APPLICATION GUIDE

for the

2022 Sea Level Rise Technical Report

FORWARD

Sooner or later, those working on coastal resilience issues come to understand an important tenet of our shared efforts: resilience is not a product which can be created—and then delivered—by the federal government. It is a condition that individuals and organizations must advance locally and on their own terms.

The federal government can and should bring its human, technical, fiscal, legal, and policy resources to bear in a manner designed to lift up and support the needs of state, local, tribal, and territorial governments. Our task is to help these entities understand and engage with coastal challenges within the unique context of their geography, their history, their priorities, and their aspirations for the future.

The recently released *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines* (2022 Sea Level Rise Technical Report) provides the best available scientific insights regarding how and when sea level is expected to change. While we rightly celebrate the success of this recent update, we know more accurate and sophisticated science does not directly translate into improved adaptation outcomes.

This document, *Application Guide for the 2022 Sea Level Rise Technical Report*, is a first-of-its-kind effort to bridge this gap. Our goal is to move from information to knowledge, with a focus on empowering those practitioners who must apply this science to decision-making. I am deeply impressed by the quality of the work in this guide but even more so by the forward-thinking cooperation which yielded it. The collaboration of the 2022 Sea Level Rise Technical Report scientists and expert practitioners from both federal and non-federal organizations is an inspiring example of partnership in service of empowering others.

The urgency of our national coastal challenges is apparent to anyone who cares to take even a passing look. Communities are facing risks emerging at a global scale in the absence of a global-scale response. This publication represents a partnership across communities and governments, born from a humble commitment to iterative learning and collaborative knowledge building. This guide demonstrates that we have both the courage and skill to forge new approaches and build an increasingly strong foundation from which to take action towards a more resilient and equitable future for our nation's coasts.

Mark S. Osler

Mark Osler

NOAA Senior Advisor for Coastal Inundation and Resilience

June 2022

Authors

Renee Collini, Ph.D.
Coastal Climate Resilience Specialist, Mississippi State University, Mississippi-Alabama Sea Grant Consortium, and Florida Sea Grant

Jamie Carter
Regional Geospatial Coordinator, NOAA Office for Coastal Management

Lisa Auermuller
Assistant Manager, Jacques Cousteau National Estuarine Research Reserve, Rutgers University

Laura Engeman
Coastal Resilience Specialist, Scripps Institution of Oceanography and California Sea Grant, University of California San Diego

Katy Hintzen
Coastal Resilience Specialist, University of Hawai‘i Sea Grant College Program

Jill Gambill
Coastal Community Resilience Specialist, University of Georgia Marine Extension and Georgia Sea Grant

Rachel Johnson
Coastal Resilience Sea Grant Knauss Policy Fellow, NOAA National Ocean Service

Ian Miller, Ph.D.
Coastal Hazards Specialist, Washington Sea Grant

Carey Schafer
Project Coordinator, EcoAdapt

Heidi Stiller
South Regional Director, NOAA Office for Coastal Management

Suggested Citation:

Collini, R.C., J. Carter, L. Auermuller, L. Engeman, K. Hintzen, J. Gambill, R.E. Johnson, I. Miller, C. Schafer, and H. Stiller. 2022. Application Guide for the 2022 Sea Level Rise Technical Report. National Oceanic and Atmospheric Administration Office for Coastal Management, Mississippi–Alabama Sea Grant Consortium (MASGP-22-028), and Florida Sea Grant (SGEB 88). *https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt02-global-regional-SLR-scenarios-US-application-guide.pdf*

Figure development led by Jamie Carter. Please reach out to him at *jamie.carter@noaa.gov* with questions regarding figure re-creation or adaptation.

TABLE OF CONTENTS

1. PURPOSE

2022 Sea Level Rise Technical Report

The recently released federal *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines* (*2022 Sea Level Rise Technical Report*) is a synthesis of the latest available science on sea level rise. It was developed by an interagency team of experts as an update to the Sweet et al. (2017) report (2017 Sea Level Rise Technical Report), and serves as a technical input to the *Fifth National Climate Assessment*. Read more about the report's *key takeaways*, *frequently asked questions*, and *additional tools and resources*.

2022 Application Guide

This document, *Application Guide for the 2022 Sea Level Rise Technical Report* (Application Guide), is designed to assist decision makers and coastal professionals with applying and integrating the information in the 2022 Sea Level Rise Technical Report into local sea level rise planning and adaptation decisions.

This Application Guide is national in scope, and it includes examples from different geographic regions. It describes how updated sea level rise scenarios and related science information in the 2022 Sea Level Rise Technical Report can be considered and applied through various coastal hazard evaluation and planning approaches.

The Application Guide is divided into the following sections.

- *Section 1*: Purpose.
- *Section 2*: Introduction to the updated science from the 2022 Sea Level Rise Technical Report.
- *Section 3*: Overall considerations when applying sea level rise scenarios in planning efforts.
- *Section 4*: Examples of specific application approaches that can be used to address the uncertainty in the amount and timing of future sea level rise when making decisions.
- *Section 5*: Additional resources for thinking about next steps.

This Application Guide is not a comprehensive guide on how to plan for sea level rise. Adapting to rising seas requires robust and continual efforts that consider a complex array of place-based sociocultural, economic, policy, physical, and ecological factors. This document provides broad guidance on where to start with sea level rise planning and on how to consider the updated information provided in the 2022 Sea Level Rise Technical Report. It includes recommended practices for decision-making in the face of uncertainty, but does not offer formal regulatory or engineering guidance.

Intended Audiences for the Application Guide

The intended audiences for this Application Guide are coastal decision makers and professionals who need to understand, communicate, or apply the best available sea level rise information.

Development of this Document

A geographically diverse team of extension, planning, and outreach professionals developed this document. Members of the 2022 Sea Level Rise Technical Report author team ensured scientific accuracy of the content, and intended end users served as external reviewers.

2. 2022 SEA LEVEL RISE TECHNICAL REPORT CONTENTS

The 2022 Sea Level Rise Technical Report provides three types of sea level rise (SLR) information:

- **Global, Regional, and Local SLR Scenarios**: These scenarios represent the range of SLR projections out to 2150. These projections consider a variety of processes that could influence sea level across a wide range of future warming conditions.
- **Observation-Based Extrapolations**: An estimated continuation of sea level changes based on extending observed tide-gauge trends from 1970-2020 out to 2050. The extrapolations extend the observed rates of SLR and SLR acceleration from the past 50 years out an additional 30 years into the future.
- **Extreme Water Level Probabilities**: Data depicting the frequency of above-average water levels at many locations across the U.S. These values highlight how often different locations may experience elevated water levels, and the increased frequency of those elevated water levels with rising seas.

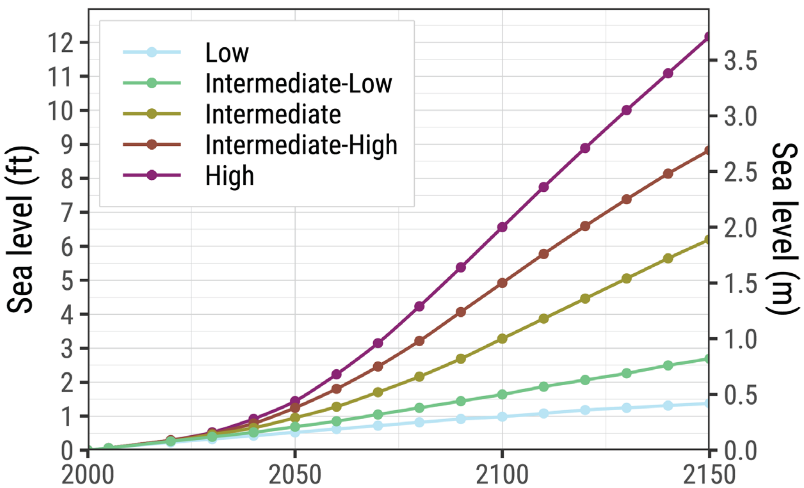
Each of these is described below in more detail. *Key Takeaways* and *Frequently Asked Questions* from the 2022 Sea Level Rise Technical Report are also available online to provide additional information and details.

2.1 Global, Regional, and Local Sea Level Rise Scenarios

The SLR scenarios from the 2022 Sea Level Rise Technical Report:

- reflect greater certainty about SLR out to 2050;
- integrate regional factors that provide better understanding of how and when SLR could impact different coastlines; and
- include the best-available science on global processes to provide updated potential SLR ranges out to 2150.

The 2022 Sea Level Rise Technical Report provides a set of five SLR scenarios, providing a range of plausible sea level changes through 2150. The scenarios were developed from a suite of modeled projections that include new advancements in the understanding of when and how various global processes may occur (e.g., glacier and ice sheet melt, mass redistribution). The five scenarios (Low, Intermediate-Low, Intermediate, Intermediate-High, and High) correspond to average global SLR magnitudes in the year 2100 (relative to a baseline of 2000; *Figure 1*). Global, regional, and local processes (including vertical land motion) were incorporated to generate regional and local-level scenarios. See *Sections 3* and *4* of this Application Guide to learn more about how to consider these scenarios based on the SLR planning situation. Readers can also reference *Section 2.2.3* of the 2022 Sea Level Rise Technical Report for more detail on the development of the different scenarios.



	Year		
Scenario	**2050**	**2100**	**2150**
Low	0.5	1.0	1.4
Intermediate-Low	0.7	1.6	2.7
Intermediate	1.0	3.3	6.2
Intermediate-High	1.2	4.9	8.8
High	1.4	6.6	12.2

Units in feet relative to year 2000

Figure 1. *Global sea level rise scenarios from the 2022 Sea Level Rise Technical Report, including projected values for the years 2050, 2100, and 2150. All values are referenced to a year 2000 baseline.*

2.2 Observation-Based Extrapolations

The 2022 Sea Level Rise Technical Report includes regional extrapolations of SLR based on tide-gauge record data and compares these to the five SLR scenarios (*Figure 2*) for eight coastal regions of the United States. The report provides a detailed explanation for how historic tide-gauge data and knowledge of regional ocean dynamics were used to determine sea level trends from 1970 to 2020. Cyclical ocean dynamics (e.g., El Niño/La Niña cycles) were removed from tide station data, the data were averaged regionally, and then rates and accelerations were used to project, or extrapolate, regional trajectories of SLR out to the year 2050 (see more in *Section 2.2.4* of the 2022 Sea Level Rise Technical Report). It is important to note that like the SLR scenarios, the observation-based extrapolations have likely ranges (also known as confidence limits). These likely ranges capture uncertainty associated with extrapolating the rate of acceleration. This uncertainty is further described in the 2022 Sea Level Rise Technical Report. Additional observation-based extrapolations are available for some individual tide gauges through NASA's *Interagency Sea Level Rise Scenario Tool*.

