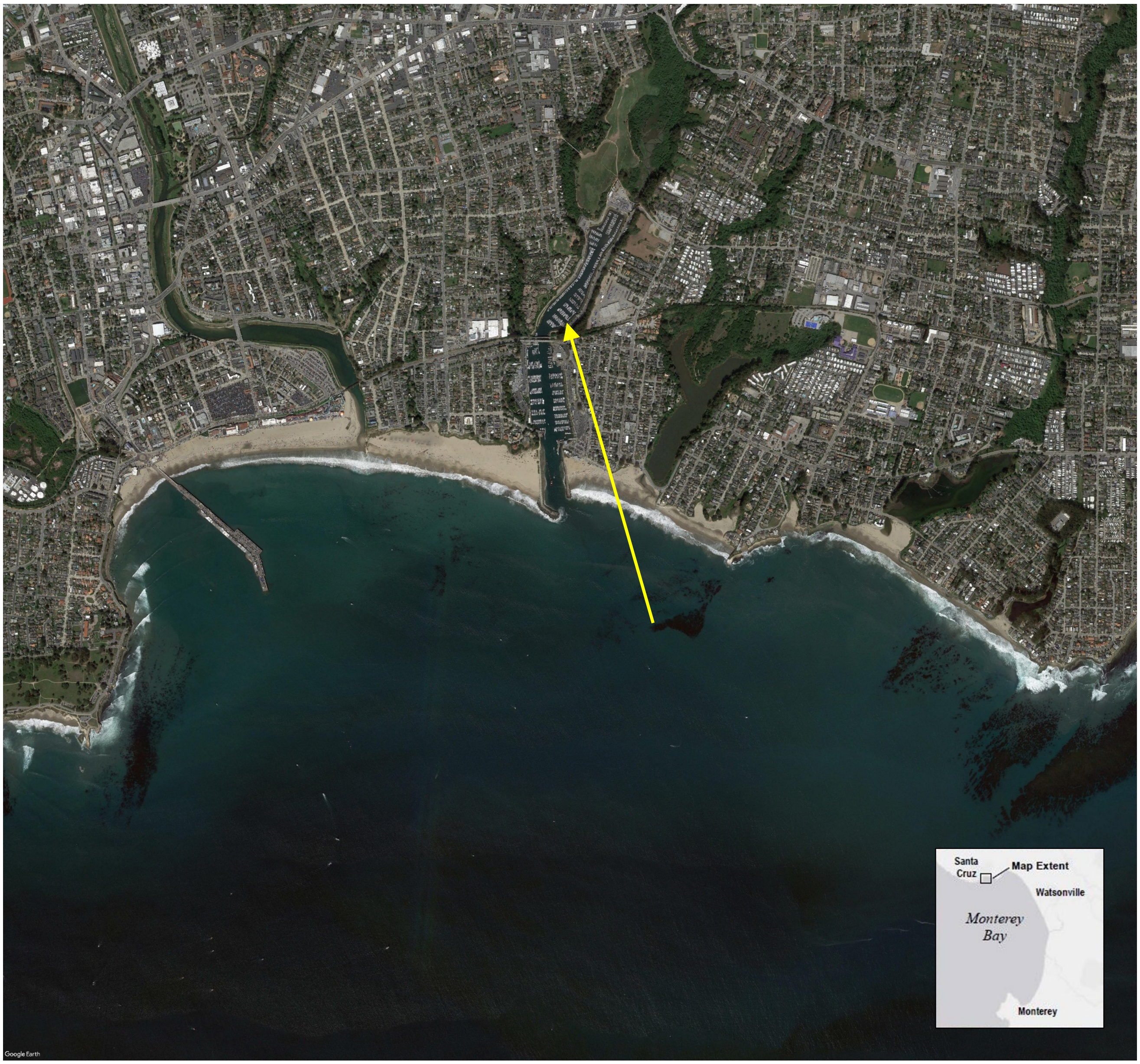
AB 691 Sea-Level Rise Assessment
Santa Cruz Port District Tide and Submerged Lands 1968 Grant
Santa Cruz Harbor

ADA COMPLIANT REPORT - June 2019



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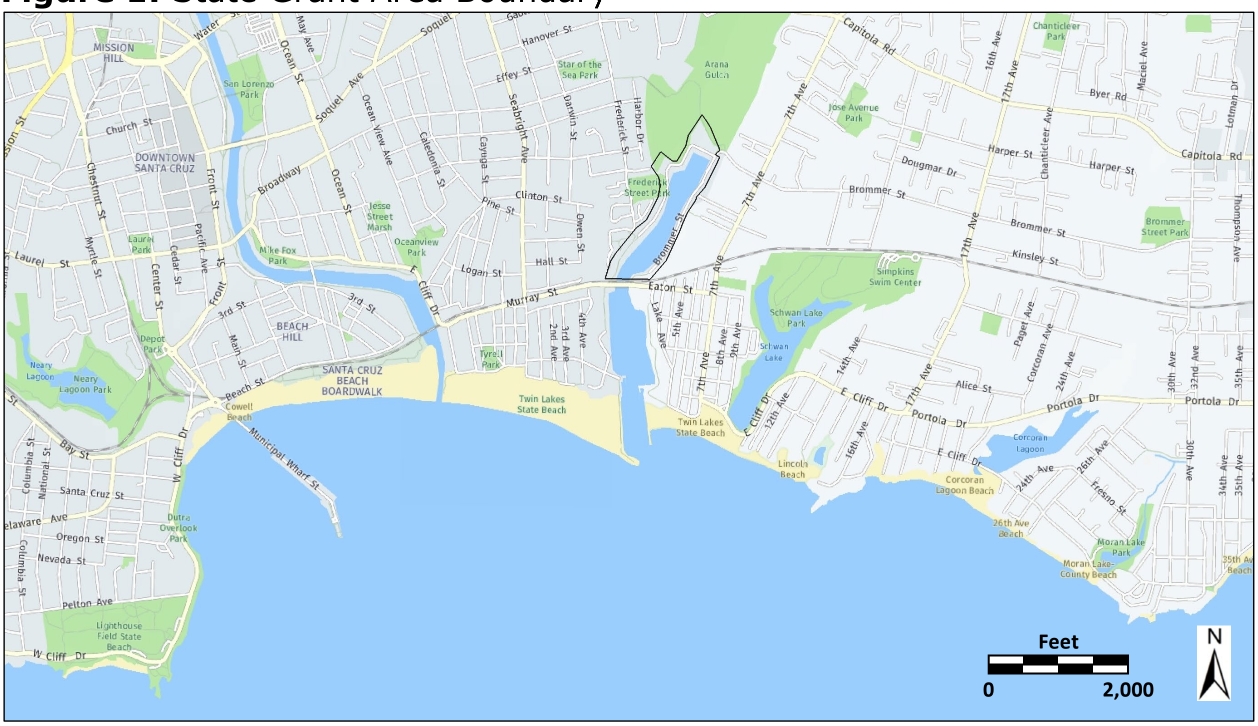
(Submitted April 2019)

State Grant Tide and Submerged Lands Description

In 1968, the State of California granted the Santa Cruz Port District (SCPD) sovereign tidelands and submerged lands within the north Santa Cruz Harbor[1] to hold in trust for the establishment, improvement, and conduct of a harbor, marina, and associated facilities. The total area of the State Grant Area is approximately 37 acres of which 16 acres are seabed (submerged) areas. Figure 1 depicts the boundaries of this area, which was granted pursuant to Chapter 818, Statutes of 1968, minerals reserved to the State.

