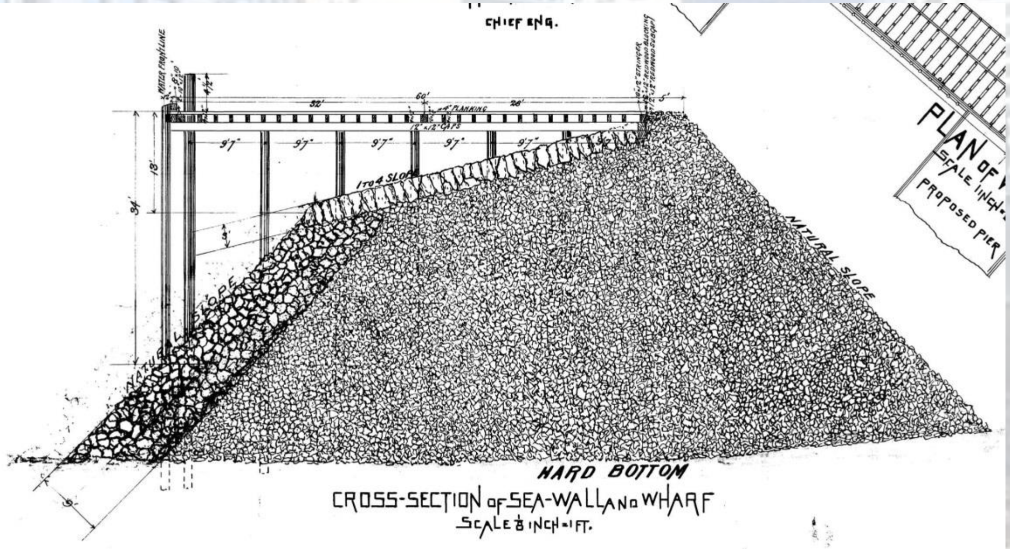
The Northern Waterfront Seawall History and Earthquake Performance



Waterfront Plan Working Group Meeting

April 13, 2016

Steven Reel, PE - Project Manager, Engineering Division, Port

The Northern Waterfront Seawall History and Earthquake Performance

Meeting

Division, Port

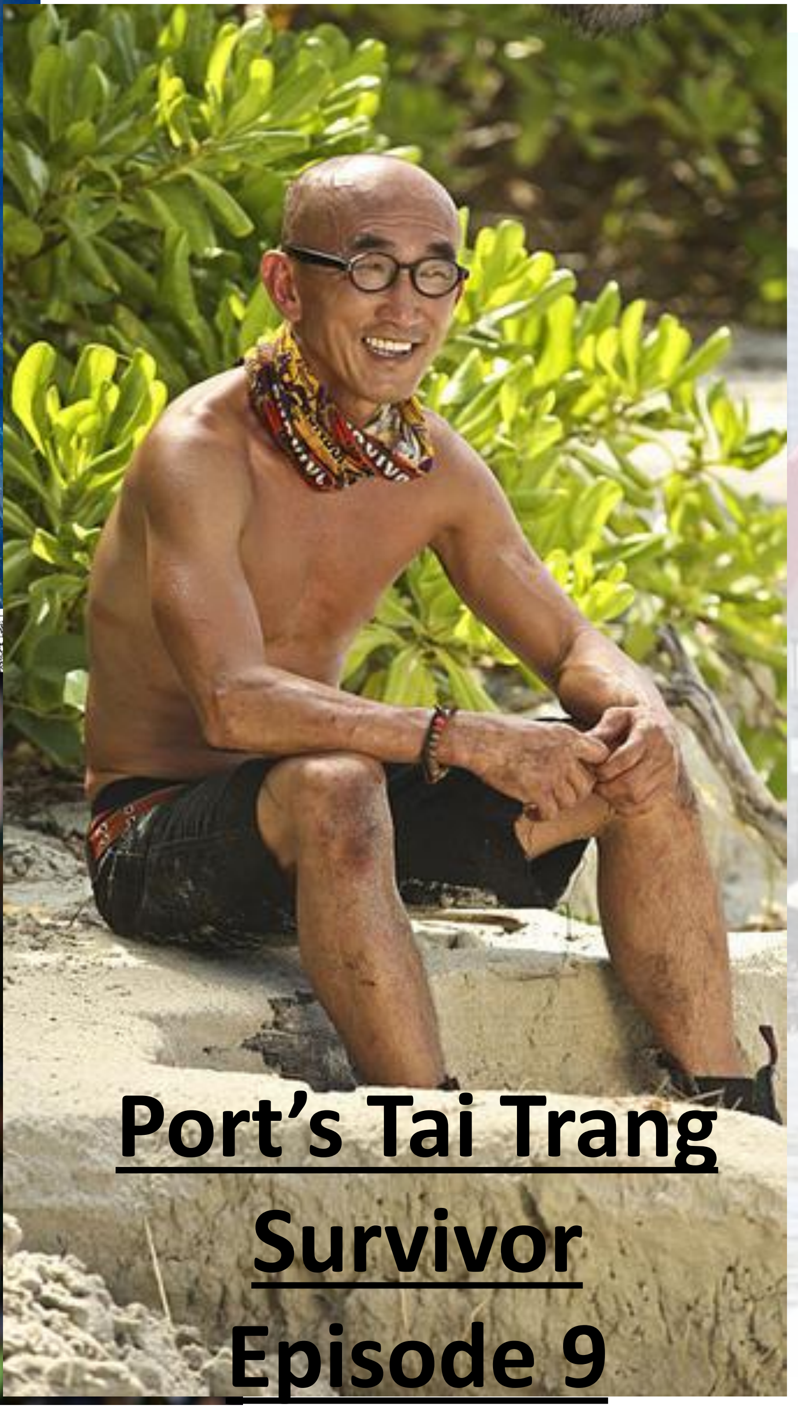
front Seawall
ke Performance

Meeting

Division, Port

Warrior's 73

Kobe's Last Game



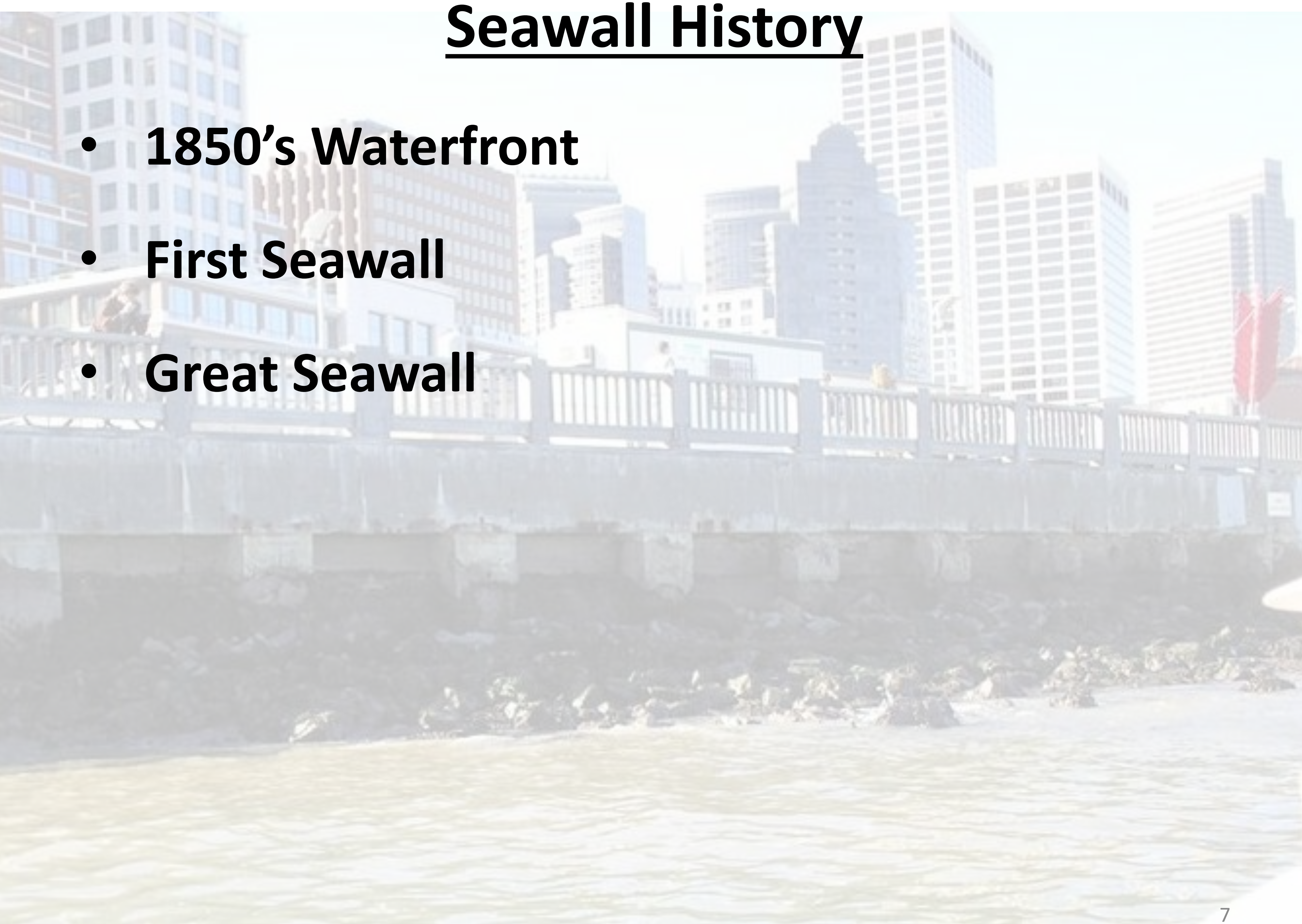
Port's Tai Trang Survivor Episode 9

Presentation Outline

- History of the Seawall
- Past Performance
- Earthquake Vulnerability Study
- Case Studies

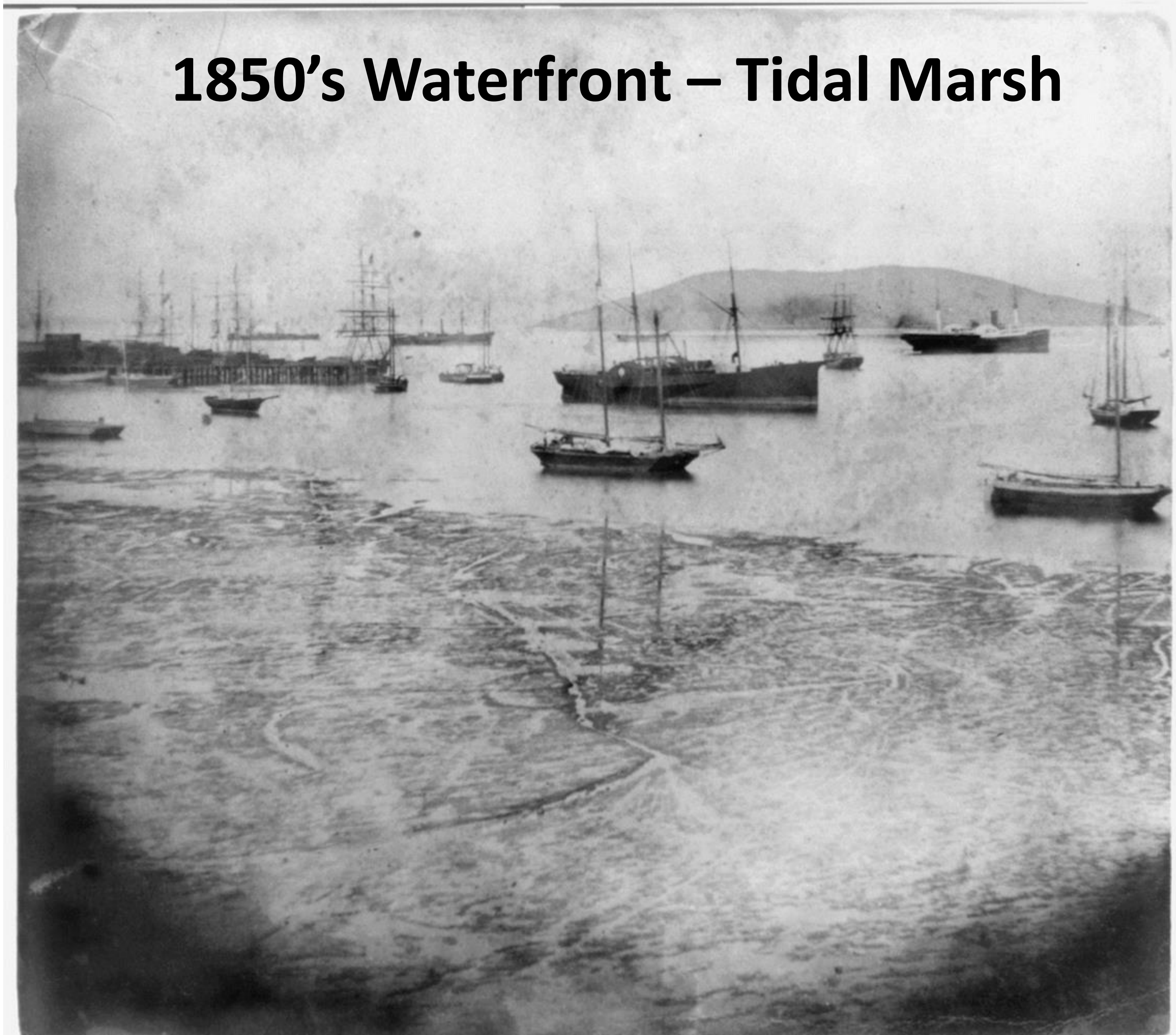
The Great Seawall stretches from Fisherman's Wharf to Mission Creek
Study Boundary is similar to the original shoreline