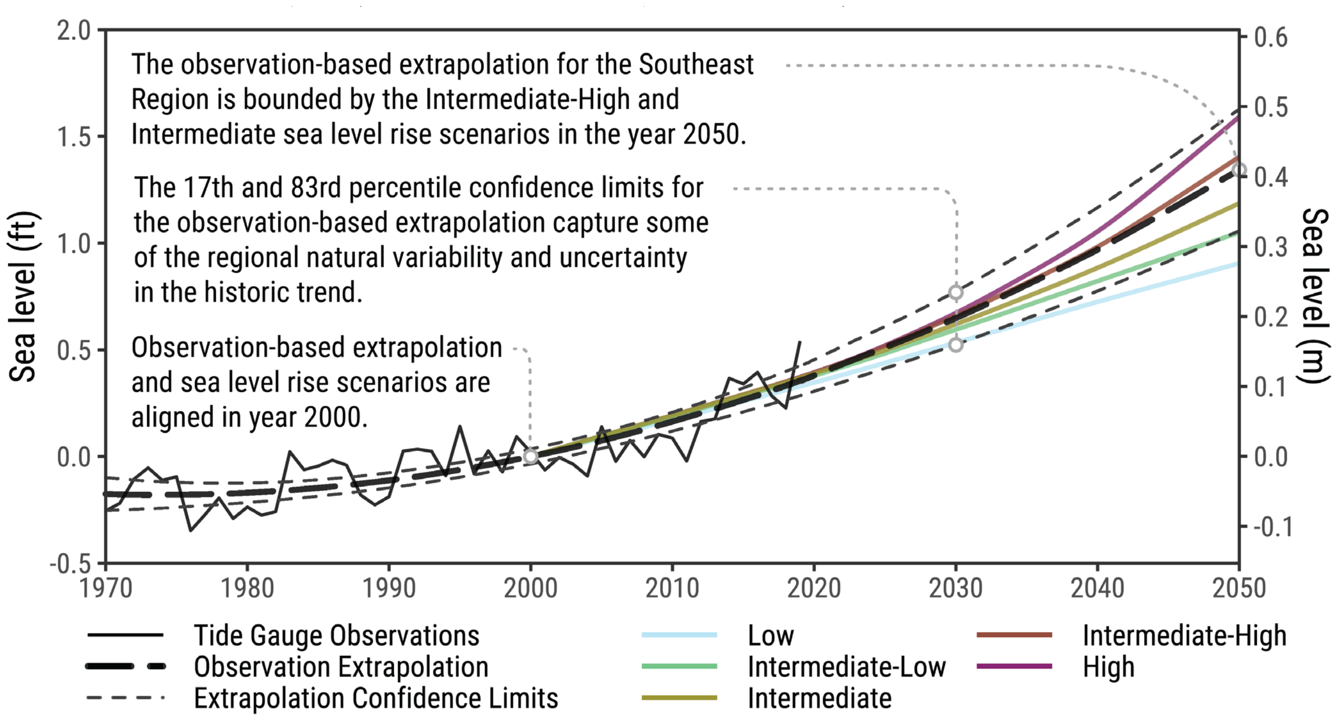


Figure 2. *Regional sea level rise scenarios, observation-based extrapolation (median [bold dash] and 17th/83rd percentile confidence limits [light dash]), and average annual water levels from tide gauges throughout the Southeast region (North Carolina to Key West, Florida).*

2.3 Extreme Water Levels

A primary impact of SLR is increased magnitude and frequency of flooding, which will change how people live, work, and play along the nation's coastlines, and drive shifts in ecosystem processes. The 2022 Sea Level Rise Technical Report, for the first time, includes estimates of how coastal flood frequency and magnitude will change with rising seas. The analysis, known as an extreme water level analysis, used tide-gauge records to assess the likelihood of extreme water levels that occur relatively infrequently, but are often associated with significant impacts.

The water level frequencies assessed ranged from more frequent events (e.g., 10 times per year) to much less frequent events (*Figure 3*). It should be noted that the 1% annual chance water levels, sometimes referred to as a 100-year flood, in this analysis are not the same as those found in the Federal Emergency Management Agency's (FEMA's) regulatory products (e.g., Flood Insurance Rate Maps). Find more detail on the relationship between this extreme water level analysis and FEMA's regulatory floodplain designations in *Section 3.1* of the 2022 Sea Level Rise Technical Report.

Extreme water level analyses can help a user understand changes in the frequency of specific water levels as seas rise, and to answer questions such as,

- If my community is currently affected by a moderate coastal flood roughly once every 10 years, how much SLR will it take for that same water level to occur every year?
- In 30 years, what will the water level be for an event likely to occur annually?

The extreme water level analysis makes it clear that the coastal U.S. can expect a shift in flood regime in the next 30 years, with more damaging and dangerous floods occurring much more frequently as seas rise. The report highlights that although wave-driven water levels are excluded from this analysis, they should be included in future assessments of exposed coastlines where waves can contribute 25-90% of extreme water levels. See *Box 3.1* in the 2022 Sea Level Rise Technical Report for more information on waves and extreme water levels. The extreme water level probabilities are available for tide gauges and 1-degree grids throughout the coastal United States. Methods are provided in the 2022 Sea Level Rise Technical Report to derive extreme water level probabilities for locations not included in the report by using tide range information or short-term records from local observations. See *Section 3* in the 2022 Sea Level Rise Technical Report for more information on how extreme water levels were calculated and to obtain methods to generate localized extreme water level probabilities.

Figure 3. *Maximum water levels in Hampton, New Hampshire, were 1.5 ft higher than normal Mean Higher High Water (MHHW) during peak tides over three consecutive days from November 5-7, 2017. This three-day event exceeded the Minor flood threshold set by the local community and is predicted to occur six times per year based on the gridded Extreme Water Level analysis in the 2022 Sea Level Rise Technical Report. Sea level rise since 2000 has already increased the frequency of this flood level.*
(Photo credit: Jennifer Dubois)

2.4 Additional Insights from the 2022 Sea Level Rise Technical Report

The 2022 Sea Level Rise Technical Report also analyzed and communicated when the five SLR scenarios will diverge from each other, and found that most of the divergence occurred after 2050. In other words, there is less uncertainty about the magnitude of SLR in the near term (i.e., before 2050), relative to the uncertainty in the more distant future (i.e., after 2050). This insight leads to a new emphasis on and distinction between planning applications for sea level information in the "near term" (i.e., before 2050), and the "long term" (i.e., after 2050). It is worth noting that the near-term planning time frame is consistent with many city and individual planning time frames (e.g., capital infrastructure upgrades, earlier than a standard 30-year mortgage). See *Section 2.5* of the 2022 Sea Level Rise Technical Report for more detail and *Section 4* of this guide for more information on how these time horizons can be considered under different planning approaches.

Importantly, the 2022 Sea Level Rise Technical Report notes the relationship between higher global average temperature, and the increased likelihood of higher amounts of SLR. For example, there is a 50% likelihood of exceeding 1.6 ft (0.5 m) of SLR on average in the United States by 2100 if global average temperature increase is limited to 3.6°F (2°C). However, if global average temperature change exceeds 5.4°F (3°C) by 2100, the probability rises to 82%, and if temperature change exceeds 9°F (5°C) by 2100, the probability is nearly certain (>99%). See *Section 2.4* and *Table 2.4* in 2022 Sea Level Rise Technical Report for more detail.

Annual Chance Events vs. Exceedance Probabilities

At times there can be confusion between different terminology that uses percentages around flood risk and rising seas. We often talk about flood risk in terms of the probability that a given water level will be reached each year. A common regulatory term is the 1% annual chance flood event, also referred to as a 100-year flood. What this represents is the fact that **there is a 1% chance every year that an event of that magnitude may occur.** The likelihood or probability that one of these events will occur **increases over multiple years.** For example, a coastal flood event that has a 1% chance of occurring in any given year (the "100-year event") has a 26% chance of occurring within a 30-year period, and sea level rise further increases the chance over that 30-year period.

The exceedance probabilities that we discuss around the likelihood of a SLR scenario being exceeded are not related to an annual chance (*Table 1*); **it is simply the likelihood that in the future it will be exceeded.** The length of time over which you consider the possibility of that SLR scenario does not change the probability of exceedance**.** A 37% chance of being exceeded is always a 37% chance of being exceeded.

3. PLANNING CONSIDERATIONS

3.1 Stakeholder Engagement and Co-Production

There is no one-size-fits-all approach to building community resilience; yet stakeholder engagement and co-production of adaptation planning are critical to success. More accurate and sophisticated climate science does not directly translate into improved climate adaptation outcomes. High quality climate services and communication are needed to translate the science into adaptation capacity at all scales. Furthermore, top-down scientific assessments are not sufficient to fully assess vulnerabilities, understand uncertainties, or inform adaptation. Local knowledge and expertise are essential in this process.

Through co-production of adaptation plans and policies, local stakeholders and communities hold active decision-making power in preparing for and responding to sea level rise. The local scale is where climate change impacts are most acutely felt and where adaptation actions are needed to translate science and policy into action. Co-production of adaptation planning also allows for those with the deepest knowledge of place-based factors to inform adaptation choices. Place-based factors are critical in assessing risk tolerance and the full range of trade-offs associated with different adaptation approaches. A wealth of guidance documents, tools, and best practices are available to support impactful co-production and stakeholder engagement in the sea level rise planning process; see *Section 5* of this document for some examples.

3.2 Uncertainty in Rising Seas

When planning for SLR it is important to understand why there is not a single scenario for how much seas will rise. Uncertainty in how much seas will rise is driven by three general sources, and these are captured by the full set of five SLR scenarios from the 2022 Technical Report (*Figure 4*). They include:

1. **Process uncertainty** encompasses how well we currently understand why sea level has changed in the past and how it will change in the future at specific times and locations. ***Process uncertainty*** is captured in the shading above and below the median values for each individual scenario. The farther forward the sea level values are projected in time, the greater the uncertainty around each scenario.
2. **Emissions uncertainty** represents how human behavior will drive future global emissions of greenhouse gasses and ensuing warming. ***Emissions uncertainty*** is captured in the ranges between the Low, Intermediate-Low, and Intermediate scenarios. In other words, the differences in SLR between the Low, Intermediate-Low, and Intermediate scenarios are closely connected to emissions uncertainty and largely are reflected in the divergence of the scenarios after 2050 and out to 2100.

3. **Low confidence processes** encompass ongoing scientific discussion and exploration about the potential for **rapid ice melt** (e.g., marine ice cliff disintegration). If rapid ice melt occurs, it would span several decades with impacts taking even longer to be felt. Sometimes referred to as ***low confidence processes***, there is not currently scientific consensus on if or when these rapid ice melt processes could occur and, if they did occur, how rapidly they would raise sea levels. Given that rapid ice sheet melt may be possible and could result in a very large increase in sea level, these processes are integrated into international and federal SLR assessments. Within the 2022 Sea Level Rise Technical Report, the possibility of rapid ice sheet melt is considered in the Intermediate, Intermediate-High, and High 2022 SLR scenarios. All three of these SLR scenarios require high emissions (defined as Shared Socioeconomic Pathways [SSPs] SSP3-7.0 and SSP5-8.5 in the 2022 Sea Level Rise Technical Report), and each SLR scenario reflects different amounts of rapid ice melt. See *Box 2.1* from the 2022 Sea Level Rise Technical Report for more information on uncertainty in SLR and *Section 2.4* from the report for more information on how low confidence processes were represented in the scenarios.

Italicized phrases indicate phrases or words that have specific scientific definitions. These are defined within the text, but further explanation can be found in the 2022 Sea Level Rise Technical Report.