Figure 1: State Grant Area Boundary



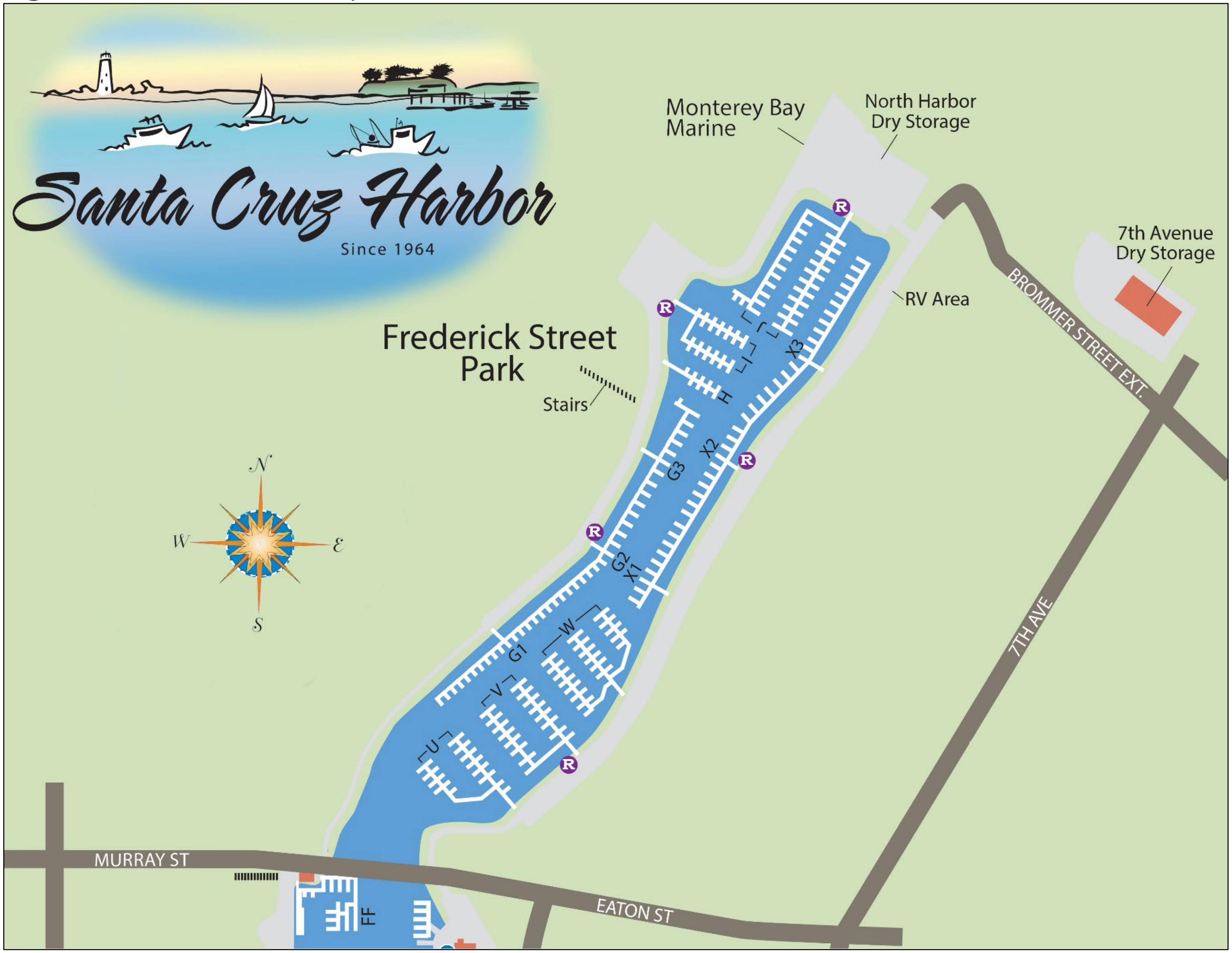
The Santa Cruz Harbor provides permanent moorage for approximately 1,200 wet-berthed and 275 dry-stored vessels and provides both residents and visitors access to the waters and shoreline of Monterey Bay. The harbor

1 On tidal waterways, the State's sovereign fee ownership extends landward to the mean high tide line, except for areas of fill or artificial accretion or where the boundary has been fixed by agreement or court decision. At this time, the California State Lands Commission does not have sufficient information to determine whether the south Santa Cruz Harbor intrudes upon state sovereign lands. The south Santa Cruz Harbor area has not been determined to be legislatively granted public tidelands and therefore is not included in this report.

area supports a wide range of landside and waterside businesses, marine surf and rescue operations, and provides a wealth of recreational and commercial boating opportunities. On an annual basis, the harbor hosts numerous events and activities both on land and on the water for the enjoyment of the public. Events and activities include fish derbies, seasonal sailboat races, school excursions, and outdoor classroom activities, photoshoots, weddings, beach barbecues, special events, and volleyball tournaments.

Figure 2 provides an overview of the layout of docks and facilities at the north harbor. Access to the north harbor is via Brommer Street. Docks are outlined in white and labeled G, H, I, J, and U, V, W, X. Parking around the harbor is indicated in gray, restroom locations indicated with ®.

Figure 2: North harbor map.



1. Assessment of Impacts of Sea-Level Rise (SLR)

Assessing the impacts of Sea-Level Rise (SLR) for legislatively granted Public Trust lands in the State of California is a management priority for local trustees. In 2013, the California legislature passed Assembly Bill 691, Chapter 592, Statutes of 2013 to address assessment criteria for SLR in the state of California. This assembly bill requires trustees to prepare and submit an assessment of how they propose to address SLR to the California State Lands Commission (CSLC).

The Santa Cruz Port District (SCPD) has conducted the current work to assess potential impacts of sea-level rise (SLR) for the areas granted to the District. The scope of the assessment includes the following elements:

- An impact assessment aimed at identifying resources and facilities potentially vulnerable to SLR, assess storms and extreme events, shoreline retreat, trends in local sea level, and potential impacts to public access, recreation, coastal habitats, and navigability.

- Flood hazard mapping, which includes development of flood hazard maps for SLR scenarios for the years 2030, 2060, and 2100.

- Adaptation measures and mitigation strategies for the prioritized resources and facilities. The vulnerabilities, estimated time frames for implementation of adaptive measures, and recommended plans to monitor impacts of SLR are also considered.

- SLR impact cost analysis based on proposed adaptation and mitigation measures with consideration to replacement and repair costs, non-market values, and anticipated costs for adaptation and mitigation measures.

This study utilizes the most recent SLR guidance for California provided in *OPC (2018)*. *OPC 2018* provides for three sea level rise scenarios, of which the 1-in-200 scenario was selected[2]. Flood hazard mapping was developed using the web-based *NOAA Sea Level Rise and Coastal Flooding Impact Viewer* combined with GIS mapping to align with the City of Santa Cruz climate change adaptation planning, *CSC (2017, 2018)*, and the underlying City Climate Change Vulnerability Assessment, *Griggs et al (2011)*. The widely used USGS *Our Coast Our Future (OCOF)* online mapping tool was not utilized as the coverage area of the Coastal Storm Surge Modeling System (CoSMoS) currently does not include Monterey Bay.

[2] OPC 2018 incorporates probabilistic sea-level rise projections, which associate a likelihood of occurrence (or probability) with sea-level rise heights and rates, and are directly tied to a range of emissions scenarios

Sea-level rise scenarios for years 2030, 2060, and 2100 were adopted to be consistent with past studies and ongoing City of Santa Cruz climate change adaptation planning, *CSC (2018).*

Executive Summary:

2030 Planning Horizon (*or 0.8 feet of SLR, Medium – High Risk Aversion*). For the 2030 planning horizon, cumulative risks of coastal climate change affecting the Santa Cruz Port District are projected to be relatively insignificant. In summary:

- The north harbor area is generally not impacted by king tides, but the highest tides will come up near the edge of the west side parking lot (G-Dock area).
- A 100-year storm could raise the water level to the point where a limited portion of the northwest parking lot (H&I Dock area) and the north parking lot (J-Dock area) could be affected by flooding in localized areas along the harbor edge.
- Remaining areas of the north harbor would not be impacted.

2060 Planning Horizon (*or 2.6 feet of SLR, Medium – High Risk Aversion*). For the 2060 planning horizon, cumulative risks of coastal climate change affecting the Santa Cruz Port District are projected to be moderate. In summary:

- King tides will flood parking spaces along the edge of the northwest (H&I Dock area) and north (J-Dock area) parking lots. The RV Park spaces, east side parking lot (X-Dock area) and roadway along the west side of the harbor will not be impacted by king tides.
- Potential for impacts to infrastructure along edge of harbor basin, including transformer boxes, electrical conduits, outlets, light fixtures, buildings, and landscaping.
- Potential for impacts to marine infrastructure, including docks, gangways, and pilings.
- A 100-year storm would cause flooding of a significant portion on the northwest parking lot (H&I Dock area) and the north parking lot (J-Dock area) along the harbor edge.
- The RV Park spaces, east parking areas (U-X Dock area), the District's maintenance yard, and roadway along the west side of the harbor would not be impacted.

2100 Planning Horizon (*or 6.9 feet of SLR, Medium – High Risk Aversion*). For the 2100 planning horizon, cumulative risks of coastal climate change affecting the Santa Cruz Port District are projected to be significant. In summary:

- King tides will flood approximately 50% of the north parking area (J-Dock area) along the harbor edge, including the District's North Harbor Dry Storage yard. The northwest parking lot (H&I Dock area), including the District's maintenance building/office, RV Park spaces, east parking lot and roadway along the west side of the harbor will be submerged on king tides.

- Public access and recreational activities will be impacted in the entire area of the north harbor during king tides. The impacted areas would include all parking areas, all pedestrian paths, access to the docks, and all viewing areas. Fishing charters and other commercial business relying on waterside access will likewise be impacted.

- Impacts to infrastructure along the edge of harbor basin, including transformer boxes, electrical conduits, outlets, light fixtures, buildings, and landscaping.

- Potential for impacts to marine infrastructure, including docks, gangways, and pilings.

- Access/egress to the north harbor at the northeast end (via Brommer Street Extension) will not be impacted by king tides.

- Flooding associated with a 100-year storm would flood approximately 50% of the north parking area (J-Dock area) along the harbor edge, including the District's North Harbor Dry Storage yard. The northwest parking lot (H&I Dock area), including the District's maintenance building/office, RV Park spaces, east parking lot and roadway along the west side of the harbor would be flooded in entirety.

- Public access and recreational activities would be impacted in the entire area of the north harbor if subject to flooding associated with a 100-year storm. The impacted areas include all parking areas, all pedestrian paths, access to the docks, and the two northwest viewing areas. Fishing charters and other commercial business relying on waterside access would likewise be impacted.

- Access/egress to the north harbor at the northeast end (via Brommer Street Extension) would not be impacted.

a. Inventory of vulnerable natural and built "manmade" resources and facilities

The entirety of the Santa Cruz north harbor area can be considered a manmade facility. The Santa Cruz Port District was enacted in 1950, as there was a need for a homeport and refuge for a growing number of fishing boats and other small craft. The harbor was situated at Woods Lagoon, a low-lying area along the eastern extent of the City of Santa Cruz. Construction of the north harbor was completed in 1973. Facilities in the north harbor area include marina restrooms and docks, including moorage for the District's dredge, an RV Park area, a marine engine repair facility, a dry storage area, maintenance and dredge yards, garbage collection/compaction area, oil recycling stations, lift stations, pedestrian walkways, and multiple scenic viewpoints with benches overlooking the harbor area, and access to the Arana Gulch watershed's pedestrian and biking trails and greenspace.