Seawall History



- 1850's Waterfront
- First Seawall
- Great Seawall

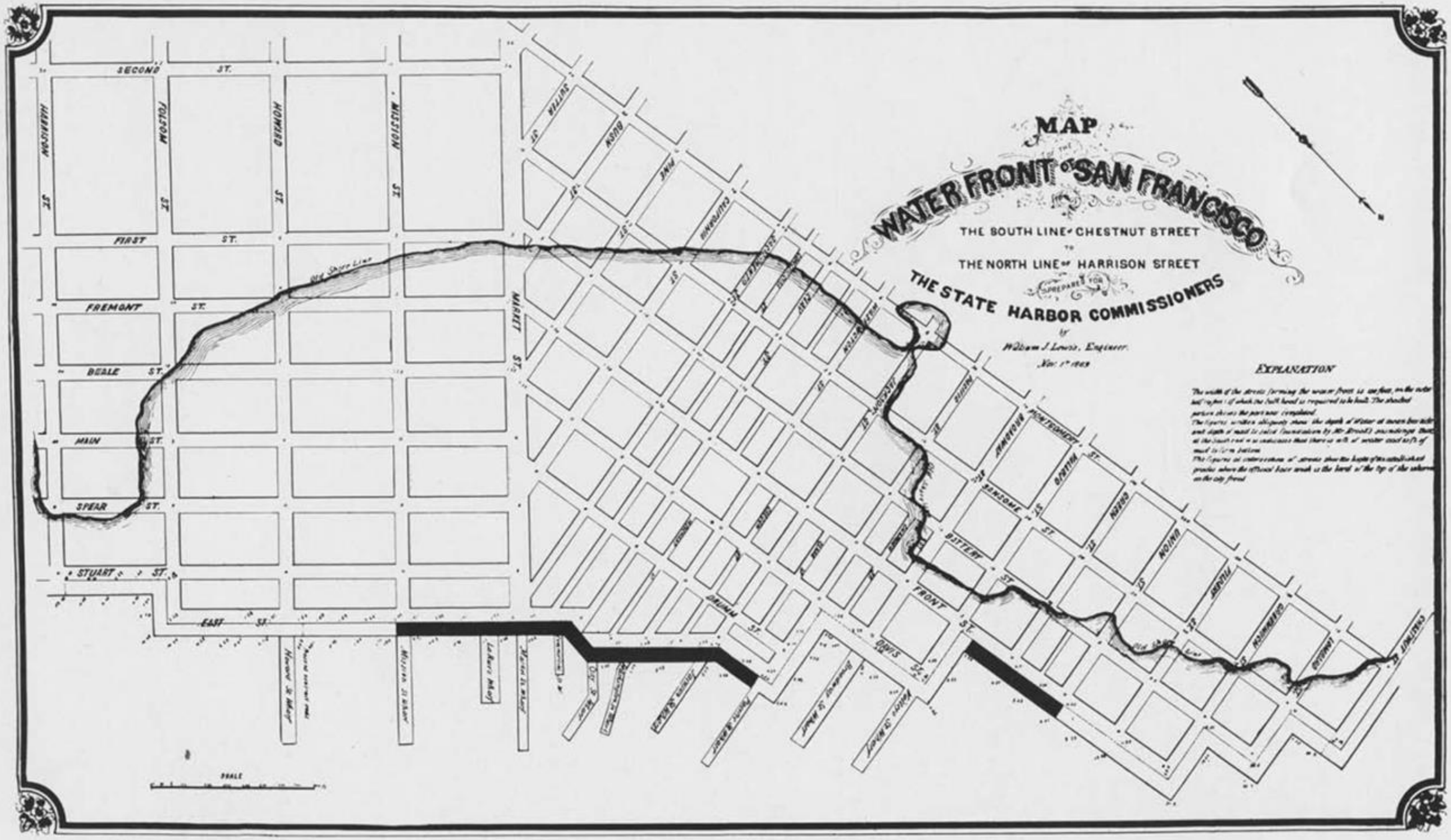
1850's Waterfront – Tidal Marsh



387. Ebb Tide, South Beach, San Francisco.

1851 Map & Yerba Buena Cove

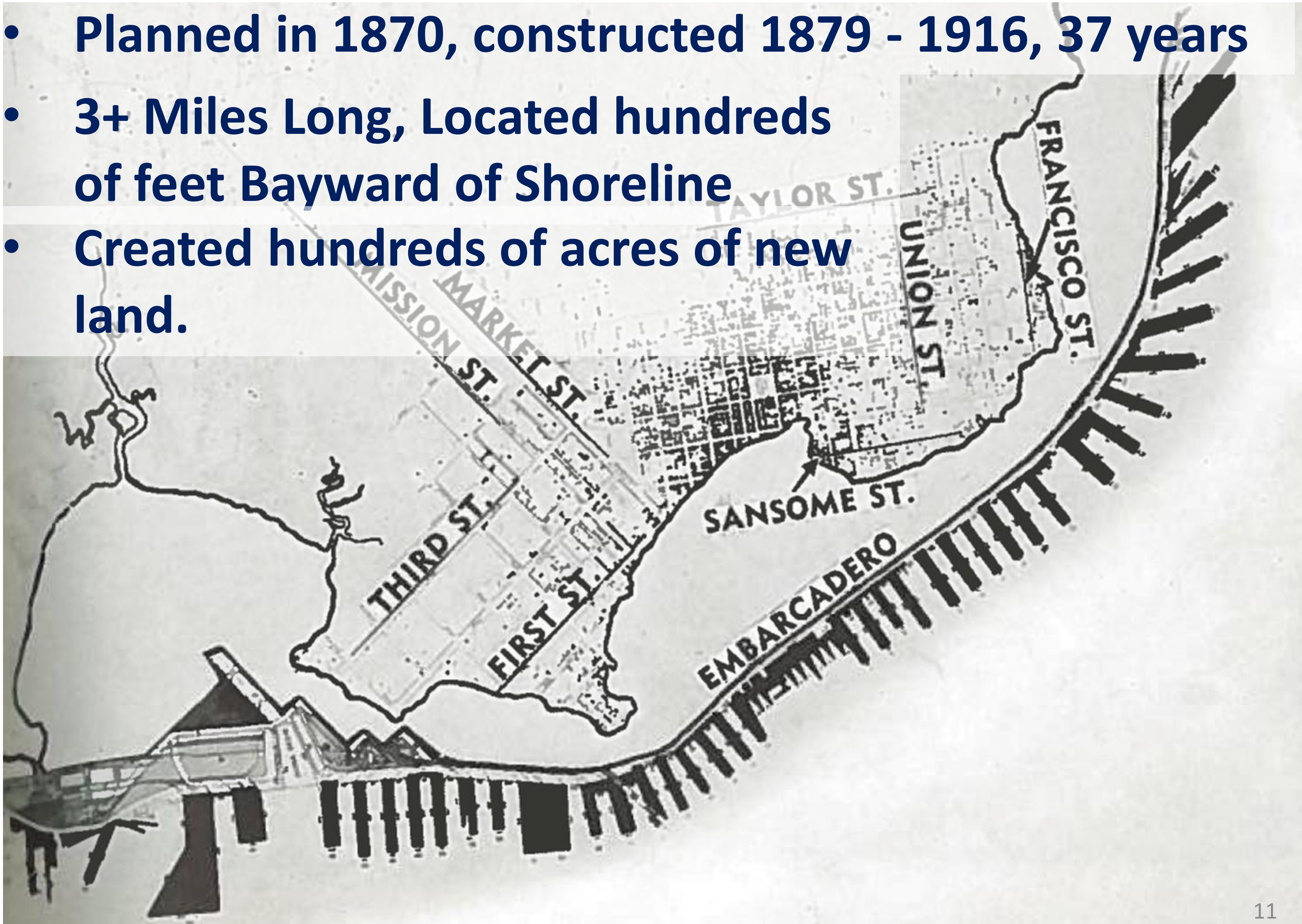
First Seawall (1866 – 1969)

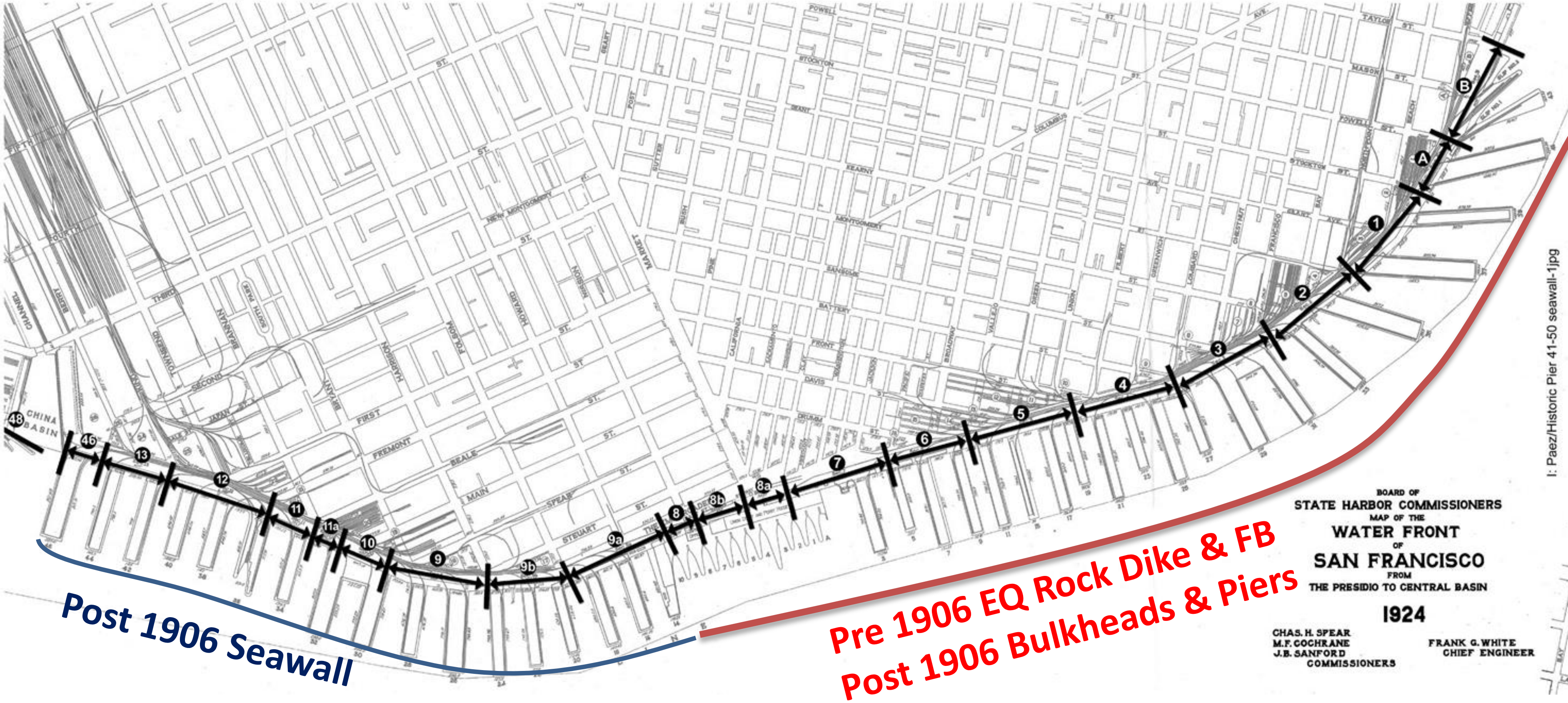


Map from the first survey made for the new State Harbor Commissioners. The waterfront has been built out a long way from the shoreline of 20 years earlier, but compare with the waterfront map of today at the back of this report

Great Seawall History

- Planned in 1870, constructed 1879 - 1916, 37 years
- 3+ Miles Long, Located hundreds of feet Bayward of Shoreline
- Created hundreds of acres of new land.





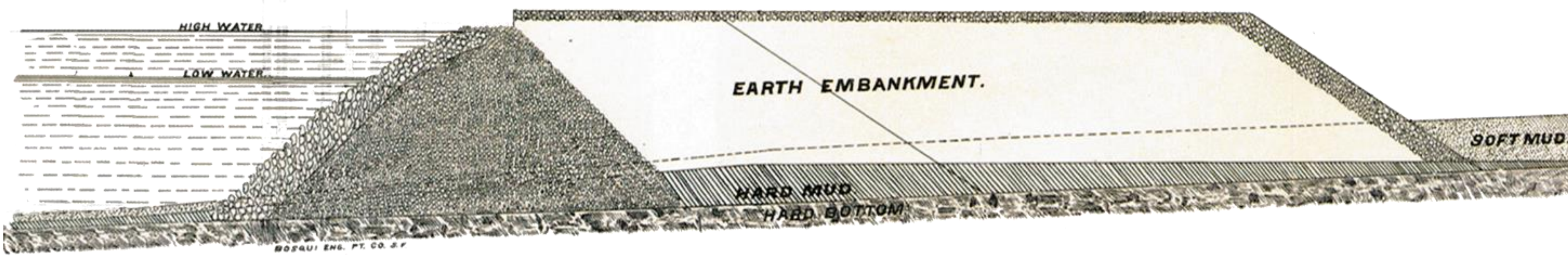
The Seawall is a complex and Historic Resource that is the foundation of the Northern Waterfront

22 Original Seawall Sections

55+ Combinations of Bulkheads and Wharves

Modifications & Repairs throughout 100 years

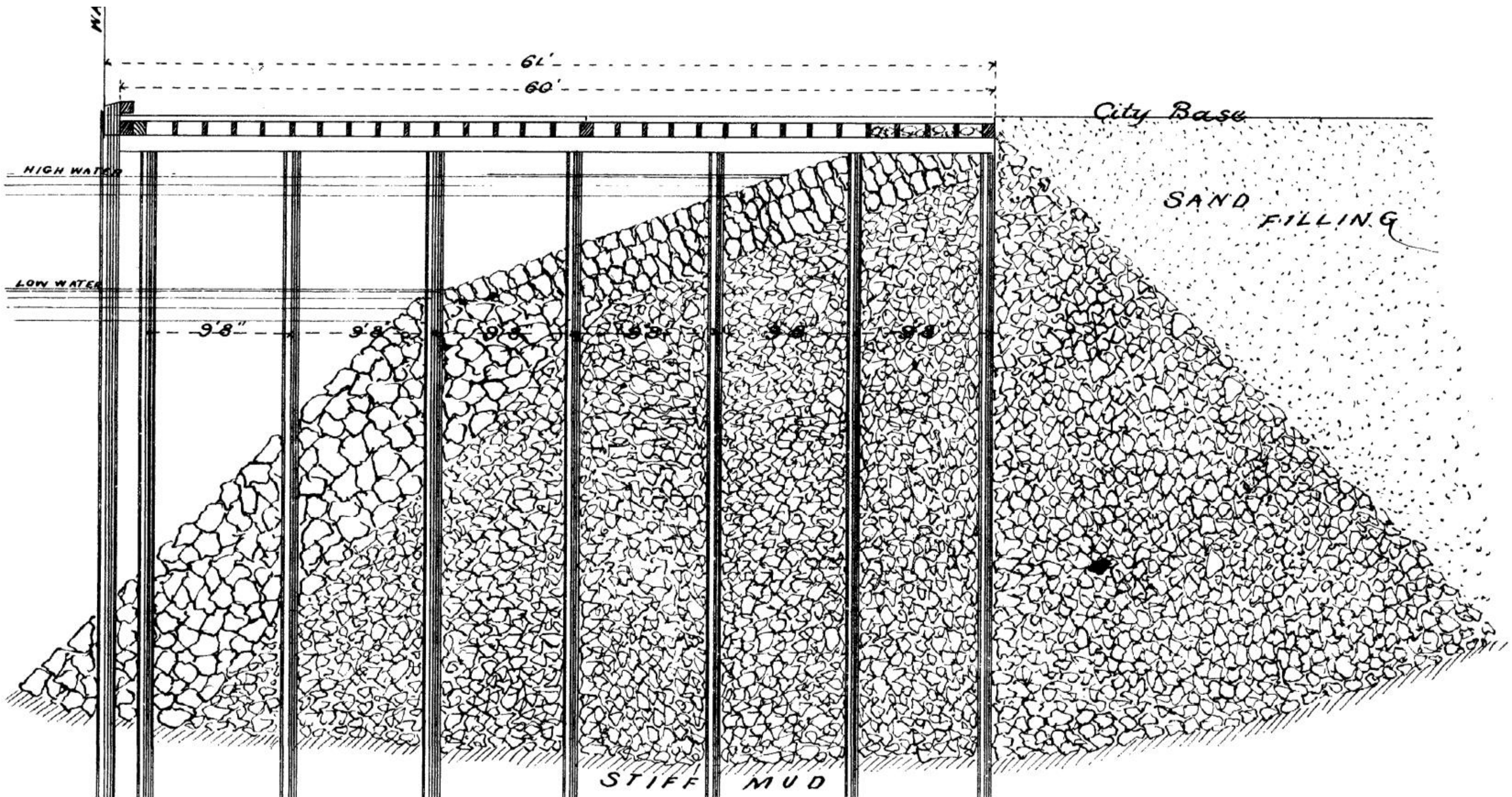
Great Seawall – Typical Early Construction



TRANSVERSE SECTION of SEA WALL and THOROUGHFARE.

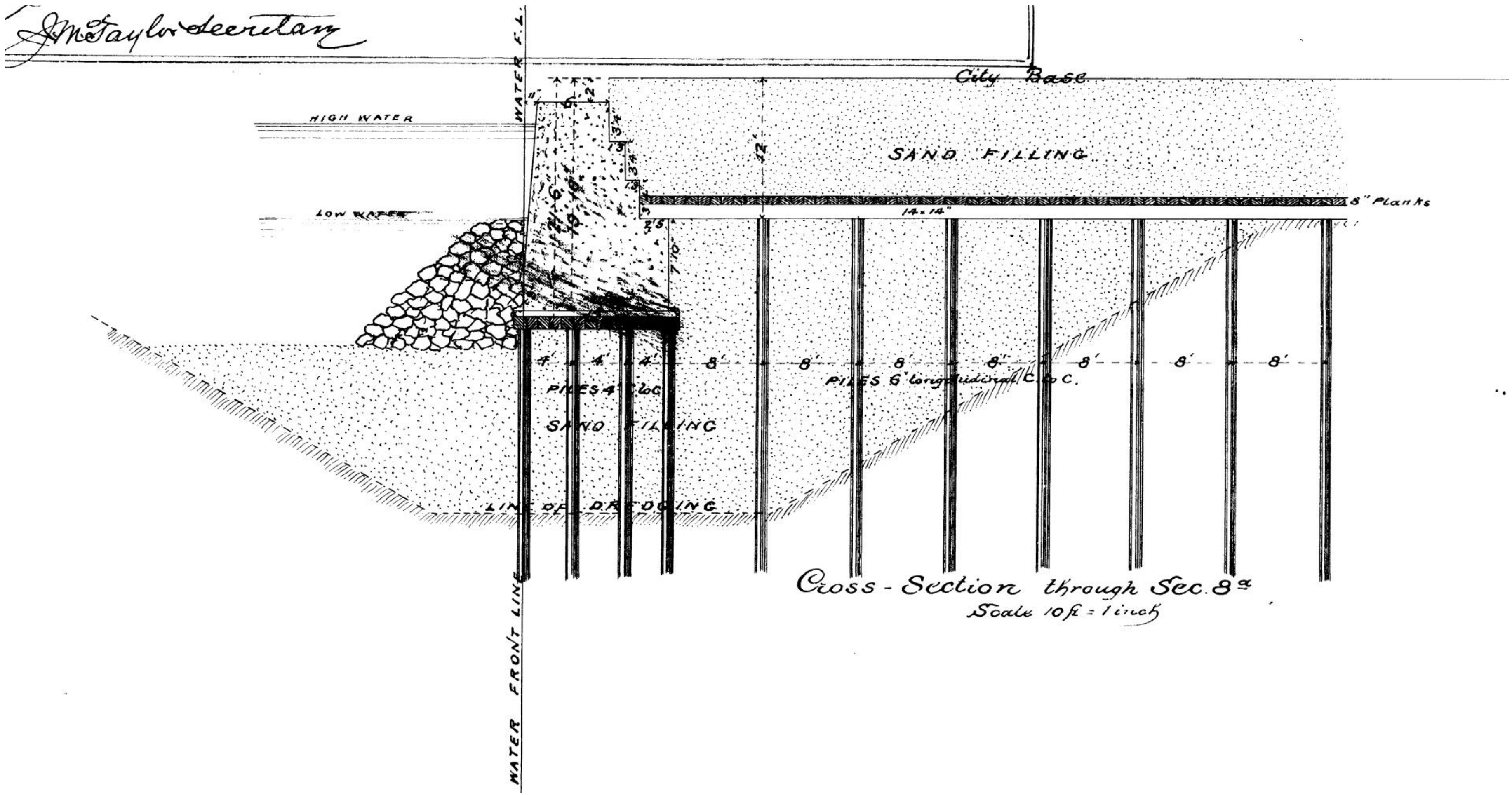
SCALE 20 ft. = 1 INCH.

