San Francisco International Airport
Shoreline Protection Program

BCDC ECRB Meeting

September 25, 2024

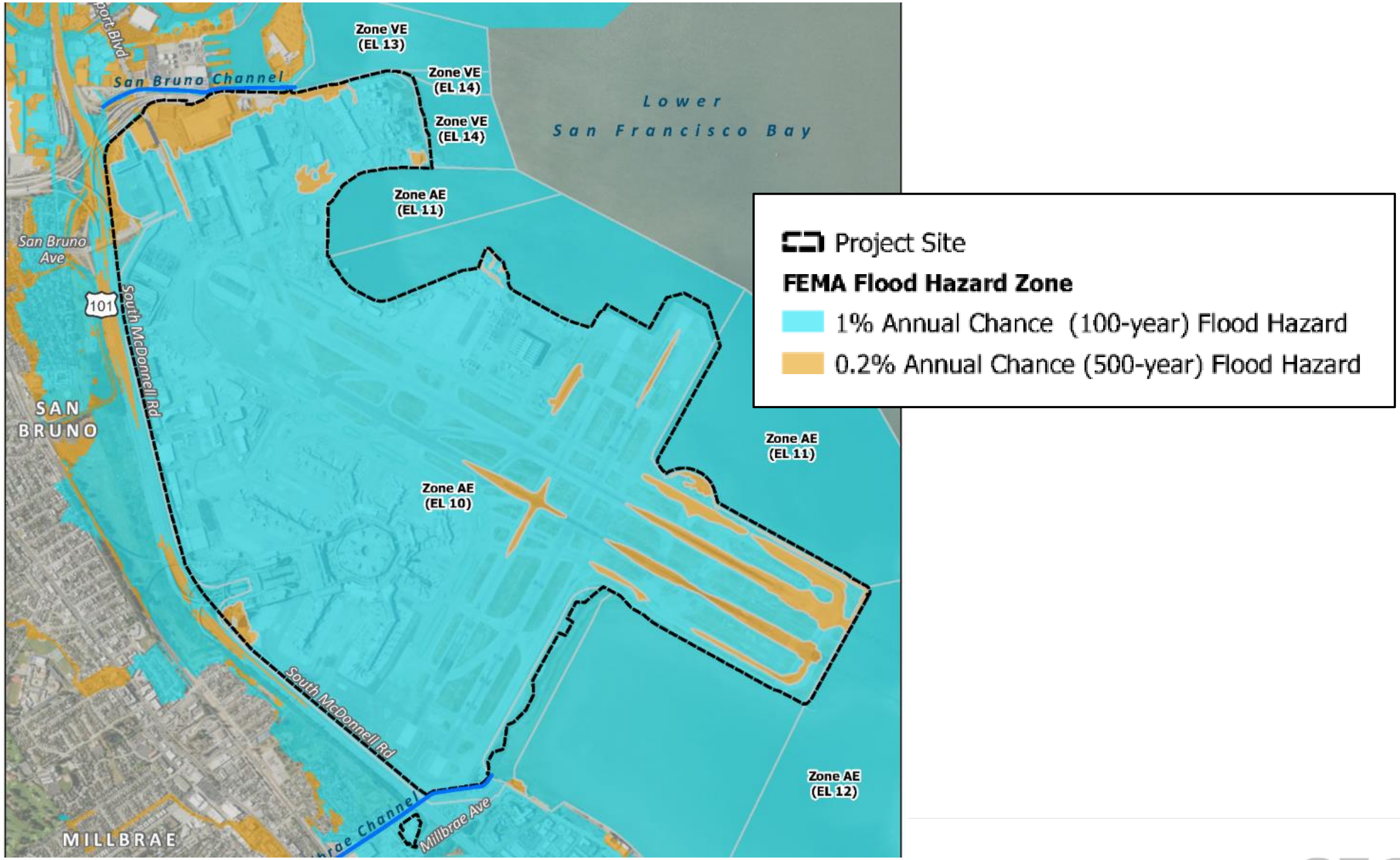
Agenda

1. Introduction & Project Purpose
2. Geotechnical Analysis (ECRB-1, ECRB-7)
3. Operations & Maintenance
    a. Combined earthquake & flooding (ECRB-5)
        i. Joint earthquake and flood loading
        ii. Risk of flooding as a function of SLR
    b. Corrosion (ECRB-4)
    c. Flood response operations
        i. Emergency operations of stormwater pumping system (ECRB-6)
        ii. Anticipated inflow volume (BCDC-1)
        iii. Flood gate deployment (BCDC-2)
        iv. Flood gates and access to SamTrans facility, Marine Emergency Response Facility (BCDC-2, BCDC-3)
        v. Flood gate operations & maintenance (BCDC)
4. Groundwater and Sea Level Rise (ECRB-8)
5. Subsidence (ECRB-9)
6. Strong Motion Instrumentation Plan (ECRB-12)

SPP Project Team

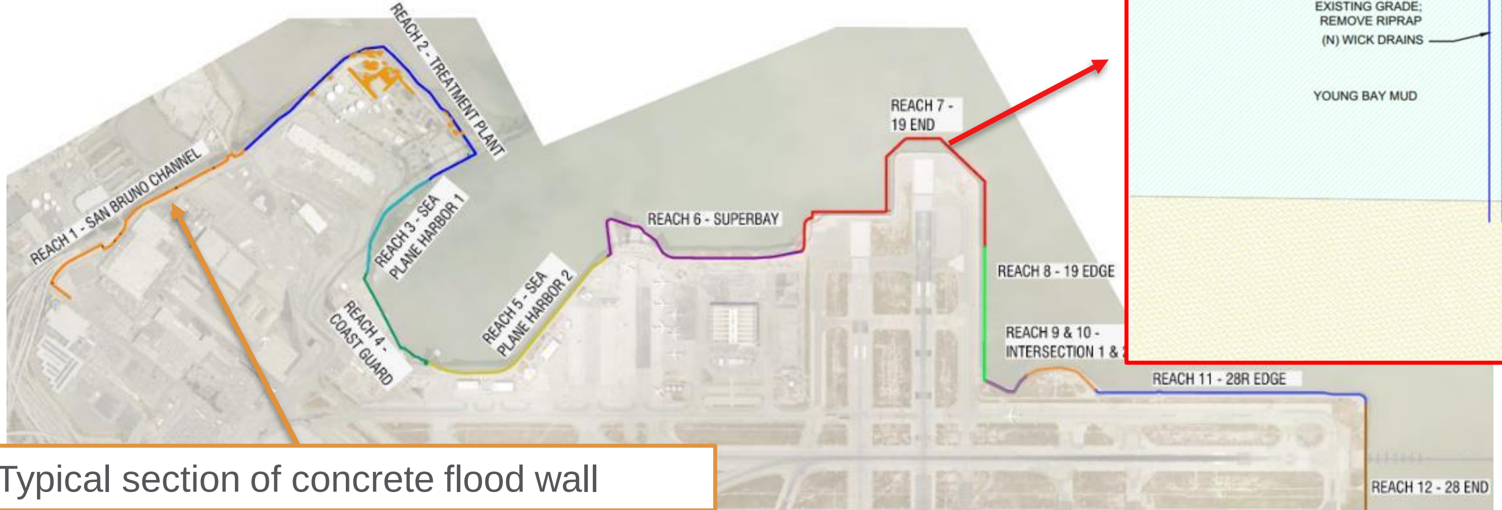
- SFO
  - David Kim, PhD
  - Rinaldi Wibowo, PE, GE
  - Audrey Park
- ESA
  - Matt Brennan, PhD, PE
  - Melissa Denena
- COWI
  - James Connolly, PE, SE
  - Evan Vinyard
- TERRA engineers
  - Bob Kirby, PE, GE
- Geosyntec
  - Chris Hunt, PhD, PE, GE
  - Julie Chambon, PhD, PE
  - Jackee Allmond, PhD, PE
  - Juan Pestana, ScD, PE

Existing Flood Hazard

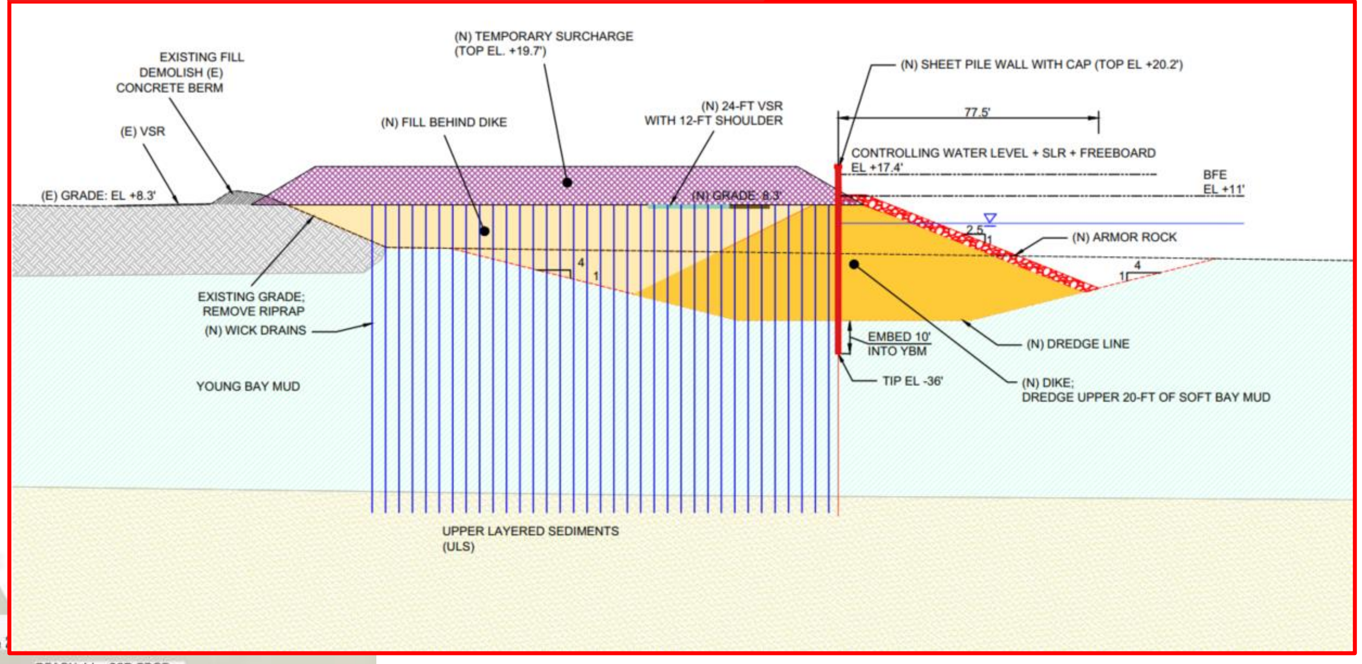


Source: FEMA (2021)

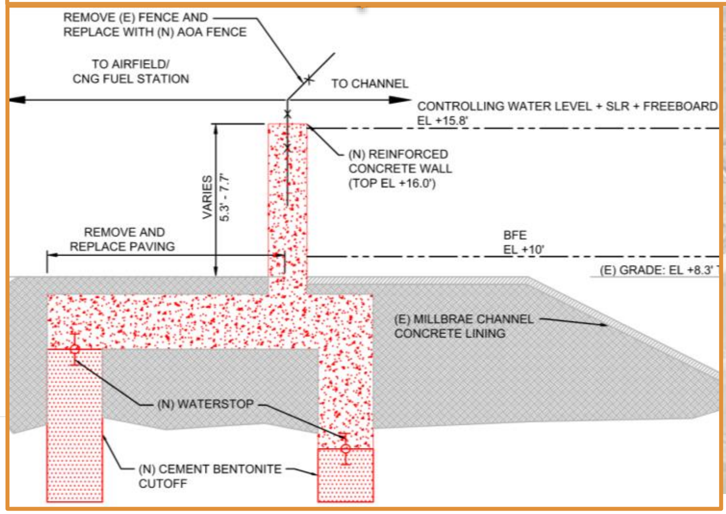
Shoreline Protection Program



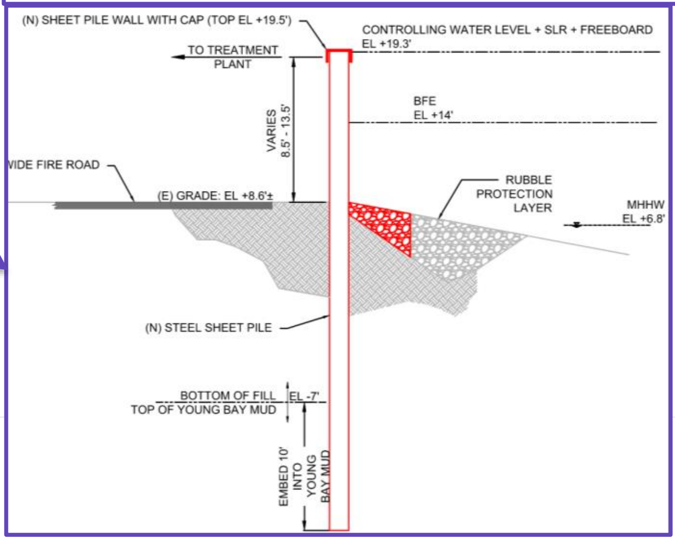
Typical section of perimeter dike and fill



Typical section of concrete flood wall



Typical section of steel sheet pile wall



Project Objectives

1. Protect travelers and workers, Airport operations, and City assets
2. Remove Airport from 100-year FEMA floodplain via C/LOMR
3. Create protection system that add 3.5 ft of future sea-level rise to present-day FEMA accreditation
4. Create protection system that poses no safety hazards to Airport operations, maintains runway capacity, and satisfies FAA design standards
5. Enhance emergency vehicle access near fuel tank farm
6. Minimize hazardous wildlife attractants to prevent bird strikes
7. Create protection system as expeditiously as possible for safe and continuous Airport operations and minimizing disruption to aircraft operations during construction

The Airport acknowledges avoidance and minimization of impacts on the San Francisco Bay to the extent practicable.

Project Description

Remove:

- Existing shoreline protection: Concrete walls, sheet pile walls, concrete debris, armor rock, sandbags, K-rails, embankment walls/dikes, earthen and vegetated berms.
- Existing infrastructure in areas where it conflicts with the proposed shoreline protection system.

Construct New Shoreline Protection System:

- Reinforced concrete walls and steel sheet pile walls, some with armor rock revetments and/or open water fill. Approximately 40,000 feet (7.6 miles) long, 3.9 to 13.5 feet above existing or newly graded ground surfaces and driven to maximum depth of approximately 50 feet.
- New perimeter dike, for Reaches 7 and 8, extend shoreline protection system additional 100 to 215 feet beyond existing shoreline into Bay.
- Seven flood gates, approx. 3 ft high, both active and passive, installed to allow access except during flood events
- Armor rock revetments used in tandem with walls to dissipate wave energy and prevent sediment scour.
- Open water fill intended to stabilize the shoreline and create a necessary slope for support of the shoreline protection system.
- Fill in wetlands in Sub-reach 2B and Reach 14 areas.

Project Description (continued)

Construct Associated Improvements:

- **Roads:** For Reaches 7–11, 13, and 14, vehicle service road relocated approximately 12 to 140 feet toward the Bay.
- **Storm Drain Pump Station Outfalls/Water Utility Lines:** Existing infrastructure retrofitted and rerouted.
- **Lighting Trestle:** To accommodate construction of perimeter dike and shoreline protection system for Reach 7 per FAA design standards, existing lighting trestle at end of Runway 19L to be demolished and new lighting trestle constructed.

Anticipated Fill Areas:

Wetland Type	Fill Area (acres)
Tidal marsh	0.38
Riprap, intertidal	1.96
Unconsolidated shore, intertidal	1.04
Salt flat	0.63
Mudflat	0.05
Open Bay, subtidal	20.01
Total	**24.07**

Project Proposed Timeline

Project Phase	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
NEPA, Mitigation, Permits	■	■	■												
Phase 1 (Reaches 1-6)				■	■	■	■	■							
Phase 2 (Reaches 7, 8, 14, 15)				■	■	■	■	■	■	■					
Phase 3 (Reaches 9, 10, 11, 12, 13)								■	■	■	■	■	■	■	

- Design-build process
- Pending funding & budget authorizations
- Design life is 60 years, e.g., 2025-2085

ECRB Discussion

- Project Description

Supplemental Geotechnical Analyses

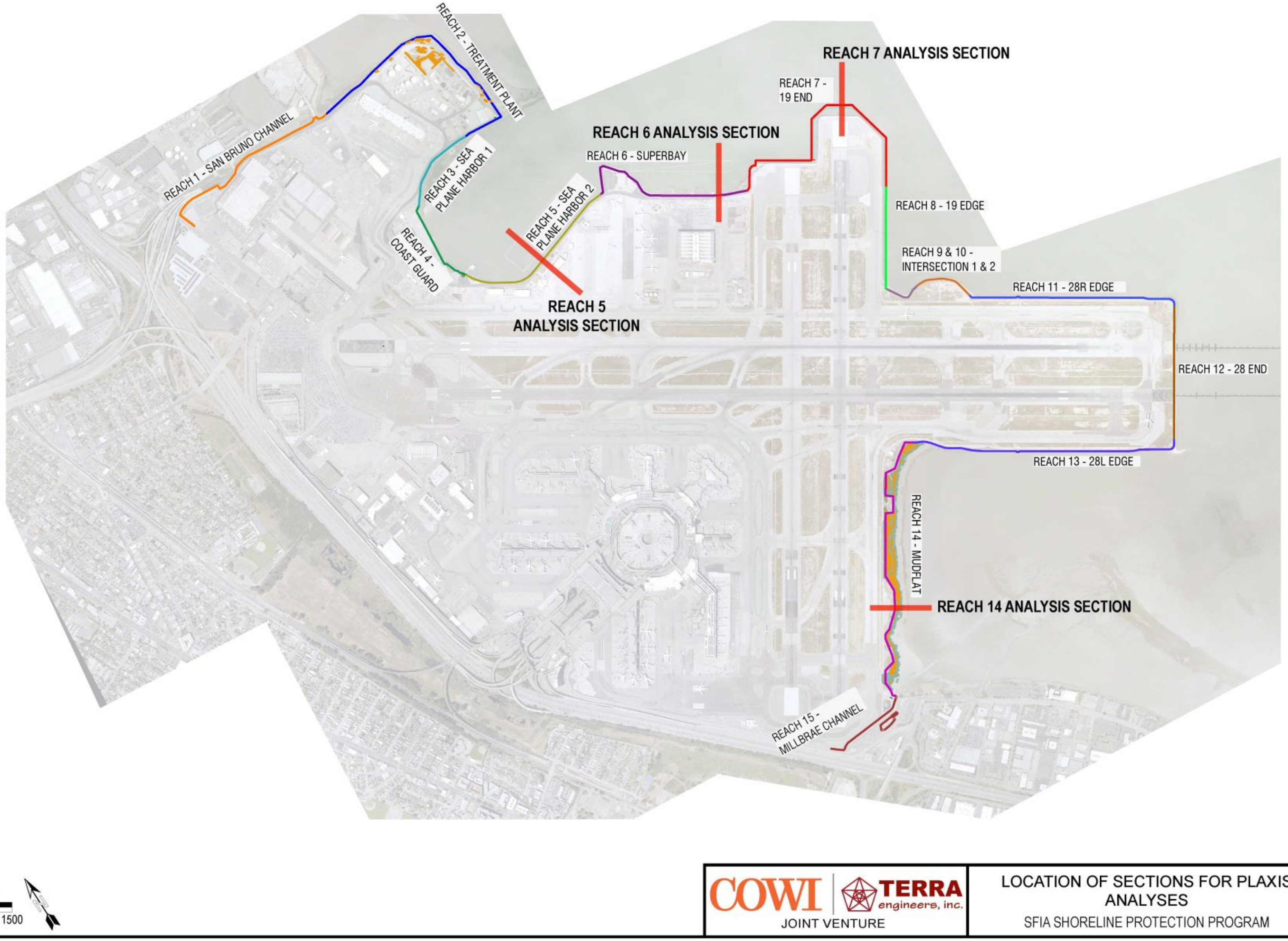
***ECRB-1**:The 2D PLAXIS modeling of the seismic site response/lateral displacement was done at Reach 6, which was assumed to be a critical area due to the thickest layer of Young Bay Mud (YBM) observed.*

- *This may not be the area with the strongest ground motions; however, thicker YBM can attenuate strong ground motion.*
- *Please perform additional analyses that include other sections to evaluate ground motions for a variety of subsurface profiles, and to evaluate which section(s) may be critical from the perspective of slope stability and seismic performance.*

Supplemental Geotechnical Analyses

Outline of Presentation

- Overview of SPP and location of sections analyzed
- Average subsurface conditions for all SPP reaches
- Soil conditions and performance at sections analyzed
- Review of supplemental 2D PLAXIS analyses at Reaches 5 and 14
- Sensitivity studies for 1D DEEPSOIL analyses at Reach 6
- 1D DEEPSOIL analyses at Reaches 5 and 14
- Summary & conclusions



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COWI TERRA engineers, inc. JOINT VENTURE	LOCATION OF SECTIONS FOR PLAXIS ANALYSES SFIA SHORELINE PROTECTION PROGRAM	Figure S-1

Subsurface Conditions and SPP Performance

TABLE S-1 – AVERAGE SUBSURFACE CONDITIONS ALONG SPP ALIGNMENT BY REACH

Reach	Reach Length (ft)	Existing Fill Thickness (ft)	Young Bay Mud Thickness (ft)	Depth to Rock (ft)	Notes
1a	1849	7	0	10	See Note
1b	1446	16	20	43.5	See Note
2	4423	15	23	131	
3	1388	25	16	180	
4	1484	19	18	161	
5	2754	28	24	217	Analyzed in Supplemental Report (2024)
6	2938	24	42	269	Analyzed in Appendix C of Preliminary Geotechnical Report
7	4295	N/A	65	268	Analyzed in Appendix C of Preliminary Geotechnical Report. New Fill
8	1582	N/A	42	176	New Fill
9	638	10	47	158	
10	925	18	36	157	
11	3285	N/A	41	199	New Fill
12	2116	12	39	286	
13	4227	13	49	253	
14	4685	8	51	229	Analyzed in Supplemental Report (2024)
15	1415	5	20	N/A	No bedrock information available.

