Adapting to Rising Tides Bay Area—Dumbarton Bridge Focus Area Study

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Acknowledgments

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Date:	January 19, 2018		

Summary of Findings

A focus area study was conducted for the Dumbarton Bridge touchdown in Menlo Park to develop a refined sea level rise (SLR) exposure analysis and develop conceptual level strategies to address near-term flood vulnerabilities. The study builds upon recently completed SLR inundation mapping work supported by the Metropolitan Transportation Commission/Bay Area Toll Authority and San Francisco Bay Conservation and Development Commission.

The focus area study developed updated SLR inundation maps accounting for a recently constructed flood barrier along the north side of State Route 84 (SR 84). Evaluation of flood pathways identified a number of low spots along the shoreline that could lead to flooding under a MHHW[1] + 24" SLR scenario. These shoreline segments could be improved to less the frequency and magnitude of flooding of the state route, access roads, and other key assets in the focus area. In addition to the transportation assets, the focus area includes a PG&E substation, the City of Menlo Park fire department training center, two pump stations, and Facebook HQ.

Four concept level flood protection strategies were identified along the shoreline and existing levee system that could address near-term flood vulnerabilities and build a foundation for longer-term improvements. Implementation of the near-term strategies would likely provide approximately 25- to 50-year flood protection for all assets within the focus area at a cost of $6.5 to $19.3M, depending on the extent and type of improvements.

The study also identified opportunities to coordinate with long-term flood protection and restoration projections such as the South Bay Salt Pond Restoration Project and SAFER Bay levee feasibility study. Implementation of the proposed near-term strategies could be phased in such a way to support these longer term flood protection and habitat restoration goals within the Dumbarton Bridge focus area.

[1] Mean Higher High Water (MHHW) is a tidal datum that represents the typical daily high tide.

1. Introduction

The Metropolitan Transportation Commission (MTC) / Bay Area Toll Authority (BATA) and San Francisco Bay Conservation and Development Commission (BCDC) recently completed the Adapting to Rising Tides (ART) Bay Area Sea Level Rise Analysis and Mapping Project (Mapping Project), which produced consistent inundation data and mapping products for all nine San Francisco Bay Area counties. The results of those analyses showed that as sea levels rise, the San Francisco Bay shoreline and communities will become increasingly exposed to tide levels currently considered extreme, and over time existing shoreline protection infrastructure will no longer provide the same level of flood protection that it does today. Such shifts in the frequency of extreme tide levels will have important design implications for flood protection infrastructure, habitats, and community resilience.

As an extension of the ART Mapping Project, a focus area study was conducted at the Dumbarton Bridge touchdown area in San Mateo County, as it was identified as a vulnerable area in the ART Mapping Project. Caltrans recently constructed a temporary barrier along the north access road as a part of a seismic retrofit project for the bridge. This barrier was not captured in the topographic digital elevation model (DEM) used in the San Mateo County ART SLR inundation mapping because it was constructed after the LiDAR collection, so its effect on local inundation and flood pathways was not represented in the existing inundation maps.

The purpose of this focus area study is to incorporate the flood barrier into the San Mateo County ART SLR inundation mapping, refine the SLR exposure assessment in this area, and identify potential physical strategies to protect the Dumbarton Bridge approach and surrounding area from flooding and SLR.

2. Background

2.1. Project Area

The Dumbarton Bridge touchdown area is located along the Bay shoreline in southern San Mateo County in Menlo Park. The bridge touchdown connects to SR 84 approximately 750 ft from the edge of shore at 14 ft NAVD88 and the roadway elevation gradually decreases to 10 to 12 ft NAVD88. An access road lines both sides of the highway, starting on the south side and wrapping under the bridge to continue along the north edge of the roadway and reconnect at the PG&E substation. This road is intended to provide a turnaround point for drivers, access for repairs and maintenance, and parking for recreational users.

Ravenswood Ponds R1 and R2 lie on the north side of the highway. The north-south Ravenswood levee (N-S levee), which separates Pond R1 from Mosley Tract, and the east-west Ravenswood levee (E-W levee), which separates Pond R1 and R2, function as flood control barriers for SR 84, the north access road and other infrastructure assets in the area. The newly restored Pond SF2 lies on the south side of the highway. The SF2 levee is intended to provide a flood barrier for the ponds, south access road and SR 84. The ponds are managed by a tide gate which mutes the tidal elevations in the ponds creating consistent water levels for shore bird habitat. The SF2 levee connects to the south access road berm at the base of the bridge, and ties into an older levee system south of the SF2 tide gate. A layout of the area is shown in Figure 1 below.

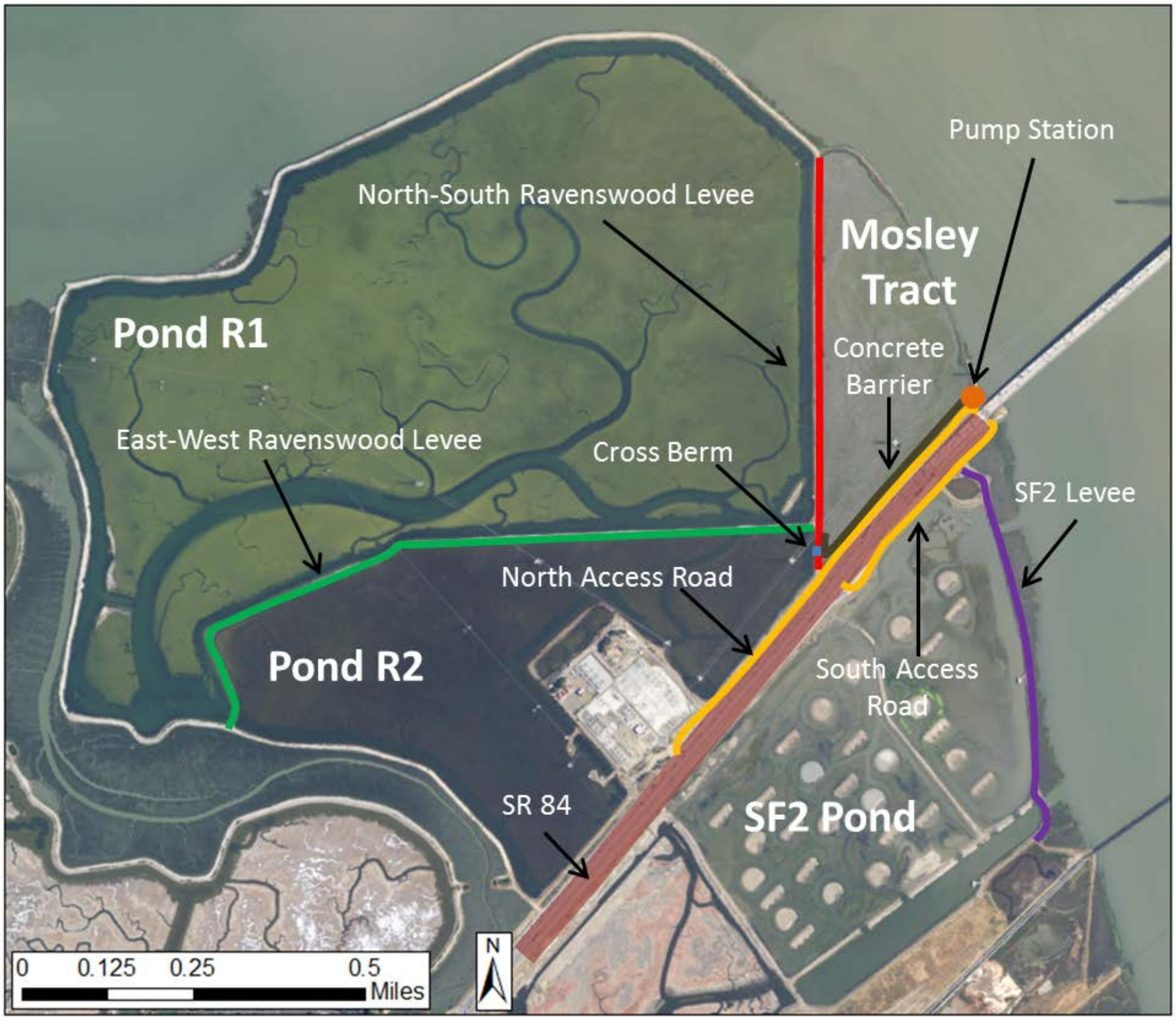

Figure 1. Focus study area showing ponds, levees, and recent temporary flood construction

Caltrans constructed a temporary barrier along the northern access road as part of the Dumbarton Bridge Seismic Retrofit Project in 2010. The barrier is composed of a sheet pile wall backed by a concrete buttress, as shown in Figure 2. It was intended to reduce high-tide flooding and keep the road open during the seismic retrofit project, as well as provide ad-hoc flood protection for the north access road and SR 84. The project report indicated that the barrier is a temporary structure, installed to ensure access during the seismic retrofit project; however, the report did not indicate what plans exist to either maintain or remove the structure in the future. As part of the same retrofit project, underground drainage, pipes, and a pump station was installed to collect runoff from the road and pump it into the Bay.

Figure 2. Sheet pile wall and concrete barrier on edge of north access road. Image is looking east, towards Dumbarton Bridge and the Bay.

2.2. Existing Inundation Mapping

Inundation maps were recently produced for San Mateo County (SMC) as part of the SMC ART Mapping Project. These county maps were then incorporated into the Bay-wide ART Mapping Project. The data sources and mapping methodology used to create the maps are presented in the ART report (AECOM 2017). The methodology is GIS-based and does not take into account the associated physics of overland flow, dissipation, levee overtopping, storm duration, or potential shoreline or levee erosion associated with extreme water levels and waves. To account for these processes, a more sophisticated modeling effort would be required. However, given the uncertainties associated with SLR and future land use changes, development, and geomorphic changes that will occur over the next 100 years, a more sophisticated modeling effort may not necessarily provide more accurate results.

The ART Mapping Project mapped 10 possible scenarios that represent combinations of 0 to 66 inches of SLR with extreme tides from the 1-year to the 100-year return period. Table 1 below presents the daily and extreme tide levels above MHHW for San Mateo County, and the associated SLR and extreme tide combinations corresponding to each mapping scenario.

The maps were used to evaluate potential inundation pathways by identifying the connection between the Bay and areas of inland flooding. For each scenario, the inland inundation was traced back to the Bay by following the mapped extent of inundation. The inundation pathways were identified through visual inspection and interpretation of the data and professional judgment. Based on the inundation mapping, the north access road is impacted by flooding in the MHHW + 12’’ scenario. Under the MHHW + 24” scenario, inundation expands to include the adjacent bike path and a one mile section of the eastbound SR 84 lane. Other public and private assets within the area also become exposed to flooding in later scenarios.

While the SF2 levee provides protection up to the MHHW + 48’’, low spots exist along the south access road berm and the older levee south of the SF2 outlet structure, which provide pathways for inundation before the MHHW + 48’’ scenario. The south access road berm overtops in the MHHW + 24’’ scenario, which allows water to travel onto the south access road and flow west to flood the bike path along SR 84, and parts of University Ave, as shown in Figure 3. Photos provided by Len Materman (San Francisquito Creek Joint Power Authority) show flooding of this area by king tides and confirm this vulnerability. Mapbooks showing the inundated areas are provided as part of the ART Mapping Project report.

Table 1. San Mateo Sea Level Rise and Extreme Tide Matrix

Sea Level Rise Scenario	Daily Tide	Extreme Tide (Storm Surge)						
	+SLR (in)	1yr	2yr	5yr	10yr	25yr	50yr	100yr
	Water Level above MHHW (in)							
Existing Conditions	0	15	19	24	27	32	37	42
MHHW + 6”	6	21	25	30	33	38	43	48
MHHW + 12”	12	27	31	36	39	44	49	54
MHHW + 18”	18	33	37	42	45	50	55	60
MHHW + 24”	24	39	43	48	51	56	61	66
MHHW + 30”	30	45	49	54	57	62	67	72
MHHW + 36”	36	51	55	60	63	68	73	78
MHHW + 42”	42	57	61	66	69	74	79	84
MHHW + 48”	48	63	67	72	75	80	85	90
MHHW + 52”	52	67	71	76	79	84	89	94
MHHW + 54”	54	69	73	78	81	86	91	96
MHHW + 60”	60	75	79	84	87	92	97	102
MHHW + 66”	66	81	85	90	93	98	103	108

in = inch(es)
MHHW = Mean Higher High Water
SLR = sea level rise
yr = year(s)

Figure 3. Inundation of area south of SR 84 in MHHW + 24'' scenario. Arrows indicate the inundation pathway.