Great Seawall – Early Construction (1879-1893)
A, 1, 2, 3, 4, 5, 6, 7, B   1-1/2 Miles



Cross-Section through Sec. 7
Scale 10 ft = 1 inch

Great Seawall – Ferry Building
Section 8a (1891-1893) & 8b (1888 – 1890)



Great Seawall – Ferry Building
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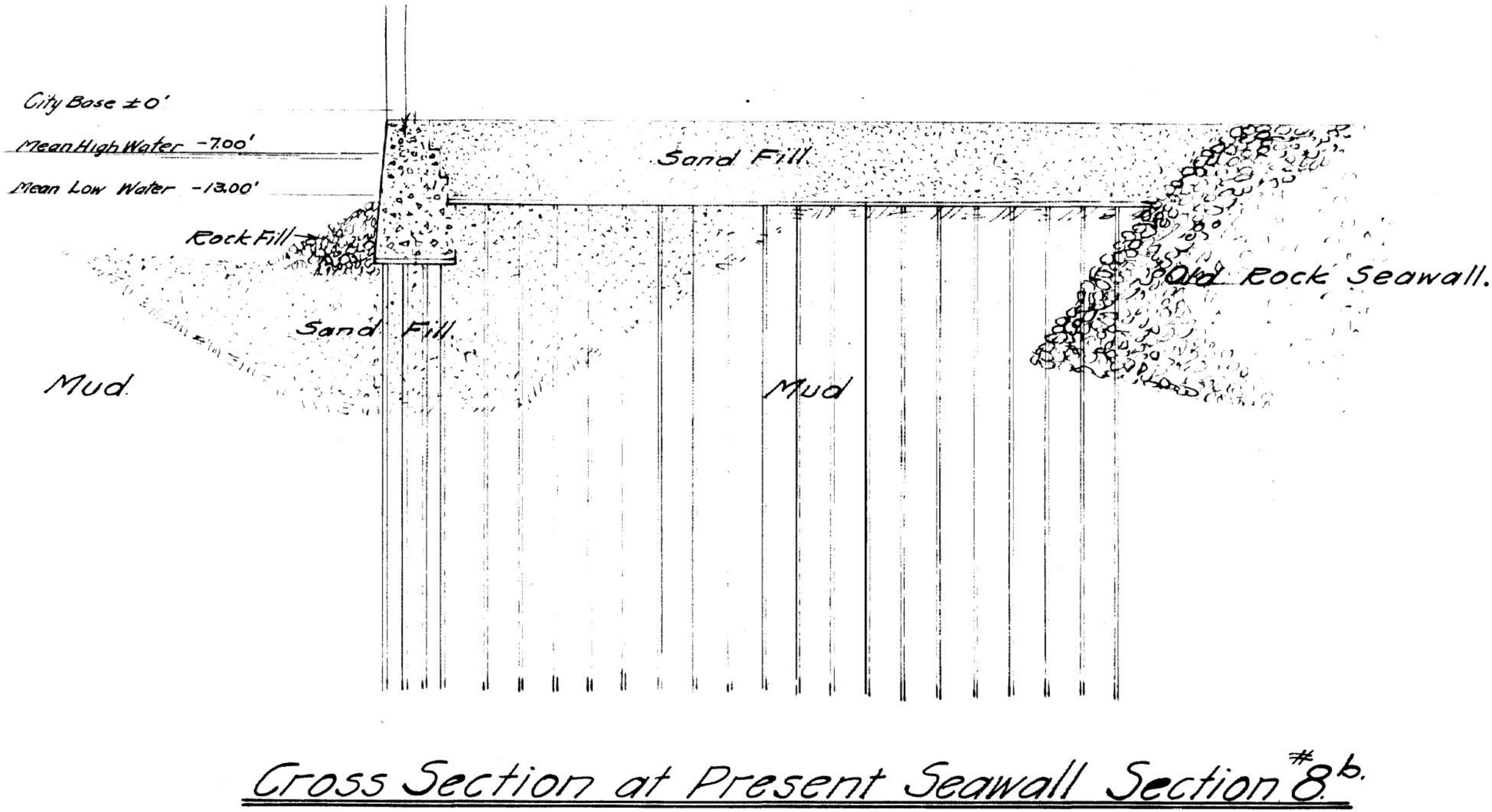
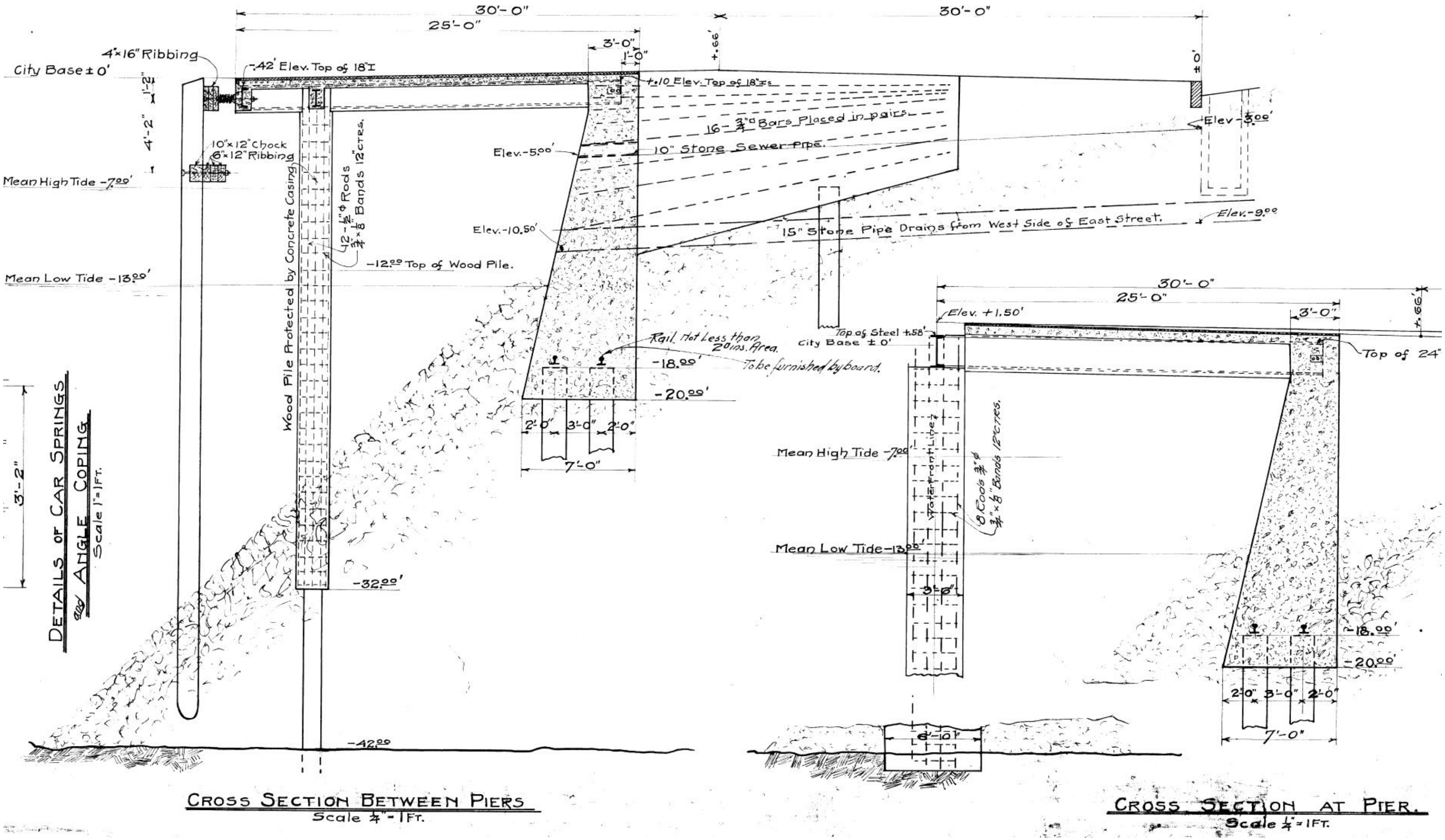
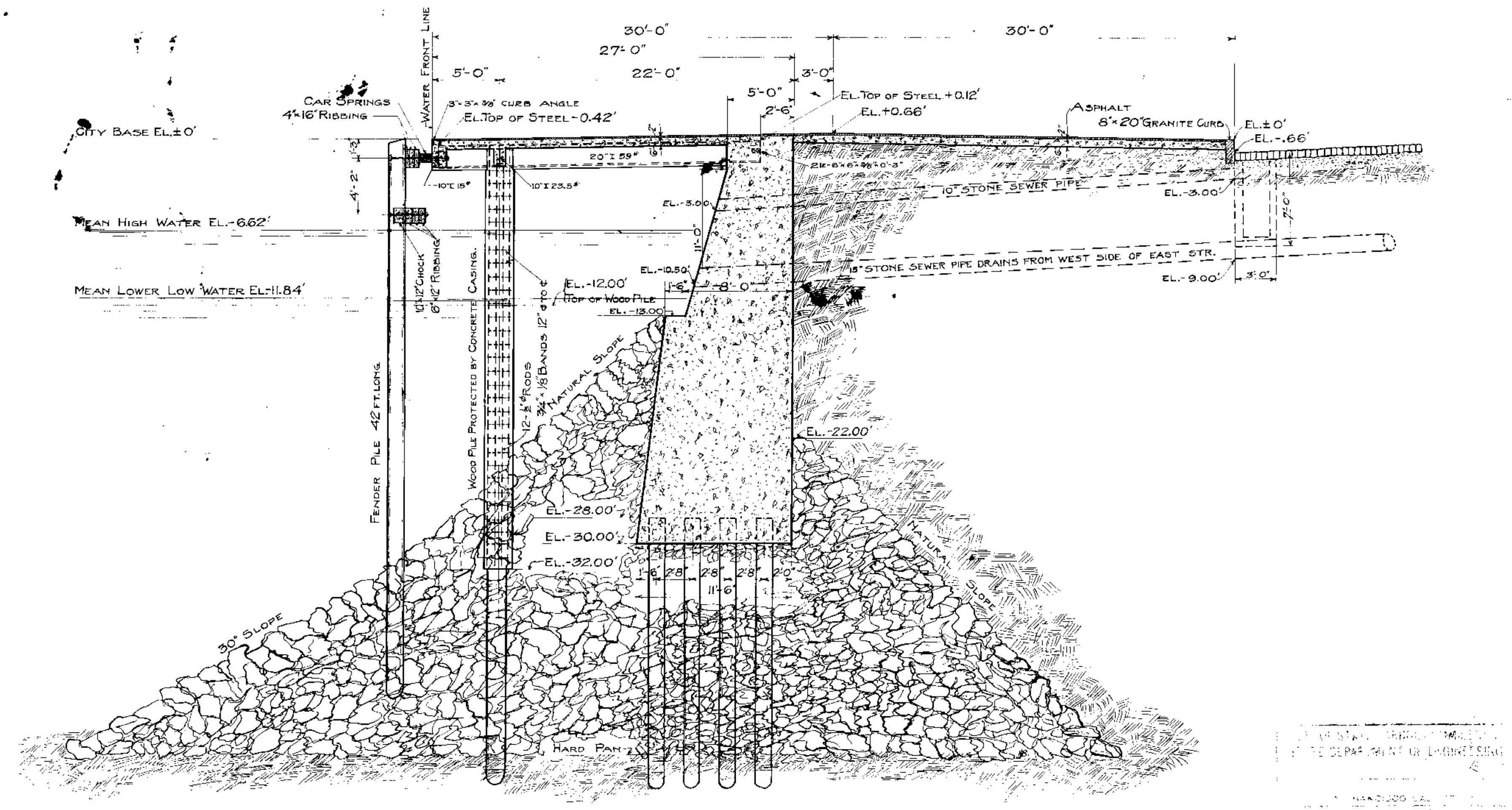


Great Seawall – Later Construction
Large Concrete Bulkhead - Section 11 (1909)



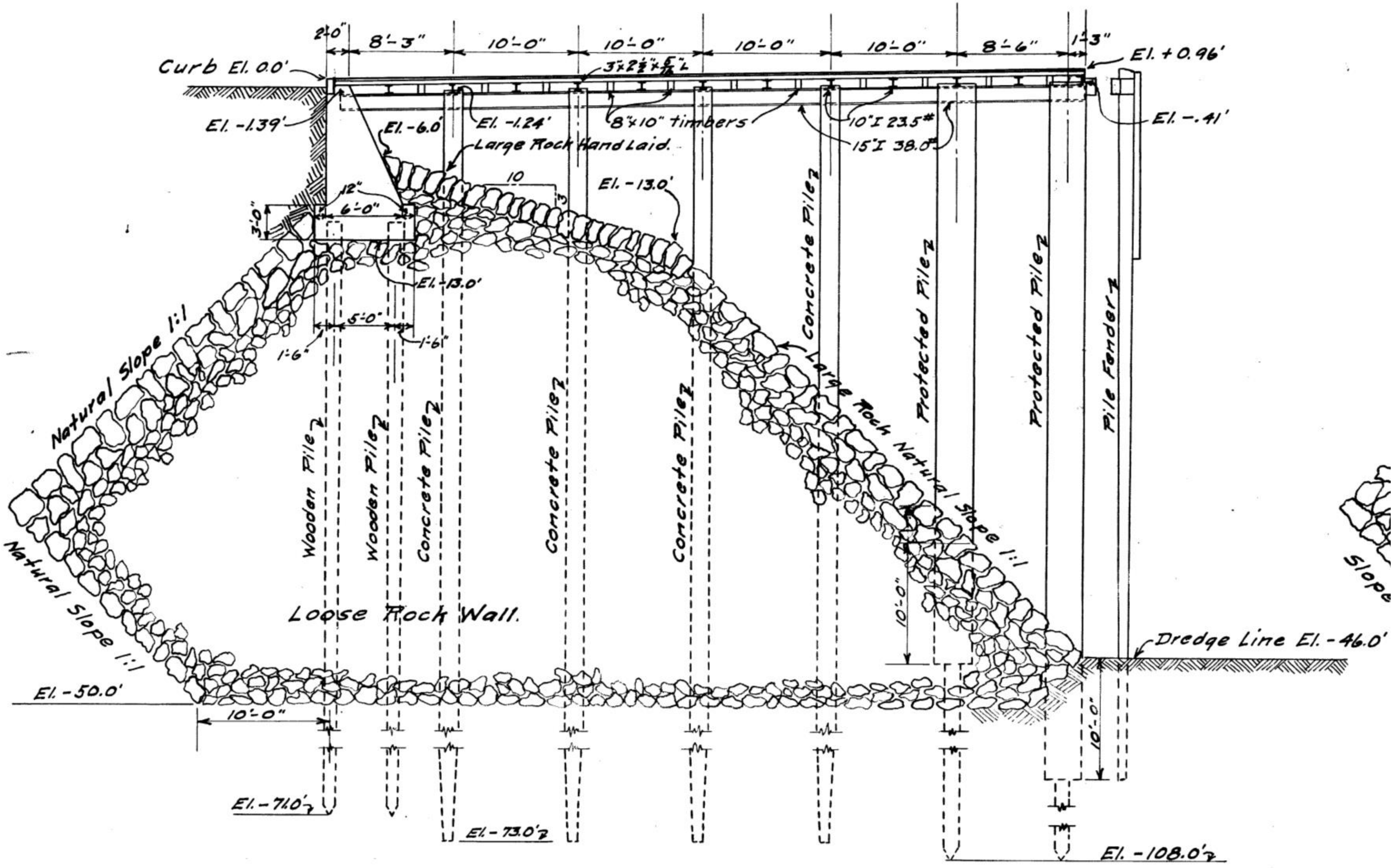
Great Seawall – Later Construction Section 10 (1910)



Cross Section of Seawall Section 10

1993-39

Great Seawall - Section9B (1912)



ELEVATION - SEC. "A-A"
Scale 1/8" = 1'-0"

Great Seawall – Constructed in the Bay
Made possible hundreds of acres of new land

Great Seawall - Section 11 (1909)
Pier 34 & Pier 36

Great Seawall - Section 8 (1910)

Construction was a major effort using technology of the day and employing thousands

Great Seawall: Sect. 9A (1915)
Looking Bayward over the Embarcadero "Canal"

Great Seawall (1932 Waterfront)

Performance

- **Settlement**
- **Condition**
- **1906 EQ**
- **1989 EQ**

1906 Earthquake

- Ferry Building Completed 1903
- Rock Dike Seawall Sections Complete from Ferry Bldg to Fisherman's Wharf (B, A, 1, 2, 3, 4, 5, 6, 7, 8a, 8b)
- Rock Dike Seawall Section 13 near Mission Creek