Aside from the submerged seabed within the harbor, the closest nearby natural resource is the Arana Gulch watershed at the north end of the harbor area, which is a 63-acre greenbelt land, featuring open meadows, oak woodland, Arana Creek, pedestrian and biking trails. The gulch is not included within the CSLC Grant Boundary. However, SCPD supports this natural resource area by maintaining the culvert connecting Arana Creek and the harbor basin, allowing discharge from the creek to reach the Pacific and enabling tidal exchange with the marshlands within the gulch. SCPD also facilitates access to the Arana Gulch Trail from the north parking lot.

b. Consider impacts of storms and extreme events.

Flooding and extreme storms are predicted to occur more frequently and with greater intensity as a result of climate change and can combine with SLR to exacerbate coastal flooding events. Southwesterly storm systems entering Monterey Bay are known to produce storm surge at Santa Cruz and are commonly responsible for coastal flooding. These storm systems are also accompanied by heavy rains, which increases the landside flood potential. When storm surge occurs simultaneously with high tides and rising sea levels, flood conditions are exacerbated. The north harbor area is sheltered from wave action, and coastal flooding is therefore associated with elements that produce a rise in the still water level. These include:

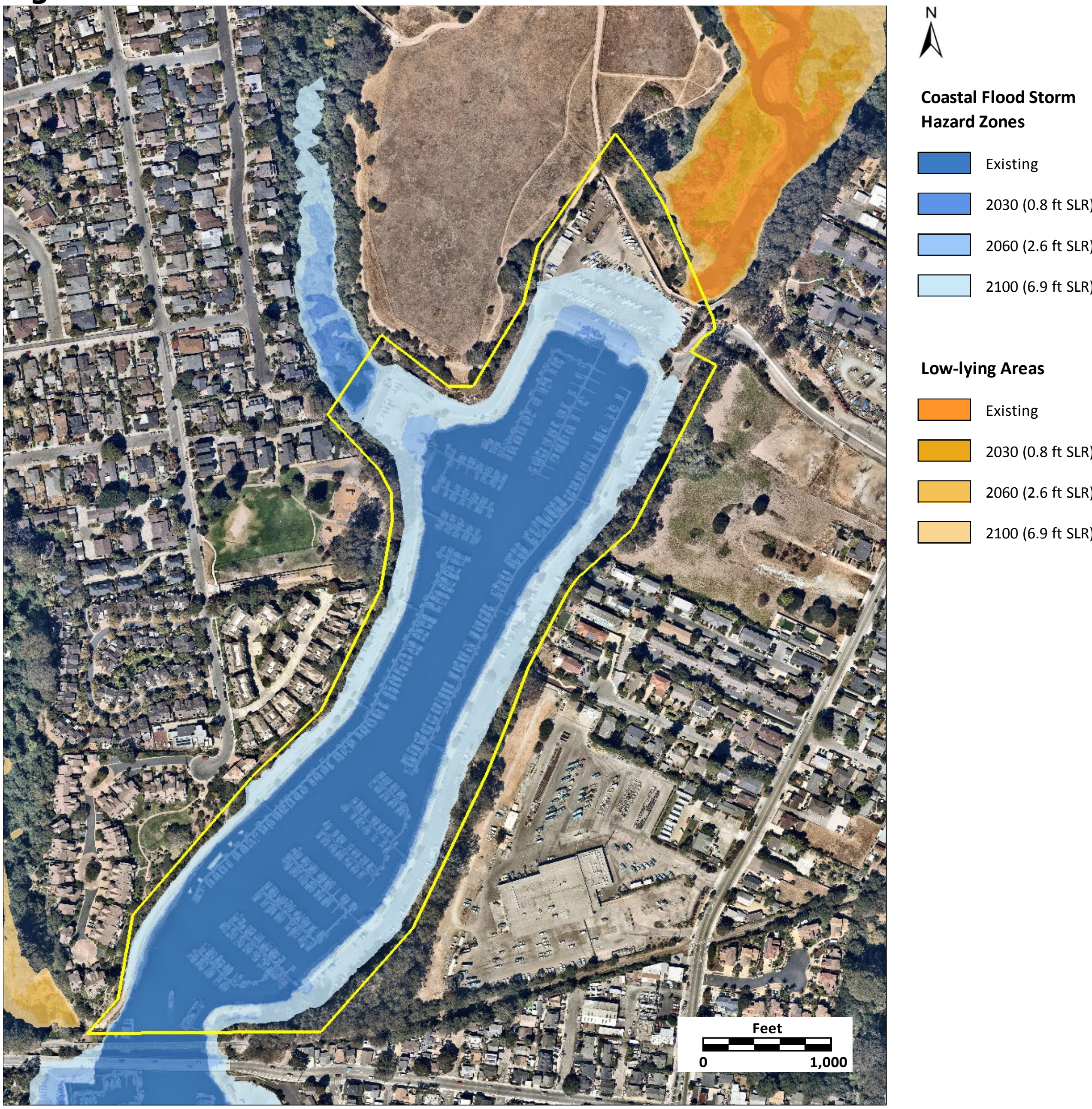
- **Tides**, in particular high tides such as spring tides which occur twice a month during the full moon and the new moon, and king tides (perigean spring tides) which occur annually in January and December when a new or full moon occurs at the same time as the moon is at its closest to the earth.

- **El Niño** (and La Niña), which are cycles of warming and cooling of the ocean, typically lasting 9 to 12 months. They often commence in June or August and reach their peak during December through April, and subsequently, decay over May through July of the following year. Their periodicity is irregular, occurring every 3 to 5 years on average. The warming associated with El Niño produces a rise of the ocean level, which can be on the order of 6 to 13 inches. The period of elevated (or lowered) ocean levels can be on the order of months, while the peak highs and lows occur on a scale of days to weeks.

- **Storm Surge**, associated with storm systems occurring annually over the winter months.
- **Global Sea-Level Rise**, which constitutes a gradual rise of the eustatic ocean level over time.

Figure 3 depicts the coastal storm flood hazard zones (i.e., 100-year storm) for the 2010 baseline year as well as for the 2030, 2060 and 2100 planning horizons. These are denoted by the areas in dark blue to light blue. Low-lying areas prone to flooding, but not connected to the ocean by a direct overland flow path are indicated in dark orange to light orange. It should be noted that potential flooding associated with outflow from Arana Creek was not analyzed in the current SLR assessment. The yellow outline indicates the general area included in the CSLC Grant Boundary.

Figure 3: Coastal Storm Flood Hazard Zones



For the baseline year of 2010, the north harbor is not particularly vulnerable to the combined hazards of storms and extreme events. The edge of the harbor area is protected and thus not prone to erosion hazards.

Projected impacts over the three future time horizons include the following:

2030 Planning Horizon (*or 0.8 feet of SLR, Medium – High Risk Aversion*). For the 2030 planning horizon, cumulative risks of coastal climate change affecting the Santa Cruz Port District are projected to be relatively insignificant. In summary:

- The north harbor area is generally not impacted by king tides, but the highest tides will come up near the edge of the west side parking lot (G-Dock area).
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- Remaining areas of the north harbor would not be impacted.

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- King tides will flood parking spaces along the edge of the northwest (H&I Dock area) and north (J-Dock area) parking lots. The RV Park spaces, east side parking lot (X-Dock area) and roadway along the west side of the harbor will not be impacted by king tides.
- Potential for impacts to infrastructure along edge of harbor basin, including transformer boxes, electrical conduits, outlets, light fixtures, buildings, and landscaping.
- Potential for impacts to marine infrastructure, including docks, gangways, and pilings.
- A 100-year storm would cause flooding of a significant portion on the northwest parking lot (H&I Dock area) and the north parking lot (J-Dock area) along the harbor edge.
- The RV Park spaces, east parking areas (U-X Dock area), The District's maintenance yard, and roadway along the west side of the harbor would not be impacted.

2100 Planning Horizon (*or 6.9 feet of SLR, Medium – High Risk Aversion*). For the 2100 planning horizon, cumulative risks of coastal climate change affecting the Santa Cruz Port District are projected to be more significant. In summary:

- King tides will flood approximately 50% of the north parking area (J-Dock area) along the harbor edge, including the District's North Harbor Dry Storage yard. The northwest parking lot (H&I Dock area), including the District's maintenance building/office, RV Park spaces, east parking lot and roadway along the west side of the harbor will be submerged on king tides.
- Public access and recreational activities will be impacted in the entire area of the north harbor during king tides. The impacted areas would include all

parking areas, all pedestrian paths, access to the docks, and all viewing areas. Fishing charters and other commercial business relying on waterside access will likewise be impacted.

- Impacts to infrastructure along edge of harbor basin, including transformer boxes, electrical conduits, outlets, light fixtures, buildings, and landscaping.
- Potential for impacts to marine infrastructure, including docks, gangways, and pilings.
- Access/egress to the north harbor at the northeast end (via Brommer Street Extension) will not be impacted by king tides.
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- Access/egress to the north harbor at the northeast end (via Brommer Street Extension) would not be impacted.

c. Consider changing shorelines

The shoreline within the harbor area is manmade and protected with riprap. Consequently, there is no significant erosion hazard. The main shoreline changes are therefore associated with rising tides as a result of SLR.

