Appendices

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Appendix A. Sea Level Rise Science and Scenarios of Future Change

DRIVERS OF SEA LEVEL RISE

The main mechanisms driving increases in *global* sea level are: 1) expansion of sea water as it gets warmer (thermal expansion) and, 2) increases in the amount of water in the ocean from melting of land-based ice sheets and glaciers. Less significant contributors include human-induced changes in water storage and groundwater pumping.[113]

Sea level at the *regional and local levels* often differs from the average global sea level.[114] Regional variability in sea level results from large-scale tectonics and ocean and atmospheric circulation patterns. The primary factors influencing local sea level include tides, waves, atmospheric pressure, winds, vertical land motion and short duration changes from seismic events, storms, and tsunamis. Other determinants of local sea level include changes in the ocean floor (Smith and Sandwell 1997), confluence of fresh and saltwater, and proximity to major ice sheets (Clark *et al.* 1978; Perette *et al.* 2013; Fox-Kemper *et al*., 2021). Table 9.7 in the IPCC Sixth Assessment Report summarizes all global, regional, and local processes driving sea level rise. In California, long tide gauge records together with recent observations suggest that the long term sea level rise trend in California will track the global average (Hamlington *et al*., 2021).

Several other factors can influence local water levels in California, and these influences should be analyzed along with local sea level rise when examining local hazard conditions. For example, California's water levels are influenced by large-scale oceanographic phenomena such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), which can increase or decrease coastal water levels for extended periods of time. For example, strong El Niño events can temporarily elevate local sea levels by six to twelve inches over several months, while more sustained changes in ocean temperature and atmospheric circulation patterns can affect sea level on the order of decades. Over the past 30 years, for example, sea level rise was essentially absent during the first 15 years and then substantially accelerated during the second half due to the combined effects of ENSO and PDO (Hamlington *et al*., 2021) Please see Appendix B for more detail on how to incorporate both sea level rise and seasonal and temporary influences on water levels into local hazards analyses.

APPROACHES FOR PROJECTING FUTURE GLOBAL SEA LEVEL RISE

As summarized above, there are several different drivers of sea level rise, and scientists are using a variety of methods to research each one and project their future contributions to sea level rise (see box below). For some, like thermal expansion, there is thorough research and fairly high agreement about how it may respond to different levels of warming and contribute

[113] Large movements of the tectonic plates have been a third major mechanism for changes in global sea level. The time periods for plate movements to significantly influence global sea level are beyond the time horizons used for even the most far-reaching land-use decisions. Plate dynamics will not be included in these discussions of changes to future sea level.

to global sea level rise in the future; whereas others, like certain ice sheet melt processes, are areas of developing research where more work is needed.

Many reports, including the IPCC Assessment Reports, build global mean sea level rise projections by totaling the contributions of each major driver of sea level rise under certain assumptions about what the global climate will look like in the future. Because each driver has its own degree of scientific uncertainty,[115] total sea level rise reflects the various uncertainties associated with each contributor. Total sea level rise projections are then presented as means (or averages) with uncertainty bands around them, and users often look at the mean, the likely range (i.e., the middle 66% of the uncertainty range, or 17th to 83rd percentiles), and the very likely range (i.e., the middle 90% of the uncertainty range, or the 5th to 95th percentiles) to understand how much sea level rise could potentially occur under the given assumptions about emissions and warming. Estimates of sea level rise produced in this manner are known as "probabilistic projections." In addition to the IPCC Assessment Reports, other studies that produced projections include Kopp *et al*., 2014, the Fourth California Climate Assessment, and *Rising Seas in California* (Griggs *et al*., 2017). Each produced projections for various Representative Concentration Pathways (RCPs), the emissions scenarios defined by the IPCC.

Besides probabilistic projections, another way that researchers often present potential future sea level rise is in the form of "scenarios." Unlike projections, which are based on pre-defined assumptions about future greenhouse gas emissions and global warming, scenarios are instead hypothetical futures that span the range of what is considered plausible sea level rise according to the best available science. They often span several sets of projections that cover multiple potential emissions futures, and they can be compared to probabilistic projections to describe their likelihoods under various emissions futures. Examples of reports that provide scenarios include Parris *et al*., 2012, Hall *et al*., 2016, Sweet *et al*., 2017, Sweet *et al*., 2022, and the State Sea Level Rise Guidance (OPC 2024).

[115] To describe the varying statuses of scientific research on different research topics, the IPCC established a common approach for evaluating and communicating the degree of certainty in findings. It defined a range of "confidence levels" to describe the level of evidence and degree of agreement in the body of scientific literature on a particular subject (very low, low, medium, high, and very high). Table 9.7 in the IPCC Sixth Assessment report summarizes the methods used to generate the projections of SLR resulting from each physical driver of SLR as well as the degree of confidence in each.

Categories of methods for projecting future change

Scientists have employed a variety of techniques to model the various mechanisms that contribute to sea level rise, including:

1. **Physical Models**. Physical climate models use mathematical equations that integrate the basic laws of physics, thermodynamics, and fluid dynamics with chemical reactions to represent physical processes such as atmospheric circulation, transfers of heat (thermodynamics), development of precipitation patterns, ocean warming, and other aspects of climate. Some models represent only a few processes, such as the dynamics of ice sheets. Other models represent larger scale atmospheric or oceanic circulation, and some of the more complex General Climate Models (GCMs) include atmospheric and oceanic interactions. AR6 sea level rise projections drew from the sixth Coupled Model Intercomparison Project (CMIP6) climate models, particularly to inform sea level rise contributions based on medium confidence processes (i.e., processes of sea level rise for which the AR6 scientists had medium or higher confidence) from thermal expansion and ice sheets.
2. **Empirical or semi-empirical methods**. The semi-empirical method for projecting sea level rise is based on developing a relationship between sea level and some factor (a proxy) – often atmospheric temperature or radiative forcing – and using this relationship to project changes to sea level. An important aspect for the proxy is that there is fairly high confidence in models of its future changes; a key assumption that is made by this method is that the historical relationship between sea level and the proxy will continue into the future. For example, Rahmstorf 2007 projected future sea levels based on the historical relationship between global temperature changes and sea level changes.
3. **Expert elicitations**. Expert elicitation is a formalized use of experts in climate science and sea level change to help either narrow uncertainty for sea level projections, or to help with specifying extremes of a range. For example, Bamber and Aspinall (2013) used a statistical analysis of a large number of expert estimates to develop their projected range of future sea level, projecting sea level rise by 2100 ranging from 1–4.3 ft (0.33–1.32 m). Bamber *et al*., 2019 used structured expert judgement to quantify contributions to total sea level rise from Greenland and Antarctica ice sheets, and these estimates were incorporated into AR6 sea level rise projections.
4. **Extrapolations of historical trends**. Using extrapolation of historical trends in sea level to project future changes in sea level assumes that there will be no abrupt changes in the processes that drive the long-term trend, and that the driving forces will not change, which is not the case. An alternative approach is to estimate rates of sea level rise during the peak of the last interglacial (LIG) period (~125,000 years before present, when some drivers of sea level rise were similar to those today)[116] and use these as proxy records to project sea level rise rates to the 21st Century. For example, Kopp *et al.* (2009) used sea level rise rates inferred from the LIG to estimate a range of sea level rise for Year 2100 between 1-3 ft (0.3-1 m).

[116] During the last interglacial, global mean temperature was 1-2ºC warmer than the pre-industrial era (Levermann *et al.* 2013), while global mean sea level was likely 16.4-29.5 ft (5-9 m) above present mean sea level (Kopp *et al.* 2009; Dutton and Lambeck 2012; Levermann *et al.* 2013).

The State Sea Level Rise Guidance (OPC 2024) drew from the sea level rise scenarios in a federal report, *Global and Regional Sea Level Rise Scenarios for the United States* (Sweet *et al*., 2022). This report updated a set of global mean sea level rise scenarios that had been included in the previous iteration of the report which was published in 2017. These 2017 scenarios included 0.3, 0.5, 1.0, 1.5, 2.0, and 2.5 meters in 2100, also called Low, Intermediate-Low, Intermediate, Intermediate-High, High, and Extreme. The 2.5-meter-in-2100 scenario was included in this 2017 set of scenarios to capture the amount of sea level rise that could occur due to possible extreme Antarctic ice sheet and ice cliff instability as described in the then-recently released 2016 report by DeConto & Pollard.

However, a subsequent report, DeConto *et al*., 2021, looked at updated regional climate model forcing and found that air temperatures are not expected to rise as quickly in Antarctica as presumed in DeConto & Pollard 2016; rather, warming may take about 25 years longer to rise enough to potentially trigger the mechanisms of rapid retreat of the Antarctic Ice Sheet[117] that were described in DeConto & Pollard 2016 – i.e., by about the year 2125. Due to this change, Sweet *et al*., 2022 did not include the 2.5-meters-in-2100 (or Extreme) sea level rise scenario, leaving 0.3, 0.5, 1.0, 1.5, and 2.0 meter-in-2100 scenarios, which were called the Low, Intermediate-Low, Intermediate, Intermediate-High and High scenarios.

In effect, this action backtracked on the reasoning that led to the inclusion of 2.5 meters-in-2100 (which was regionalized to 10.2 feet-in-2100 in California) in Sweet et al., 2017, Rising Seas in California, and the 2018 version of the State Sea Level Rise Guidance. This change caused Sweet et al., 2022 to state, "the 'Extreme' scenario from the 2017 report (2.5 m global mean sea level rise by 2100) is now viewed as less plausible and has been removed." In other words, while 2.5 meters of sea level rise could occur a few decades after the year 2100 in the worst-case scenario, updated research has generally concluded that there is little to no possibility of that amount of sea level rise occurring as early as the year 2100 (DeConto *et al*., 2021).

Similar to Sweet *et al*., 2017, which overlaid its sea level rise scenarios with probabilistic sea level rise projections based on a group of papers, Sweet *et al*., 2022 overlaid its scenarios with the probabilistic projections from AR6. An associated FAQ describing the methods used in Sweet *et al*., 2022 states,

> "To generate the scenarios used in this report, the ensemble – or set – of projections in the AR6 that are tied to specific shared societal pathways (SSPs) are filtered to identify subsets of pathways that are consistent with the scenario target values in 2100 (i.e., 0.3 m, 0.5 m, 1 m, 1.5 m and 2 m). As in the AR6, these scenarios are regionalized and then

[117] DeConto *et al*., 2021 states, "With more extreme RCP8.5 warming, thinning and hydrofracturing of buttressing ice shelves becomes widespread, triggering marine ice instabilities in both West and East Antarctica. The RCP8.5 median contribution to GMSL is 34 cm by 2100. This is substantially less than reported by ref. 8 [DeConto & Pollard 2016] (64–105 cm), owing to a combination of improved model physics and revised atmospheric forcing (Methods) that delays the onset of surface melt by about 25 years. Nonetheless, the median contribution to GMSL reaches 1 m by 2125 and rates exceed 6 cm yr−1 by 2150 (Extended Data Figs. 6, 7). By 2300, Antarctica contributes 9.6 m of GMSL rise under RCP8.5, almost 10 times more than simulations limiting warming to +1.5 °C."

> provided at individual tide gauge locations. The median, 17th and 83rd percentile values are provided for each scenario at each region and location."

In other words, a subset of sea level rise curves from the sets of AR6 projections that go through 0.3, 0.5, 1.0, 1.5 and 2.0 meters in the year 2100 were identified, thus informing each Sweet *et al*., 2022 scenario. This exercise was also summarized in Chapter 2 of the State Sea Level Rise Guidance (2024).

The information pulled through from AR6 also yielded a "storyline" for each scenario, which is summarized in Figure 4 of the report and copied below. For example, the Intermediate, Intermediate-High and High scenarios correspond to projections in AR6 that assume high emissions and warming and various levels of contribution from low confidence ice sheet processes (see below). The information from AR6 also allowed Sweet *et al*., 2022 to provide exceedance probabilities for various sea level rise amounts at various times in the future and under different amounts of global warming.

BEST AVAILABLE SCIENCE ON SEA LEVEL RISE

In the past century, global mean sea level (GMSL) has increased by nearly 8 inches (20 cm; Fox-Kemper *et al*., 2021). Observations of sea level rise rates have also shown that sea level rise has been accelerating in recent decades. While tide gauge measurements show roughly 5 inches of sea level rise during the entirety of the 20th century (Frederikse *et al*., 2020), satellite altimeters have measured an additional 4 inches of sea level rise since 1993, a period of only 30 years (Willis, Hamlington, Fournier, 2023). The current rate of GMSL rise (1.7 inches/decade) is triple the 20th century rate (Dangendorf *et al*., 2019; Nerem *et al*., 2018). The best available science on projected future sea level rise is summarized here and in the Ocean Protection Council's State Sea Level Rise Guidance (OPC 2024).

Global Projections of Sea Level Rise

IPCC AR6: The best available science on global sea level rise projections is currently the IPCC Sixth Assessment Report: Climate Change 2013 (AR6) released in 2021 (IPCC, 2021). AR6 projects slightly more rapid sea level rise compared to the Fifth Assessment (AR5) released in 2013. By Year 2100, the AR6 projects likely global sea level rise in the year 2100 to be 0.63–1.01 m whereas AR5 projected 0.49–0.95 m (AR5) when comparing similar, high emission scenarios.

Like AR5, AR6 produced projections of sea level rise by compiling the latest research on the various drivers of sea level rise, including thermal expansion of seawater, melting of land-based ice in Antarctica and Greenland, and other processes. Some drivers of sea level rise were well studied and there was strong agreement about their potential future contributions to sea level rise, whereas others were less studied and not as well understood. The AR6 authors distinguished between drivers of sea level rise in which there was at least medium confidence and drivers in which there was low confidence. Projections based on medium-confidence processes were computed for the emissions and global development futures called SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5[118]. For two of these five emissions scenarios, SSP1-2.6 and SSP5-8.5, additional work was done to also incorporate low confidence processes of extreme ice melt in Antarctica, including those described in DeConto *et al*., 2021[119], creating two additional sets of projections for a total of seven different sets of sea level rise projections. Figure A-1 is a graph generated by NASA and the IPCC's Sea Level Projection Tool that depicts the global mean sea level rise projections under all seven SSPs. Together, these seven sets of projections describe the IPCC's full plausible range of future sea level rise, reflecting how sea level rise would vary under the IPCC's range of conceivable global development, emissions, and warming futures as well as the possibility of rapid ice sheet disintegration.

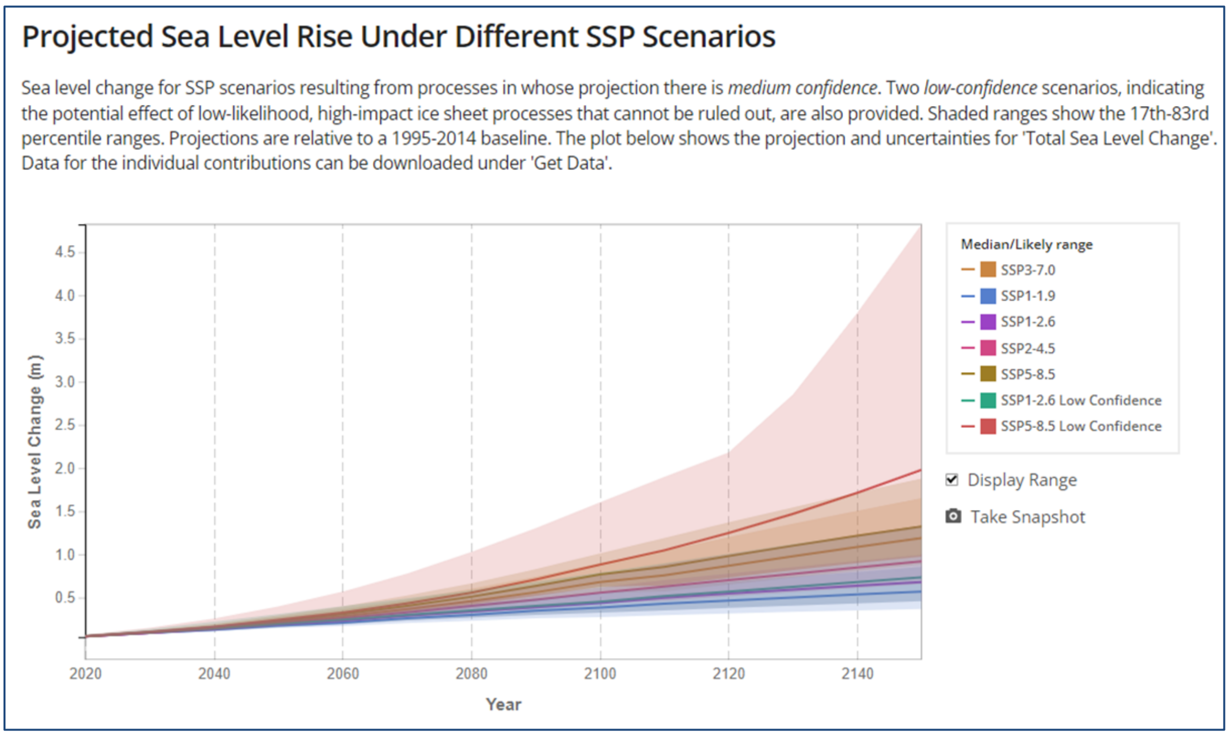

Figure A-1. IPCC AR6 plausible range of future SLR. A graph generated by NASA and the IPCC's Sea Level Projection Tool that depicts the global mean SLR projections under all five SSPs, plus the two additional scenarios that incorporate additional low confidence ice sheet processes.

[118] The Scenario Model Intercomparison Project (ScenarioMIP) for the Coupled Model Intercomparison Project Phase 6 (CMIP6) developed five different Shared Socioeconomic Pathways (SSP1 through SSP5) (O'Neill *et al*., 2016). These SSPs capture different ways the world could evolve in terms of population, economic growth, education, urbanization, and technological development, which, without additional new efforts to curb climate change. Each would result in various amounts of radiative forcing, which is expressed in the second half of the SSP name. For example, SSP3-7.0 comes from SSP3 and results in 7.0 Watts/m^2 of radiative forcing.

[119] Low confidence processes include earlier-than-projected disintegration of marine ice shelves and the abrupt, widespread onset of Marine Ice Sheet Instability (MISI) and Marine Ice Cliff Instability (MICI) around Antarctica, as well as faster-than-projected changes in the surface mass balance and dynamical ice loss from Greenland. AR6's low confidence SLR projections stemmed from a structured expert-judgement study (Bamber *et al*., 2019) and a single Antarctic ice-sheet modeling study (DeConto *et al*., 2021). See §9.6.3.2, §9.6.3.3, and Box 9.4 of Fox-Kemper *et al*., 2021, for further discussion. Box 9.4 of AR6's Chapter 9, in particular, discusses AR6's separation of medium-confidence sea level rise SLR projections from low-confidence sea level rise projections.

