flood Extent at 11.8 NAVD88 Stillwater Level
- Flood Extent at 12.9 NAVD88 Stillwater Level
- Flood Extent at 14.2 NAVD88 Stillwater Level



Electrical System Asset Exposure at Various Water Levels
 No Damage Estimates

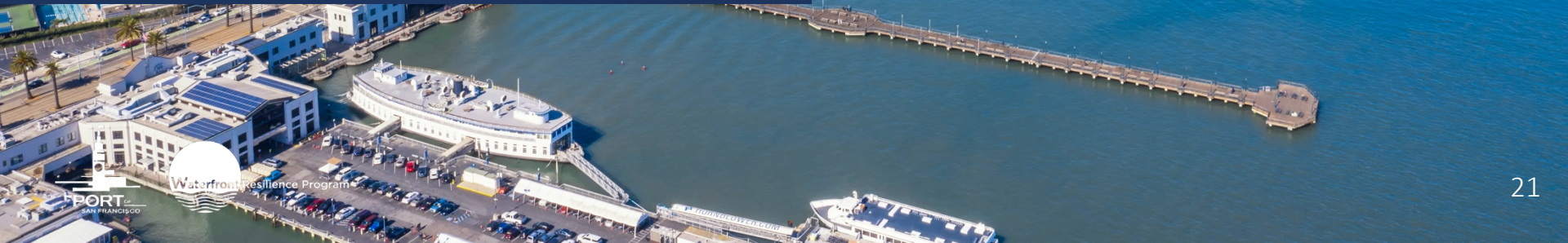
DISASTER RESPONSE, Survivor Evacuation System, Ferry Building Area





Risk Assessment

Key Takeaways

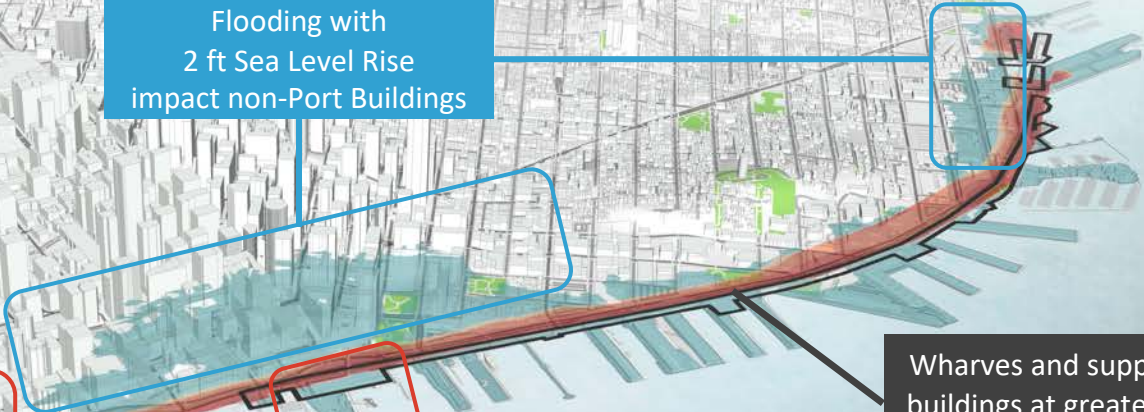


BUILDINGS AND STRUCTURES

Concrete bulkhead wharves south of Bay Bridge highly vulnerable to ground shaking