The shoreline along the harbor basin will effectively recede with SLR. The net effect is that the water level will rise and the shoreline edge come closer to the landside areas. Over time, these may therefore be more prone to flood hazards.

Figure 4 depicts rising tide hazard zones. In this context, the shoreline is defined by the Mean High Water (MHW) line per *NOAA (2001)*.

The flood zones indicate that the harbor area would be unaffected by high tides through to 2060, but would experience progressive inundation of the parking and overland areas around the harbor towards the end of the century.

Figure 5 shows areas impacted by king tides. These tides typically occur a few times in January to December and July to August.

Figure 4: Rising Tides Hazard Zones

Figure 5: King Tide Hazard Zones

d. Consider trends in relative local sea level

The California Coastal Commission recommends evaluation of SLR impacts using a scenario-based analysis, *CCC (2015)*. This method builds on the approach by the Intergovernmental Panel on Climate Change (IPCC) to understand how SLR and other drivers interact to threaten health, safety, and resources of coastal communities. Specific guidance for California was developed by the National Research Council in 2012, *NRC (2012).* The guidance relies on the best available science at the time to identify a range of sea-level rise scenarios including high, low, and intermediate projections, taking into account regional factors such as El Niño and extreme storm events that affect ocean levels, precipitation, and storm surge. This approach allows planners to understand the full range of possible impacts that can be reasonably expected based on the best available science, and build an understanding of the overall risk posed by potential future SLR.

The best available science and most recent guidance is provided in *OPC (2018)* and has been adopted for this study. Table 1 summarizes SLR scenarios adopted from *OPC (2018)* for the selected planning horizons and reflects a medium – high risk aversion to hazards associated with sea-level rise. The figures presented in Table 1 represent sea-level rise as it relates to an increase of the mean sea level (the static water level without tides or wave action).

Table 1: Sea-Level Rise Scenarios Selected for Analysis

Time Horizon	SLR Scenario	Notes
2030	0.8 feet	Includes the potential of a large storm event (e.g. 100-year storm)
2060	2.6 feet	Future scenario, which includes increased storminess (doubling of El Niño storm impacts in a decade)
2100	6.9 feet	Includes the potential of a large storm event (e.g. 100-year storm) Future scenario of increased storminess (doubling of El Niño storm impacts in a decade)

Table 2 summarizes SLR projections for Monterey from the *OPC (2018)* Sea-Level Rise Guidance for the State of California. Figure 6 depicts the estimates from Table 2 in graphical form. The values indicated are in feet. Probabilistic projections for the height of sea-level rise are shown along with the H++ extreme risk aversion scenario (depicted in blue in the far right column of Table 2). The H++ projection is a single scenario and does not have an associated likelihood of occurrence as do the probabilistic projections. Probabilistic projections are with respect to a baseline of the year 2000, or more specifically the average relative sea level over 1991 - 2009. High emissions represents RCP 8.5; low emissions represents RCP 2.6. Recommended projections for use in low, medium-high and extreme risk aversion decisions are outlined in blue boxes below. The RCP's stand for Representative Concentration Pathways and can be described as follows:

RCP 2.6 is representative of scenarios that lead to very low greenhouse gas concentration levels. It is a "peak-and-decline" scenario; where the radiative forcing level first reaches a value of around 3.1 W/m² by mid-century and returns to 2.6 W/m² by 2100. In order to reach such radiative forcing levels, greenhouse gas emissions (and indirectly emissions of air pollutants) would need to be significantly curtailed over time, an effort that would need to be achieved on a global level for national and individuals alike.

As the world has not yet taken significant steps to curb emissions, the outlook for this scenario is at present deemed too optimistic.

RCP 8.5 is characterized by increasing greenhouse gas emissions over time, representative of scenarios that lead to high greenhouse gas concentration levels. The *OPC (2018)* guidance requires that this scenario be adopted at least through to 2050. RCP 8.5 is often referred to as the "business-as-usual" scenario and is consistent with a future where there are few global efforts to limit or reduce emissions.

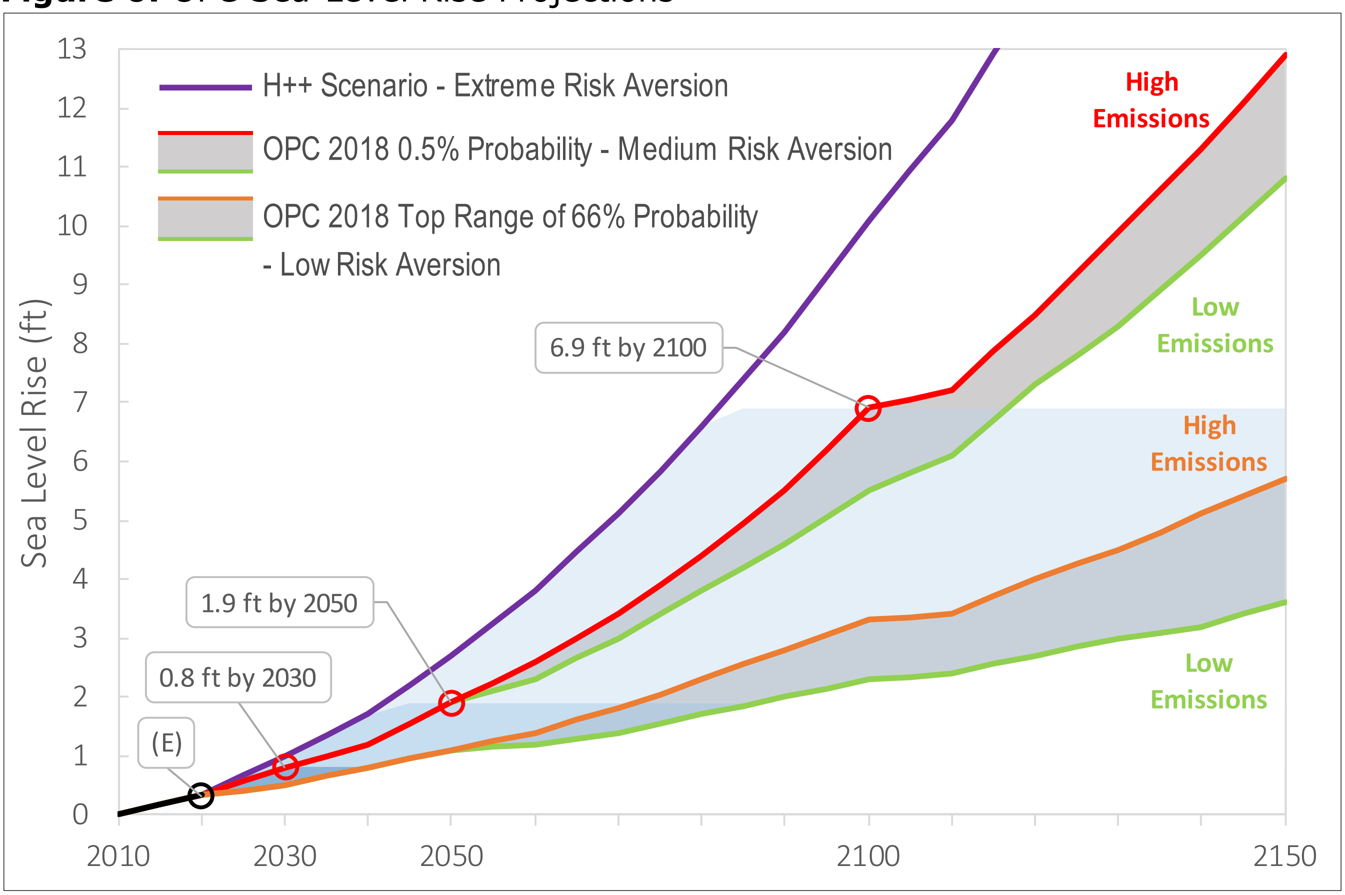
Thus far, our greenhouse gas emissions worldwide have continued to follow the business-as-usual trajectory. The present study therefore adopts the Medium – High Risk Aversion/High Emissions Sea-Level Rise Projection for a planning horizon out to 2030, 2060, and 2100. This scenario has a 1-in-200 chance (or 0.5% probability) of sea-level rise meeting or exceeding the tabled values.

