National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for San Francisco Maritime National Historical Park

Summary of Results

NPS 350/197705, March 2025

PROGRAM FOR THE STUDY OF DEVELOPED SHORELINES

Western Carolina University

ON THE COVER
San Francisco Maritime National Historical Park
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Program for the Study of Developed Shorelines
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This document has been developed by the NPS Climate Change Response Program and Park Facilities Management Division in partnership with Western Carolina University through a Task Agreement with the Southern Appalachian Cooperative Ecosystems Studies Unit.

Please cite this publication as:

Peek, K.M., H.L. Thompson, B.R. Tormey, and R.S. Young. 2025. Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for San Francisco Maritime National Historical Park: Summary of Results. NPS 350/197705. Program for the Study of Developed Shorelines, Western Carolina University, Cullowhee, N.C.

Executive Summary

This document presents the results of the **Coastal Hazards & Sea-Level Rise (SLR) Asset Vulnerability Assessment (VA)** completed by Western Carolina University at San Francisco Maritime National Historical Park (SAFR) in 2024. In this VA, we evaluate the vulnerability (as a combination of exposure and sensitivity) of NPS buildings and transportation assets[1] to identified coastal hazards and climate change factors, approximately to the year 2050 (for full methodology, see Peek et al. 2022).

We assessed 22 buildings (including comfort stations, sheds, structures, and a seawall), and 20 transportation assets (roads, parking lots, trails/walkways, piers, and historic vessels) at SAFR. Almost two-thirds of the assets evaluated at SAFR have high (64%) vulnerability to the evaluated coastal hazards and SLR, while 10% have moderate vulnerability, and 26% have low vulnerability. None of the evaluated assets have minimal vulnerability (outside of all hazard zones). Scoring details and results for all assets evaluated at SAFR are reported in the provided Excel sheets.

The NPS is planning to relocate the historic ship fleet at SAFR to a more site inland located on Mare Island in Vallejo, California. To help understand coastal exposure of the relocation site, we acquired the standard coastal hazard flood data, as well as a digital elevation model and potential wave height model. These data show relatively low coastal hazard exposure and reduced wave heights (compared to the current fleet location), suggesting Mare Island will likely provide a more sheltered environment for the sensitive historic vessels at SAFR.

[1] The NPS Facility Management Software System (FMSS) database defines assets as "...a physical structure or grouping of structures, land features, or other tangible property that has a specific service or function, such as a farm, cemetery, campground, marina, or sewage treatment plant. The term 'asset' shall also be applied to movable items, such as vehicles and equipment."

Exposure Results

Exposure is a measure of the character, magnitude, and rate of changes a target may experience (e.g., from the impacts of natural hazards or climate change; NPS 2021). In this VA, we evaluate the exposure of each asset to the following coastal hazard indicators: flooding potential, shoreline change, SLR inundation, extreme event flooding, and reported coastal hazards (Table 1).

Table 1. Exposure indicators and hazard data sources used for SAFR.

Exposure Indicator (Description)	Data (Citation)
Flooding potential (1% annual-chance)	Effective FEMA VE & A zones (FEMA 2018; 2021)
Shoreline change (coastal proximity)	30-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050 proxy) *	NPS 2100 4.5 RCP SLR model; 0.41 m rise (Caffrey et al. 2018) NOAA 1 ft SLR inundation zone (NOAA 2022)
Extreme event flooding	California Tsunami Hazard Areas (Graehl et al. 2022)
Reported coastal hazards (historic flooding)	Questionnaire results & discussions (Peek et al. 2022)

*See Unique Considerations

Assets with high exposure are within at least four exposure indicator hazard zones. Assets with moderate exposure are within two or three exposure indicator hazard zones. Assets with low exposure are within only one exposure indicator hazard zone. Low exposure assets could still be seriously impacted by this hazard. Assets with minimal exposure are not in any exposure indicator hazard zone. Minimal exposure does not mean that the asset has no exposure to coastal hazards, but it is not within the mapped exposure hazard zones used in this study.