3. Updated Inundation Mapping

3.1. DEM Updates

The temporary flood barrier (also referred to as concrete barrier) and pump station constructed by Caltrans were constructed after the LiDAR collection and were not included in the topographic DEM used in the ART Mapping Project. As part of this focus area study, AECOM obtained the elevations of the retrofits from Caltrans and inserted them into the project DEM. Design drawings of the seismic retrofit work improvements were reviewed that report the elevation of the concrete barrier and pump station pad as 11.2 and 9.5 ft NAVD88, respectively. AECOM staff visited the site in August 2017 to confirm the height and alignment of the barrier and identify flood pathways in the field. The field visit identified an earth cross-berm constructed across the N-S levee at the end of the concrete barrier. The height of the berm was measured as being 18'' below the top of the concrete barrier as shown in Figure 4. This estimated elevation was also included in the updated DEM; however, visual inspection of the berm indicates that it is not uniform in elevation and may be lower at the west end where it ties into the adjacent pond berm. Figure 5 below shows the three updates to the DEM.

Figure 4. Cross berm along crest of N-S levee and concrete barrier. Photo is looking north.

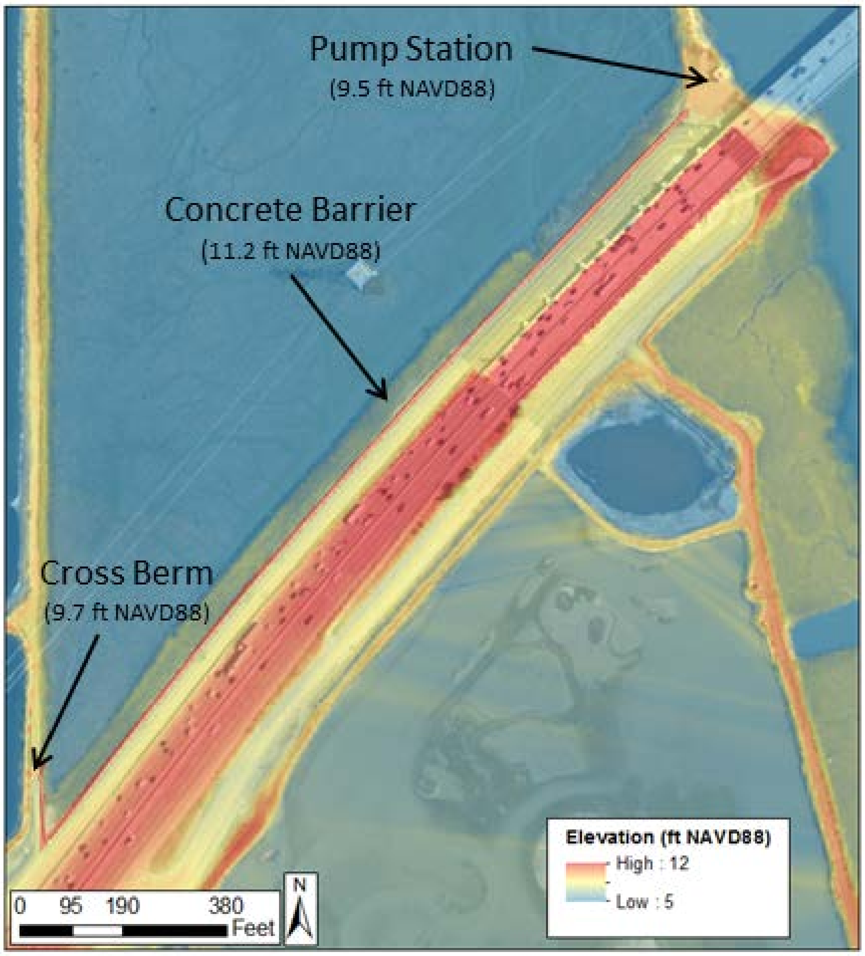

Figure 5. Updates to site DEM due to construction of recent retrofit project

3.2. Flooding Pathways

The mapping scenarios presented in Table 1 were remapped using the updated DEM to evaluate the effect of the flood barrier on the projected inundation. The updated inundation maps indicate that construction of the barrier does prevent flooding of the north access road for low SLR scenarios. Without the barrier, the maps indicated that the road would partially inundate in the MHHW + 12’’ scenario. The updated mapping shows that the barrier effectively prevents water from crossing over and flooding the road under this scenario.

In the MHHW + 24’’ scenario, the effect of the barrier is negligible because water travels around the barrier through low spots on the N-S Ravenswood levee to flood the same areas as before the construction of the barrier, as shown in Figure 6. The sheet pile/concrete barrier eventually overtops in the MHHW + 48” scenario.

Figure 6. Effect of the sheet pile/concrete barrier and cross berm on inundation pathways in the MHHW + 12'' and 24'' scenarios.

Apart from the differences described above, the mapping before and after the inclusion of the sheet pile/concrete barrier does not result in substantial differences to the inundation patterns. Inundation of the area south of SR 84 is not affected by the addition of the flood barrier and the barrier does not prevent flooding of the south access road. The inundation of the area south of SR 84 remains the same as prior to the construction of the barrier and is described in Section 2.2 above.

4. Vulnerability Assessment

4.1. Water Levels

Tidal datums and extreme water levels at the Dumbarton Bridge focus area are shown in Table 2.

Table 2. Tidal Datums and Extreme Tide Levels at Dumbarton Bridge

Water Level	Elevation (ft NAVD88)
MHHW	7.27
1-yr	8.55
2-yr	8.92
5-yr	9.27
10-yr	9.56
25-yr	10.01
50-yr	10.42
100-yr	10.90

Source: AECOM (2016)

4.2. Asset inventory

Key assets in the focus area were identified from aerial imagery and site familiarity. The assets were separated into three categories: flood protection assets, transportation assets, and infrastructure assets. The asset list and elevation ranges are presented in Table 3. The elevation range was extracted from the DEM. Figure 7 shows the location of the infrastructure assets; flood protection and transportation assets are shown in Figure 2.

Table 3. Dumbarton Bridge Focus Area Key Assets and Typical Elevations

Asset	Typical Elevation (ft NAVD88)
Flood Protection Assets	
Temporary concrete barrier	11.2
Ravenswood pond levee (North-South)	8.6 to 10.0
Ravenswood pond levee (East-West)	7.6 to 10.0
Pond SF2 Levee	10.5 to 11.0
Cross-berm	9.2
Facebook Headquarters Levee	12.5 to 14.0
Transportation Assets	
Access road	7.6 to 9.0
SR 84	9.5 to 13.0
University Avenue	9.5 to 10.5
Infrastructure Assets	
PG&E substation	8.0 to 10.5
Menlo Park fire protection training center	11.0 to 12.0
East Pump Station pad	9.5
West Pump Station pad (Ravenswood Pumping Station)	9.0 to 10.0
Facebook Headquarters	7.0 to 13.0

Figure 7. Dumbarton Bridge Focus Area Infrastructure Asset Locations

Asset elevations were compared to extreme tides and SLR to show the timing of potential impact, as shown in Figure 8. This figure shows that with each increment of SLR, assets become exposed at lower storm return periods. For example, the temporary concrete barrier is at an elevation greater than the 100-yr storm today, but with 24’’ of SLR, it can be overtopped during a 10-yr event. Note that while some assets may be at an elevation below a given Bay flood level, they may be protected by other flood protection features, such as flood walls or levees. For example, Figure 8 shows that the north access road would be inundated by a 1-yr tide; however, because the road is protected by the concrete barrier and the N-S levee, it does not flood until the levee is overtopped, as shown in Figure 6. This figure can be used in conjunction with the inundation maps to estimate the timing of exposure for various assets.

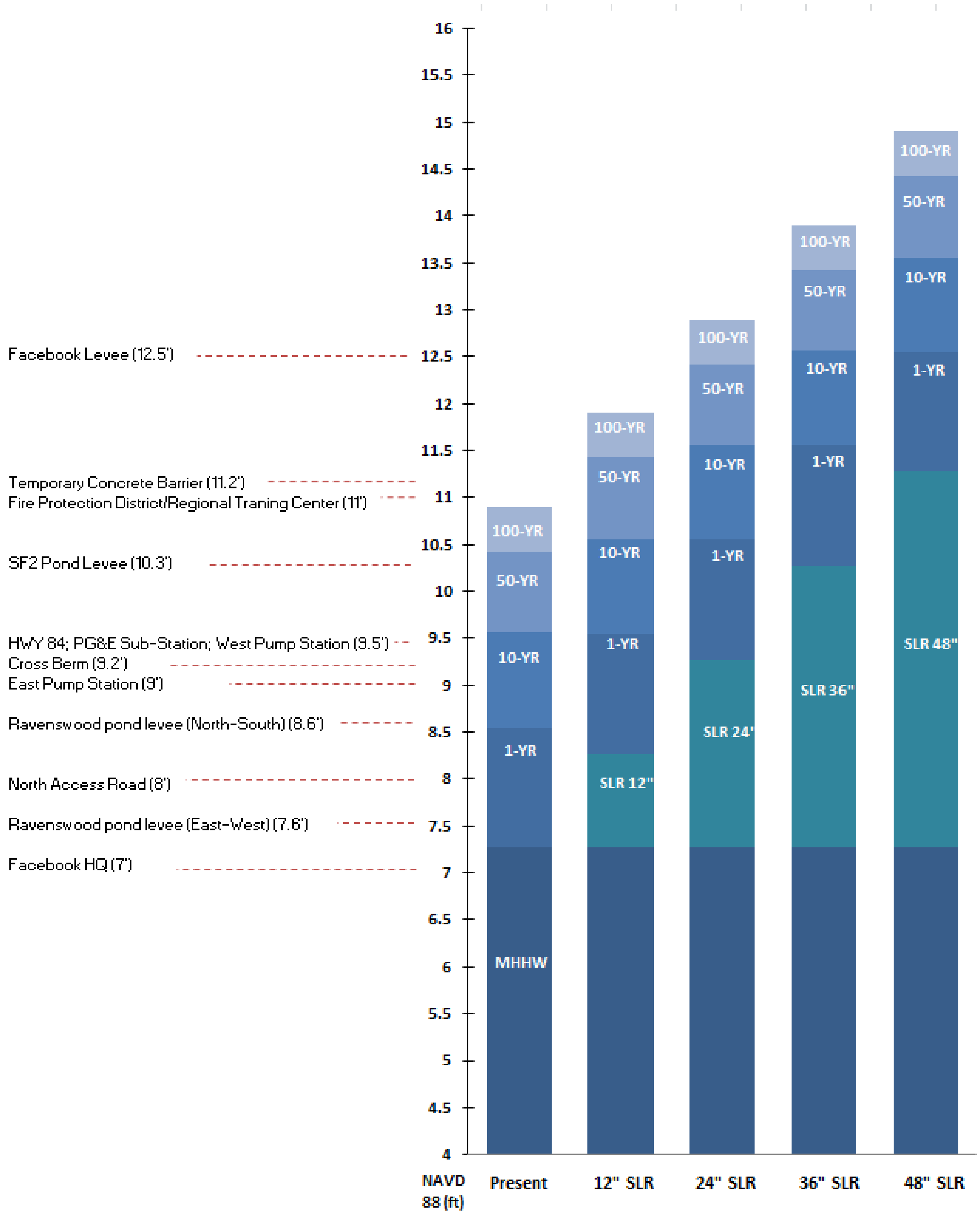

Figure 8. Typical asset elevations shown relative to existing Bay water levels and SLR. This figure is based only on elevation and does not take into account the effect of flood protection barriers.

4.3. Vulnerability Assessment

A high level exposure analysis was conducted to estimate the timing and source of inundation for key assets in the focus area. The analysis identifies the point at which assets are exposed to inundation and the source, or pathway that causes the inundation. A distinction is made between flood protection assets and the remainder of the assets. This is done to emphasize the cause and effect of flooding. For example, the cause of flooding could be due to overtopping of a levee (flood protection asset) and the effect would be the inundation of an infrastructure asset. The results of the analysis are presented in tables in Appendix A. Table A1 lists the flood protection assets and describes the effect of overtopping. Table A2 lists the transportation and infrastructure assets and describes the source of flooding. Sensitivity and adaptive capacity considerations are also documented to provide a high-level overview of the sensitivity and adaptive capacity (including redundancy) of key assets. The results of this analysis are presented in Table A3. The vulnerability assessment findings can be used to help prioritize and phase flood mitigation strategies within the focus area.

5. Conceptual Flood Protection Strategies

In this section, near-term flood protection strategies to alleviate temporary flooding in the focus area are presented. This focus area study evaluated near-term flood protection solutions because long-term solutions are already being considered through existing flood protection and restoration efforts from local and state agencies. Near-term strategies differ from long-term strategies because they generally only consider temporary flooding instead of permanent inundation as a result of SLR (or they consider small amounts of SLR). Temporary flooding occurs when an area is exposed to episodic, short-duration, extreme tide and storm surge events of greater magnitude than normal tide levels (such as during storm surge or El Niño events). Long-term strategies are intended to protect from permanent inundation and typically will consider 2-3 ft of SLR (or more) in combination with the 100-year storm event. Some long-term strategies have already been developed in prior feasibility studies such as SAFER Bay and the South Bay Salt Pond Restoration Projects.