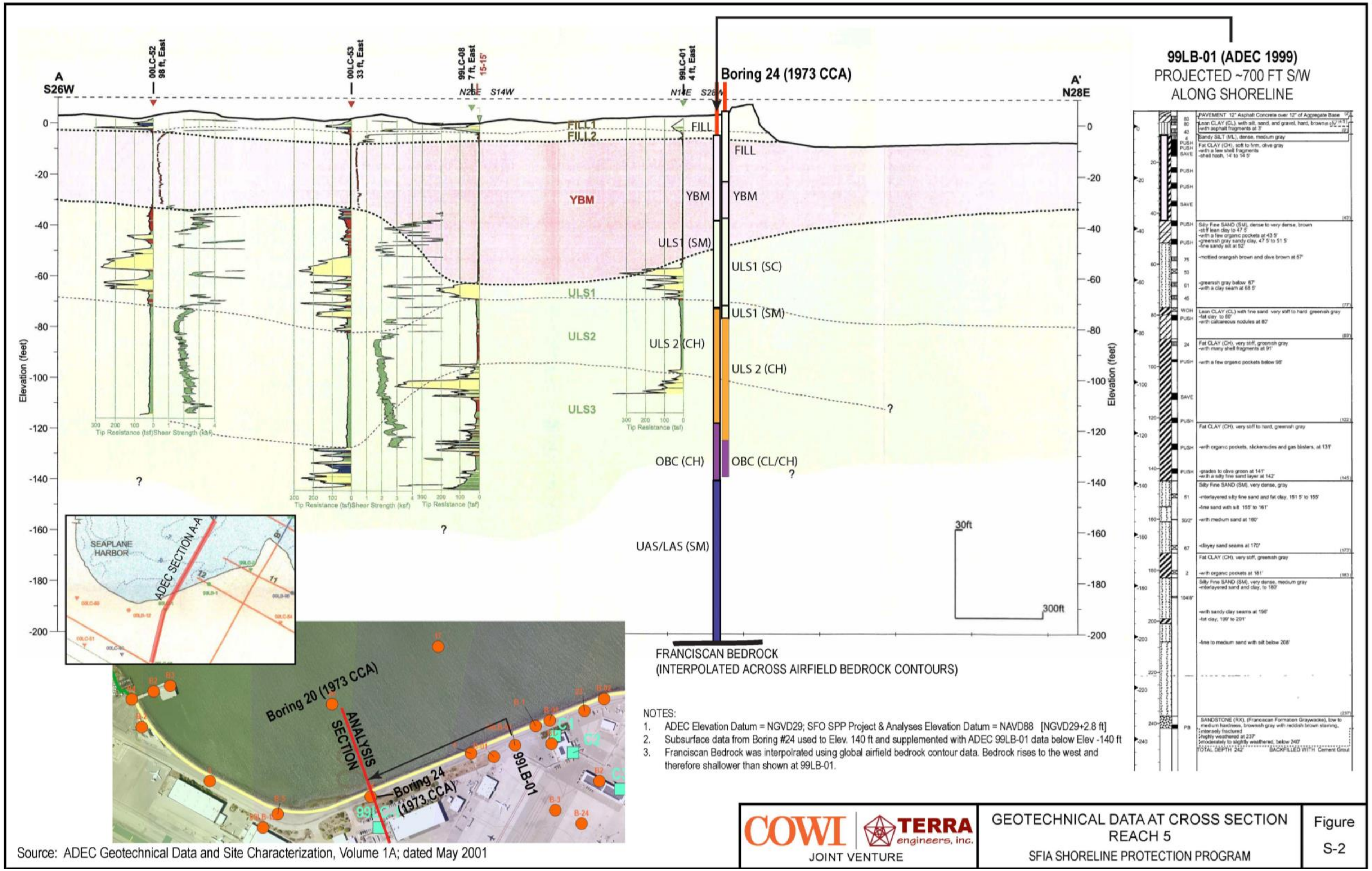
* Note: At Reach 1, roughly half of the alignment prior to SamTrans Island is mostly shallow rock with no Young Bay Mud and less than 6-7 feet of Fill. Closer to SamTrans Island, the bedrock rapidly deepens with increasing thickness of Fill and the presence of Young Bay Mud.

TABLE S-8 –COMPARISON OF PERFORMANCE AT REACHES 5, 6, 7 AND 14

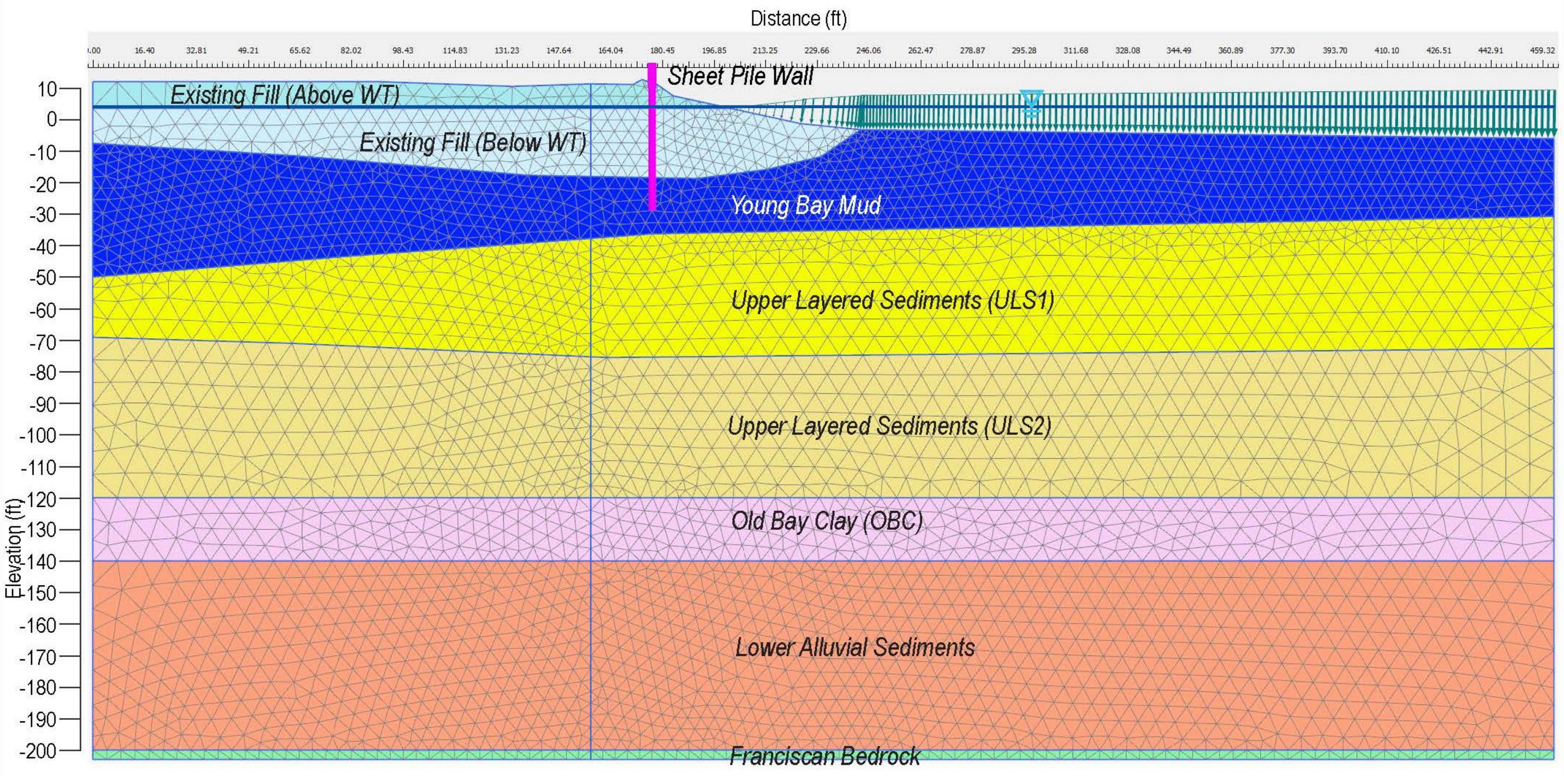
	Reach 5	Reach 14	Reach 6	Reach 7
Lateral Displacement Statistics				
Average Displacement (ft)	0.81	0.85	1.24	2.12
Median Displacement (ft)	0.84	0.91	1.32	1.97
Std. Deviation of Displacement (ft)	0.29	0.36	0.46	0.71
Minimum Displacement (ft)	0.38	0.38	0.76	1.38
Maximum Displacement (ft)	1.15	1.24	2.07	3.44
Thickness of Fill (ft)	29.5	6.7	19.9	28.0
Thickness of YBM (ft)	17	43.5	61.3	65.5
Max. Bending Moment (kip-ft)	31.9	9.4	18.8	29.4
Max. Bending Stress (ksi)	10.9	3.2	6.4	10.1
PGA in Fill (g), Design Earthquake	0.20	0.20	0.18	0.23

* Reach 6 and Reach 7 analyses described in the Preliminary Geotechnical Report (TERRA, 2023)

Subsurface Soil Column Conditions – Reach 5



2D PLAXIS Finite Element Mesh – Reach 5

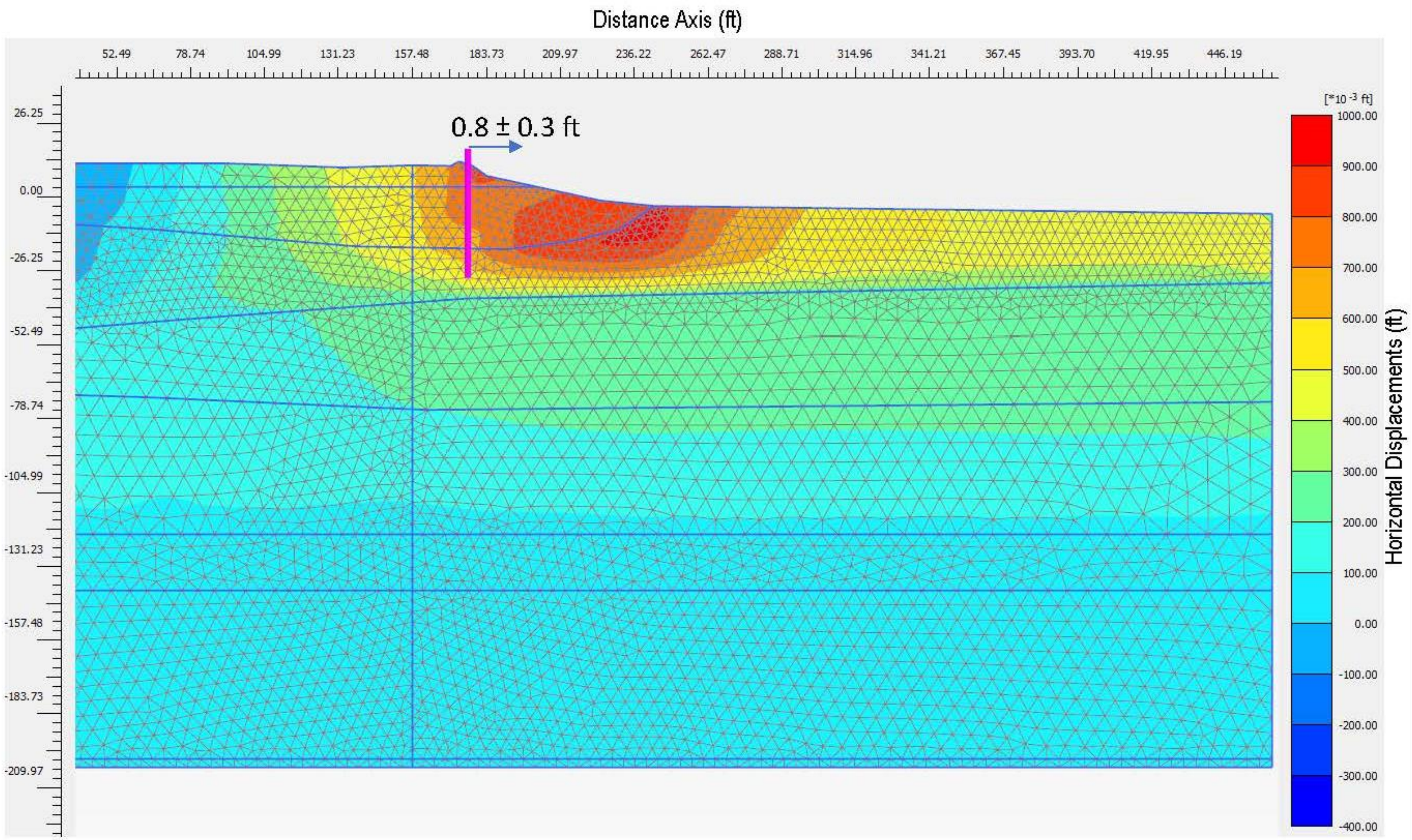


NOTES:

1. Topography data from SFO LiDAR Survey (c. 2020)
2. Bathymetry data from SFO Multibeam Bathymetric Survey by eTrac (2020)
3. Subsurface data from ADEC Geotechnical Data and Site Characterization (2001) and CCA Sea Plane Harbor Report (1973)
4. Elevation Datum = NAVD88

COWI / TERRA engineers, inc. JOINT VENTURE	FINITE ELEMENT MESH REACH 5 SFIA SHORELINE PROTECTION PROGRAM	Figure S-4

Typical Lateral Displacements – Reach 5, 475-year Event



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TYPICAL LATERAL DISPLACEMENTS
REACH 5
SFIA SHORELINE PROTECTION PROGRAM

Figure
S-5

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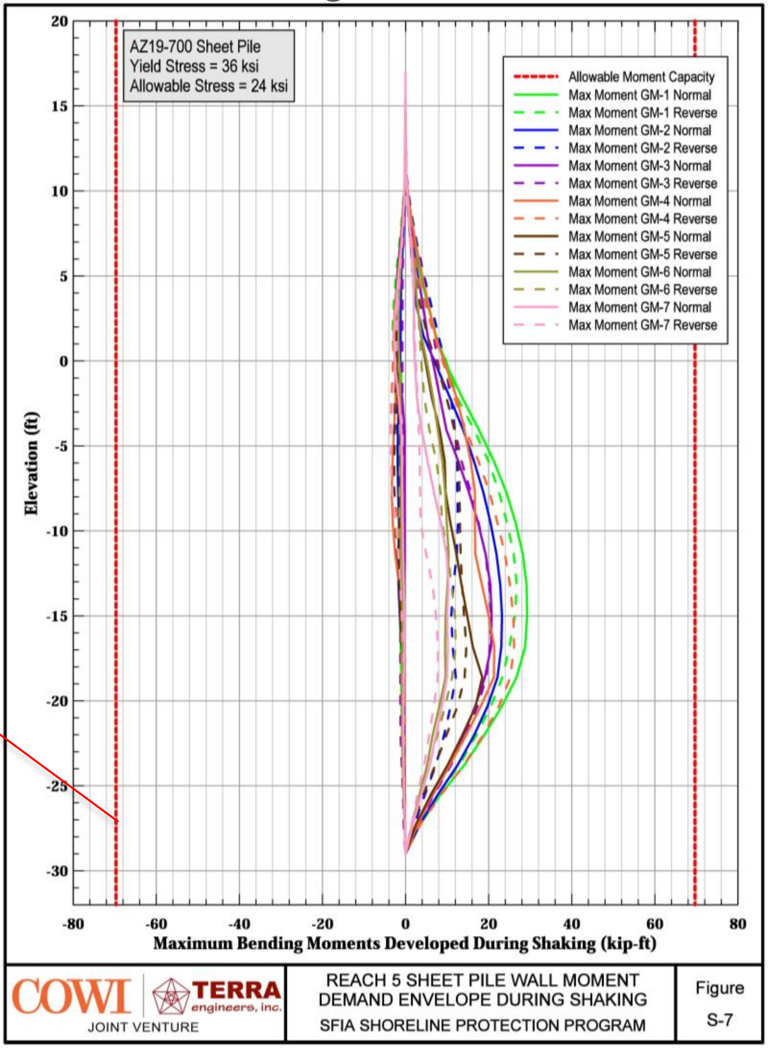
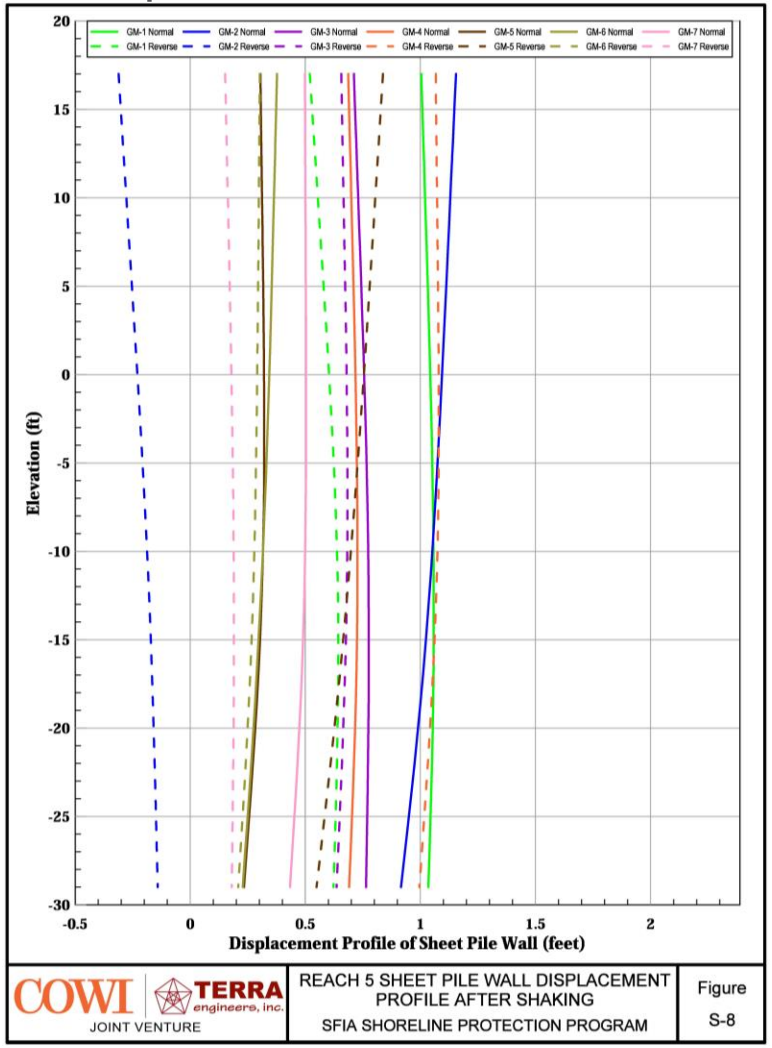
Performance of Sheet Pile – Reach 5