1906 EQ – Ferry Building

1906 EQ – Ferry Building

1906 EQ – Foot of Market St

1906 EQ – Embarcadero (East St)

1906 EQ – Embarcadero near Lombard

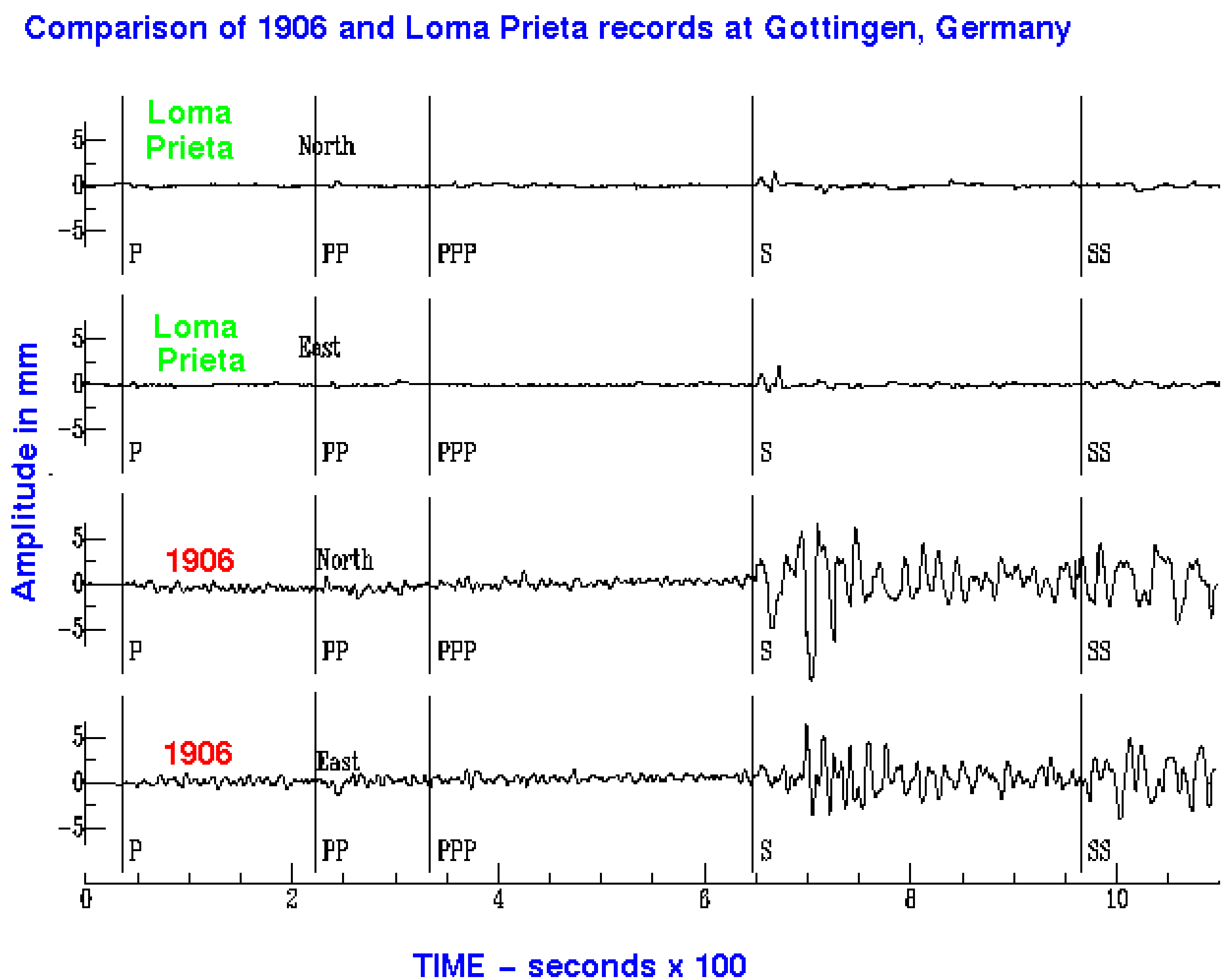
1906 EQ – Embarcadero near Lombard

1906 EQ – Mission St Pier No. 2

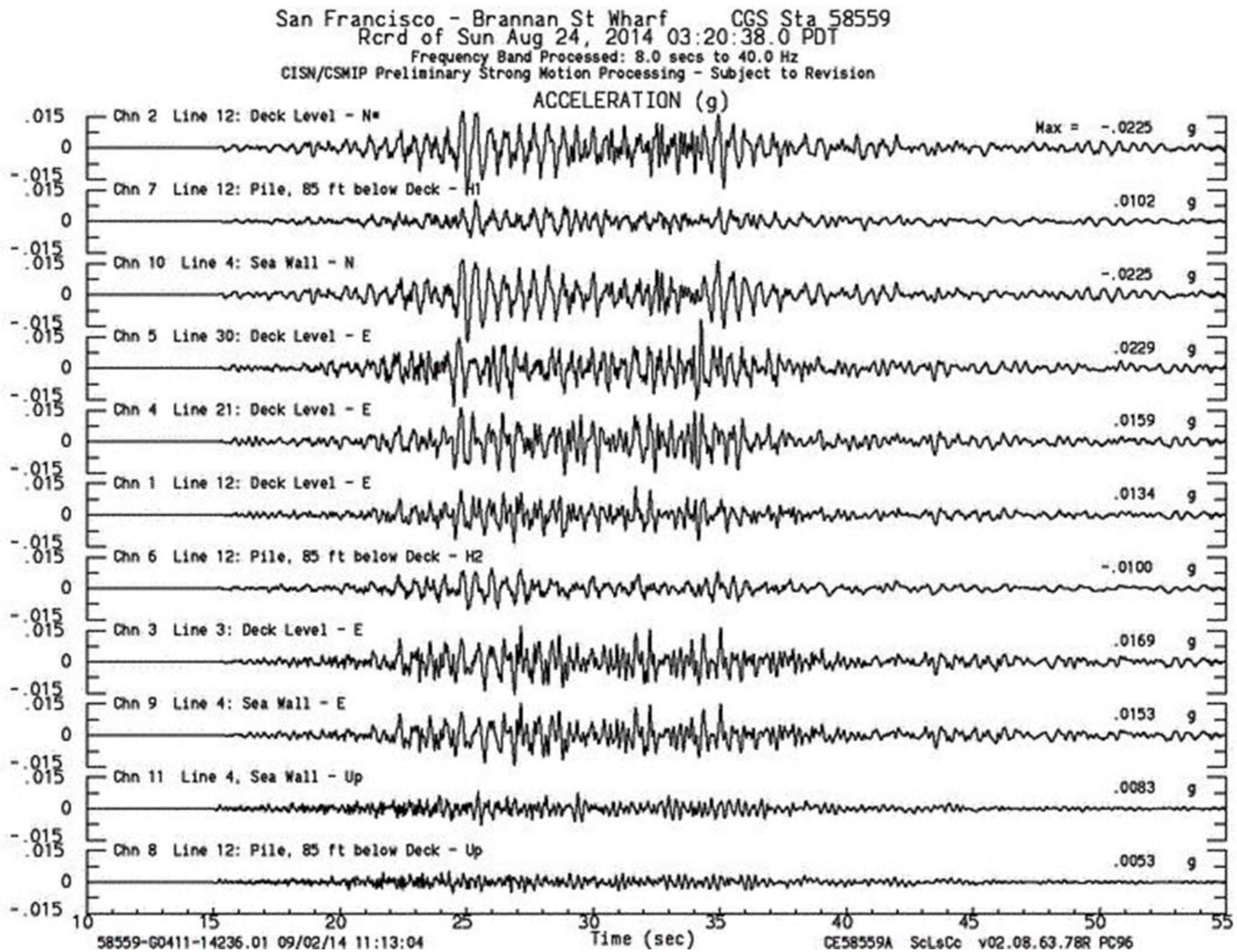
1906 EQ – Ferry Building

1989 Loma Prieta Earthquake

1906 vs 1989 Loma Prieta Earthquake Ground shaking recorded in Germany



2014 South Napa Earthquake (M6.0, 29 mi) Strong Motion Recording from Brannan St Wharf

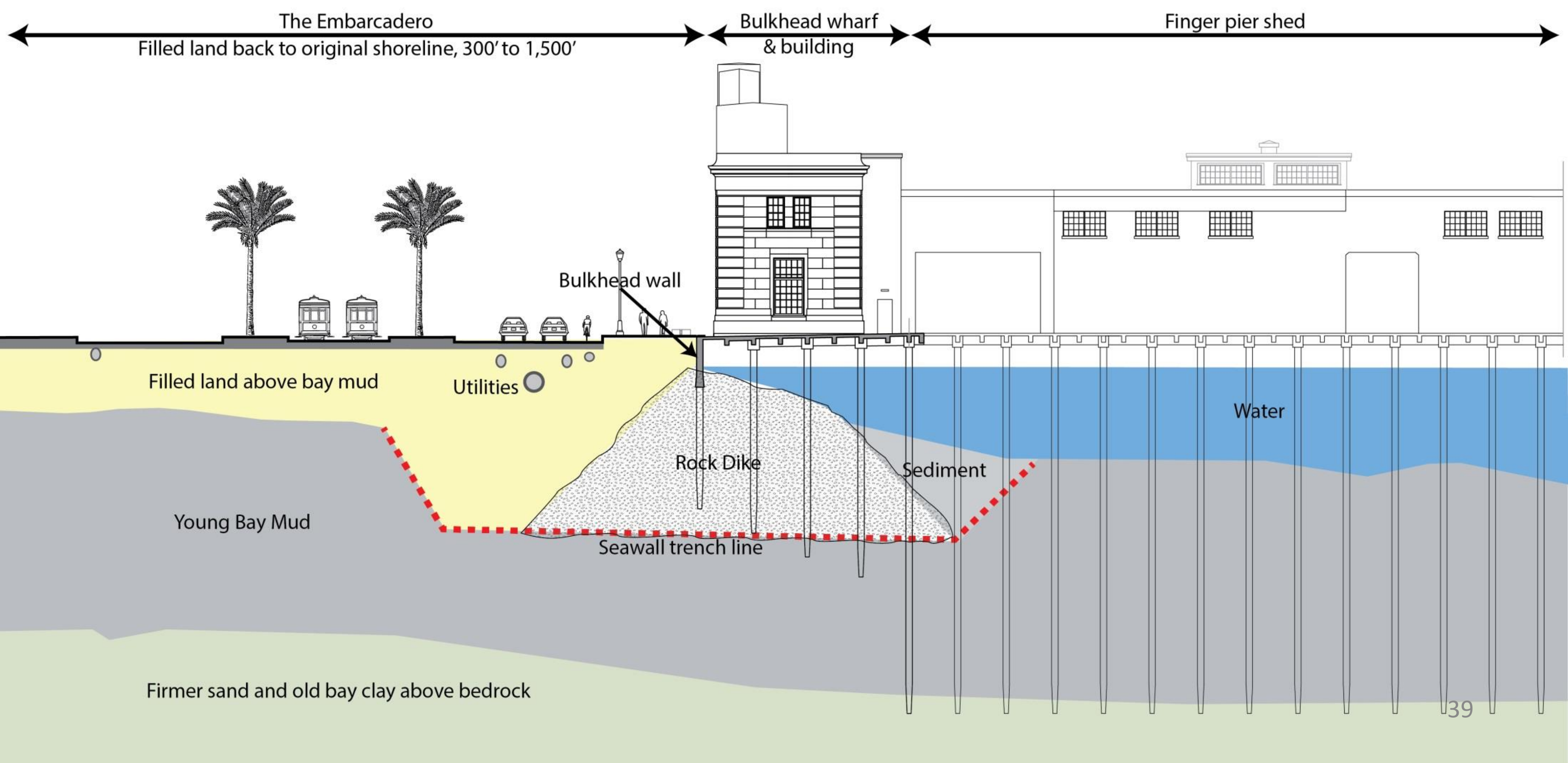


Earthquake Vulnerability Study

- Ground Mapping
- Seismic Hazard – Ground Shaking
- Stability, Lateral Spreading, and Settlement Analysis
- Vulnerabilities
- Flooding
- Impacts
- Mitigations

Seawall – Existing Conditions, Typical

Seawall = Rock Dike, Bulkhead Wall, Bulkhead Wharf



EQ Vulnerability Study Contract Scope

Prime Consultant: **GHD/GTC JV**

Peer Review: **COWI/Langan**

- Establish Zone of Influence
- Develop detailed subsurface maps & profiles
- Generate site specific earthquake hazard ground shaking trends
- Analyze Seawall for stability and impact upon lateral spreading and settlement of Embarcadero
- Calibrate with 1906 & 1989 EQ observations

EQ Vulnerability Study Contract Scope

- Structural analysis of select bulkhead walls and wharves (IN PROGRESS)
- Map utilities and assess impacts (IN PROGRESS)
- Assess post earthquake flood hazards
- High level economic impact analysis
- Develop conceptual level mitigation measures
- Rank and prioritize areas for mitigation and/or detailed investigation (NEXT STEPS)

Subsurface Mapping – Artificial Fill Thickness

The Study Team collected existing geotechnical borings and cataloged in GIS to create subsurface maps of the soils within the Zone of Influence

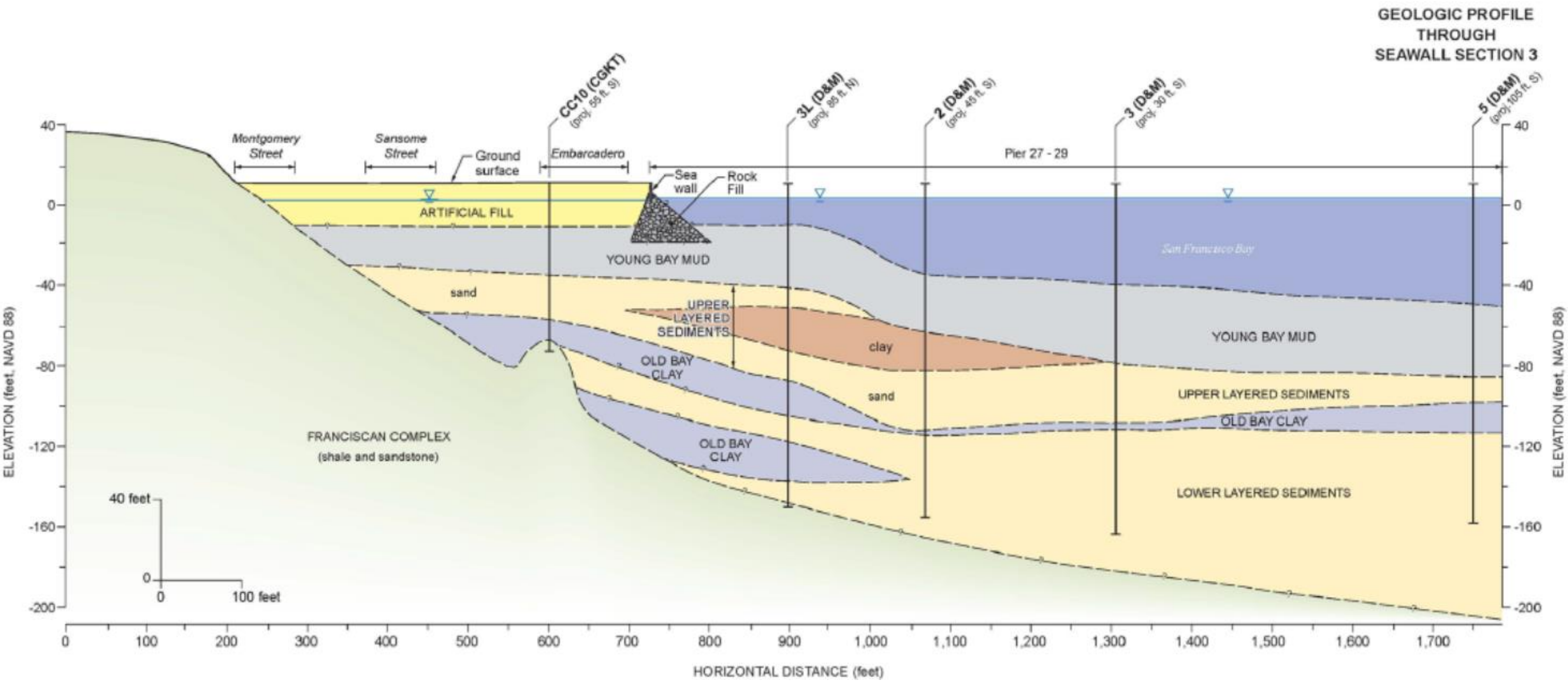
Subsurface Mapping – Young Bay Mud Thickness

LEGEND

- Seawall Bulkhead
- Zone of Influence, within 1200 feet of the Seawall Bulkhead and within the Lateral Spread Hazard Zone
- Historic Geotechnical Borings
- 20 foot Contours of Elevation of Top of Bedrock (NAVD88)