Over half (52%) of all assets analyzed at SAFR have high exposure to the coastal hazards evaluated (Table 2, and Figures 1-2). Transportation assets make up the majority of the high exposure assets across the park, most of which are water-related assets such as piers, docks, and historic vessels. Eight buildings/structures have high exposure, two of which are within all evaluated exposure zones (Sea Scout Base Building and Aquatic Park Seawall, Figure 2A). Almost one-quarter of assets evaluated at SAFR have moderate exposure, over one-quarter have low exposure, and no assets have minimal exposure (all assets are within the tsunami hazard zone).

Table 2. SAFR exposure results. Sum of percentages may not equal 100 due to rounding.

	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	8	36%	7	32%	7	32%	0	0%	22
Transportation	14	70%	2	10%	4	20%	0	0%	20
All Assets	22	52%	9	21%	11	26%	0	0%	42

Figure 1. SAFR exposure results summary for the A) Fort Mason and B) San Leandro areas. Background is 2022 ESRI world imagery.

Figure 2. SAFR exposure results summary for the A) Aquatic Cove and B) Adjacent Piers areas. Only high or moderate areas and assets are labeled. Background is 2022 ESRI world imagery.

Sensitivity Results

Sensitivity reflects the degree to which a resource is affected by exposure (NPS 2021). In this VA, we assess the following sensitivity indicators: flood damage potential/elevated, storm resistance and condition, historic damage, and protective engineering. In general, assets with high sensitivity have unfavorable determinations for three or four of these indicators, moderate sensitivity assets have unfavorable determinations for two indicators, and low sensitivity assets have unfavorable determinations for zero or one indicator. Assets with minimal exposure are not analyzed for sensitivity (no assets at SAFR have minimal exposure).

Over one-third (36%) of all assets analyzed at SAFR have high sensitivity to the coastal hazards evaluated (Table 3). The remaining assets (64%) have moderate sensitivity (no assets have low sensitivity). In most cases, assets had high sensitivity (versus moderate) due to the condition indicator. No assets were reported to be storm resistant or to have effective protective engineering.

More transportation assets at SAFR have high sensitivity compared to buildings (18% difference). Four assets received unfavorable rankings for all sensitivity indicators: Sea Scout Marina; Hyde Street Pier (NPS-Owned Portion); Hyde Street Pier Area, Docks, Piers; and Hyde Street Pier (Old Highway 101).

Table 3. SAFR sensitivity results. Sum of percentages may not equal 100 due to rounding.

	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**#**
Buildings	6	27%	16	73%	0	0%	22	0
Transportation	9	45%	11	55%	0	0%	20	0
All Assets	15	36%	27	64%	0	0%	42	0

*Minimal exposure assets were excluded from the sensitivity analysis; total number analyzed is different for sensitivity.

Vulnerability Results

Vulnerability is a measure of the degree to which park resources and assets are "susceptible to harm from direct and indirect effects of climate change, including variability and extremes" (NPS 2021). In this VA, we evaluate the vulnerability of infrastructure assets as a simple combination of exposure and sensitivity ratings. It should be noted that the vulnerability of any asset can change with time (e.g., due to adaptation actions or the result of geomorphic change).

Almost two-thirds of the evaluated assets at SAFR have high vulnerability to the assessed coastal hazards and SLR (Table 4, and Figures 3-4). Two buildings and 10 transportation assets have both high vulnerability and a high asset priority index (API ≥ 70, as reported in FMSS). Three assets have

high vulnerability and the highest possible priority (API = 100): HS-Scow Schooner Alma, HS-SV Balclutha, and HS-Ferryboat Eureka.

Ten assets have both high exposure and sensitivity, including the Aquatic Park Service Road (Promenade), Sea Scout Base Building, and all piers, docks, and marinas. Only 10% of all assets evaluated at SAFR have moderate vulnerability, 26% have low vulnerability, and no assets have minimal vulnerability (Table 4, and Figures 3-4).