The sections below summarize existing long-term planning efforts and present initial concept level flood protection strategies to address near-term flood vulnerabilities on the north and south sides of SR 84.

5.1. Existing Long-term Plans

There are ongoing efforts through a number of agencies to develop long-term strategies to protect and enhance this part of the Bay shoreline. Two of these efforts, the South Bay Salt Pond Restoration Project and SAFER Bay Project are highlighted below.

5.1.1. South Bay Salt Pond Restoration Project

The South Bay Salt Pond (SBSP) Restoration Project is a tidal wetland restoration project currently underway in South San Francisco Bay. When complete, the restoration will convert 15,100 acres of commercial salt ponds at the south end of San Francisco Bay to a mix of tidal marsh, mudflat, and other wetland habitats. The goal of the project is to restore and enhance the wetlands in the South San Francisco

Bay while providing for flood management and wildlife-oriented public access and recreation. SBSP aims to provide at least the same amount of flood protection currently provided by the existing levee system.

Long-range plans for the project include the conversion of the Ravenswood Ponds Complex into tidal marsh. The design for the restoration of Ponds R3, R4 and R5 have been completed to date and are currently under environmental review; however no designs or plans have been developed for Ponds R1 and R2, which have the greatest effect on inundation in the Dumbarton Bridge focus area. The eventual goal of the SBSP project is to restore or enhance ponds R1 and R2 once the work in Ponds R3, R4 and R5 have been completed; however, the timeline for these actions is not yet determined.

5.1.2. SAFER Bay Project

The Strategy to Address Flood protection, Ecosystems and Recreation (SAFER) along the San Francisco Bay Project is run by the San Francisquito Creek Joint Powers Authority (SFCJPA) and is planning for the development of new or improved flood risk reduction features along the Bay shoreline from the Menlo Park/Redwood City border south to San Francisquito Creek to protect those areas from coastal flooding. One of the goals of the project is to implement flood protection in a way that sustains marsh habitat and facilitates marsh restoration associated with SBSP and other restoration efforts. The SAFER Bay Project proposes matching and exceeding the level of flood protection proposed by SBSP by including up to 36” of SLR in the levee designs. SAFER Bay recently completed a feasibility study that outlines conceptual level alternative designs of flood protection measures.

5.1.3. Coordination with Existing Efforts

The efforts mentioned above, once implemented, will provide long-term flood protection within the Dumbarton Bridge focus area. In the meantime, near-term strategies can be used to provide relief from temporary flooding and near-term SLR. The implementation of these near-term strategies should be designed, if feasible, to not limit, and potentially enhance, the design and construction of these long-term plans. In other words, near-term implementation should be integrated with long-term planning and the two should complement each other. As an example, a levee can be built to an intermediate elevation for near-term protection, but be designed to accommodate being raised and an expanded footprint to provide long-term flood protection in the future. Further details and discussion are provided in Section 5.2.4.

5.2. North-Side Strategies

Three near-term strategies were identified to provide flood protection on the north side of SR 84. These strategies were developed based on the inundation maps which identified the direct pathways that lead to the flooding of the north access road and SR 84. The three strategies are listed below and their general locations are shown in Figure 9:

1. Raise crest of N-S Ravenswood levee from the north access road to the E-W Ravenswood levee.
2. Extend flood protection to the southwest along the outside edge of the north access road
3. Extend flood protection to the northeast from the end of sheet pile/concrete barrier

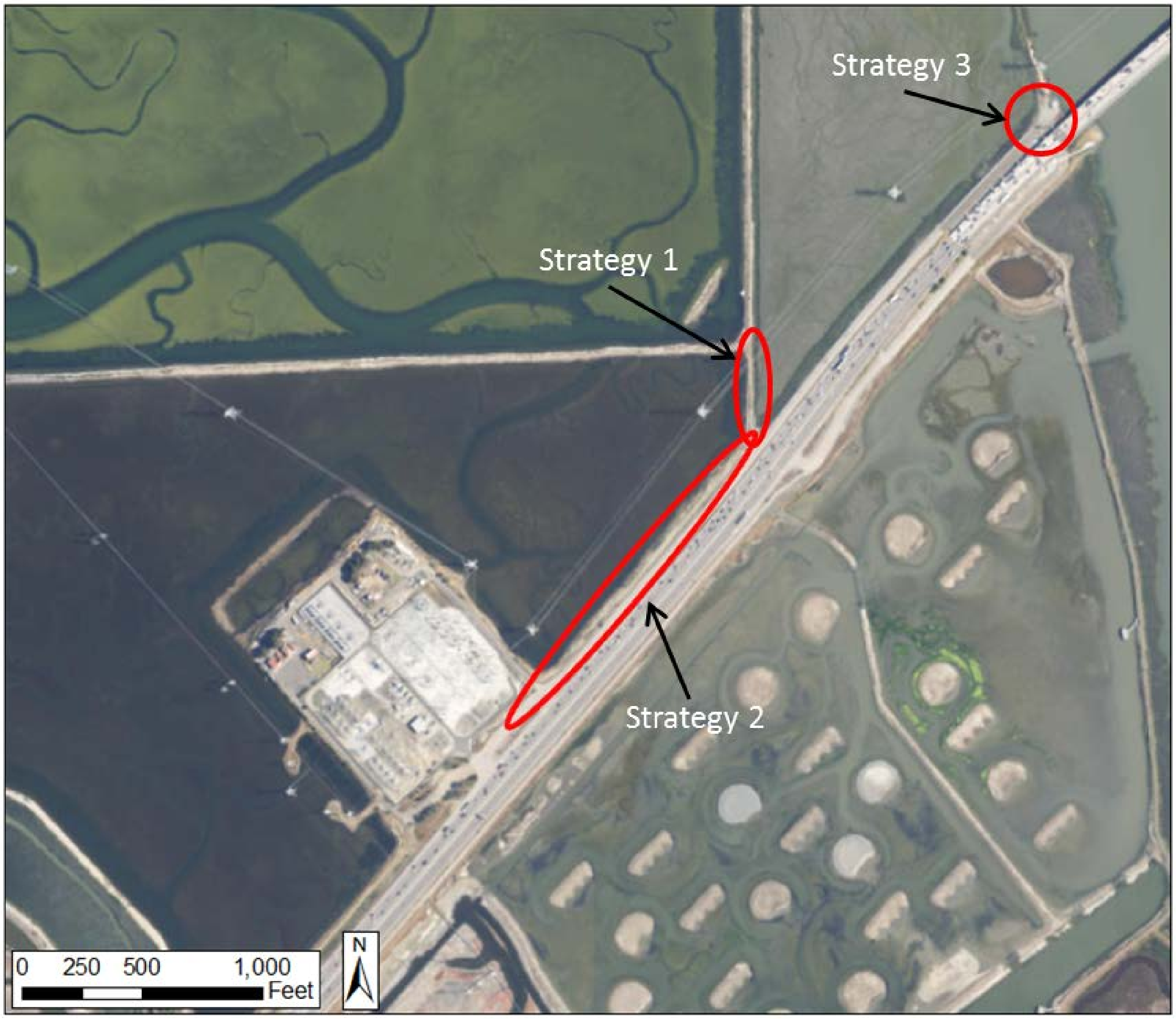

Figure 9. Approximate locations of north-side near-term flood protection strategies

5.2.1. Strategy 1: Raise crest of north-south Ravenswood levee

This strategy would raise the crest of the N-S Ravenswood levee from the north access road to the E-W Ravenswood levee by placing fill on the N-S levee. This strategy would prevent water in Mosley Tract from flowing around the concrete barrier and onto the north access road and SR 84. The location of the proposed levee raising is shown in Figure 10. A layout view of the proposed alignment is shown in Figure 11.

Figure 10. Location of proposed levee raising along N-S access road adjacent to Moseley Tract and Pond R2

The crest will be raised by placing approximately three feet of fill along a 400 foot section of the existing levee access road. The existing vegetation and gravel road that line the levee crest and side slopes would be removed prior to fill placement and the gravel road would be replaced on top of the new levee. Because more than about one foot of fill would be added, the levee should be overbuilt to accommodate future settlement caused by consolidation of foundation soils. Figure 12 shows two typical configurations for levee raising. The levee should also be assessed for erosion, seepage and stability and these issues should be rectified prior or during levee raising, as this can lead to failure of the levee.

This strategy will protect only the north access road and SR 84. This option does not protect the east pump station or assets on the south side of SR 84. Additionally, the Ravenswood substation and fire training facility would still be at risk because water can travel over the E-W Ravenswood levee and flood Pond R2. Although the flood pathway from Pond R2 to the north access road would not be addressed by Strategy 1, it is expected that Pond R2 would fill with water during flood events and then drain at low tide before spilling over to the north access road. The hydrodynamics of such a flood scenario are not evaluated in this memorandum and could be evaluated in more detail through hydrodynamic modeling. If implemented, this strategy will provide protection at MHHW + 24'', with the potential of protecting up to MHHW + 36''.