Table 2: *OPC (2018)* Sea-Level Rise (SLR) Projections for Monterey, CA

Probabilistic Projections (in feet) (based on Kopp et al. 2014)	**MEDIAN**	**LIKELY**	**1 IN 20**	**1 IN 100**	**H+++**
High emissions 2030	0.4	0.3 – **0.5**	0.6	**0.8**	**1.0**
2040	0.6	0.4 – **0.8**	0.9	**1.2**	**1.7**
2050	0.8	0.5 – **1.1**	1.3	**1.9**	**2.7**
Low emissions 2060	0.9	0.5 – **1.2**	1.5	**2.3**	
High emission 2060	1.0	0.7 – **1.4**	1.8	**2.6**	**3.8**
Low emissions 2070	1.0	0.6 – **1.4**	1.9	**3.0**	
High emission 2070	1.3	0.9 – **1.8**	2.3	**3.4**	**5.1**
Low emissions 2080	1.2	0.7 – **1.7**	2.3	**3.8**	
High emission 2080	1.6	1.1 – **2.3**	2.9	**4.4**	**6.6**
Low emissions 2090	1.3	0.8 – **2.0**	2.7	**4.6**	
High emission 2090	2.0	1.3 – **2.8**	3.5	**5.5**	**8.2**
Low emissions 2100	1.5	0.9 – **2.3**	3.1	**5.5**	
High emission 2100	2.3	1.5 – **3.3**	4.3	**6.9**	**10.1**
Low emissions 2110*	1.6	1.0 – **2.4**	3.3	**6.1**	
High emission 2110*	2.5	1.7 – **3.4**	4.4	**7.2**	**11.8**

Probabilistic Projections (in feet) (based on Kopp et al. 2014)	**MEDIAN** 50% probability sea-level rise meets or exceeds	**LIKELY RANGE** 66% probability sea-level rise is between (low risk aversion)	**1 IN 20 CHANCE** 5% probability sea-level rise meets or exceeds (medium-high risk aversion)	**1 IN 100 CHANCE** 0.5% probability sea-level rise meets or exceeds	**H+++ scenario** (Sweet et al. 2017) *Single scenario (extreme risk aversion)
Low emissions 2120	1.7	1.0 – **2.7**	3.8	**7.3**	
High emission 2120	2.8	2.0 – **4.0**	5.2	**8.5**	**14.0**
Low emissions 2130	1.9	1.1 – **3.0**	4.2	**8.3**	
High emission 2130	3.1	2.2 – **4.5**	5.9	**9.9**	**16.4**
Low emissions 2140	2.0	1.1 – **3.2**	4.7	**9.5**	
High emission 2140	3.5	2.4 – **5.1**	6.7	**11.3**	**18.9**
Low emissions 2150	2.1	1.1 – **3.6**	5.3	**10.8**	
High emission 2150	3.8	2.6 – **5.7**	7.6	**12.9**	**21.8**

Figure 6: OPC Sea-Level Rise Projections

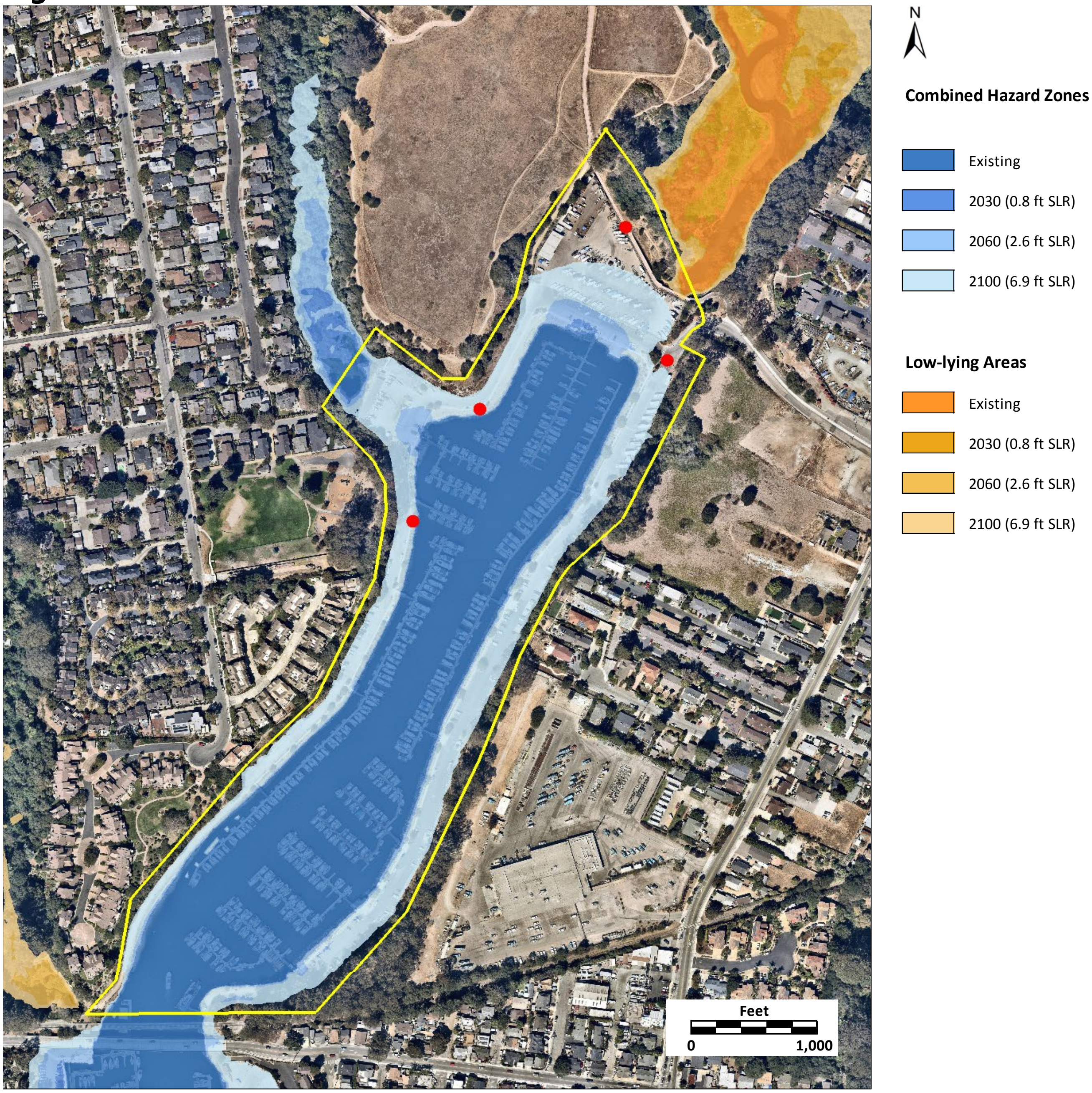


e. Consider impacts to the public trust resources and values, including but not limited to public access, commerce, recreation, coastal habitats, and navigability

The main public trust resources to be impacted by SLR in the State Grant Area are public access, commerce, and recreational/commercial activities. Navigability will not be impacted as the water depth increases with sea-level rise and the docks float and will follow the water level elevation. However, docks will only remain on position as long as they are moving vertically within the range of the guide piles. Depending on the cap elevation of guide piles relative to the rise in sea level, it is in some cases conceivable that docks can float up over the guide piles. Mitigation for this type of impact can be via extension of the existing guide piles (lower cost but not very practical), or via replacement of existing guide piles with longer piles (more practical in terms of installation but also at a higher cost).

The impacts will be in the form of rising tides submerging portions of the upland areas. This localized flooding will occur in low-lying areas along the harbor edge. The flooding will occur at the peak of the highest tides, and will initially be brief, limited in extent and the depths of flooding limited to a few inches. This form of flooding is termed nuisance flooding and can be tolerated up to a certain point. The flood extents, frequency of flooding and flood depths will progressively worsen with sea-level rise.

Figure 7: Coastal Access Points and Combined SLR Hazard Zones



Port District assets are indicated by red dot on above figure.

f. Prioritize vulnerabilities to be addressed

There are several strategies that can be considered, which are:

- Do nothing, if the flooding is so minor as to only constitute a nuisance.
- Adapt to localized minor flooding. Temporarily fence off areas subject to flooding prior to and during episodes of flooding. The flood prone areas will be known and recurring flooding will always occur in the same low-lying areas.

- Adapt to and plan for more extensive flooding. Advise the public about upcoming episodes of flooding. These will be known to occur during times of peak tides. As flooding becomes more extensive, portions of the harbor upland areas can be closed temporarily. This approach may work well as the roadway and entry point at the northeast corner of the harbor area are on higher ground and will remain unaffected by flooding. Consequently, there will always be a means of egress from the harbor area, if need be. However, access to the docks and vessels would be cut off. If and when a flooding event is anticipated, advisories should be issued and temporary fencing put in place far enough in advance of the flood event that boaters won't be out on the water and have to return at the peak of the flood events.

- Mitigate flooding. Prevent flooding of upland areas by installing a low wall along the perimeter of the harbor basin. This may require existing access points to be raised to facilitate access over the wall. Alternatively, openings in the wall can be outfitted with inflatable barriers or flashboards to prevent flooding when the water level rises.

Any impacts associated with episodic flooding are likely to encompass public access, recreation, and commerce simultaneously as the harbor area largely facilitates both recreational and commercial activities.

Physical impacts to SCPD infrastructure are estimated to be limited but may lead to a higher level of maintenance of upland areas, increasing with the frequency of flood episodes.

There will be a monetary loss when users are unable to access and make use of the facilities at the harbor. However, the initial losses are estimated to be limited as the flooding to a large extent will be in the form of nuisance flooding. Some users may arrive and be turned away by flooding, while more determined users will work around flooded areas and still be able to make use of facilities at the harbor area. Flood events will initially be episodic and limited in terms of duration and flood extents. Some of the high tides may peak in the morning/evening hours or overnight and may therefore not be as impactful.

Table 3 summarizes proposed adaptation strategies for the north harbor area.