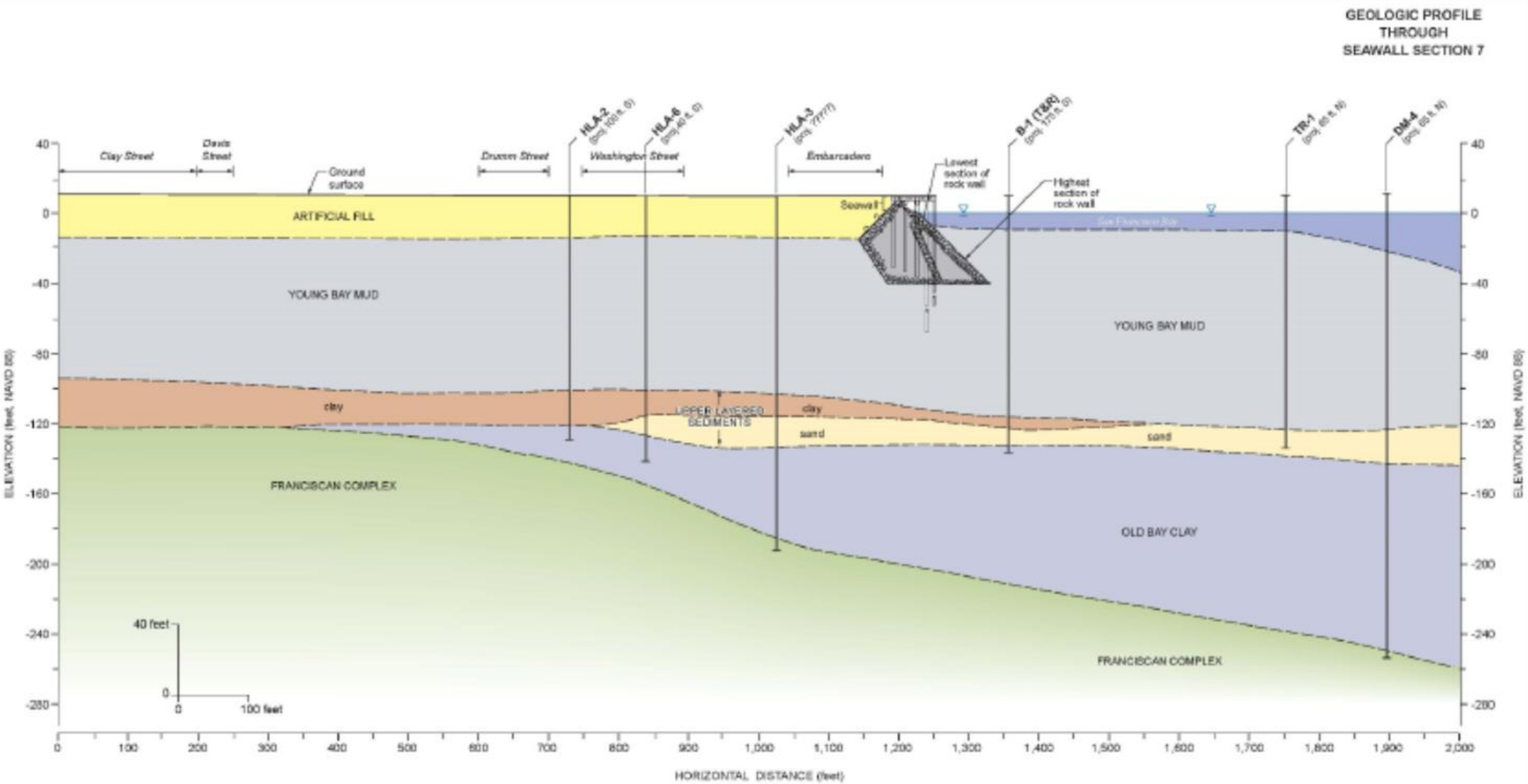
0 600 1,200 2,400 Feet

Subsurface Mapping – Bedrock Elevation

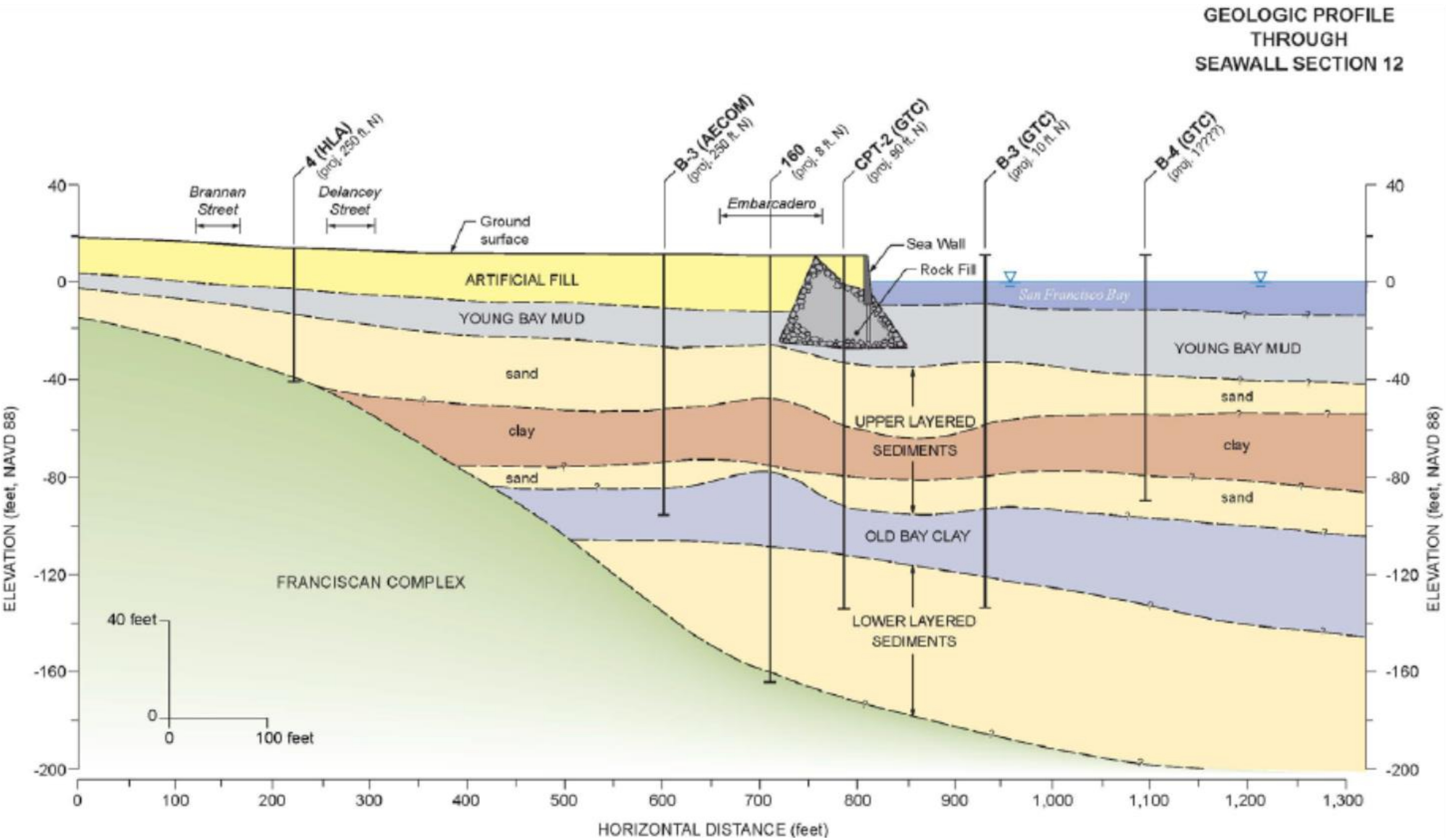


The Study Team chose 8 representative sections for detailed analysis

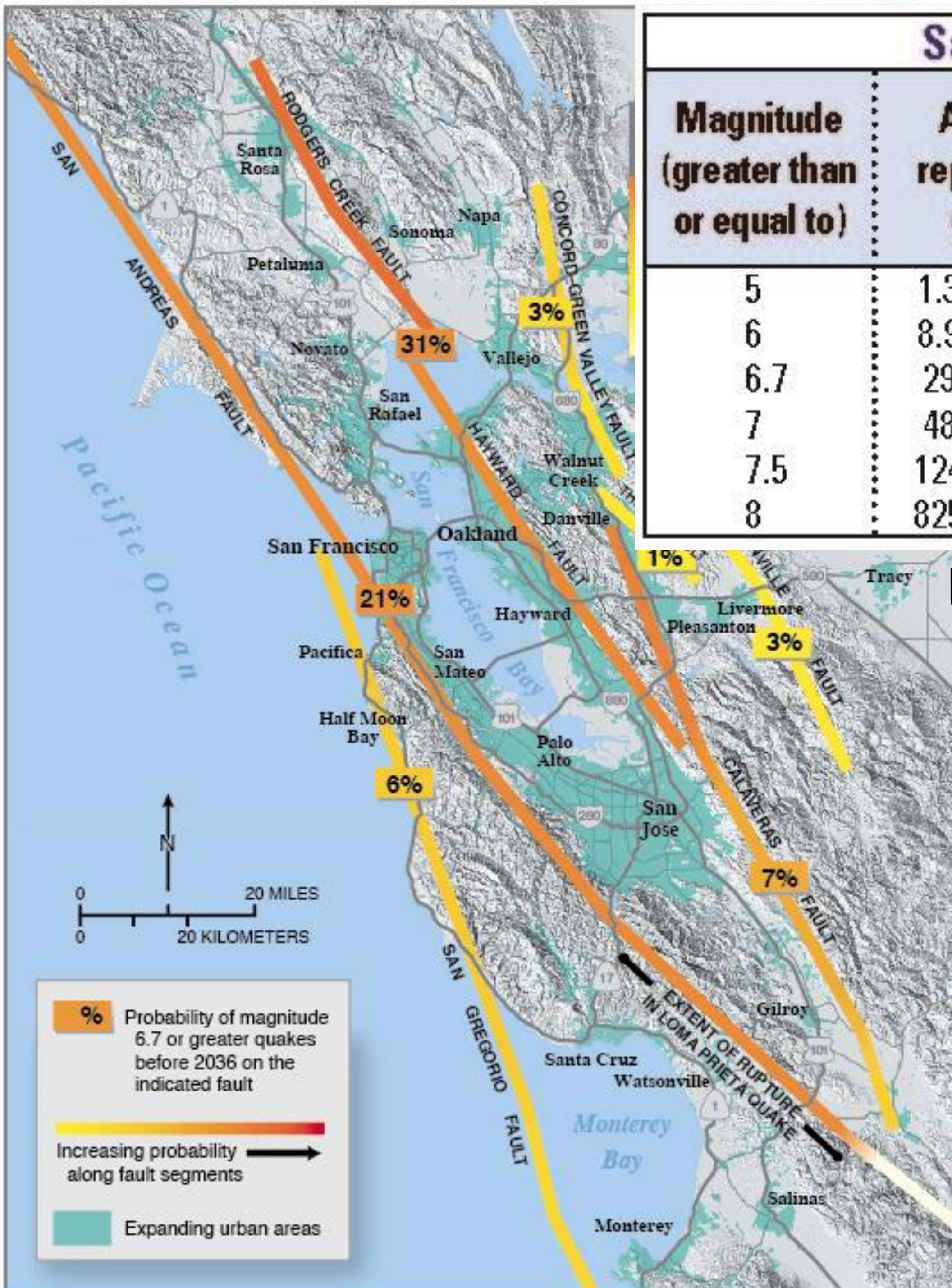
Geotechnical Section
Section 3 - Vicinity of Pier 29



Geotechnical Section
Section 7 - Vicinity of Pier 3



Geotechnical Section
Section 12 – Vicinity of Pier 38

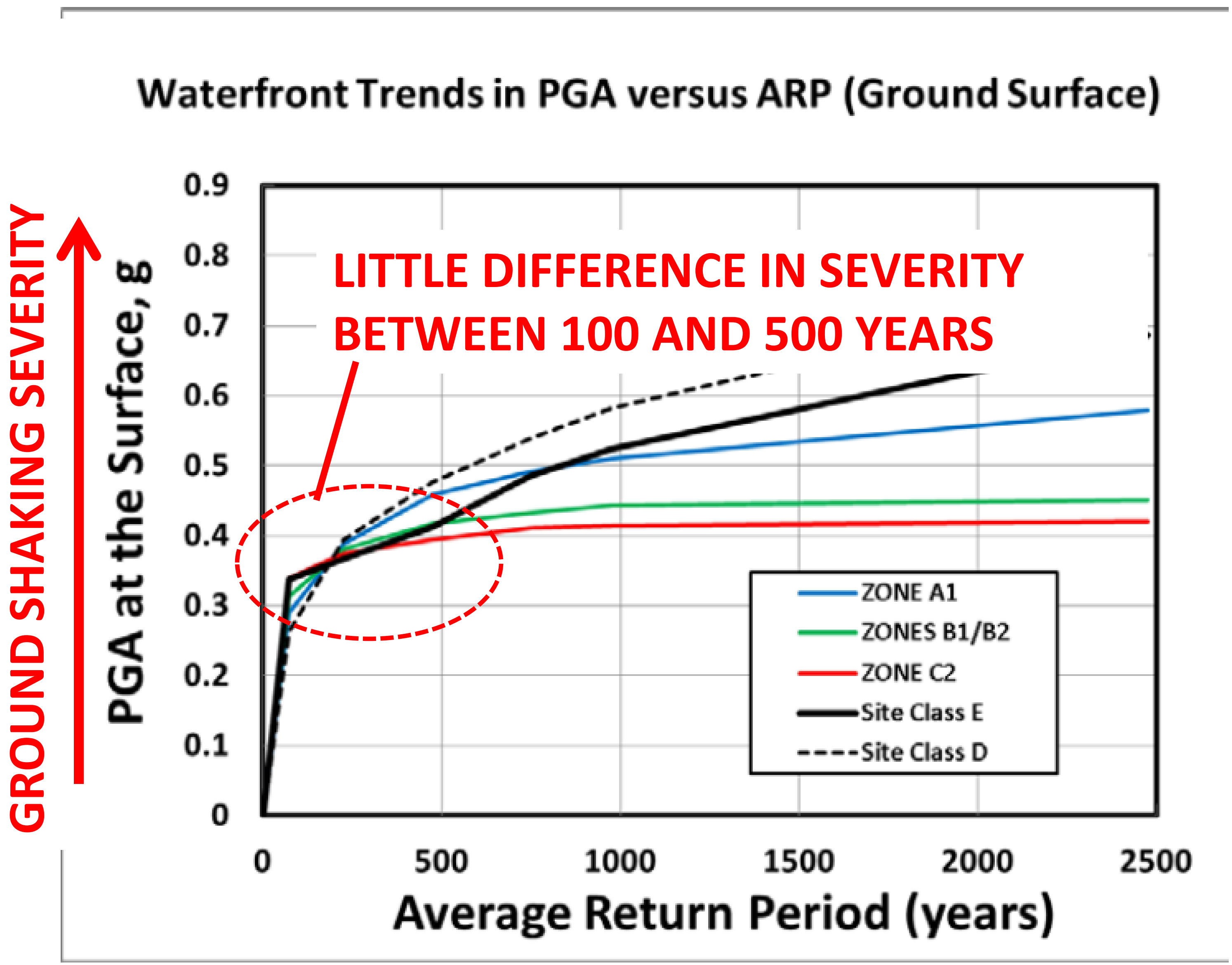


San Francisco region

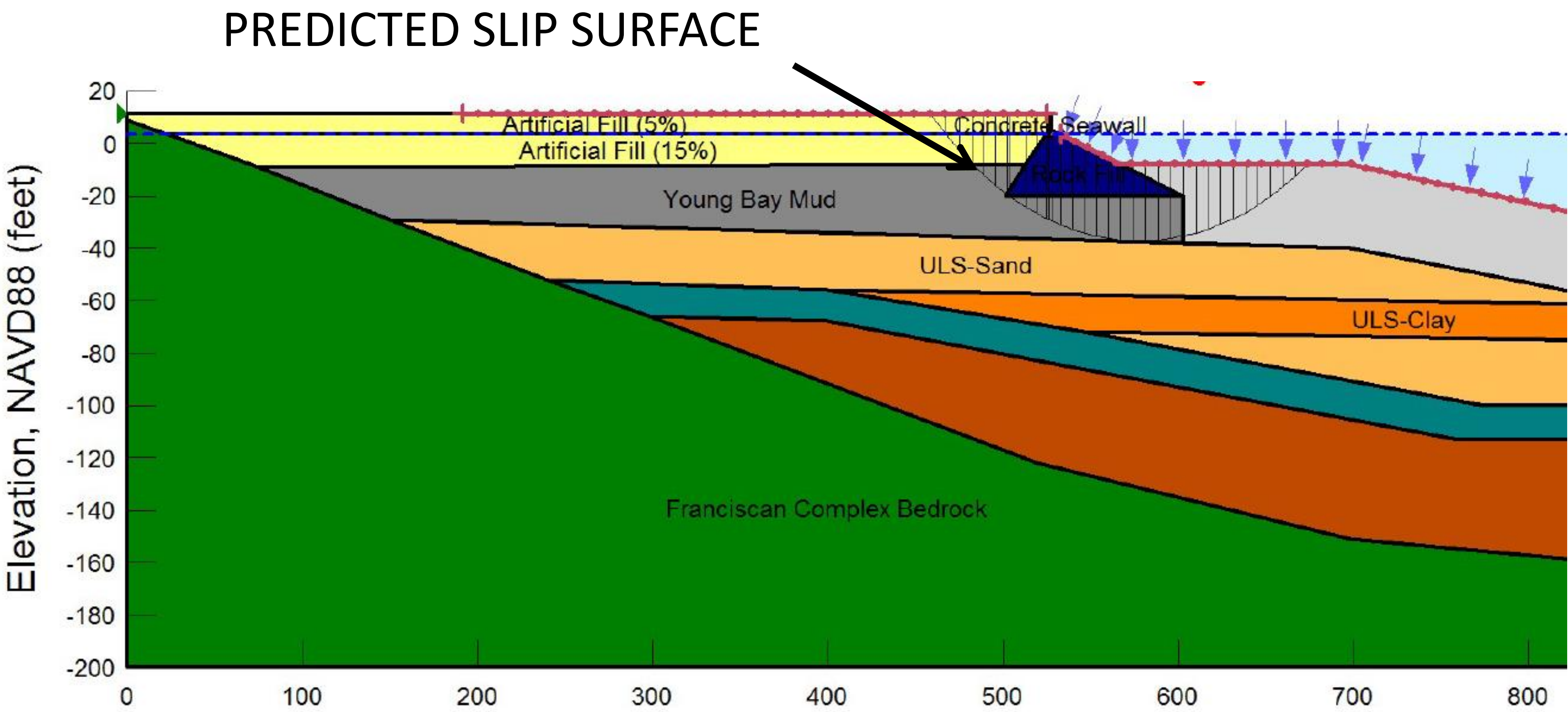
Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	1.3	(0.7)	100%	(1.0)	1.0
6	8.9	(1.0)	98%	(1.0)	1.0
6.7	29	(1.1)	72%	(1.1)	1.1
7	48	(0.9)	51%	(1.3)	1.1
7.5	124	(0.7)	20%	(1.6)	0.9
8	825	(0.7)	4%	(1.9)	1.0