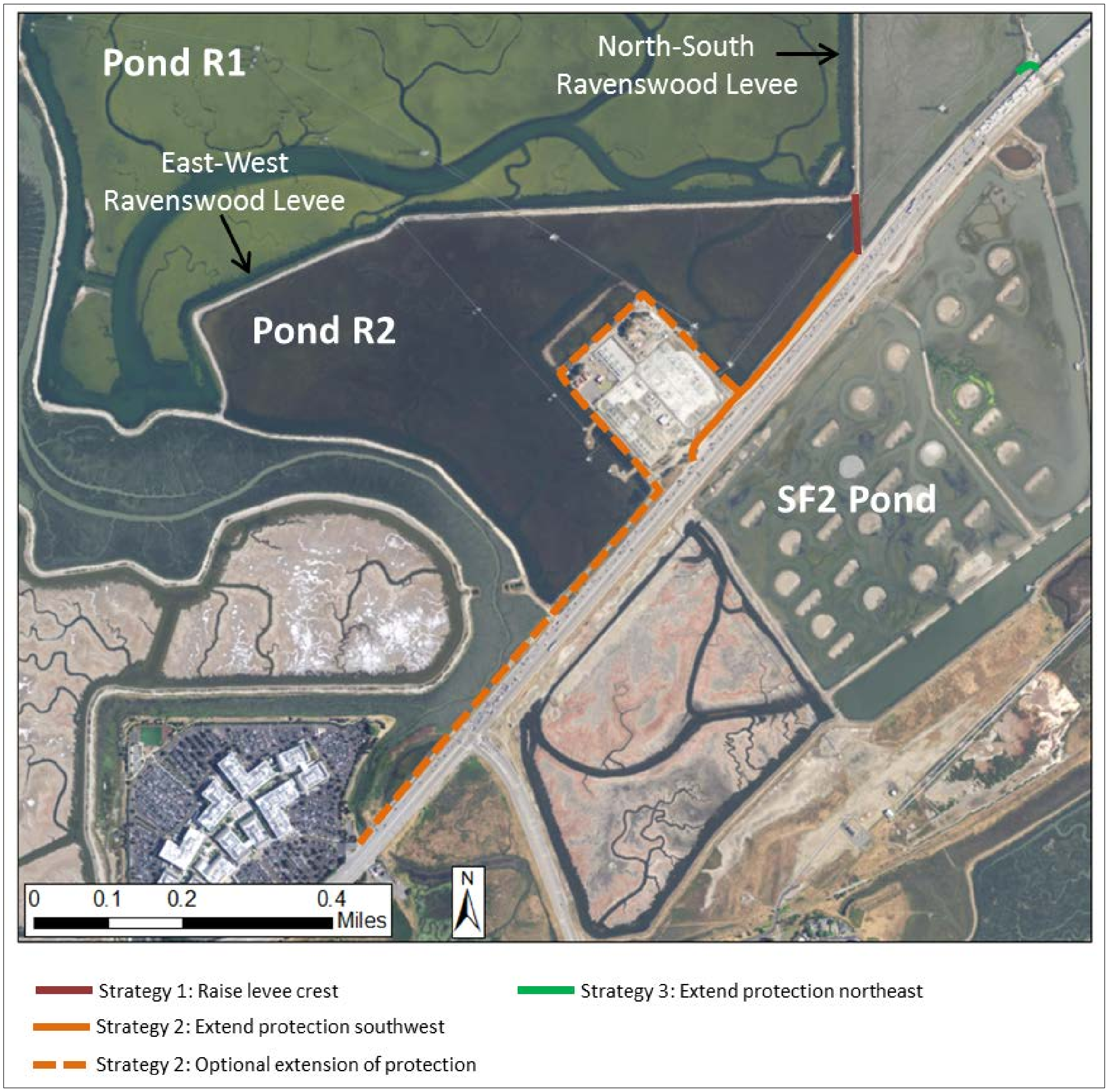

Figure 11. Summary of strategies for north side protection

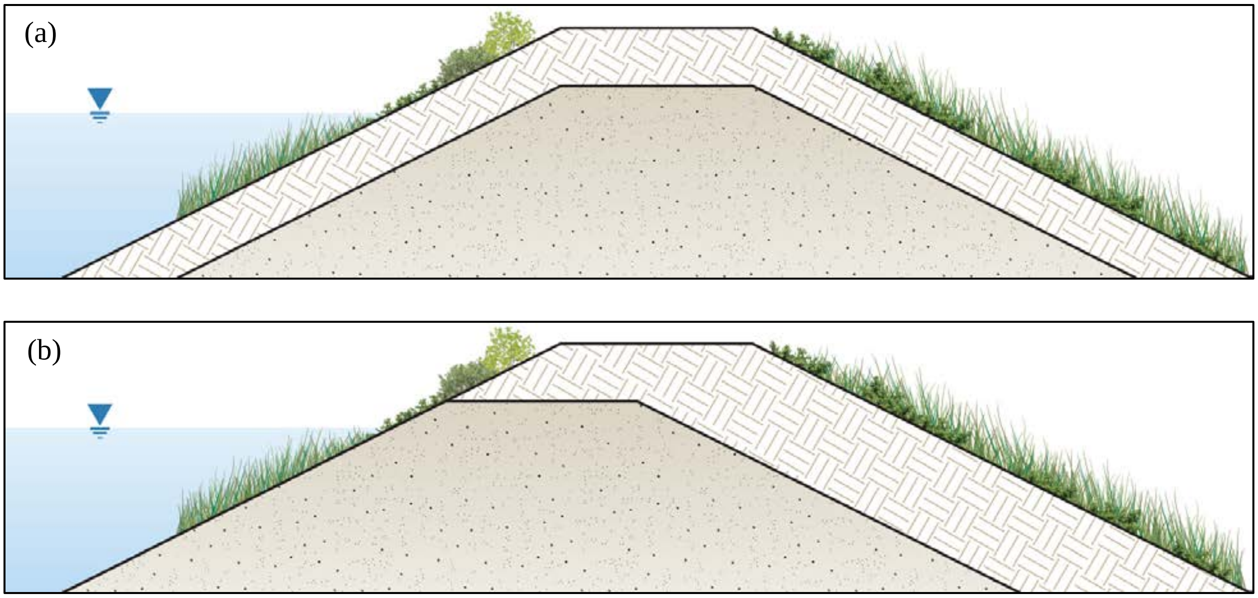

Figure 12. Conceptual strategies to raise existing levee crest elevation: (a) land- and waterside fill placement; (b) landside fill placement only

5.2.2. Strategy 2: Extend flood protection southwest along north access road

This strategy would extend protection along the north access road by constructing either a hard barrier or a levee. The options for the flood protection barrier include:

- **Sheet pile wall:** A wall composed of preformed segments (normally constructed of steel) that are driven (and/or vibrated) into the ground. The segments of each sheet interlock to form a continuous flood barrier. Sheet piled walls are often designed with a reinforced concrete cap to help stabilize the wall and keep the segments connected and acting as a continuous structure.

- **Concrete wall:** A wall composed of reinforced concrete that is either cast-in place or formed of pre-cast units joined together. The wall would usually be constructed with a shallow foundation to provide stability to the wall.

- **Sheet pile wall with concrete buttress:** A concrete buttress that is backed by a sheet pile wall. Typically the sheet pile wall is driven into the ground and the concrete buttress is cast in place in front of the sheet pile. The concrete buttress is typically wider than a concrete wall and does not required as large or deep of a footing. This option was used by Caltrans to construct the temporary concrete barrier.

- **Raise existing levee crest:** This would involve placing fill material on the levee crest and side slopes to raise the crest of the levee. Fill placement on the side slopes is necessary to avoid over-steepening when raising levee crests.

A barrier would be constructed parallel to the north access road to prevent flooding from Pond R2. This strategy could be implemented with Strategy 1 to provide a continuous line of flood protection while maintaining pedestrian and vehicle access to the N-S Ravenswood levee access road. The barrier would start near the end of the existing sheet pile/concrete barrier at the N-S Ravenswood levee access road and extend southwest to the intersection of the north access road and SR 84, at the Ravenswood substation. Alternatively, the levee along the backside of Pond R2 could be raised to address flooding of the access road and state route.

Even with implementation of Strategies 1 and 2, the substation and fire station would still be at risk of flooding from Pond R2 because water can travel over the E-W Ravenswood levee to flood Pond R2. It may be possible to coordinate with PG&E to extend the barrier or levee and wrap it around the substation to provide protection for the substation and fire training facility (this is similar to options identified under the SAFER Bay project). This is noted as an optional levee extension in the cost estimate. If implemented, this strategy will provide protection starting at MHHW + 24'', with the potential of protecting up to MHHW + 36''.

5.2.3. Strategy 3: Extend flood protection northeast

This strategy would extend flood protection along the north access road to the northeast to prevent Bay floodwaters from inundating the north access road. A flood barrier would extend from the existing sheet pile/concrete barrier 100 ft beyond the end of the north access road and connect to the bridge to form a closed protection system. Currently, the sheet pile/concrete barrier terminates at the edge of the pump station pad, creating a gap (see Figure 13). The inundation maps indicated that in the MHHW + 36'' scenario, water can overtop the shoreline and flow through this gap to flood the north access road. A layout view of the proposed alignment is shown in Figure 11. The barrier can be constructed in the same manner as the exiting barrier, or it can be composed of an independent steel sheet pile wall or concrete wall. Due to the presence of buried stormwater infrastructure in the vicinity of the pump station, additional investigation would be required to determine the exact alignment of the flood barrier to avoid impacts to existing infrastructure.

This strategy is intended to close the small gap in the existing flood protection system to prevent inundation of the north access road. It should be combined with Strategy 1 or 2 to create a continuous protection system for the north access road. If this gap is not closed, it limits the effectiveness of the other strategies as water will flow through this open pathway to flood low-lying areas. If implemented, this strategy will provide protection at MHHW + 36''.

Figure 13. Location of gap in flood protection system at east pump station.

Note: The gap is indicated by red line.

5.2.4. Considerations for North Side Protection

Design Elevation for Strategies 1 and 3

Strategies 1 and 3 are intended to protect against direct flooding of the north access road by Bay floodwaters. As such, the proposed barriers would experience the same flood elevations as the Bay shoreline (Table 2). Strategies 1 and 3 should be tied into the existing sheet pile/concrete barrier to create a continuous flood protection system for the north side of SR 84. The proposed strategies would likely match the elevation of the existing flood protection system, which is 11.2 ft NAVD88. Raising the shoreline elevations higher than 11.2 ft NAVD88 will not result in added protection because water will overtop the existing sheet pile/concrete barrier. Raising shoreline elevations to 11.2 ft NAVD88 would raise crest elevations approximately 0.3 feet above the 100-year flood level; however, this would not provide even a minimum recommended freeboard of 1 foot. Accounting for a 1 foot freeboard allowance, a flood protection system at an elevation of 11.2 ft NAVD88 would provide between a 25- and 50-year level of flood protection with appropriate freeboard.

Design Elevation for Strategy 2

The design elevation of the flood protection presented in Strategy 2 would likely match the elevation of the existing flood protection system, which is 11.2 ft NAVD88. Used in combination with Strategy 1, the design elevation may be lower because Pond R2 will store a large volume of water during a flood event. As a result, Pond R2 may not completely fill up to the same water level as the Bay before flood waters recede. Modeling of the water level in the pond due to extreme tides over several tidal cycles is required to select an appropriate design elevation of this flood protection measure.

Obtaining Protection for Higher Scenarios

To obtain protection greater than 11.2 ft NAVD88 (the elevation of the existing sheet pile/concrete barrier), the elevation of the existing concrete barrier and proposed protection measures would have to be raised. The existing barrier could be raised either through the construction of a taller barrier or by placing a concrete cap on top of the existing barrier. Installation of a concrete cap may be a possibility but would require further investigation into the structural integrity of the existing structure. Design drawings indicate that low strength concrete fill is placed between the concrete barrier and the sheet pile wall. Drilling into this low-strength layer may cause it to crack and loosen the bond between the fill concrete, the sheet pile, and the concrete barrier.

Furthermore, to provide protection beyond 11.2 ft NAVD88, any additional pathways that occur due to the elevated water level would need to be addressed. For example, in the MHHW + 48’’ scenario, water from Ravenswood Slough overtops the banks and floods the outer lanes of SR 84, so a barrier or levee along this stretch of road may be needed to provide extended protection. One option could be to extend the flood protection system presented in Strategy 2 from the Facebook campus to the N-S levee, along the bank of Ravenswood Slough and backside of Pond R2 as shown in Figure 11. This is similar to one of the proposed options in the SAFER Bay feasibility study. This would protect against direct flooding from Ravenswood Slough and Moseley Tract for scenarios greater than MHHW + 48”, provided that the existing sheet pile/concrete barrier is raised to match the elevation of the newly constructed system. It would also provide protection against indirect flooding caused by the overflow of Pond R2.

Integration with Long-term Restoration Efforts

Strategies 1 and 2 provide options to raise the levees that back Pond R2, which has been identified as an area for future tidal restoration by SBSP. It is possible that restoration activities for this pond will involve raising the backside levee to provide long-term flood protection and may include the construction of an ecotone[2] levee to provide upland and transitional habitat. To facilitate the implementation of subsequent restoration activities, Strategies 1 and 2 could be designed and implemented in a way that allows for additional raising and widening in the future. This would mean the levees would be designed to have a wider base to allow for the additional placement of fill or a mild ecotone slope in the future.

[2] An ecotone levee is an earth levee with a very mild side slope that allows for wave dissipation and space for transitional habitat.

5.3. South Side Strategies

5.3.1. Strategy 4: Raise low spots on outboard levee

The inundation maps indicate that flooding on the south side of SR 84 is caused by the overtopping of two low spots on the outboard levee system. This strategy would raise the elevation of the levee in these two locations by placing fill on the levee crest and protect all the assets on the south side of SR 84 including the south access road and bike lane, west pump station, and University Avenue from flooding up to the MHHW + 36'' scenario.

Figure 14 shows the locations along the levee to be raised. The crest will be raised by placing fill on the existing levee. Material would be added to the side slopes of the levee to avoid over steepening of the slopes. The existing vegetation and gravel road that line the levee crest and side slopes must be removed prior to fill placement. Where more than about one foot of fill is added in locations that have a soft soil foundation, the levee should be overbuilt to accommodate future settlement caused by consolidation of foundation soils.

The first location, and the most important, is a 400 ft section of levee along the south access road between the Pond SF2 levee and the shoreline. Elevations along this reach are as low as 8.6 ft NAVD88, and it overtops in the MHHW + 24'' scenario to flood the south access road. Flooding of this area is a result of direct exposure to elevated water levels in the Bay (Table 2). The elevation of the raised levee could potentially be higher than the adjacent SF2 levee crest, which is 10.6 ft NAVD88, and still provide added flood protection benefit. This is because water overtopping the Pond SF2 levee will collect in the pond system before overtopping onto the south access road and SR 84. Fill along the south access road levee will most likely be placed on the marsh side as there is limited space on the road side to extend the levee. The existing riprap would have to be removed and replaced. If space is a constraint and it is not desired to place fill on existing marsh, a concrete wall or sheet pile wall could be constructed on the outside edge of the south access road at higher cost. If implemented, raising this low spot will provide protection at MHHW + 24'', with the potential of protecting up to MHHW + 36''.

The second low spot is located 3,000 ft south of SR 84, just south of the SF2 outlet structure. It is at the intersection of the Pond SF2 levee and the older levee system. The low-lying area is 50 ft in length and at an elevation of approximately 9.2 ft NAVD88. This section overtops in the MHHW + 36'' scenario. The overtopping of this section could lead to flooding in Pond SF2, the south access road, SR 84, University Ave, and the Ravenswood pump station. It is expected that flood waters would collect in Pond SF2 before overfilling to inundate SR 84 and University Ave. Modeling of the water level in the ponds due to extreme tides over several tidal cycles is required to select an appropriate design elevation of the raised levee. Fill along this levee can be placed on the landside to reduce impact of placing fill on the fronting marsh. If implemented, raising this low spot will provide protection at MHHW + 36''.