Table 3: Adaptation Strategies for the north harbor area

Title	Timeline	Priority
A-1: Increase public awareness, education, and public outreach in areas with social vulnerabilities that coincide with hazard zones	2060-2100	High
A-2: Prepare for potential SLR throughout the harbor	2060-2100	Medium
A-3: Identify priority areas for managed retreat to retain public access for recreational use; plan to adapt to local flooding	2060-2100	Medium
A-4: Adopt policies to evaluate limiting municipal capital improvements that would be at risk	2060-2100	High
A-5: Prioritize SLR mitigation when structures are planned for upgrade or replacement	2040-2100	High
A-6: Protect visitor serving venues and support natural resources	Ongoing	Very High
B-1: Promote and preserve economic base and tourism industry in the face of a changing climate	Ongoing	High
B-2: Disseminate flood hazard information	2060–2100	High
C-1: Protect and preserve tree canopy and other native coastal vegetation	Ongoing	Important

g. Consider impacts and recommendations described in the current version of the Ocean Protection Council's (OPC) Sea-Level Rise Guidance Document

Recommendations from the *OPC (2018)* Guidance Document suggest that adaptation strategies should prioritize use of natural or green infrastructure solutions. The harbor area is manmade and slopes around the perimeter of the harbor basin are protected with riprap. Salinity levels can range from fresh/brackish to saline. There is therefore limited opportunity for incorporation of natural solutions along the harbor edge. It would be possible to incorporate additional planting in upland areas, but these would have to be considered carefully with respect to existing allocations for parking to prevent impacts to revenue and survive periodic inundation by tides.

The greatest opportunity for natural solutions is preservation of the Arana Gulch area north of the harbor. SCPD would continue to support and maintain access to this area.

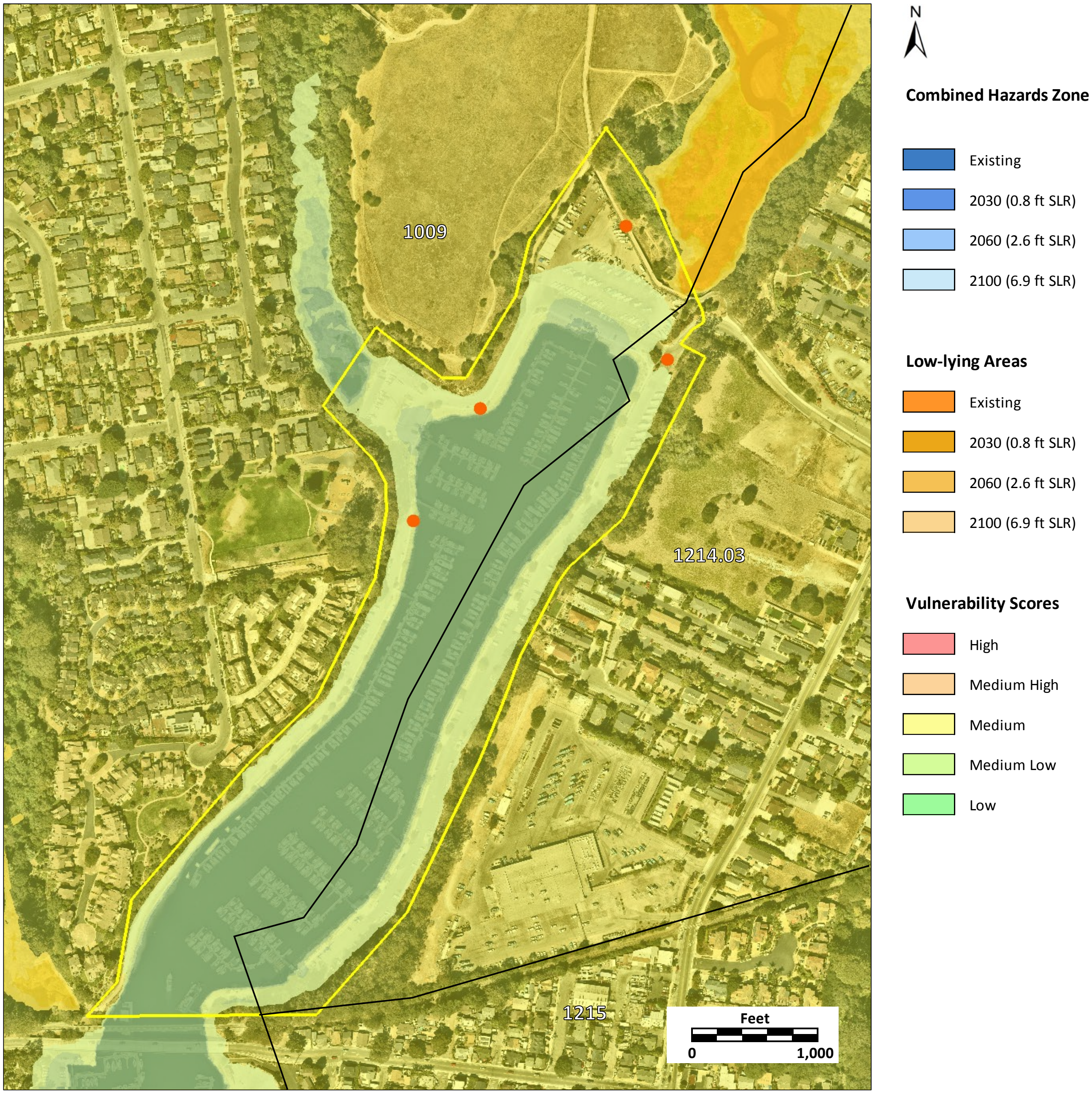
According to the Ocean Protection Council's SLR Guidance Document, adaptation planning and strategies should also prioritize social equity, environmental justice and the needs of vulnerable communities. Environmental justice and social equity is considered in the City of Santa Cruz overall planning efforts, *CSC (2018)*. Census block groups are peripheral to the State Grant Area which does not contain any specific census groups.

However, with due consideration to social vulnerability, Figure 8 shows social vulnerability index scoring for census blocks in the vicinity of the harbor from *PI (2012)*. The data indicates that social vulnerability in the areas around the harbor is near medium, slightly above or below neutral relative to other census block groups. The social vulnerability indicators considered in the data are summarized in Table 4.

Table 4: Factors Affecting Social Vulnerability to Climate Hazards

Factors	**Census Block Group 1009**	**Census Block Group 1214.03**	**Census Block Group 1215**
Living Alone over 65	15%	13%	11%
Population under 18	15%	19%	15%
Renters	62%	51%	68%
Households speaking little English	3%	11%	12%
People of Color	16%	33%	33%
Low Income	23%	40%	42%
Population w/o High School Diploma	95%	79%	88%
Living in Group Quarters	0%	11%	3%
Unemployed	5%	5%	4%
Women giving birth last 12 mos.	5%	7%	5%
Outdoor Workers	6%	11%	5%
Foreign Born	10%	18%	17%
Lack Access to Grocery Stores	25%	31%	50%
Overweight/Obese Youth	42%	0%	41%
Impervious Land Cover	53%	42%	49%
Treeless Area	4%	10%	7%
Households without a Vehicle	14%	6%	8%
Pre-term Birth Rate	8%	8%	8%
Households without Air con.	11%	11%	11%
Vulnerability Index Score Range (less vulnerable ↔ more vulnerable)	**-0.17**	**+0.02**	**-0.02**

Figure 8: Social Vulnerability to Climate Hazards by Census Block Group



Port District assets are indicated by red dot on above figure.

2. Maps of 2030, 2060 and 2100 Impacts

Figure 9 depicts the combined impacts of climate change SLR hazards (rising tide, 100-year coastal storm flooding and erosion) projected in the years 2010 (baseline year), 2030, 2060 and 2100 in the State Grant Area.

Figure 9: Combined SLR Hazard Zones

Port District assets are indicated by red dot on above figure.

Section 1 contains a detailed description and maps of the separate SLR related climate hazards (e.g., rising tides, and coastal storm flooding) as well as the cumulative risks and impacts of SLR and coastal climate change projected for the 2030, 2060 and 2100 planning horizons. Table 5 describes the specific assets within and adjacent to the State Grant Area that are projected to be vulnerable to the cumulative risks of coastal climate change and SLR.

Table 5: Specific Assets Projected to be Vulnerable to SLR in or adjacent to the State Grant Area

Asset/Area *SLR Hazard Impact: Rising Tides, King Tides, Coastal Storm Flooding*	**Type**	**Impact Threshold**
Visitor Parking West Lot	Parking area	2070
Northwest Parking Lot	Parking area	2050
North Parking Lot	Parking area	2050
RV Parking	Parking area	2080
Visitor Parking East Lot	Parking area	2060
Docks, Gangways, Pilings	Appurtenances	2050
Restroom facilities	Appurtenances	2040
Stormwater outlets	Utilities	2040
Transformer boxes, electrical conduits, electrical outlets, light fixtures.	Electrical Utilities	2040
Landscaping	Vegetation	2060
Viewing platforms and benches	Appurtenances	2070
Garbage Disposal and Recycling Stations	Appurtenances	2080
Used Oil Recycling Stations	Appurtenances	2080
Fish Cleaning Stations	Appurtenances	2080
Transformer Pads	Appurtenances	2090
Sanitary Tank Disposal (lift station)	Appurtenances	2090

The impact thresholds outlined in Table 5 indicates when impacts are projected to commence. These estimates are approximate and assume that future sea-level rise will follow the medium to high risk aversion scenario. The impacts will initially consist of shallow flooding of low-lying areas bordering the harbor basin. The flooding will occur on high tides and will persist for 1-2 hours. Initial flood events that occur in the early morning, late evening or overnight hours may go largely unnoticed. The ponding associated with the flooding may be on the same order as what can be expected during episodes of heavy rainfall. If flood events occur during the daytime hours, they may initially be seen as an attraction. The novelty of high water within the harbor basin and flooding of shallow areas tends to attract the public but annoy regular users of the harbor. Because the water depth will change rapidly from shallow to deep near the harbor edge this presents a hazardous condition to the public. Such hazards can be mitigated with temporary fencing put in place around areas of shallow flooding with signage warning users of flooding.