There are several strategies for addressing the uncertainty in how much seas will rise when planning. These are described in detail in *Section 4* of this report.

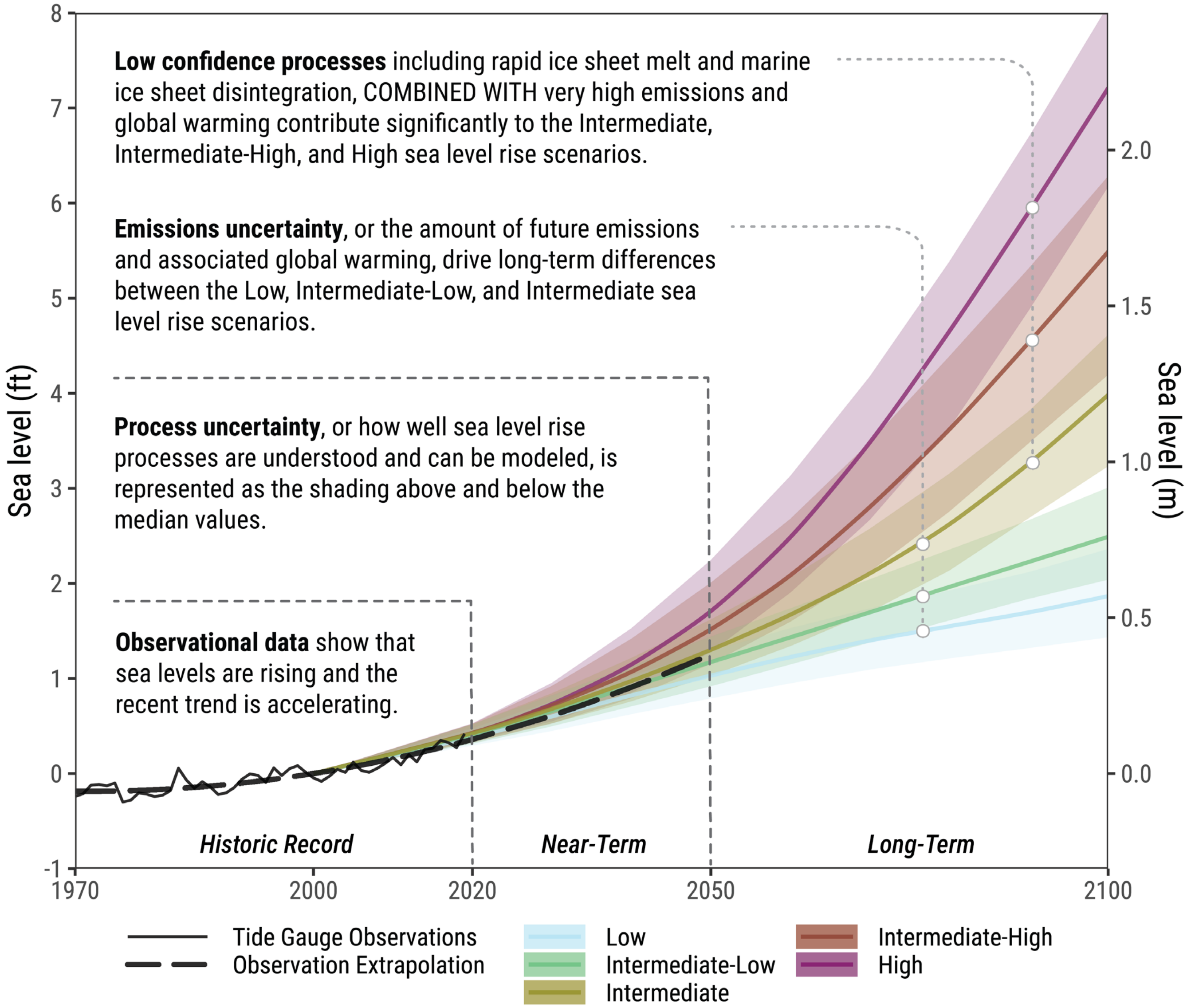


Figure 4. *Sea level rise scenarios for the contiguous United States relative to a year 2000 baseline. The ranges within and between the five scenarios represent different sources of uncertainty. Average annual tide-gauge observations and the observation-based extrapolation are overlaid for context.*

3.3 Using Observation-Based Extrapolations

The historic trends and observation-based extrapolations are useful for coastal professionals and decision makers for several reasons. The historic trends provide evidence of recent SLR—and of an acceleration in the rate of rise—to help ground discussions with stakeholders using tangible and observed measurements to which they can relate. The observation-based extrapolations provide insight about how observed sea level is tracking against the SLR scenarios and can be a useful comparison for assessing the likelihood of SLR scenarios and ranges out to 2050. For example, the observation-based extrapolation for the Northwest region tracks 6.3 inches (0.16 m) by 2050 (*Figure 5*). This falls between the Northwest region's Intermediate-Low scenario (5.9 inches; 0.15 m by 2050) and Intermediate scenario (7.1 inches; 0.18 m by 2050). If a planner or coastal professional is interested in understanding which SLR scenario the observations are tracking or a likely scenario for 2050, as a set the regional comparisons are among the best pieces of information available for doing that. Collectively the regional extrapolated observations for the U.S. show SLR tracking between the Intermediate-Low and Intermediate-High SLR scenarios in the near term. Regional and U.S. trends can be found in the 2022 Sea Level Rise Technical Report and the associated online portals and data sources. *NASA's Interagency Sea Level Rise Scenario Tool* also includes tide-gauge-specific extrapolations for locations that have at least 30 years of observations and meet other quality criteria. See *Section 5* of this report for a list of resources.

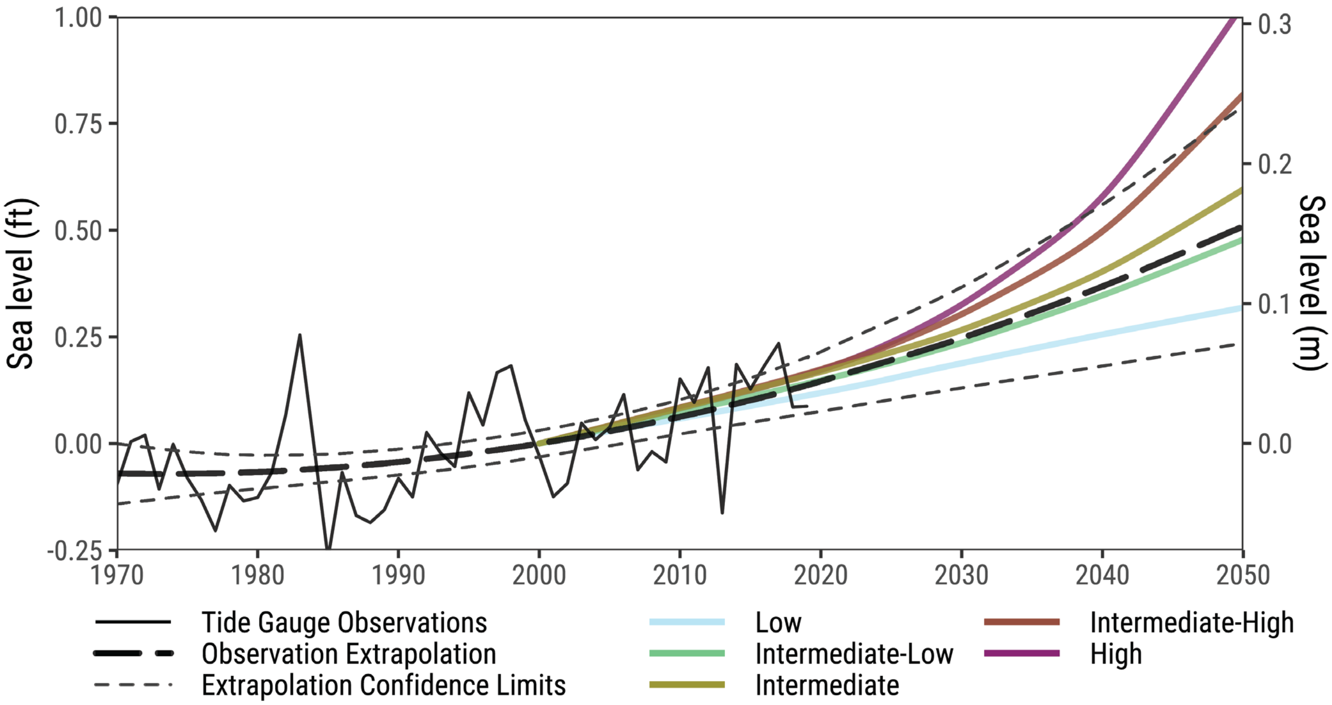


Figure 5. *Regional sea level rise scenarios and the observation-based extrapolation for the Northwest Region (Washington and Northern Oregon). Average annual water levels from tide gauges throughout the region show the variability due to cyclical ocean dynamics (i.e., ENSO) and are overlaid for context. This variability was removed prior to generating the observation-based extrapolation.*

However, it is important to note that some regional or tide-gauge-specific observation-based extrapolations may not align with SLR scenarios. This can be a reflection of a local land movement or sea level process not captured in the SLR models. For example, in American Samoa there is ongoing vertical land movement due to an earthquake in 2009. The tectonic response to the earthquake (i.e., an increase in the rate of subsidence) is not captured in the local SLR scenarios, so the observation-based extrapolations are higher than the local SLR scenarios (*Figure 6*). Knowing this allows planners in American Samoa to consider the extrapolation-based observations in the near term or consider using the tectonic movements to adjust the SLR scenarios. Understanding why there are misalignments in some regions and local areas is both the focus of future research and should also be considered during local and regional planning. See the callout box below for an example of how to consider observation-based extrapolations in a broader suite of SLR scenarios in cases where there is no alignment due to processes other than vertical land movement.