USGS WORKING GROUP ON CALIFORNIA EARTHQUAKE PROBABILITIES 2014 UPDATE

72% PROBABILITY OF MAJOR EARTHQUAKE BY 2044



Probabilistic Site Hazard Analysis
Peak Ground Acceleration vs Return Period

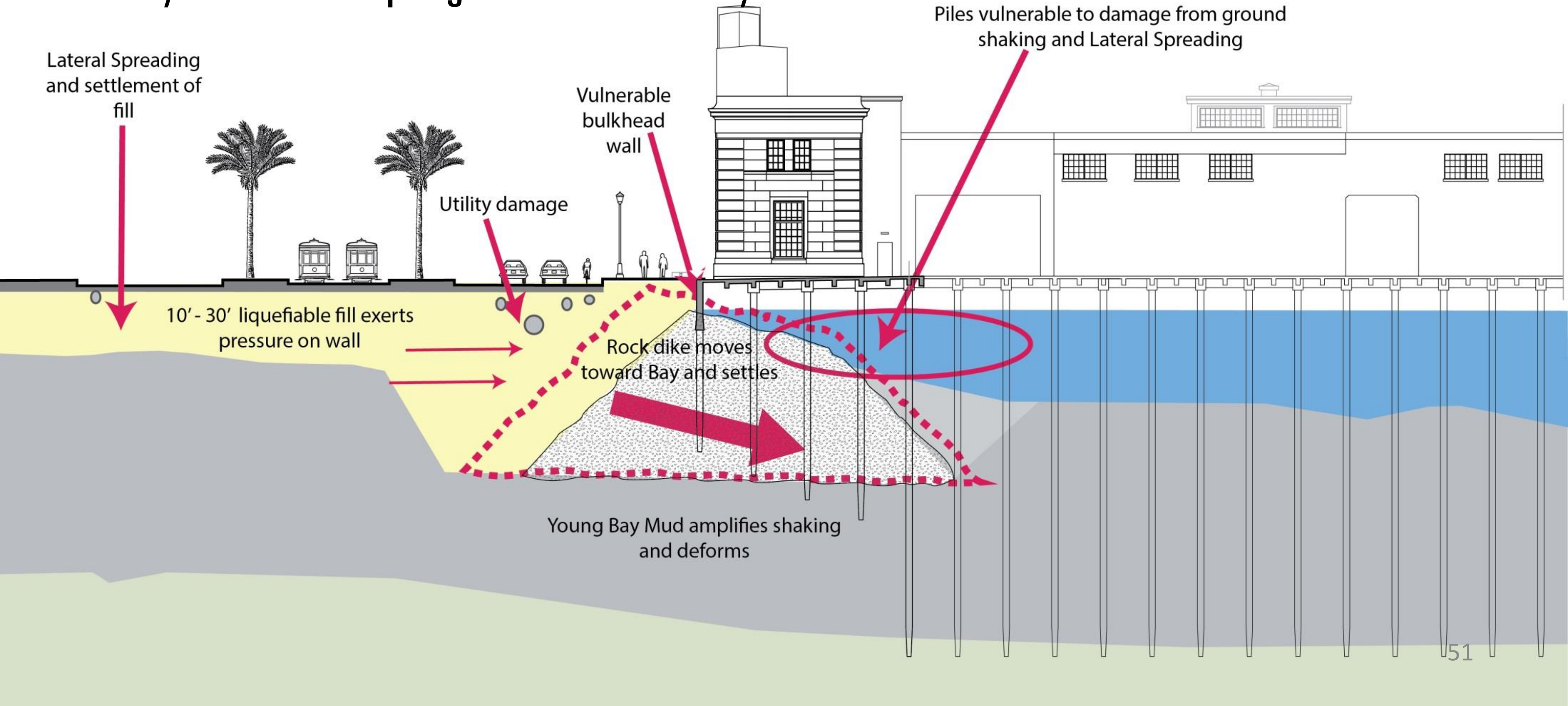


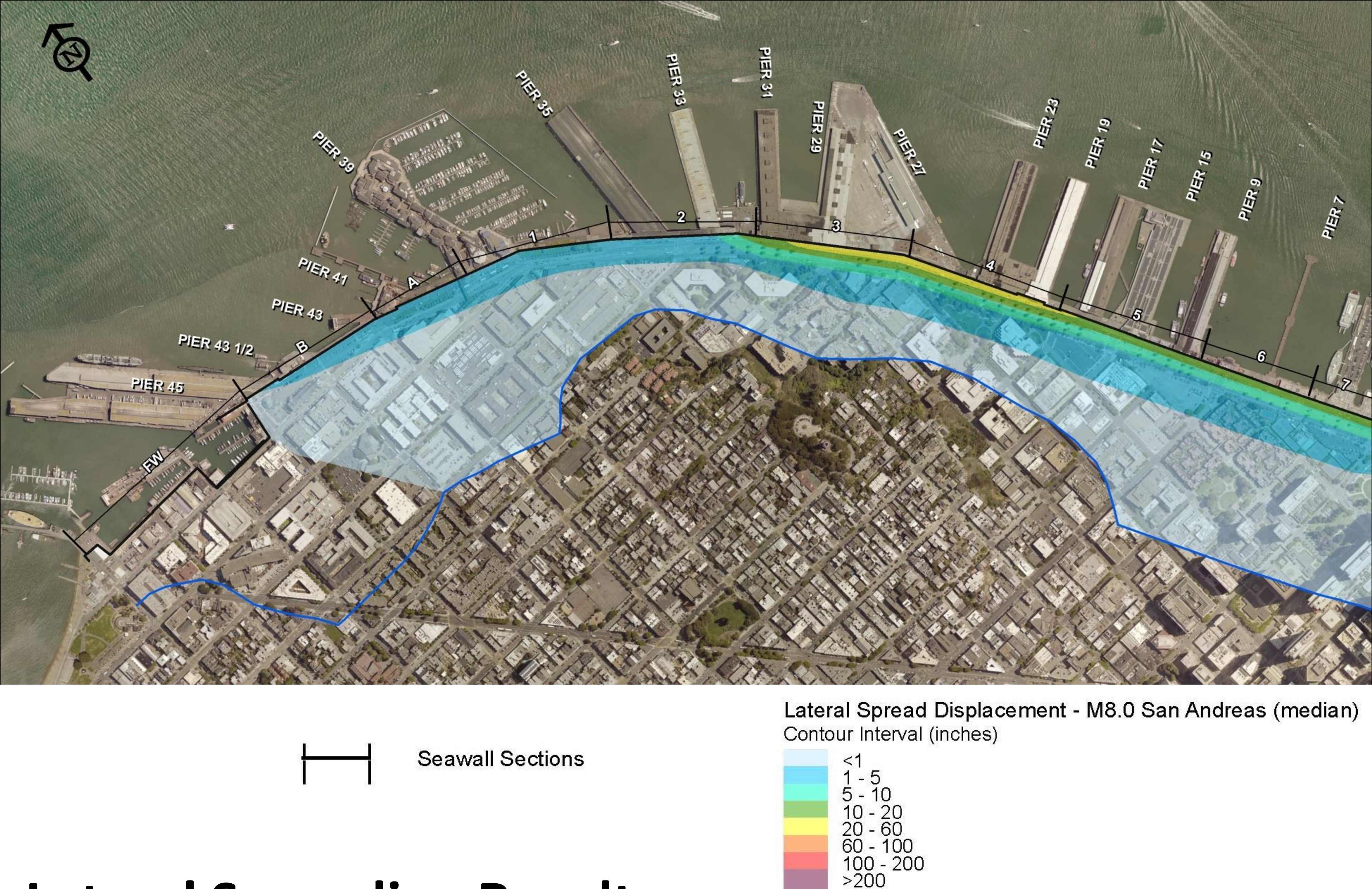
Slope Stability Analysis of Seawall

Various methods used, Calibrated to observations,
Non-linear Bay Mud Properties and data from recent earthquakes

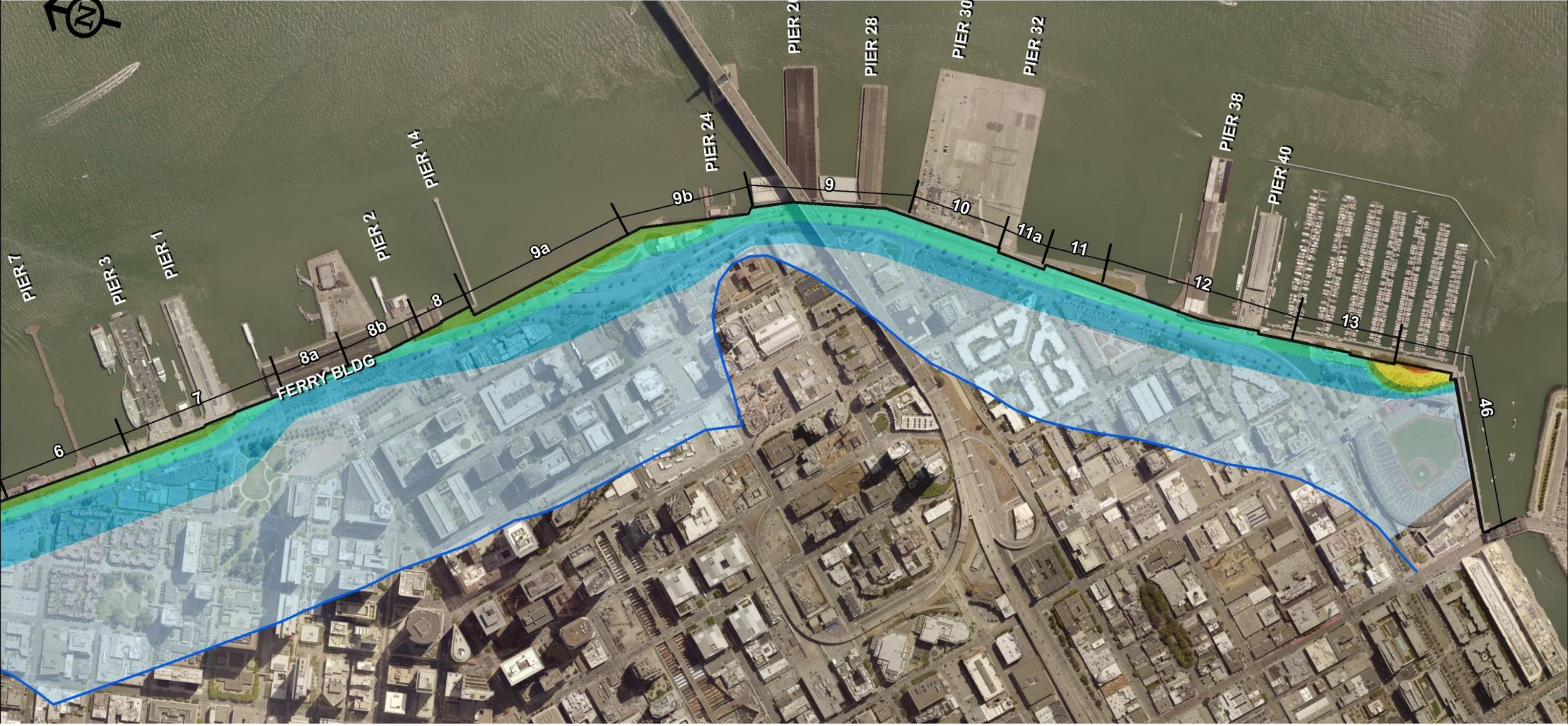
Seawall – Vulnerabilities

- Liquefiable Fill & Soft Mud Cause Rock Seawall to move toward Bay and Settle
- Damage to Historic Bulkhead Wharves & Buildings supported on Piles over Seawall
- Compromised Access to Piers, Ferry's and Ships
- Cracking & Settlement of Embarcadero Roadway and Promenade
- Distortion of Light Rail Tracks
- Utility Breaks Disrupting Service to the City and Port





Lateral Spreading Results:
M8.0 San Andreas (median) (approx. 20%/50yrs)



Seawall Sections

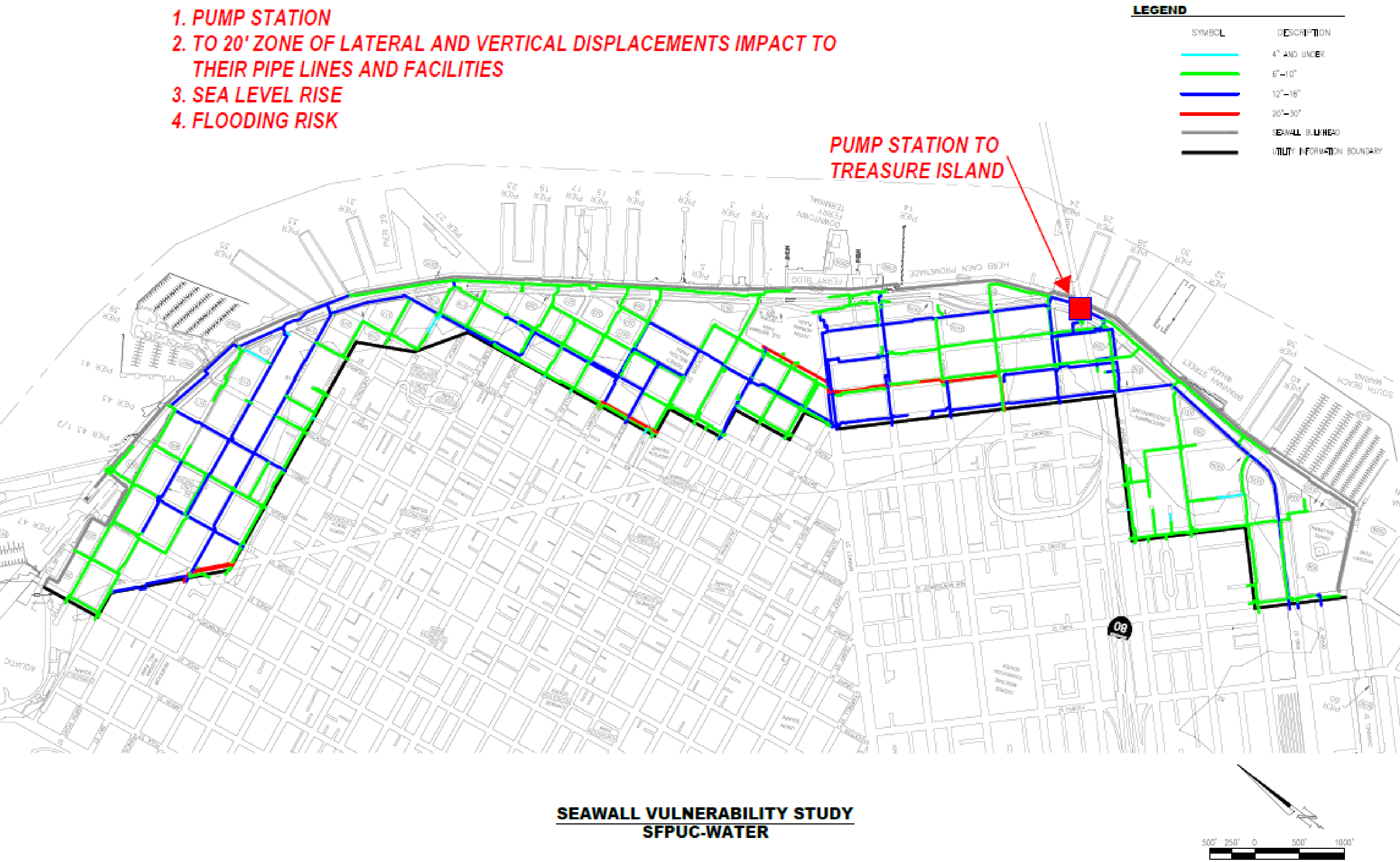
Lateral Spread Displacement - M8.0 San Andreas (median)
Contour Interval (inches)

- <1
- 1 - 5
- 5 - 10
- 10 - 20
- 20 - 60
- 60 - 100
- 100 - 200
- >200

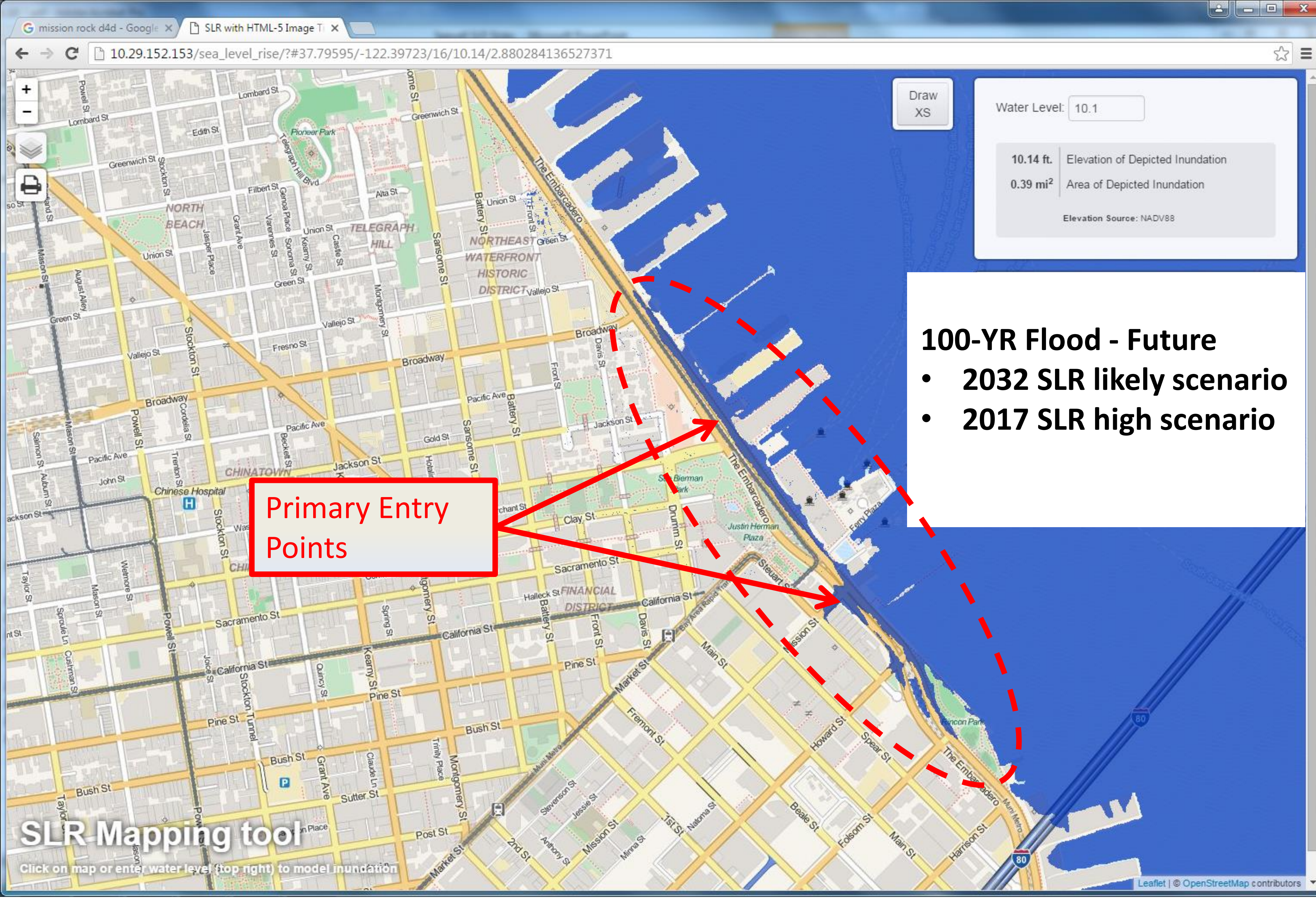
Lateral Spreading Results:
M8.0 San Andreas (median) (approx. 20%/50yrs)