As sea level rises, the extent and duration of flood events will increase progressively. The novelty of flooding occurring on high tides will transition to nuisance flooding. Although parking areas will be partially affected, the flooding may to a large extent be addressed with temporary fencing put in place and signage informing users about the flooding. To users arriving at the harbor facilities, it may mean that they defer to other (non-flooded) areas for parking, or they might leave the area and return at a later time when the floodwaters have receded. Regular users of the harbor area may to a large extent perceive the flooding as a nuisance but otherwise go about their usual activities.

The initial flooding will primarily affect parking areas and may equate to a loss in revenue. Later, flooding may reach an extent where harbor appurtenances are impacted and there could be associated cost impacts for repair and/or relocation. Infrastructure which is critical to the daily operation of the harbor will require monitoring during flood events. This infrastructure includes sanitary sewer lift stations, electrical utilities, and marine related infrastructure, including docks, gangway, and pilings.

Because the flooding mostly will be timed with the occurrence of high tides, it will be relatively simple to predict when flood events will occur and for how long they will persist. Published tide tables provide accurate estimates of when the highest tides will occur. The height of tides is also well known but may be affected by wind events (storm surge) or El Niño events. The latter will become important around the time of the impact thresholds indicated in Table 5. This because El Niño conditions produce a temporary rise in sea level, which can lead to more extensive and more frequent flooding.

3. Estimate of financial costs of sea-level rise

a. Replacement or repair costs of resources and facilities that could be impacted by sea-level rise and climate change processes

One of the primary impacts associated with sea-level rise will be flooding of north harbor parking areas, which will directly affect dock access during high tides. There is a loss associated with parking space and the inability to access vessels when flooding occurs.

Table 6 summarizes potential sea-level rise related impacts to parking areas for years 2030, 2060 and 2100. No impacts are anticipated for any parking areas by 2030. Initial impacts in the form of shallow flooding in areas of the North Parking Lot and Northwest Parking Lot are estimated to occur around 2050. By 2060, the Northwest Parking Lot and the North Parking Lot will be impacted without adaptation. These two parking areas will be progressively impacted as the rate of sea-level rise becomes more pronounced towards the latter half of the century. By 2100, the sea level will have risen to the point where all parking areas will be impacted due to flooding on high tides.

Table 6: Potential Sea-Level Rise Related Impacts to Parking Areas

Parking Area, Dock Access	Parking Spaces Impacted by Year: 2030	Parking Spaces Impacted by Year: 2060	Parking Spaces Impacted by Year: 2100
West Parking Lot	0%	0%	100%
Northwest Parking Lot and dock access	0%	75%	100%
North Parking Lot and dock access	0%	57%	100%
East Parking Lot	0%	2%	100%
RV Parking Lot	0%	0%	100%
Total, All Areas (percent of area total)	**0%**	**15%**	**100%**

It is estimated that losses in revenue due to impacts to parking areas could be on the order of $50/day by 2050, $100/day by 2060, and $1,000/day by 2100. These costs reflect impacts to hourly parking in the daytime hours from 8 am to 6 pm based on parking area information from *WDI (2016)*. These cost impacts and projected cumulative costs are summarized in Table 7.

Table 7: Estimated Daily and Cumulative Impacts Associated with Parking Area Impacts

Cost Impact	Parking Spaces Impacted by Year: 2030	Parking Spaces Impacted by Year: 2050	Parking Spaces Impacted by Year: 2060	Parking Spaces Impacted by Year: 2100
Daily	$0	$50	$100	$1,000
Cumulative	$0	$1,125	$11,160	$11M

Cost estimates reflect present value of future cost with price escalation based on the U.S. Average Consumer Price Index (CPI) and index base period (1982-84 = 100), *BLS (2019)*.

The data indicates that sea-level rise related impacts out to around the mid-century point will mostly be in the form of nuisance flooding. From 2060, to the end of the century, significant cost impacts become evident as the frequency and extent of flooding becomes more pronounced.

4. Description of how trustee proposes to protect and preserve resources and structures that would be impacted by the sea-level rise

a. Describe proposed mitigation/adaptation measures, and how vulnerabilities will be addressed

Adaptation to Near Term Sea-Level Rise Impacts: Initial sea-level rise related impacts will be limited and infrequent. Initial mitigation can therefore focus on information to the public about when and where potential flooding events may occur. Apart from incidental flooding associated with storms that may occur during the winter months, the dates and times of high tides will be known in advance. Low areas exposed to shallow flooding can be identified via terrain mapping, and/or will be known from prior episodes of flooding.

Information to the public about episodes of potential flooding can be provided via use of the annual tide tables, signage, electronic messaging, and by fencing off areas known to be subject to flooding. Such measures may prove effective at the onset of sea-level rise related flood impacts. However, as flood episodes become more frequent in terms of recurrence, and areas subject to flooding grow larger, and flood depths transition from shallow to intermediate, a more comprehensive solution may be needed to address sea-level rise related hazards and associated impacts. Related impacts may be in the form of flood damage, recurring saltwater exposure, and localized erosion due to water exchange between the harbor basin and upland parking areas.

While the docks within the harbor are not obviously impacted by sea-level rise as they float and readily accommodate changes in water level, they may be some of the first infrastructure to experience sea-level rise related impacts.

Figure 10 shows an example of how rising water levels due to king tides can impact docks. While the outer end of the dock can move up and down freely, the connection to the landside abutment is fixed, which can lead to a number of impacts such as: gaining access to the dock impacted by flooding, structural connections being overloaded, and elevated saltwater exposure at the landside tie-in. A solution to this type of impact can be to rebuild the abutment and access paths with a higher hinge point for the float or install a new abutment structure that allows vertical adjustments to be made over time. Depending on the level of sea rise, and the top elevation of the guide-piles, there could be a concern of docks floating up over the guide-piles.

Figure 10: Example king tide flooding impacting access to float, *CCC (2019)*.

Other existing infrastructure that may need early sea-level rise adaptation might include any stormwater outlets within the harbor area. Such outlets can in many cases be outfitted with duckbill valves or similar backflow prevention devices. This in turn may mean that the infrastructure can experience shutdowns when water levels are high, e.g. when gravity draining systems are unable to discharge under head. Systems affected by such impacts may need to incorporate pumps in order to be able to provide continuous discharge.

The above-mentioned areas of mitigation/adaptation can be incorporated under the regular maintenance of the harbor facilities and planned for in the District's annual Capital Improvement Program.

Elements that need to be considered for adaptation before 2050 include all infrastructure in low lying areas around the edge of the harbor basin, including electrical installations such as conduits, transformer boxes, electrical outlets, and light fixtures; buildings (restroom facilities); fire hydrants; and vegetation and landscaping. These elements should be incorporated into early planning so that adaptation/mitigation measures can be put in place in advance of potential sea-level rise related impacts. These elements all have a low tolerance to flood exposure and the consequences of exposure may be considerable. For example, transformer boxes should be elevated and/or waterproofed to avoid the greater impact if the system is exposed to water and compromised. Restrooms should be upgraded or elevated to prevent flood damage and potential overflow of the sewer systems. Landscaping may die off if the surrounding soil and root systems are exposed to saltwater.

Adaptation to Future Sea-Level Rise Impacts: If future sea-level rise follows the *medium to high risk* projection, impacts to upland areas around the north harbor could commence around 2050 to 2060. Mitigation to address shallow flooding in parking areas could initially consist of notifying users about the timing and extent of impacts, which will be known in advance from the use of tide tables. If and when flooding becomes more extensive in terms of frequency, areal extent and inundation depths it would make sense to raise grades around the north harbor to prevent flooding.

Elevating the area around the harbor could be achieved by raising the grade of landside areas with fill and reestablishing paving, access pathways, and existing infrastructure. Buildings can in most cases be elevated, but building replacement could also be planned as elements of a maintenance program.

As an alternative to raising site grades in general, the harbor basin perimeter could be improved with a raised berm to confine floodwaters to the harbor basin. This type of solution might only be feasible up to a point, as access to and from the harbor basin would need to ramp up and over the berm.

b. Describe the timeframe for implementation of such measures

Based on the current outlook, initial sea-level rise related impacts could start to affect the north harbor around 2050 to 2060. These estimates are based on the *medium to high risk* sea-level rise projection, which has a 1 in 200 chance (0.5% risk) of occurring. Conversely, this means that there is a 99.5% chance that the mean sea level will not rise by that much by 2050 to 2060.

In terms of sea-level rise threshold, the above equates to a rise of the mean sea level of 1.9 to 2.6 feet. In the context of the 50% chance projection, this amount of sea-level rise could occur by around 2090 to 2110.

Adaptation and mitigation to improve sea-level rise resilience at the north harbor can therefore be timed with a threshold of 1.9 to 2.6 feet of sea-level rise from present day. At that time the projected rate of sea-level rise remains moderate at around 0.8 inches per year or 8 inches over a decade, which leaves room for planning of capital improvement projects, including identifying funding options.

c. Describe plans to monitor impacts of sea-level rise and climate changes, as well as effectiveness of mitigation and adaptation measures

Aside from infrequent winter storms capable of producing coastal flooding, the primary sea-level rise related hazard for the north harbor area is potential flooding associated with high tides in combination with future sea-level rise.