Table 4. SAFR vulnerability results. Sum of percentages may not equal 100 due to rounding.

	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	12	55%	3	14%	7	32%	0	0%	22
Transportation	15	75%	1	5%	4	20%	0	0%	20
All Assets	27	64%	4	10%	11	26%	0	0%	42

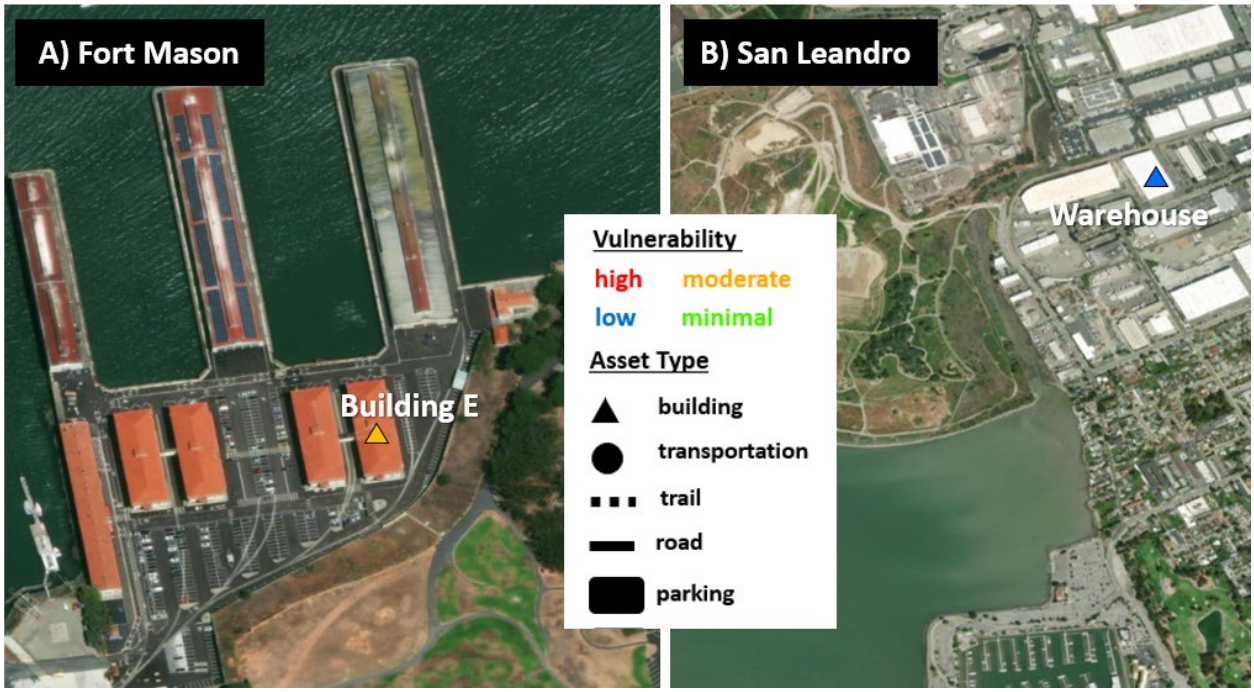

Figure 3. SAFR vulnerability results summary for the A) Fort Mason and B) San Leandro areas. Background is 2022 ESRI world imagery.

Figure 4. SAFR vulnerability results summary for the A) Aquatic Cove and B) Adjacent Piers areas. Only high or moderate areas and assets are labeled. Background is 2022 ESRI world imagery.

Mare Island Exposure

Due to the age, condition, and coastal hazard exposure of the Hyde Street Pier, the NPS is planning to relocate the historic ship fleet beginning in March of 2025. The NPS has secured a long-term lease of property along the shoreline of the Napa River on Mare Island in Vallejo, California for this relocation (Figure 5). The NPS is interested in the exposure of the leased property, as well as the larger Mare Island area for potential future use.