Flooding with 2 ft Sea Level Rise impact non-Port Buildings



Wharves and supported buildings at greatest risk of earthquake damage

Ferry Building: Unique substructure suggests further analysis



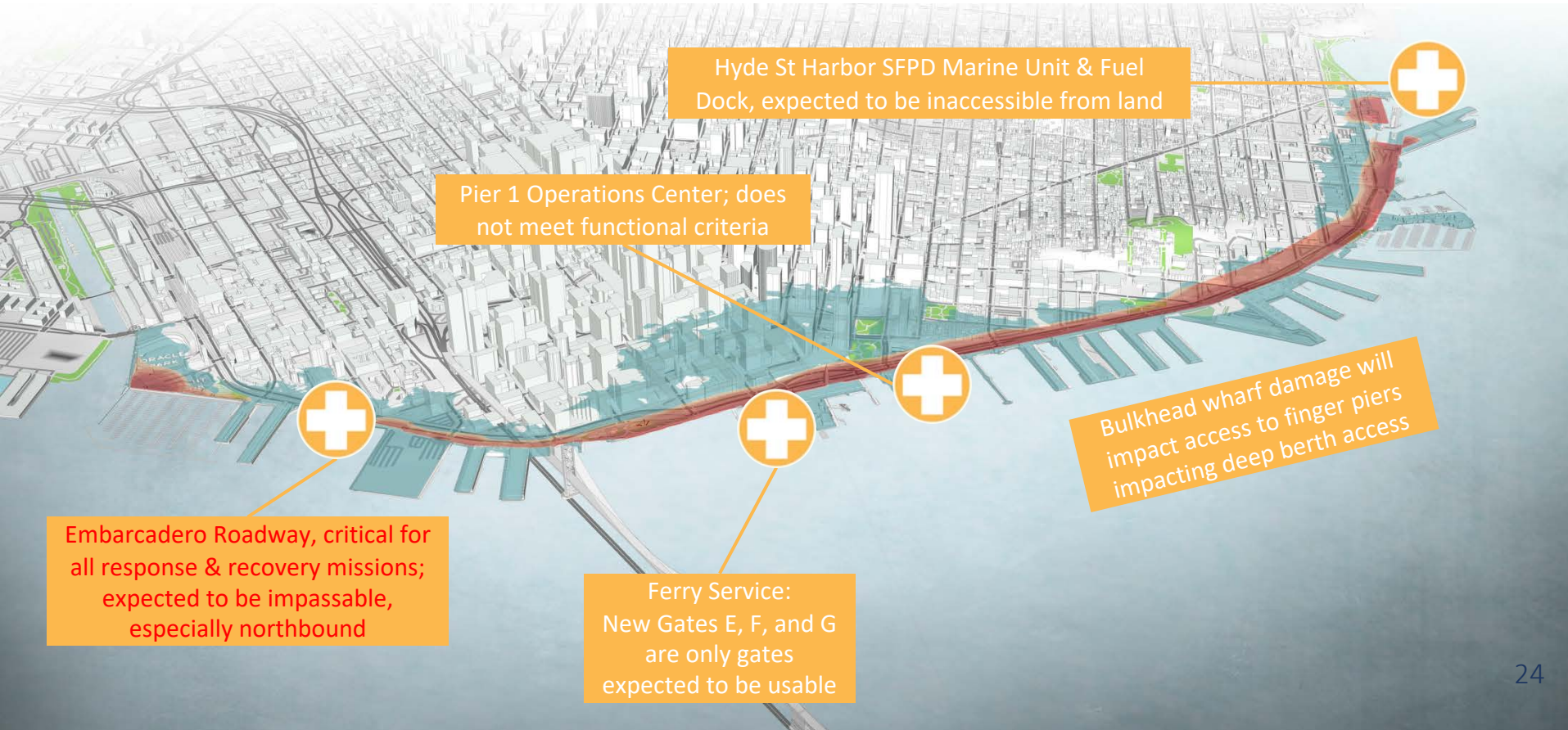
LIFE SAFETY



Average density
of people on the
waterfront

- 20,500 average number of people over the water, can be as high as 38,000 during special events
- Highest life safety risk in bulkheads, a repeat of 1906 is estimated to cause 600 injuries & deaths, 70% Seawall related
- Seawall damage will leave people stranded on Piers and in need of waterside evacuation, fire may increase rescue urgency, fire impacts not assessed
- Historic pier sheds are a vulnerable structure type

DISASTER RESPONSE – Earthquake Only



Hyde St Harbor SFPD Marine Unit & Fuel Dock, expected to be inaccessible from land

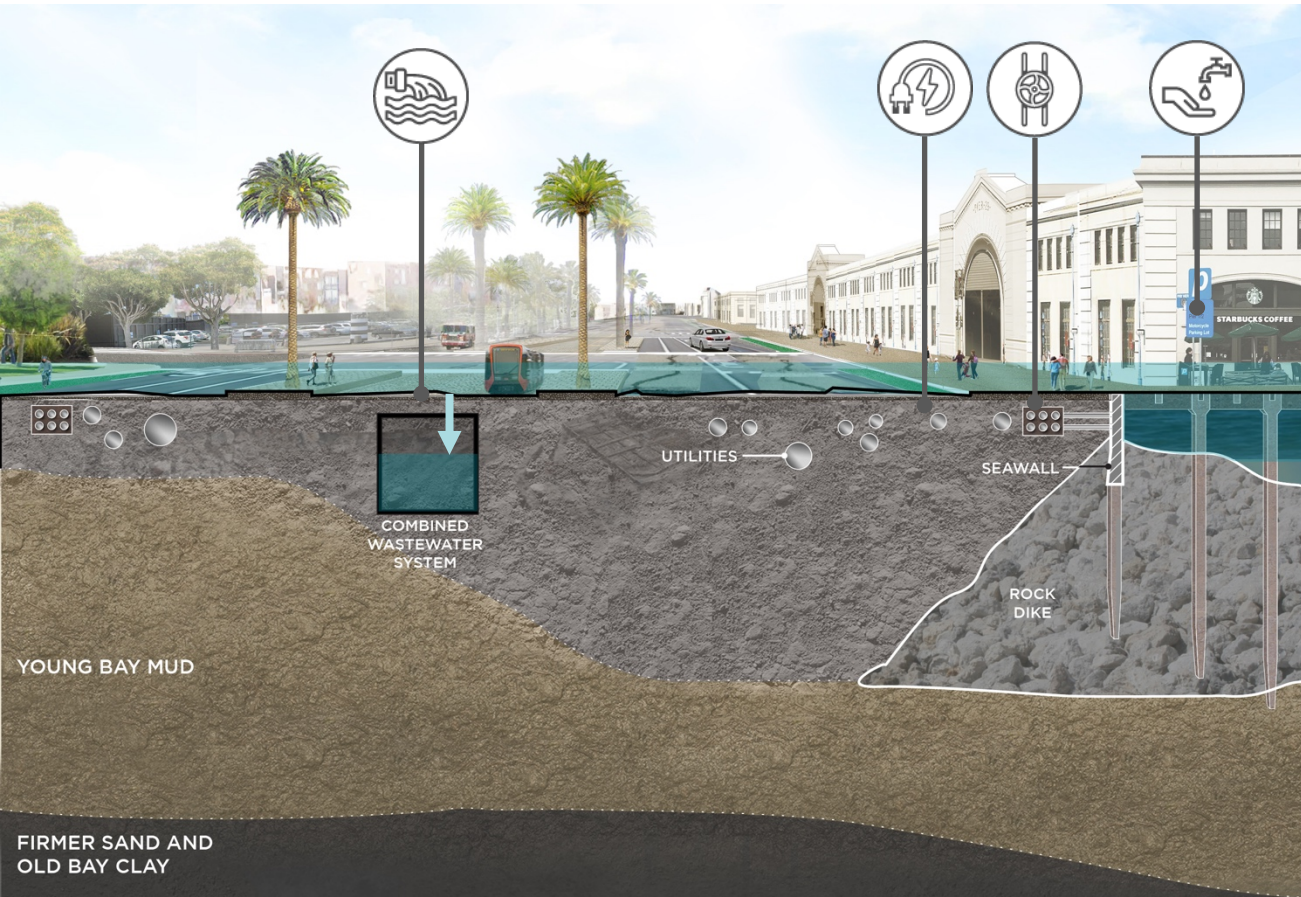
Pier 1 Operations Center; does not meet functional criteria

Embarcadero Roadway, critical for all response & recovery missions; expected to be impassable, especially northbound

Ferry Service:
New Gates E, F, and G
are only gates
expected to be usable

Bulkhead wharf damage will impact access to finger piers impacting deep berth access

UTILITIES



Earthquake:

Damage from both Seawall instability & liquefaction of fill

High damage in 100yr earthquake, sewer & water primarily, may take up to 1 year to repair

Critical City serving combined wastewater infrastructure at risk

Gas service breaks at seawall can lead to fire loss.