Maximum Bending Moments



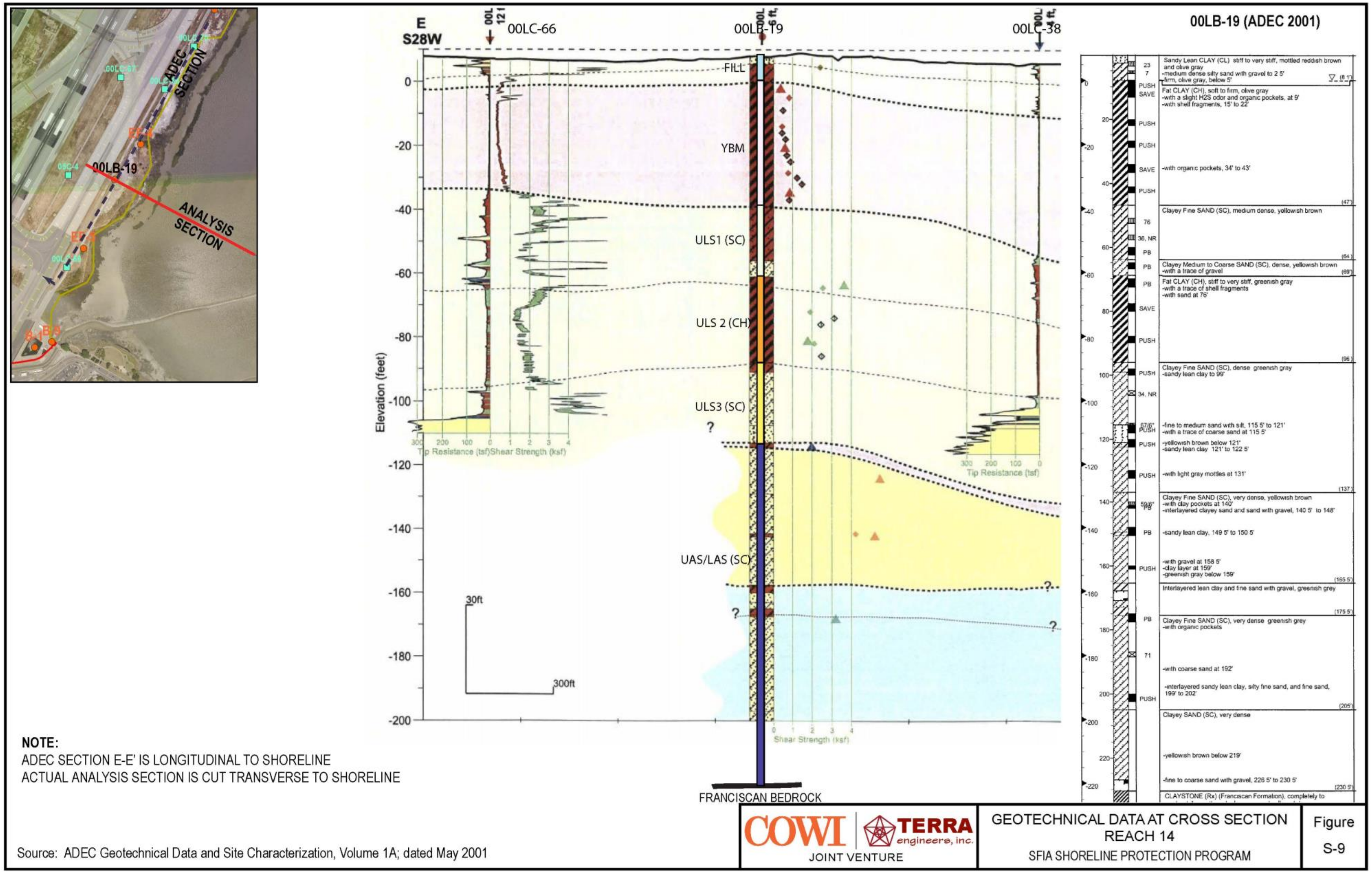
Allowable Bending Moment ±69 kip-ft

Wall Displacement Profile

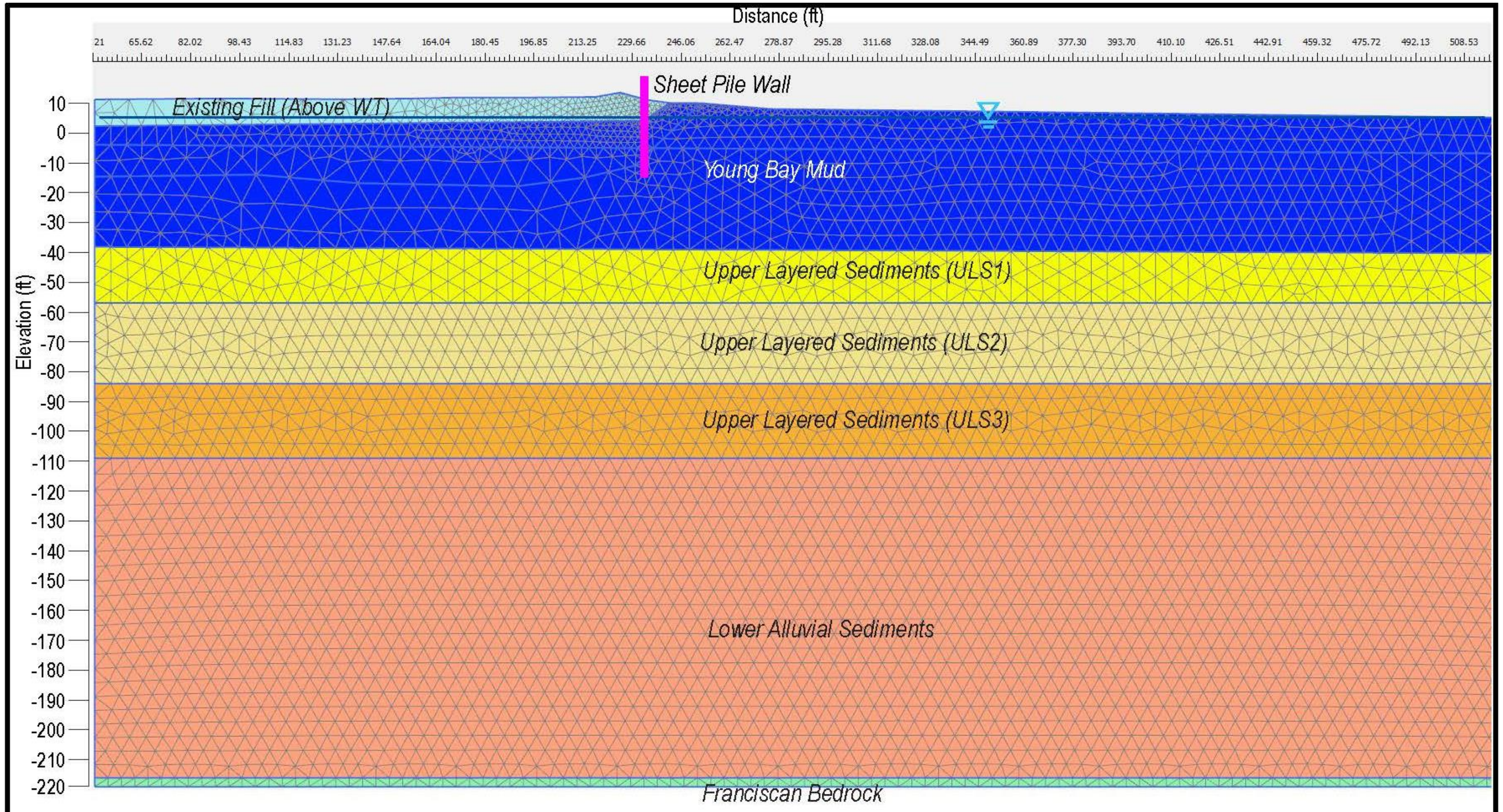


Seven time histories, scaled to 475-year amplitude

Subsurface Soil Column Conditions – Reach 14



2D PLAXIS Finite Element Mesh – Reach 14



NOTES:
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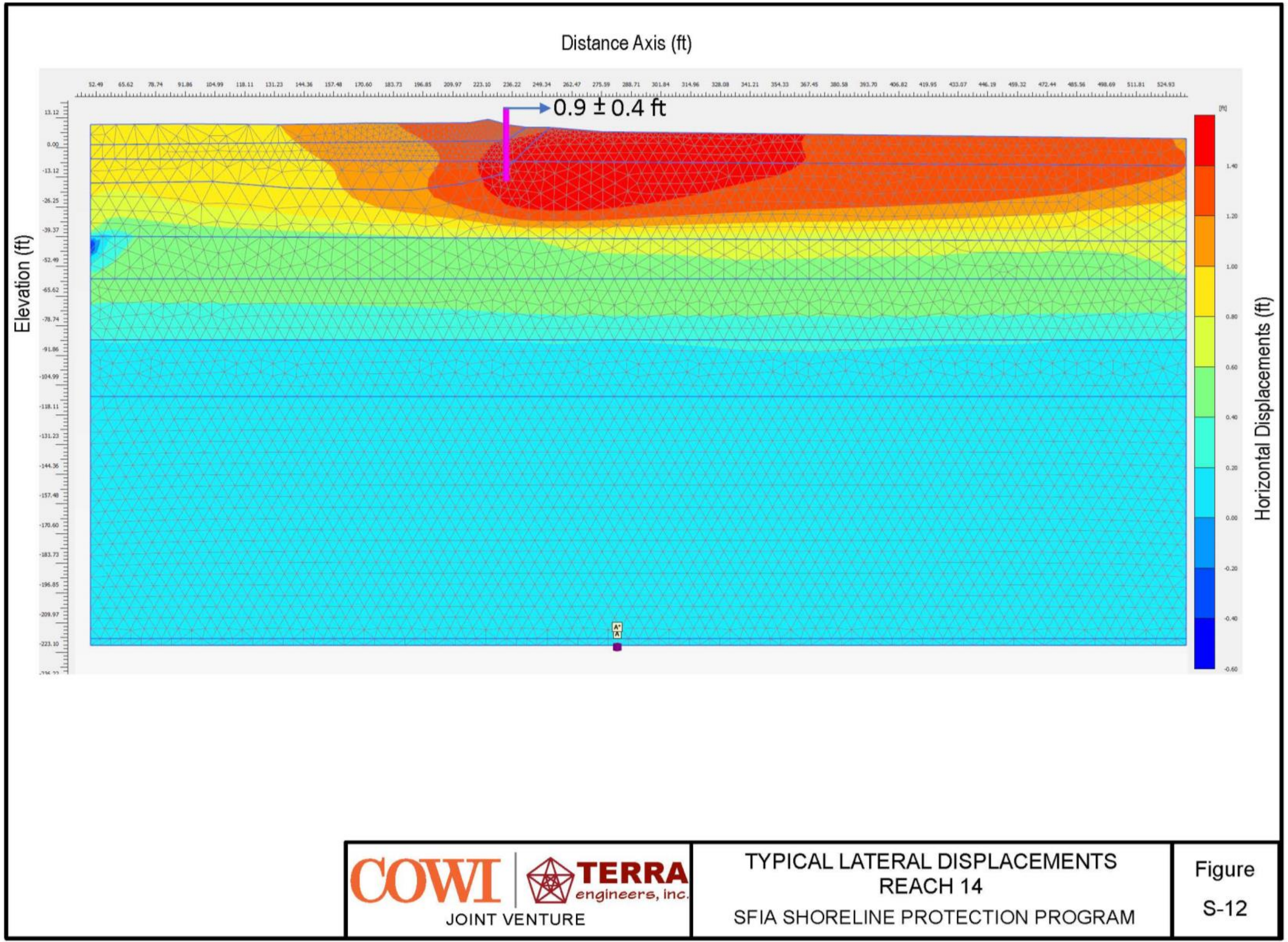
3. Elevation Datum = NAVD88

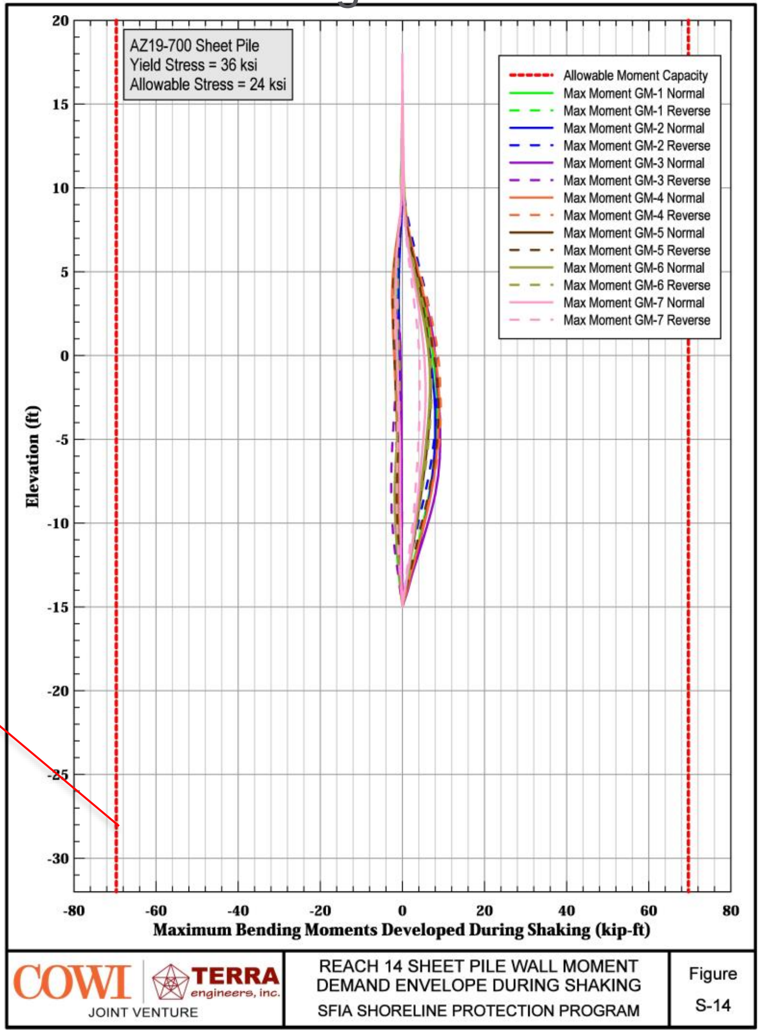
COWI / TERRA engineers, inc. JOINT VENTURE	FINITE ELEMENT MESH REACH 14 SFIA SHORELINE PROTECTION PROGRAM	Figure S-11

Typical Lateral Displacements – Reach 14, 475-year Event



Performance of Sheet Pile – Reach 14

Maximum Bending Moments



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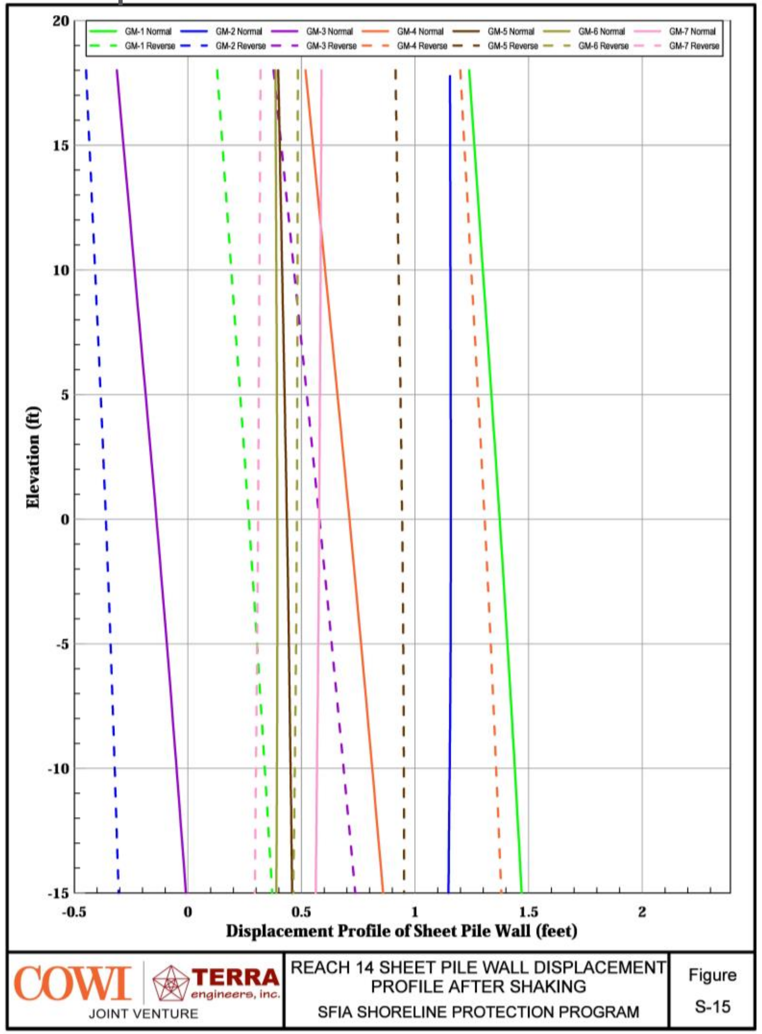
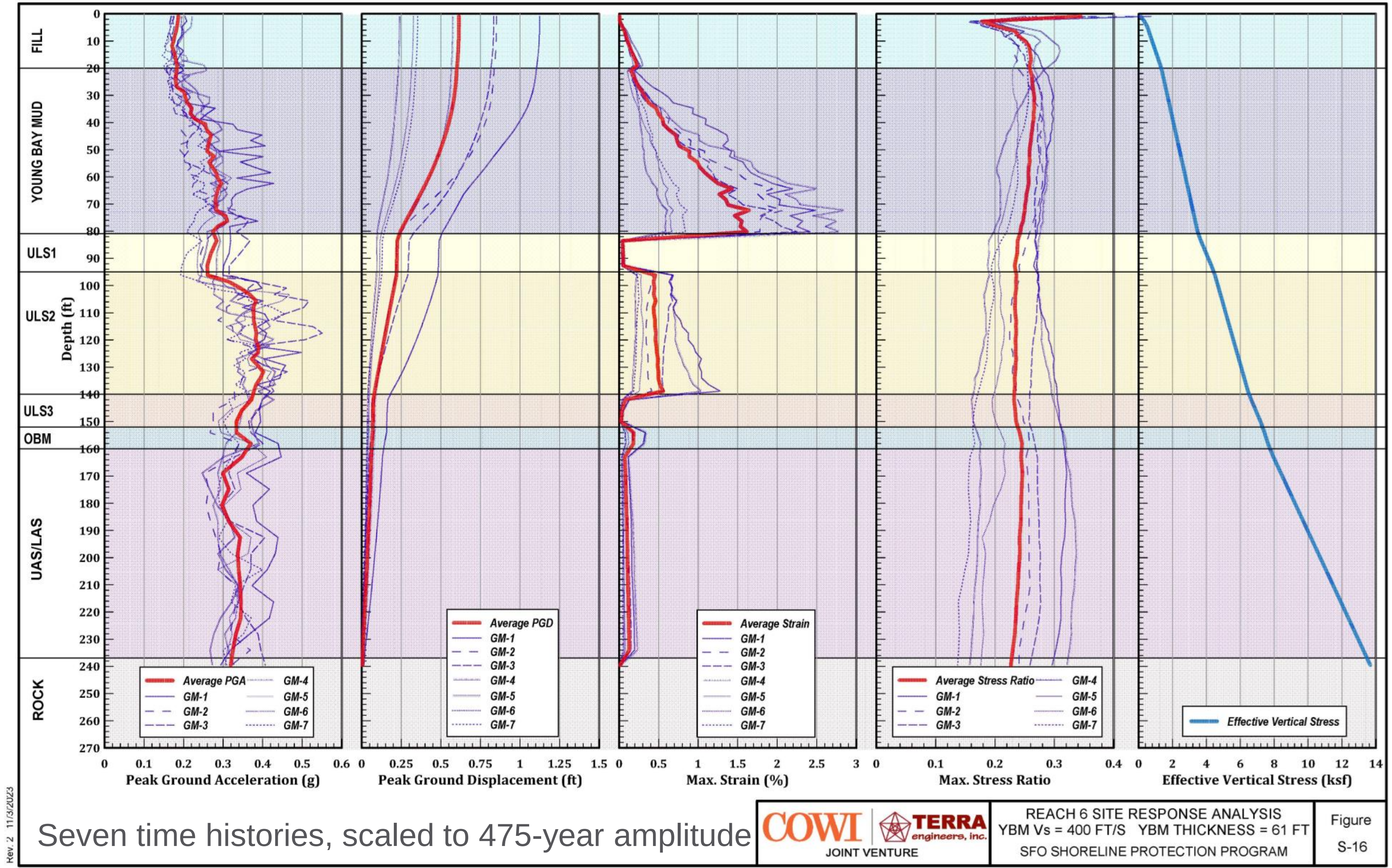