NOAA technical report: In 2017, NOAA released a report entitled Global and Regional Sea Level Rise Scenarios for the United States (Sweet et al., 2017) which provided global sea level rise scenarios and projections[120]. It provided scenarios of 0.3, 0.5, 1.0, 1.5, 2.0, and 2.5 meters in 2100 (also called Low, Intermediate-Low, Intermediate, Intermediate-High, High, and Extreme), and overlaid them with emissions-based, probabilistic sea level rise projections compiled from Church *et al*., 2013a (which is IPCC's Fifth Assessment Report, or AR5), Miller *et al*., 2013; Kopp *et al*., 2014, 2016a; Slangen *et al*., 2014; and Mengel *et al*., 2016, which produced probabilistic projections under assumed climate trajectories of RCPs 2.6, 4.5, and 8.5.

When discussing how to apply the scenarios, Sweet *et al* 2017 suggested a potential strategy as follows: "Define a scientifically plausible upper-bound (which might be thought of as a worst-case or extreme scenario) as the amount of sea level rise that, while low probability, cannot be ruled out over the time horizon being considered. Use this upper-bound scenario as a guide for overall system risk and long-term adaptation strategies. Define a central estimate or mid-range scenario (given assumptions about greenhouse gas emissions and other major drivers). Use this scenario as baseline for shorter-term planning, such as setting initial adaptation plans for the next two decades."

In 2022, an update to Sweet et al., 2017 titled, Global and Regional Sea Level Rise Scenarios for the United States (Sweet et al., 2022) was released, which incorporated new research that occurred between 2017 and 2022. Of the many papers published in that time period was DeConto et al., 2021, which built on the DeConto & Pollard 2016 paper that was key in justifying the inclusion of 2.5 meters-in-2100 as a sea level rise scenario in Sweet et al., 2017. DeConto et al., 2021 looked at updated regional climate model forcing and found that air temperatures are not expected to rise as quickly in Antarctica as presumed in DeConto & Pollard 2016; rather, warming may take about 25 years longer to rise enough to potentially trigger the mechanisms of rapid retreat of the Antarctic Ice Sheet[121] that were described in DeConto & Pollard 2016 – i.e., by about the year 2125. Due to this change, Sweet et al., 2022 removed 2.5-meters-in-2100 (or Extreme) sea level rise scenario, leaving 0.3, 0.5, 1.0, 1.5, and 2.0 meter-in-2100 global mean scenarios, which were called the Low, Intermediate-Low, Intermediate, Intermediate-High and High scenarios. Figure A-2 is a graph generated by NASA Interagency Sea Level Rise Scenario Tool that depicts Sweet *et al*., 2022's five sea level rise scenarios.

[120] Note that The Fourth National Climate Assessment (USGCRP, 2018) points to the scenarios of Sweet et al., 2017 and includes a discussion of other studies that provide sea level rise estimates as well as a discussion of overall uncertainty (see pages 106-109).

[121] DeConto et al., 2021 states, "With more extreme RCP8.5 warming, thinning and hydrofracturing of buttressing ice shelves becomes widespread, triggering marine ice instabilities in both West and East Antarctica. The RCP8.5 median contribution to GMSL is 34 cm by 2100. This is substantially less than reported by ref. 8 [DeConto & Pollard 2016] (64–105 cm), owing to a combination of improved model physics and revised atmospheric forcing (Methods) that delays the onset of surface melt by about 25 years. Nonetheless, the median contribution to GMSL reaches 1 m by 2125 and rates exceed 6 cm yr−1 by 2150 (Extended Data Figs. 6, 7). By 2300, Antarctica contributes 9.6 m of GMSL rise under RCP8.5, almost 10 times more than simulations limiting warming to +1.5 °C."

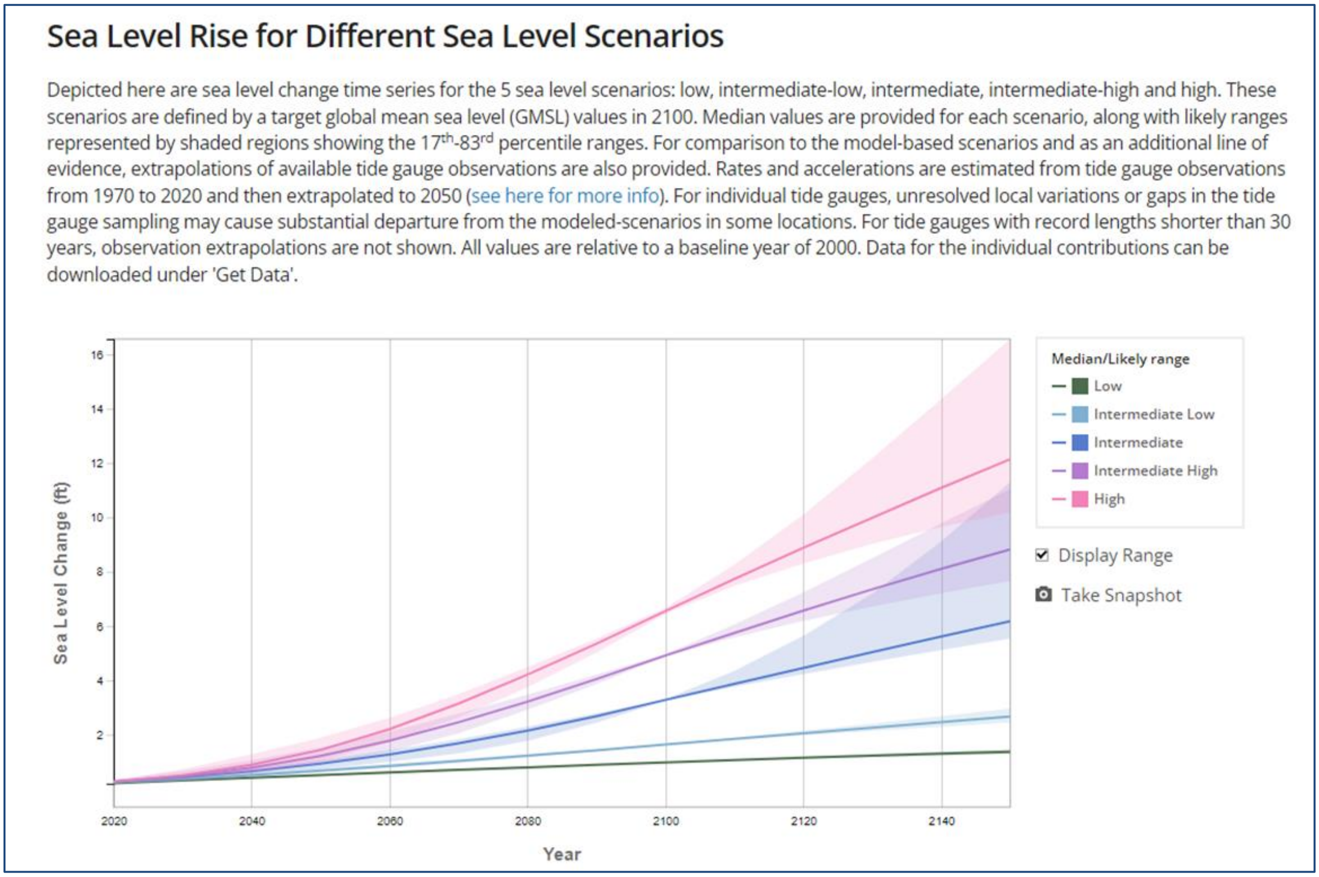

Figure A-2. Global SLR Scenarios from Sweet *et al*., 2022. This graph was generated by NASA Interagency Sea Level Rise Scenario Tool and depicts Sweet *et al*., 2022's five global mean sea level rise scenarios.

National Projections of Sea Level Rise

NOAA technical report: In addition to providing global mean sea level rise scenarios, Global and Regional Sea Level Rise Scenarios for the United States (Sweet *et al*., 2022) provided scenarios for the contiguous United States by regionalizing the global scenarios. This process reflects how sea level rise around the United States may differ from the global average due to ocean dynamics (i.e., changes to the ocean's currents and density due to climate change), large scale vertical land motion (i.e., glacial isostatic adjustment (GIA), tectonics, sediment compaction, and/or groundwater and fossil fuel withdrawals), and the impacts of gravitational, rotational, and deformational changes (i.e., GRD, or ice sheet fingerprinting). In general, sea level rise scenarios for the United States are at or higher than global mean sea level rise due to effects from vertical land motion, GRD, and ocean circulation changes (Sweet *et al*., 2022). Figure A-3 is a graph generated by NASA Interagency Sea Level Rise Scenario Tool that depicts the five sea level rise scenarios regionalized for the contiguous United States.

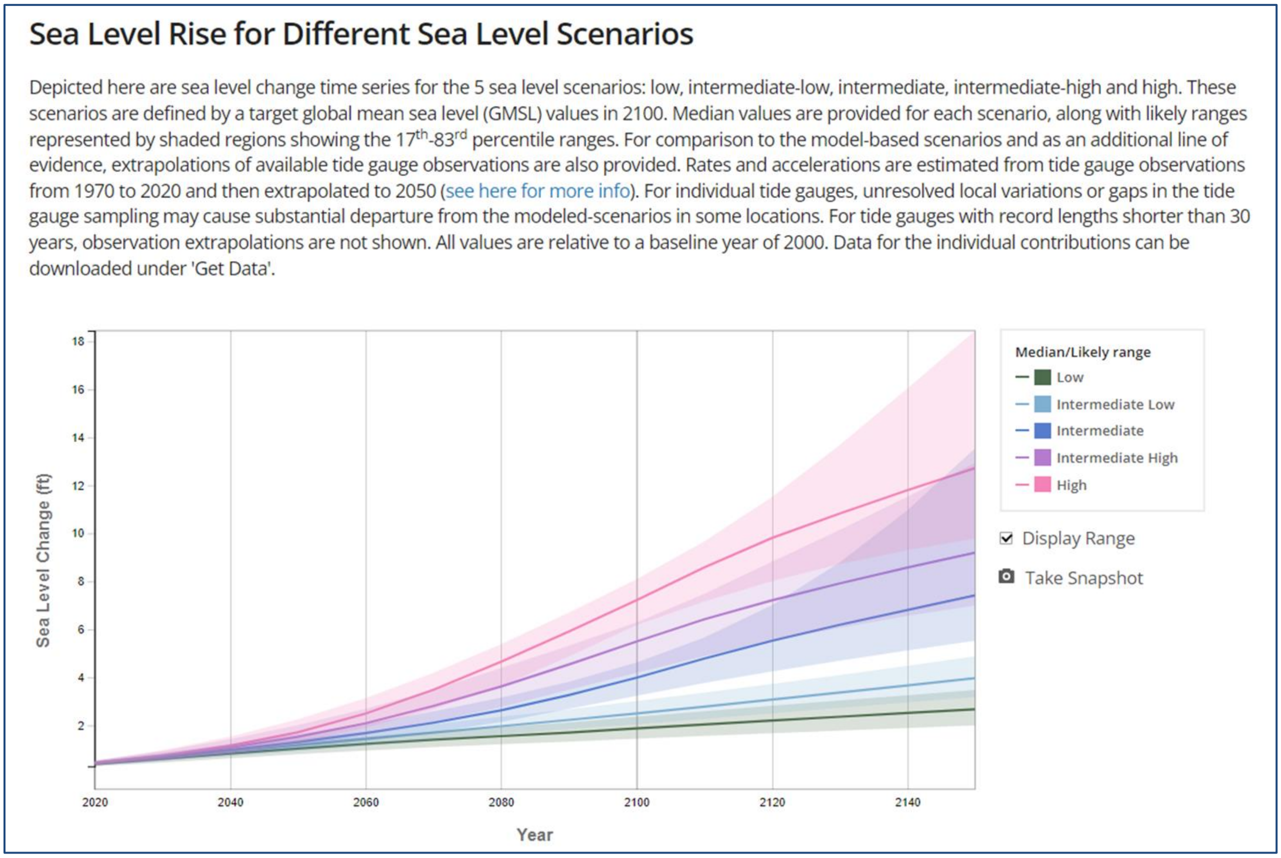

Figure A-3. SLR Scenarios for the contiguous United States from Sweet *et al*., 2022. This graph was generated by NASA Interagency Sea Level Rise Scenario Tool and depicts Sweet *et al*., 2022's five sea level rise scenarios for the contiguous United States.

California-Specific Sea Level Rise Scenarios and Best Available Science

The State of California has long supported the development of scientific information on climate change and sea level rise to help guide planning and decision-making. Several iterations of the *State Sea Level Rise Guidance* have been informed by key research that, at the time, provided the best available science on sea level rise projections:

- The 2013 State Sea-Level Rise Guidance (OPC 2013) was informed by the 2012 National Research Council (NRC) report, Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.
- The 2018 State Sea Level Rise Guidance (OPC 2018) was informed by Rising Seas in California: An Update on Sea-Level Rise Science (Griggs et al., 2017).
- The 2024 State Sea Level Rise Guidance (OPC 2024) was informed by Global and Regional Sea Level Rise Scenarios for the United States (Sweet et al., 2022).

The 2024 State Sea Level Rise Guidance provides sea level rise scenarios based on Sweet et al., 2022.[122] Like Sweet et al., 2022, the State Guidance establishes the plausible range of global mean sea level rise in 2100 to be between 0.3 and 2.0 m and identifies roughly even increments of sea level rise to span that range: 0.3-, 0.5-, 1.0-, 1.5-, and 2.0 m-in-2100. These five scenarios are named Low, Intermediate-Low, Intermediate, Intermediate-High, and High.

Next, these sea level rise amounts were compared to the thousands of sea level rise projections within the seven sea level rise projections the provided in AR6. A +/- 2 cm "gate" around each scenario was created (i.e., 0.3m +/- 2cm in 2100, 0.5m +/- 2cm in 2100, 1.0m +/- 2cm in 2100, etc.) and the samples of AR6 projections that go through each gate were extracted, creating five sample sets, as shown in Figure A-4.

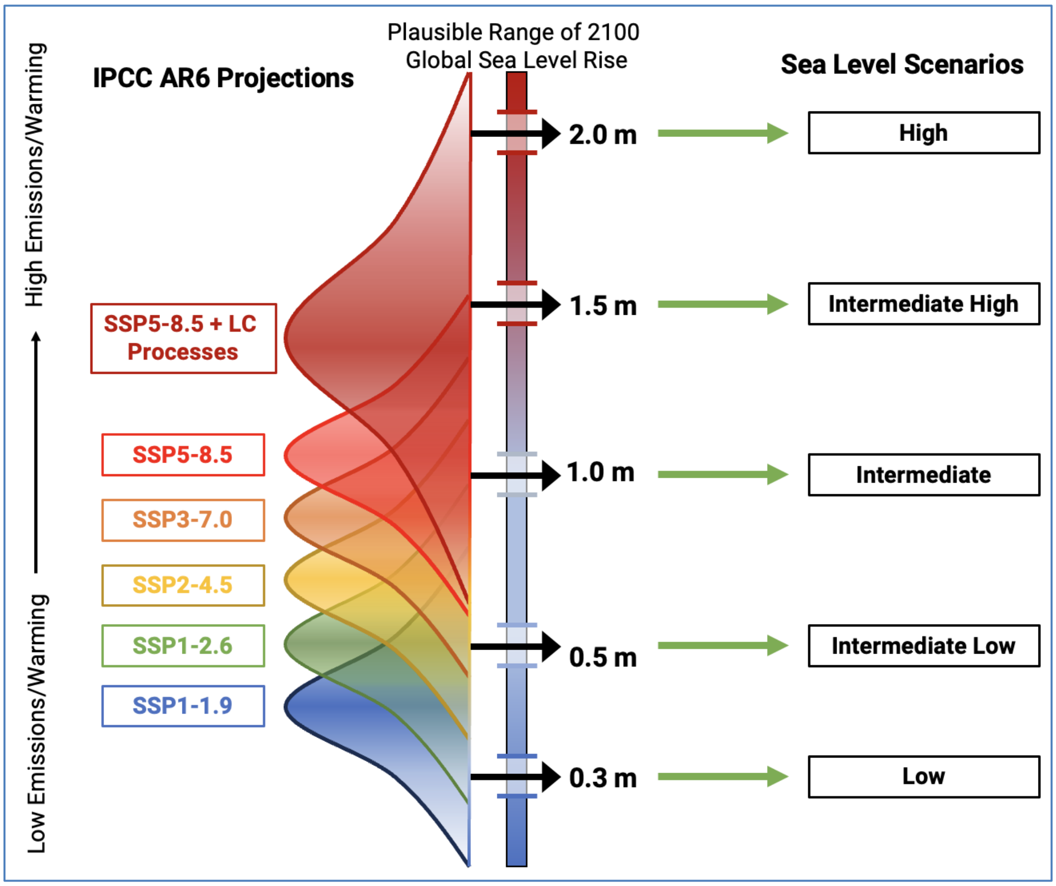

Figure A-4. Schematic showing that the construction of the sea level scenarios is based on SSPs, which inform a range of plausible future sea level rise. Provided as Figure 2.2 in the *California State Sea Level Rise Guidance* (OPC 2024)

The composition of these sample sets informed both the trajectory of each sea level rise scenario over time and a "storyline" for each scenario. In other words, the sample set for each scenario was used to describe the climate conditions under which each may occur. The State

[122] Please see Chapter 2 of the 2024 State Sea Level Rise Guidance to read the report's full summary of how the sea level rise scenarios were generated.

Sea Level Rise Guidance provides these storylines in Section 2.4 and summarizes them in its Executive Summary as follows:

- **"Low Scenario**: The target of 1 foot of increase in global sea level rise by 2100 is set under the assumption of the current rate of sea level rise continuing on into the future. This assumption is inconsistent with current observations of an acceleration in sea level rise, but could still be considered plausible under the most aggressive emission reduction scenarios. As a result, the Low Scenario provides the lower bound for plausible sea level rise in 2100 and sits below the median value for all AR6 scenarios at all times between 2020 to 2150. The likelihood of exceeding this Sea Level Scenario is greater than 90% at all warming levels.
    - SUMMARY: Aggressive emissions reductions leading to very low future emissions; the scenario is on the lower bounding edge of plausibility given current warming and sea level trajectories, and current societal and policy momentum.

- **Intermediate-Low Scenario:** This scenario arises under a range of both future warming levels and possible SSPs, spanning low, intermediate and high emissions pathways, and integrates many of the AR6 SSP pathways as a result (see Figure 2.2) This scenario is consistent with the median projected sea level rise in a 2°C world, which means there is a 50% probability of exceeding this scenario with 2°C of additional warming by 2100. At a warming level of 3°C in 2100, the probability of exceeding this scenario is 82%. Given the extrapolation of GMSL to 2100 (approximately 2.2 feet36), the current projection of future warming of 3°C, and the range of sea level rise across the IPCC AR6 scenarios (Figure 2.4), the Intermediate Low Scenario provides a reasonable lower bound for the most likely range of sea level rise by 2100. Since the low confidence processes are not important to this scenario, the range of possible sea level rise after 2100 does not expand significantly.
    - SUMMARY: A range of future emissions pathways; a reasonable estimate of the lower bound of most likely sea level rise in 2100 based on support from sea level observations and current estimates of future warming.