Figure 14. Summary of strategies for south side protection

5.4. Phasing of Strategies

The above sections presented a series of individual strategies at discrete locations along the shoreline that could be implemented in stages to provide the desired level of flood protection. Table 4 below summarizes the actions required to provide protection for each near-term water level scenario. The phasing is informed by the timing of inundation of SR 84 and the access road, as shown in Figure 15.

Table 4. Phasing of proposed strategies

Level of Protection	Required strategies	Notes
MHHW + 24	Strategy 1 and Strategy 2; Strategy 4	Strategy 1 and 2 should be implemented together
MHHW + 36	Strategy 1 and Strategy 2; Strategy 4 + Strategy 3	Strategy 1 and 2 should be implemented together
MHHW + 48’’ and beyond	Strategy 1 and Strategy 2; Strategy 4 + Strategy 3 + Strategy 2 (w/ optional extension);	Barrier in optional Strategy 2 would need to extend to Facebook HQ. Existing sheet pile/concrete barrier would have to be raised

Figure 15. Flooding of SR 84 and access road in increasing water level scenarios. Red circles show locations of overtopping that lead to direct flooding of roadway.

5.5. Alternatives not evaluated

One strategy to prevent inundation of the access road and SR 84 is to raise the elevation of the road surface. This strategy was initially considered, but not carried forward due to feasibility, cost, and project scale. The cost required to raise the access road and roadway to provide the same amount of protection as provided by the proposed strategies above, would be far greater than the costs of the proposed strategies. Construction would also involve temporary partial closure of the access road and SR 84 which would cause long delays along the Dumbarton Bridge. As a short term strategy, these options are not viable as they involve more effort and cost than the options presented above.

6. Implementation and Cost Considerations

6.1. Cost Considerations

A rough order-of-magnitude of probable costs to construct the strategies was developed and is presented based on a linear foot (LF) of implementation. Details on how the unit costs were evaluated are provided in Appendix B. The estimated total cost per LF comprised the following components:

Direct Unit Costs: These include labor rates, equipment (including maintenance, fuel, oil & grease), permanent materials, and temporary materials.

Indirect Unit Costs: These include freight, mobilization and demobilization, job supervision and office personnel, temporary buildings, temporary utilities, temporary job construction, job transportation, job office expenses, insurances (except labor insurance), bonds, quality control (QC), and surveying. This was assumed as 15% of the direct unit cost.

Overhead and Profit (OH&P): This includes 10% for home office overhead and 10% for profit (compounded as a 21% allowance of the direct and indirect unit cost).

Construction Contingency: This includes a 25% allowance for changes in construction rates and the project design details between the current concept design stage until the future construction bidding phase.

Design Fee and Design Contingency: This includes a 15% allowance for the engineering design fee and a 10% allowance for project design changes during the detailed design phase of the project, as more current and updated information for the project and site conditions is obtained and developed.

Environmental Clearance: This includes a 10% allowance for environmental permitting and clearance requirements.

The unit cost for each strategy was multiplied by the length of the protection required to develop rough cost estimates for the implementation of the strategies. The costs do not include any environmental mitigation or land acquisition fees that may be required as a result of the project implementation. Cost summaries for all strategies are presented in Table 5 and Table 6.

Table 5. Cost Summary of North-Side Strategies

Strategy		Unit Cost	Length (ft)	Total Cost
Strategy 1: Raise levee crest		$ 1350	435	$ 600k
Strategy 2: Extend flood protection southwest along Pond R2	(a) Sheet pile wall	$ 2560	1920	$ 4.9M
	(b) Concrete wall	$ 1840	1920	$ 3.5M
	(c) Sheet pile wall with concrete buttress	$ 2780	1920	$ 5.3M
	(d) Raise levee crest	$ 1350	1370	$ 1.8M
	(e) Optional levee extension	$ 1350	7550	$ 10.2M
Strategy 3: Extend flood protection northeast	(a) Sheet pile wall	$ 2560	124	$ 320k
	(b) Concrete wall	$ 1840	124	$ 230k
	(c) Sheet pile wall with concrete buttress	$ 2780	124	$ 340k
Total (north side)				$6.1-18.2M

Table 6. Cost Summary of South-Side Strategies

Strategy		Unit Cost	Length (ft)	Total Cost
Strategy 4: Raise low spots on outboard levee system	(a) Raise access road berm	$ 870	400	$ 350k
	(b) Construct sheet pile wall along south access road	$ 2560	400	$ 1M
	(c) Raise low spot at intersection of SF2 and old levee	$ 870	50	$ 50k
Total (south side)				$0.4-1.1M

6.2. Implementation Considerations

Many issues need to be considered when choosing which strategy to implement. This section provides a summary description of potential issues to consider. For each strategy, the considerations are rated low, medium, or high to provide a qualitative assessment of the relative impact of each consideration. Table 7 presents a summary of the implementation considerations for each strategy.

Construction and Feasibility. This considers all items to do with the construction of the strategy, such as the complexity of construction, the type of equipment necessary, site access and construction staging, and construction impacts to surrounding areas such as road closures. It would also consider the impacts to existing infrastructure as a result of implementation, such as levee or roadway settlement.

- **Low:** Construction is anticipated to be relatively easy; no access issues or specialized equipment needed; minimal disruption to traffic
- **Medium:** A moderate amount of work is required, some access issues may be present
- **High:** A significant amount of construction or difficult work is anticipated, site access may be challenging, traffic disruption will mostly likely occur.

Environmental Impact. This considers the various environmental impacts that could result from implementation, such as placing fill in wetlands, in-water impacts, disturbances to wildlife and marine habitats, and any required mitigation as a result of wetland impacts. This also considers the various permits required for implementation. Potential permitting requirements are discussed in Section 6.3.

- **Low:** Minimal impacts to regulatory wetlands
- **Medium:** Moderate impacts to regulatory wetlands
- **High:** Significant impacts to regulatory wetlands

Ownership and Coordination. This considers the degree of coordination required to implement the strategy, such as coordination with the landowner, if it is located outside Caltrans ROW, coordination with environmental, state or local agencies, or coordination with existing flood protection or restoration efforts, such as SBSP and SAFER Bay. Potential agencies or stakeholders that may require coordination are PG&E, Caltrans, Menlo Park Fire Department, and SFCJPA. Furthermore, the Ravenswood pond complex is part of the Don Edwards National Wildlife Refuge, which is owned and managed by the department of U.S. Fish and Wildlife Service (USFWS). Coordination with USFWS would be required for any work done in the ponds or on the levees.

- **Low:** Strategy located within Caltrans right-of-way; minimal coordination with other entities
- **Medium:** Footprint of the strategy may extend outside the Caltrans right-of-way and coordination with adjacent landowners may be required
- **High:** Strategy will be located outside Caltrans right-of-way and coordination with the landowner, stakeholders, and agencies required

Construction Cost. This considers the cost of construction. Other costs such as land acquisition, design and permitting, and operations and maintenance are not considered.

- **Low:** < $1M
- **Medium:** $1M to $3M
- **High:** > $3M

Table 7. Summary of implementation considerations for each strategy

Construction & Feasibility	Environmental Impact	Ownership & Coordination	Cost
Strategy 1: Raise levee crest along N-S levee			
Medium Top of levee crest is free of vegetation and can be accessed by vehicle. Area is accessible by north access road. Levee would need to be evaluated for stability and the additional fill may induce settlement in levee.	**Medium** Fill may need to be placed on marsh or within pond. Strategy can be designed such that fill is placed on pond side to limit impacts of placing fill on established tidal marsh.	**High** Levee and ponds owned and managed by USFWS. Coordination with SBSP and SFCJPA should also occur as modification of this levee may be part of long-term flood protection restoration strategy	**Low** Levee raising is on lower end of cost range and length of levee to be raised is short
Strategy 2a, 2b, 2c: Extend flood protection southwest via a hard barrier (sheet pile or concrete wall)			
High Construction of sheet pile and/or concrete wall will involve excavation and/or piling. Site can be accessed from north access road. Temporary closure of westbound lane of north access road may be required during construction. Utility lines would have to be identified and may need to be relocated	**Low** Alignment of wall can be along edge of access road as to limit impact to adjacent pond.	**Medium** Strategy is mostly located within Caltrans right-of-way. May required coordination with USFWS if alignment falls on their property	**High** Construction of hard barriers are on higher end of cost range and length of wall is relatively long
Strategy 2d: Extend flood protection southwest by raising levee crest			
Medium Levee crest and side slopes would need to be cleared of vegetation prior to fill placement. Area can be accessed from north access road. Temporary closure of westbound lane of north	**Medium** Fill will need to be placed within pond to mitigate for stability and erosion issues. Existing vegetation will be removed during construction.	**High** Will require coordination with DFW as they own and manage the levee. Coordination with SBSP and SFCJPA should also	**Medium** Levee raising is on lower end of cost range but length of levee to be raised is long

Construction & Feasibility	Environmental Impact	Ownership & Coordination	Cost
access road may be required during construction. Levee would need to be evaluated for stability and the additional fill may induce settlement in levee.		occur as modification of this levee may be part of long-term flood protection and restoration strategy	
Strategy 2e: Optional levee extension			
High The suitability of the underlying soil to accommodate additional fill would need to be evaluated. Access would need to occur from PG&E property.	**Medium** Fill may need to be placed within pond to mitigate for stability and erosion issues. Existing vegetation will be disturbed and possibly removed during construction.	**High** Will require coordination with USFWS and PG&E. Coordination with SBSP and SFCJPA should also occur as restoration of the pond is part of long-term flood protection and restoration strategy	**High** Length of levee is relatively long, so construction of levee will be on higher end of cost range
Strategy 3a, 3b, 3c: Extend flood protection northeast to shoreline			
Medium Construction of sheet pile and/or concrete wall will involve excavation and/or piling. Site can be accessed from north access road, work can be done from shoulder and pump station pad. Utility lines would have to be identified and may be relocated; however, length of wall is short.	**Low** Wall will be built on existing developed road surface and will not interfere with adjacent marsh areas.	**Medium** Strategy is mostly located within Caltrans right-of-way. May required coordination with owner of pump station, as alignment may fall within that property.	**Low** Construction of hard barriers are on higher end of cost range, but length of wall is short
Strategy 4a, 4c: Raise low spots on outboard levee system			
Low Levee crest and side slopes would need to be cleared of vegetation prior to fill placement. Area is accessible	**Medium** Fill may need to be placed on established marsh to raise height or mitigate for levee	**Medium** Will require coordination with USFWS as they own and manage the	**Low** Levee raising is on lower end of cost range, and length of levee to be raised is

Construction & Feasibility	Environmental Impact	Ownership & Coordination	Cost
by south access road. Temporary closure of bike lane may be required during construction. Levee would need to be evaluated for stability and the additional fill may induce settlement in levee.	stability. Existing vegetation will be disturbed and possibly removed during construction.	levee system.	short
Strategy 4b: Construct sheet pile wall along south access road			
Medium Construction of sheet pile wall will involve piling. Site can be accessed from south access road, work can be done from shoulder and bike lane. Utility lines would have to be identified and may be relocated.	**Low** Wall will be built on existing developed road surface and will not interfere with adjacent marsh areas.	**Low** Strategy falls within Caltrans right-of-way	**Low** Construction of hard barriers are on higher end of cost range, but length of wall is short

6.3. Environmental Impacts and Permitting

The implementation of these strategies will incorporate several different planning and development activities that fall within the jurisdiction of various agencies. Below lists the agencies that will require consultations and/or regulatory permits for the construction of the adaptation strategies. The permits for all strategies are generally similar because they are all located near or at the shoreline and may involve placement of fill in environmentally sensitive areas. This list is not exhaustive and other permits and agency consultation may be required.

- USACE Section 404/10 permit for construction
- NOAA Fisheries (formerly NMFS) Magnuson-Stevens Fishery Conservation and Management Act consultation
- NOAA Fisheries and US Fish and Wildlife Service Endangered Species Act (ESA) Section 10 consultation
- CA Department of Fish and Game (CDFG) California Endangered Species Act (CESA) consultation
- BCDC compliance with the McAteer-Petris Act that promotes responsible planning and to eliminate unnecessary placement of fill (i.e., upland alternative analysis, minimum fill necessary)
- BCDC administration of the Coastal Zone Management Act (CZMA)
- California State Lands Commission (SLC) for Aquatic Lands Lease if located on such lands
- San Francisco Bay Regional Water Quality Board (RWQCB) Clean Water Act (CWA) 401 Water

- Quality Certification
- RWQCB Porter-Cologne Water Quality Control Act – State law equivalent of the 401 Water
- Quality Certification
- Bay Area Air Quality Management District (BAAQMD) Engine Permit – Required for heavy diesel powered equipment. This may or may not be applicable.