Seven time histories, scaled to 475-year amplitude

Site Response Analysis – Reach 6

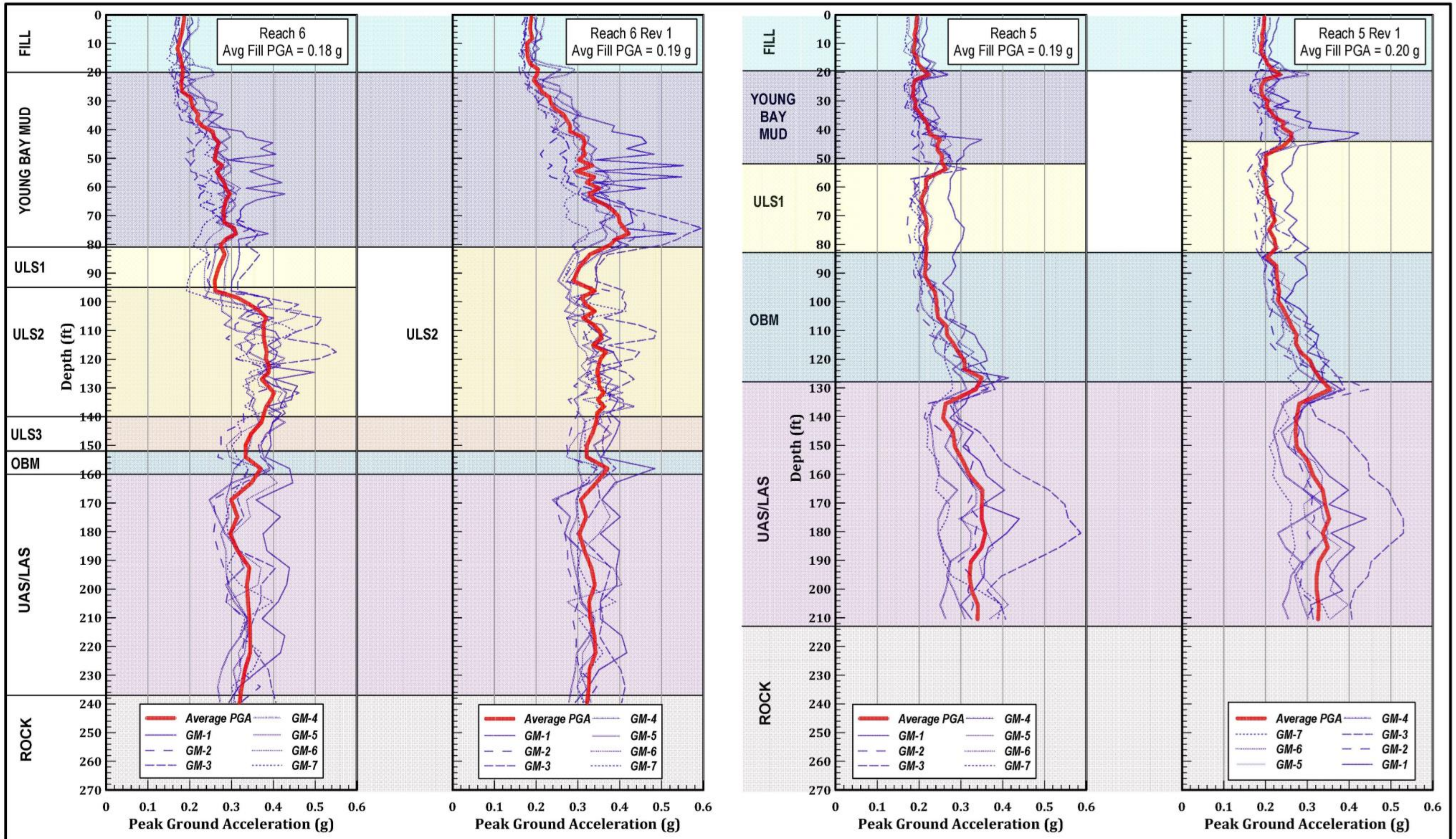
Peak Ground Acceleration | Peak Ground Displacement | Maximum Strain | Maximum Stress Ratio | Effective Vertical Stress



Seven time histories, scaled to 475-year amplitude

SFO

Comparison of Site Response Analysis –
Sensitivity of Peak Ground Acceleration to Young Bay Mud Thickness



Seven time histories, scaled to 475-year amplitude

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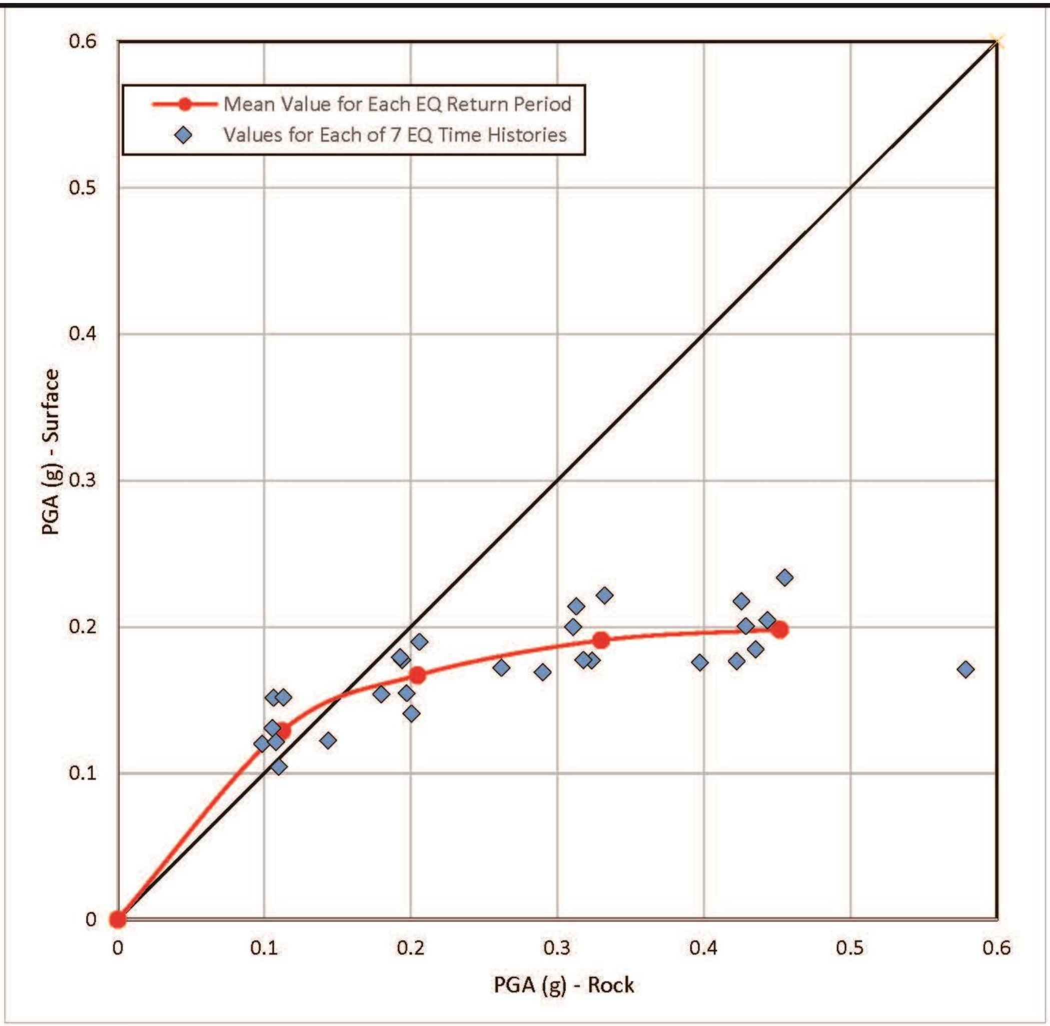
COMPARISON OF SITE RESPONSE ANALYSES
SENSITIVITY OF PGA IN FILL TO YBM THICKNESS
SFO SHORELINE PROTECTION PROGRAM

Figure S-17

Sensitivity of PGA at Surface to PGA at Bedrock



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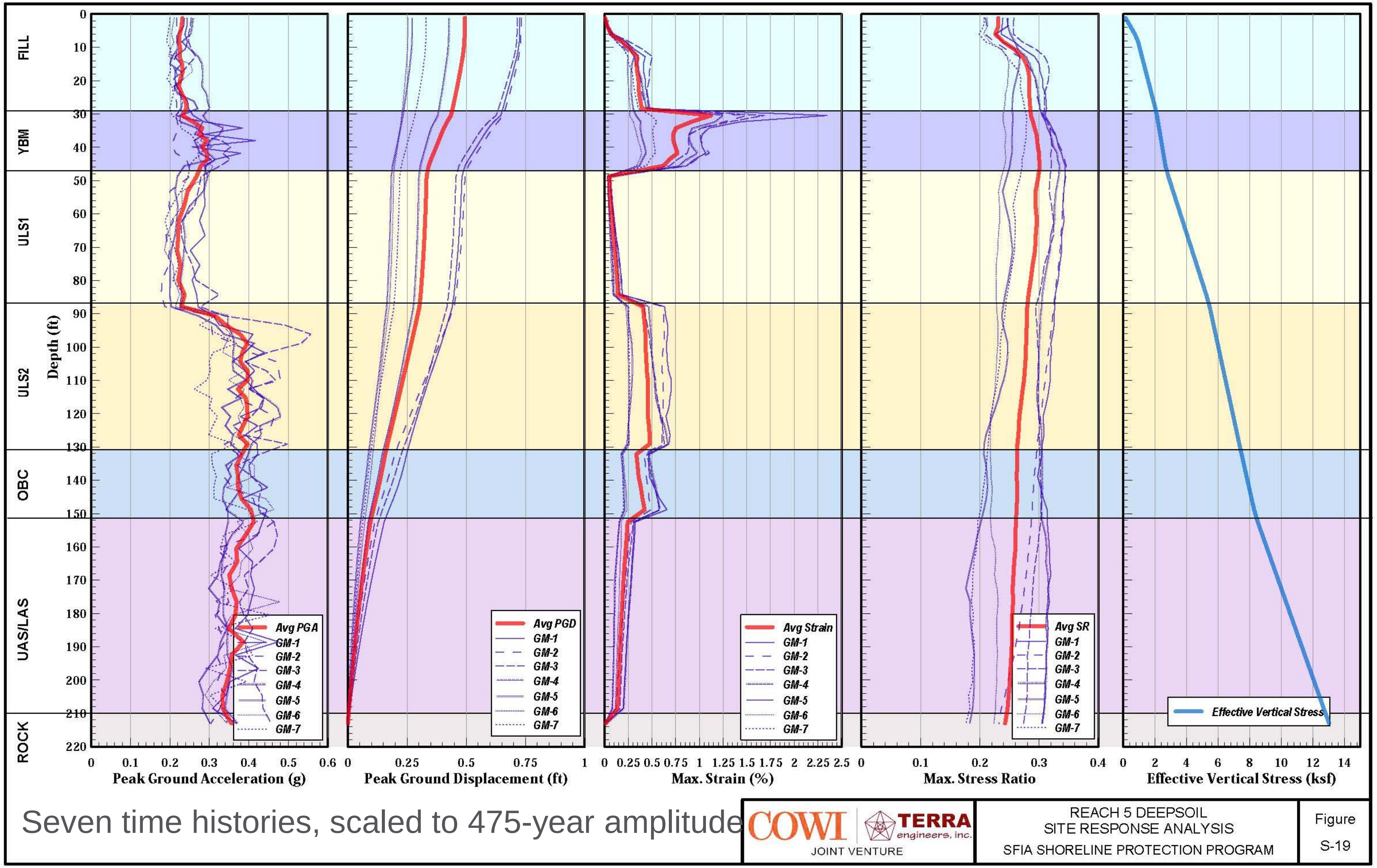
SENSITIVITY OF PGA IN FILL TO PGA IN SOIL AT BEDROCK -- REACH 6
SFIA SHORELINE PROTECTION PROGRAM

Figure S-18

Site Response Analysis – Reach 5

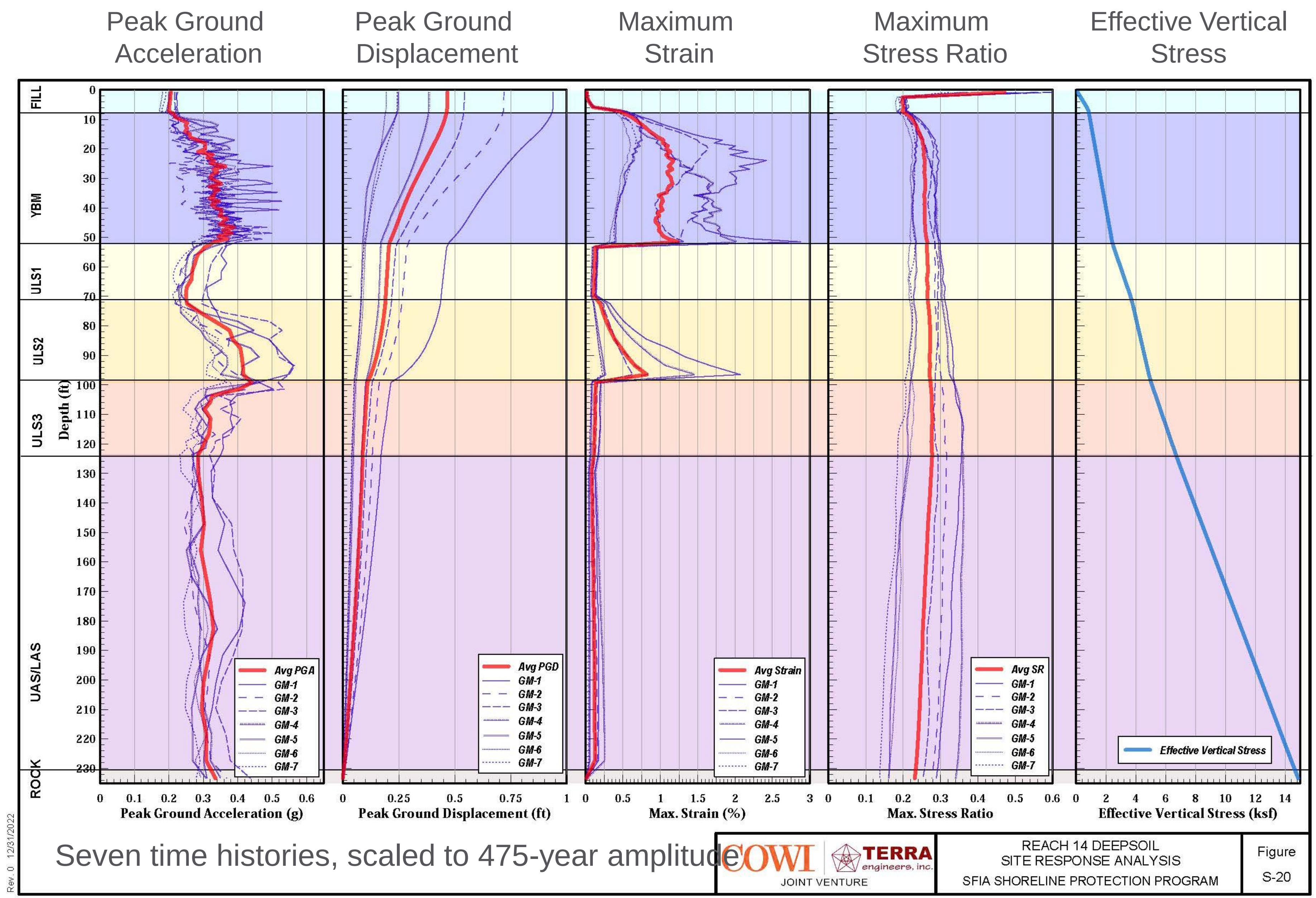
Peak Ground Acceleration | Peak Ground Displacement | Maximum Strain | Maximum Stress Ratio | Effective Vertical Stress



Seven time histories, scaled to 475-year amplitude

SFO

Site Response Analysis – Reach 14



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PGA in Fill (g)	0.20	0.20	0.18	0.23

* Reach 6 and Reach 7 analyses described in the Preliminary Geotechnical Report (TERRA, 2023)

Supplemental Geotechnical Analyses

Summary & conclusions (1 of 2)

- The four reaches analyzed bracket most subsurface conditions along the SPP alignment
- The additional 2D PLAXIS analyses and 1D DEEPSOIL SRA analyses at Reaches 5 and 14 indicate that Reach 6 provides conservative estimates of the magnitude of the lateral displacement of the sheet pile wall for reaches where the thickness of YBM is less than at Reach 6 and new fill is not added.
- The calculated stresses for the floodwalls under flood loading are larger than the calculated stresses due to soil-structure interaction under seismic loading.
- Sensitivity studies that varied the magnitude of shaking and thickness of YBM at Reach 6 show that the maximum expected PGA within the fill is about 0.2 g. Similar results were found for the SRA analyses at Reaches 5 and 7.

Supplemental Geotechnical Analyses

Summary & conclusions (2 of 2)

- The placement of new fill at Reach 7 would cause somewhat larger estimated lateral displacements under seismic loading than at Reach 6 (2.1 feet vs 1.3 feet), but the maximum transient bending stresses in the sheet pile wall at Reaches 6 and 7 would be less than 11 ksi for all cases and far below the allowable bending stress for steel under permanent loading.
- Final design will require closely spaced CPTs to characterize localized average thickness and liquefaction potential of fill to delineate areas that may require improvement of the engineering properties of the fill.

ECRB Discussion

- Geotechnical Analysis

Operations & Maintenance:
Combined Earthquake & Flooding

Joint Earthquake & Flooding

Summary of Analysis

- The SFO shoreline protection system was analyzed for both earthquake and flood loading scenarios independent of each other.
  - 100-year flood elevation (with 3.5-ft SLR) – No damage
  - Medium Seismic Hazard Level (72-year) – No damage
  - High Seismic Hazard Level (475-year) – Localized, repairable damage anticipated.
- A load case where the floodwall experiences High Seismic Hazard Level event (475-year return period) simultaneously with the design flood event (100-year flood) is not a realistic load combination used for design. Since they are independent events, this would represent an extremely improbable event.
- To evaluate the effectiveness of the SFO shoreline protection system to prevent flooding after the High Seismic Hazard Level event, the risk of widespread flooding and localized flooding has been evaluated.

Attachment 4: COWI. 2024. Analysis of scenarios with both earthquake and flooding.

Joint Earthquake & Flooding

Key Analysis Considerations

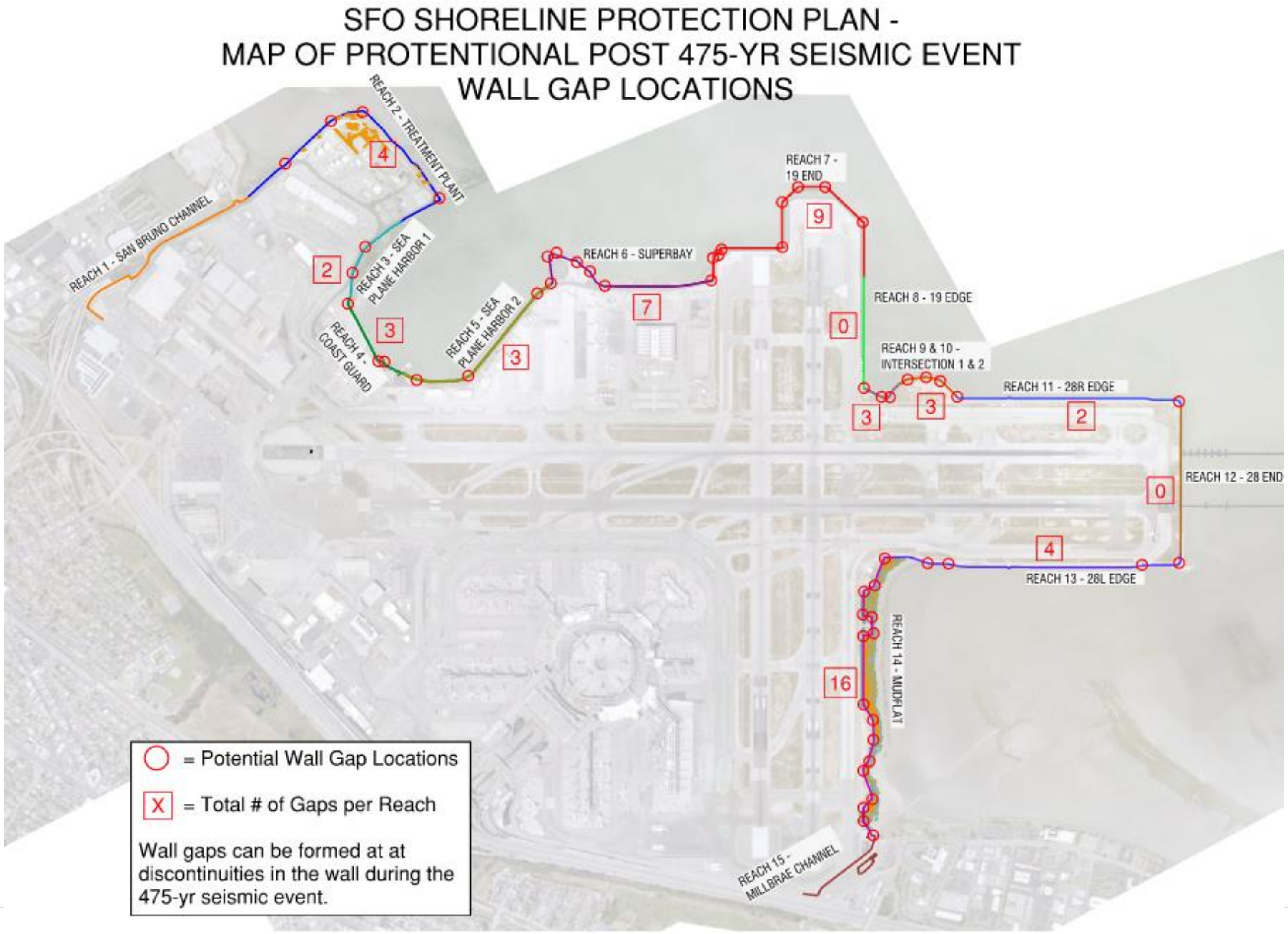
Exposure After High Seismic Hazard Level event (475-year return period)

- Day 0 to Week 1
  - Gaps may form at discontinuities in in wall during earthquake where differential movement cause sheets to break at the interlocks
  - Worst case, the flood protection is reduced to the existing ground elevation at the gaps
- Week 1 to Month 6
  - Gaps are closed with sandbags/fill up to 3 ft above ground elevation within one week of the event
  - Repairs restore partial flood protection
- Months 6+
  - Wall is repaired using new sheet piles/plating within 6 months of the event
  - Repairs restore full flood protection