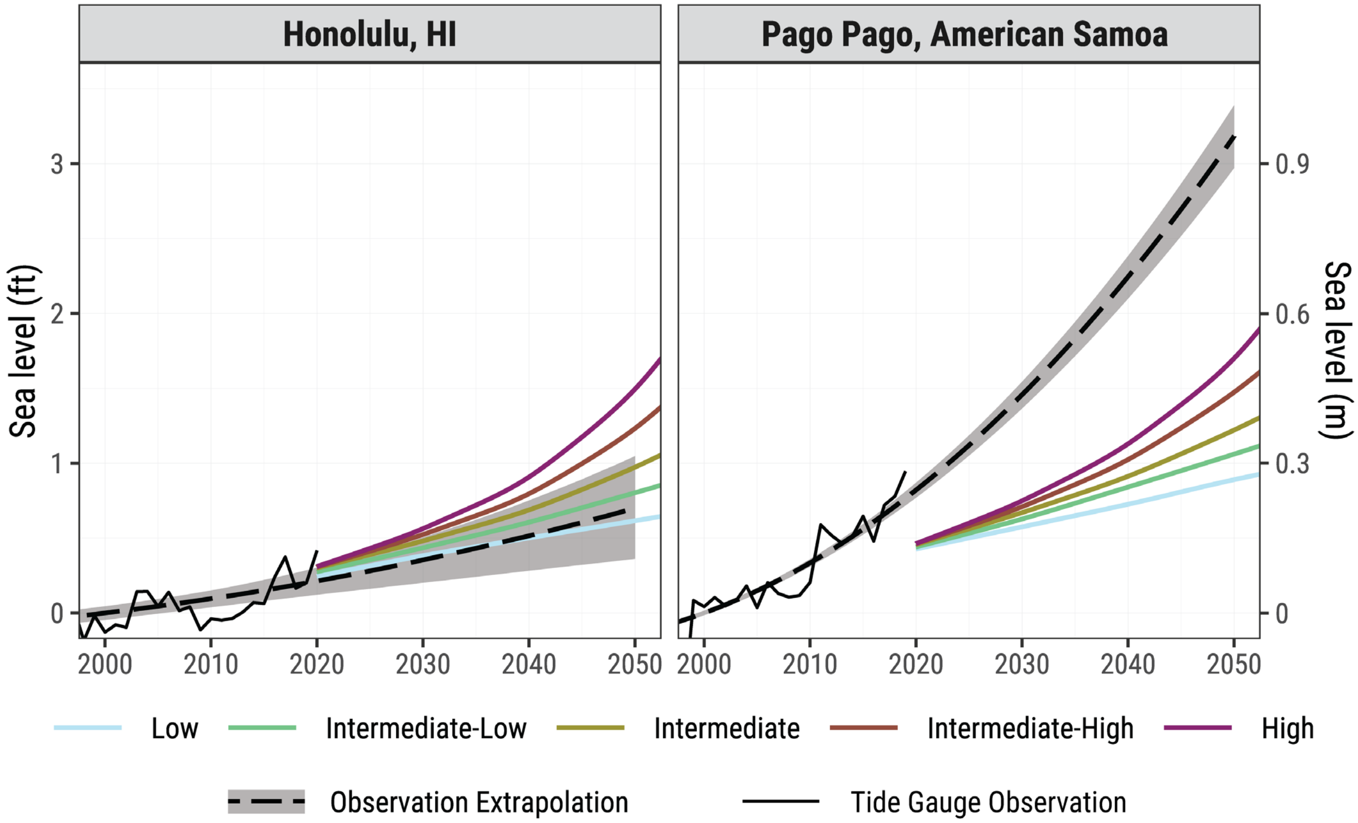


Figure 6. *The tide-gauge observations, observation-based extrapolations, and local sea level rise scenarios for Honolulu, Hawai'i, and Pago Pago, American Samoa. The observation extrapolation shows the median (black dashed line) and the 17th and 83rd percentile confidence interval (gray shading). The Honolulu extrapolation falls between the Low and Intermediate-Low scenarios in 2050. The Pago Pago extrapolation is higher than all scenarios because of rapid subsidence since the 2009 earthquake, as seen in the tide-gauge observation (thin black line).*

Understanding the Eastern Gulf of Mexico Region Observation-Based Extrapolations

The regional observation-based extrapolations in the Gulf of Mexico are trending higher than other regions. In the Eastern Gulf, particularly across coastal Mississippi, Alabama, and Northwest Florida, the observed increase in acceleration is consistent for most tide gauges and is also observed in the historic satellite altimetry data. This means that the trend in acceleration is not being driven by land movement (e.g., subsidence), but is coming from ocean dynamics (i.e., how the ocean moves and heats). A consequence of this phenomenon is that observation-based extrapolations for many tide gauges in the Eastern Gulf are trending above the SLR scenarios in the near term (out to 2050).

What scientists are unsure of, and why the scenarios are different from the observation-based extrapolations, is if the observed acceleration in SLR will be sustained out to 2050 and beyond, or if the rate of acceleration may slow down in the mid-term (next 15 to 30 years). It could be that the observations are currently trending higher due to a temporary upswing in a cyclical process that is not yet well understood, or it could be that there are climate change-related processes that will continue this rate of acceleration into the long term.

Either way, *it must be acknowledged that SLR rates in the northeastern Gulf of Mexico have been rising quickly. Scientists are not sure exactly why, but it is likely to continue in the near term*. Therefore, the observation-based extrapolations should be considered during near-term planning in this sub-region. For long-term planning, observation-based extrapolations are not relevant because they only provide an estimated SLR trajectory out to 2050.

Over time, with additional observing data and research of climatic processes, it will become clearer where we are headed. In the meantime, we have sufficient information to make informed decisions to increase our resilience to future flooding.

3.4 Using Extreme Water Levels

The extreme water level analyses from the 2022 Sea Level Rise Technical Report can be used to examine how the frequency of water levels exceeding different flood thresholds is expected to increase as seas rise (*Figure 7*). The 2022 Sea Level Rise Technical Report defined specific water level thresholds that reflect

- Critical frequencies (e.g., the water level that has an average recurrence interval of 10 years, also referred to as a 10% annual chance event) or
- Impacts (e.g., minor, moderate, or major flooding).

Because SLR will increase the frequency of flood events, the extreme water level analyses can be used in conjunction with the 2022 SLR scenarios to determine when flood regime shifts will occur (e.g., when today's *moderate* flood will occur as frequently as today's *minor* flood).

This information provides contextualized understanding of how SLR will change the frequency of these extreme water levels and the time frame in which they may occur, enabling coastal professionals and decision makers to assess priorities for action and the timeline for accomplishing those actions.

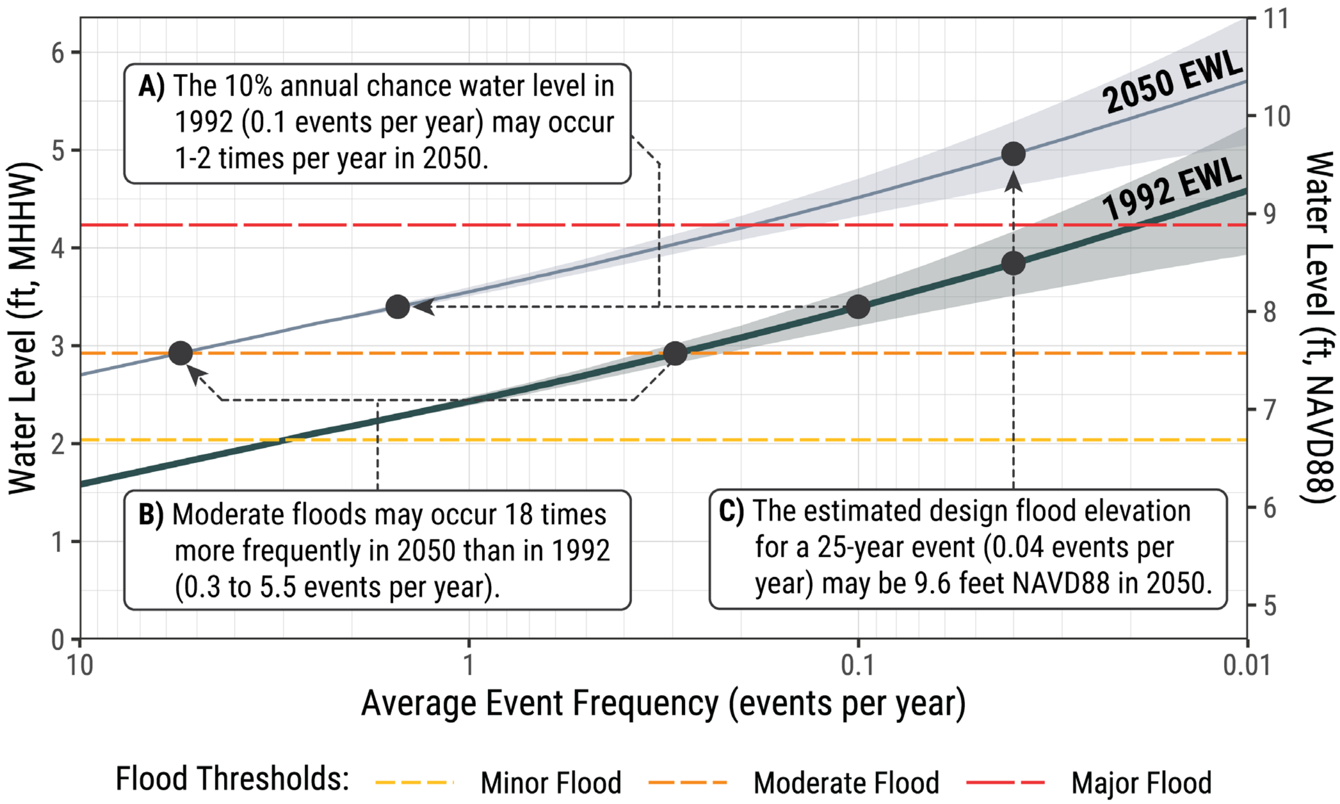


Figure 7. *Change in frequency and magnitude of extreme coastal water level events in Portland, Maine, as sea level rises based on the supplementary extreme water level tables from the 2022 Technical Report. The lower curve represents extreme water levels (EWL) with average event frequencies ranging from 10 events per year to 0.01 events per year (the "100-year event") calibrated to the year 1992. Frequent events have lower magnitude water levels and vice versa. The upper curve represents the extreme water levels for the year 2050 using data from the Intermediate SLR scenario (approximately 1 foot). The Intermediate SLR scenario was selected because it is the upper bound for the observation-based extrapolation at this location. Local statistically derived flood thresholds are overlaid for context. Three annotations show* **A)** *the 10% annual chance event in 1992 shifts to an event that may occur at least once a year in 2050,* **B)** *the Moderate flood threshold may be exceeded 18 times more frequently in 2050 than in 1992 (which is more frequent than a Minor flood in 1992), and* **C)** *the design flood elevation for a 25-year event may increase from 8.5 to 9.6 feet NAVD88 between 1992 and 2050.*

For communities that do not already have flood thresholds related to flooding impacts, or if the NOAA thresholds don't adequately represent the local flood risk, they can determine their own critical thresholds of flood frequencies and heights. For example, the City of Imperial Beach, California, partnered with Scripps Institution of Oceanography to *develop minor and moderate flood thresholds* based on water level observations. Once thresholds have been established, communities can use the extreme water level data to assess how frequently those thresholds may be met or exceeded as seas rise.

For more information on establishing critical flood thresholds, understanding the additive impacts from SLR, and utilizing these thresholds in coastal decision-making, view the *NOAA Stormwater Tool*, which has been updated to include the 2022 SLR scenarios. Through application of the "Assess" section of the tool, users can produce a "Quick Flood Assessment Report" that includes

- A user-defined coastal flood threshold,
- An estimate of how often the flood threshold level will be experienced,
- The effects of future SLR on the user's threshold,
- The number of high-tide flooding days and how it might change in the future, and
- How often significant flood events might occur in the future.

For more examples of how the extreme water level information can be used and to access the current available analyses, see *Sections 3* and *4* of the 2022 Sea Level Rise Technical Report.