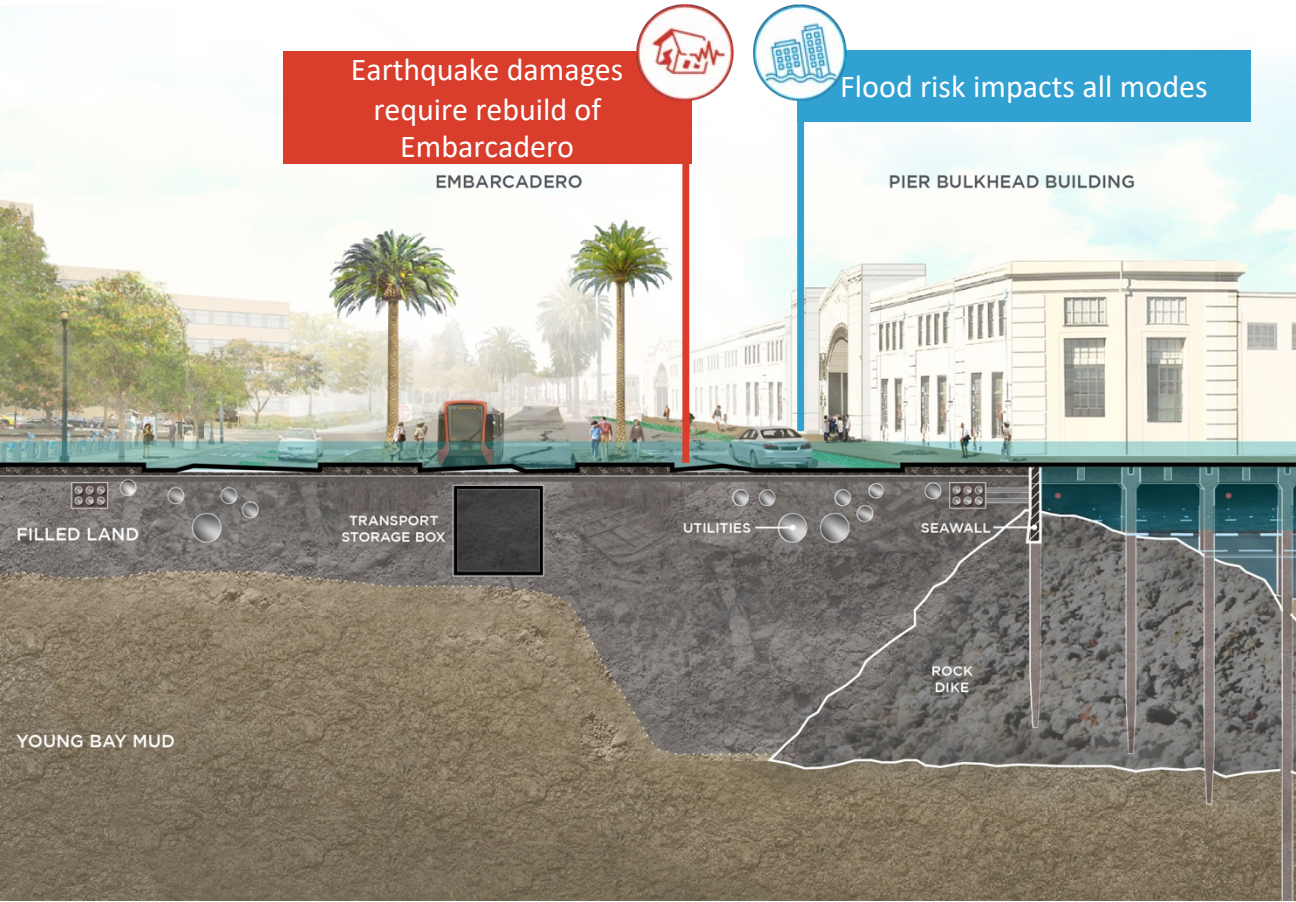
Flood:

Function of Wastewater system will be impaired with 1ft of SLR and overwhelmed at 2ft of SLR

Saltwater damage to electrical equipment

Groundwater impacts with 2ft of SLR

TRANSPORTATION



Earthquake damages require rebuild of Embarcadero

EMBARCADERO

Flood risk impacts all modes

PIER BULKHEAD BUILDING

Earthquake:

Damage from both Seawall instability & liquefaction of fill

High damage in 100yr earthquake combined with utility repairs, may cause disruption for 1+ year

Severe damage in 225yr earthquake may cause disruption for 2+ years.

Northeast waterfront, northbound lanes, and Promenade expected to see higher damage.

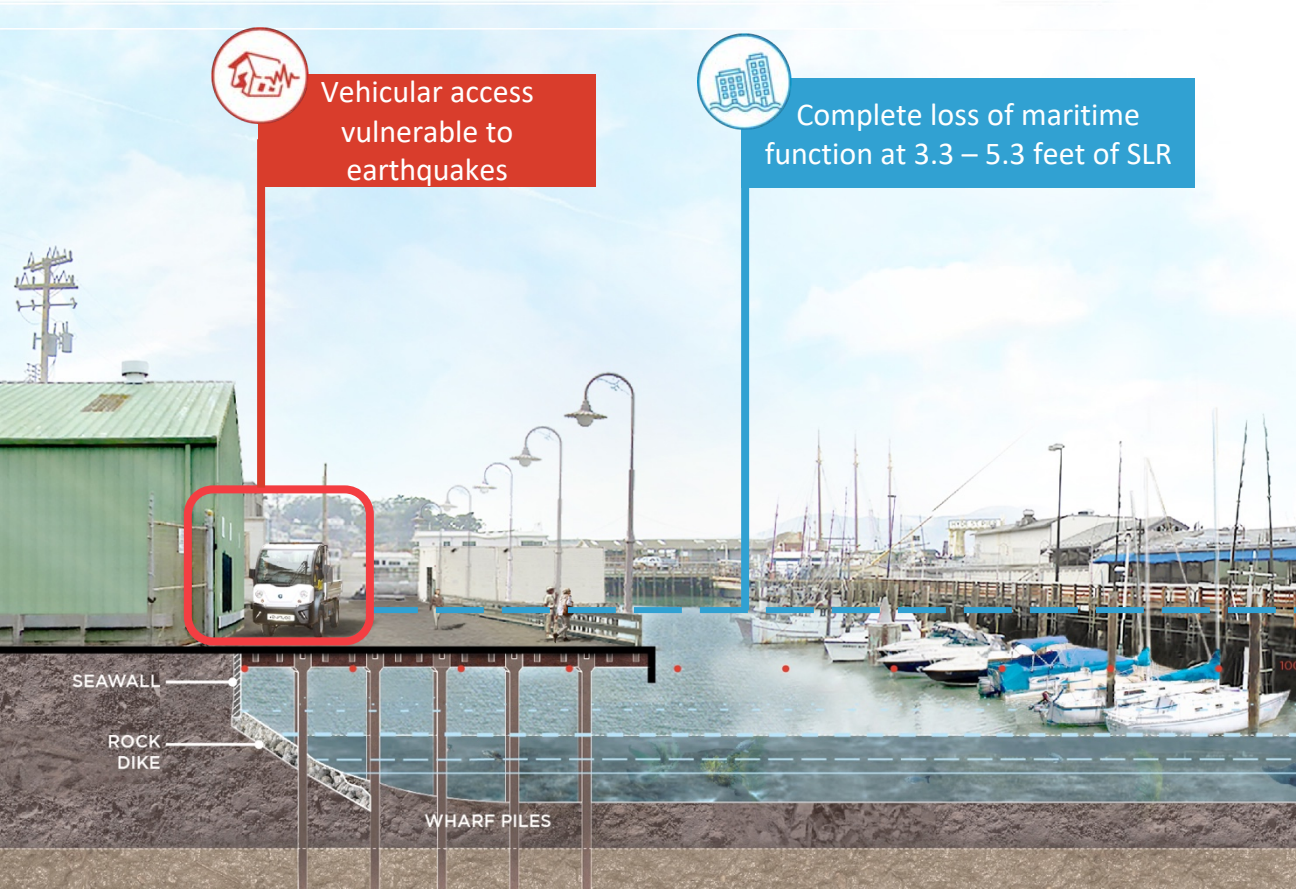
Flood:

BART & MUNI, moderate disruption with 1ft of SLR & major disruption and damage with 2 ft SLR; 460,000 trips with regional impact.

Groundwater rise will begin damaging subgrade at 2ft of SLR.

Embarcadero severely impacted by 2ft of SLR.

MARITIME



Vehicular access vulnerable to earthquakes



Complete loss of maritime function at 3.3 – 5.3 feet of SLR

Earthquake:

Vehicular access along waterfront is critical to function, disruption starts at 100yr EQ, severe at 225

Table 6: Seismic Consequence Summary - Maritime Commerce April 2020

Maritime Industry	43	100	225	975
Cruise				
Excursion				
Water Recreation				
Fishing				
Harbor Service				
Ferry & Water Taxi				
Temporary & Ceremonial				
Inactive/Reserve				

Flood:

Resilient to minor flooding, but frequent flooding will result in complete loss of maritime function by end of century

Jobs and industries that built the waterfront impacted, including industries related to commercial fisheries, vessel inspectors, marine engineers, bar pilots

OPEN SPACE AND PARKS

24 million people per year use the promenade

Promenade is most heavily used part of the regional Bay Trail

Earthquake:

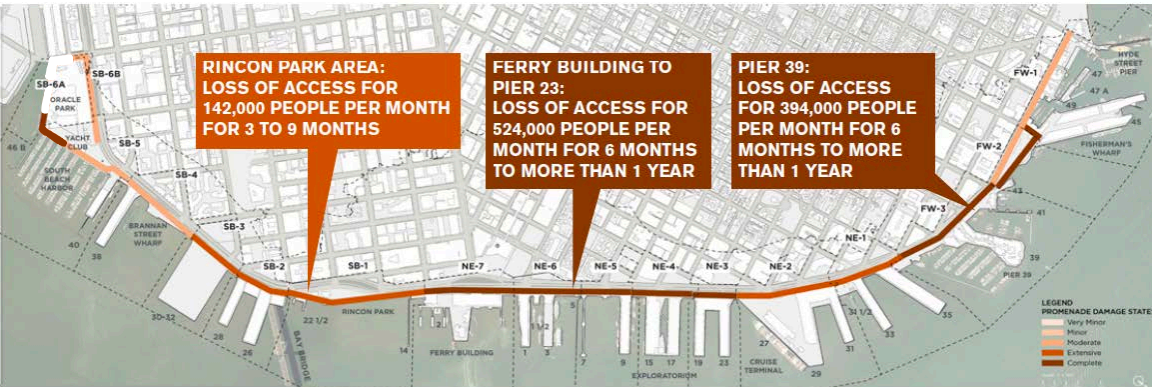
Table 2-6. Promenade Seismic Consequences Summary

	Consequences - Extent of Damage		
Seismic Event	Area 1 - South Beach	Area 2 - Northeast	Area 3 - Fisherman's Wharf
43-year	Low	Medium	Low
100-year	Medium	High	High
225-year	High	High	High
975-year	High	High	High