Joint Earthquake & Flooding

Key Analysis Considerations

- Locations of possible damage after High Seismic Hazard Level (475-year) event
- Gaps are expected at locations where alignment of flood wall sheet piles change direction more than 30 degrees and differential movement can occur



SFO

Joint Earthquake & Flooding

Key Analysis Considerations

Changes in flood risk over time due to SLR

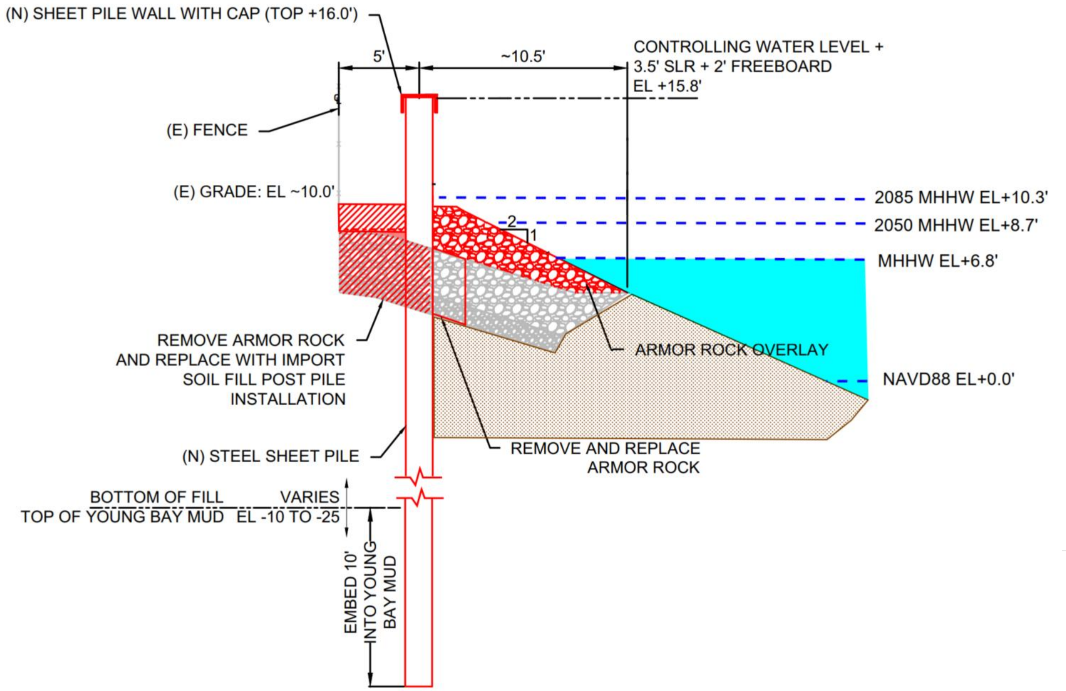
- Sea Level Rise (SLR) based on OPC Projection Medium-High Risk Aversion (1-in-200 chance (0.5%) probability SLR meets or exceeds value)
- Flood risk post seismic event was considered at three time periods:
  - Scenario 1: 2030
    - SLR = 0 ft
  - Scenario 2: 2050
    - SLR = 1.9 ft
  - Scenarios 3: 2085
    - SLR = 3.5 ft
    - End of project design life

Joint Earthquake & Flooding

Key Analysis Considerations

Extent of flooding based on water elevation

- The existing ground elevation on the waterside of the proposed wall will normally be dry (i.e., above the tide elevations)
- If Mean Higher High Water (MHHW) exceeds level of flood protection widespread flooding would occur. MHHW would be expected to occur multiple times each month.
- If Still Water Elevation (SWEL) exceeds level of flood protection widespread flooding would occur if the 100-year flood event occurs
- If Total Water Elevation (TWL) exceeds level of flood protection localized flooding near the wall would occur if the 100-year flood event occurs



Joint Earthquake & Flooding

Summary of Results - 2030

2.1.3.1 Scenario 1 – Flood Risk post High Seismic Hazard Level Event – 2030

					2030 (SLR = 0 ft)		
Reach	Top of Floodwall Design Elevation [ft NAVD88]	Existing Min Ground Elevation [ft NAVD88]	Min Ground Elevation after temporary Repairs post Seismic Event [ft NAVD88]	Assumed number of gaps expected after seismic event.	MHHW [ft NAVD88]	1% SWEL [ft NAVD88]	1% TWL [ft NAVD88]
2	16.0	10.5	13.5	4	6.8	10.3	11.9
3	16.0	10.5	13.5	2	6.8	10.3	11.7
4	16.0	10.0	13.0	3	6.8	10.3	11.0
5	17.0	11.0	14.0	3	6.8	10.3	11.7
6	17.0	11.5	14.5	7	6.8	10.3	11.5
7	20.2	12.0	15.0	9	6.8	10.3	12.8
8	17.5	12.0	15.0	0	6.8	10.3	13.0
9	17.0	11.5	14.5	3	6.8	10.3	11.8
10	17.0	12.5	15.5	3	6.8	10.3	12.8
11	17.0	13.5	16.5	2	6.8	10.3	12.5
12	17.0	10.5	13.5	0	6.8	10.3	12.5
13	17.0	11.5	14.5	4	6.8	10.3	10.8
14	18.0	12.0	15.0	16	6.8	10.3	12.5

- MHHW for current tidal epoch 1983-2001
- Very limited risk of widespread flooding post seismic event as existing ground EL > MHHW & 1% SWEL
- Similar risk of flooding as currently exists at the airport

Joint Earthquake & Flooding

Summary of Results - 2050

2.1.3.2 Scenario 2 – Flood Risk post High Seismic Hazard Level Event – 2050

Reach	Top of Floodwall Design Elevation [ft NAVD88]	Existing Min Ground Elevation [ft NAVD88]	Min Ground Elevation after temporary Repairs post Seismic Event [ft NAVD88]	Assumed number of gaps expected after seismic event.	2050 (SLR = 1.9 ft) MHHW+SLR [ft NAVD88]	2050 (SLR = 1.9 ft) 1% SWEL+SLR [ft NAVD88]	2050 (SLR = 1.9 ft) 1% TWL+SLR [ft NAVD88]
2	16.0	10.5	13.5	4	8.7	12.2	13.6
3	16.0	10.5	13.5	2	8.7	12.2	13.3
4	16.0	10.0	13.0	3	8.7	12.2	13.0
5	17.0	11.0	14.0	3	8.7	12.2	14.0
6	17.0	11.5	14.5	7	8.7	12.2	13.4
7	20.2	12.0	15.0	9	8.7	12.2	14.9
8	17.5	12.0	15.0	0	8.7	12.2	15.0
9	17.0	11.5	14.5	3	8.7	12.2	14.1
10	17.0	12.5	15.5	3	8.7	12.2	14.6
11	17.0	13.5	16.5	2	8.7	12.2	14.6
12	17.0	10.5	13.5	0	8.7	12.2	14.6
13	17.0	11.5	14.5	4	8.7	12.2	12.6
14	18.0	12.0	15.0	16	8.7	12.2	14.9

- Minimal risk of widespread flooding post seismic event as existing ground EL > MHHW but less than SWEL. After temporary repairs are placed 7 days post event, risk is eliminated.
- Minimal risk of localized wave overtopping at one location for 6 months after post seismic event. Flooding would be limited.

Joint Earthquake & Flooding

Summary of Results - 2085

2.1.3.3 Scenario 3 – Flood Risk post High Seismic Hazard Level Event – 2085

Reach	Top of Floodwall Design Elevation [ft NAVD88]	Existing Min Ground Elevation [ft NAVD88]	Min Ground Elevation after temporary Repairs post Seismic Event [ft NAVD88]	Assumed number of gaps expected after seismic event.	2085 (SLR = 3.5ft) MHHW+SLR [ft NAVD88]	2085 (SLR = 3.5ft) 1% SWEL+SLR [ft NAVD88]	2085 (SLR = 3.5ft) 1% TWL+SLR [ft NAVD88]
2	16.0	10.5	13.5	4	10.3	13.8	14.9
3	16.0	10.5	13.5	2	10.3	13.8	14.6
4	16.0	10.0	13.0	3	10.3	13.8	14.7
5	17.0	11.0	14.0	3	10.3	13.8	16.0
6	17.0	11.5	14.5	7	10.3	13.8	15.0
7	20.2	12.0	15.0	9	10.3	13.8	16.5
8	17.5	12.0	15.0	0	10.3	13.8	16.6
9	17.0	11.5	14.5	3	10.3	13.8	16.0
10	17.0	12.5	15.5	3	10.3	13.8	16.2
11	17.0	13.5	16.5	2	10.3	13.8	16.3
12	17.0	10.5	13.5	0	10.3	13.8	16.3
13	17.0	11.5	14.5	4	10.3	13.8	14.2
14	18.0	12.0	15.0	16	10.3	13.8	17.0

- Risk of widespread flooding immediately after seismic event. At Reach 4 existing ground elevation would be less than MHHW+SLR. This assumes the US Coast Guard will make no improvements to the landside area of Reach 4 prior to 2085. It is likely the paved area will be regraded sometime in next 60 years.
- Minor risk of widespread flooding for 6 months until full repairs are completed. SWL exceeds elevation of temporary repairs at some reaches.

Joint Earthquake & Flooding

Key Conclusions

- The probability of a 100-year flood event occurring within 6 months of the High Seismic Hazard Level (475-year) is low.
- Risk of widespread flooding post seismic event is very low.
- The site is not at risk of flooding due to monthly high tides until near the end of the design life
- Flood risk changes over time due to SLR. The SLR assumed for the project represents a 1-in-200 chance of exceedance.
- Post-seismic event the wall is repairable with conventional materials. Temporary repairs can be placed within 7 days to restore partial flood protection and reducing risk significantly until permanent repairs can be completed. Full repairs expected to be completed in 6 months.
- To prevent damage to the flood wall from the High Seismic Hazard Level (475-year) event would require costly ground improvement along the wall alignment. As risk of flooding is low post seismic event it does not make economic sense to spend the money as part of this project construction.

ECRB Discussion

- Combined Earthquake & Flooding

Operations & Maintenance:
Corrosion

Corrosion *Design*

***ECRB-4**: Corrosion is important to address since it can weaken the steel wall. According to the design team, corrosion of the steel sheet piles is being addressed by a coating system. Analysis of corrosion rates in the design to date rely on published numbers when corrosion rates are site specific. Provide a monitoring program to measure actual corrosion rates at the site so coating maintenance can be timed appropriately.*

- Wall designed with additional thickness (sacrificial steel) and corrosion coating
- Sheet piles to have 3/8” minimum wall thickness and coated from top to 10 ft below mudline
- All structural analysis done with assumed corroded wall thickness per California DOT Corrosion Guidelines Version 3.2. Design life is 60 years with worst case of 50 years’ corrosion assumed.

TABLE 4.11-1 CORROSION RATES

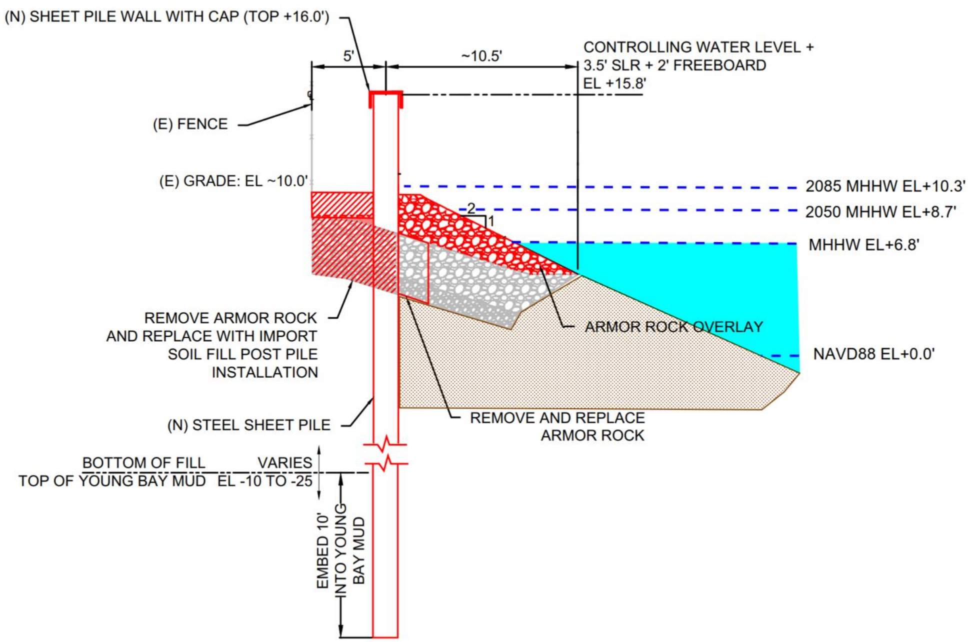
Nominal Zone	Elevation Range	Steel Corrosion Rate (in. / year)
Atmospheric Zone	Exposed Landside and Floodside Faces of Sheet Pile	0.002
Fill or Disturbed Natural Soils	Existing Grade to Top of YBM	0.0015
Subsoil	Top of YBM to Pile Tip	0.001

Corrosion

O&M, Inspection

***ECRB-4**: Corrosion is important to address since it can weaken the steel wall. According to the design team, corrosion of the steel sheet piles is being addressed by a coating system. Analysis of corrosion rates in the design to date rely on published numbers when corrosion rates are site specific. Provide a monitoring program to measure actual corrosion rates at the site so coating maintenance can be timed appropriately.*

- O&M manual calls for sheet piles to be visually inspected every 5 years, and any damage to be repaired. Sheet piles are fully accessible landside and at majority of tides on water side.
- Inspection per ASCE Waterfront Facilities Inspection and Assessment. Level 1 general visual inspection planned. If corrosion is encountered, Level 3 UTM inspection may be required
- No presence of corrosive soils identified on site. To be confirmed during detail design phase



SFO

ECRB Discussion

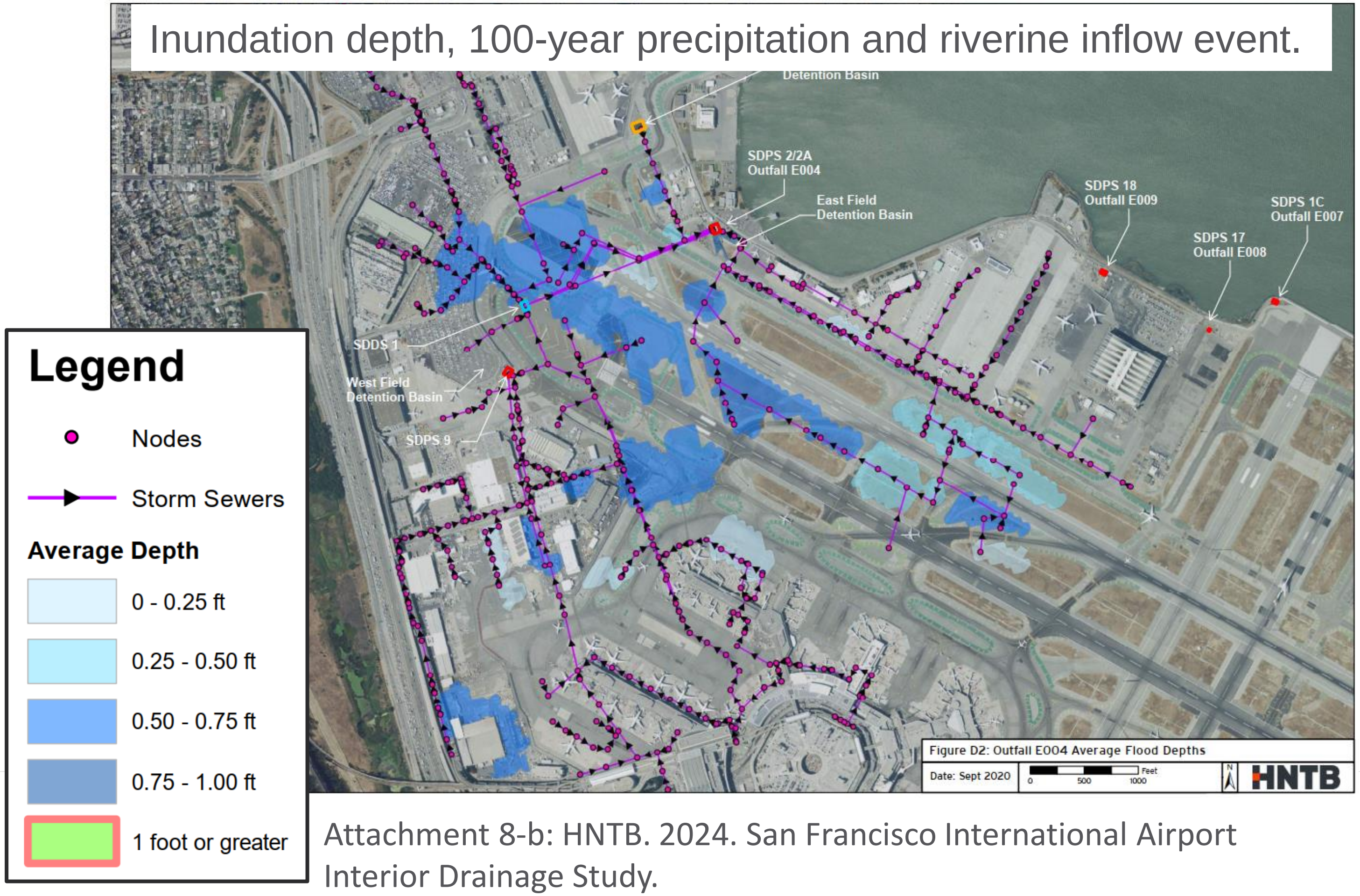
- Corrosion

Operations & Maintenance:
Flood Response Operations

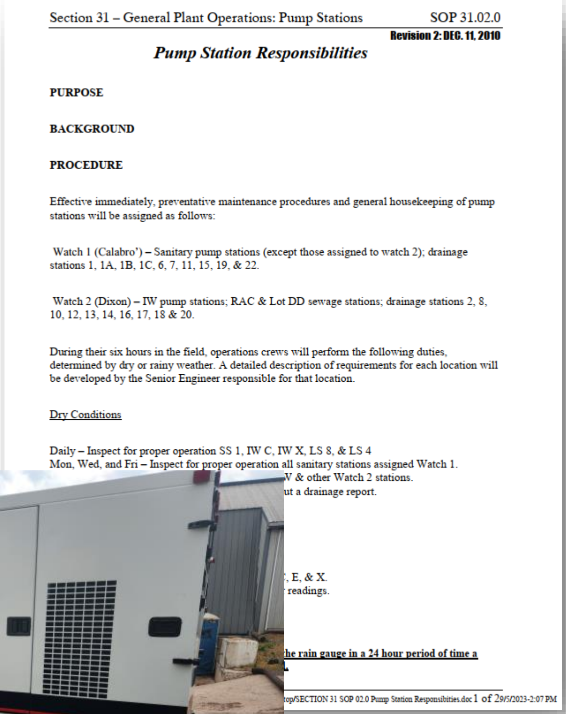
Stormwater Emergency Operations

***ECRB-6**: In an emergency event such as a flood or earthquake, the ability for the airport to get back into operation is expected to depend on the operation of the stormwater pumping system. Therefore, provide information on how the pumping system is powered, if backup power is available, and present what measures will be taken to have a resilient stormwater pumping system in the project. At what elevation have the backup power systems been placed (compared to tides and flood levels)?*

Inundation depth, 100-year precipitation and riverine inflow event.



Attachment 8-b: HNTB. 2024. San Francisco International Airport Interior Drainage Study.



Section 31 – General Plant Operations: Pump Stations SOP 31.02.0

Revision 2: DEC. 11, 2010

Pump Station Responsibilities

PURPOSE

BACKGROUND

PROCEDURE

Effective immediately, preventative maintenance procedures and general housekeeping of pump stations will be assigned as follows:

Watch 1 (Calabro') – Sanitary pump stations (except those assigned to watch 2); drainage stations 1, 1A, 1B, 1C, 6, 7, 11, 15, 19, & 22.

Watch 2 (Dixon) – IW pump stations; RAC & Lot DD sewage stations; drainage stations 2, 8, 10, 12, 13, 14, 16, 17, 18 & 20.

During their six hours in the field, operations crews will perform the following duties, determined by dry or rainy weather. A detailed description of requirements for each location will be developed by the Senior Engineer responsible for that location.

Dry Conditions

Daily – Inspect for proper operation SS 1, IW C, IW X, LS 8, & LS 4
Mon, Wed, and Fri – Inspect for proper operation all sanitary stations assigned Watch 1.
W & other Watch 2 stations.
ut a drainage report.

, E, & X.
readings.