- **Intermediate Scenario**: The Intermediate Scenario is driven dominantly by high emissions scenarios, and thus higher warming levels. For the first time in the scenarios, the low confidence projections from the IPCC AR6 contribute significantly and provide about 25% of the pathways for reaching the Intermediate Scenario target by 2100. Given the extrapolation of GMSL to 2100 and the range of sea level rise across the IPCC AR6 scenarios (Figure 2.4), the Intermediate Scenario provides a reasonable upper bound for the most likely range of sea level rise by 2100. At a warming level of 3°C in 2100, the probability of exceeding this scenario is 5%. In a very-high emissions future with low confidence processes, there is about a 50% chance of exceeding the Intermediate scenario in 2100.

  - SUMMARY: A range of future emissions pathways; could include contribution from low confidence processes. Based on sea level observations and current estimates of future warming, a reasonable estimate of the upper bound of most likely sea level rise in 2100.

- **Intermediate-High Scenario**: Pathways combining both higher emissions and low confidence processes become the majority, with over 50% of the samples used to construct this scenario coming from the SSP5-8.5 scenario. At all times from 2020 to 2150, the Intermediate High Scenario exceeds the median value of the AR6 scenarios. This scenario is similar to the high-end estimate from van de Wal et al. (2022) under the assumption of high levels of warming in 2100. At a warming level of 3°C in 2100, the probability of exceeding this scenario is 0.1% when not considering the low confidence processes, emphasizing the degree to which these processes are needed to get to this scenario. With the low confidence processes, the probability of exceeding this scenario is approximately 20% for very high warming levels.
  - SUMMARY: Intermediate-to-high future emissions and high warming; this scenario is heavily reflective of a world where rapid ice sheet loss processes are contributing to sea level rise.

- **High Scenario:** Pathways combining both high emissions and low confidence processes are dominant, providing over 80% of the samples to construct the scenario. Low emissions pathways are not plausible under this scenario, and intermediate emissions pathways require a significant contribution from rapid ice sheet loss processes. Before 2100, the High Scenario is significantly above the range of SSP AR6 scenarios, although the range of plausible sea level expands beyond 2150. The probability of exceeding the High Scenario in 2100 is less than 0.1% for all warming levels without considering low confidence processes. With very high emissions and warming and contributions from the low confidence processes, this probability increases to 8%.
  - SUMMARY: High future emissions and high warming with large potential contributions from rapid ice-sheet loss processes; given the reliance on sea level contributions for processes in which there is currently low confidence in their understanding, a statement on the likelihood of reaching this scenario is not possible."

These five trajectories of sea level rise were then regionalized to California, and the California State Sea Level Rise Guidance presented a single set of scenarios representing the median sea level rise scenarios for California that reflect an average statewide value of vertical land motion, which is a negligible rate of 0.1 mm (0.0003 ft) per year uplift. These median statewide values are presented below in Table A-1.

Table A-1. Sea Level Rise Scenarios for California [123]

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.3	0.4	0.4	0.4	0.4
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.6	0.8	1.0	1.2
2060	0.6	0.8	1.1	1.5	2.0
2070	0.7	1.0	1.4	2.2	3.0
2080	0.8	1.2	1.8	3.0	4.1
2090	0.9	1.4	2.4	3.9	5.4
2100	1.0	1.6	3.1	4.9	6.6
2110	1.1	1.8	3.8	5.7	8.0
2120	1.1	2.0	4.5	6.4	9.1
2130	1.2	2.2	5.0	7.1	10.0
2140	1.3	2.4	5.6	7.7	11.0
2150	1.3	2.6	6.1	8.3	11.9

These average statewide scenarios were also further regionalized to reflect the observed rates of vertical land motion at each of California's 14 coastal tide gauges. These tide gauge-specific scenarios are provided in in Appendix 2 of the State Sea Level Rise Guidance (OPC 2024) and in Appendix G of this document.

The State Sea Level Rise Guidance also provided information about how likely each scenario is to occur in the year 2100 under various amounts of plausible future warming (Table A-2). Likelihoods were also provided assuming rapid ice sheet disintegration processes come into play in the 2100s. These likelihoods were derived from the sample sets of projections from AR6 on which each scenario was based, and they provide valuable information to shape our understanding of the likelihood that each scenario will or will not come to pass, and the risks the higher or lower scenarios may occur. As explained in the State Guidance, this table can be

[123] This table provides median values for sea level scenarios for California, in feet, relative to a year 2000 baseline. These statewide values all incorporate an average statewide value of vertical land motion – a negligible rate of 0.1 mm (0.0003 ft) per year uplift (OPC 2024). The red box highlights the three scenarios that the *State Sea Level Rise Guidance* and this guidance recommend for use in various planning and project contexts.

read as saying, "assuming 3°C of warming in 2100 and no influence from low-confidence ice sheet processes, there is a 5% chance of exceeding the Intermediate scenario in 2100" or "assuming high levels of warming in 2100 and contributions from the low confidence processes, there is a 49% chance of exceeding the Intermediate Scenario in 2100" and so on. The State Guidance also explains that global surface temperatures are currently on track to reach 3.0°C above pre-industrial levels by 2100, assuming current rates of emissions-driven warming.

Table A-2. Exceedance probabilities for the sea level scenarios based on IPCC warming level–based global mean sea level projections[124]

Global Mean Surface Air Temperature 2081-2100	1.5°C	2.0°C	3.0°C	4.0°C	5.0°C	Low Confidence Processes, Low Warming	Low Confidence Processes, High Warming
Low Scenario	92%	98%	99.5%	99.9%	>99.9%	90%	99.5%
Intermediate-Low Scenario	37%	50%	82%	97%	99.5%	49%	96%
Intermediate Scenario	0.5%	2%	5%	10%	23%	7%	49%
Intermediate-High Scenario	0.1%	0.1%	0.1%	1%	2%	1%	20%
High Scenario	<0.1%	<0.1%	<0.1%	<0.1%	0.1%	<0.1%	8%

The State Sea Level Rise Guidance (OPC 2024) offers the following Key Takeaways about the best available science on sea level rise:

- **"The California Sea Level Scenarios show greater certainty in the amount of sea level rise expected in the next 30 years** than previous reports and demonstrate a narrow range across all possible emissions scenarios. Statewide, sea levels are most likely to rise 0.8 ft (Intermediate Scenario) by 2050.
- **In the mid-term (2050-2100), the range of possible sea level rise expands** due to more uncertainty in projected future warming from different emissions pathways and certain physical processes (i.e. rapid ice sheet melt). By 2100, statewide averaged sea levels are expected to rise between 1.6 ft and 3.1 ft (Intermediate-Low to Intermediate Scenarios), although higher amounts are possible.

[124] The *California State Sea Level Rise Guidance* provides the following explanatory information for this table: "Global mean surface air temperature anomalies are projected for years 2081–2100 relative to the 1850–1900 climatology. Global surface temperatures are currently on track to reach 3.0°C above pre-industrial levels by 2100, assuming current rates of emissions-driven warming…The probabilities shown here are imprecise probabilities, representing a consensus among all projection methods applied by the IPCC AR6."

- **Over the long-term (towards 2100 and beyond), the range of sea level rise becomes increasingly large** due to uncertainties associated with physical processes, such as earlier-than-expected ice sheet loss and resulting future sea level rise. Sea levels may rise from 2.6 ft to 11.9 ft (Intermediate-Low to High Scenarios) by 2150, and even higher amounts cannot be ruled out.

- **Vertical land motion is the primary driver of local variations in sea level rise across the state**, driven by a combination of tectonics, sediment compaction, and groundwater and hydrocarbon withdrawal. Vertical land motion is incorporated into the sea level scenarios for each National Oceanic and Atmospheric Administration (NOAA) tide gauge and illuminates locations experiencing subsidence or uplift. The pathway associated with the extreme sea level rise scenario (i.e. H++) from Rising Seas 2017 is higher than the best available science now supports. The key lines of evidence that resulted in the extreme sea level rise scenario (i.e. H++) from Rising Seas 2017 have been updated and are now reflected in the Intermediate-High and High Scenarios.

- **Today's coastal storms provide a glimpse into our future** in which storm events will become more damaging and dangerous as climate change and sea level rise continue. Coastal storms under future sea level scenarios will cause accelerated cliff and bluff erosion, coastal flooding and beach loss, and mobilization of subsurface contaminants. Sea level rise will increase the exposure of communities, assets, services and culturally important areas to significant impacts from coastal storms.

- **Sea level rise will increase the frequency of coastal flooding events**, which occur when sea level rise amplifies short-term elevated water levels associated with higher tides, large storms, El Niño events, or when large waves coincide with high tides. California communities need to be aware of and prepared for a likely rapid increase in the frequency of coastal flooding in the 2030s, even beyond the increases in coastal flood frequency already occurring as a result of extreme storms.

- **Groundwater rise poses a threat to below-ground infrastructure and freshwater aquifers under future Sea Level Scenarios**. In areas with shallow unconfined groundwater, the water table will generally rise with sea level, depending on local geomorphology. Rising groundwater may mobilize subsurface contaminants in soils, expose underground infrastructure to corrosive saltwater, and put freshwater aquifers at risk of saltwater intrusion. The low-lying Sacramento-San Joaquin Delta, which supplies fresh water to two-thirds of the state's population and millions of acres of farmland, is particularly vulnerable to saltwater intrusion into freshwater aquifers."

The table of median sea level rise scenarios for California is provided above (Table A-1), and tables for each California tide gauges are presented in Appendix F. The State Sea Level Rise Guidance (OPC 2024) is currently considered best available science on sea level rise for the State of California.

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Appendix B. Developing Local Hazard Conditions Based on Regional or Local Sea Level Rise Using Best Available Science

This Appendix provides technical information addressing how to determine local hazard conditions for sea level rise planning efforts. This process is described more broadly as Steps 1-4 in Chapters 5 and 6 in this document and includes determining a range of sea level rise scenarios and analyzing the physical effects and possible resource impacts of sea level rise hazards.

This appendix provides an overview of the physical effects of sea level rise on coastal hazards and other physical processes. The appendix is organized by the most commonly considered coastal hazards and physical processes and will describe how sea level rise is expected to influence them into the future. Similarly, each section will describe how sea level can be considered in assessments for each coastal hazard or physical process.

It can be challenging to "right size" analyses that look to identify the physical effects of sea level rise. Screening level analyses can be useful to identify the types of hazards that may need to be more closely evaluated, for example with more detailed modeling or analysis, in certain areas. As discussed in more detail in Chapters 5 and 6, it is a good idea to reach out to Coastal Commission Staff early in the process to advise on what level of hazards analyses may be recommended for different planning or permitting processes.

Water level varies locally, so these analyses must be performed on a regional or site-specific basis, and applicants and planners should prioritize obtaining data or conducting research at the correct geographical scale. The 2024 State Sea Level Rise Guidance (OPC 2024) is considered the best available science on California's regional sea level rise, and the Commission recommends using it when sea level rise projections are needed. Equivalent resources may be used by local governments and applicants provided that the resource is peer-reviewed, widely accepted within the scientific community, and locally relevant.

Sea level rise raises the background water level from which many more dynamic changes start. Sea level rise will have many physical effects, some of which will increase non-linearly, such as the amount of wave energy that reaches California's coastlines. The following box identifies some of the key situations in which it is important for coastal managers and applicants to consider sea level rise during planning or project reviews.

General situations needing sea level rise analysis include when the project site or planning area is:

- Currently in or adjacent to an identified floodplain
- Currently or has been exposed to flooding or erosion from waves or tides
- Currently in a location protected from flooding by constructed dikes, levees, bulkheads, or other flood-control or protective structures
- On or close to a beach, estuary, lagoon, or wetland
- On a coastal bluff with historic evidence of erosion
- Reliant upon shallow wells for water supply
- Shown as exposed to hazards on a SLR viewer such as COSMOS under the 2.0m SLR scenario

The following coastal hazards and other physical processes are some of the more commonly considered hazards for planning and development in coastal areas in the State. These are described in more detail in the following sections.

- Coastal erosion
- Wetland change
- Coastal flooding
- Fluvial/riverine flooding
- Pluvial/stormwater flooding
- Groundwater rise
- Tsunamis

Coastal Erosion

The coast is shaped by the powerful forces from waves, currents, rainfall, and wind. This section will describe the effects of sea level rise on beach change and bluff erosion.

Beach Change

Beaches are highly dynamic and respond to changes in sediment inputs and wave conditions. Beaches change on a variety of timescales. It can be useful to think about the timescales of this change as long-term, decadal, seasonal, and storm event-driven.

Beaches can be understood generally to be in equilibrium with sea level. As sea level rises, beaches will generally shift upward (vertically) and recede landward (horizontally), proportional to the slope of the beach. This concept is generally known as the Bruun Rule. It involves several key assumptions, including that, at equilibrium, the shape of the beach profile is maintained through time, that sand transport into and out of the area of interest is constant, that the upper beach is eroded as the shore profile moves landward, and that the eroded material is deposited offshore to reestablish the equilibrium profile – meaning that the Bruun Rule assumes an erodible backshore as opposed to, for example, a seawall. As sea level rise accelerates, the retreat of beaches due to the Bruun Rule is expected to become an increasingly large factor in beach change.

There are several approaches to evaluating the potential for beach erosion for the purposes of planning and development. The level of complexity in terms of the processes considered as well as the data and skill needed for analysis varies greatly.

One of the simplest approaches to estimating beach change is to examine long-term shoreline trends. This can be done by looking at historical imagery. Recent advances in the processing of satellite data have opened up large datasets of historic shoreline change, such as CoastSat, that can also be useful for identifying long-term trends. Similarly, looking at historic observed seasonal or event-driven changes can be useful for estimating the potential range of shoreline positions that might be observed beyond long-term shifts in mean shoreline position. Notably, just evaluating historic trends alone will not adequately account for the effects of future sea level rise. Observed trends can be combined with the retreat estimated by the Bruun Rule or other similar equilibrium models.

One of the more comprehensive tools for looking at long-term beach change is the CoSMoS Coastal One-line Assimilated Simulation Tool (CoSMoS-COAST). The CoSMoS-COAST tool uses historic shoreline change data to calibrate a shoreline change model that takes into account many of the easier-to-measure factors that contribute to beach change. These include Bruun Rule recession, longshore drift, and cross-shore beach change. Sand supply, a major factor in beach change, is not explicitly considered due to the difficulty in projecting changes to sand supply; however, observed long-term erosional or accretional trends not explained by the more easily forecastable factors are assumed to continue in the future. While CoSMoS-COAST includes considerable uncertainty, this uncertainty is quantified. CoSMoS-COAST is also available at a 100-meter resolution for all open coast beaches statewide which makes it a powerful tool for evaluating future beach change.

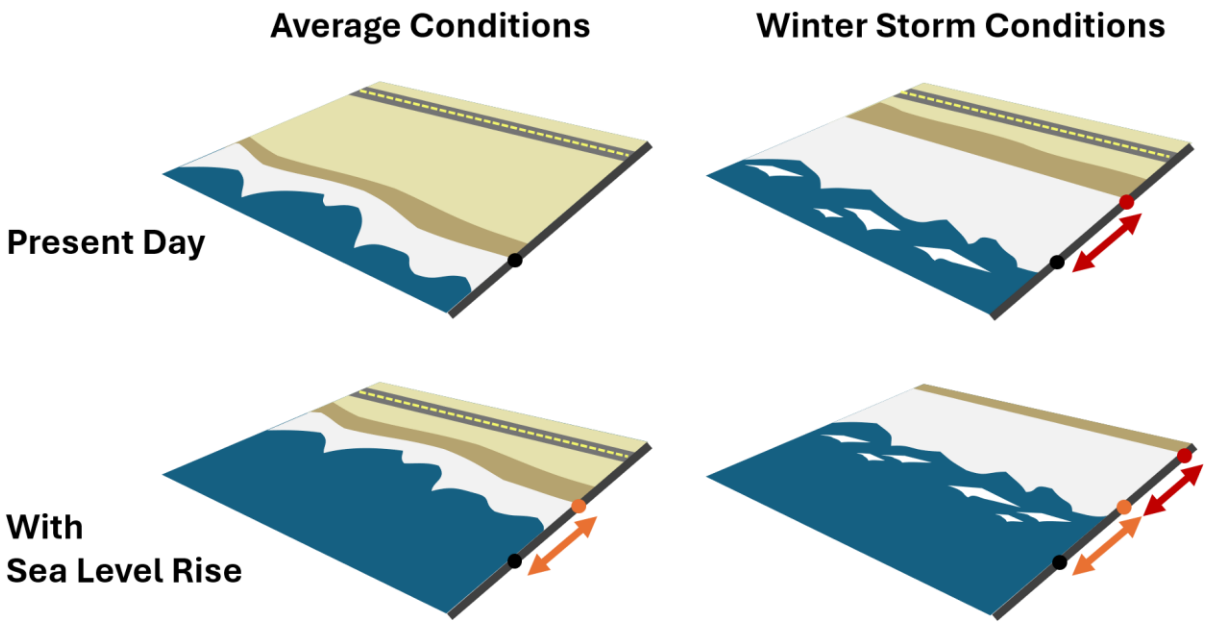

Figure B-1. Diagram showing beach erosion from both sea level rise and winter storm conditions (Source: J. Smith, 2024)

Bluff Erosion

California has a diversity of coastal bluffs which will, in general, continue to erode over time. The rate of a retreat of a coastal bluff is closely related to its geologic composition and the erosional processes at work in a given location. Bluffs composed of hard, resistant bedrock will erode slowly compared to bluffs with a base of relatively weak and poorly cemented terrace deposits. Coastal bluff erosion is also driven by a variety of factors including both marine (e.g., wave attack and wave spray) and subaerial processes (e.g., intense rainfall and runoff). In general, sea level rise will intensify marine erosion by increasing the frequency and force and wave attack at the base of coastal bluffs. For example, with sea level rise, some bluffs that are currently protected by wide sandy beaches and seldom experience significant wave attack may start to erode more quickly when higher water levels or beach erosion causes the frequency and intensity of wave attack to increase.

Long-term historical trends in bluff retreat provide an important indicator of the potential for future bluff erosion with sea level rise. Similar to beach change, past bluff retreat can be estimated through the use of historical aerial imagery. However, bluff retreat is often episodic. In other words, bluffs can remain unchanged for sustained periods then fail and erode relatively rapidly. As a result, a significant amount of time (ideally as long as possible) is often needed to be able to determine long-term average erosional trends for coastal bluffs. There have been several efforts to develop statewide retreat rates for coastal bluffs with varying levels of associated uncertainty and spatial resolution. Some of the most commonly referenced datasets include Hapke & Reid, 2007, which uses georeferenced historical maps and aerial imagery, and Swirad and Young, 2022, which uses airborne LiDAR.

