# SAN FRANCISCO WATERFRONT COASTAL FLOOD STUDY, CA

# APPENDIX B.2 – COASTAL LIFE SAFETY

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USACE TULSA DISTRICT | THE PORT OF SAN FRANCISCO

US Army Corps of Engineers

PORT OF SAN FRANCISCO

## General Methodology

USACE PB 2019-04 provides guidance for incorporating Life Safety into Coastal Storm Risk Management (CSRM) Studies. This guidance is based on levees and the San Francisco CSRM essentially functions as a levee at higher rates of SLC when the flood protection structures are loaded more frequently (or constantly) than they are during rare storm events. Paragraph 4b requires sources of life risk to be identified, while evaluating the increase, or transformation of risk to life due to sea level rise and protection provided by the CSRM. Paragraph 5d requires a life safety risk assessment to be conducted for all new levee systems. The Project Delivery Team (PDT) plans to conduct the detailed life safety assessment after the TSP is selected. For the initial alternatives array, the PDT has conducted a qualitative assessment which is documented in this supplemental report.

The metrics documented in this supplemental report are qualitative and intended to provide a high level, relative comparison of performance between the future without project (FWOP) condition and the various project alternatives. Evaluations considered two CSRM failure modes and two water level scenarios. As such, the metric scores are provided on a scale of 1 to 5, with the score of 1 indicating a poor outcome and 5 indicating a positive outcome with respect to the metric being evaluated. The information used to reach these scores is based upon professional judgment within the PDT. The specific methodology for each metric and generalized rubric for scoring for each is provided in the sections below.

## Life-Safety Performance Relative to Coastal Storm Risk

This metric is intended to qualitatively compare the performance of the alternatives with the life-safety hazard caused by coastal water levels that are unabated by the CSRM system, and/or exacerbated by a failure of the CSRM system when resisting coastal waters (i.e., fragility). The evaluation of the life-safety hazard is dependent on the coastal water levels and the frequency at which they are expected to be present. Safety is considered compromised when an unexpected failure of the CSRM system results in 2 feet or more of water suddenly entering urban areas of the city without warning.

## Future without Project Condition

In the future without project (FWOP) condition, the life-safety hazard associated with inundation of coastal water is expected to be low, due to the long and slow development of the coastal hazard. Tides rise and fall daily, and extreme storm events coinciding with high tides will lead to exceptionally high-water levels. However, these tidal fluctuations do not occur suddenly, which allows time for most of the population to safely evacuate without presenting a life safety hazard. In addition to the higher water levels, storm events may also bring significant wave energy to the shoreline, causing waves to overtop structures, as was experienced during the Winter 2023 storms. These waves may present a low to moderate hazard, for members of the public that do not heed warnings.

## Future with Project Condition

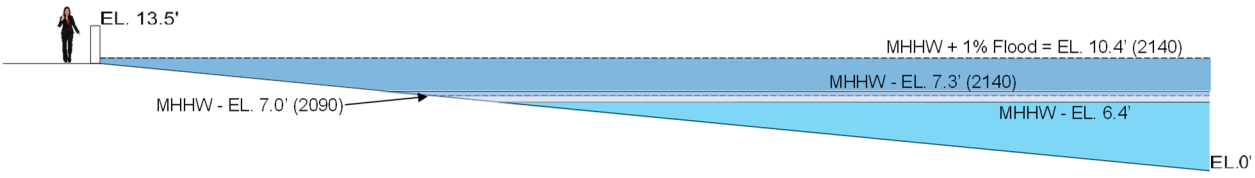
For the future with project (FWP) condition, the life-safety hazard relates to each SLC curve considering the following conditions:

- CSRM Overtopped with water level equal to the MHHW plus the 1% storm surge.
- CSRM Overtopped with water level equal to the MHHW (i.e., Sunny Day Failure).
- CSRM sudden failure with water level equal to the MHHW plus the 1% storm surge.
- CSRM sudden failure with water level equal to the MHHW.
- Failure of the CSRM system due to an earthquake, while loaded with the typically expected water level *(*Note: Not addressed in this analysis)*

The 1-5 rating scale for the anticipated outcome is as follows: 1=Poor, 2=Moderately Poor, 3=Neutral, 4=Moderately Positive, 5=Positive. In the absence of performing a risk assessment for each alternative, the following assumptions were made when assessing the performance of each condition above. For overtopping, each flood defense measure is assumed to not fail during an overtopping event. Sufficient advance warning would be provided to residents as several gages are along the waterfront and the National Weather Service (NWS) provides sufficient warning when large storms are forecasted in the bay area. A Sunny Day Failure is based on normal loading conditions, therefore minimal warning time would be provided as structures are not expected to fail in these circumstances. Depending on the SLC curve adopted for design and the amount of sea level rise at the time of failure, the life safety risk due to flooding can range between positive and poor outcomes. The figures below represent the forecasted elevations based on the USACE low, intermediate, and high curves.