3.5 How to Apply Sea Level Rise Scenarios at Different Spatial Scales

To support planning, policy, and decision-making at multiple spatial scales, the 2022 Sea Level Rise Technical Report provides SLR scenarios at different geographic scales. Variations in ocean and earth surface processes (e.g., uneven heating, changes in ocean currents, and vertical land motion) cause the rate and magnitude of SLR to be location-specific, often referred to as relative SLR. For example, under an Intermediate-High scenario, the Western Gulf Coast is expected to see an increase of 2.1 ft (0.6 m) by 2050 relative to a year 2000 baseline, but Southern California is projected to see an increase of 1.0 ft (0.3 m). In the 2022 Sea Level Rise Technical Report, the provided geographic scales are

- Global (i.e., a global average sea level change),
- National (i.e., averaged for the shorelines of the contiguous United States),
- Regional for eight regions in the United States, and
- Local for tide stations and grid stations distributed along the shorelines of the U.S.

Grid stations are theoretical stations that are located at the center of 1 degree latitude by 1 degree longitude cells and cover the entire U.S. coastline (*Figures 8* and *9*). Using this gridded approach allows the generation of SLR scenarios for locations that do not have a nearby tide station. While tide station scenarios can be appropriately applied at the city level for the city in which they are located, grid stations should be used beyond the local vicinity of tide gauges (i.e., county scale or larger).

Projections for each grid station can be accessed through the CSV file located on the *Technical Report Data and Tools* web page, NOAA's *API URL Builder*, and NASA's *Interagency Sea Level Rise Scenario Tool*. See *Section 3.8* of this Application Guide for additional information on accessing the 2022 Sea Level Rise Technical Report data.

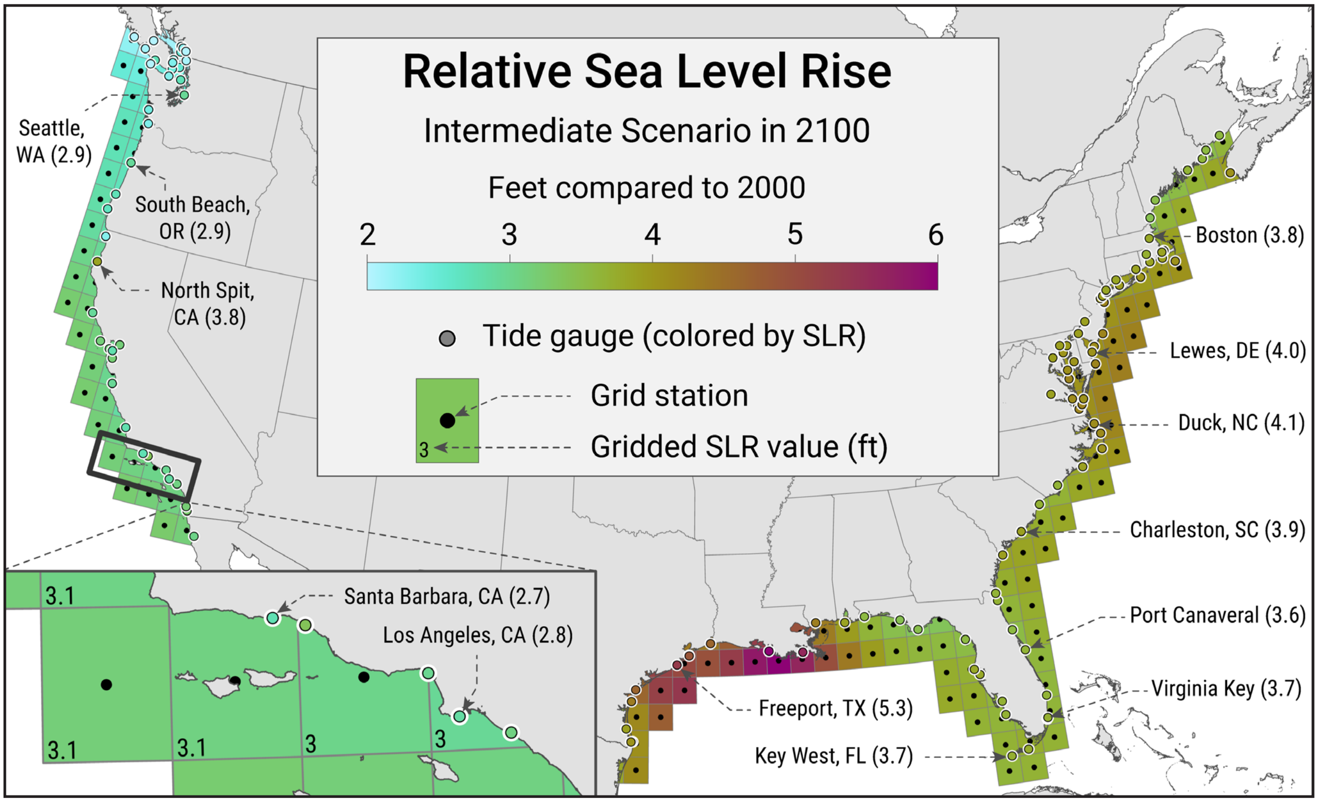


Figure 8. *Gridded median projections of sea level change estimates in 2100 for the Intermediate SLR scenario with tide gauges overlaid. The inset highlights the Channel Islands, California, sub-region and illustrates the continuous coverage provided by the gridded data to fill gaps between tide gauges.*

SLR vulnerability assessments and planning are typically conducted at a regional or local scale. Therefore, it is generally recommended to use the local or regional SLR scenarios because these capture important processes that can influence SLR at that specific location. For example, in Florida, the current recommendation from the state's *Department of Environmental Protection* is that communities use the SLR scenarios for local tide gauges when planning. In locations where tide gauges are more limited or when planning extends across a range of tide gauges, using regional scenarios may be appropriate. The Maine Climate Council's *Scientific and Technical Subcommittee* assessed a suite of scenarios averaged across multiple tide gauges to generate a single set of SLR projections that are applicable statewide. This regionalization approach is useful when the variability among gauges is low and states or regional entities need to issue guidance that is broadly applicable. Regional scenarios can also provide a point of comparison when there is a high level of uncertainty at a particular grid or gauge, such as Philadelphia's Pier 9N tide gauge.

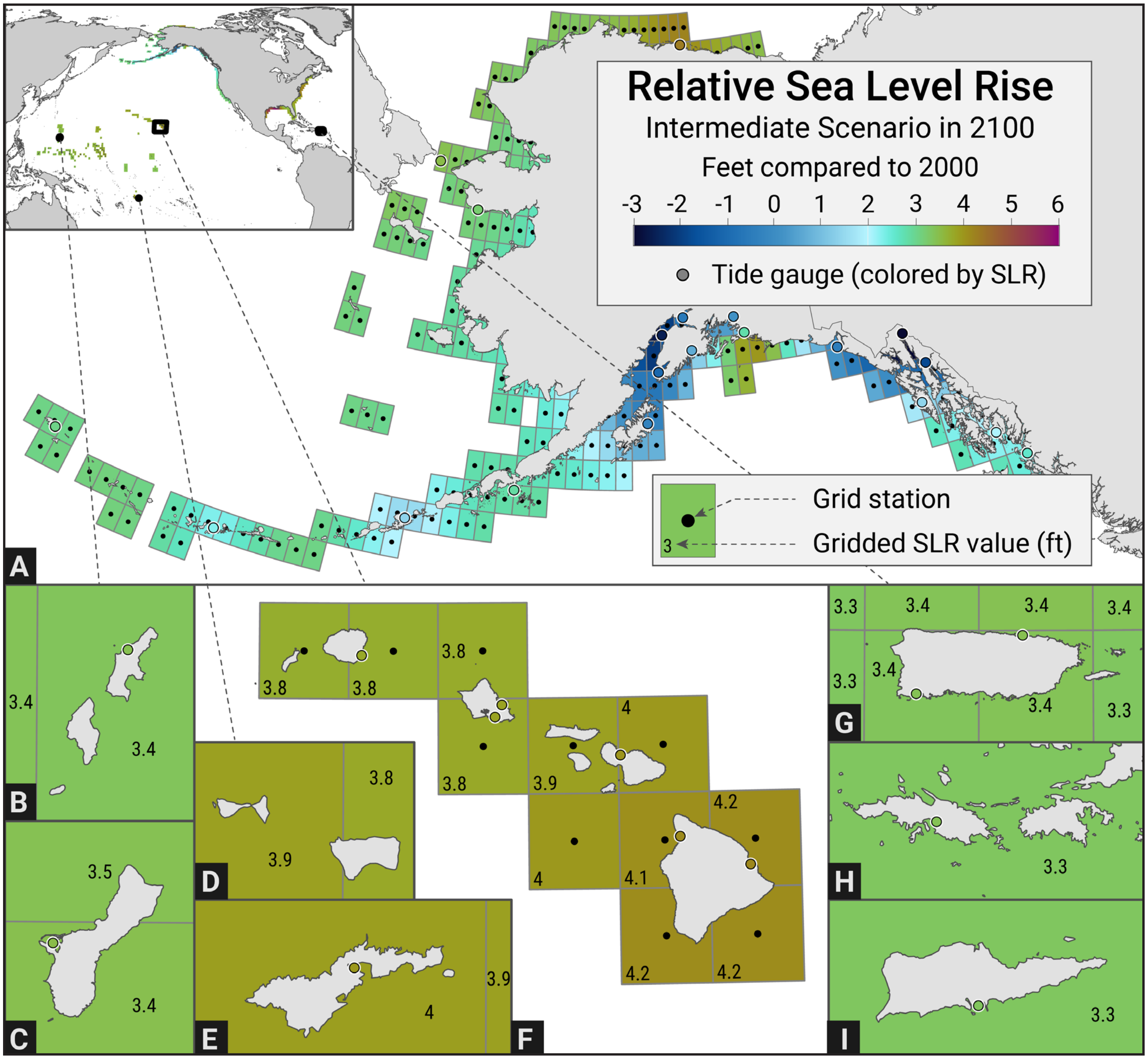


Figure 9. *Gridded median projections of sea level change estimates in 2100 for the Intermediate SLR scenario with tide gauges overlaid. Panel includes data for A) Alaska, B) Saipan and Tinian in the Commonwealth of the Northern Mariana Islands, C) Guam, D) the Manua Islands in American Samoa, E) Tutuila in American Samoa, F) Hawai'i, G) Puerto Rico, H) St. Thomas and St. John in the U.S. Virgin Islands, and I) St. Croix in the U.S. Virgin Islands.*

3.6 Considering 2022 Scenarios When Other Sea Level Rise Scenarios Are Already in Use

For coastal planners and decision makers that have already started SLR planning using the 2017 SLR scenarios (Sweet et al. 2017) or other older scenarios, there are several ways to consider the 2022 SLR scenarios.

Some key changes to keep in mind that may be relevant to current planning (*Figure 10*):

- There is no longer an Extreme scenario. This was removed based on advancements in science that indicated reaching an average global SLR of 8.2 ft (2.5 m) by 2100 had a very low probability of occurring. Global average sea level could still reach or exceed this threshold after 2100 (e.g., Intermediate-High and High scenarios in 2150).
- While the 2017 and 2022 SLR scenarios reach the same global mean sea level values by 2100, the 2022 SLR scenario pathways reflect slower acceleration of SLR in the near term, but a greater acceleration in rates of SLR after 2050. See *Section 2.2.3* in the 2022 Sea Level Rise Technical Report for details on the science advancements that led to these pathways.
- 2022 SLR scenarios out to 2050 reflect greater scientific alignment and certainty and this narrowed the SLR scenario ranges for this time period.
- Local and regional-level SLR scenarios were also updated. Compared to the 2017 SLR scenarios, the 2022 scenarios are generally higher for the Low and Intermediate-Low scenarios and lower for the Intermediate through High scenarios in 2100.