There are several approaches available to estimate how bluff retreat would be accelerated by sea level rise. As part of the work done by USGS for their CoSMoS Cliff Retreat tool, Limber *et al*., 2018, summarize several modeling approaches. One model bluff retreat, an extension of the Bruun Rule discussed above, assumes coastal bluffs are in equilibrium with their fronting beaches and that, with sea level rise, bluff erosion will accelerate in relation to both the shape of the beach profile and amount of beach-quality sediment the bluffs would provide to the beach profile as they erode. Another model assumes that the bluff retreat rate will increase in proportion to the frequency with which waves are able to runup and reach the toe of the bluff with sea level rise. Other models accelerate cliff erosion in proportion to increases in the rate of sea level rise, with options to select the relationship (linear or exponential) between the rate of sea level rise and the bluff erosion response. Still other models relate bluff erosion rates to sea level driven changes in wave energy, the force delivered at the bluff toe, and fronting beach widths. While no single modeling approach can capture all the factors governing how coastal bluffs will respond to sea level rise, these modeling approaches can provide insight into the range of potential outcomes under different sea level rise scenarios.

USGS developed bluff retreat projections statewide using an ensemble of multiple bluff retreat models (some of which are outlined above) for four sea level rise scenarios (CoSMoS-Cliff). The calibrated, but unvalidated, ensemble includes five simple models that project bluff retreat from historical bluff retreat, wave impacts, sea level rise, and the geometry of the shore profile. The projections are available at a spatial resolution of 100 meters, though projections are meant to project time-averaged, multidecadal bluff retreat over large spatial scales. These projections are valuable for community-scale hazards analyses and land use planning, though more detailed analyses are often needed for site-specific analyses, including those used for siting and design of individual development projects.

Most models and tools used for bluff retreat project the long-term time-averaged retreat of a bluff’s edge. However, as mentioned previously, bluff retreat typically occurs episodically, with retreat sometimes occurring on the order of tens of feet in a single event, followed by extended periods with little retreat. For this reason, it is critical that development setbacks from bluff edges consider the potential magnitudes of episodic erosion or failure events in addition to long-term, average retreat rates. This can be done through looking at past bluff failure events or analyzing slope stability (e.g., determining the failure plane of a slope with a 1.5 factor of safety).

Additional Considerations

Additionally, there are several important considerations when evaluating the potential for coastal erosion as influenced by sea level rise. Sandy beaches may have significant deposits of coarser material, such as cobble, which may change both their response to seasonal erosion and long-term responses to sea level rise. Beaches may also exist as a relatively thin layer of sand above high bedrock platforms which may influence both their ability to persist in the future (if these platforms form a steep and erosion resistant backshore) as well as how the beaches respond to seasonal forcing from waves. Also, developed backshores can sometimes be made of highly erodible fill material with high percentages of fines which may lead to accelerated erosion, particularly as shorelines retreat and expose these backshores to more frequent storm wave activity.

Sand dunes are also an important part of many beach systems. Dunes can vary greatly in both size and dynamics. Natural dunes in addition to engineered dune or dune-like systems can provide significant flood reduction benefits in addition to being an important source of sand to beaches during erosive events. Portions of dune systems can also be highly dynamic, like beaches, and are also expected to shift upward and inland with sea level rise under equilibrium conditions. Where dunes are a significant part of the shore or where they are being proposed as strategies to address hazards, particular care should be taken to incorporate dune change as part of estimates of coastal erosion.

COASTAL WETLAND CHANGE

Coastal wetlands such as mudflats and saltmarshes are affected by the way sediment moves in and through estuarine systems. Intertidal features and habitats are very sensitive to water levels and will change with sea level rise (Spencer *et al.*, 2016).

Different levels of analysis for evaluating coastal wetland change vary in the amount of data and skill required. Much of this variation comes from how or if changes to landforms are considered. Figure B-2 illustrates how sea level rise will shift the tidal range vertically and vegetated areas may shift in response to both future water levels and changes in landforms.

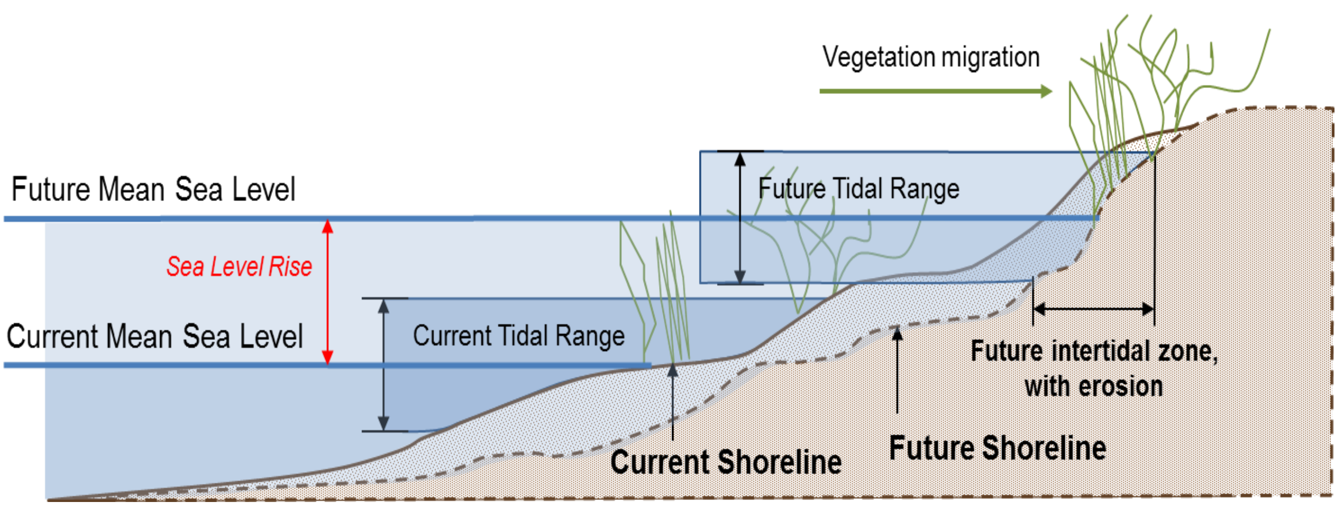

Figure B-2. Changes to the intertidal zone with sea level rise and erosion, without wave impacts. (Source: L. Ewing, 2013).

The simplest approach to evaluating coastal wetland change is to assume landforms remain the same and habitats will re-equilibrate to changing sea levels. In some wetlands, landform change can be dramatic even over short time periods (**Fig.** B-3). As mentioned previously, coastal wetlands are very sensitive to water levels and their distribution is largely controlled by the elevation of land relative to the local tide range. While sea level rise may change the range of the tides in certain areas, it is often simpler and sufficiently accurate to assume this change will not be significant and simply shift the existing tide range vertically by the amount of sea level rise being analyzed.

Figure B-3. Photo series documenting rapid bank and wetland erosion in Elkhorn Slough (adapted from California Department of Fish and Wildlife, 2021 with additional photo from B. Ammen, 2023)

More complex approaches would include creating a hydrodynamic model that simulates the water levels and currents that can then be used to model the movement of sediment and vertical erosion or accretion that may change landforms in an estuarine system. These kinds of models often require significant effort to develop, calibrate, and validate but can be used to answer specific management questions such as which coastal wetland areas may have sufficient natural sediment supplies to be able to keep pace with sea level rise and which areas may need more significant management actions to preserve ecosystem functions.

When deciding how to estimate coastal wetland change considering sea level rise, an initial assessment should consider how stable landforms have been within recent history, why landforms have or have not changed (for example, considering if existing marshes are in equilibrium with current sediment supply or tidal currents), and then evaluate whether it is reasonable to assume those factors would continue unchanged into the future with sea level rise.

COASTAL FLOODING

Extreme water levels are caused by a combination of high tides, storm surge, oceanographic forcing, and waves. Along the open coast of California, waves are typically, if not always, a major factor in driving extreme water levels and coastal flooding. The biggest storm waves often come from “swell” which originates far out in the Pacific Ocean. In sheltered areas where there is sufficient “fetch,” wind waves can become sizeable enough to warrant consideration in analyses.

The deeper the water close to shore, the larger the size of waves that can reach the shore becomes. Waves will eventually break when the depth is shallow enough and runup on or over land. When analyzing wave hazards along beaches, an eroded beach condition should be evaluated as this often results in the most hazardous conditions. Furthermore, large waves also occur during large coastal storms which tend to occur most frequently in winter months, when beaches are typically at their narrowest.

There are multiple ways to evaluate coastal flooding that consider sea level rise with ranging levels of complexity as well as data, effort, and skill required. Another important factor when analyzing flooding is the resolution and accuracy of available topographic data. Small changes in topography can result in vastly different results.

Certain low-lying coastal areas may not be exposed to either swell or significant wind waves and, in these areas, coastal flooding is likely dominated by extremely high ocean water levels that can occur during a combination of high tides, atmospheric influences like storm surge, and oceanographic influences like El Niño. This section will generally progress through methods for evaluating coastal flooding where increasing attention is given to the influence of wave hazards starting with a discussion on “bathtub” approaches and moving to site specific wave hazard analyses.

“Bathtub” Approach

One of the simplest approaches to analyzing flood risk is to compare ground elevations to current or future flood levels. A “bathtub” approach, as it’s commonly called, takes a flood elevation, e.g., 10 ft above mean sea level, and then assumes all elevations in the area of interest below that flood elevation will be flooded. This approach can easily consider sea level rise by simply increasing the flood elevation by the amount of sea level rise being analyzed e.g., 10 ft + 1 ft of sea level rise = 11 ft. The most important factors for this kind of analysis are determining the appropriate flood elevations and finding appropriate topographic data.

Bathtub approaches are extremely simplistic, which makes them very easy to implement. However, they may not be appropriate in some cases. Bathtub approaches can make sense for areas where flooding is expected to increase linearly with sea level rise; this is often the case for low-lying areas along partially enclosed bays or inlets that experience flooding as result of extreme still water levels and where significant erosion and shoreline change is not expected. It is not appropriate for areas where water is expected to be dynamic such as areas exposed to large waves or fast-moving flow down rivers or creeks. Bathtub approaches to projecting future flooding also rely on estimates for existing floodwater elevations which could come from previous studies such as FEMA studies or estimates of extreme coastal water levels for NOAA tide stations.

Hydrodynamic Models

Another approach for evaluating coastal flood risk is through the development or use of hydrodynamic models. Hydrodynamic models simulate the water levels and currents that occur during storm conditions and can take considerable effort to develop, calibrate, and validate. Hydrodynamic models can also simulate waves, including wave runup and overtopping, in great detail. Generally, it only makes sense to develop site-specific hydrodynamic models for a larger areas on the order of miles since the models need to consider appropriate boundaries that capture relevant features, such as the entirety of a coastal lagoon, to avoid undue modeling errors. To consider sea level rise, hydrodynamic models are essentially re-run with the sea level rise incorporated in the input conditions.

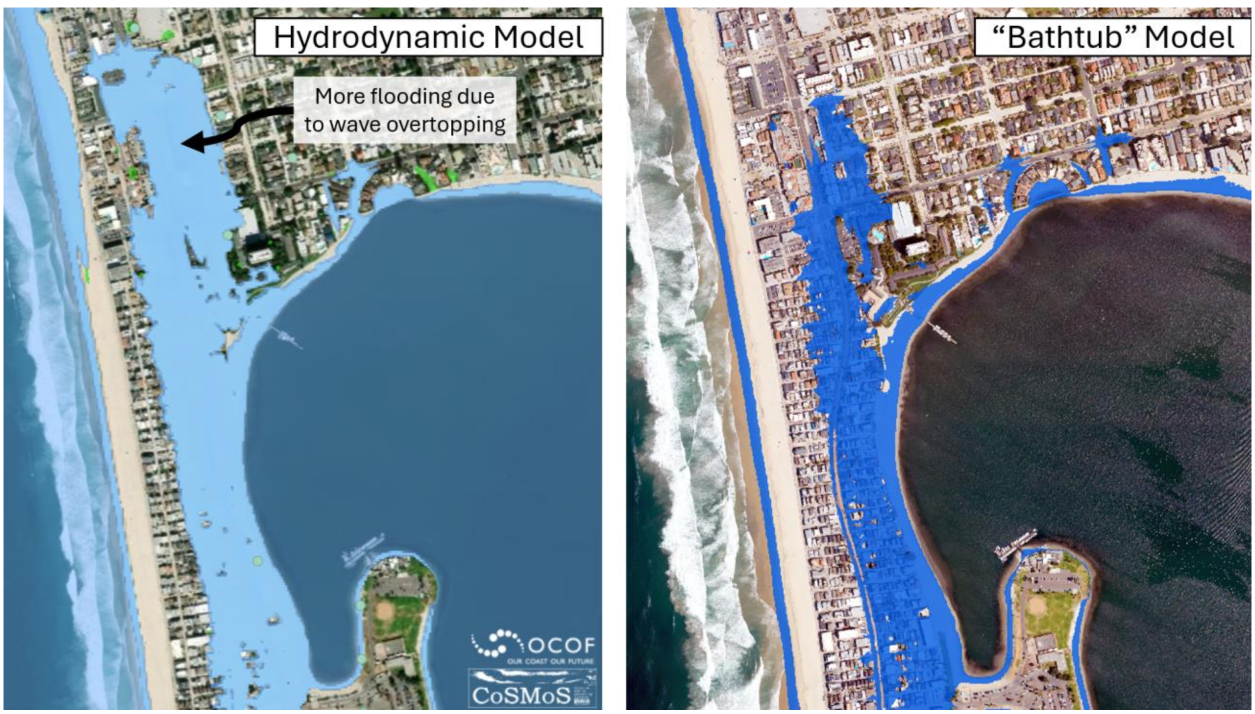

Figure B-4. Illustration of differences between a hydrodynamic model (CoSMoS; 100-year flooding 0 ft SLR) and a "bathtub" model (all areas below 8 feet, NAVD88 shaded blue)

The USGS has developed flood models and published hydrodynamic flood modeling results statewide for increments of sea level rise ranging from 0.25 meters to 5 meters, providing a useful tool for evaluating both existing coastal flood risk and future flood risk as worsened by sea level rise. Importantly, CoSMoS models were developed on large scales and, while a great tool for screening and high-level planning analysis, require sound technical judgement when interpreting results for uses that might require higher levels of detail. When evaluating the results from any model, it is generally good practice to examine the results for similar conditions from separate models or, if possible, validate with observations (e.g., flooded areas) for real events with similar storm conditions. When a higher degree of confidence and resolution might be desired such as for evaluating the potential performance of a proposed tide gate or pump system, developing a site-specific model would provide results more appropriate for use in design.

FEMA Flood Zones

FEMA develops and maps flood zones including for areas subject to coastal flooding from both waves and extreme static water levels. These flood zones do not consider future sea level rise and generally represent areas that could be impacted by flooding from events with a 1% probability of occurring in a year. In coastal areas, "VE" Zones generally represent areas of high wave hazards, while "A" and "AE" Zones generally represent areas of moderate to minimal wave hazards. Zones VE and AE will specify a base flood elevation (BFE) which is meant to represent the elevation of the 1% annual exceedance probability total water level. Total water level combines all contributions to the water level at a given time, including mean sea level, tides, seasonal and storm effects, wave runup and other factors (**Fig.** B-5).

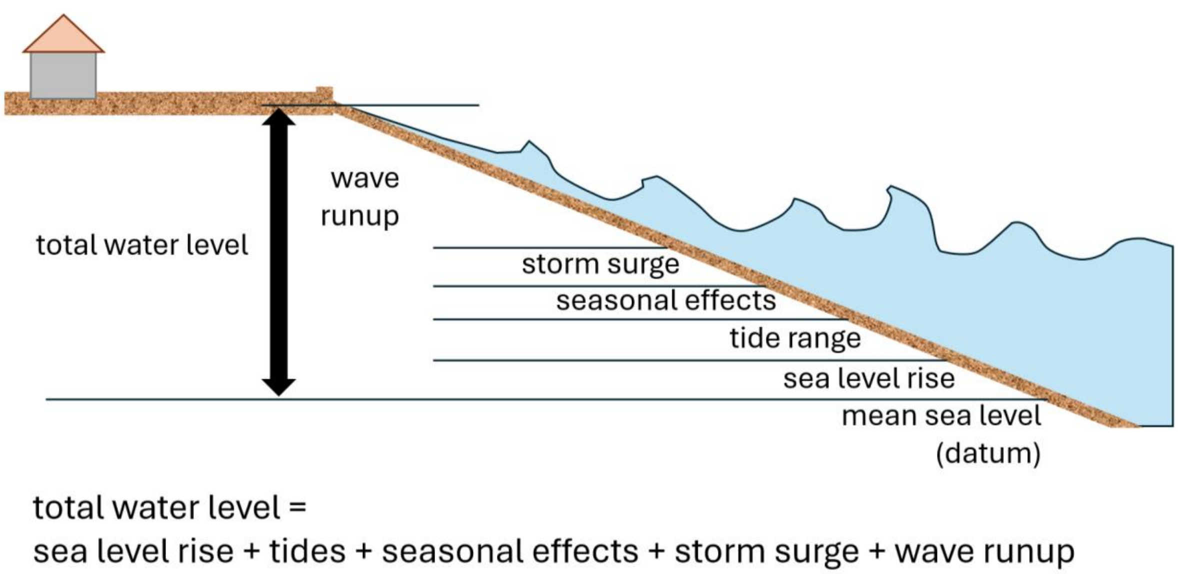

Figure B-5. Illustration of components of coastal total water levels (adapted and simplified figure 1 of Barnard *et al.*, 2019)

There are several relatively simple analytical approaches that relate current FEMA flood zones to future coastal conditions considering sea level rise. These approaches often don't require the level of data and effort as developing new hydrodynamic models and can provide reasonable, rough estimates for future flood risk that leverage the detailed studies conducted by FEMA. One example of this kind of an approach is detailed in a Technical Methods Manual by Battalio *et al*., 2016 and involves determining the portion of the total water level (or Base Flood

Elevation) due to wave runup, increasing the wave runup based on a “morphology function” determined by the erodibility of the backshore, and calculating a new total water level by adding both sea level rise and the increase in wave runup. This method is relatively simple when the information on the wave runup estimates used to determine the FEMA total water levels is available and accounts for the compounding effects of sea level rise on total water levels illustrated in Figure B-6 below. Translating current FEMA flood zones to future coastal conditions may make sense for jurisdictions looking to create hazard maps that consider sea level rise but are also familiar in form to existing flood zones, which may aid with the application of existing flood ordinances.

Site Specific Wave Hazard Analyses

In some cases, site-specific wave hazards analyses that consider the effects of sea level rise may be needed to adequately assess risks to new development along the coastline. This often requires consideration of the potential wave runup elevations that consider higher static water levels, sea level rise induced beach change, and expected 100-year storm conditions. There is a diversity of methods for estimating wave runup and overtopping. Because of the dynamic nature of extreme wave events, empirical equations can be an important tool for simplifying analyses while maintaining appropriate consideration of engineering uncertainty. These empirical equations typically relate inputs such as wave conditions (wave height and period), beach slope, a structure’s (such as a revetment's or seawall’s) roughness, and a structure’s slope.