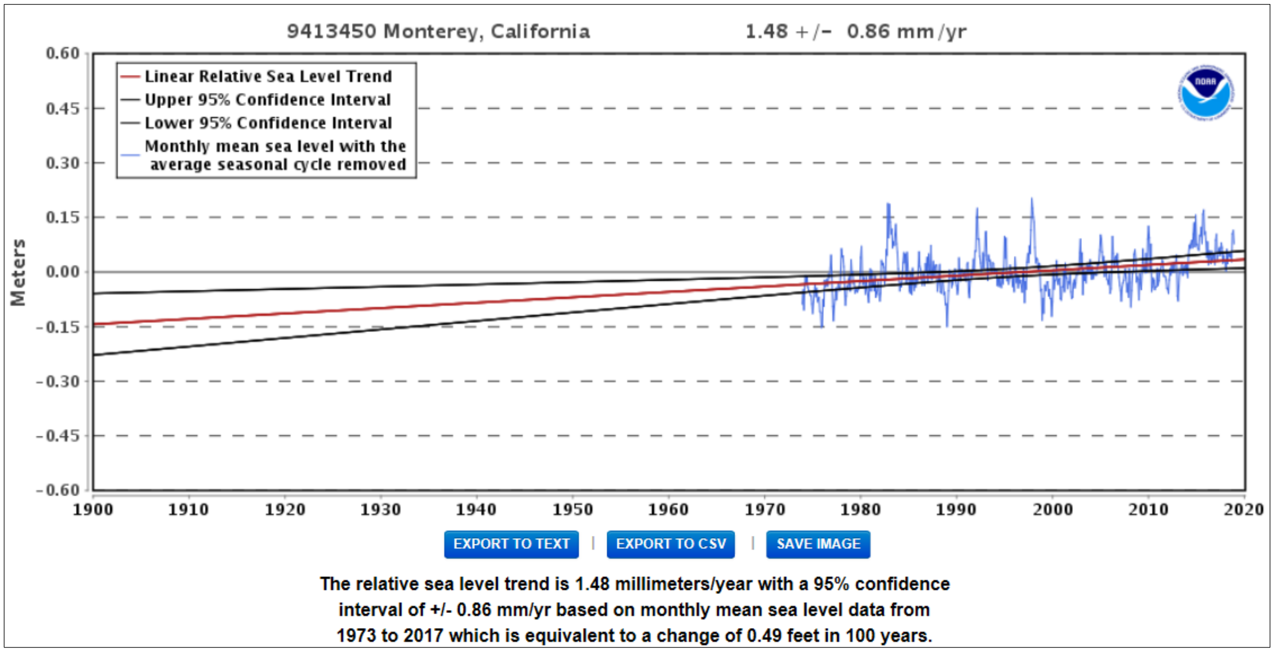
NOAA maintains a tide gauge at Monterey to measure tides in Monterey Bay. This station has collected data since 1973 and enables NOAA to provide tide predictions for the area of the Santa Cruz Municipal Pier. The occurrence and timing of high tides can be accurately forecast and is published in annual tide tables. These are an important tool for predicting when potential sea-level rise related flooding can occur with future sea-level rise.

Measurements of actual sea-level rise currently follows two pathways, which detect changes in the ocean level from tide gauges, and alternatively from satellite altimetry.

Mean Sea-Level Trend from Tide Gauges. The first method, which NOAA utilizes is detecting the mean sea level trend based on many years of recorded tides. Figure 11 shows the historical record of tides measured at Monterey (blue curve) and the estimated linear relative sea level trend (red line). A difficulty with this approach is detecting a limited trend of sea-level rise in the tide data, where water level variations are far greater than the measured sea-level rise. Additional elements that add uncertainty to the data include seasonal fluctuations of the water level due to coastal ocean temperatures (El Niño and La Niña effects), salinity variation, wind shear, atmospheric pressure variation, and ocean currents. Another complication can be ground motion as any vertical movement of the ground will offset the water level measurements. Causes of vertical land motion in California can include creep, subsidence, earthquakes and post-glacial rebound.

Most climate change scenarios predict trends where the rate of sea-level rise increases in the future, i.e. sea-level rise accelerates over time. Such trends have not yet been detected in the data, but the data NOAA has been collecting at Monterey since 1973 will prove valuable for documentation of the mean sea-level rise trend as sea-level rise unfolds. NOAA is working actively to advance sea-level rise science and it is likely that NOAA scientists will improve their tools for prediction of the sea-level rise trend.

Figure 11: Sea-level rise monitoring at Monterey.



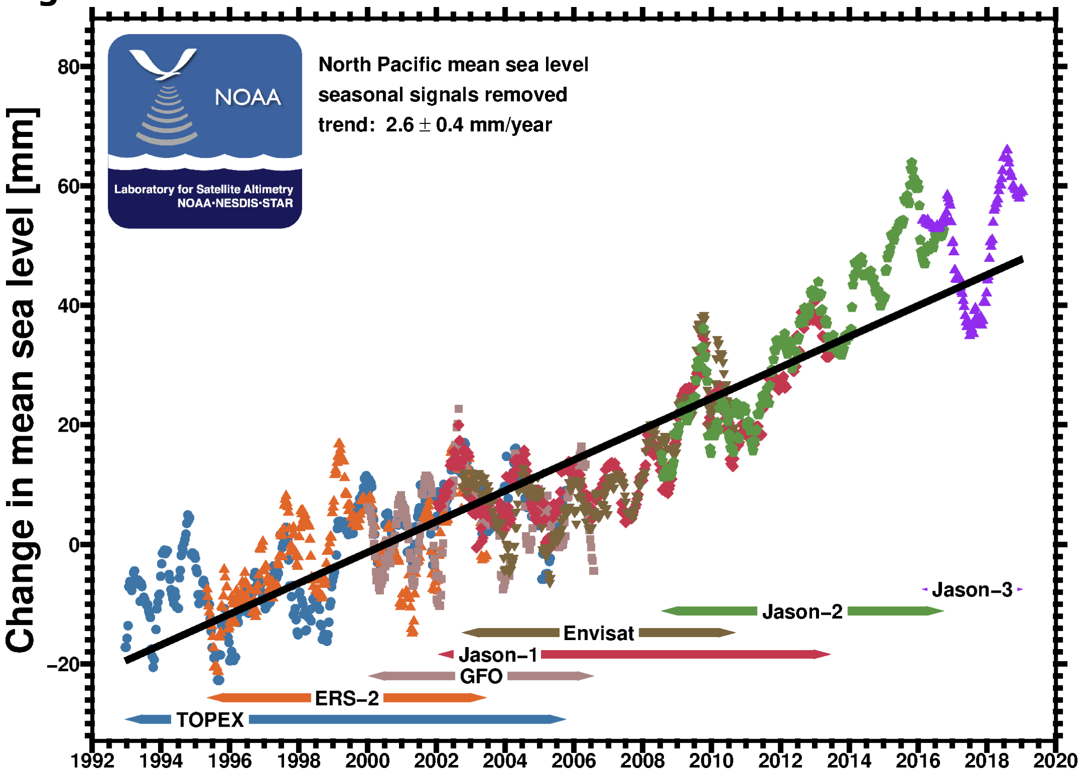
As part of climate adaptation planning, the City of Santa Cruz and Santa Cruz County are proposing to install a permanent tide gauge at Santa Cruz which would benefit NOAA sea-level rise monitoring programs and aid the Port District with improved local sea-level rise monitoring.

Mean Sea-Level Trend from Satellite Altimetry. The second method for tracking sea-level rise is monitoring of ocean levels via satellite altimetry. These efforts are sponsored by NASA and partner organizations worldwide. Recent efforts have focused on aligning satellite measurements of ocean levels with measurements from tide gauges as the two methods initially produced different estimates. Measurements of the ocean level from satellites has its own difficulties, and effects that can offset the measurements include ionospheric effects from the slight delay of the altimeter radar wave as it propagates through the atmosphere; changes in atmospheric moisture content; ocean surface variation due to wave action, tides and barometric pressure variations, and gravitational effects due to variations in the topography of the seafloor.

NASA satellite data estimates that global mean sea level has risen by 8 inches since 1870, which is an average rate of 1.35 mm/year and comparable to the linear trend determined by NOAA in Figure 11.

In the more recent timeline, NASA estimates that the rate of sea-level rise has doubled in the past two decades and global ocean levels have risen by an average of nearly 3 inches since 1992. Figure 12, summarizes the satellite altimetry data for the North Pacific collected since 1992 via a number of satellite measurement programs (TOPEX, ERS-2, GFO, Jason-1, Envisat, Jason-2, and Jason-3). This estimated average mean sea-level trend for the North Pacific is 2.6 mm/year. It is not known if the differences in the estimated rates of sea-level rise are due to factors offsetting the results, or whether global sea-level rise is accelerating.

Figure 12: North Pacific sea-level trend estimated based on satellite altimetry.



d. Describe any regional partnerships the trustee is part to or intending to form that would address sea-level and climate change vulnerability or increase resiliency

It is a goal of the Santa Cruz Port District to actively work on sea-level rise related planning. To ensure increased resiliency, the Port District will work to identify and prioritize future sea-level rise related projects and potential funding sources.

The Port District intends to engage technical consultants with expertise in climate science who monitor relevant information released by organizations, such as the California Ocean Protection Council and the California Ocean Science Trust. Additionally, the District intends to participate in educational opportunities, such as those offered online by advocacy groups such as the Climate Readiness Institute.

In the future, the Port District may choose to partner with the City of Santa Cruz' Climate Action Task Force Adaptation Subcommittee to coordinate and address concerns relative to sea-level rise.

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