Figure 2-3. Promenade Damage States for 100-year Seismic Event



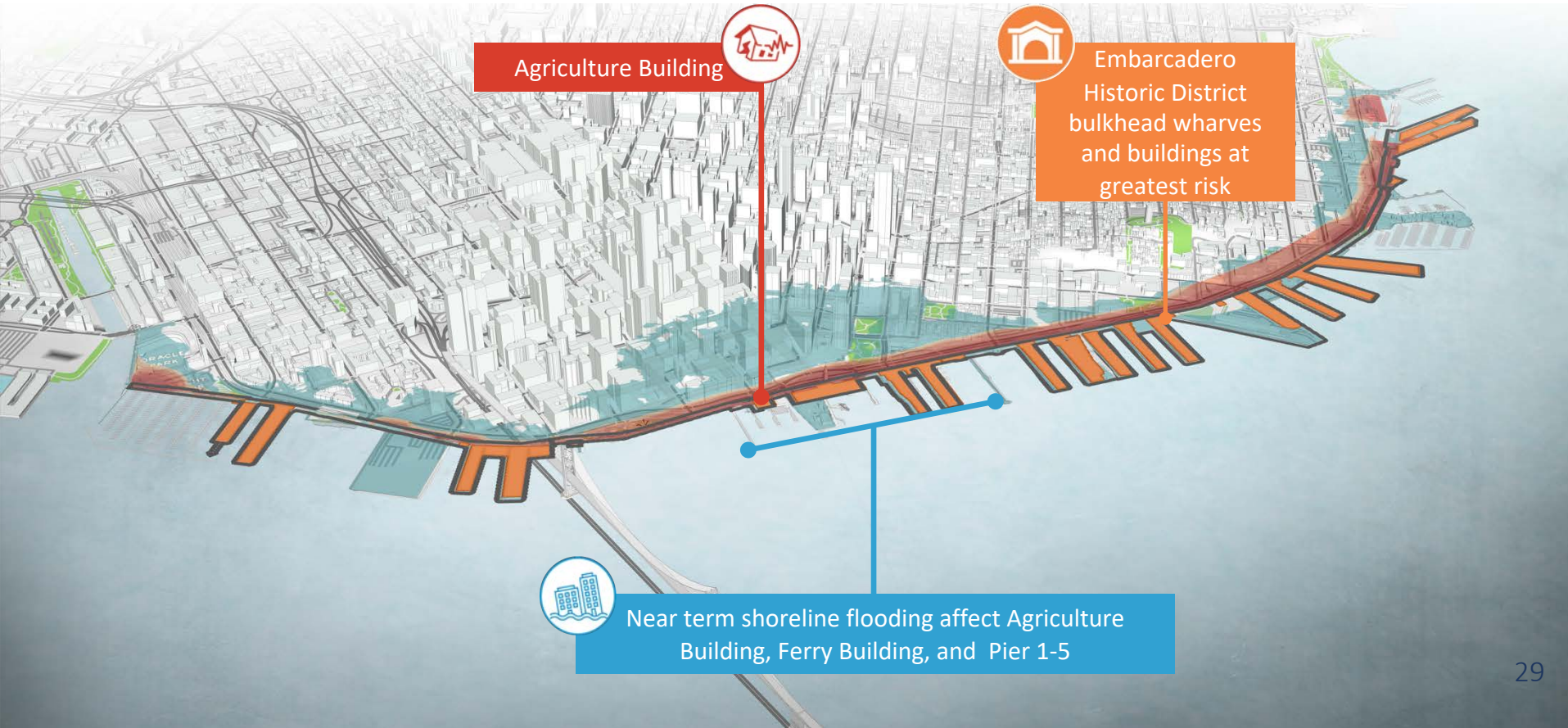
Figure 2-4. Promenade Damage States for 225-year Seismic Event



Flood:

With 2 ft of sea level rise the promenade and parks will be disrupted or closed, impacting users, causing damage and increasing maintenance costs

HISTORIC RESOURCES



Agriculture Building

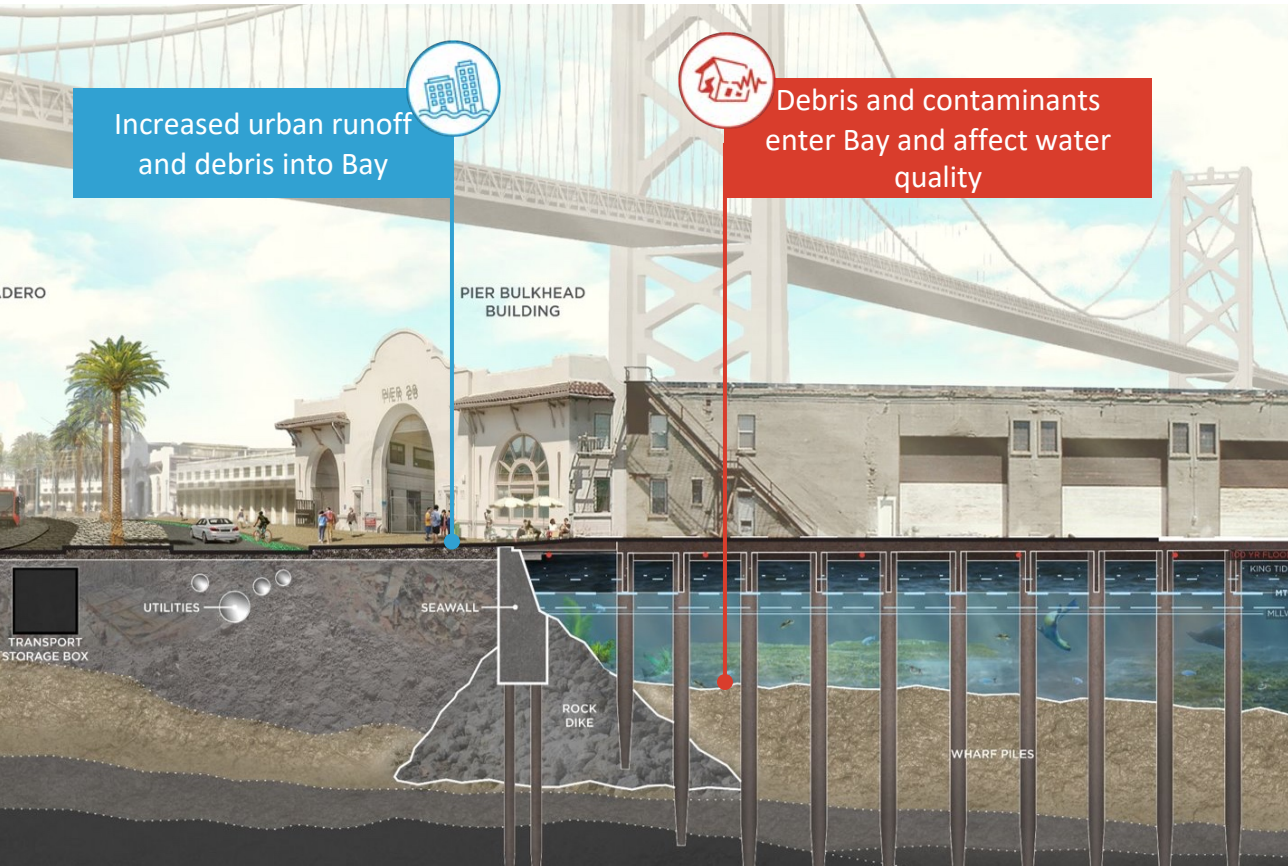


Embarcadero
Historic District
bulkhead wharves
and buildings at
greatest risk



Near term shoreline flooding affect Agriculture
Building, Ferry Building, and Pier 1-5