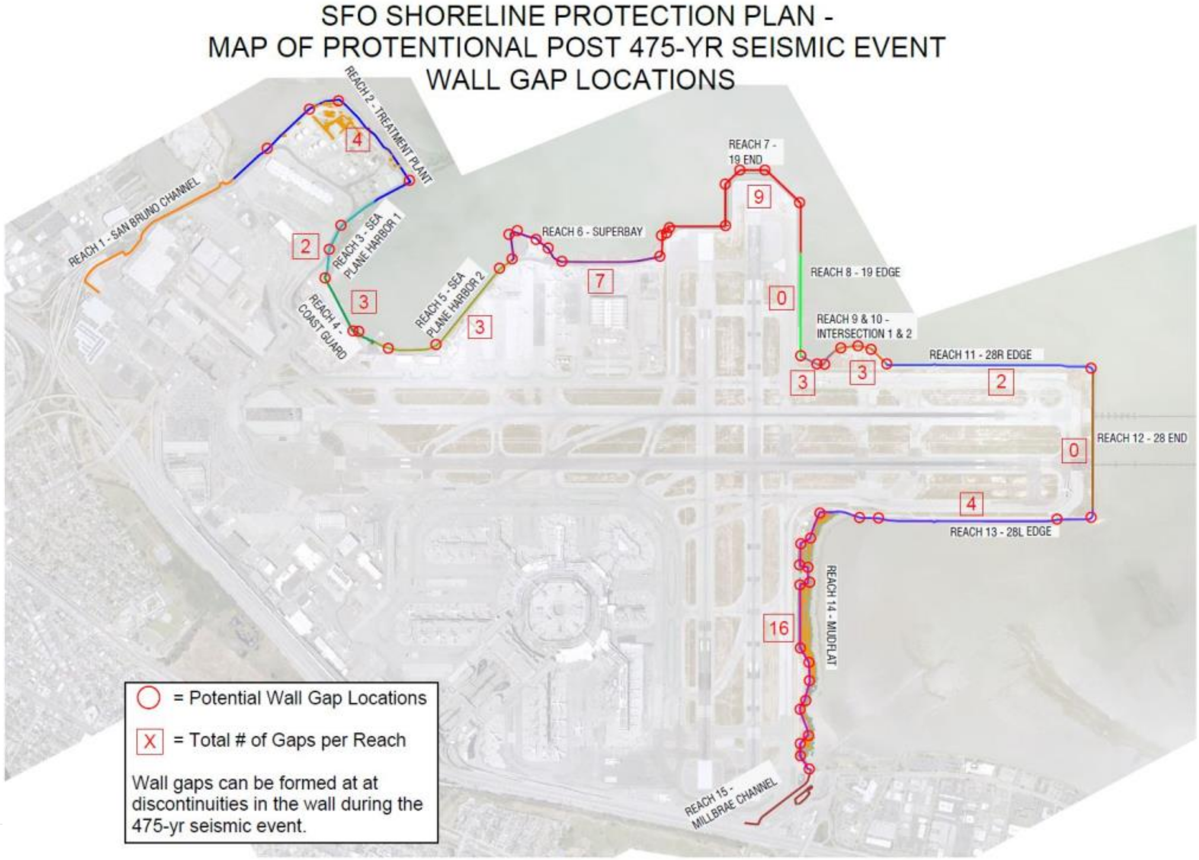
he rain gauge in a 24 hour period of time a

top/SECTION 31 SOP 02.0 Pump Station Responsibities.doc 1 of 29/5/2023-2:07 PM

Typical portable emergency generator

Floodwall Repair

***BCDC-1**: In a future high tide scenario, with all the flood gates deployed, with an earthquake that damages the wall, what is the process and timeline for repairing the sea wall? Will outside contractors need to access the site?*



- High Seismic Hazard Level event (475-year) could experience localized damage consisting of gaps forming at wall junctions
- Potential number mapped, by reach (see map)
- Temporary repair: Within one week of an earthquake, close gaps up to 3 ft above the existing grade with sandbags, soil, and/or K-rail
- Permanent repair: Within six months of an earthquake, close gaps to original design elevation with steel plates, new piles, etc.
- Flood gates anticipated to only be needed to block water levels for a few hours
- Temporary repair may involve SFO and/or outside contractor. Permanent repairs likely to involve outside contractor.

SFO

***BCDC-1 (con't)**: How much water could pour in and, is the existing stormwater pumping system expected to handle it?*

Inflow Volumes

					+3.5 ft SLR			
Reach	Floodwall Design Elevation ft NAVD	Minimum Ground Elevation ft NAVD	Minimum Elevation after Temporary Repairs ft NAVD	Assumed # of gaps	MHHW + SLR ft NAVD	1% SWL + SLR ft NAVD	Freeboard ft	Inflow volume gallons
2	16	10.5	13.5	4	10.3	13.8	-0.3	3,452,544
3	16	10.5	13.5	2	10.3	13.8	-0.3	1,726,272
4	16	10	13	3	10.3	13.8	-0.8	18,413,568
5	17	11	14	3	10.3	13.8	0.2	
6	17	11.5	14.5	7	10.3	13.8	0.7	
7	20.2	12	15	9	10.3	13.8	1.2	
8	17.5	12	15	0	10.3	13.8	1.2	
9	17	11.5	14.5	3	10.3	13.8	0.7	
10	17	12.5	15.5	3	10.3	13.8	1.7	
11	17	13.5	16.5	2	10.3	13.8	2.7	
12	17	10.5	13.5	0	10.3	13.8	-0.3	
13	17	11.5	14.5	4	10.3	13.8	0.7	
14	18	12	15	16	10.3	13.8	1.2	

Total SWL inflow = 24,000,000 gal
SFO stormwater pumping capacity = 480,000 gpm
Time to remove SWL inflow = 0.8 hr

Total SWL + wave overtopping inflow = 62,000,000 gal
SFO stormwater pumping capacity = 480,000 gpm
Time to remove SWL inflow = 2.1 hr

Assumptions: MHHW for current tidal epoch 1983-2001, gap width=10 ft, inflow velocity 10 ft/s, water level change rate= 3.6 hr/ft, overtopping rate=65 l/s/m

Sources: COWI (2024), EurOtop (2018)

Flood Gate Locations

__BCDC-2__:During the life of the project, how frequently do you expect the passive flood gates and deployable flood gate to be up? Please provide proposed grades at each flood gate.

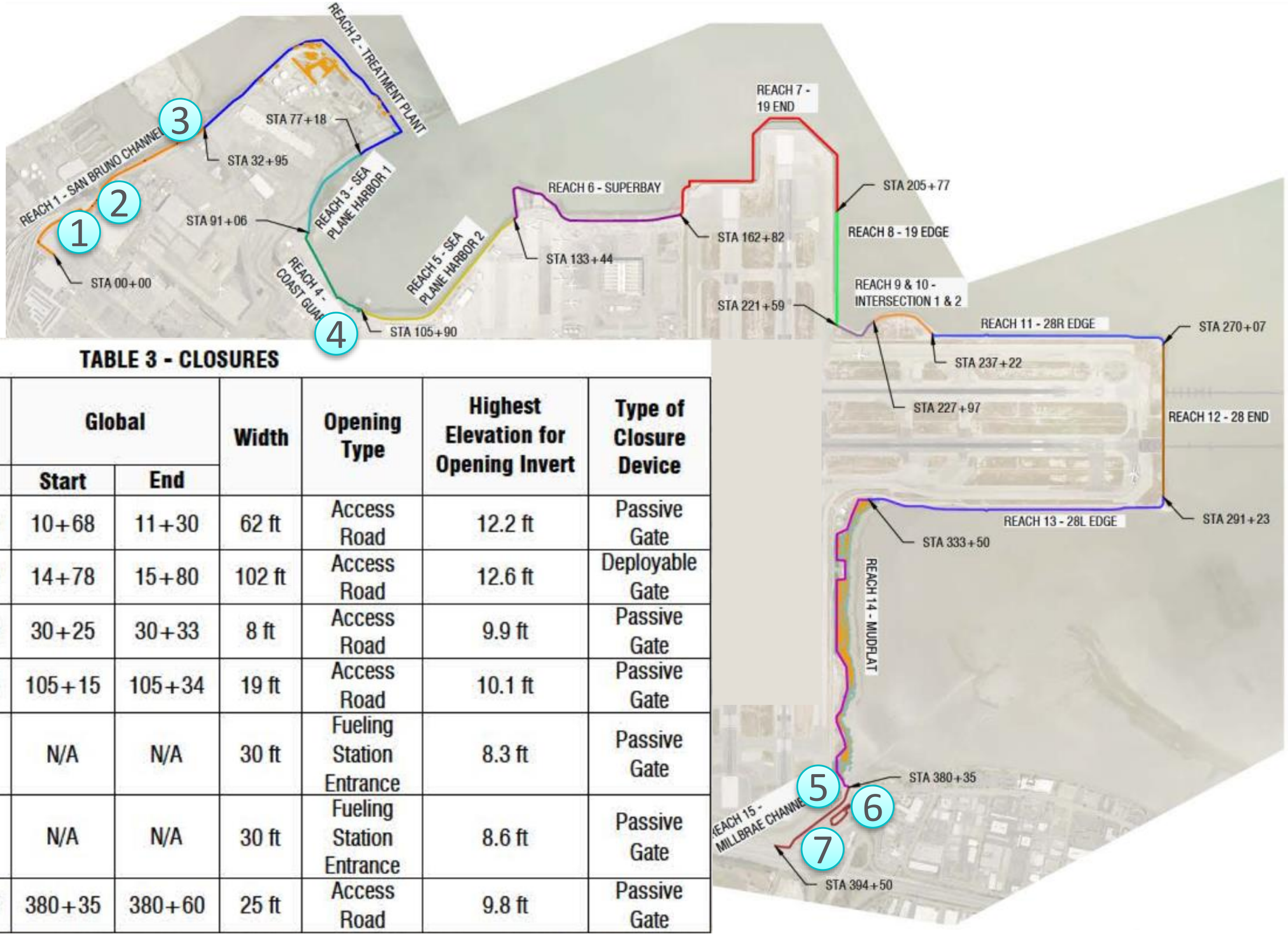


TABLE 3 - CLOSURES

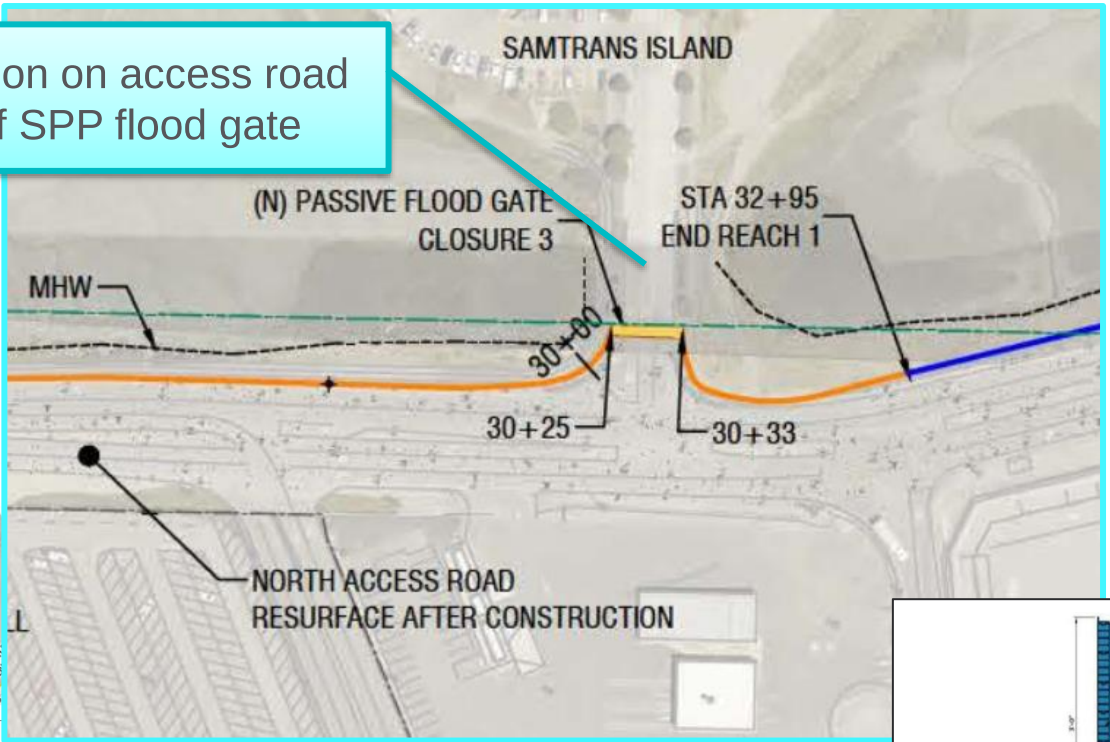
Closure No.	Reach No.	Local		Global		Width	Opening Type	Highest Elevation for Opening Invert	Type of Closure Device
		Start	End	Start	End				
1	1	10+68	11+30	10+68	11+30	62 ft	Access Road	12.2 ft	Passive Gate
2	1	14+78	15+80	14+78	15+80	102 ft	Access Road	12.6 ft	Deployable Gate
3	1	30+25	30+33	30+25	30+33	8 ft	Access Road	9.9 ft	Passive Gate
4	4	14+09	14+28	105+15	105+34	19 ft	Access Road	10.1 ft	Passive Gate
5	15	N/A	N/A	N/A	N/A	30 ft	Fueling Station Entrance	8.3 ft	Passive Gate
6	15	N/A	N/A	N/A	N/A	30 ft	Fueling Station Entrance	8.6 ft	Passive Gate
7	15	00+00	00+25	380+35	380+60	25 ft	Access Road	9.8 ft	Passive Gate

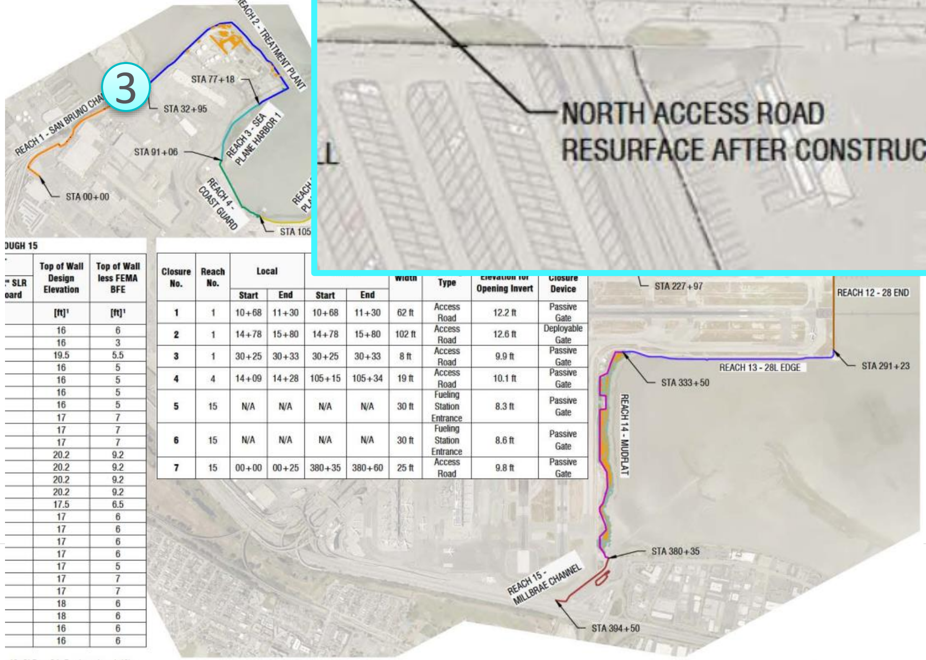
Flood Gate Closure Frequency

Gate Info		Existing Conditions (0 ft SLR)		Future Conditions (+1.5 ft SLR)		Future Conditions (+3.5 ft SLR)	
Closure #	Invert ft NAVD	MHHW freeboard, ft	1% SWL Freeboard, ft	MHHW freeboard, ft	1% SWL Freeboard, ft	MHHW freeboard, ft	1% SWL Freeboard, ft
1	12.2	5.4	1.9	3.9	0.4	1.9	-1.6
2	12.6	5.8	2.3	4.3	0.8	2.3	-1.2
3	9.9	3.1	-0.4	1.6	-1.9	-0.4	-3.9
4	10.1	3.3	-0.2	1.8	-1.7	-0.2	-3.7
5	8.3	1.5	-2.0	0.0	-3.5	-2.0	-5.5
6	8.6	1.8	-1.7	0.3	-3.2	-1.7	-5.2
7	9.8	3.0	-0.5	1.5	-2.0	-0.5	-4.0

SamTrans Island

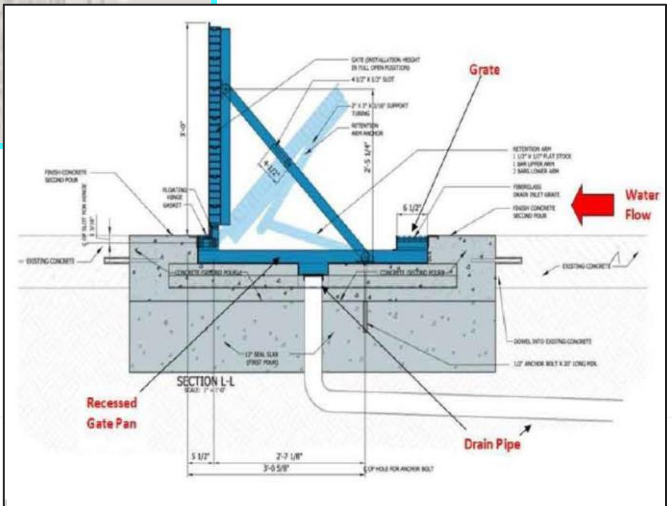
Lower elevation on access road bayward of SPP flood gate





Invert = 9.9 ft NAVD88

SLR, ft	MHHW freeboard, ft	1% SWL Freeboard, ft
0	3.1	-0.4
1.5	1.6	-1.9
3.5	-0.4	-3.9



CONCEPTUAL PASSIVE FLOOD GATE

Marine Emergency Response Facility

BCDC-3:What is the Marine Emergency Response facility in Reach 4 and is there an issue with it being inaccessible when the passive gate is up between it and the airport?

The MERF is an over-water facility to store marine rescue vehicles

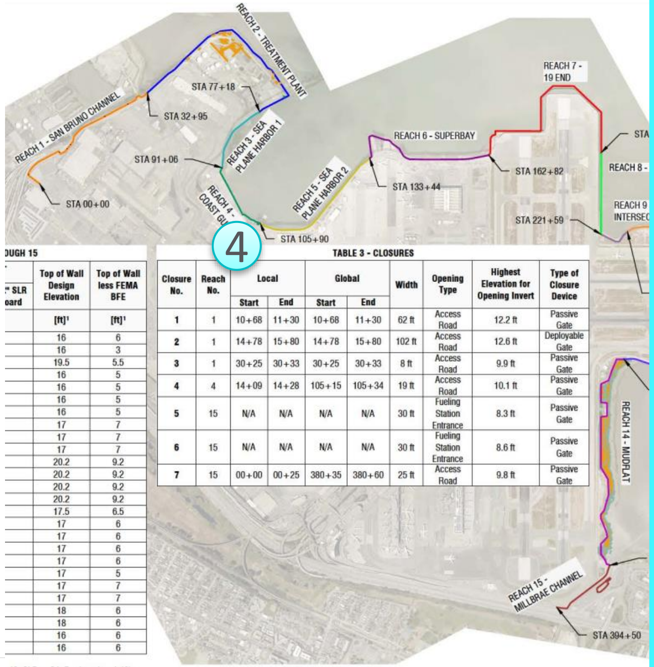
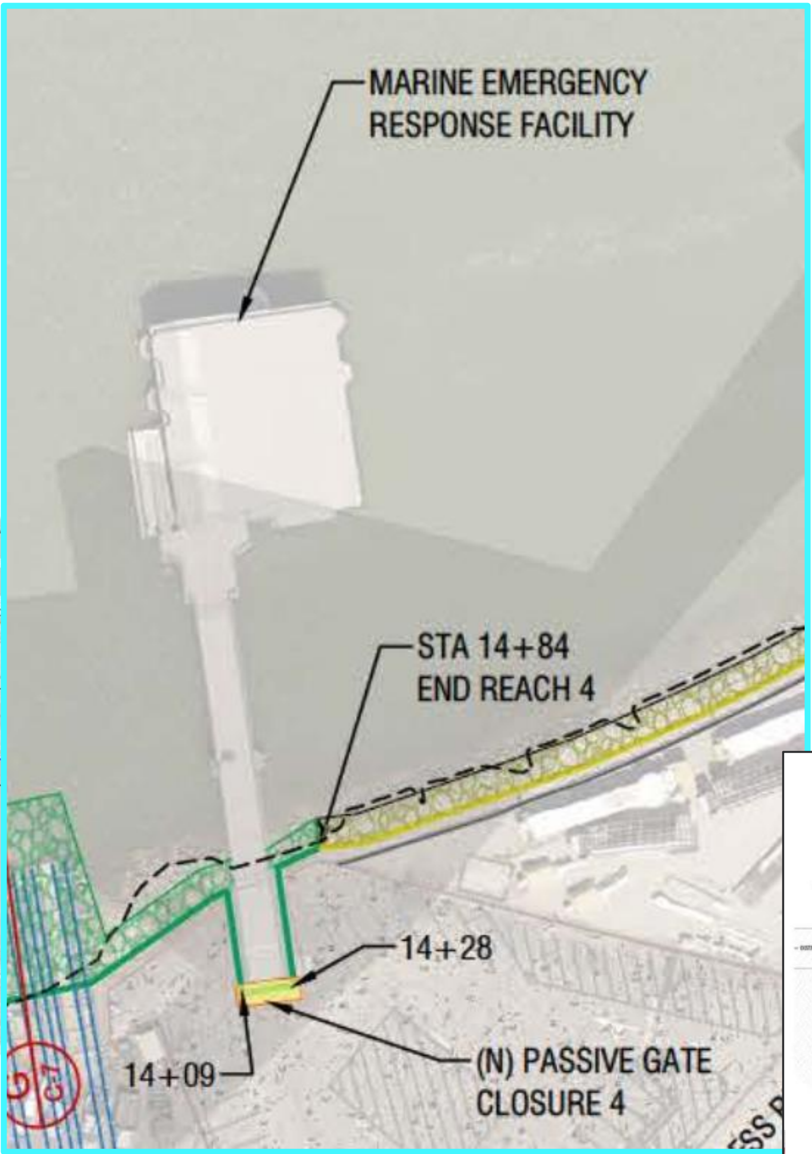