CONCERNS:

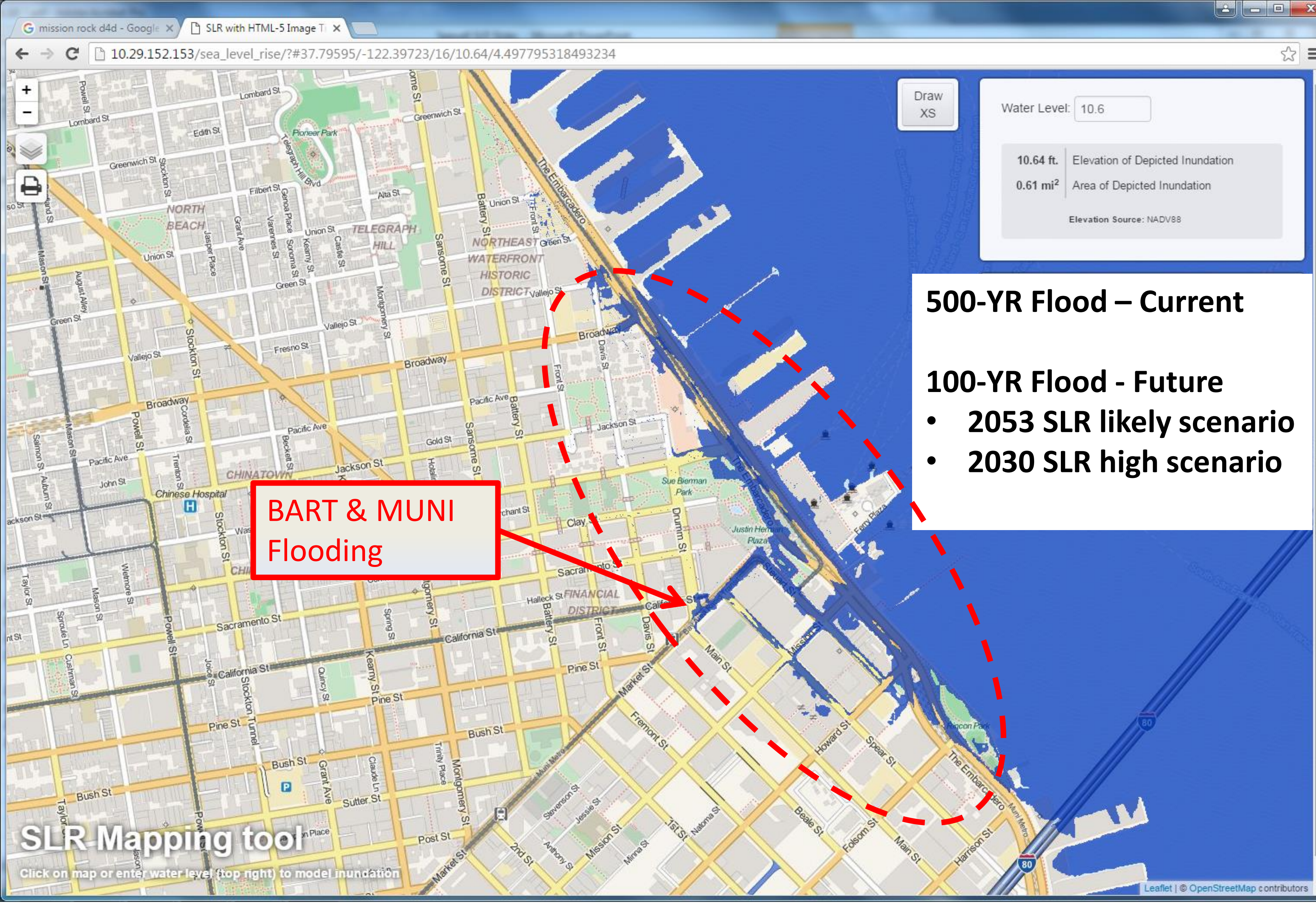
1. PUMP STATION
2. TO 20' ZONE OF LATERAL AND VERTICAL DISPLACEMENTS IMPACT TO THEIR PIPE LINES AND FACILITIES
3. SEA LEVEL RISE
4. FLOODING RISK



Utility Mapping Example – Continuing work with Providers to understand system implications



SLR: 100 yr Storm + 6 inch



SLR: 100 yr Storm + 12 inch

Primary Impacts

Safety: Primarily in bulkhead wharves, buildings and promenade sections over bulkheads.

Disruption:

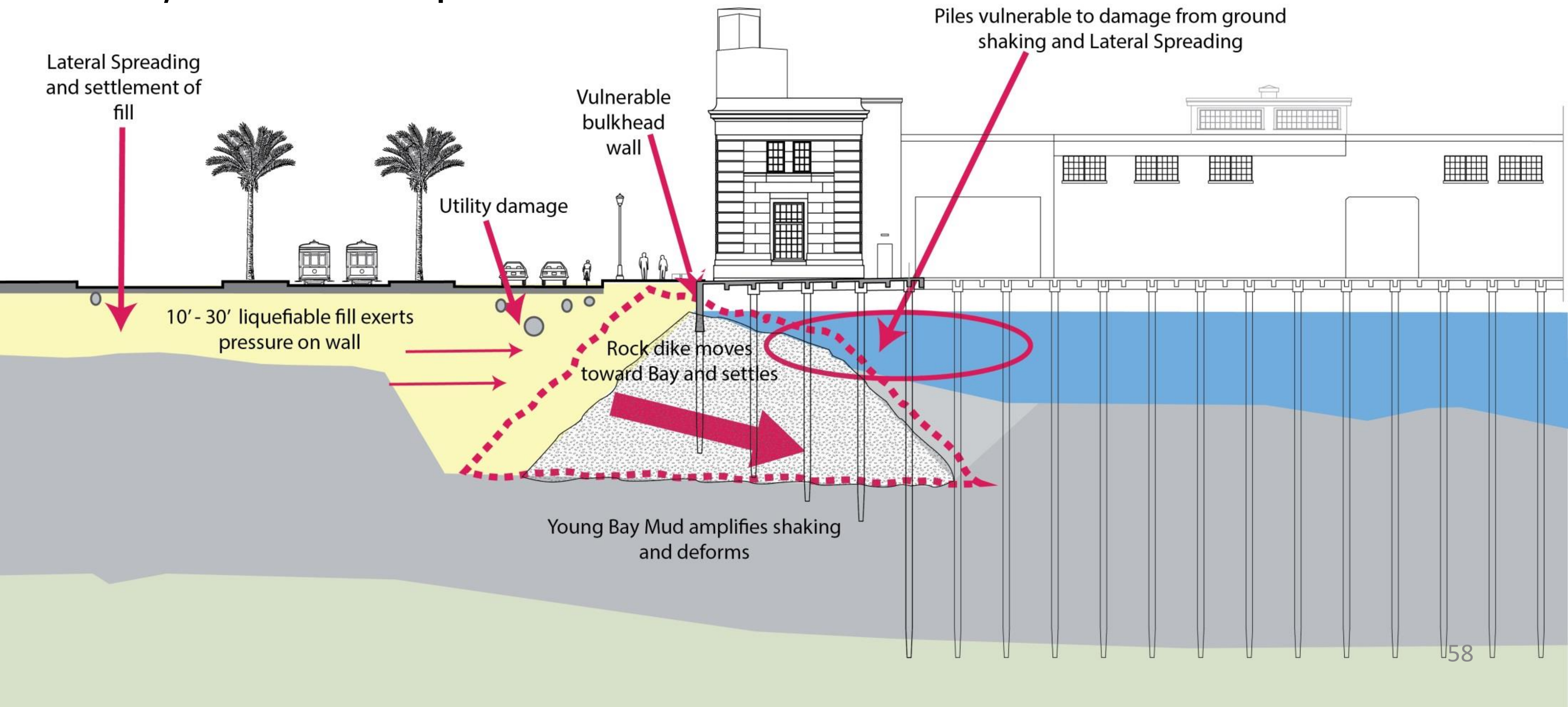
- Tourism: 18M visitors, $11B spending, $3B payroll
- Port: $2.1 B/yr Port rent, business income, wages
- Transportation: Ferry, Muni, Cars, Bikes, Pedestrian
- Maritime: Ferry and Cruise Industry, Bar Pilots, Water Taxi
- Emergency Response: Ferry system, waterside transit
- Utility Services: Loss of services to waterfront and City

Damage:

- $1.6B Port Assets at Risk

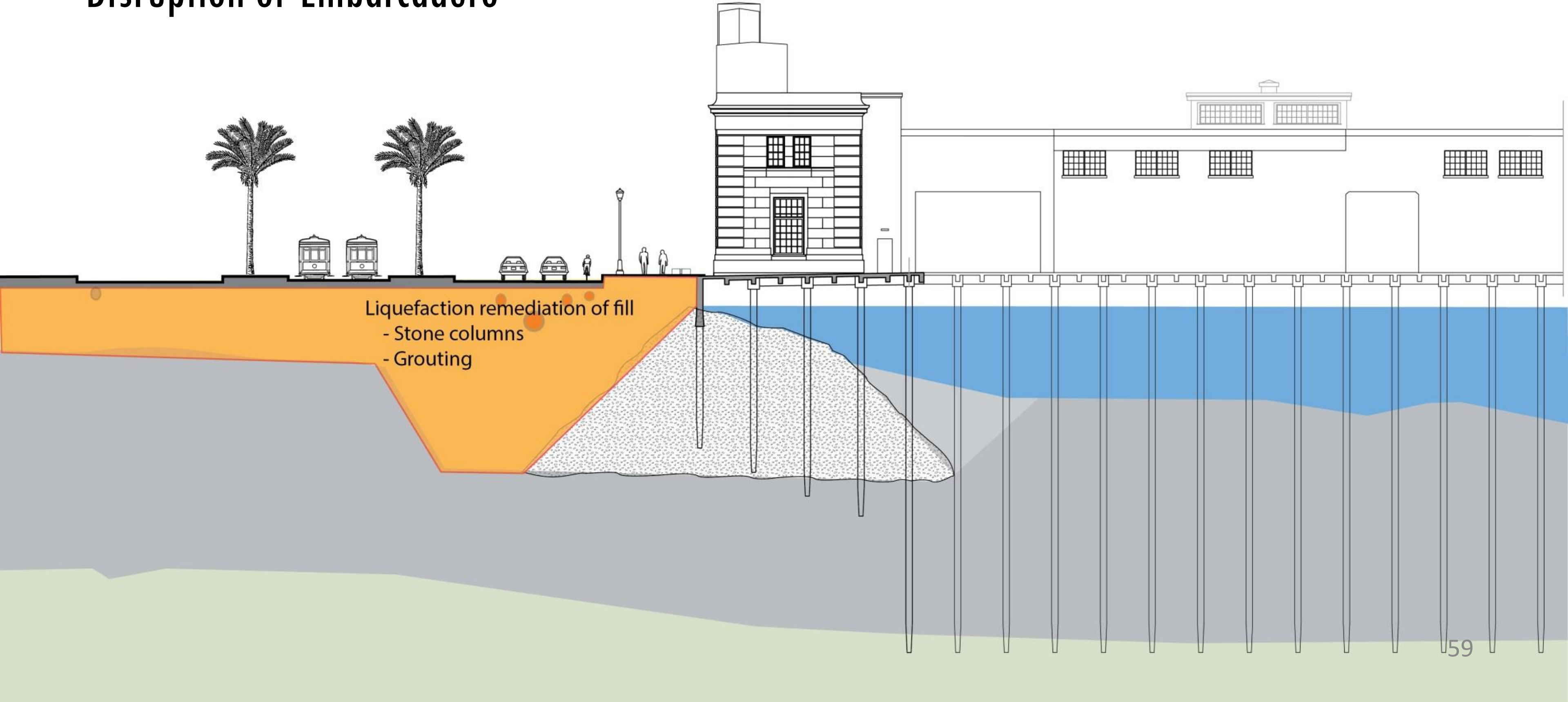
Seawall – Mitigation Options

- Liquefaction Remediation of Upland Fill (Stone Columns, Grouting, Densification)
- Ground Improvement below Rock Dike (Jet Grouting)
- Ground Improvement Landside of Bulkhead (Jet Grouting, Deep Soil Mixing)
- Seawall Replacement, Bayside
- Bulkhead Wall & Wharf Retrofits or Replacement
- Utility Relocation or Replacement



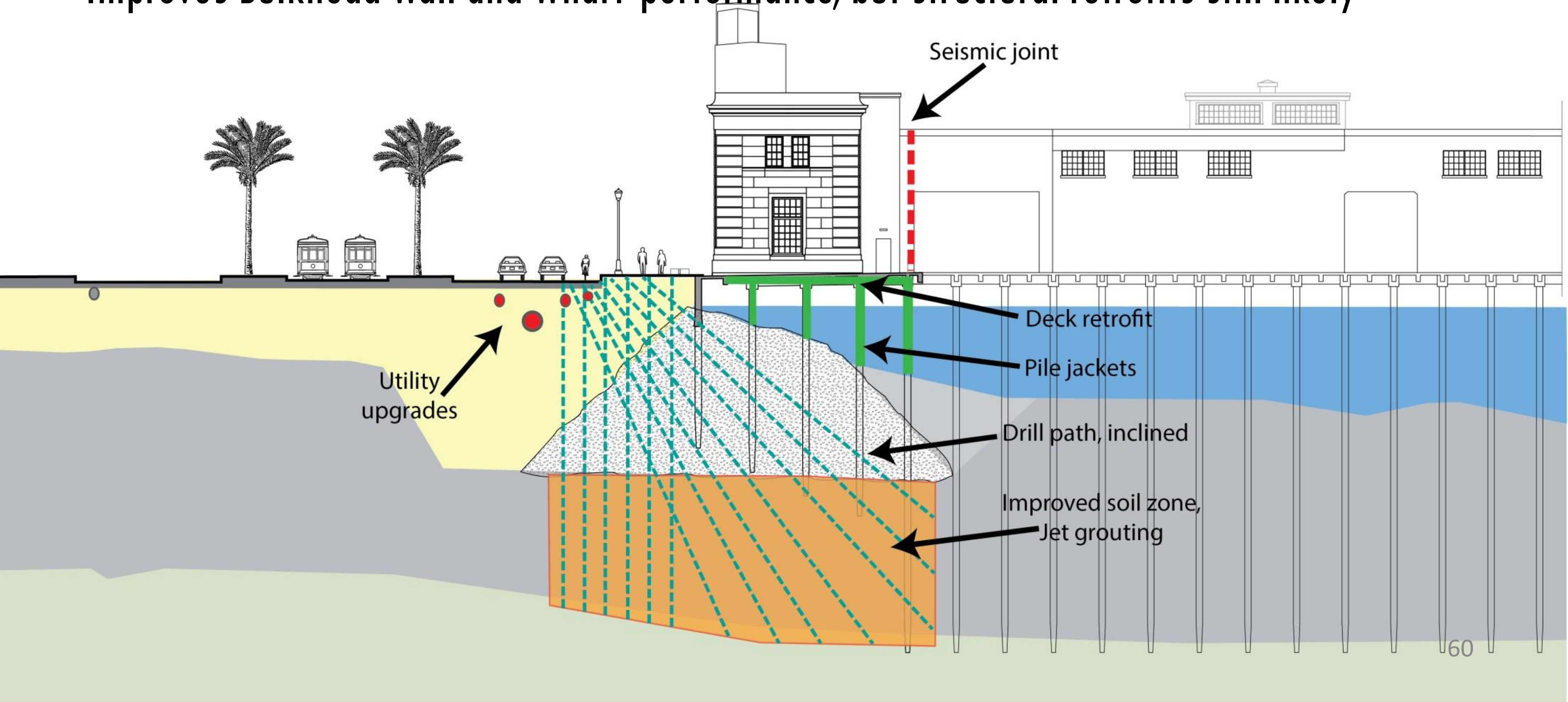
Option 1: Liquefaction Remediation of Upland Fill

- Techniques: Stone Columns, Grouting, Soil Mixing, Compaction
- Reduces earthquake pressure on Seawall and lowers permanent ground displacements
- Reduces utility, roadway & Muni earthquake damage
- Does not provide stable base for SLR adaptation
- Disruption of Embarcadero