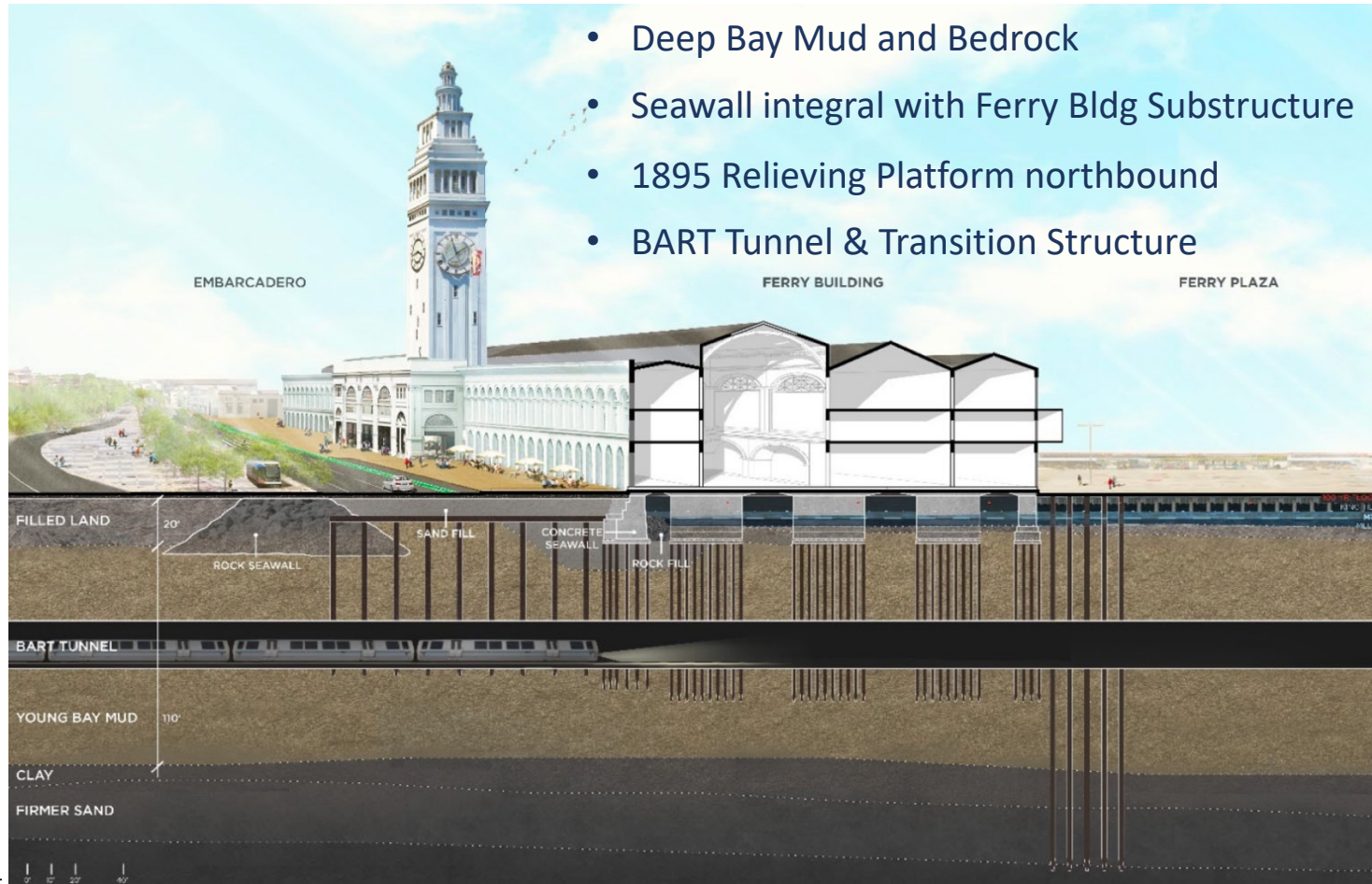
HABITAT, ECOLOGY, AND ENVIRONMENT



- Urbanized waterfront contains important native aquatic habitat that is important for commercial and recreation functions.
- Onshore contaminants, building and contents, may enter the Bay
- Opportunities to connect the Bay ecology to millions of people

FERRY BUILDING AREA COMPLEXITIES

- Deep Bay Mud and Bedrock
- Seawall integral with Ferry Bldg Substructure
- 1895 Relieving Platform northbound
- BART Tunnel & Transition Structure



ECONOMIC COST OF INACTION

EQ and Flood Economic Risk

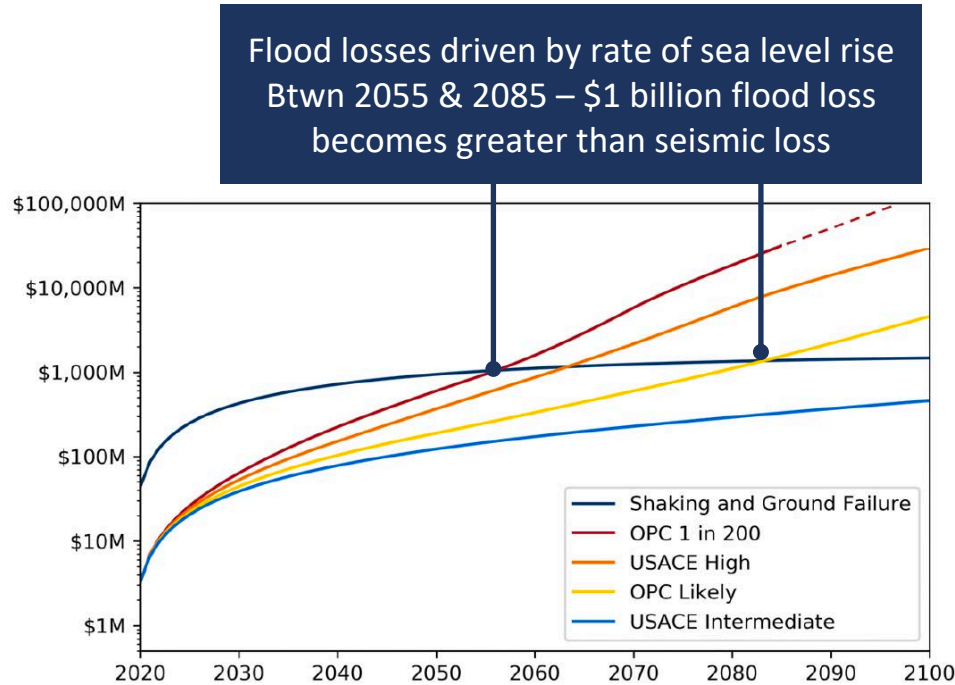


Figure 5-1. Total Economic Impact Present Value Losses for the Embarcadero Seawall Program Area

Note: Figure includes buildings, marine structures, mobility, and regional cascading impacts.