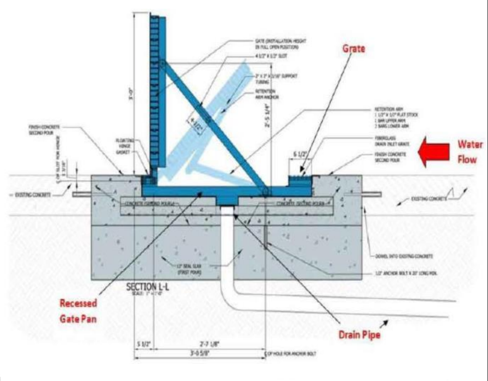
TABLE 3 - CLOSURES

Closure No.	Reach No.	Local Start	Local End	Global Start	Global End	Width	Opening Type	Highest Elevation for Opening Invert	Type of Closure Device
1	1	10+68	11+30	10+68	11+30	62 ft	Access Road	12.2 ft	Passive Gate
2	1	14+78	15+80	14+78	15+80	102 ft	Access Road	12.6 ft	Deployable Gate
3	1	30+25	30+33	30+25	30+33	8 ft	Access Road	9.9 ft	Passive Gate
4	4	14+09	14+28	105+15	105+34	19 ft	Access Road	10.1 ft	Passive Gate
5	15	N/A	N/A	N/A	N/A	30 ft	Fueling Station Entrance	8.3 ft	Passive Gate
6	15	N/A	N/A	N/A	N/A	30 ft	Fueling Station Entrance	8.6 ft	Passive Gate
7	15	00+00	00+25	380+35	380+60	25 ft	Access Road	9.8 ft	Passive Gate



Invert = 10.1 ft NAVD88

SLR, ft	MHHW freeboard, ft	1% SWL Freeboard, ft
0	3.3	-0.2
1.5	1.8	-1.7
3.5	-0.2	-3.7



CONCEPTUAL PASSIVE FLOOD GATE

SFO

Flood Gate Operations & Maintenance

Six passive gates – self-activating without need for power or human intervention

One deployable gate – modular panels, self-stabilized by weight of flood water, to be deployed by SFO staff

- All gates will be:
  - Managed by SFO Facilities - Paving and Ground group
  - Inspected annually, repaired as needed
  - Follow vendor maintenance procedures
  - Inspected and monitored for duration of an operational deployment
  - After deployment, cleaned and re-staged

ECRB Discussion

- Flood Response Operations

Groundwater and Sea Level Rise

***ECRB-8**: Do you expect the new sheet pile wall to raise groundwater levels onsite during storms, exacerbating flooding risk? Provide a quantitative study or rationale to justify your conclusion.*

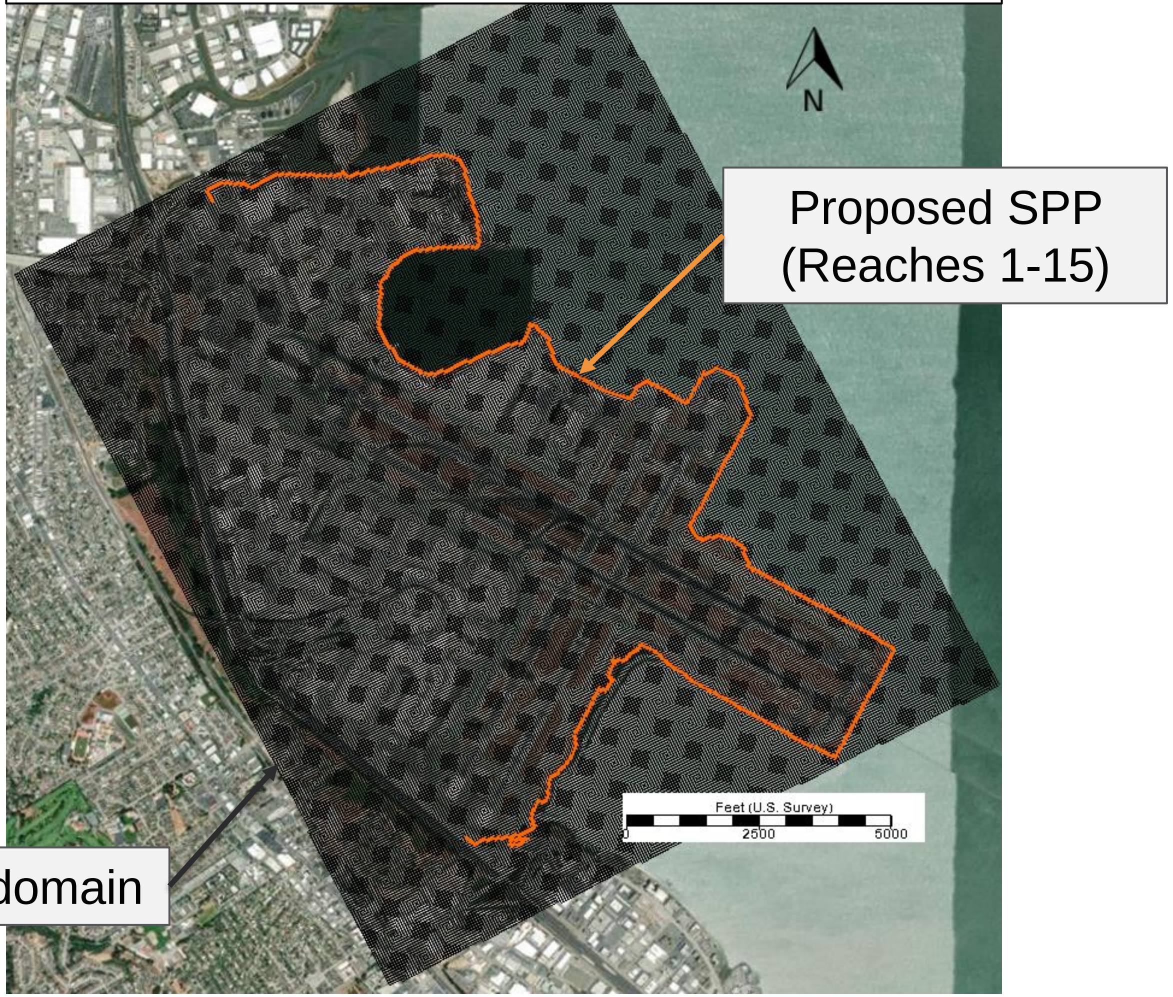
Groundwater Levels

Assessment

Geosyntec performed a quantitative assessment of potential changes in groundwater levels due to the SPP and sea-level rise (SLR) using a **screening-level groundwater model** for SFO and its immediate vicinity

- Simulate current groundwater conditions
- Evaluate potential influence on groundwater conditions of:
  - Projections of future SLR without SPP
  - Projections of future SLR with SPP

Model Domain, Grid and Proposed SPP



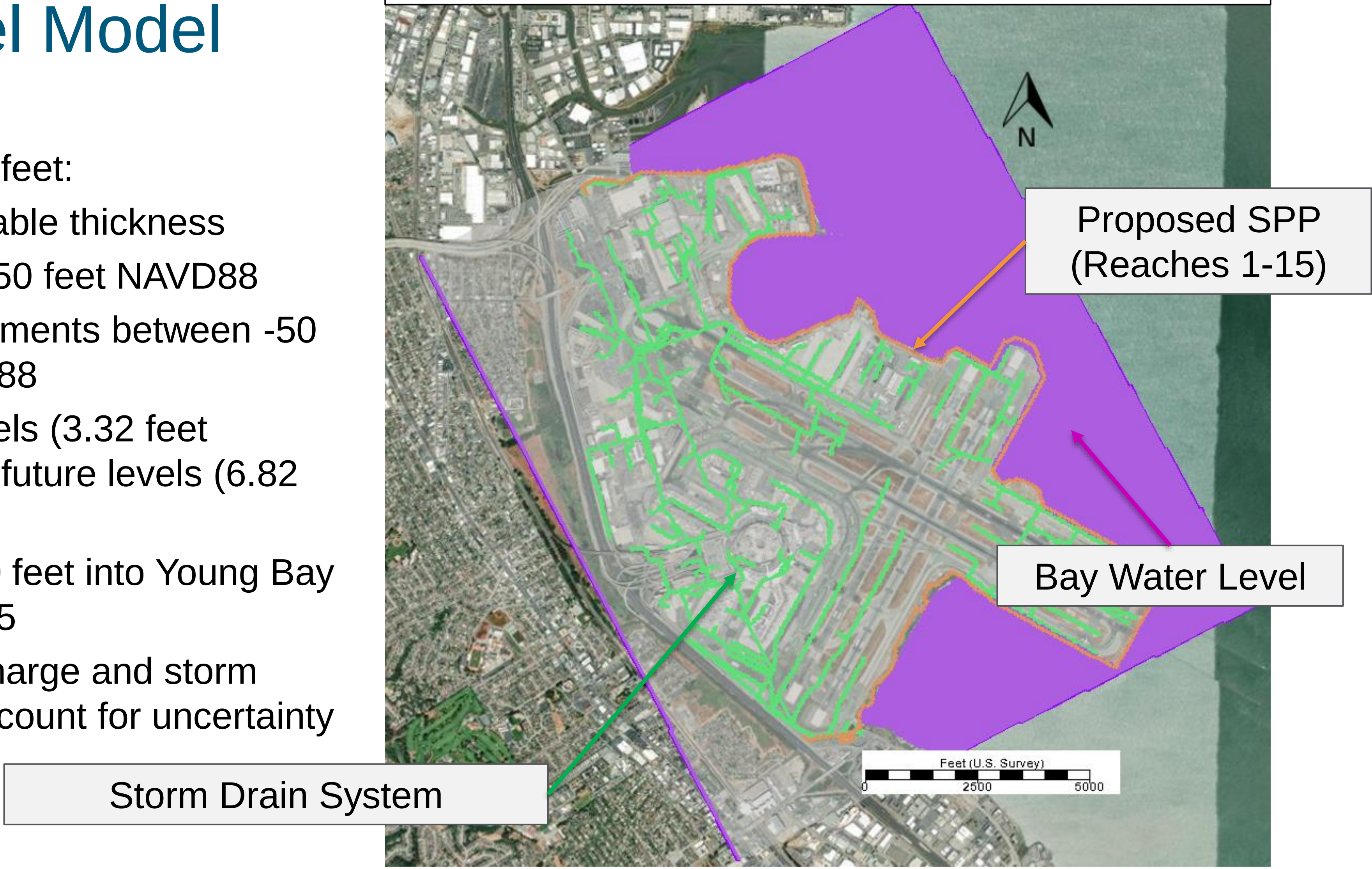
Attachment 5: "Screening-Level Evaluation of Groundwater Conditions with Sea Level Rise and Implementation of the Proposed Shoreline Protection Program at San Francisco International Airport." Technical Memorandum prepared by Geosyntec for SFO, dated August 5, 2024.

Screening-Level Model

Setup

- Represents upper ~120 feet:
  - Artificial fill with variable thickness
  - Young Bay Mud to -50 feet NAVD88
  - Upper-Layered Sediments between -50 and -100 feet NAVD88
- Bay at current water levels (3.32 feet NAVD88) and projected future levels (6.82 feet NAVD88)[1]
- Hydraulic flow barrier 10 feet into Young Bay Mud along Reaches 1-15
- Three pairs of areal recharge and storm drain conductance to account for uncertainty

Model Domain, Boundary Conditions and Proposed SPP

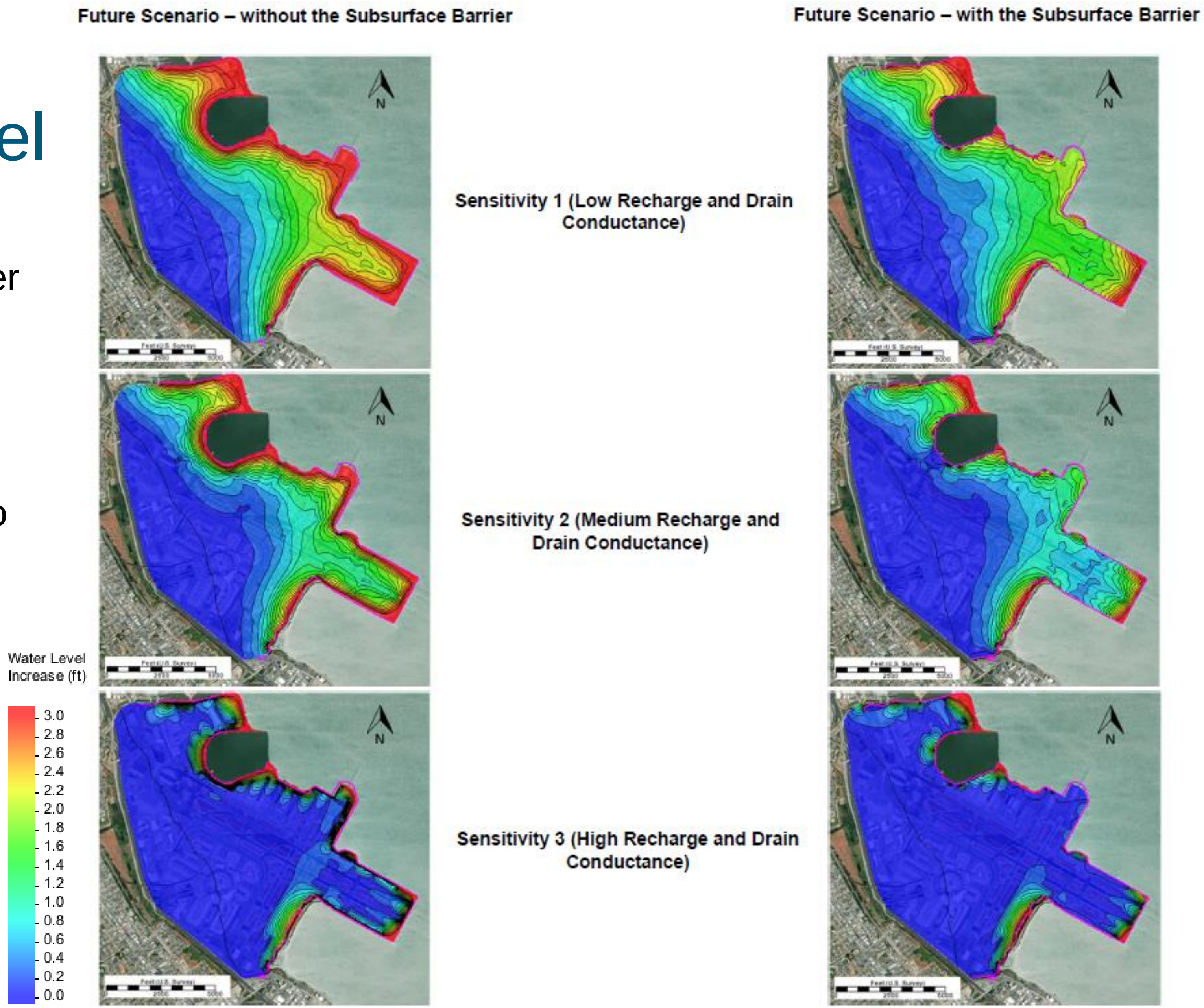


1. 3.5 feet of SLR assumed for modeling assessment

Screening-Level Model

Groundwater Level Increase

- Extent of the simulated groundwater level increase from the shoreline depends on the drain conductance (i.e., groundwater infiltration to storm drain system)
- The proposed SPP is anticipated to result in less increase to future groundwater levels at SFO as compared to future conditions with SLR but without the SPP subsurface barrier
- More than half of the western portion of SFO is not significantly influenced by SLR and the proposed SPP



Simulated Groundwater Level Increase as Compared to Current Conditions

This simplified screening-level model does not necessarily provide an accurate representation of current or future conditions and groundwater flows at SFO. The model is used to evaluate potential changes between current (baseline) and potential future conditions

Screening-Level Model

Groundwater Flows

- Simulated inflows into the drainage system, and from the Bay into the fill are lower with the proposed SPP as compared to future conditions with SLR but without the SPP subsurface barrier
- Simulated increases in groundwater infiltrating into the storm drainage system (less than 50 gpm) are negligible compared to storm drain system capacity

	Current Conditions		Future Conditions Without Proposed SPP		Future Conditions With Proposed SPP		Increase Compared to Current Conditions (GPM)	
	ft^3/d	GPM	ft^3/d	GPM	ft^3/d	GPM	Without Proposed SPP	With Proposed SPP
Infiltration to Storm Drain System								
Sensitivity 1 (Low Recharge and Drain Conductance)	13,000	68	18,000	94	17,000	88	26	20
Sensitivity 2 (Medium Recharge and Drain Conductance)	25,000	130	35,000	180	31,000	160	50	30
Sensitivity 3 (High Recharge and Drain Conductance)	88,000	460	120,000	620	90,000	470	160	10
Inflow from the Bay into the Fill along Shoreline								
Sensitivity 1 (Low Recharge and Drain Conductance)	-100	-1	5,000	26	3,000	16	27	17
Sensitivity 2 (Medium Recharge and Drain Conductance)	500	3	10,000	52	4,000	21	49	18
Sensitivity 3 (High Recharge and Drain Conductance)	8,000	42	39,000	200	7,000	36	158	-6

This simplified screening-level model does not necessarily provide an accurate representation of current or future conditions and groundwater flows at SFO. The model is used to evaluate potential changes between current (baseline) and potential future conditions

Groundwater Levels

Conclusions

- Proposed SPP would likely result in **less increase to future groundwater levels** as compared to without the SPP subsurface barrier limiting groundwater intrusion from the bay
- Increase in groundwater levels over more than half of the western portion of the Airport are anticipated to be **less than a foot**
- Influence of SLR on groundwater is **limited westward (landward)** due to attenuation with distance from the Bay and the existing storm drainage system
- Estimated groundwater infiltration increase (< 50 gpm) is **negligible compared to storm drain system capacity** of 480,000 gpm
- Recommendation to **monitor** to refine understanding and detect changes that warrant adaptive measures

ECRB Discussion

- Groundwater and Sea Level Rise

Subsidence

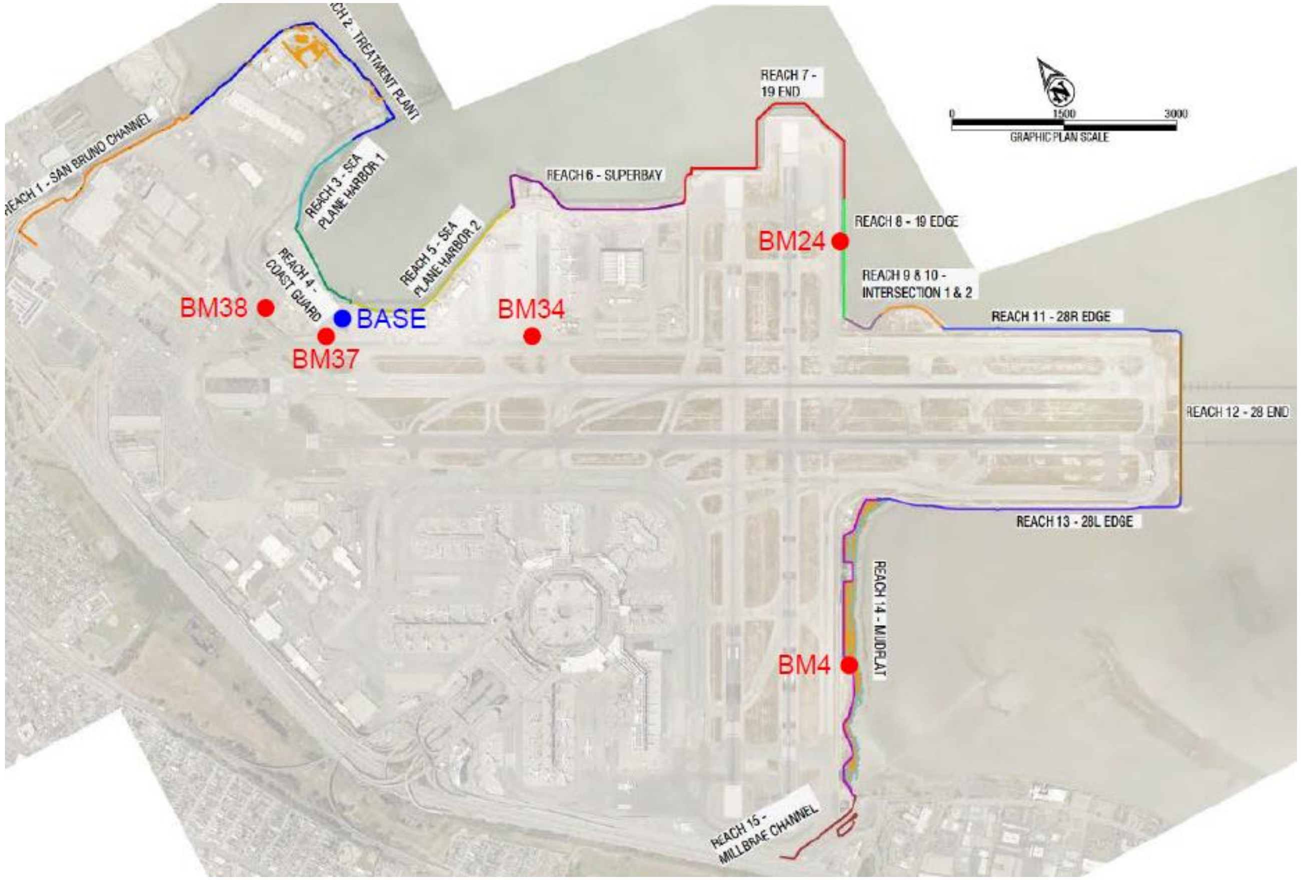
ECRB-9: *Discuss the expected amount of land subsidence that could cause the proposed wall to sink over the life of the project.*

Subsidence

Assessment

Geosyntec performed an assessment of recent and future settlement at SFO in the vicinity of the SPP using:

- Global Navigation Satellite System (GNSS) elevation data collected weekly at the SFO base station between 2011 and 2022.
- Annual survey data in 2012 and 2015 for numerous benchmarks around SFO. A 2018 data set was reviewed with noted inconsistencies, and therefore not used.
- Towill (2024) ground validation survey at 151 points around SFO in December 2023, for comparison with USGS 2010 and 2017 LiDAR elevations. LiDAR data was not sufficiently accurate for the purposes of the settlement assessment.