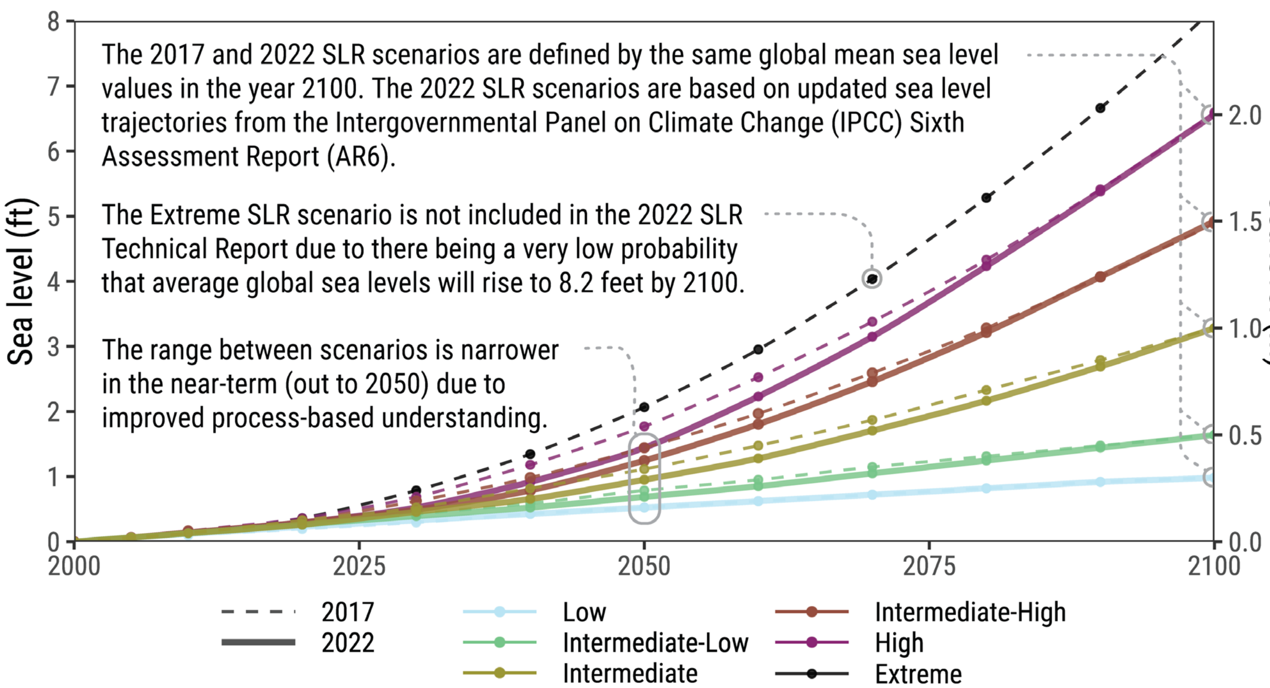


Figure 10. *Global mean sea level rise scenarios from the 2017 to the 2022 Sea Level Rise Technical Reports referenced to a year 2000 baseline. Updates include the removal of the Extreme scenario and a narrower range among scenarios over the next few decades.*

Integration of the updated scenarios depends on stage and type of planning, along with aspects such as available resources, planning time frame, data needs, and political will. If a project or planning effort is already underway, the difference between the 2017 and the 2022 SLR scenarios should be considered, but the decision whether to change specific numbers in use will be determined by the project. For new projects and projects in the early planning stages, the 2022 SLR scenarios are the most appropriate to apply as they reflect the latest science.

3.7 Understanding Datums, Baselines, and Epochs

Applying SLR projections to real-world projects requires an understanding of the relationships between various elevation references, or vertical datums, and the points in time that they represent. Ensuring that SLR data and local vertical datums are comparable is an important practical aspect of SLR planning. Tidal datums are referenced to specific periods of time known as epochs. SLR projections are initiated from a starting year, often referred to as a baseline year. When applying SLR scenarios to local land elevations or comparing them to local tidal datums, it is important that the SLR scenario baseline and the midpoint of the tidal datum epoch are aligned. This section will explore a few important concepts related to datums and baselines. NOAA's National Geodetic Survey (NGS) provides more information on *geodetic datums*, and NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) provides more information on *tidal datums*.

Water levels or depths are most often referenced to tidal datums that are location-specific and are based on local tidal dynamics. National tidal datums as defined by NOAA, such as mean sea level (MSL), are generally calculated at individual tide gauges by averaging water level measurements over a 19-year period, or epoch, to account for long-term variations in the moon's orbit and associated tide ranges (NOAA offers more information on the *National Tidal Datum Epoch*, or NTDE, and the significance of the 18.6 year astronomical cycle). MSL tidal datum values for the current NTDE, for example, represent the average of hourly water level heights measured over the 19-year period from 1983 to 2001 (or a Modified 5-Year Epoch in regions with anomalous sea level changes, such as those resulting from rapid or episodic vertical land motion), and therefore represent average sea level heights for this time period. Tidal datum epochs are updated at regular intervals to account for sea level change. The NTDE 83-01 epoch has a midpoint of 1992, which can be considered the baseline year for the NTDE 83-01 tidal datum. Other commonly used vertical datums include Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW), which represent the average of the higher high (or lower low) water height of each tide observed during the epoch.

Elevations on land are most often referenced to geodetic or orthometric datums, which are nationally consistent reference systems that are based on benchmarks. The North American Vertical Datum of 1988 (NAVD88) is an orthometric datum that is primarily used as a land-based reference for measuring elevations (e.g., base flood elevation, road elevation, bridge deck height). Tools such as *VDatum* provide methods for transforming between different tidal, orthometric, and other datums. Local vertical control datums are also developed by municipalities and others for specific engineering, planning, and design applications, and these require yet another transformation when aligning with national tidal and orthometric datums. Local experts can often provide technical assistance to further refine datum transformations to make sure that everything is comparable and using the same frame of reference. It is important to note that the datums discussed here are official national datums and are updated over time. Both the current National Tidal Datum Epoch (1983-2001) and the North American Vertical Datum of 1988 are in the process of being updated and will be superseded by new datums in the near future (by 2025).

In order to understand how future water levels will relate to existing tidal datums, it is necessary to align the SLR scenario(s) and the datum of interest (e.g., MSL, MHHW) to the same baseline year. It is not sufficient to simply overlay a 2022 SLR scenario on an existing tidal record because they often use different baseline years. This type of temporal baseline adjustment typically involves applying a vertical offset that corresponds to the amount of sea level change observed between the different baseline years. Different approaches can be used to align baseline years depending on the datum(s) of interest. Aligning baseline years of existing tidal datums with the 2022 SLR scenarios can be done by shifting the tidal datum baselines to match the SLR baseline year (e.g., 1992 to 2000), or by shifting the SLR baseline year to match the tidal datum baseline year (e.g., 2000 to 1992). There are different ways this can be achieved using existing data. The 2022 Sea Level Rise Technical Report provides regional vertical offsets for the periods 1992-2000, 2000-2005, and 2005-2020. These offsets were generated from the regional-scale observation-based extrapolations and capture recent non-linear SLR. Time-series data of average annual water levels were developed to support the observation-based extrapolation analysis for the 2022 Sea Level Rise Technical Report and can be used to adjust the SLR scenarios or tidal datums to other baseline years. These time-series data are accessible via the *NASA Interagency Sea Level Rise Scenario Tool*. For more detailed information and methodological choices, data sources, and an example for Washington, DC, see *Appendix A*.

When translating current and future water levels to equivalent land-based elevations (NAVD88), it is necessary to use an appropriate local transformation because the relationships between tidal datums and NAVD88 vary spatially. The relationship between tidal datums and NAVD88 is most accurately defined at individual tide stations. Therefore, when determining the land-based elevations of future water levels it is necessary to 1) align the SLR and tidal datum baseline years, and 2) ensure that the tidal datum-to-NAVD88 relationship is maintained or adjusted depending on the direction that the baseline year is shifted. In practice, this usually means that SLR scenarios are adjusted to the midpoint of the tidal datum epoch for a given tide station (1992 in most cases) in order to use the published relationship between a given tidal datum and NAVD88.

The 2022 SLR scenarios were developed with a starting year of 2005. The 2022 Sea Level Rise Technical Report presents the 2022 SLR scenarios with the baseline year adjusted to 2000 for consistency with the 2017 SLR scenarios, which were provided in all locations with a baseline year of 2000. However, the data associated with the 2022 Sea Level Rise Technical Report are available from various sources and the baseline years vary from source to source (2000 or 2005). So, if the 2022 scenarios are being compared to the 2017 scenarios, it is important to be sure that they are using the same baseline year. Offset values are provided in the 2022 Sea Level Rise Technical Report to adjust the baseline year of the 2022 SLR scenario data from 2005 to 2000. The offsets for this 5-year period range from 0.4 to 1.6 inches, and the average value for the contiguous U.S. is 1.2 inches.

When using different SLR tools, check which baseline(s) are being used; tools that compare across tidal and land-based datums will continue to use the 1992 baseline until the National Tidal Datum Epoch is updated.

3.8 Accessing the 2022 Sea Level Rise Technical Report Data

The 2022 SLR scenarios presented in the 2022 Sea Level Rise Technical Report can be downloaded from three primary locations:

1. The *NOAA 2022 Sea Level Rise Technical Report Data and Tools* website provides access to SLR and extreme water level data in comma separated value (CSV) files. The SLR data represent projected changes in sea level from a baseline year of 2005. The CSV file for the SLR data includes regional offset values to adjust the baseline year to 1992 or 2000.
2. The *NOAA CO-OPS API URL Builder* provides access to SLR scenario data from the 2017 and 2022 reports in JSON and XML formats. The 2017 SLR data are served with a baseline year of 2000, while the 2022 data are served with a baseline year of 2005. The API allows users to specify units (inches or centimeters) and filter for specific scenarios and projection years.
3. The *NASA Interagency Sea Level Rise Scenario Tool* provides the SLR scenarios and observation-based extrapolation data discussed in the 2022 Sea Level Rise Technical Report. These data are available for download in Microsoft Excel (XLSX) and NetCDF formats and are provided with a year-2000 baseline. The adjustment of the SLR data from 2005 to 2000 was performed using the observation-based extrapolation data.

4. APPROACHES FOR INTEGRATING THE 2022 SEA LEVEL RISE SCENARIOS INTO PLANNING

When planning for SLR, there is no “wrong” answer to how much SLR to plan for. Like all planning decisions, preparing for SLR involves using the best available information to anticipate potential impacts for a specific set of planning and decision-making goals. The 2022 Sea Level Rise Technical Report provides multiple lines of evidence based on improved science to help guide planning for future SLR and addressing uncertainty by distinguishing between two planning time horizons: 1) near-term (present to 2050) and 2) long-term (2050 to 2150).