In general, hazards analyses should consider risk from extreme conditions (often the 1% annual exceedance probability or “100-year” event). Because coastal flood events typically involve a combination of several partially related factors such as storm surge, wave conditions, and acute erosion, it can be challenging to determine exact probabilities. To address this complexity, deterministic approaches attempt to estimate the conditions of a 100-year event, generally assuming reasonable conservative estimates for things like wave height, period, and event-based beach erosion often through professional experience or judgment. Other more probabilistic approaches leverage existing datasets for things like observed water levels and wave conditions to create a hindcast of wave runup elevations that can inform a statistical analysis to estimate a range of extreme events.

Notably, while the field of coastal engineering has developed a range of methods for predicting wave hazards across the globe, different methods have been shown to be more or less appropriate for California’s (and the Pacific North American coast more broadly) oceanographic context. In California, much of coastal wave hazard is influenced by the large swell which creates large fluctuations in water levels at the shore through what are called infragravity waves. This dynamic setup, as it is also called, can create deeper waters long enough for larger waves to break closer to shore where there is less space for their energy to be dissipated. This dynamic is notably different than the Gulf and Atlantic coasts where extreme wave hazard is typically dominated by large storm surge from strong storm systems like hurricanes. FEMA, as part of its update for coastal hazard mapping on California's open coast, developed guidelines to this end that can be found here.[125]

Proper consideration should be given to selecting an appropriate method for estimating wave hazards including how sea level rise will be included in the inputs used for such an analysis. Most notably, sea level rise will increase static water elevations which not only increases the baseline from which wave runup is calculated but also increases the size of waves able to reach the shore. Similarly, where wave hazards are being analyzed on coastal structures, sea level rise induced beach retreat should be considered such that the depth of water at the toe of structures will increase. In shorelines where the backshore is armored or otherwise resistant to erosion, this leads to a compounding effect from sea level rise where one foot of sea level rise could lead to a two to four foot increase in total water level (Battalio *et al.*, 2016). These compounding effects are illustrated below (**Fig.** B-6).

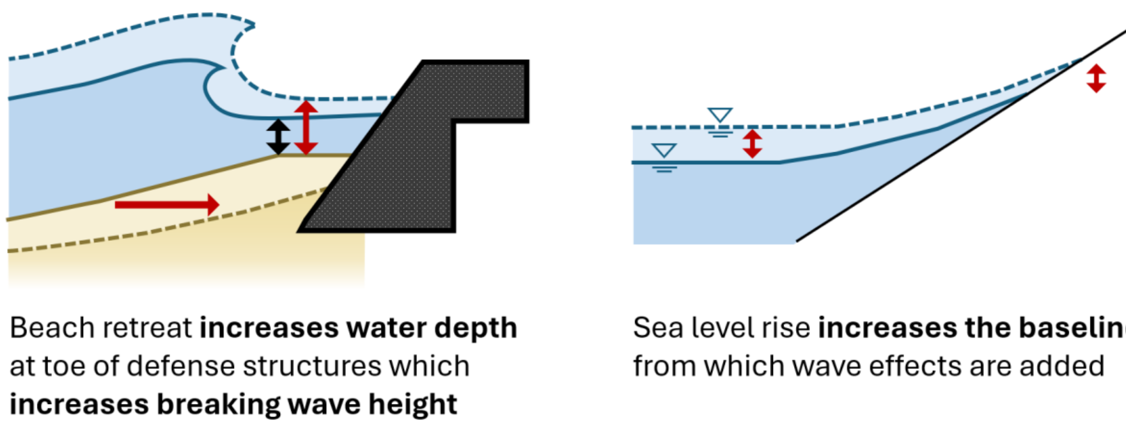

Figure B-6. Diagram illustrating the compounding effects of sea level rise on coastal wave hazards (Source: J. Smith, 2024)

Summary

In summary, coastal flooding events can be influenced by a variety of factors but in simple terms can be grouped in two categories: flooding strongly influenced by waves and coastal flooding not-strongly influenced by waves. While there is a variety of approaches to estimating future coastal flood risk as worsened by sea level rise, selecting the appropriate approach should be based on the levels of uncertainty and precaution desired by the relevant decision makers.

[125] Note that while the document linked here has been superseded by the FEMA Policy for Flood Risk Analysis and Mapping, the document contains useful guidance to support implementation of the new standards

FLUVIAL/RIVERINE FLOODING

Where rivers, creeks, and drainage channels meet the ocean, high water levels can "back up" upstream. Sea level rise will increase water levels at the downstream end of watersheds and so can increase fluvial flood risk even on days when coastal flooding may not be a concern (**Fig.** B-7). Most fluvial flood risk in the State has been assessed as part of FEMA flood insurance rate maps which generally map flood zones for the 100-year recurrence interval or 1% annual exceedance probability event, which reflect historical observations and do not capture the effects of future sea level rise. These zones have been developed over decades from a multitude of FEMA-commissioned studies.

Fluvial flood risk is generally reassessed when there are proposed changes to topography within or near floodplains, when bridges are being constructed, retrofitted, or replaced, and as part of flood control improvement projects. Generally, fluvial flood risk is assessed through the use of hydraulic models of varying levels of complexity.

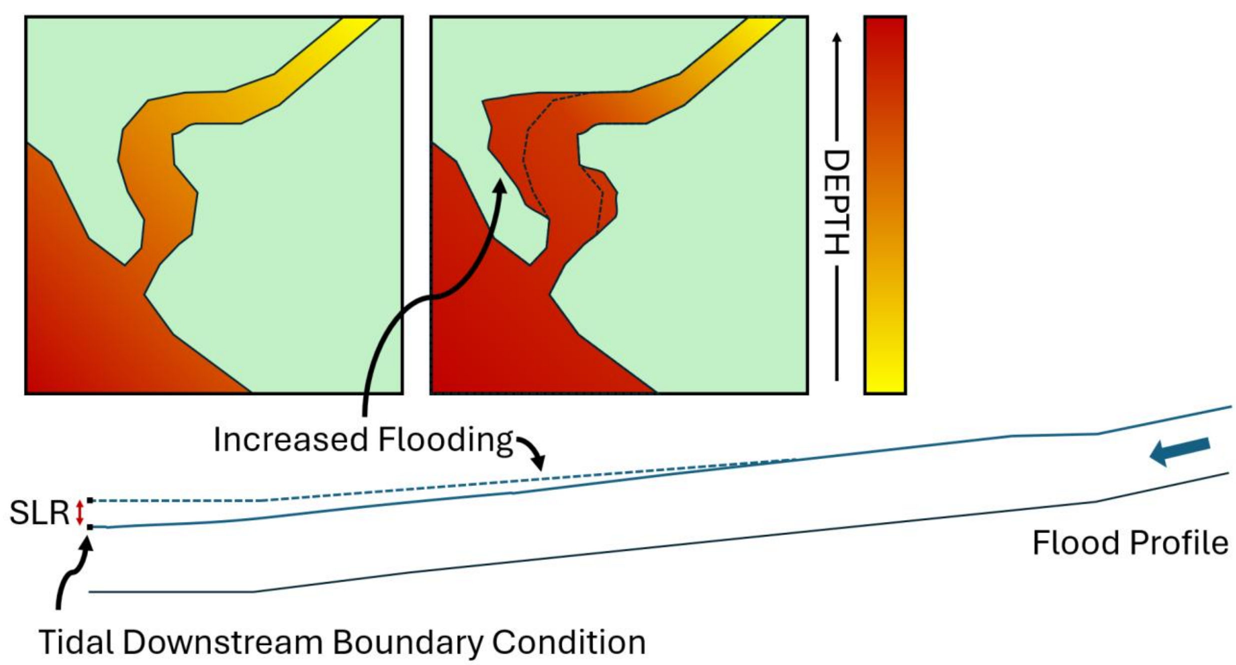

Figure B-7. Diagram illustrating how sea level rise can influence fluvial flooding upstream (Source: J. Smith, 2024).

The inland geographic extent of where sea level rise is expected to affect fluvial flooding levels varies. Generally, channels with flatter slopes will see a greater extent where higher sea levels affect fluvial flood levels. Channels where flow is constricted due to a narrowing in the channel or a flow control structure will generally not see effects from higher sea levels upstream of those constricted areas because the flow is controlled by that constriction rather than downstream water levels.

To evaluate the effects of sea level rise on fluvial flood risk, hydraulic models should use conservative downstream boundary conditions increased with the amount of sea level rise being analyzed.

For most situations, the 100-year event should be used as the design event for hazards like coastal or fluvial flooding. The term "100-year" is equivalent to saying a storm or flow event has a 1% annual probability of exceedance. There is a 22% probability that a 100-year storm event or greater will occur during a 25-year period and over 53% probability that a 100-year storm or greater will occur at least once during a 75-year period. Even so, the 100-year event, like the 100-year flood event, is often used as a design standard for development. However, for structures with a very long projected life or for which storm protection is very critical, a larger, 200-year or 500-year event might be appropriate.

PLUVIAL/STORMWATER FLOODING

Pluvial flooding (also called "urban" flooding) is flooding that occurs as a result of runoff from rainstorms. While pluvial flooding can happen in natural watersheds its often most severe in altered watersheds. Examples include ponding in depressions, along the edges of topographic barriers, or around constrained stormwater infrastructure. Ponding can occur in depressions when runoff exceeds the capacity of stormwater infrastructure like drains or pumps such as underpasses (see an example in **Fig.** B-8 below). Any areas where stormwater is controlled and drained to coastal waters could potentially see worsened flooding as a result of sea level rise. This is because stormwater drainage capacity can be reduced by higher coastal water levels (including as increased by sea level rise) causing a "backing up" of stormwater drainage systems.

It can be difficult to initially identify areas where stormwater drainage systems could be significantly impacted by higher sea levels. Generally, the areas with the greatest potential vulnerability are areas that are close to or below the elevation of daily highest tides (mean higher high water). Some drainage systems already require special infrastructure for their drainage to coastal areas, such as drainage systems that rely on pumps or tide gates. These areas are an example where the effects of sea level rise on the function of the stormwater systems should be assessed.

Stormwater systems are often evaluated through hydrology and hydraulics (or H+H) modeling which can have varying levels of complexity but which ultimately simplifies drainage systems as a network of drainage infrastructure (stormwater pipes, inlets, pumps, etc.) and drainage areas (e.g., small watersheds) which, with rainfall estimates and information about the drainage area such as the slopes, surface types, etc., are used to determine the flow of water into the drainage system.

Sea level rise can be considered in these modeling efforts by increasing downstream water level conditions, altering pump capacities by evaluating the effects of higher water levels on pump curves, and increasing assumed baseloads to the drainage system from increased groundwater inputs from groundwater rise.

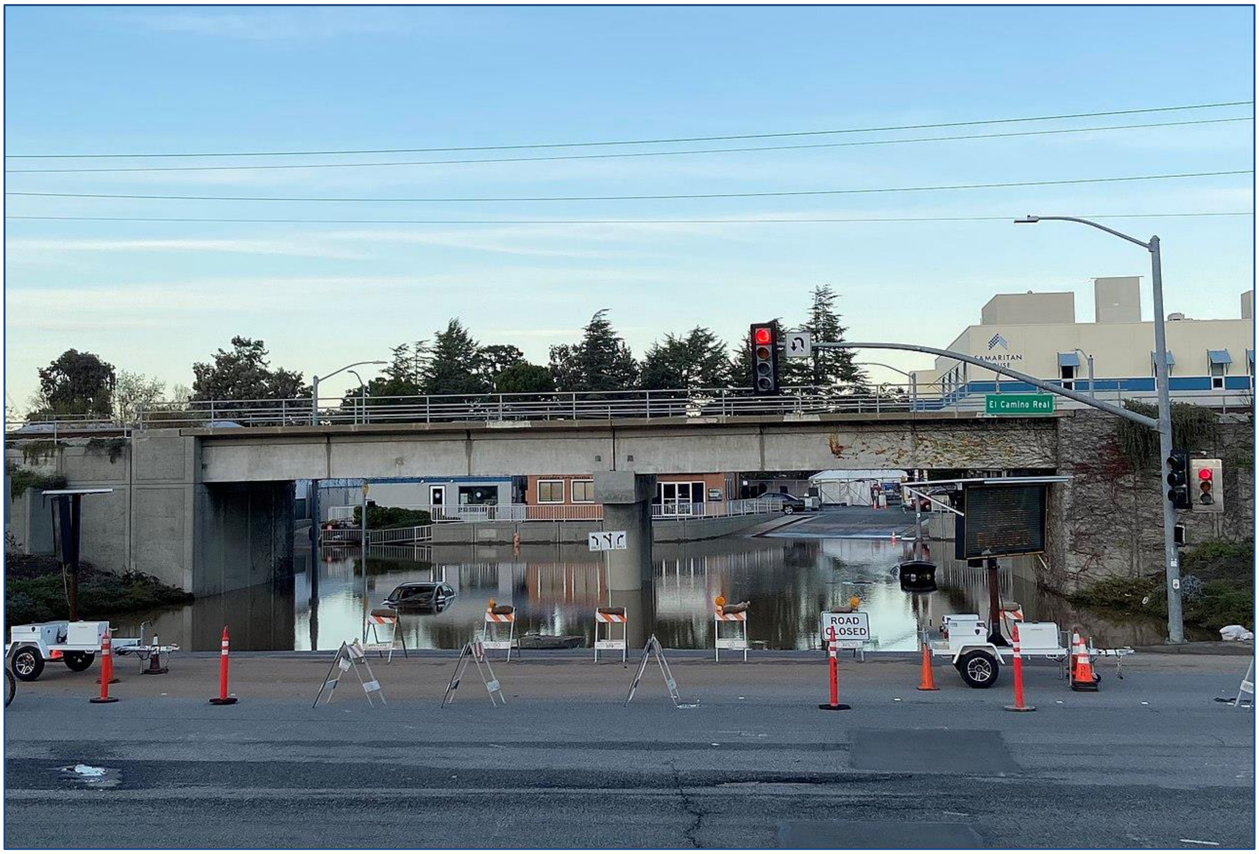

Figure B-8. Photo of pluvial flooding at an undercrossing in San Mateo, CA (Source: B. Washburn, www.flicker.com/btwashburn; CCA 2.0)

GROUNDWATER RISE

Where surficial groundwater is hydraulically connected to the ocean, sea level rise can cause an increase in groundwater tables (decreasing depths from surface to groundwater), increased salinity of groundwater, and/or increased groundwater flow (Rotzoll & Fletcher, 2013).

Higher groundwater elevations can cause a variety of problems ranging from increased liquefaction risk, damage to roads and buried structures (e.g., basements, pipes, and utilities), decreased capacity for infiltration of rainfall, mobilization of contaminants in soil, and in some cases, temporary or permanent emergence of groundwater onto the surface (Hill *et al.*, 2023).

Saline intrusion into groundwater used for irrigation or potable water uses can be a major issue where such groundwater is the only or a major source of fresh water. When saline ocean water interacts with fresh water in the ground, it typically forms what is referred to as a saline groundwater wedge with boundary between fresh and saline groundwater decreasing in elevation with distance away from coastal waterbodies. This wedge is expected to move inland with sea level rise (Glover, 1959) which will increase the geographic extent of saline intrusion into shallow groundwater wells landward. This concept is illustrated in Figure B-9 below.

In some areas, groundwater infiltrates buried stormwater or wastewater pipes which can both influence groundwater elevations around them. The leaking of groundwater into pipes can increase “baseloads” at stormwater or wastewater treatment facilities, limiting capacity and increasing operating costs (May *et al.,* 2022).

Changes to groundwater as a result of sea level rise can be modeled but are often limited in the availability of critical information such as existing or historic groundwater levels and local geology, which are needed for calibration and validation. There are several approaches where groundwater change could be considered in analyses using more conceptual or qualitative approaches as well.

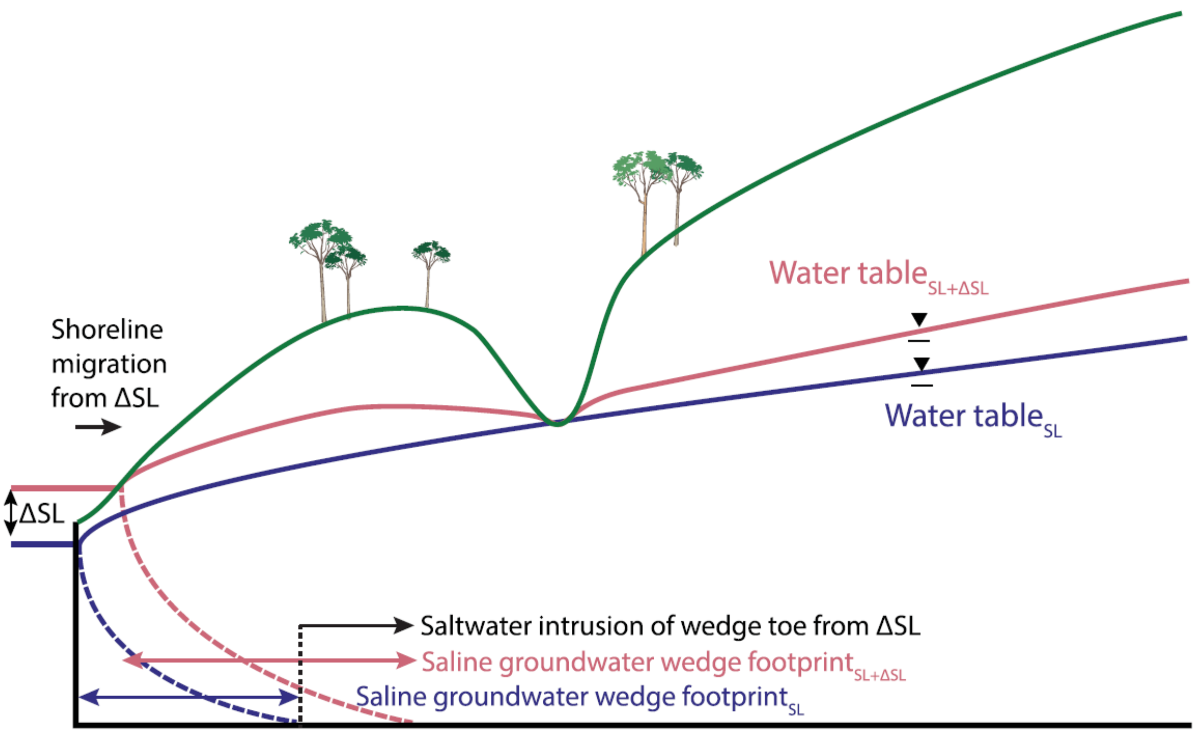

Figure B-9. Diagram from Befus *et al.* 2020 illustrating current groundwater table and saline groundwater wedge in blue and future groundwater table and saline groundwater wedge in pink. Note groundwater table is limited controlled by local topography in this example.