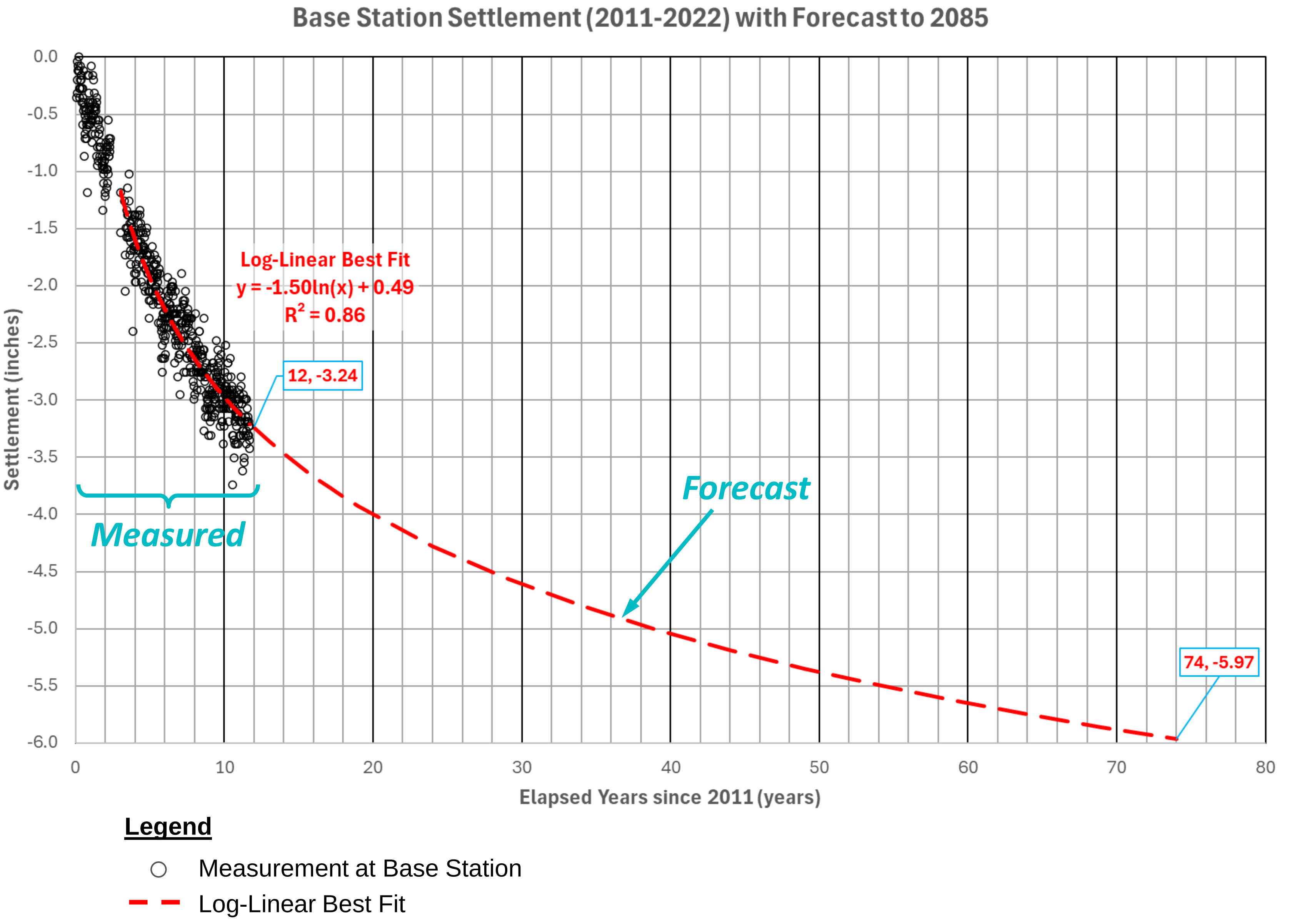
Base Station [GNSS Data]
Benchmarks [2012, 2015, and Towill (2024) Data]

Attachment 6. "SFO Shoreline Protection Program, Subsidence Assessment." Technical Memorandum prepared by Geosyntec for SFO, dated July 31, 2024.

Subsidence

Base Station Results

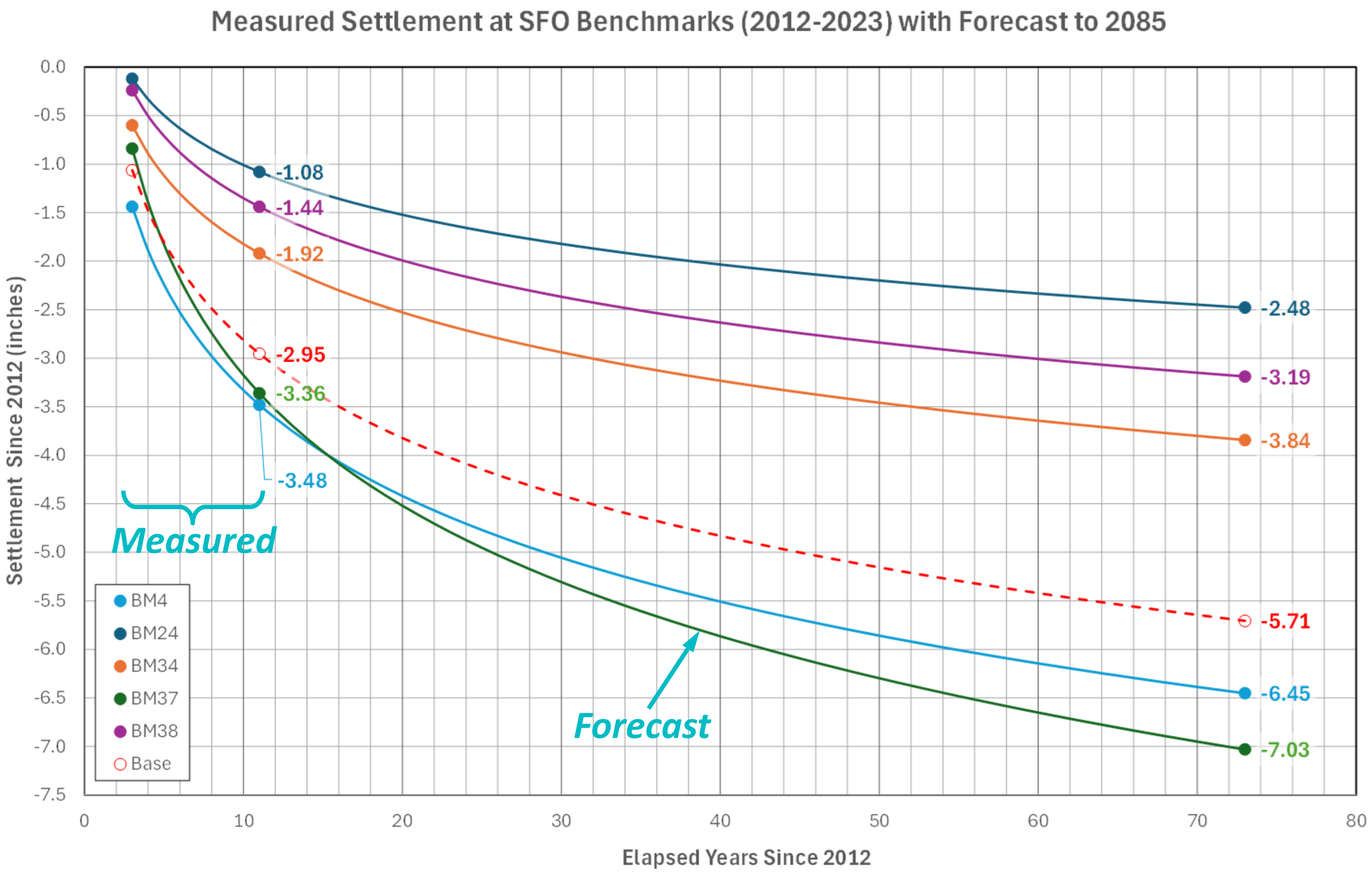
- ~3.5 in of settlement at the base station since 2011.
- Settlement between 2014 and 2022 (yrs 3 to 11) occurred at a rate of ~0.22 in/yr.
- Forecast is ~2.7 in over the next 60 years (to 2085).



Subsidence

Benchmark Results

- Settlement ranged from 1 in (BM24) to 3.5 in (BM4) between 2012 and 2023.
- Settlement rate between 2015 and 2023 ranged from 0.12 in/yr (BM24) to 0.32 in/yr (BM37), with a mean of 0.21 in/yr.
- Forecast is 1.4 in (BM24) to 3.7 in (BM37) over the next 60 years (to 2085).



		Relative Change (Settlement) from 2012 (in)					
Year	**Elapsed**	**BM4**	**BM24**	**BM34**	**BM37**	**BM38**	**Base**
2012	0	0.00	0.00	0.00	0.00	0.00	0.00
2015	3	-1.44	-0.12	-0.60	-0.84	-0.24	-1.06
2023	11	-3.48	-1.08	-1.92	-3.36	-1.44	-2.95
2085	73	-6.45	-2.48	-3.84	-7.03	-3.19	-5.71
2023 to 2085		2.97	1.40	1.92	3.67	1.75	2.75

Subsidence

Validation by Comparison of $C_{\varepsilon\alpha}$ Values

- Calculated $C_{\varepsilon\alpha}$ using equation for secondary compression settlement (S) since the end of primary compression:

$$S = H \cdot \underbrace{\frac{C_\alpha}{1 + e_0}}_{C_{\varepsilon\alpha}} \cdot \log \frac{t}{t_p}$$

  - using settlement survey data (**Table 2**)
  - using reported laboratory values (**Table 3**)

- The $C_{\varepsilon\alpha}$ values from the survey data range from 0.004 to 0.011, with a mean of 0.007.
- The $C_{\varepsilon\alpha}$ values from the lab data range from 0.004 to 0.012, with a best estimate of 0.008.

Table 2: Evaluation of $C_{\varepsilon\alpha}$ from Settlement at Benchmarks

	Settlement and Strain from 2015 to 2023					
	BM4	BM24	BM34	BM37	BM38	Base
Settlement (ft)	0.17	0.08	0.11	0.21	0.10	0.16
~YBM Thickness (ft)	50	40	55	35	20	35
Strain	0.34%	0.20%	0.20%	0.60%	0.50%	0.45%
Strain / log (11/3)	0.006	0.004	0.004	0.011	0.009	0.008

	Range		Mean
Strain	0.20%	0.60%	0.38%
$C_{\varepsilon\alpha}$	0.004	0.011	0.007

Table 3: Evaluation of $C_{\varepsilon\alpha}$ from ADEC (2000) Reported Geotechnical Testing

$C_{\varepsilon\alpha}$ Calculation Based on Cα and e			
C_α	Void Ratio		
	1.1	1.5	1.8
0.01	0.005	0.004	0.004
0.02	0.010	0.008	0.007
0.03	0.014	0.012	0.011

Subsidence

Conclusions

- Geosyntec confirmed the results of the subsidence assessment are consistent with basic soil mechanics principles using results from previously reported geotechnical laboratory tests.
- While recent rates of settlement ranged from **0.12 to 0.32 in/yr (mean of 0.21 in/yr)**, these **rates are anticipated to reduce over the long term** as secondary compression of YBM follows an exponential decay path.
- Forecasts of settlement based on projection of the existing survey data indicate that, in the absence of additional filling or other site modifications that would change the stress levels in the YBM, an **additional 1.5 to 4 inches of settlement can be expected in the vicinity of the SPP through 2085**.
- Implications of this settlement should be considered by the design team, along with any additional settlement that may be caused by changes in stress levels within the YBM as a result of the SPP or other construction in the vicinity of the SPP.

ECRB Discussion

- Subsidence

Strong Motion Instrumentation Plan

Strong Motion Instrumentation

***ECRB-12**: After checking in with Hamid Haddadi, the Program Manager of the California Strong Motion Instrumentation Program (CSMIP), provide a draft Seismic Instrumentation Plan with recommended locations for strong motion seismographs to be incorporated into the state's seismic instrumentation network.*

May 13, 2024 Meeting with

California Geological Survey (CGS):

- Members of the project design team (SFO, Geosyntec, COWI) met with Hamid Haddadi, the CGS CSMIP Program Manager, and two CGS technical leads.
- The project design team gave a brief description of the SFO SPP.
- CGS summarized the instrumentation requirement and process and provided BCDC's written steps for required instrumentation projects (shown at right).
- **Takeaway**: The instrumentation planning process is a collaborative effort between the design team, the BCDC, CGS, and the CGS Strong Motion Instrumentation Advisory Council (SMIAC).

Steps for SF BCDC required instrumentation projects:

- The Engineering Criteria Review Board (ECRB) of the SF BCDC requires instrumentation of a project as a condition of project approval.
- CSMIP is informed of the instrumentation requirement by ECRB/BCDC and project design team.
- CSMIP receives design drawings and other project information from design team.
- CSMIP presents project as a candidate for instrumentation to SMIAC subcommittee and receives recommendation.
- CSMIP coordinates with ECRB/BCDC, SMIAC subcommittee members, and design team to develop sensor layout for project.
- CSMIP prepares TSL for project and provides document to design team.
- Design team prepares instrumentation plans incorporating TSL information and provides CSMIP with copy of plans for review and approval.
- CSMIP conducts site visit to mark sensor locations when project construction has reached appropriate point.
- CSMIP conducts buy-off of instrumentation after installation is completed.
- CSMIP sends acceptance letter upon completion of instrumentation project.

Strong Motion Instrumentation

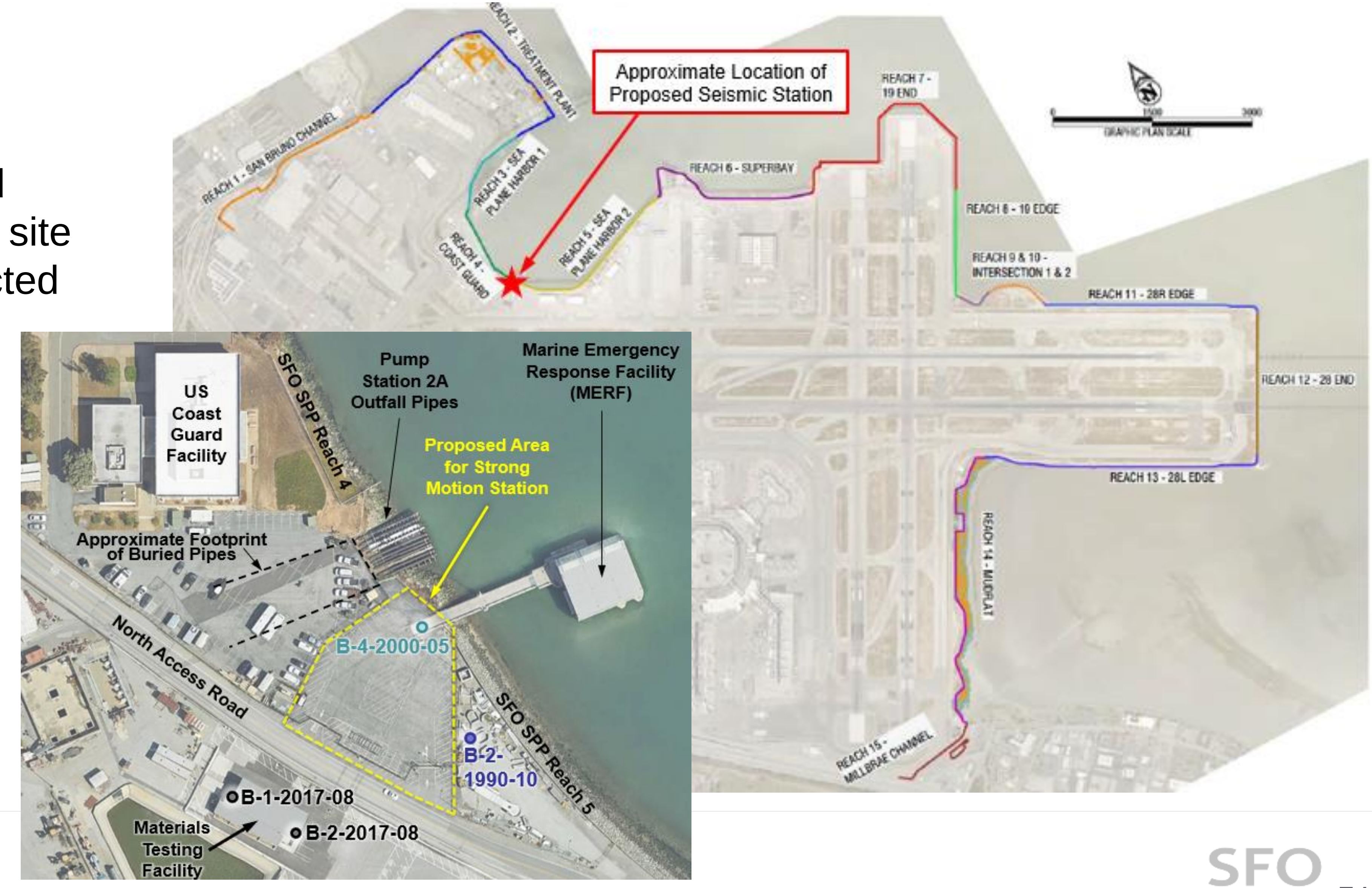
Following the May 13, 2024 Meeting with CGS

- SFO provided CGS with pertinent SPP design drawings and documents in support of their review process.
- In response to ECRB-12, Geosyntec prepared a memorandum with recommendations for a strong motion instrumentation plan, including:
  - **Station Location**
  - Foundation Layout
  - Enclosure Layout
  - Equipment
  - Power Supply
  - Communication
  - Site Access Information
  - SFO Point of Contact
- Recommendations were developed to meet the instrumentation requirement for the SFO SPP with consideration of the BCDC instrumentation process, state instrumentation specifications, and guidelines presented in COSMOS (2001).

Strong Motion Instrumentation

Station Location Selection Criteria

- Airport runway and operations activity, site access, and restricted entry points.
- Distance from existing buildings and infrastructure.
- Subsurface geologic information.



Strong Motion Instrumentation

Next Steps and Path Forward

- CGS recently presented candidate locations via email to SFO and requested review, feedback, and preferences regarding the proposed locations.
- The design team will meet with CGS to discuss the candidate locations and other elements of the strong motion instrumentation plan.
- The design team will continue collaboration with BCDC, CGS, and their SMIAC subcommittee to develop the Strong Motion Instrumentation Plan as part of the SFO SPP.

ECRB Discussion

- Strong Motion Implementation Plan

Questions?

David Kim
Senior Environmental Planner
david.t.kim@flysfo.com
650.821.1426

Audrey Park
Environmental Affairs Manager
audrey.park@flysfo.com
650.821.7844