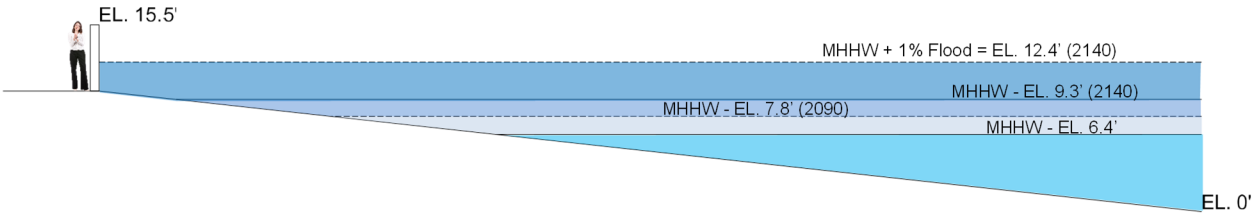
## USACE Low SLC Curve

For the low SLC curve, which is estimated to be +0.9’ at 2140, the MHHW plus SLC is at elevation 7.3’ (representing the tide-only sunny day scenario), and at 10.4’ when including a 1% (100-year) storm surge and SLC. A sunny day failure would result in no additional flooding to the study areas since a majority of the waterfront shoreline is between elevations 10.0’ and 12.0’, with the lowest elevation down to elevation +8.5’.  Stillwater levels associated with the low SLC curve in 2140 and storm surge would also only slightly exceed the existing shoreline elevations in portions of the project length and touch the proposed CSRM measures based on an assumed low SLC curve. If a failure of an isolated area of a CSRM measure did occur, minimal flooding depths would be seen, approximately equal to what currently occurs today, with most areas experiencing no flooding. Life loss associated with failure of any proposed CSRM measure with these potentially retained water levels are judged to be zero in the low SLC curve scenario.



## USACE Intermediate SLC Curve

The intermediate curve is forecasted to raise sea level by 1.4’ in 2090 and 2.9’ by 2140. This results in MHHW elevations of 7.8’ (2090) and 9.3’ (2140). On a sunny day (tide only in 2140), none of the proposed CSRM measures would be loaded, thus resulting in no flooding in the event of failure. Including the 1% storm surge in 2140, increases the water elevation to 12.4’, thus loading the proposed CSRM measures with approximately 0.4’ to 2.4’ depth of water. A failure of the flood defenses with water levels at elevation 12.4’ would result in somewhat continuous flooding with water depths of 2’ or less across most of the study area. Life loss associated with failure of any proposed CSRM measure with the intermediate SLC curve and associated retained water levels are judged to be minimal, since water depths are less than 2’ on average.

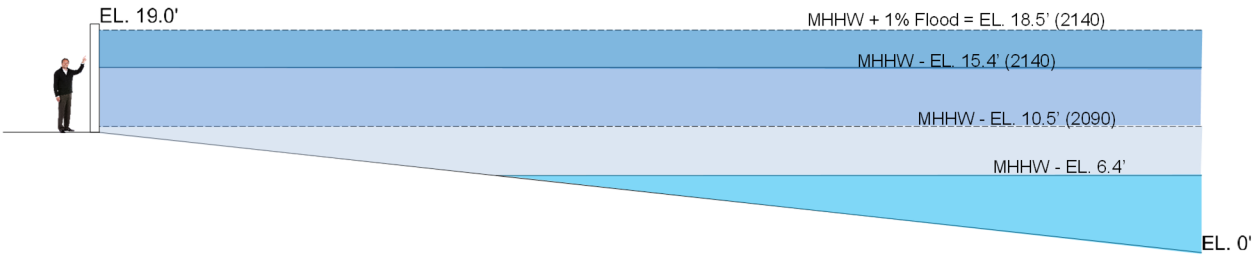



## USACE High SLC Curve

The high SLC curve is forecasted to raise sea levels by 4.1’ in 2090 and 9’ in 2140. This results in MHHW elevations of 10.5’ (2090) and 15.4’ (2140) for the sunny day (tide only) case. No matter which structural CSRM measures are implemented (i.e., for low, intermediate, high SLC curves) there will be minimal to no flooding in the sunny day event under the high SLC curve by 2090. The sunny day MHHW elevation is forecasted to be 15.4’ in 2140, thus requiring CSRM measures to be built to at least elevation 15.5’ resulting in water depths at the structure between approximately 2.5’ to 5.5’ during a higher high tide event. A failure of the flood defense in this scenario would result in widespread flooding and potentially significant life loss. Minimal to no warning would be provided as the failure would not be related to a forecasted storm event and the local population would not expect a failure to occur.