As part of CoSMoS, USGS partnered with groundwater modeling experts to create a statewide dataset of modeled equilibrium groundwater depths for both present sea level and increments of sea level rise (Befus *et al*., 2020, **Fig.** B-9). The modeled equilibrium groundwater surface represents the long-term average elevation of groundwater flowing along the coast for the tidal datums considered (local mean sea level and mean high water) and can be viewed as a baseline that seasonal, tidal or shorter-term influences such as storms would start from. The model results are largely a function of topography, distance from coastal water bodies, and how readily water moves through the ground (via pore spaces, fracture networks, etc.), a property known as hydraulic conductivity. The USGS model produced projections for three different hydraulic conductivity values ranging across three orders of magnitude due to a lack of detailed information on hydraulic conductivity at both fine scales and available statewide. These three hydraulic conductivity results help demonstrate the range in uncertainty, and users can focus on the dataset associated with the hydraulic connectivity value they know to be representative of their local geology. While the CoSMoS-GW results are helpful for high level analyses and screening for where groundwater rise may be an issue in local hazard planning, site-specific groundwater models developed with higher resolution topographic and geologic data would provide results appropriate for use in planning stormwater and flood control systems, or in designing individual projects.

Tsunamis

Tsunamis are large, long-period waves that can be generated by submarine landslides, subaerial landslides (slope failures from land into a water body), large submarine earthquakes, meteors, or volcanic eruptions. They are rare events but can be extremely destructive when they occur. The extent of tsunami damage will increase as rising water levels allow tsunami waves to extend farther inland. Thus, the tsunami inundation zone will expand inland with rising sea level. There has been no research that suggests that climate change will increase the intensity or frequency of seismically-generated tsunamis. However, the number and size of coastal subaerial landslides may increase because of increased coastal erosion due to sea level rise, which in turn may increase the potential for tsunamigenic landslides along the California coast (Highland 2004; Walder *et al*. 2003).

Figure B-10. Screenshot of ASCE Tsunami Hazard Tool showing results for the Venice-Marina del Rey area for the 2,475-year probabilistic tsunami hazard analysis

Recent advancements by the California Geological Survey (CGS) have significantly improved the availability of high quality tsunami data statewide for use in hazard analyses and planning. These data including the maps of California Tsunami Hazard Area (which was created for use in disaster preparedness and evacuation planning) are available on the CGS website. Several third party websites are also available as tools or viewers to access products that utilize the statewide probabilistic tsunami hazard analysis results such as the American Society of Civil Engineers (ASCE) Tsunami Design Geodatabase which is used to determine tsunami loads for critical facilities as part of the building code (Fig. B-10). There are currently no statewide datasets for tsunami inundation areas that consider sea level rise, though these are in progress. A rough estimate of how to adjust existing available tsunami inundation data to consider sea level rise is by assuming a 1:1 increase in tsunami flow depths with sea level rise i.e., if any area is shown to have a 4 ft tsunami flow depth, with 1 ft of sea level rise, it could have 5 ft of tsunami flow depth.

SUMMARY

Sea level rise will worsen many of today's hazards. Incorporating the effects of sea level rise into estimates of hazard conditions is not always simple. This appendix can serve as a resource that outlines the variety of ways sea level rise can be considered for different hazards as well as some of the tradeoffs in difficulty or level of detail that come from the diversity of methods.

As this appendix has outlined, sea level rise will be a persistent increase to baseline sea levels from which a variety of more dynamic factors such as storm surge and coastal wave storms will be increase, sometimes non-linearly with each foot of additional sea level rise. The approximate magnitudes and timescales of these factors are outlined in Table B-1 below.

When developing local hazard conditions for use in coastal planning and analyzing coastal development, there is a wide array of available tools, some of which have already been mentioned, available to aid in analysis of future hazards. These range from viewers of detailed modeling efforts to technical datasets and guidance that will aid in the development of localized or site-specific hazard analyses. These tools and resources are outlined in Table B-2 below.

Table B-1. Factors that Influence Local Water Level Conditions

Factors Affecting Water Level	Typical Range for CA Coast (ft)	Typical Range for CA Coast (m)	Period of Influence	Frequency
Tides	3 – 10	1 – 3	Hours	Twice daily
Low pressure	1.5	0.5	Days	Many times a year
Storm Surge	2 – 3	0.6 – 1.0	Days	Several times a year
Storm Waves	3 – 15	1 – 5	Hours	Several times a year
El Niño events (within the ENSO cycle)	<1.5	< 0.5	Months - Years	2 – 7 years
Tsunami waves	20 – 50 (max) 3 – 10 (typical)	6 – 15 (max) 1 – 3 (typical)	Minutes, Hours, Days	Infrequent but unpredictable
Historical Sea Level, over 100 years	0.7	0.2	Ongoing	Persistent
OPC Sea Level Projections 2000 – 2050 (SF tide gauge; see also App. F)	0.5 – 1.3	0.15 – 0.4	Ongoing	Persistent
OPC Sea Level Projections 2000 – 2100 (SF tide gauge; see also App. F)	1.0 – 6.5	0.3 – 2.0	Ongoing	Persistent

Note that all values are approximations. The conversions between feet and meters have been rounded to maintain the general ranges and they are not exact conversions. *Sources*: Flick 1998; OPC 2018; Personal communications from Dr. Robert Guza (Scripps Institution of Oceanography), Dr. William O'Reilly (Scripps Institution of Oceanography and University of California, Berkeley), and Rick Wilson, California Geological Survey; and professional judgment of staff.

Table B-2. General Resources for Developing Local Hazard Conditions

Resource	Description	Link
California Coastal Records Project	Oblique photograph time series; useful for general information on shore type, trends in beach or bluff retreat.	www.californiacoastline.org
UCSB FrameFinder	Historic aerial imagery spanning 20th and 21st centuries.	https://mil.library.ucsb.edu/ap_indexes/FrameFinder/
U.S. Coast Survey Maps "T-Sheets" (Southern California)	Historic surveys from mid-19th century; detail geomorphic and shoreline features; have been adapted to identify historic habitats.	https://www.caltsheets.org/socal/index.html https://scwrp.databasin.org/maps/new/#datasets=159884c34c9848949d76ef1f72d468b4

NOAA Data Access Viewer	Land cover, elevation (LiDAR datasets and digital elevation models), aerial imagery (including pre- and post-storm events).	https://coast.noaa.gov/dataviewer/#/
Regional Sediment Management Studies	Range of studies covering oceanographic conditions, beach and bluff change data, flooding and wave impacts, and historic conditions.	https://dbw.parks.ca.gov/?page_id=29239
CoastSat	Viewer to explore global shoreline change trends and information on the open-source CoastSat tool for extracting shoreline data from satellite imagery.	http://coastsat.wrl.unsw.edu.au/
USGS Coastal Change Hazards Portal	Viewer to explore a range of USGS datasets on extreme storms, shoreline change, historical shoreline positions.	https://marine.usgs.gov/coastalchangehazardsportal/
California Coastal Cliff Erosion Viewer	Viewer to explore cliff erosion rates observed from 1998 to 2011 and 2009 to 2016.	https://siocpg.ucsd.edu/data-products/ca-cliff-viewer/
Coastal Storm Modeling System (CoSMoS)	Detailed predictions of storm-induced coastal flooding, erosion, and groundwater rise over large geographic scales.	https://www.usgs.gov/centers/pcmsc/science/coastal-storm-modeling-system-cosmos#overview
Our Coast Our Future (OCOF)	Viewer with hazard map to explore range of data from USGS CoSMoS.	https://ourcoastourfuture.org/
FEMA California Coastal Analysis and Mapping Project | Open Pacific Coast Study	Statewide effort commissioned by FEMA to update open Pacific Coast coastal hazard maps for Flood Rate Insurance Maps. Intermediate Data Submittals include range of wave hazards information.	Not easily available online. Reports and studies conducted at the county level and may be available from county hazard offices or FEMA Region 9 https://www.fema.gov/locations/contact/california
Coastal Data Information Program (CDIP)	Current and historical information on wind, waves, and water temperature, wave and swell models and forecasting. Localized nearshore wave data available at "MOP" lines.	https://cdip.ucsd.edu/ https://cdip.ucsd.edu/mops/
FEMA National Flood Hazard Layer	Viewer includes Flood Rate Insurance Maps (FIRMs). Note that FIRMs do not consider sea level rise or other effects of climate change.	https://www.fema.gov/flood-maps/national-flood-hazard-layer
USACE Wave Information Study (WIS)	National resource with long-term wave climate and multi-decade hindcasts of wave conditions.	https://wis.erdc.dren.mil/

FEMA Guidelines for Flood Risk Analysis and Mapping Activities	Extensive range of guidance and standards including focused guidance on coastal wave hazard analysis.	https://www.fema.gov/flood-maps/guidance-reports/guidelines-standards
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	"Bathtub" model showing areas below mean higher high water with a range of 1-foot increments of sea level rise.	https://coast.noaa.gov/slr/
Cal-Adapt Climate Tools	Range of tools and datasets for considering the effects of climate change including sea level rise and projected changes in intensity and frequency of extreme precipitation events.	https://cal-adapt.org/tools/
California Geological Survey Tsunami Page	Includes information on tsunami hazards, preparedness and evacuation resources, and data and reports for statewide probabilistic tsunami hazard analysis.	https://www.conservation.ca.gov/cgs/tsunami
ASCE Tsunami Design Geodatabase	Mapped runup extents and runup elevations used in ASCE 7 Standards.	https://asce7tsunami.online/

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Appendix C. Resources for Addressing Sea Level Rise

This section contains lists of sea level rise viewers, guidance documents, and state agency-produced resources and data clearing houses related to sea level rise. These resources will be particularly relevant for informing Steps 1-7 of the LCP planning process (Chapter 5). This section also provides a summary of the Commission's Environmental Justice and LCP Toolkit that is a resource for local jurisdictions to consider and incorporate environmental justice into their LCP planning process.

Resource	Description	Link
Key State Guidance and Research		
California State Sea Level Rise Guidance (OPC 2024)	The Ocean Protection Council's *State of California Sea-Level Rise Guidance* (Guidance) provides a synthesis of the best available science on sea level rise scenarios for California, a stepwise approach for state agencies and local governments to evaluate those scenarios and related hazard information in decision-making and preferred coastal adaptation approaches. This Coastal Commission SLR Policy Guidance includes the same sea level rise scenarios. It also includes recommendations about the application of the best available science that are aligned with those in the *State Sea Level Rise Guidance* but most specific to the Coastal Commission context.	https://opc.ca.gov/wp-content/uploads/2024/05/Item-4-Exhibit-A-Final-Draft-Sea-Level-Rise-Guidance-Update-2024-508.pdf
California Climate Assessments **Fourth California Climate Assessment (2018)** **Fifth California Climate Assessment (2023-2025)**	Senate Bill 1320 (Stern, 2020) called on the State to advance action-based science by developing California Climate Change Assessments at least every five years. Previous Assessments (2006, 2009, 2012, 2018) contributed to a growing understanding about the impacts of climate change in California and offer communities and decision makers the tools to take action, including a technical report that provides sea level rise projections. The Fifth Assessment is currently underway.	Home page: https://www.climateassessment.ca.gov/ Access 4th Assessment SLR projections here. Fifth Assessment data products are available via Cal-Adapt Analytics Engine
California Climate Adaptation Strategy (2021)	The *California Climate Adaptation Strategy*, mandated by Assembly Bill 1482 (Gordon, 2015), links together the state's existing and planned climate adaptation efforts, showing how they collectively achieve	https://climateresilience.ca.gov/

	California's six climate resilience priorities. Its goal is to enable a coordinated, integrated approach to building climate resilience.	
Making California's Coast Resilient to Sea Level Rise: Principles for Aligned State Action (2020)	Adopted by California state agencies with coastal, bay, and shoreline climate resilience responsibilities, these principles guide unified action toward sea level rise resilience for California's coastal communities, ecosystems, and economies. The principles relate to the following subjects: Best Available Science, Partnerships, Alignment, Communications, Local Support, Coastal Resilience Projects, and Equity.	https://opc.ca.gov/wp-content/uploads/2021/01/State-SLR-Principles-Doc_Oct2020.pdf
State Agency Sea-Level Rise Action Plan for California (2022)	This Action Plan is a statewide, collaborative document designed to carry out a preceding document, *Making California's Coast Resilient to Sea Level Rise: Principles for Aligned State Action.* It identifies proposed new and ongoing work for 2022-2027 and includes over 80 trackable actions, covering both a regional and statewide scope.	https://www.opc.ca.gov/webmaster/_media_library/2022/02/Item-7_Exhibit-A_SLR-Action-Plan-Final.pdf
Coastal Hazard Resilience Plan Alignment Guide (2023)	The Coastal Resilience Compass is a planning guide that helps planners along the California coast align their planning efforts to address climate change and manage future risks. It discusses how to align Local Coastal Programs (LCPs), Local Hazard Mitigation Plans (LHMPs), General plans (with a specific focus on safety and Housing Elements), climate adaptation plans, and implementation plans.	https://resilientca.org/plan-alignment/coastal-resilience-compass/
Other Coastal Commission Guidance Documents		
Critical Infrastructure at Risk: Sea Level Rise Adaptation Planning for California's Coastal Zone (CCC 2021)	This guidance promotes resilient coastal infrastructure and protection of coastal resources by providing recommendations for stakeholders on how to plan effectively for the impacts of sea level rise on coastal infrastructure, a description of the regulatory framework that applies to adaptation planning for infrastructure, and model policies that can be used by local governments as a tool for updating LCPs. It addresses two main types of infrastructure – transportation and water – and presents six key considerations for successful adaptation planning.	https://www.coastal.ca.gov/climate/slr/vulnerability-adaptation/infrastructure/
Public Trust Guiding Principles and	This Commission-adopted document describes how the public trust doctrine relates to the Coastal Commission's and local governments' work on sea level rise planning under the Coastal Act. It presents a	https://www.coastal.ca.gov/public-trust/

Action Plan (CCC 2023)	series of principles to guide the Commission's and local governments' work on this subject as well as a set of next steps and research priorities for the Commission.	
California Coastal Commission Sustainability Principles: A Framework for Reducing Greenhouse Gas Emissions in the Coastal Zone (CCC 2023)	This set of Commission-adopted principles aim to improve climate resiliency and minimize the effects of climate change throughout the coastal zone. The principles align with and help carry out the Commission's 2021 to 2025 Strategic Plan, particularly with respect to Objective 4.5 to facilitate greenhouse gas reductions in LCPs, CDPs, and other efforts. The principles also align with the state's goal of carbon neutrality by 2045 and related statewide climate strategies.	https://documents.coastal.ca.gov/assets/lcp/LUPUpdate/Sustainability%20Principles_Adopted%20August%209%202023%20Final.pdf
Progress in California: status of adaptation planning, LCPs, and case studies		
Coastal Commission website	The Coastal Commission's LCP Local Assistance Grant Program webpage provides a "Status of Grantees" chart that links to various local governments' sea level rise vulnerability assessments, adaptation plans, and LCP updates. This chart is a good resource for those looking for examples of recently completed studies and plans related to SLR.	https://www.coastal.ca.gov/lcp/grants/
California Coastal Adaptation Planning Inventory	This online Storymap summarizes the status of coastal adaptation planning in California's 76 coastal jurisdictions along the outer coast, including community vulnerability assessments, adaptation strategies, and local coastal planning under the Coastal Act. The inventory was developed by the research team at UCSB's Ocean and Coastal Policy Center, with major funding from the California Ocean Protection Council (OPC) under Proposition 68, and will be periodically updated.	https://storymaps.arcgis.com/stories/5c3ec4198b564750886cc75b95a8e492
California Adaptation Clearinghouse	Hosted by the OPR Integrated Climate Adaptation and Resiliency Program (ICARP), the *California Adaptation Clearinghouse* is a searchable database of adaptation and resilience resources organized by climate impact, topic, and region. Types of resources in the Clearinghouse include assessments, plans, or strategies; communication and educational materials; planning and policy guidance; data, tools, and research; and case studies, projects, and example planning documents.	https://resilientca.org/

Funding		
Coastal Commission LCP Local Assistance Grant Program	The Coastal Commission's LCP Local Assistance Grant Program provides funds to support local governments in completing or updating Local Coastal Programs (LCP) consistent with the California Coastal Act, with special emphasis on planning for sea level rise and climate change. Grant-funded work has included the sea level rise vulnerability assessments, technical studies, economic analyses, adaptation planning and reports, public outreach and engagement, and LCP policy development. Additional program details, including eligibility information and evaluation criteria, are provided on the program website.	https://www.coastal.ca.gov/lcp/grants/
Ocean Protection Council SB1 Grant Program	OPC's SB 1 SLR Adaptation Planning Grant Program (SB 1 Grant Program) aims to provide funding for coastal communities to develop consistent sea level rise adaptation plans and projects to build resilience to sea level rise along the entire coast of California and San Francisco Bay. One track funds projects in the pre-planning, data collection, and planning phases, and another funds projects in the implementation phase.	https://www.opc.ca.gov/sb-1-funding/
State Coastal Conservancy	The California State Coastal Conservancy has a variety of grant programs to support increased public access to and along the coast, protection and restoration of natural lands and wildlife habitat, preservation of working lands, and increased community resilience to climate change. Funding can support a variety of project stages including feasibility studies, property acquisition, community engagement, environmental review, and monitoring. More information on Conservancy grants can be found on their website.	https://scc.ca.gov/grants/
Grants.ca.gov	The California Grants Portal, a project by the California State Library, is a search engine for all grants and loans offered on a competitive or first-come basis by California state agencies. Agencies that have historically funded projects related to SLR adaptation include: the Federal Emergency Management Agency (FEMA), California Governor's Office of Emergency Services (CalOES), Ocean Protection Council (OPC), Office of Planning and Research (OPR), Strategic Growth Council (SGC), State Coastal Conservancy (SCC), and California Coastal Commission (CCC).	Grants.ca.gov

Coastal Quest Coastal Funding Database	This database provides current funding opportunities that support coastal resilience programs and coastal multi-benefit nature-based solutions, including disaster resilience, 30×30 protection, conservation, and restoration. The database is updated weekly.	https://www.coastal-quest.org/our-programs/coastal-funding-database/
SLR Mapping & Scenario Tools		
Our Coast Our Future (CoSMoS)	The USGS's Coastal Storm Modeling System (CoSMoS) provides maps of various sea level rise-related hazards under half-meter incremental sea level rise scenarios. CoSMoS provides more detailed predictions of coastal flooding due to both future sea level rise and storms integrated with long-term coastal evolution (i.e., beach changes and cliff/bluff retreat) over large geographic areas (100s of kilometers). While projections of groundwater rise and shoreline change are available statewide, other hazards are available from Point Arena to the Mexico border and will be available statewide in the coming years.	Access the online viewer at ourcoastourfuture.org Download GIS data layers at https://www.sciencebase.gov/catalog/item/5633fea2e4b048076347f1cf and view them on Cal Adapt at Cal-Adapt.org (Data is also hosted on the 30x30 California Climate Explorer)
Hazard Exposure Reporting and Analytics (HERA) (CoSMoS data)	The USGS's CoSMoS data is hosted on both ourcoastourfuture.org (above) and on HERA, the Hazard Exposure Reporting and Analytics website. HERA allows users to overlay the hazard data layers of CoSMoS with a host of different spatial datasets on communities, residents, employees, land types, habitats, parcels, and various types of critical infrastructure and facilities. It provides users with statistics regarding the number of people and assets within any give hazard zone.	https://www.usgs.gov/apps/hera/
NOAA Sea Level Rise Viewer	An example of a "bathtub model," this viewer shows areas that are hydrologically connected to the ocean and are located at 1-foot increments of elevation above mean sea level rise, representing the geographic areas that would become inundated with sea level rise up to 10 feet. Storms, waves, erosion, and other coastal processes are not represented.	https://coast.noaa.gov/digitalcoast/tools/slr.html