Figure 5. Map of the Bay area, showing the primary SAFR site and Mare Island relocation site (background is 2022 ESRI world imagery). Inset shows the Mare Island and NPS lease areas along the Napa River. Note the direction of north for the inset (background is 2020 Google Earth imagery).

While this VA protocol (Peek et al. 2022) is not designed to evaluate the vulnerability of a landscape, hazard data can be used to highlight the overall coastal exposure of an area. We acquired the standard coastal hazard flood data for Mare Island: flood hazard maps (FEMA 2016), 1-foot SLR inundation zones (NOAA 2022), and tsunami hazard zones (Graehl et al. 2022).

The coastal hazard maps do not show flood waters overtopping the bulkhead along Waterfront Avenue in the NPS Lease area (Figure 6). All three flooding data models show potential inundation north of the causeway (where the land is less developed) and to the south near the dry docks. The Federal Emergency Management Agency (FEMA) AE (1% annual chance flood zone) shows the most extensive flooding in these areas. Because most of this portion of the Mare Island shoreline is hardened/engineered (except north of the causeway), it is unlikely to experience significant erosion or shoreline retreat.

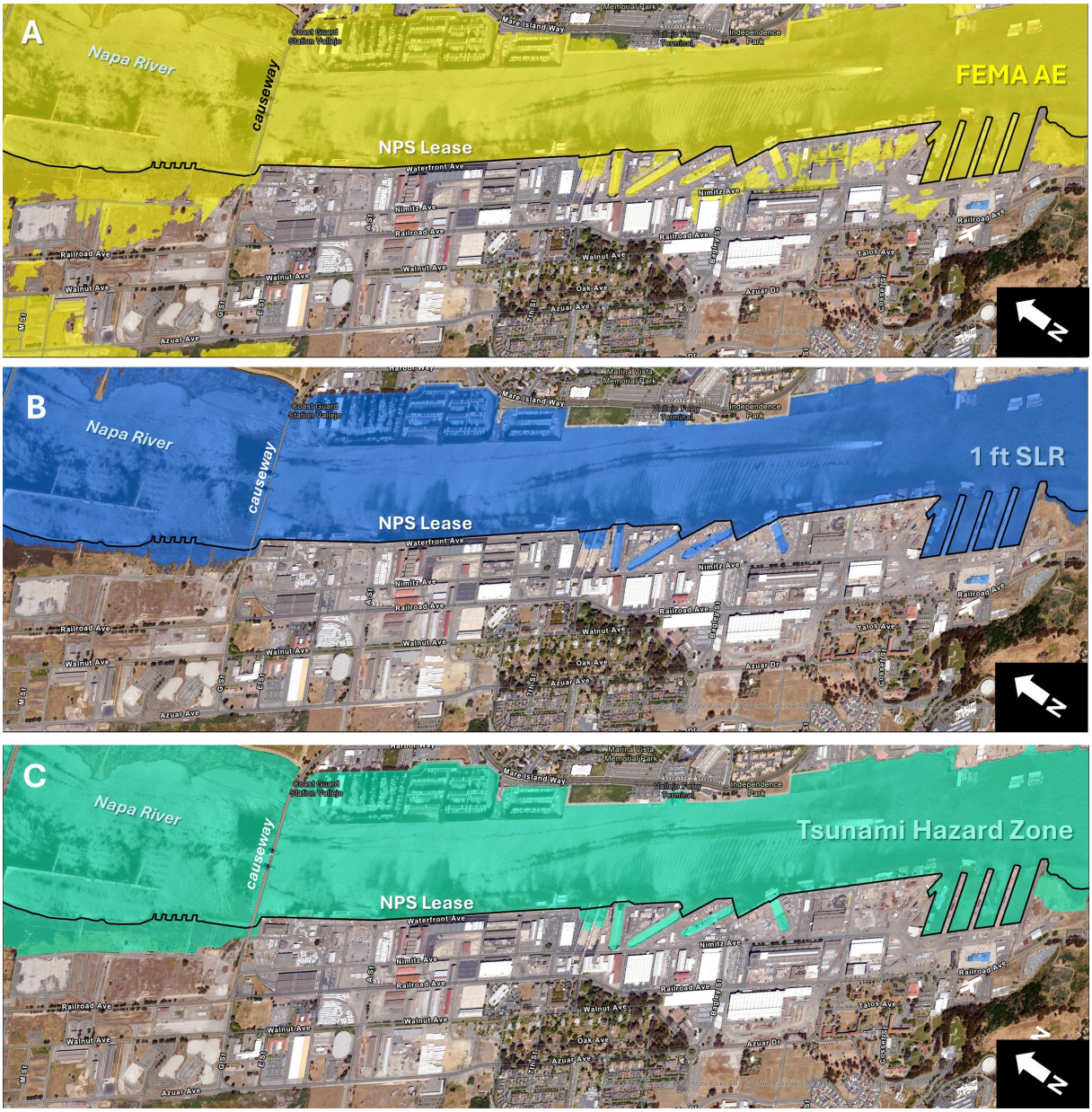

Figure 6. Coastal hazard exposure data for the Mare Island area of interest: A) FEMA AE - 1% annual chance flood zone, B) NOAA 1-foot SLR inundation zone, and C) California tsunami hazard zone. Background is 2022 California NAIP imagery (OCM 2025b). The black line represents the 2022 Mare Island Napa River shoreline. Note the direction of north.

To further evaluate the exposure of this area, we obtained a digital elevation model (OCM 2025a) and potential wave height model (Barnard et al. 2019). Mare Island has significant elevation (over 200 feet above NAVD88), particularly on the southern end within the Mare Island Shoreline Heritage Preserve. The lowest elevations are found along the non-engineered shorelines on the far north and south ends of the study area (6-8 feet above NAVD88). Higher elevations are found along the NPS Lease area, ranging from 10-12 feet above NAVD88 (Figure 7A).