For the near term, the narrow range of SLR scenarios in the 2022 Sea Level Rise Technical Report emphasizes greater certainty in the amount of SLR to expect through 2050. This can assist coastal decision makers and professionals by providing greater confidence for making decisions or investments regarding assets and resources needed to address SLR that will occur in the next 30 years. For long-term planning, the 2022 Sea Level Rise Technical Report synthesizes current scientific consensus around future long-term (2050 to 2150) SLR across a range of potential processes, emissions, and warming.

This section

- Discusses a preliminary step of evaluating sea level rise exposure and vulnerability to determine what is at risk; and
- Provides an overview of commonly used approaches for SLR planning in the face of uncertainty—Risk Tolerance, Scenario Planning, and Adaptation Pathways approaches—
  - By providing methods for integrating the data from the 2022 Sea Level Rise Technical Report into each of these planning approaches; and
  - By including references along with actual and theoretical examples of applying SLR science for each of these planning approaches.

This section is not meant to be an exhaustive list of all approaches; it is meant to identify broader conceptual approaches, and we acknowledge that in practice the use of these concepts will be adapted to meet the unique needs and capacity of each community. Furthermore, terminology associated with these concepts can vary. Terms and phrases are defined for clarity. These approaches are also not mutually exclusive and are often combined to address SLR—there is no one-size-fits-all approach.

4.1 Evaluating Sea Level Rise Exposure and Vulnerability

The first step for community planners and decision makers when considering SLR is to understand what assets, services, and culturally and ecologically significant areas in the region will potentially be exposed to SLR-related impacts over relevant time frames. As part of the process, communities evaluate what local areas and assets are likely to be exposed to flooding and permanent inundation across a spectrum of possible SLR scenarios. Evaluating exposure can also include an assessment of related coastal hazards that are intensified by rising sea levels, such as coastal erosion and elevated groundwater. Depending on the location, even slight increases in sea level can amplify flooding extent and magnitude during periods of high tides, storm surge, large wave events, or elevated groundwater levels. These hazards can also be amplified by heavy rainfall or higher sea levels, reducing the on-land drainage capacity.

Exposure information can then be used to assess the vulnerability of specific infrastructure, natural and cultural resources, people, or services. The International Panel on Climate Change (IPCC) (2012) defined vulnerability as a function of the exposure of a particular system to climatic changes (e.g., SLR), its sensitivity to specific hazards, and its capacity to adapt to those changes (also referred to as adaptive capacity). In some situations, a community or agency may choose to assess vulnerability across the full range of Low to High SLR scenarios for specific future planning horizons (e.g., 2050, 2075, 2100) to gain a broad understanding of potential risks. Other entities choose to narrow the range of SLR scenarios for consistency across multiple vulnerability assessments or to reduce computational expense. For example, in 2022 the State of Florida Resilient Coastlines Program required that any community vulnerability assessments they funded use the local 2017 Sea Level Rise Technical Report Intermediate-Low and Intermediate-High SLR scenarios. The outcome of a vulnerability assessment is often a list of those assets or services that are most likely to be negatively impacted as sea level rises, which can then be used to aid and inform sea level rise planning, including the selection or prioritization of adaptation projects or strategies.

4.2 Sea Level Rise Planning Using a Risk Tolerance Approach

When planning for SLR, one common approach is to determine what level of risk tolerance is acceptable and then use this filter to narrow the range of SLR scenarios included in planning. Risk tolerance is subjective and is unique to the community and the infrastructure, project, or landscape being considered. However, there are common considerations for setting risk tolerance that fosters objectivity. These include understanding how critical the location or asset is to the community, the cost of damage, sociocultural value, how easily it can be adapted to accommodate SLR (adaptive capacity), and its life expectancy. For example, a coastal wastewater treatment facility deemed critical to the community for the next 50-60 years, and difficult to adapt or relocate, would likely be assigned a low risk tolerance. In this type of situation where risk tolerance is low, a community will often focus on the Intermediate-High or High SLR scenarios. Although these scenarios have a lower probability of occurring than the Low or Intermediate-Low scenarios, they could happen, and would have severe impacts if they did. Conversely, if a project is categorized as having a high risk tolerance (e.g., doesn’t have a long life span, is easier to move or adapt, or has a relatively low value to the community), a community may instead look at applying the SLR scenarios most likely to occur (Low to Intermediate).

Risk tolerance should be based on socioeconomic and cultural values and be developed with local community stakeholders to understand place-based significance and sensitivities regarding these assets and their tolerance for SLR impacts. Characterizing risk tolerance for a specific project with stakeholders fosters increased buy-in and understanding of the process, and improved agreement with the amount of SLR that was chosen. Stakeholder engagement also contributes critical local knowledge to more accurately and fully assess risk tolerance.

A risk-tolerance approach can be useful for narrowing the range of SLR scenarios used for adaptation planning in situations where the landscape is less dynamic and does not change frequently (e.g., upland areas). Conversely, a risk-tolerance approach is not well-suited for coastal landscapes with a high propensity for shoreline change (e.g., barrier islands) because the landscape is likely to undergo frequent and substantial changes, making it extremely difficult to anticipate conditions in the mid- and long-term future. Risk-tolerance planning is also not compatible with some aspects of coastal restoration. For example, planning the height of a restored marsh platform requires it be built within the existing tidal range, not where the tidal range will be in the future. Finally, risk-tolerance planning can potentially lead to over-investment or over-design; therefore, it is essential that communities also consider technology innovations, energy-climate policies, and social priorities and how these may shift in 30-50 years, affecting the life expectancy or value of certain community spaces or infrastructure.

2022 Sea Level Rise Technical Report Considerations for Risk-Tolerance Planning

For near-term planning, the narrow range of SLR scenarios out to 2050 coupled with the regional observation-based extrapolations provide a valuable guide about likely SLR out to 2050. For example, in the Southwest region, the observation-based extrapolations are closely tracking the Intermediate SLR scenario (*Figure 11*). In this case, planners working on a project with a high tolerance for risk may want to focus on the Intermediate SLR scenario because even if SLR exceeded the Intermediate SLR scenario, the impacts to that asset would be relatively minor. However, planners working on a project with a low risk tolerance may want to focus on the Intermediate-High or High SLR scenarios that, while still possible, are less likely to be exceeded. It is also important to keep in mind that due to the overall smaller range in scenarios in the near term, the difference between the Intermediate-High and High scenarios is fairly modest (less than three inches).

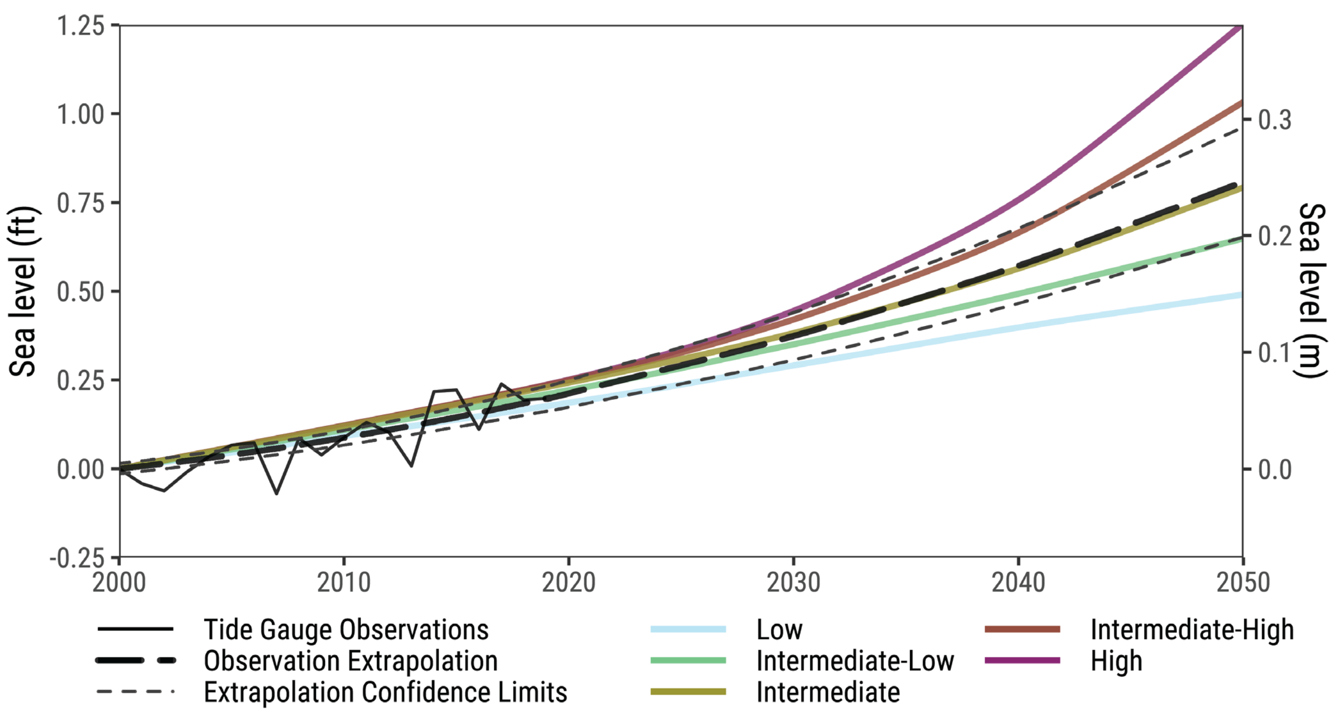


Figure 11. *Regional sea level rise scenarios and the observation-based extrapolation for the Southwest Region (California and Southern Oregon). Average annual water levels from tide gauges throughout the region are overlaid for context.*

After 2050, there are greater uncertainties and different processes driving the range of SLR scenarios; therefore, other mechanisms are required to assess the likelihood of exceeding a specific SLR scenario. The 2022 Sea Level Rise Technical Report assesses the likelihood of SLR scenarios being exceeded depending on different temperatures and related emissions scenarios. From these assessments, two concepts are clear: the greater the warming, the more likely SLR will be higher; and the lower SLR scenarios are very likely to be exceeded and the higher scenarios are very unlikely to be exceeded. When using the risk-tolerance approach for longer-term planning, likelihoods of scenarios being exceeded can be assessed using *Table 1*, instead of the observation-based extrapolations. For example, when planning a project with a long life span (beyond 2050) with a low tolerance for risk, choosing the higher SLR scenarios that are less likely to be exceeded, would result in greater risk avoidance.

Table 1. *This table shows the probability, or likelihood, of exceeding the associated global SLR scenario by 2100 under a range of different temperature and related emissions scenarios (emissions scenarios are represented through Shared Socioeconomic Pathways [SSPs]). For the low confidence processes (last row) a single temperature is not listed because the exceedance probabilities were based on a framework of high emissions, high warming, and the occurrence of low confidence processes. The greater the warming, the more likely SLR will be higher, and overall, lower scenarios are more likely to be exceeded and higher scenarios are very unlikely to be exceeded.*

Increase in Average Global Air Temperature in 2100	Closest Emissions Scenario	Likelihood of Exceeding a SLR Scenario				
		Low	Intermediate-Low	Intermediate	Intermediate-High	High
2.7°F (1.5°C)	Low Emissions (SSP 1-2.6)	92%	37%	<1%	<1%	<1%
5.4°F (3.0°C)	Intermediate to High Emissions (SSP 2-4.5 – SSP 3-7.0)	>99%	82%	5%	<1%	<1%
9.0°F (5.0°C)	Very High Emissions (SSP 5-8.5)	>99%	>99%	23%	2%	<1%
*	Very High Emissions (SSP 5-8.5) with Low Confidence Processes	>99%	96%	49%	20%	8%

* Single temperature not listed because the exceedance probabilities were based on a framework of high emissions, high warming, and the occurrence of low confidence processes.