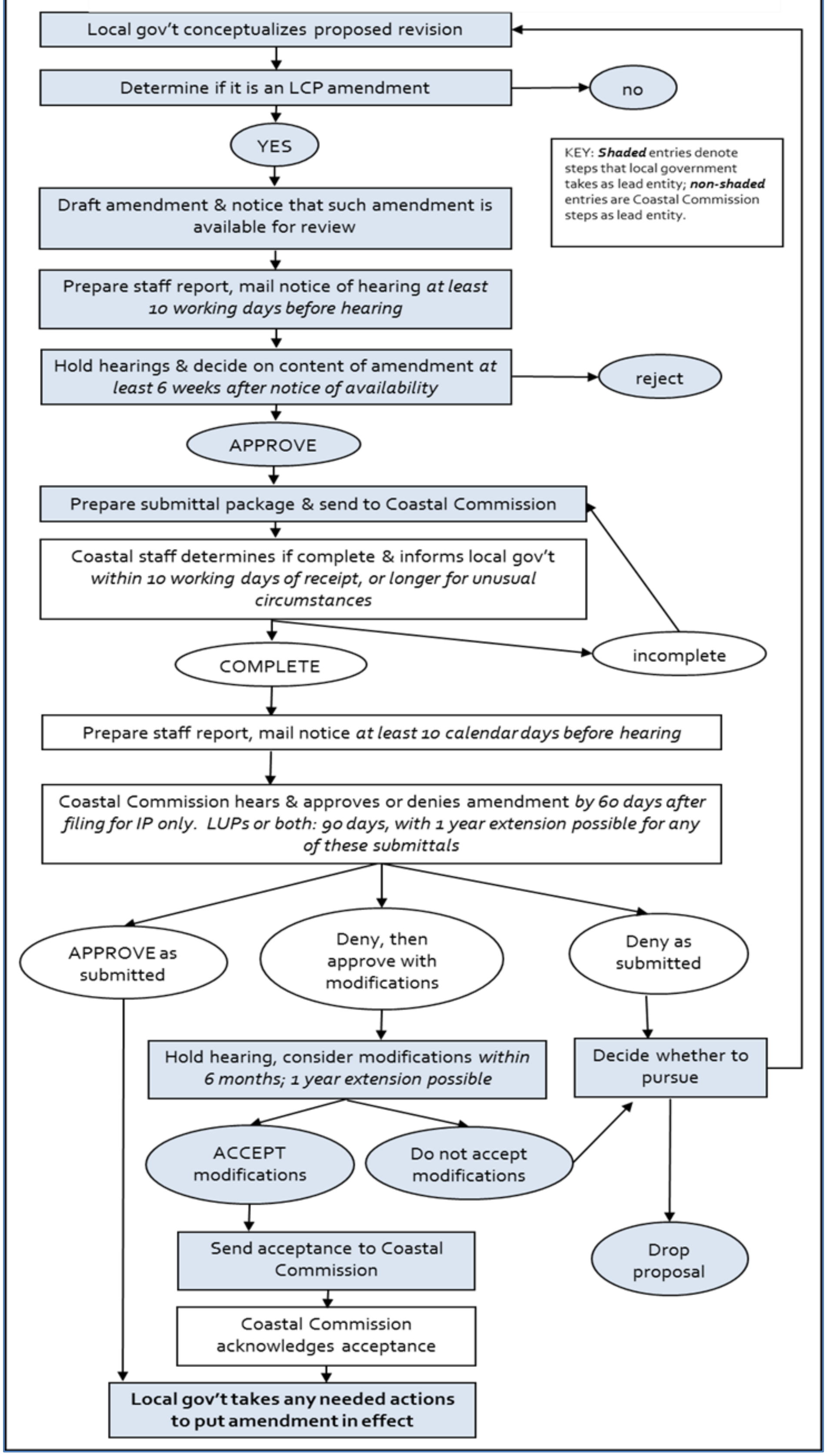
NASA Flooding Analysis Tool	This tool describes the frequency of high-tide flooding will change under various sea level rise scenarios. Users can view sea-level observations and assess past high-tide flooding frequency, view future changes in high-tide flooding frequency under various sea level rise scenarios, and view statistics and inflection points that support decision making. The tool was developed with funding from the NASA Sea Level Change Team by scientists at the University of Hawaii Sea Level Center and is based on the methods of Thompson *et al*., 2021.	https://sealevel.nasa.gov/data_tools/15/
Cal-Adapt – Exploring California's Climate	Cal-Adapt hosts two datasets on sea level rise hazards: CoSMoS data and CalFloD3D-TFS. The CoSMoS data is the same as the dataset described above. The CalFloD3D-TFS assesses potential coastal flooding exposure to areas of interest to the Transportation Fuel Sector (TFS) over five 20-year planning horizons and the Fourth Assessment scenarios using a 3Di hydrodynamic model during extremely high sea level events (72 hour storm event). Due to the inclusion of aboveground objects such as buildings and levees, CalFloD-3D depicts detailed land surface details. Details are described in Radke *et al*., 2018. Cal-Adapt Analytics Engine provides the foundational climate and environmental data that underpins the California Climate Change Assessment, including sea level rise information.	http://cal-adapt.org/tools/slr-calflod-3d/ https://analytics.cal-adapt.org/
NASA Interagency Sea Level Rise Scenario Tool	The NASA Interagency Sea Level Rise Scenario Tool provides graphs of the sea level rise scenarios in the report, *Global and Regional Sea Level Rise Scenarios for the United States* (Sweet *et al*., 2022). Scenarios are available for all U.S. states and territories, out to the year 2150.	https://sealevel.nasa.gov/task-force-scenario-tool?psmsl_id=1352
NASA & IPCC Sea Level Rise Projection Tool	The NASA Sea Level Projection Tool allows users to visualize and download the sea level projections from the IPCC *Sixth Assessment Report* (AR6). Along with global mean sea level rise projections, projections are available for various regions and tide gauge locations around the globe.	https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool?type=global

The Coastal Commission has developed a resource guide to assist local governments in integrating environmental justice into their LCPs. This guide is a direct response to the Commission's Environmental Justice Policy, which encourages local authorities to include environmental justice considerations in their coastal management efforts, particularly in addressing sea level rise and ensuring community involvement. The guide is enriched with extensive research, best practices, and examples from jurisdictions like Morro Bay and Half Moon Bay, which have successfully incorporated environmental justice measures into their LCPs. It offers practical advice on amending LCPs to reflect environmental justice concerns, building meaningful relationships with affected communities, and ensuring that these communities' perspectives and needs are central to the planning process. This resource is designed to be a comprehensive tool for local governments to enhance their coastal management strategies and protect vulnerable populations while managing coastal resources effectively. For more detailed information and guidance on how to integrate environmental justice into Local Coastal Programs, you can access the full Resources for Addressing Environmental Justice Through Local Coastal Programs guide on the Commission's webpage.

Appendix D. General LCP Amendment Processing Steps and Best Practices

Sea level rise is one of many topics that should be addressed in a Local Coastal Program (LCP) or LCP amendment. The Coastal Commission offers a Local Coastal Program (LCP) Update Guide that outlines the broad process for amending or certifying an LCP, including guidance for both Land Use Plans and Implementation Plans. It addresses major Coastal Act concerns, including public access, recreation and visitor serving facilities, water quality protection, ESHA and natural resources, agricultural resources, new development, archaeological and cultural resources, scenic and visual resources, coastal hazards, shoreline erosion and protective devices, energy and industrial development, and timberlands. Therefore, this *Sea Level Rise Policy Guidance* should be used in conjunction with the LCP Update Guide to perform complete LCP amendments or certifications. The following figure depicts the general LCP amendment process.

Figure I: General LCP Amendment Processing Steps



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Appendix E. Primary Coastal Act Policies Related to Sea Level Rise and Coastal Hazards

Legislative Findings Relating to Sea Level Rise

Section 30006.5 of the Coastal Act states (Legislative findings and declarations; technical advice and recommendations) states (emphasis added):

> The Legislature further finds and declares that sound and timely scientific recommendations are necessary for many coastal planning, conservation, and development decisions and that the commission should, in addition to developing its own expertise in significant applicable fields of science, interact with members of the scientific and academic communities in the social, physical, and natural sciences so that the commission may receive technical advice and recommendations with regard to its decision-making, especially with regard to issues such as coastal erosion and geology, marine biodiversity, wetland restoration, the question of sea level rise, desalination plants, and the cumulative impact of coastal zone developments.

Environmental Justice

Section 30013 of the Coastal Act (Environmental Justice) states:

> The Legislature further finds and declares that in order to advance the principles of environmental justice and equality, subdivision (a) of Section 11135 of the Government Code and subdivision (e) of Section 65040.12 of the Government Code apply to the commission and all public agencies implementing the provisions of this division. As required by Section 11135 of the Government Code, no person in the State of California, on the basis of race, national origin, ethnic group identification, religion, age, sex, sexual orientation, color, genetic information, or disability, shall be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination, under any program or activity that is conducted, operated, or administered pursuant to this division, is funded directly by the state for purposes of this division, or receives any financial assistance from the state pursuant to this division. (Added by Ch. 578, Stats. 2016.)

Public Access and Recreation

Section 30210 of the Coastal Act (Access; recreational opportunities; posting) states:

> In carrying out the requirement of Section 4 of Article X of the California Constitution, maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.

Section 30211 of the Coastal Act (Development not to interfere with access) states:

> Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization, including, but not limited to, the use

> of dry sand and rocky coastal beaches to the first line of terrestrial vegetation.

Section 30212 of the Coastal Act (New development projects) states:

> (a) Public access from the nearest public roadway to the shoreline and along the coast shall be provided in new development projects except where: (1) it is inconsistent with public safety, military security needs, or the protection of fragile coastal resources, (2) adequate access exists nearby, or (3) agriculture would be adversely affected. Dedicated accessway shall not be required to be opened to public use until a public agency or private association agrees to accept responsibility for maintenance and liability of the accessway.

Section 30214 of the Coastal Act (Implementation of public access policies; legislative intent) states:

> (a) The public access policies of this article shall be implemented in a manner that takes into account the need to regulate the time, place, and manner of public access depending on the facts and circumstances in each case including, but not limited to, the following:
>
> (1) Topographic and geologic site characteristics.
>
> (2) The capacity of the site to sustain use and at what level of intensity.
>
> (3) The appropriateness of limiting public access to the right to pass and repass depending on such factors as the fragility of the natural resources in the area and the proximity of the access area to adjacent residential uses.
>
> (4) The need to provide for the management of access areas so as to protect the privacy of adjacent property owners and to protect the aesthetic values of the area by providing for the collection of litter.
>
> (b) It is the intent of the Legislature that the public access policies of this article be carried out in a reasonable manner that considers the equities and that balances the rights of the individual property owner with the public's constitutional right of access pursuant to Section 4 of Article X of the California Constitution. Nothing in this section or any amendment thereto shall be construed as a limitation on the rights guaranteed to the public under Section 4 of Article X of the California Constitution.
>
> (c) In carrying out the public access policies of this article, the commission and any other responsible public agency shall consider and encourage the utilization of innovative access management techniques, including, but not limited to, agreements with private organizations which would minimize management costs and encourage the use of volunteer programs.

Section 30220 of the Coastal Act (Protection of certain water-oriented activities) states:

> Coastal areas suited for water-oriented recreational activities that cannot readily be provided at inland water areas shall be protected for such uses.

Section 30221 of the Coastal Act (Oceanfront land; protection for recreational use and development) states:

> Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.

Section 30223 of the Coastal Act (Upland areas) states:

> Upland areas necessary to support coastal recreational uses shall be reserved for such uses, where feasible.

Wetlands and Environmentally Sensitive Resources

Section 30231 of the Coastal Act (Biological productivity; water quality) states in part:

> The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored…

Section 30233 of the Coastal Act (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> (a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects, and shall be limited to the following:

Section 30240 of the Coastal Act (Environmentally sensitive habitat areas; adjacent developments) states:

> (a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas.
>
> (b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.

Coastal Act Section 30121 defines “Wetland” as follows:

> "Wetland" means lands within the coastal zone which may be covered periodically or permanently with shallow water and include saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens.

The California Code of Regulations Section 13577(b) of Title 14, Division 5.5, Article 18 defines “Wetland” as follows:

> (1) Measure 100 feet landward from the upland limit of the wetland. Wetland shall be defined as land where the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes, and shall also include those types of wetlands where vegetation is lacking and soil is poorly developed or absent as a result of frequent and drastic fluctuations of surface water levels, wave action, water flow, turbidity or high concentrations of salts or other substances in the substrate. Such wetlands can be recognized by the presence of surface water or saturated substrate at some time during each year and their location within, or adjacent to, vegetated wetlands or deep-water habitats. For purposes of this section, the upland limit of a wetland shall be defined as:
>
> (A) the boundary between land with predominantly hydrophytic cover and land with predominantly mesophytic or xerophytic cover;
>
> (B) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or
>
> (C) in the case of wetlands without vegetation or soils, the boundary between land that is flooded or saturated at some time during years of normal precipitation, and land that is not.
>
> (2) For the purposes of this section, the term “wetland” shall not include wetland habitat created by the presence of and associated with agricultural ponds and reservoirs where:
>
> (A) the pond or reservoir was in fact constructed by a farmer or rancher for agricultural purposes; and
>
> (B) there is no evidence (e.g., aerial photographs, historical survey, etc.) showing that wetland habitat pre-dated the existence of the pond or reservoir. Areas with drained hydric soils that are no longer capable of supporting hydrophytes shall not be considered wetlands.

In addition, Coastal Act Section 30107.5 defines “Environmentally sensitive area" as follows:

> "Environmentally sensitive area" means any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments.

Agricultural and Timber Lands

Section 30241 of the Coastal Act (Prime agricultural land; maintenance in agricultural production) states:

> The maximum amount of prime agricultural land shall be maintained in agricultural production to assure the protection of the areas' agricultural economy, and conflicts shall be minimized between agricultural and urban land uses…

Section 30242 of the Coastal Act (Lands suitable for agricultural use; conversion) states:

> All other lands suitable for agricultural use shall not be converted to nonagricultural uses unless (1) continued or renewed agriculture use is not feasible, or (2) such conversion would preserve prime agricultural land or concentrate development consistent with Section 30250. Any such permitted conversion shall be compatible with continue agricultural use on surrounding lands.

Section 30243 of the Coastal Act (Productivity of soils and timberlands; conversions) states:

> The long-term productivity of soils and timberlands shall be protected, and conversions of coastal commercial timberlands in units of commercial size to other uses or their division into units of noncommercial size shall be limited to providing for necessary timber processing and related facilities.

Archaeological and Paleontological Resources

Section 30244 of the Coastal Act (Archaeological or paleontological resources) states:

> Where development would adversely impact archaeological or paleontological resources as identified by the State Historic Preservation Officer, reasonable mitigation measures shall be required.

Marine Resources

Section 30230 of the Coastal Act (Marine resources; maintenance) states:

> Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.

Section 30231 of the Coastal Act (Biological productivity; water quality) states:

> The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms

> and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface waterflow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.

Section 30233 of the Coastal Act (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> (a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects…
>
> (d) Erosion control and flood control facilities constructed on watercourses can impede the movement of sediment and nutrients that would otherwise be carried by storm runoff into coastal waters. To facilitate the continued delivery of these sediments to the littoral zone, whenever feasible, the material removed from these facilities may be placed at appropriate points on the shoreline in accordance with other applicable provisions of this division, where feasible mitigation measures have been provided to minimize adverse environmental effects. Aspects that shall be considered before issuing a Coastal Development Permit for these purposes are the method of placement, time of year of placement, and sensitivity of the placement area.

Section 30234 of the Coastal Act (Commercial fishing and recreational boating facilities**)** states:

> Facilities serving the commercial fishing and recreational boating industries shall be protected and, where feasible, upgraded. Existing commercial fishing and recreational boating harbor space shall not be reduced unless the demand for those facilities no longer exists or adequate substitute space has been provided. Proposed recreational boating facilities shall, where feasible, be designed and located in such a fashion as not to interfere with the needs of the commercial fishing industry.

Section 30234.5 of the Coastal Act (Economic, commercial, and recreational importance of fishing) states:

> The economic, commercial, and recreational importance of fishing activities shall be recognized and protected.

Coastal Development

Section 30250 of the Coastal Act (Location; existing developed area) states:

> (a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able

> to accommodate it, in other areas with adequate public services and where it will not have significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.
>
> (b) Where feasible, new hazardous industrial development shall be located away from existing developed areas.
>
> (c) Visitor-serving facilities that cannot feasibly be located in existing developed areas shall be located in existing isolated developments or at selected points of attraction for visitors.

Section 30251 of the Coastal Act (Scenic and visual qualities) states:

> The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas...

Section 30253 the Coastal Act (Minimization of adverse impacts) states in part:

> New development shall do all of the following:
>
> (a) Minimize risks to life and property in areas of high geologic, flood, and fire hazard.
>
> (b) Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs...

Section 30235 of the Coastal Act (Construction altering natural shoreline) states:

> Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible.

Section 30236 of the Coastal Act (Water supply and flood control) states:

> Channelizations, dams, or other substantial alterations of rivers and streams shall incorporate the best mitigation measures feasible, and be limited to (l) necessary water

> supply projects, (2) flood control projects where no other method for protecting existing structures in the flood plain is feasible and where such protection is necessary for public safety or to protect existing development, or (3) developments where the primary function is the improvement of fish and wildlife habitat.

Sea Level Rise

Section 30270 of the Coastal Act (Sea level rise) states:

> The Commission shall take into account the effects of sea level rise in coastal resources planning and management policies and activities in order to identify, assess, and, to the extent feasible, avoid and mitigate the adverse effects of sea level rise.

Ports

Section 30705 of the Coastal Act (Diking, filling or dredging water areas) states:

> (a) Water areas may be diked, filled, or dredged when consistent with a certified port master plan only for the following: …
>
> (b) The design and location of new or expanded facilities shall, to the extent practicable, take advantage of existing water depths, water circulation, siltation patterns, and means available to reduce controllable sedimentation so as to diminish the need for future dredging.
>
> (c) Dredging shall be planned, scheduled, and carried out to minimize disruption to fish and bird breeding and migrations, marine habitats, and water circulation. Bottom sediments or sediment elutriate shall be analyzed for toxicants prior to dredging or mining, and where water quality standards are met, dredge spoils may be deposited in open coastal water sites designated to minimize potential adverse impacts on marine organisms, or in confined coastal waters designated as fill sites by the master plan where such spoil can be isolated and contained, or in fill basins on upland sites. Dredge material shall not be transported from coastal waters into estuarine or fresh water areas for disposal.