7. Conclusion and Next Steps

A focus area study was conducted for the Dumbarton Bridge touchdown area to refine the SLR exposure assessment and develop conceptual level strategies to address near-term flooding of the focus area. This area was identified because a recent bridge retrofit project installed new flood protection barriers that were not included in the ART Mapping Project. The new inundation mapping shows that the addition of the concrete barrier and pump station pad prevents flooding of the north access road and pump station in the MHHW + 12’’ scenario; however in higher SLR scenarios, the water flows around the barrier to flood the same areas as it did before the addition of the barrier.

Strategies were developed to address short-term flood protection of the highway and access road. These strategies can be applied individually or in phases to protect against specific storm scenarios and localized flooding. However, it is recommended to combine the strategies to provide a continuous flood protection system. These strategies are intended to protect against short-term flooding (up to MHHW + 36’’) due to extreme tides, storm surge, and SLR. Efforts to address flooding in the long-term are being undertaken by local agencies and stakeholders. Coordination with these agencies and local stakeholders will be required to ensure that the near-term strategies developed to protect the roadway align with long-term flood protection and ecosystem restoration plans of the surrounding area and community.

Next steps could include additional hydraulic modeling to confirm the identified flood pathways under a range of tide, storm, and SLR scenarios and to evaluate the ability of the adjacent ponds to store Bay floodwaters and reduce flooding during levee overtopping events. Understanding the flood hydraulics will help develop and refine the near-term strategies presented in this memo and will result in better estimates of the design elevation and location of the proposed strategies.

8. References

AECOM. 2016. San Francisco Bay Tidal Datums and Extreme Tides Study. Prepared for: Federal Emergency Management Agency and San Francisco Bay Conservation and Development Commission.

AECOM. 2017. Adapting to Rising Tides Bay Area Sea Level Rise Analysis and Mapping Project. Prepared for: Metropolitan Transportation Commission, Bay Area Toll Authority, and San Francisco Bay Conservation and Development Commission. September 2017.

San Francisquito Creek Joint Powers Authority. 2016. SAFER Bay Project Public Draft Feasibility Report. East Palo Alto and Menlo Park. October 2016.

Appendix A. Vulnerability Assessment Tables for Dumbarton Bridge Focus Area Study

Table A-1. Exposure Analysis of Flood Protection Assets

Flood Protection Asset	Elevation (ft NAVD)	Intended to Protect	First Overtops	Overtopping Notes
Temporary Concrete Barrier	11.2	North frontage road and SR 84	MHHW + 48''	Only effective in preventing flooding of north frontage road in MHHW + 12'' scenario. In higher scenarios, water travels around the wall to reach the north frontage road and SR 84.
North-South Ravenswood Pond Levee	8.6	Ravenswood R1 and R2 ponds, PG&E substation, Fire training facility, north frontage road, SR 84	MHHW + 24''	Overtopping of this levee leads to inundation of most of the assets it is intended to protect. Raising this levee may prevent some flooding, but other pathways are present that will eventually inundate the ponds and substation.
East-West Ravenswood Pond Levee	7.6	Ravenswood R1 and R2 ponds, PG&E substation, Fire training facility, north frontage road, SR 84	MHHW + 24''	Overtopping could occur in earlier scenario, but not exposed to flooding due to north-south levee which prevents water from entering the adjacent pond until MHHW + 24''
South Frontage Road Berm	8.7	South frontage road, SR 84	MHHW + 24''	Overtopping leads to inundation of south frontage road, SR 84 and University Ave
SF2 Pond Levee	10.3	SF2 Pond, south frontage road, SR 84, University Ave	MHHW + 48	Only effective in preventing flooding in MHHW + 12'' scenario. In higher scenarios, water bypasses levee via the low spots along the south frontage berm and old levee system.
Cross Berm	9.2	North frontage road and SR 84	MHHW + 36''	Not effective at preventing flooding because pathways exist around the berm. Leads to flooding of north frontage road and SR 84

Table A-2. Exposure Analysis of Transportation and Infrastructure Assets

Assets	Elevation (ft NAVD)	Cause of Flooding	First Inundates	Inundation Notes
Transportation Assets				
North Frontage Road	8.0	Overtopping of North-South Ravenswood levee	MHHW + 24''	The entirety of the north frontage road is flooded. Flooding occurs via flow around the cross berm along the crest of the N-S levee. Protection would require raising the N-S levee or constructing a barrier parallel to road along back edge of R2 pond.
SR 84	9.5	Overtopping of North-South Ravenswood Levee and low asset elevation	MHHW + 36''	A short low-lying section of 200' first floods in MHHW + 36'', and significantly more sections of road show flooding in MHHW + 48''. Protection would require raising N-S levee or constructing a barrier parallel to north frontage road along back edge of R2 pond. Highway is exposed to inundation at earlier scenarios but does not flood due to elevation of asset relative to water surface.
Infrastructure Assets				
PG&E Sub-Station	9.5	Overtopping of both Ravenswood levees and low asset elevation	MHHW + 24''	About half of area is flooded at MHHW + 24'', and most of it is flooded in 36''. Protection would require raising of perimeter wall or Ravenswood pond levees.
Fire Protection District/Regional Training Center	11.00	Low asset elevation. Adjacent areas are flooded earlier	MHHW + 48''	First floods in MHHW + 48'' and gets more severe in MHHW + 52''. Protection would require raising of perimeter wall or Ravenswood pond levees. Is exposed to inundation at earlier scenarios but does not flood due to elevation of asset relative to water surface.
Pump Station	9.5	Low asset elevation. Adjacent areas are flooded earlier	MHHW + 36''	Entire footprint is flooded at MHHW + 36''. Protection would require raising pump station or constructing perimeter wall. . Is exposed to inundation at earlier scenarios but does not flood due to elevation of asset relative to water surface.
West Pump Station	9	Overtopping of south frontage berm	MHHW + 24''	Low spot along south access road berm overtops and water travels far inland flood the pump station.
Facebook HQ	12.5	Low asset elevation. Adjacent areas are	MHHW + 48''	Levees surrounding the HQ overtop in MHHW + 48'' and floods parking lot.

		flooded earlier		Protection would require raising perimeter levees. Asset is exposed to inundation at earlier scenarios but does not flood due to elevation of levees relative to water surface.
University Ave	10	Overtopping of south frontage berm	MHHW + 24''	First floods in MHHW + 24'' due to low spot along south access road berm; water travels far inland flood the south section of University Ave. Protection would require raising the outboard berm and levee system

Table A-3. Sensitivity and Adaptive Capacity Analysis

Flood Protection Assets	Sensitivity	Adaptive Capacity and Redundancy
Temporary Concrete Wall	Continual exposure to flood conditions may increase corrosion on sheet pile wall and reinforcement in concrete barrier.	Barrier may be raised via concrete cap but requires investigation of construction feasibility and structural integrity of existing barrier
Ravenswood pond levee (North-South)	Levee is in poor condition and exposure to flood conditions can erode and degrade the levee	Levee along backside of Pond R2 and the capacity of the pond can provide some relief for flooding if this levee were to overtop
Ravenswood pond levee (East-West)	Levee is in poor condition and exposure to flood conditions can erode and degrade the levee	Levee along backside of Pond R2 and the capacity of the pond can provide some relief for flooding if this levee were to overtop
SF2 Pond Levee	Continual exposure to flood conditions can cause erosion and levee instabilities, which can lead to levee failure	The capacity of the Pond SF2 system can provide some capacity for flooding if this levee were to overtop
Cross Berm	Berm is not engineered and exposure to flood conditions may eroded the berm	Levee along backside of Pond R2 and the capacity of the pond can provide some relief for flooding if this levee were to overtop
Transportation Assets		
Frontage Road	Long term continual exposure to flooding can degrade roadway, and cause cracks and potholes In the road surface	Flooding of this road would eliminate the last turnaround point for the bridge. Nearest road that provides the same service is University Ave, located 4500 ft prior.
SR 84	Long term continual exposure to flooding can degrade roadway, and cause cracks and potholes In the road surface	Flooding of highway would shut down access to Dumbarton Bridge. Rerouting of traffic on both sides of bridge to San Mateo Bridge (or south to SR 237) would need to occur.
University Ave	Long term continual exposure to flooding can degrade roadway, and cause cracks and potholes In the road surface	Flooding of this road would cut off a main access point to SR 84. Nearest access point would be Willow road located 2800 ft west of University Ave.

Flood Protection Assets	Sensitivity	Adaptive Capacity and Redundancy
Other Infrastructure		
PG&E Sub-Station	Water entering site may damage electrical systems and affect sub-station operation	Sensitive equipment may be raised. Likely little to no redundancy to this facility.
Fire Protection District/Regional Training Center	Facility equipment may be damaged if flooded	Training facility serves the Menlo Park Fire Department, proximity of nearest training site is unknown.
Pump Station Pad (East)	Water may enter facility through doors, vents, and other flood pathways. Electrical equipment may be damaged if flooded	No backup system is available to service this area if pump station is inoperable. Sensitive electrical components may be raised and conduits openings can be sealed to increase adaptive capacity
Pump Station Pad (West)	Water may enter facility through doors, vents, and other flood pathways. Electrical equipment may be damaged if flooded	No backup system is available to service this area if pump station is inoperable. Sensitive electrical components may be raised and conduits openings can be sealed to increase adaptive capacity
Facebook HQ	Buildings are sensitive to flooding, especially if critical electrical and mechanical equipment is located on ground floor.	Flooding may temporarily limit building access and operation

Appendix B. Dumbarton Bridge Focus Area Conceptual Cost Estimate

Project:	Dumbarton Bridge Focus Area Conceptual Level Cost Estimate for Flood Protection Strategies
Date:	January 8, 2018
Prepared By:	Sarah Kassem (AECOM)

NOTES

This presents the estimated cost to implement each improvement strategy on a linear foot (LF) basis.
Unit costs per LF were calculated based on assumed dimensions of each improvement strategy.
The total cost to implement the strategies for each SLR scenario was determined by multiplying the cost per LF by the length of shoreline that required mitigation. This calculation is provided in the memo.
This spreadsheet just provides documentation on how the costs per LF was estimated.

ASSUMPTIONS

Costs do not include environmental mitigation, land acquisition, easements, and utility relocation.
Drainage costs do not include the costs of pump stations.

North Side				**South Side**				**Total**		
Low cost range	$	6.1	M	Low cost range	$	0.4	M	$	6.5	M
High cost range	$	18.2	M	High cost range	$	1.1	M	$	19.3	M

Strategy 1 - North Side

Raise Levee		435	FT

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
RAISING LEVEE CREST (BORROW FILL)			**$ 563**	$ 84	**$ 136**	**$ 196**	**$ 245**	**$ 122**	**$ 1,350**
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
TEMPORARY EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
CLEARING AND GRUBBING	ACRE	$ 6,882	$ 13	$ 2	$ 3	$ 5	$ 6	$ 3	$ 32
EARTH STRIPPING	CY	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 11
HAULING MATERIAL (40 MILE RT)	CY	$ 34	$ 243	$ 36	$ 59	$ 85	$ 106	$ 53	$ 581
PLACING AND COMPACTION	CY	$ 20	$ 144	$ 22	$ 35	$ 50	$ 63	$ 31	$ 344
FINISH GRADING	CY	$ 0.3	$ 2	$ 0	$ 1	$ 1	$ 1	$ 1	$ 6
GEOTEXTILE	SY	$ 10	$ 97	$ 15	$ 24	$ 34	$ 42	$ 21	$ 233
EROSION CONTROL - soil binder and hydroseed	SY	$ 5	$ 47	$ 7	$ 11	$ 16	$ 20	$ 10	$ 112

$ 0.60 M

NOTES:

LEVEE SIDE SLOPE	0.5	
EXISTING LEVEE ELEVATION	8.6	FT NAVD
FINAL ELEVATION ELEVATION	11.2	FT NAVD
CREST WIDTH	35	FT
LENGTH OF SIDE SLOPE	25.0	FT
VOLUME OF NEW SOIL	194	FT^3/FT
LENGTH TO GRADE	85	FT
STRIP 4''	0.33	FT