- **Near-term economic damages mainly from earthquakes:** \$940 M in estimated earthquake losses over 30 yrs increasing to \$1.5B over 80 yrs
- **Longer-term economic damages from sea level rise:** flood losses increase from \$190 M in 30 years to \$4.5 B in 80 years with the likely SLR scenario, and to \$30 billion with the high SLR scenario. Significant damages are outside of Port.
- As we saw with the recent Pier 45 fire, damages can have major impacts on people, businesses, jobs, and more

HOW DOES THIS ADVANCE THE PORT'S APPROACH TO PROP A PROJECTS?

Findings Point to Targeted Interventions in Phase 1 of Embarcadero Seawall Program



Earthquake instability of the Seawall is high between Rincon Park & Fisherman's Wharf, but moderate to low in South Beach. Ferry Building area (P14 to P9) is most challenging to improve due to very thick Young Bay Mud and deep bedrock. Solutions here may be different and more expensive than areas to the north.



Bulkhead walls & wharves are high earthquake risk due to both seawall instability and ground shaking vulnerability; these are also shoreline and flood protection structures for the City, improvements need to consider mid and long-term sea level rise strategies and how investments can be adapted over time.



The Embarcadero is at risk from Seawall instability and liquefaction of the fill, improvements to both may eventually be needed to serve as a lifeline corridor.



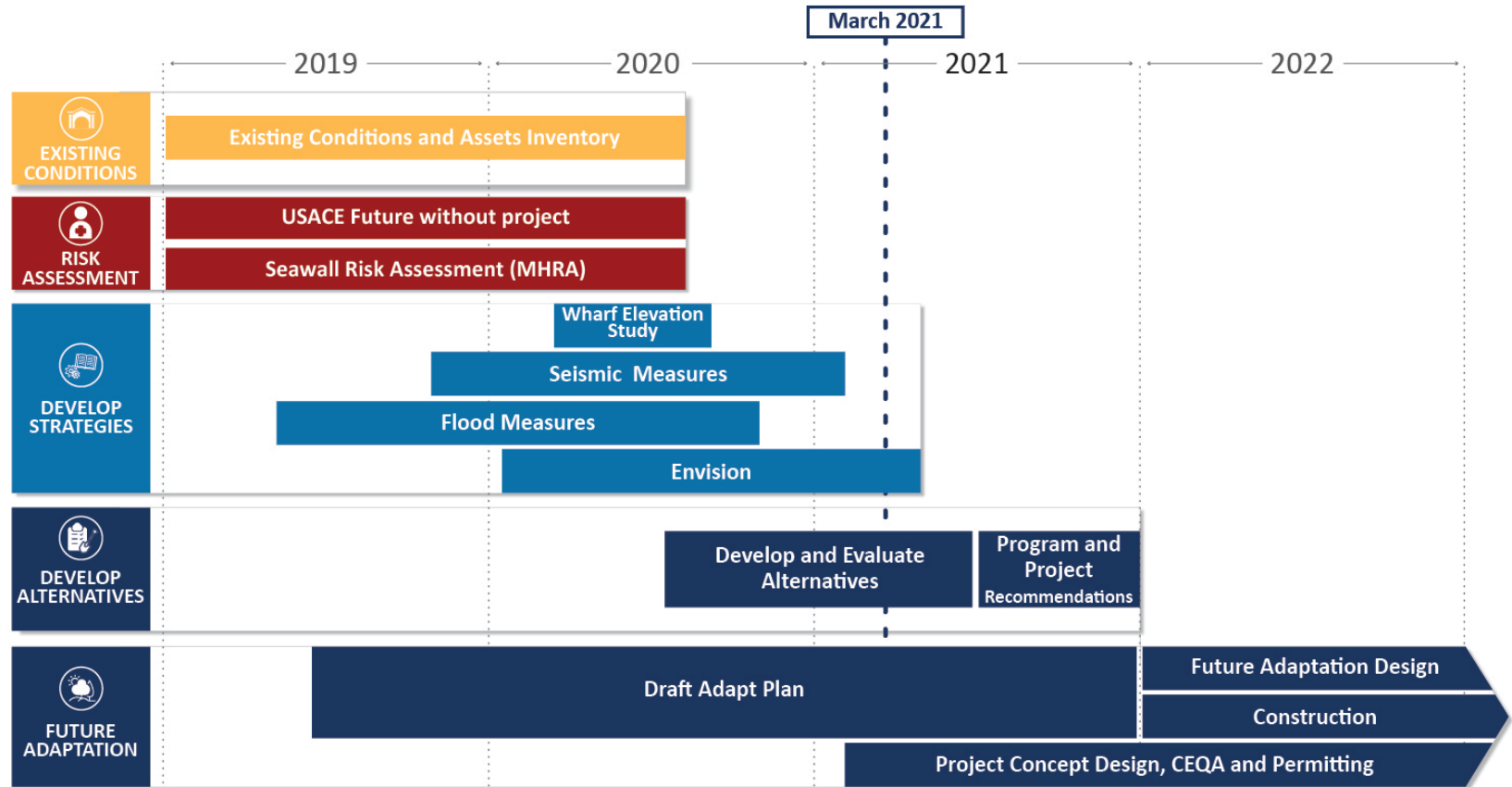
The Embarcadero Waterfront is very **sensitive to flood thresholds**, with major consequences by 2 feet of sea level rise, Ferry Building Area (Folsom to Broadway) is highest risk.