Assuming rationale and responsive behavior of businesses and residences protected by the CSRM system, measures built to an elevation of 13.5’ would result in fewer lives lost since the 2140 sunny day water elevation would be known to overtop this line of protection and action would be taken to ensure adequate warning is provided to the public to warn against anticipated flooding. Adding the 1% storm surge in 2140, produces an elevation of 18.5’, thus requiring proposed CSRM measures to be built to an elevation of 19.0’ with approximately 6.5’ to 8.5’ of retained water depth if high SLC and the 1% storm event occurs. A failure with the bay water level at this elevation would result in catastrophic, widespread flooding and significant life loss occurring. Life loss potential would be significantly less and potentially zero for CSRM measures built to elevations of 13.5’ and 15.5’ as the 2140 MHHW plus 1% storm surge water

elevation would be known to overtop these lines of protection and adequate warning could be provided to the public to warn against anticipated flooding.




For this qualitative assessment the alternatives were determined to score as follows for the failure conditions and sea level change scenarios as follows:

**Overtopping with 2140 MHHW+1% storm surge (note that overtopping is only anticipated for Alts C & D with the High SLC curve)**

| Alt | Low SLC (El 10.4') | Int SLC (El 12.4') | High SLC (El 18.5') |
|---|---|---|---|
| A | NA | NA | NA |
| B | 5 | 4 | 2 |
| C (13.5') | 5 | 5 | 4 |
| D (15.5') | 5 | 5 | 4 |
| E (19.0') | 5 | 5 | 5 |
| F (19.0') | 5 | 5 | 5 |
| G (19.0') | 5 | 5 | 5 |

**Overtopping with 2140 MHHW, Sunny Day (note that overtopping is only anticipated for Alt C with the High SLC curve)**

| Alt | Low SLC (El 7.3') | Int SLC (El 9.3') | High SLC (El 15.4') |
|---|---|---|---|
| A | NA | NA | NA |
| B | 5 | 4 | 2 |
| C (13.5') | 5 | 5 | 4 |
| D (15.5') | 5 | 5 | 5 |
| E (19.0') | 5 | 5 | 5 |
| F (19.0') | 5 | 5 | 5 |
| G (19.0') | 5 | 5 | 5 |

**Sudden Failure with 2140 MHHW+1% storm surge (* indicates Alt already overtopped)**

| Alt | Low SLC (El 10.4') | Int SLC (El 12.4') | High SLC (El 18.5') |
|---|---|---|---|
| A | NA | NA | NA |
| B | 5 | 3 | 2 |
| C (13.5') | 5 | 5 | NA* |
| D (15.5') | 5 | 5 | NA* |
| E (19.0') | 5 | 5 | 1 |
| F (19.0') | 5 | 5 | 1 |
| G (19.0') | 5 | 5 | 1 |

**Sudden Failure with 2140 MHHW, Sunny Day (* indicates Alt already overtopped)**

| Alt | Low SLC (El 7.3') | Int SLC (El 9.3') | High SLC (El 15.4') |
|---|---|---|---|
| A | NA | NA | NA |
| B | 5 | 3 | 2 |
| C (13.5') | 5 | 5 | NA* |
| D (15.5') | 5 | 5 | 2 |
| E (19.0') | 5 | 5 | 1 |
| F (19.0') | 5 | 5 | 1 |
| G (19.0') | 5 | 5 | 1 |

The PDT evaluated each alternative as a whole and did not separate the northern waterfront from the southern. The retreat, or fall back, alternatives (F and G) would result in more positive outcomes if the scores were assigned per reach as portions of the population at risk would be removed from the area, the existing ground surface generally being higher resulting in shorter CSRM measures and resulting

discontinuity of back flooding potential across the project length. However, the scores reflect the single, worst-case scenario which assumes failure in one location would allow back flooding of the entire project. Additionally, a detailed risk assessment would account for the probability of failure as it relates to the type and design of the CSRM system, which was not taken into consideration for this qualitative risk assessment. As such this coastal life safety score should be taken into consideration for plan selection but should not be used as a screening tool based upon individual alternative scoring.