Strategy 2 - North Side

Construct new wall	1920	FT	

SHEETPILE WALL

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
SHEET PILE WALL INSTALLED IN EXISTING ROADWAY			$ 1,069	$ 160	$ 258	$ 372	$ 465	$ 232	$ 2,560
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
SITE PREP FOR EXISTING ROADWAY (SAW CUT PAVEMENT)	LF	$ 11	$ 11	$ 2	$ 3	$ 4	$ 5	$ 2	$ 25
PAVEMENT REMOVAL	SY	$ 7	$ 4	$ 1	$ 1	$ 1	$ 2	$ 1	$ 9
BASE REMOVAL	CY	$ 25	$ 2	$ 0	$ 1	$ 1	$ 1	$ 1	$ 6
HAUL AND DISPOSE OF SPOILS	CY	$ 19	$ 8	$ 1	$ 2	$ 3	$ 4	$ 2	$ 20
STEEL SHEET PILING (AZ-12-770)	SF	$ 66	$ 778	$ 117	$ 188	$ 271	$ 338	$ 169	$ 1,860
CONCRETE REINF CAP ON SSP	CY	$ 2,328	$ 172	$ 26	$ 42	$ 60	$ 75	$ 37	$ 412
DRAINAGE	ACRE	$ 41,885	$ 63	$ 9	$ 15	$ 22	$ 27	$ 14	$ 149
BASE PLACEMENT	CY	$ 47	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
PAVING	CY	$ 162	$ 15	$ 2	$ 4	$ 5	$ 7	$ 3	$ 36
									$ 4.9 M

NOTES:

EXISTING ELEVATION	8.25	FT NAVD
ELEVATION OF SHEETPILE	11.2	FT NAVD
HEIGHT OF SHEETPILE ABOVE GROUND	2.95	FT
ASSUMED 2ft x 1ft CONCRETE CAP	2	FT^3/FT
ASSUMED 5FT FOOTPRINT PER LF OF SHEETPILE	5	FT^2/FT
ASSUMED SHEET PILE WALL IS IMBEDDED 3X EXPOSED HEIGHT	8.85	FT
ROADWAY WIDTH	65	FT
ASSUMED BASE DEPTH	0.5	FT
ASSUME PAVING DEPTH	0.5	FT
ASSUMED SOIL SPOILS PER LF OF SHEET PILE DRIVING	0.25	CY

CONCRETE WALL

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
CONCRETE WALL INSTALLED IN EXISTING ROADWAY			$ 768	$ 115	$ 185	$ 267	$ 334	$ 167	$ 1,840
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
SITE PREP FOR EXISTING ROADWAY (SAW CUT PAVEMENT)	LF	$ 11	$ 11	$ 2	$ 3	$ 4	$ 5	$ 2	$ 25
PAVEMENT REMOVAL	SY	$ 7	$ 8	$ 1	$ 2	$ 3	$ 3	$ 2	$ 19
BASE REMOVAL	CY	$ 25	$ 5	$ 1	$ 1	$ 2	$ 2	$ 1	$ 12
STR EXCAVATION	CY	$ 34	$ 46	$ 7	$ 11	$ 16	$ 20	$ 10	$ 111
HAUL AND DISPOSE OF SPOILS	CY	$ 19	$ 18	$ 3	$ 4	$ 6	$ 8	$ 4	$ 43
STRUCTURAL BEDDING & BACKFILL	CY	$ 36	$ 14	$ 2	$ 3	$ 5	$ 6	$ 3	$ 33
EXCESS SOIL BACKFILL	CY	$ 20	$ 16	$ 2	$ 4	$ 6	$ 7	$ 4	$ 39
FOOTING REINF CONCRETE	CY	$ 534	$ 223	$ 33	$ 54	$ 77	$ 97	$ 48	$ 532
STEM WALL REINF CONCRETE	CY	$ 2,137	$ 313	$ 47	$ 76	$ 109	$ 136	$ 68	$ 748
DRAINAGE	ACRE	$ 41,885	$ 63	$ 9	$ 15	$ 22	$ 27	$ 14	$ 149
BASE PLACEMENT	CY	$ 47	$ 9	$ 1	$ 2	$ 3	$ 4	$ 2	$ 22
PAVING	CY	$ 162	$ 32	$ 5	$ 8	$ 11	$ 14	$ 7	$ 75
									$ 3.5 M

NOTES:

EXISTING ELEVATION	8.25	FT NAVD
ELEVATION OF CONCRETE WALL	11.2	FT NAVD
HEIGHT OF CONCRETE WALL	2.95	FT
ASSUMED FOOTING WIDTH	7.5	FT
ASSUMED FOOTING DEPTH	1.5	FT
ASSUMED BEDDING THICKNESS	1	FT
MINIMUM COVER OVER FOOTING	1	FT
CONSTRUCTION ACCESSIBILITY WIDTH	3	FT
EXCAVATION WIDTH	10.5	FT
EXCAVATION DEPTH	3.5	FT
ASSUMED WALL IS 1 FT THICK	1	FT
BACKFILL 60% OF EXCAVATION	22.1	FT^3/FT
ROADWAY WIDTH	65	FT
ASSUMED BASE DEPTH	0.5	FT
ASSUME PAVING DEPTH	0.5	FT

SHEETPILE WALL WITH CONCRETE BUTTRESS

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
SHEETPILE WALL WITH CONCRETE BUTTRESS INSTALLED IN EXISTING ROADWAY			$ 1,159	$ 174	$ 280	$ 403	$ 504	$ 252	$ 2,780
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
SITE PREP FOR EXISTING ROADWAY (SAW CUT PAVEMENT)	LF	$ 11	$ 11	$ 2	$ 3	$ 4	$ 5	$ 2	$ 25
PAVEMENT REMOVAL	SY	$ 7	$ 4	$ 1	$ 1	$ 1	$ 2	$ 1	$ 10
BASE REMOVAL	CY	$ 25	$ 3	$ 0	$ 1	$ 1	$ 1	$ 1	$ 6
STR EXCAVATION	CY	$ 34	$ 14	$ 2	$ 3	$ 5	$ 6	$ 3	$ 33
HAUL AND DISPOSE OF SPOILS	CY	$ 19	$ 12	$ 2	$ 3	$ 4	$ 5	$ 3	$ 30
STRUCTURAL BEDDING & BACKFILL	CY	$ 36	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 17
EXCESS SOIL BACKFILL	CY	$ 20	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 11
STEM WALL REINF CONCRETE	CY	$ 586	$ 230	$ 35	$ 56	$ 80	$ 100	$ 50	$ 550
STEEL SHEET PILING (AZ-12-770)	SF	$ 66	$ 778	$ 117	$ 188	$ 271	$ 338	$ 169	$ 1,860
DRAINAGE	ACRE	$ 41,885	$ 63	$ 9	$ 15	$ 22	$ 27	$ 14	$ 149
BASE PLACEMENT	CY	$ 47	$ 5	$ 1	$ 1	$ 2	$ 2	$ 1	$ 11
PAVING	CY	$ 162	$ 17	$ 2	$ 4	$ 6	$ 7	$ 4	$ 40
									$ 5.3 M

NOTES:

EXISTING ELEVATION	8.25	FT NAVD
ELEVATION OF SHEETPILE	11.2	FT NAVD
HEIGHT OF SHEETPILE ABOVE GROUND	2.95	FT
ASSUMED SHEET PILE WALL IS IMBEDDED 3X EXPOSED HEIGHT	8.85	FT
ASSUMED VOLUME OF BUTTRESS	10.6	FT^3/FT
BUTTRESS WIDTH	2.5	FT
EMBEDDED DEPTH	1	FT
CONSTRUCTION ACCESSIBILITY WIDTH	3	FT
ASSUMED BEDDING THICKNESS	1	FT
EXCAVATION WIDTH	5.5	FT
EXCAVATION DEPTH	2	FT
BACKFILL	6	FT^3/FT
ROADWAY WIDTH	65	FT
ASSUMED BASE DEPTH	0.5	FT
ASSUME PAVING DEPTH	0.5	FT
ASSUMED SOIL SPOILS PER LF OF SHEET PILE DRIVING	0.25	CY

Raise Levee	1370	FT	
Optional	7550	FT	

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
RAISING LEVEE CREST (BORROW FILL)			$ 563	$ 84	$ 136	$ 196	$ 245	$ 122	$ 1,350
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
TEMPORARY EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
CLEARING AND GRUBBING	ACRE	$ 6,882	$ 13	$ 2	$ 3	$ 5	$ 6	$ 3	$ 32
EARTH STRIPPING	CY	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 11
HAULING MATERIAL (40 MILE RT)	CY	$ 34	$ 243	$ 36	$ 59	$ 85	$ 106	$ 53	$ 581
PLACING AND COMPACTION	CY	$ 20	$ 144	$ 22	$ 35	$ 50	$ 63	$ 31	$ 344
FINISH GRADING	SY	$ 0.3	$ 2	$ 0	$ 1	$ 1	$ 1	$ 1	$ 6
GEOTEXTILE	SY	$ 10	$ 97	$ 15	$ 24	$ 34	$ 42	$ 21	$ 233
EROSION CONTROL - soil binder and hydroseed	SY	$ 5	$ 47	$ 7	$ 11	$ 16	$ 20	$ 10	$ 112
									$ 1.8 M
									$ 10.2 M

NOTES:

LEVEE SIDE SLOPE	0.5	
EXISTING LEVEE ELEVATION	8.6	FT NAVD
FINAL ELEVATION ELEVATION	11.2	FT NAVD
CREST WIDTH	35	FT
LENGTH OF SIDE SLOPE	25.0	FT
VOLUME OF NEW SOIL	194	FT^3/FT
LENGTH TO GRADE	85	FT
STRIP 4"	0.33	FT

Strategy 3 - North Side

Construct new wall	124	FT

SHEETPILE WALL

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
SHEET PILE WALL INSTALLED IN EXISTING ROADWAY			**$ 1,069**	**$ 160**	**$ 258**	**$ 372**	**$ 465**	**$ 232**	**$ 2,560**
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
SITE PREP FOR EXISTING ROADWAY (SAW CUT PAVEMENT)	LF	$ 11	$ 11	$ 2	$ 3	$ 4	$ 5	$ 2	$ 25
PAVEMENT REMOVAL	SY	$ 7	$ 4	$ 1	$ 1	$ 1	$ 2	$ 1	$ 9
BASE REMOVAL	CY	$ 25	$ 2	$ 0	$ 1	$ 1	$ 1	$ 1	$ 6
HAUL AND DISPOSE OF SPOILS	CY	$ 19	$ 8	$ 1	$ 2	$ 3	$ 4	$ 2	$ 20
STEEL SHEET PILING (AZ-12-770)	SF	$ 66	$ 778	$ 117	$ 188	$ 271	$ 338	$ 169	$ 1,860
CONCRETE REINF CAP ON SSP	CY	$ 2,328	$ 172	$ 26	$ 42	$ 60	$ 75	$ 37	$ 412
DRAINAGE	ACRE	$ 41,885	$ 63	$ 9	$ 15	$ 22	$ 27	$ 14	$ 149
BASE PLACEMENT	CY	$ 47	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
PAVING	CY	$ 162	$ 15	$ 2	$ 4	$ 5	$ 7	$ 3	$ 36
									$ 0.32 M

NOTES:		
EXISTING ELEVATION	8.25	FT NAVD
ELEVATION OF SHEETPILE	11.2	FT NAVD
HEIGHT OF SHEETPILE ABOVE GROUND	2.95	FT
ASSUMED 2ft x 1ft CONCRETE CAP	2	FT^3/FT
ASSUMED 5FT FOOTPRINT PER LF OF SHEETPILE	5	FT^2/FT
ASSUMED SHEET PILE WALL IS IMBEDDED 3X EXPOSED HEIGHT	8.85	FT
ROADWAY WIDTH	65	FT
ASSUMED BASE DEPTH	0.5	FT
ASSUME PAVING DEPTH	0.5	FT
ASSUMED SOIL SPOILS PER LF OF SHEET PILE DRIVING	0.25	CY

CONCRETE WALL

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
CONCRETE WALL INSTALLED IN EXISTING ROADWAY			**$ 768**	**$ 115**	**$ 185**	**$ 267**	**$ 334**	**$ 167**	**$ 1,840**
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
SITE PREP FOR EXISTING ROADWAY (SAW CUT PAVEMENT)	LF	$ 11	$ 11	$ 2	$ 3	$ 4	$ 5	$ 2	$ 25
PAVEMENT REMOVAL	SY	$ 7	$ 8	$ 1	$ 2	$ 3	$ 3	$ 2	$ 19
BASE REMOVAL	CY	$ 25	$ 5	$ 1	$ 1	$ 2	$ 2	$ 1	$ 12
STR EXCAVATION	CY	$ 34	$ 46	$ 7	$ 11	$ 16	$ 20	$ 10	$ 111
HAUL AND DISPOSE OF SPOILS	CY	$ 19	$ 18	$ 3	$ 4	$ 6	$ 8	$ 4	$ 43
STRUCTURAL BEDDING & BACKFILL	CY	$ 36	$ 14	$ 2	$ 3	$ 5	$ 6	$ 3	$ 33
EXCESS SOIL BACKFILL	CY	$ 20	$ 16	$ 2	$ 4	$ 6	$ 7	$ 4	$ 39
FOOTING REINF CONCRETE	CY	$ 534	$ 223	$ 33	$ 54	$ 77	$ 97	$ 48	$ 532
STEM WALL REINF CONCRETE	CY	$ 2,137	$ 313	$ 47	$ 76	$ 109	$ 136	$ 68	$ 748
DRAINAGE	ACRE	$ 41,885	$ 63	$ 9	$ 15	$ 22	$ 27	$ 14	$ 149
BASE PLACEMENT	CY	$ 47	$ 9	$ 1	$ 2	$ 3	$ 4	$ 2	$ 22
PAVING	CY	$ 162	$ 32	$ 5	$ 8	$ 11	$ 14	$ 7	$ 75
									$ 0.23 M