Next Steps



DEVELOPMENT OF THE WATERFRONT RESILIENCE PROGRAM



CEQA: California Environmental Quality Act

ADAPT PLAN

Overview and Key Highlights



- **Project Area:** Fisherman's Wharf to Heron's Head Park
- **Timing:** End of 2021
- **Focus:** Guide action to reduce seismic and climate change risks; includes recommendations for Proposition A projects and additional early project recommendations, the USACE Flood Resiliency Study alternatives and the other adaptation actions to achieve the Program vision statement.

ADAPT PLAN ALTERNATIVES

Actions Comprising an Adapt Plan Alternative



CONSTRUCTION PROJECTS

Including physical improvements such as seismic upgrades and/or coastal flood risk reduction infrastructure



POLICIES

Seismic performance standards for buildings and infrastructure
City flood protection standard
Relocation of critical assets

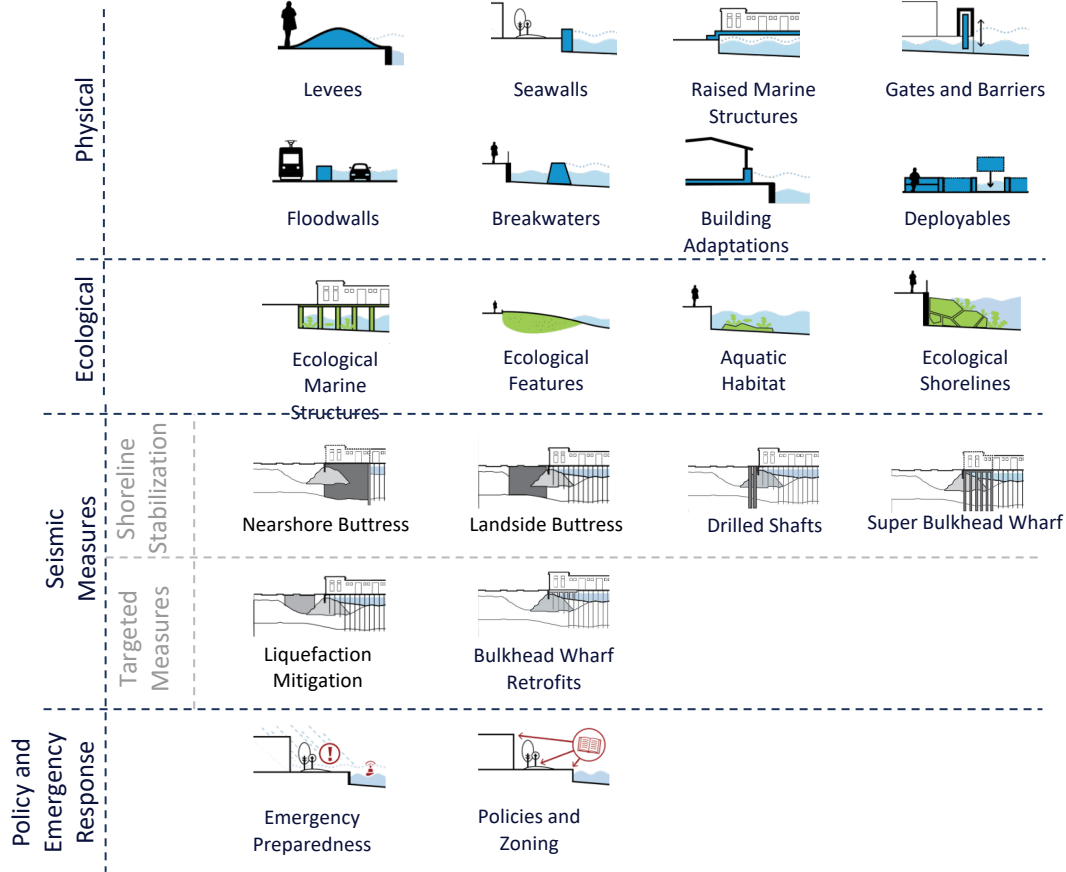


PLANNING STUDIES + STAKEHOLDER ENGAGEMENT

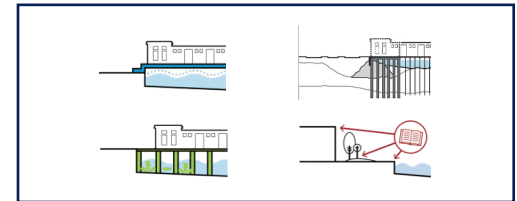
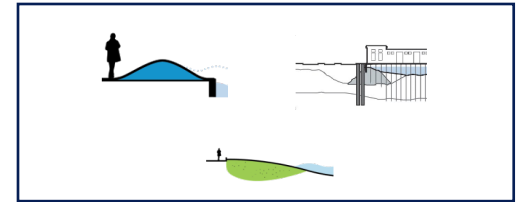
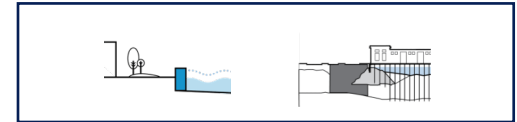
Including further engineering and technical evaluations or multi-stakeholder planning efforts

MEASURES AND APPROACHES

WRP Adapt Plan



APPROACHES



Seismic and flood measures will be combined to develop alternatives that reduce both risks.

WRP EVALUATION CRITERIA

Why are they important?

- Ensure that **Program development** considers vision statement, principles, and objectives as developed with stakeholders
- Provide stakeholders with **direct input** into Program development
- Create a **transparent and accountable approach** to Program development
- Clearly identify **trade-offs** or additional **benefits**
- Allow Port team to **compare alternatives in each geography** and to **recommend preferred alternatives**



**Feasibility &
Performance**



**Society &
Equity**



Economic



Environment

WRP EVALUATION CRITERIA

Categories and Criteria



FEASIBILITY & PERFORMANCE

Feasibility

Adaptability

Performance

Partnerships

Construction

Utilities



SOCIETY + EQUITY

Life Safety

Historic character

Emergency Response

Social Cohesion and

Mobility

Community Resilience

Urban Design

Equitable investments

Equitable outcomes



ECONOMIC

Direct Physical Damage

Capital Costs

Avoided

Lifecycle Considerations

Disruption Avoided

Number of jobs

Economic Resilience

Diversity of jobs



ENVIRONMENT

Environmental Risks

Environmental

Opportunities

Questions & Discussion

Steven Reel
Port of San Francisco
sfport.com