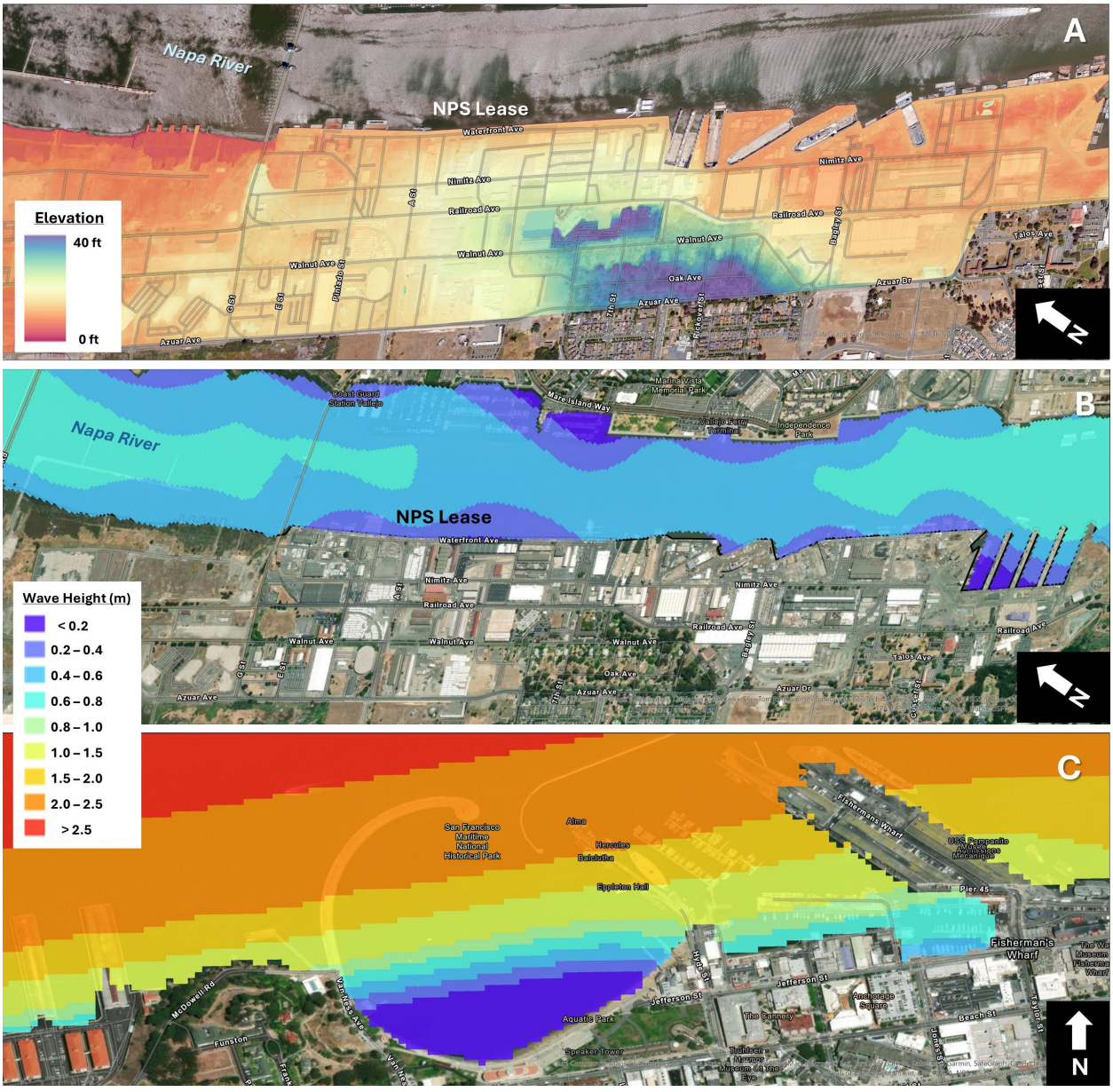

Figure 7. A) LiDAR digital elevation model (in feet above NAVD88) of approximate land area between the Napa River shoreline and Azuar Avenue. Potential wave heights (in meters) during a modeled 100-year flood for the B) Napa River near Mare Island and C) primary SAFR site near San Francisco. Background is 2022 California NAIP imagery (OCM 2025a). Note the direction of north in each figure.

Wave heights in this area of the Napa River are predicted to reach up to 0.8 m (2.6 ft) during a 100-year flood event (Figure 7B). Directly adjacent to the NPS Lease area, wave heights in the river are modeled to be less than 0.5 m (1.6 ft). This is approximately 1 m (3.3 ft) less than the modeled wave heights in Aquatic Cove at Hyde Street Pier (Figure 7C). The inland location, relatively low coastal hazard exposure (Figure 6), and lower potential wave heights (Figure 7) suggest Mare Island is a suitable site for the relocation of the sensitive historic vessels at SAFR (and other future use). These conditions provide a more sheltered environment compared to the higher energy shoreline of San Francisco Bay.

SAFR Unique Considerations

FMSS Assets: We analyzed two assets at SAFR that are not currently listed in FMSS: USS Pampanito and SS Jeremiah O'Brien. These are park adjacent historic vessels included in the founding legislation for SAFR.

Flood damage potential data: In addition to the effective FEMA data for San Francisco (2021) and Alameda (2018) counties, we consulted the Adapting to Rising Tides (ART) 12 inches plus 100-year flood inundation model (ART 2020).

SLR data: We used two sources for the SLR indicator: 1) National Oceanic and Atmospheric Administration (NOAA) 1 ft SLR model (2022), and 2) NPS 2100 4.5 Representative Concentration Pathway SLR projection and inundation model (Caffrey et al. 2018; 0.41 m or 1.3 ft rise for SAFR). These data are used as a proxy for 2050 SLR to accommodate higher SLR projections recently released by NOAA (see Peek et al. 2022).

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NPS 350/197705, March 2025