Section 30706 of the Coastal Act (Fill) states:

> In addition to the other provisions of this chapter, the policies contained in this section shall govern filling seaward of the mean high tide line within the jurisdiction of ports:
>
> > (a) The water area to be filled shall be the minimum necessary to achieve the purpose of the fill.
> >
> > (b) The nature, location, and extent of any fill, including the disposal of dredge spoils within an area designated for fill, shall minimize harmful effects to coastal resources, such as water quality, fish or wildlife resources, recreational

> resources, or sand transport systems, and shall minimize reductions of the volume, surface area, or circulation of water.
>
> (c) The fill is constructed in accordance with sound safety standards which will afford reasonable protection to persons and property against the hazards of unstable geologic or soil conditions or of flood or storm waters.
>
> (d) The fill is consistent with navigational safety.

Section 30708 of the Coastal Act (Location, design and construction of port related developments) states:

> All port-related developments shall be located, designed, and constructed so as to:
>
> (a) Minimize substantial adverse environmental impacts.
>
> (b) Minimize potential traffic conflicts between vessels.
>
> (c) Give highest priority to the use of existing land space within harbors for port purposes, including, but not limited to, navigational facilities, shipping industries, and necessary support and access facilities.
>
> (d) Provide for other beneficial uses consistent with the public trust, including, but not limited to, recreation and wildlife habitat uses, to the extent feasible.
>
> (e) Encourage rail service to port areas and multicompany use of facilities.

Public Works Facilities

According to Coastal Act Section 30114, public works facilities include:

> (a) All production, storage, transmission, and recovery facilities for water, sewerage, telephone, and other similar utilities owned or operated by any public agency or by any utility subject to the jurisdiction of the Public Utilities Commission, except for energy facilities.
>
> (b) All public transportation facilities, including streets, roads, highways, public parking lots and structures, ports, harbors, airports, railroads, and mass transit facilities and stations, bridges, trolley wires, and other related facilities. For purposes of this division, neither the Ports of Hueneme, Long Beach, Los Angeles, nor San Diego Unified Port District nor any of the developments within these ports shall be considered public works.
>
> (c) All publicly financed recreational facilities, all projects of the State Coastal Conservancy, and any development by a special district.
>
> (d) All community college facilities.

Greenhouse Gas Emissions Reduction

Section 30250(a) of the Coastal Act (Location, existing developed areas states) in part:

> (a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able to accommodate it, in other areas with adequate public services and where it will not have significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.

Section 30252 of the Coastal Act (Maintenance and enhancement of public access) states:

> The location and amount of new development should maintain and enhance public access to the coast by (1) facilitating the provision or extension of transit service, (2) providing commercial facilities within or adjoining residential development or in other areas that will minimize the use of coastal access roads, (3) providing nonautomobile circulation within the development, (4) providing adequate parking facilities or providing substitute means of serving the development with public transportation, (5) assuring the potential for public transit for high intensity uses such as high-rise office buildings, and by (6) assuring that the recreational needs of new residents will not overload nearby coastal recreation areas by correlating the amount of development with local park acquisition and development plans with the provision of onsite recreational facilities to serve the new development.

Section 30253(d) of the Coastal Act (Minimization of adverse impacts) states in part:

> New Development shall:
>
> > (d) Minimize energy consumption and vehicle miles traveled….

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Appendix F. Sea Level Rise Scenarios for 14 California Tide Gauges

Map of Tide Gauge Locations

Figure F-1. Map of tide gauge locations (from OPC 2024)

Table F-1. Sea Level Scenarios for Crescent City

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.1	0.1	0.2	0.2	0.2
2040	0.1	0.2	0.2	0.3	0.4
2050	0.1	0.3	0.4	0.6	0.8
2060	0.1	0.4	0.6	1.0	1.5
2070	0.2	0.4	0.8	1.6	2.3
2080	0.2	0.6	1.2	2.3	3.4
2090	0.2	0.7	1.7	3.0	4.5
2100	0.2	0.8	2.3	3.9	5.6
2110	0.2	0.9	2.9	4.7	6.9
2120	0.2	1.0	3.4	5.3	7.9
2130	0.2	1.2	3.8	5.8	8.7
2140	0.2	1.3	4.2	6.3	9.6
2150	0.2	1.4	4.7	6.8	10.3

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-2. Sea Level Scenarios for North Spit, Humboldt Bay

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.5	0.6	0.6	0.6	0.7
2040	0.7	0.8	0.9	1	1.1
2050	0.9	1	1.2	1.4	1.6
2060	1.1	1.3	1.5	2	2.4
2070	1.3	1.5	1.9	2.7	3.5
2080	1.4	1.8	2.5	3.6	4.7
2090	1.6	2.1	3.1	4.5	6
2100	1.8	2.4	3.9	5.5	7.3
2110	1.9	2.7	4.6	6.5	8.7
2120	2.1	3	5.3	7.3	9.9
2130	2.3	3.3	5.9	8	10.8
2140	2.4	3.5	6.5	8.6	11.9
2150	2.6	3.8	7.1	9.3	12.8

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-3. Sea Level Scenarios for Arena Cove

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.2	0.3	0.3	0.4	0.4
2040	0.3	0.4	0.5	0.6	0.7
2050	0.4	0.5	0.7	0.9	1.1
2060	0.5	0.7	0.9	1.4	1.8
2070	0.5	0.8	1.2	2.1	2.8
2080	0.6	1.0	1.7	2.8	3.9
2090	0.7	1.2	2.2	3.6	5.1
2100	0.8	1.4	2.9	4.5	6.4
2110	0.8	1.6	3.6	5.4	7.6
2120	0.9	1.7	4.1	6.1	8.7
2130	0.9	1.9	4.6	6.7	9.6
2140	1.0	2.1	5.1	7.3	10.5
2150	1.0	2.3	5.6	7.8	11.4

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-4. Sea Level Scenarios for Point Reyes

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.3	0.4	0.4	0.4	0.5
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.7	0.8	1.0	1.3
2060	0.6	0.8	1.1	1.6	2.0
2070	0.7	1.0	1.4	2.2	3.0
2080	0.8	1.2	1.9	3.0	4.1
2090	0.9	1.4	2.5	3.9	5.4
2100	1.0	1.6	3.1	4.8	6.6
2110	1.1	1.8	3.8	5.7	7.9
2120	1.2	2.0	4.4	6.4	9.0
2130	1.2	2.2	4.9	7.0	9.9
2140	1.3	2.4	5.5	7.6	10.9
2150	1.4	2.7	6.0	8.2	11.8

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-5. Sea Level Scenarios for San Francisco

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.3	0.4	0.4	0.4	0.4
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.6	0.8	1.0	1.3
2060	0.6	0.8	1.1	1.5	2.0
2070	0.7	1.0	1.4	2.2	2.9
2080	0.8	1.2	1.8	3.0	4.1
2090	0.9	1.4	2.4	3.8	5.3
2100	1.0	1.6	3.1	4.8	6.5
2110	1.0	1.8	3.8	5.6	7.8
2120	1.1	2.0	4.4	6.4	9.0
2130	1.2	2.2	4.9	7.0	9.9
2140	1.3	2.4	5.4	7.6	10.8
2150	1.3	2.6	6.0	8.1	11.7

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-6. Sea Level Scenarios for Alameda

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.2	0.3	0.3	0.3	0.4
2040	0.3	0.4	0.4	0.5	0.6
2050	0.3	0.5	0.6	0.9	1.1
2060	0.4	0.6	0.9	1.4	1.8
2070	0.5	0.8	1.2	2.0	2.7
2080	0.5	0.9	1.6	2.8	3.8
2090	0.6	1.1	2.1	3.5	5.0
2100	0.6	1.2	2.8	4.4	6.2
2110	0.7	1.4	3.4	5.3	7.5
2120	0.7	1.6	4.0	5.9	8.5
2130	0.8	1.7	4.5	6.5	9.4
2140	0.8	1.9	4.9	7.1	10.3
2150	0.8	2.1	5.4	7.6	11.2

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-7. Sea Level Scenarios for Port Chicago

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.3	0.4	0.4	0.4	0.4
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.6	0.8	1.0	1.3
2060	0.6	0.8	1.1	1.5	2.0
2070	0.7	1.0	1.4	2.2	2.9
2080	0.8	1.2	1.8	3.0	4.1
2090	0.9	1.4	2.4	3.8	5.3
2100	1.0	1.6	3.1	4.8	6.5
2110	1.0	1.8	3.8	5.6	7.8
2120	1.1	2.0	4.4	6.4	9.0
2130	1.2	2.2	4.9	7.0	9.9
2140	1.3	2.4	5.4	7.6	10.8
2150	1.4	2.6	6.0	8.1	11.7

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-8. Sea Level Scenarios for Monterey

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.2	0.3	0.3	0.4	0.4
2040	0.3	0.4	0.5	0.6	0.7
2050	0.4	0.6	0.7	0.9	1.2
2060	0.5	0.7	1.0	1.4	1.9
2070	0.6	0.9	1.3	2.1	2.8
2080	0.6	1.0	1.7	2.9	3.9
2090	0.7	1.2	2.3	3.7	5.2
2100	0.8	1.4	2.9	4.6	6.4
2110	0.8	1.6	3.6	5.5	7.7
2120	0.9	1.8	4.2	6.2	8.8
2130	0.9	1.9	4.7	6.8	9.7
2140	1.0	2.1	5.2	7.3	10.6
2150	1.1	2.3	5.7	7.9	11.5

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-9. Sea Level Scenarios for Port San Luis

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.2	0.3	0.3	0.3	0.4
2040	0.3	0.4	0.4	0.5	0.6
2050	0.3	0.5	0.6	0.9	1.1
2060	0.4	0.6	0.9	1.4	1.8
2070	0.5	0.7	1.2	2.0	2.7
2080	0.5	0.9	1.6	2.8	3.8
2090	0.5	1.1	2.1	3.5	5.0
2100	0.6	1.2	2.8	4.5	6.3
2110	0.6	1.4	3.4	5.3	7.5
2120	0.7	1.5	4.0	6.0	8.6
2130	0.7	1.7	4.4	6.6	9.5
2140	0.7	1.9	4.9	7.1	10.4
2150	0.8	2.0	5.5	7.6	11.3

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-10. Sea Level Scenarios for Santa Barbara

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.2	0.3	0.3	0.3	0.4
2040	0.3	0.4	0.4	0.5	0.6
2050	0.3	0.5	0.6	0.9	1.1
2060	0.4	0.6	0.9	1.4	1.8
2070	0.5	0.7	1.2	2.0	2.7
2080	0.5	0.9	1.6	2.8	3.8
2090	0.5	1.1	2.1	3.5	5.0
2100	0.6	1.2	2.8	4.5	6.3
2110	0.6	1.4	3.4	5.3	7.5
2120	0.7	1.5	4.0	6.0	8.6
2130	0.7	1.7	4.4	6.6	9.5
2140	0.7	1.9	4.9	7.1	10.4
2150	0.8	2.0	5.5	7.6	11.3

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-11. Sea Level Scenarios for Santa Monica

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.3	0.3	0.4	0.4	0.4
2040	0.3	0.4	0.5	0.6	0.7
2050	0.4	0.6	0.7	0.9	1.2
2060	0.5	0.7	1.0	1.5	1.9
2070	0.6	0.9	1.3	2.1	2.8
2080	0.6	1.0	1.7	2.9	3.9
2090	0.7	1.2	2.3	3.7	5.2
2100	0.8	1.4	2.9	4.6	6.4
2110	0.8	1.6	3.6	5.5	7.7
2120	0.9	1.8	4.2	6.2	8.8
2130	0.9	1.9	4.7	6.8	9.7
2140	1.0	2.1	5.2	7.3	10.6
2150	1.1	2.3	5.7	7.9	11.5

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-12. Sea Level Scenarios for Los Angeles

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.2	0.3	0.3	0.4	0.4
2040	0.3	0.4	0.5	0.6	0.7
2050	0.4	0.5	0.7	0.9	1.1
2060	0.4	0.6	0.9	1.4	1.8
2070	0.5	0.8	1.2	2.1	2.7
2080	0.5	0.9	1.6	2.8	3.8
2090	0.6	1.1	2.2	3.6	5.0
2100	0.6	1.3	2.8	4.5	6.3
2110	0.7	1.4	3.5	5.3	7.6
2120	0.7	1.6	4.0	6.0	8.6
2130	0.8	1.8	4.5	6.6	9.5
2140	0.8	1.9	5.0	7.1	10.4
2150	0.8	2.1	5.5	7.7	11.3

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-13. Sea Level Scenarios for La Jolla

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.3	0.4	0.4	0.4	0.5
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.7	0.8	1.0	1.3
2060	0.6	0.8	1.1	1.6	2.0
2070	0.7	1.0	1.4	2.3	3.0
2080	0.8	1.2	1.8	3.1	4.1
2090	0.9	1.4	2.4	3.9	5.3
2100	0.9	1.6	3.1	4.8	6.6
2110	1.0	1.8	3.8	5.7	7.9
2120	1.1	2.0	4.4	6.4	9.0
2130	1.2	2.2	4.9	7.1	9.9
2140	1.2	2.4	5.5	7.6	10.9
2150	1.3	2.6	6.0	8.2	11.8

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Table F-14. Sea Level Scenarios for San Diego

Projected SLR Amounts (in feet)					
	Low	**Intermediate-Low**	**Intermediate**	**Intermediate-High**	**High**
2030	0.3	0.4	0.4	0.5	0.5
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.7	0.8	1.1	1.3
2060	0.6	0.9	1.1	1.6	2.0
2070	0.7	1.0	1.4	2.3	3.0
2080	0.8	1.2	1.9	3.1	4.1
2090	0.9	1.4	2.5	3.9	5.4
2100	1.0	1.6	3.2	4.9	6.7
2110	1.1	1.8	3.9	5.7	8.0
2120	1.2	2.1	4.5	6.5	9.1
2130	1.3	2.3	5.0	7.1	10.0
2140	1.3	2.5	5.6	7.7	11.0
2150	1.4	2.7	6.1	8.3	11.9

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion. The red box highlights the three scenarios that the *State Sea Level Rise Guidance* (OPC 2024) and this guidance recommend for use in various planning and project contexts.

Appendix G. Coastal Commission Contact Information

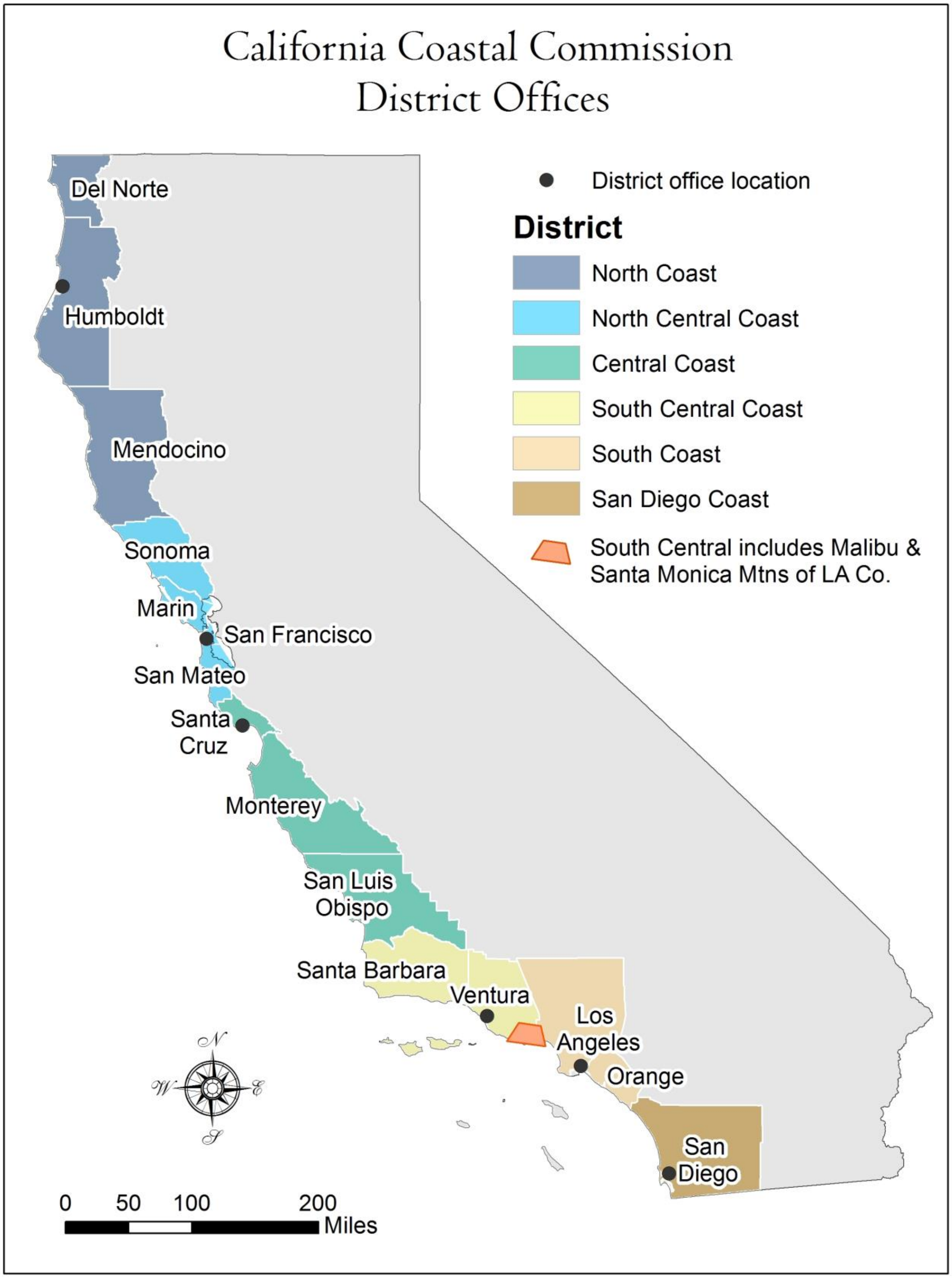

Figure G-1. Location of Coastal Commission Offices

Coastal Commission District Office Contact Information

North Coast (Del Norte, Humboldt, Mendocino Counties)
(707) 826-8950

North Central Coast (Sonoma, Marin, San Francisco, San Mateo Counties)
(415) 904-5260

Headquarters
(415)-904-5202

Central Coast (Santa Cruz, Monterey, San Luis Obispo Counties)
(831) 427-4863

South Central Coast (Santa Barbara and Ventura Counties, and the Malibu portion of Los Angeles County)
(805) 585-1800

South Coast (Los Angeles (except Malibu) and Orange Counties)
(562) 590-5071

San Diego (San Diego County)
(619) 767-2370