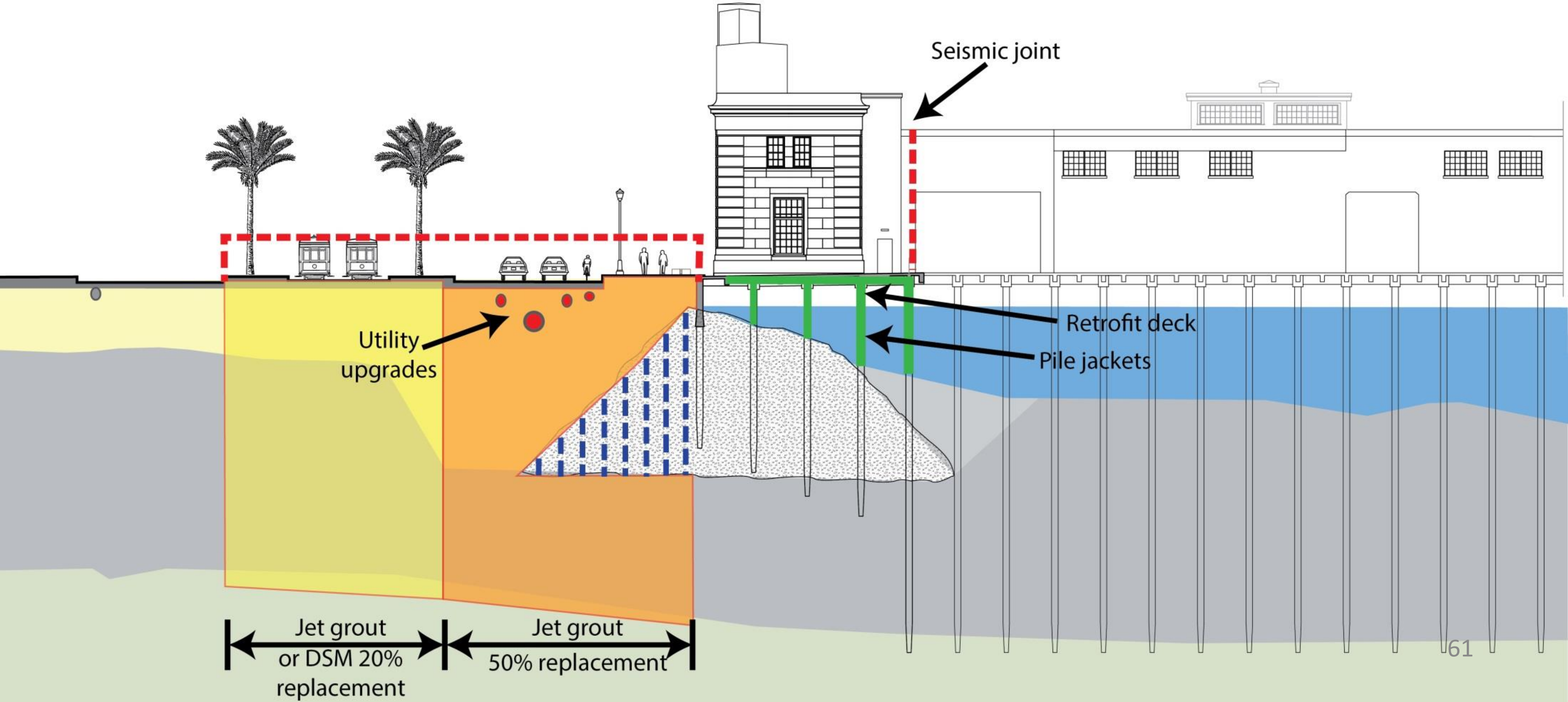
Option 2: Ground Improvement Under Seawall

- Improve soil under Seawall rock dike using jet grouting (vertical or inclined)
- Significantly reduces lateral spreading and settlement
- Allows raising of ground elevation in future
- Landside disruption during construction, Replace brittle utilities at same time
- Costly ground improvement technique, need to drill through Rock Dike
- Improves Bulkhead Wall and Wharf performance, but structural retrofits still likely



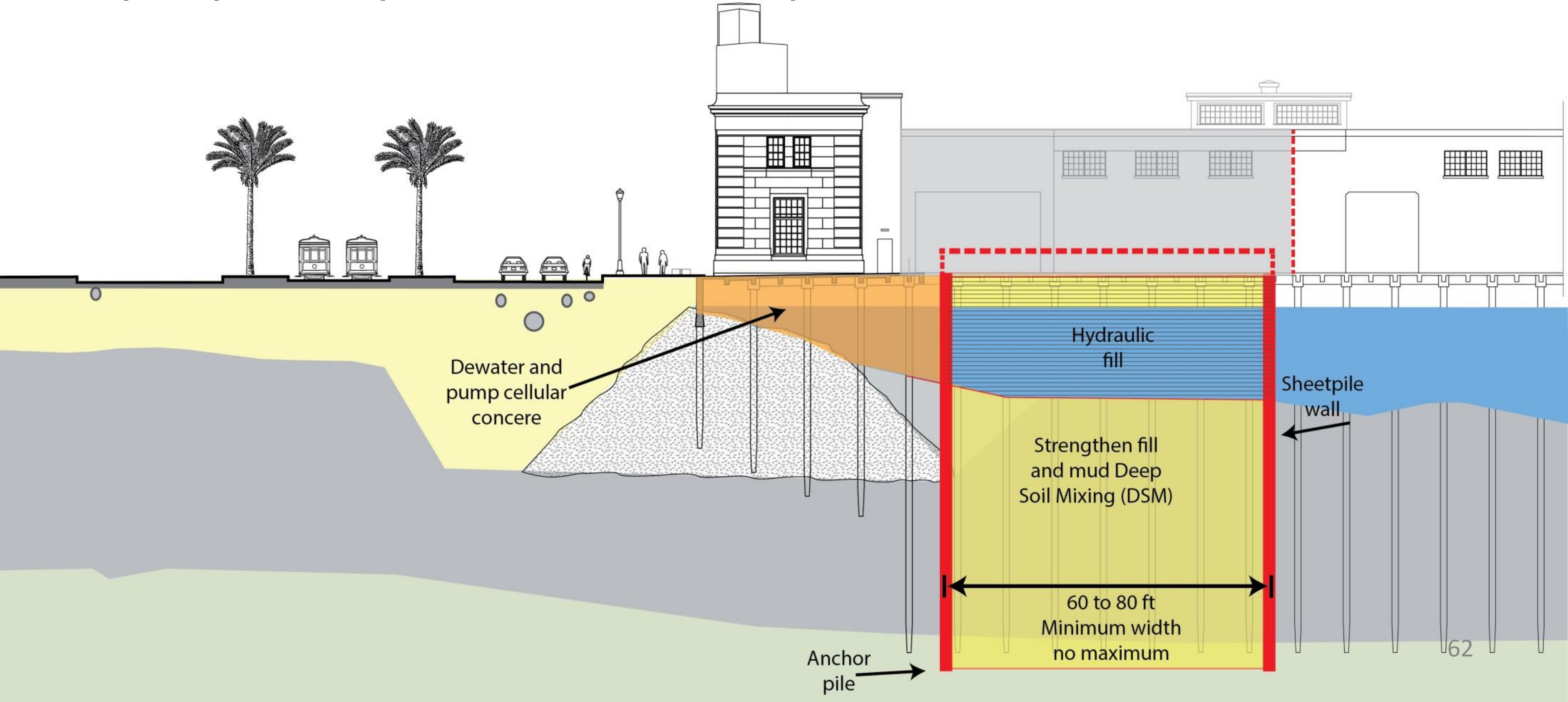
Option 3: Ground Improvement Landside of Seawall

- Jet Grouting and Deep Soil Mixing to improve landside fill
- Stabilizes Embarcadero and reduces lateral spreading and settlement
- Combine with Bulkhead Wharf Pile and Deck Retrofits
- Replace brittle utility mains and laterals
- Provides stable base for SLR adaptation



Option 4: New Bayward Seawall

- Relocate portion of pier shed & demolish affected portion of pier deck
- Drive inner and outer sheetpile walls, place hydraulic fill in between
- Strengthen fill and mud using deep soil mixing
- Dewater below bulkhead wharf and pump lightweight fill
- Replace portion of pier shed; elevation is adaptable



Preliminary Conclusions - Needs

$2B to $3B Overall Need, up to $5B with Sea Level Rise

Initial focus on safety and critical facilities: Requires more study, outreach, pilot projects

- Improve Earthquake Safety, particularly to Non-Ductile Concrete Bulkhead Wharves
- Reduce Earthquake Damage/Disruption for Essential Facilities and Lifelines
- Flood Protection Improvements south of Ferry Bldg to Pier 22-1/2: Embarcadero / MUNI / BART

San Francisco Resiliency Strategy – Earthquake Resilient Waterfront by 2040

Next Steps

April/May 2016

- Outreach and comments from Port tenants & partners

Summer 2016

- Finalize Seawall Earthquake Vulnerability Study (June)
- Status report to Port Commission (late summer)

2016 - 2017

- Coordinate with City Lifelines Council, City Resiliency Plan, & Mayor's Sea Level Rise Action Plan
- Include in Port's Waterfront Land Use Plan Update
- $10M ($8M City, $2M Port) for Seawall Resiliency Program
- Seek US Army Corps of Engineer Flood Protection Study
- Participate in Living Cities Infrastructure Financing Cohort

Case Studies

- Brannan Street Wharf
- Pier 43 Bay Trail Link
- Seattle Seawall

Pier 43 Bay Trail Link (2012): $10.2 M

Pier 43 Bay Trail Link (2012): Seawall Section B

Pier 43 Bay Trail Link (2012): Timber Bulkhead Wall and Wharf in Poor Condition, removed

Pier 43 Bay Trail Link(2012): New Bulkhead

Brannan Street Wharf Project (2013): $25M

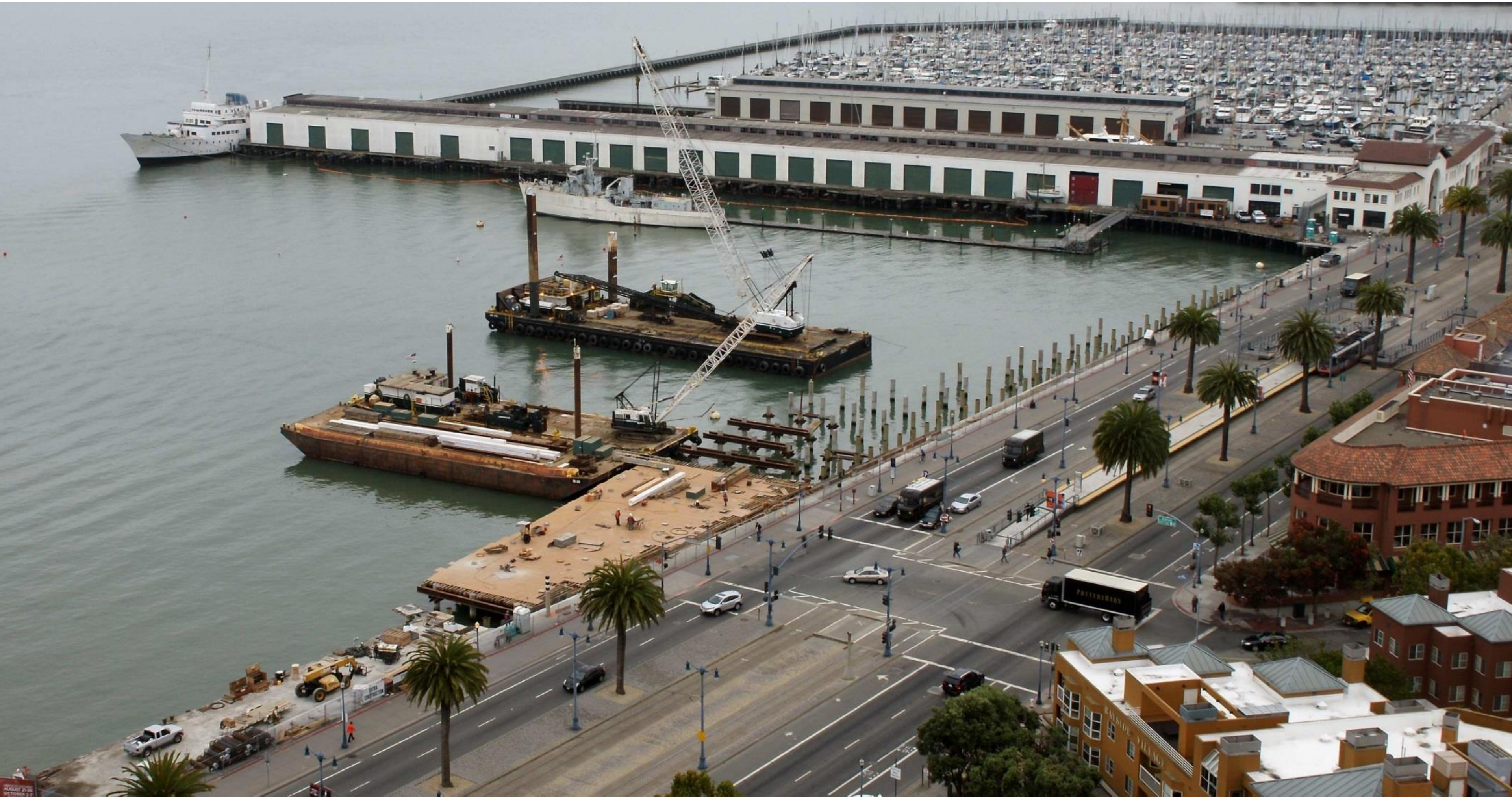
Brannan Street Wharf (2013): Bulkhead Wall, Section 11 – To Remain

Brannan Street Wharf (2013): Pier 36 Shed Removal

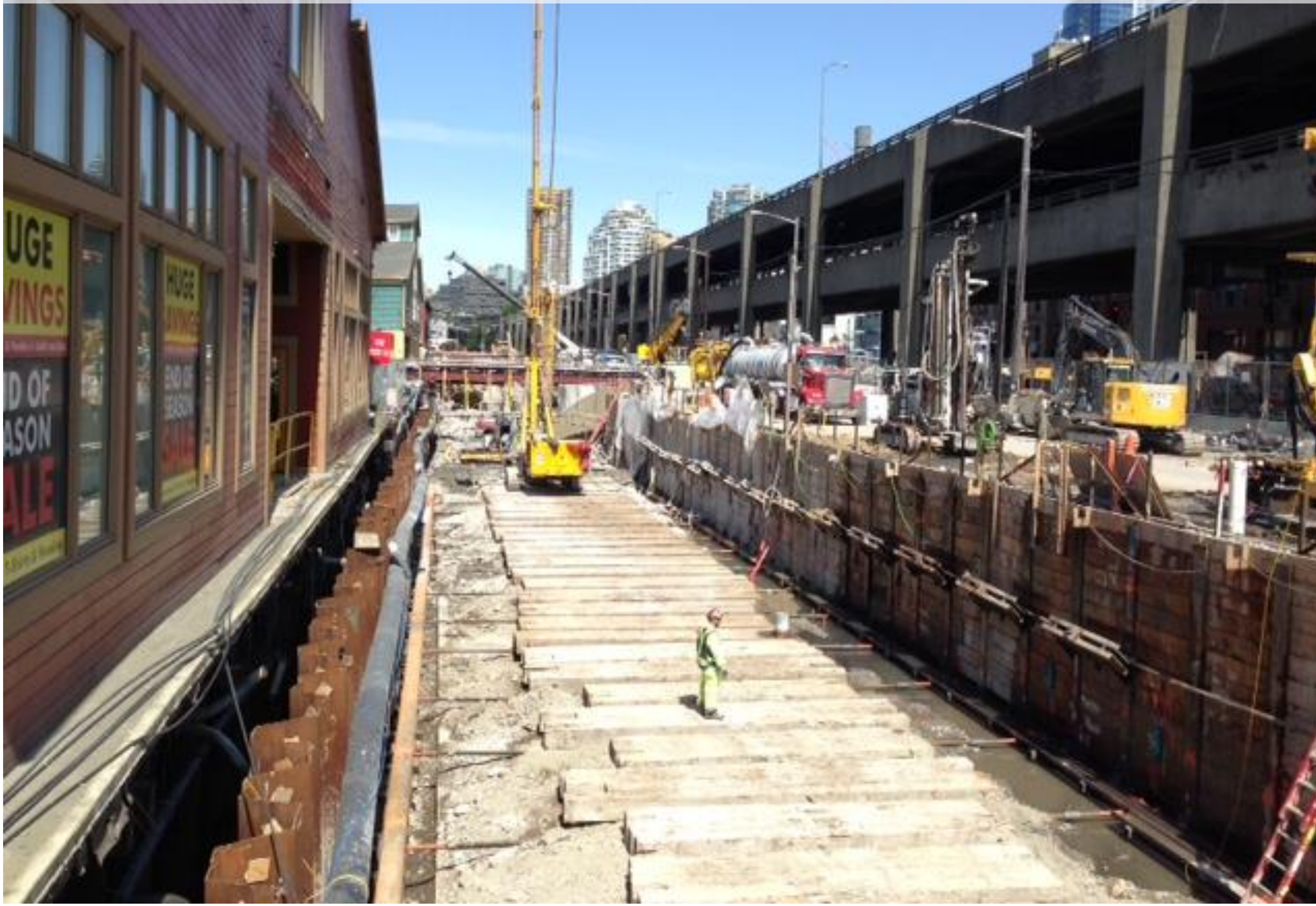
Brannan Street Wharf (2013): Removal of Pier 36

Brannan Street Wharf (2013): Removal of Bulkhead Wharf Section 11

Brannan Street Wharf (2013):
New Wharf, Ductile Piles accommodate movement
Construction from Water



Seattle Seawall Replacement



0.8 Mile $400M Cost

THANK YOU – QUESTIONS?

1906 EQ – Embarcadero near Lombard