NOTES:		
EXISTING ELEVATION	8.25	FT NAVD
ELEVATION OF CONCRETE WALL	11.2	FT NAVD
HEIGHT OF CONCRETE WALL	2.95	FT
ASSUMED FOOTING WIDTH	7.5	FT
ASSUMED FOOTING DEPTH	1.5	FT
ASSUMED BEDDING THICKNESS	1	FT
MINIMUM COVER OVER FOOTING	1	FT
CONSTRUCTION ACCESSIBILITY WIDTH	3	FT
EXCAVATION WIDTH	10.5	FT
EXCAVATION DEPTH	3.5	FT
ASSUMED WALL IS 1 FT THICK	1	FT
BACKFILL 60% OF EXCAVATION	22.1	FT^3/FT
ROADWAY WIDTH	65	FT
ASSUMED BASE DEPTH	0.5	FT
ASSUME PAVING DEPTH	0.5	FT

SHEETPILE WALL WITH CONCRETE BUTTRESS

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
SHEETPILE WALL WITH CONCRETE BUTTRESS INSTALLED IN EXISTING ROADWAY			**$ 1,159**	**$ 174**	**$ 280**	**$ 403**	**$ 504**	**$ 252**	**$ 2,780**
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
SITE PREP FOR EXISTING ROADWAY (SAW CUT PAVEMENT)	LF	$ 11	$ 11	$ 2	$ 3	$ 4	$ 5	$ 2	$ 25
PAVEMENT REMOVAL	SY	$ 7	$ 4	$ 1	$ 1	$ 1	$ 2	$ 1	$ 10
BASE REMOVAL	CY	$ 25	$ 3	$ 0	$ 1	$ 1	$ 1	$ 1	$ 6
STR EXCAVATION	CY	$ 34	$ 14	$ 2	$ 3	$ 5	$ 6	$ 3	$ 33
HAUL AND DISPOSE OF SPOILS	CY	$ 19	$ 12	$ 2	$ 3	$ 4	$ 5	$ 3	$ 30
STRUCTURAL BEDDING & BACKFILL	CY	$ 36	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 17
EXCESS SOIL BACKFILL	CY	$ 20	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 11
STEM WALL REINF CONCRETE	CY	$ 586	$ 230	$ 35	$ 56	$ 80	$ 100	$ 50	$ 550
STEEL SHEET PILING (AZ-12-770)	SF	$ 66	$ 778	$ 117	$ 188	$ 271	$ 338	$ 169	$ 1,860
DRAINAGE	ACRE	$ 41,885	$ 63	$ 9	$ 15	$ 22	$ 27	$ 14	$ 149
BASE PLACEMENT	CY	$ 47	$ 5	$ 1	$ 1	$ 2	$ 2	$ 1	$ 11
PAVING	CY	$ 162	$ 17	$ 2	$ 4	$ 6	$ 7	$ 4	$ 40
									$ 0.34 M

NOTES:		
EXISTING ELEVATION	8.25	FT NAVD
ELEVATION OF SHEETPILE	11.2	FT NAVD
HEIGHT OF SHEETPILE ABOVE GROUND	2.95	FT
ASSUMED SHEET PILE WALL IS IMBEDDED 3X EXPOSED HEIGHT	8.85	FT
ASSUMED VOLUME OF BUTTRESS	10.6	FT^3/FT
BUTTRESS WIDTH	2.5	FT
EMBEDDED DEPTH	1	FT
CONSTRUCTION ACCESSIBILITY WIDTH	3	FT
ASSUMED BEDDING THICKNESS	1	FT
EXCAVATION WIDTH	5.5	FT
EXCAVATION DEPTH	2	FT
BACKFILL	6	FT^3/FT
ROADWAY WIDTH	65	FT
ASSUMED BASE DEPTH	0.5	FT
ASSUME PAVING DEPTH	0.5	FT
ASSUMED SOIL SPOILS PER LF OF SHEET PILE DRIVING	0.25	CY

Strategy 4 - South Side

Raise Levee	400	FT
Raise Levee	50	FT

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
RAISING LEVEE CREST (BORROW FILL)			**$ 363**	**$ 54**	**$ 88**	**$ 126**	**$ 158**	**$ 79**	**$ 870**
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
TEMPORARY EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
CLEARING AND GRUBBING	ACRE	$ 6,882	$ 10	$ 2	$ 2	$ 4	$ 4	$ 2	$ 25
EARTH STRIPPING	CY	$ 4	$ 3	$ 1	$ 1	$ 1	$ 1	$ 1	$ 8
HAULING MATERIAL (40 MILE RT)	CY	$ 34	$ 141	$ 21	$ 34	$ 49	$ 61	$ 31	$ 338
PLACING AND COMPACTION	CY	$ 20	$ 84	$ 13	$ 20	$ 29	$ 36	$ 18	$ 200
FINISH GRADING	SY	$ 0	$ 2	$ 0	$ 0	$ 1	$ 1	$ 0	$ 5
GEOTEXTILE	SY	$ 10	$ 75	$ 11	$ 18	$ 26	$ 33	$ 16	$ 179
EROSION CONTROL - soil binder and hydroseed	SY	$ 5	$ 36	$ 5	$ 9	$ 12	$ 16	$ 8	$ 86

NOTES:

LEVEE SIDE SLOPE	0.5	
EXISTING LEVEE ELEVATION	8.6	FT NAVD
FINAL ELEVATION ELEVATION	10.6	FT NAVD
CREST WIDTH	18	FT
LENGTH OF SIDE SLOPE	23.7	FT
VOLUME OF NEW SOIL	113	FT^3/FT
LENGTH TO GRADE	65	FT
STRIP 4"	0.33	FT

$ 0.35 M
$ 0.050 M

SHEETPILE WALL

Bid Description	Units	Unit Cost	Direct Costs per LF	Mobilization/ Demobilization (15%)	Overhead and Profit Costs (21%)	Construction Contingency (25%)	Design Contingency and Fee (25%)	Environmental Clearance/ Permitting (10%)	Estimated Total Costs
SHEET PILE WALL INSTALLED IN EXISTING ROADWAY			**$ 1,069**	**$ 160**	**$ 258**	**$ 372**	**$ 465**	**$ 232**	**$ 2,560**
TEMPORARY FENCE	LF	$ 4	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
EROSION CONTROL MEASURES	LF	$ 7	$ 7	$ 1	$ 2	$ 3	$ 3	$ 2	$ 18
SITE PREP FOR EXISTING ROADWAY (SAW CUT PAVEMENT)	LF	$ 11	$ 11	$ 2	$ 3	$ 4	$ 5	$ 2	$ 25
PAVEMENT REMOVAL	SY	$ 7	$ 4	$ 1	$ 1	$ 1	$ 2	$ 1	$ 9
BASE REMOVAL	CY	$ 25	$ 2	$ 0	$ 1	$ 1	$ 1	$ 1	$ 6
HAUL AND DISPOSE OF SPOILS	CY	$ 19	$ 8	$ 1	$ 2	$ 3	$ 4	$ 2	$ 20
STEEL SHEET PILING (AZ-12-770)	SF	$ 66	$ 778	$ 117	$ 188	$ 271	$ 338	$ 169	$ 1,860
CONCRETE REINF CAP ON SSP	CY	$ 2,328	$ 172	$ 26	$ 42	$ 60	$ 75	$ 37	$ 412
DRAINAGE	ACRE	$ 41,885	$ 63	$ 9	$ 15	$ 22	$ 27	$ 14	$ 149
BASE PLACEMENT	CY	$ 47	$ 4	$ 1	$ 1	$ 2	$ 2	$ 1	$ 10
PAVING	CY	$ 162	$ 15	$ 2	$ 4	$ 5	$ 7	$ 3	$ 36

NOTES:

EXISTING ELEVATION	8.25	FT NAVD
ELEVATION OF SHEETPILE	11.2	FT NAVD
HEIGHT OF SHEETPILE ABOVE GROUND	2.95	FT
ASSUMED 2ft x 1ft CONCRETE CAP	2	FT^3/FT
ASSUMED 5FT FOOTPRINT PER LF OF SHEETPILE	5	FT^2/FT
ASSUMED SHEET PILE WALL IS IMBEDDED 3X EXPOSED HEIGHT	8.85	FT
ROADWAY WIDTH	65	FT
ASSUMED BASE DEPTH	0.5	FT
ASSUME PAVING DEPTH	0.5	FT
ASSUMED SOIL SPOILS PER LF OF SHEET PILE DRIVING	0.25	CY

$ 1.02 M

References

Line Item #	Line Item	Sub Item	2017 Unit Cost	Unit	Notes	Source	Source Index Number	YEAR
	Site Preparation							
	Site Clearance							
		Clear & Grub (along levee, along shoreline)	$ 6,882.25	ACRE	Clearing & Grubbing, Brush, including Stumps	RS MEANS	311110100160	2017
		Sawcut Pavement	$ 10.66	LF	Site prep for roadway work, cutting through pavement	SFO shoreline project		2017
		Pavement Removal 4"-6"	$ 6.72	SY	demolish and remove pavement	RS MEANS	24113175050	2017
		Base Removal	$ 24.96	CY	remove base	Caltrans Cost Index	150860	2016
		Haul and Dispose of Spoils	$ 19.32	CY	12 CY truck, cycle 40 miles (RT), 35 mph, 15 min/ld/uld	RS MEANS	312323201270	2017
		Temporary Fence	$ 4.33	LF	procurement and installation	Caltrans Cost Index	141000	2016
		Temporary Silt Fence	$ 7.33	LF	procurement and installation	Caltrans Cost Index	130670	2016
	Earthwork							
	Levee Raising (haul & fill)							
		Procurement of Fill Material	$ 14.50	CY	Material cost of common borrow	RS MEANS	310513100200	2017
		Haul Import Fill From Borrow to Site	$ 19.32	CY	12 CY truck, cycle 40 miles (RT), 35 MPH ave, 15min wait/ld/uld	RS MEANS	312323201270	2017
		Placement of Fill through out site	$ 18.35	CY	Backfill, Spread with dozer	RS MEANS	312323160020	2017
		Earth Strip	$ 2.55	CY	topsoil stripping, medium hard, adverse conditions	RS MEANS	311413231100	2017
		Grade	$ 0.26	SY	Finish grading slopes, gentle	RS MEANS	312216103310	2017
		Compact	$ 1.67	CY	Sheetsfoot or wobbly wheel roller 6" lifts, 2 passes	RS MEANS	312323240300	2017
		Geotextile	$ 10.30	SY		Caltrans Cost Index	198209	2016
		Soil Binder	$ 0.41	SY		Caltrans Cost Index	130560	2016
		Hydroseed	$ 4.53	SY		Caltrans Cost Index	130550	2016
	Excavation							
		Structural Excavation	$ 33.99	CY		Caltrans Cost Index	192001	2016
	Sheet pile							
	Steel Sheet Piling							
		Furnish Steel Sheet Piling	$ 14.42	SF	Procurement and delivery	Caltrans Cost Index	490553	2016
		Drive Steel Sheet Piling	$ 51.50	SF	Installation	Caltrans Cost Index	490554	2016
		Concrete cap	$ 2,328.00	CY	Installation and material cost for a reinforced concrete cap on sheet pile wall.	SFO shoreline project		2017
	Concrete Wall							
	Concrete Wall							
		Reinforced Concrete Footing	$ 534.00	CY	Installation and material costs	SFO shoreline project		2017
		Reinforced Concrete Stem Wall	$ 2,137.00	CY	Installation and material costs	SFO shoreline project		2017
		Structural Concrete, Retaining Wall	$ 586.07	CY		Caltrans Cost Index	510060	2016
	Roadwork							
		Compact Embankment	$ 1.67	CY	Sheetsfoot or wobbly wheel roller 6" lifts, 2 passes	RS MEANS	312323240300	2017
		Furnish Aggregate Base Class 2	$ 45.32	CY		Caltrans Cost Index	260203	2016
		Hot Mix Asphalt	$ 160.60	CY		Caltrans Cost Index	390132	2016
	Drainage							
		Drainage	$ 41,884.65	ACRE	includes manholes, catch basins, pipes, trench drains	Port of LA project		2017