Examples of the Risk-Tolerance Approach in Application

The Jackson County Utility Authority (JCUA) in Mississippi was considering consolidating three wastewater treatment facilities into one. This facility would open in 2030 and be operational for 50 years. JCUA determined this project had a low tolerance for risk because of its low adaptive capacity, the expense to build it, and the fact that it provided a critical public health and environmental function to many community members. Given these considerations, the utility opted to design a flood protection berm that would account for the 0.2% annual chance flood event under the High SLR scenario for the county in the year 2080 (accounting for the treatment plant's full life expectancy).

JCUA also used the risk-tolerance approach to prioritize where to focus its near-term efforts for transitioning parcels with septic tanks to centralized wastewater. In planning for the transitioning of septic tanks, there was a high risk tolerance because all septic tanks were intended to be transferred (eventually) to centralized wastewater. Therefore, JCUA decided to use the Intermediate-Low SLR scenario, which was very likely to occur and even be exceeded. This type of approach helped prioritize the septic to centralized wastewater in parcels most likely to be affected so they could be addressed first. From there, the utility examined where future high tide and the 1% annual chance flood event (with SLR) would directly begin to impact additional septic tanks. Note: this was before the observation-based extrapolation data were available.

4.3 Sea Level Rise Planning Using a Scenario-Based Approach

Another approach to planning for changes in sea level is scenario-based planning. In this approach, a planning team examines a range of "future scenarios" that represent future conditions inclusive of both human and environmental changes (e.g., land use changes, rising seas, precipitation changes). In this approach, multiple potential mitigation or adaptation strategies are evaluated under different future scenarios to determine which strategies best meet the desired outcomes. This may mean that a community does not pick an action that is the best under any one future scenario, but that could be somewhat effective under multiple scenarios (*Figure 12*).

Figure 12. *Conceptualization of scenario planning. Scenarios refer to various climate scenarios (e.g., high sea-level rise and low land-use change vs. low sea-level rise and low land-use change). Management strategies are different approaches for achieving a specific planning goal. The colors designate how well a management strategy meets a desired outcome (***red =** *does not meet outcome,* **yellow =** *moderately meets the desired outcome,* **green =** *meets the desired outcome well). In this conceptualization, Management Strategy 2 would likely be the best investment (indicated by the dashed outline) because while it is not the best (green) under all scenarios, it supports the desired outcome to some level under all future conditions explored.*

Scenario planning provides opportunities for integrating stakeholders into the planning process, and may include characterizing the different future scenarios to explore, identifying which mitigation or adaptation strategies to evaluate, or defining measures of success by which to evaluate the mitigation or adaptation strategies. Integrating stakeholders in scenario-planning processes provides additional opportunities for equitable SLR resilience.

Scenario planning can be useful for complex coastal landscapes and management regimes where multifaceted, interacting processes make it difficult to determine how a landscape will respond over time. It is also useful when there are multiple natural resource and management responses that can have significant benefits or impacts to the landscape's ability to adapt, recover, or transition over time. However, scenario planning can be time consuming and often requires additional research or modeling work. This may not be a good approach for projects where it is known that a mitigation or adaptation strategy must function in a worst or near-worst case scenario. It would also not be the best option for simple efforts with only one stressor or outcome of interest, or in situations where decisions need to be made quickly.

2022 Sea Level Rise Technical Report Considerations for Scenario Planning

For near-term scenario planning, the observation-based extrapolations and the overall narrow range between SLR scenarios in 2050 can help to limit the analysis needed to evaluate future potential SLR. Returning to the Southwest example (*Figure 11*), a community may want to narrow its scenario-planning exercise to only the Intermediate-Low (0.66 ft), Intermediate (0.79 ft), and Intermediate-High (1.02 ft) SLR scenarios, as these are the ones that most closely align with the observation-based extrapolation's entire range of uncertainty. Or, since the Low (0.49 ft) and High (1.25 ft) SLR scenarios are less than a foot apart, they could decide the full range is worth evaluating. Using fewer scenarios may permit a more detailed evaluation of other stressors in the planning scenarios.

When scenario planning beyond 2050, a community should consider using a broad range of SLR scenarios to create a robust picture of potential future conditions. However, this may not mean evaluating every SLR scenario, but strategically selecting specific time horizons and scenarios that can best represent potential future conditions. This can help to focus additional modeling and analysis so that it meets the needs and expectations of the scenario-planning effort.

Examples of Scenario-Planning Application

Scenario planning has a long and robust history with examples from the military and land use planning. There are many available resources (*Section 5*) on how to successfully pursue scenario planning, including some specifically for natural resource management in the face of climate change. We highly encourage anyone considering scenario planning to review some of these resources.

One example is a planning process focused on the Florida Everglades, where it is uncertain how climate change will impact the hydrologic functions that support wildlife in freshwater wetlands. Using climate change projections for 2060, four possible futures were explored that characterized different temperature, SLR, and precipitation conditions. Each climate scenario was examined for how birds, fish, alligators, amphibians, and invasive species would be impacted. This scenario-based planning framework identified specific locations where habitat important for sustaining priority wildlife appeared to maintain health and function under multiple future conditions. It also identified locations where important habitats did poorly under multiple scenarios. This allows considerations of which areas within the Everglades may be more appropriate for conservation or restoration. Further, the analyses identified that overall restoration strategies that are focused on increasing the delivery of freshwater into marshes and coastal wetlands should be a high priority, as this would benefit many of the critical species across a range of planning scenarios.

Another common example of scenario planning is when adaptation strategies designed to protect an area of coastline from erosion are evaluated against a range of SLR scenarios combined with a range of storm events. Planners may evaluate how well different options such as seawalls, rock revetments, shoreline planting, or oyster reefs might perform in the different scenarios, as well as evaluating the feasibility of deploying these different options to provide protection from different magnitude events.

4.4 Sea Level Rise Planning Using an Adaptation Pathways Approach

Adaptation pathways allow planners and decision makers to map out a sequence of adaptation strategies in response to rising seas. Adaptation pathways can help a community plan for a range of uncertain futures while only investing in adaptation strategies when necessary. Adaptation pathways are built around specific goals (e.g., protecting specific infrastructure) and examine possible futures and potential adaptation or mitigation strategies to achieve those project goals. Adaptation strategies considered may cover a range of costs, effort, and desirability. Adaptation pathways identify thresholds, or "tipping points" when an adaptation strategy will no longer be effective (*Figure 13*). In SLR planning processes, a tipping point can be tied to observed amounts of relative SLR, or any number of other physical, economic, or biological thresholds. The various pathways or sequences of actions are also often ordered such that more cost-effective or desired actions are implemented first, whereas more significant or expensive capital projects are deferred to allow time to prepare for more significant and expensive capital projects.

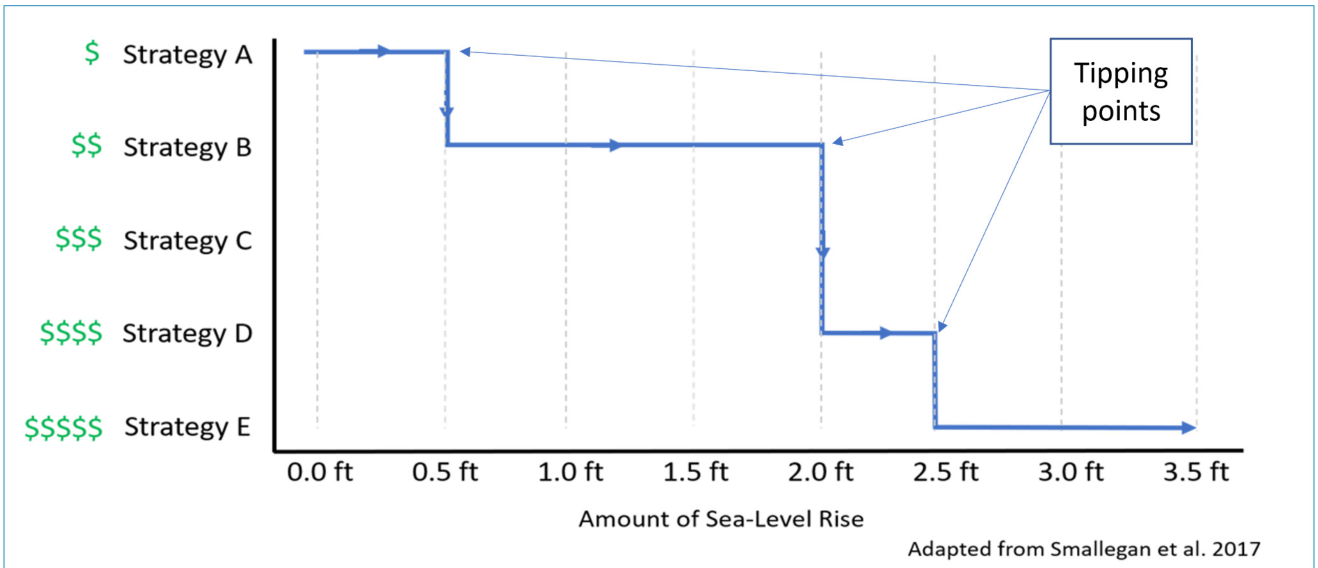


Figure 13. *Conceptualized diagram of an adaptation pathway planning approach. Tipping points in this case are associated with observed sea level change, and strategies are ordered within the pathway based on cost and effort. In some cases, it may make sense to skip a strategy (i.e., Strategy B and C) if it will have already been rendered ineffective as well by the amount of sea level rise.*

Community residents and other stakeholders can be engaged in the adaptation planning process by involving them in determining and evaluating potential strategies (e.g., in defining success and failure, success could be defined as a dune not breaching, or failure could be defined as critical infrastructure being exposed during a storm). This will foster shared understanding of why some efforts are being undertaken and not others, and provide for more clear communications when it is time for decisions regarding additional actions.

Adaptation pathways can allow for greater flexibility while minimizing upfront investment costs that may be required to address higher magnitude, but less certain, sea level possibilities. This approach is also useful in highly dynamic environments (e.g., beaches, dunes, barrier islands), in situations where there are limited funds, or where there is little political will to plan for rising seas. It can also be suitable for communities looking to make immediate investments in nature-based or smaller-scale flood protection measures, like earth berms, coastal dunes, or wetland restoration, while still indicating their commitment for more costly and complex adaptation strategies such as elevating or realigning coastal transportation corridors. Adaptation pathways may be less appropriate when there is little adaptive capacity or in highly complex settings where there may be multiple objectives or desired outcomes.

2022 Sea Level Rise Technical Report Considerations for Adaptation Pathway Planning

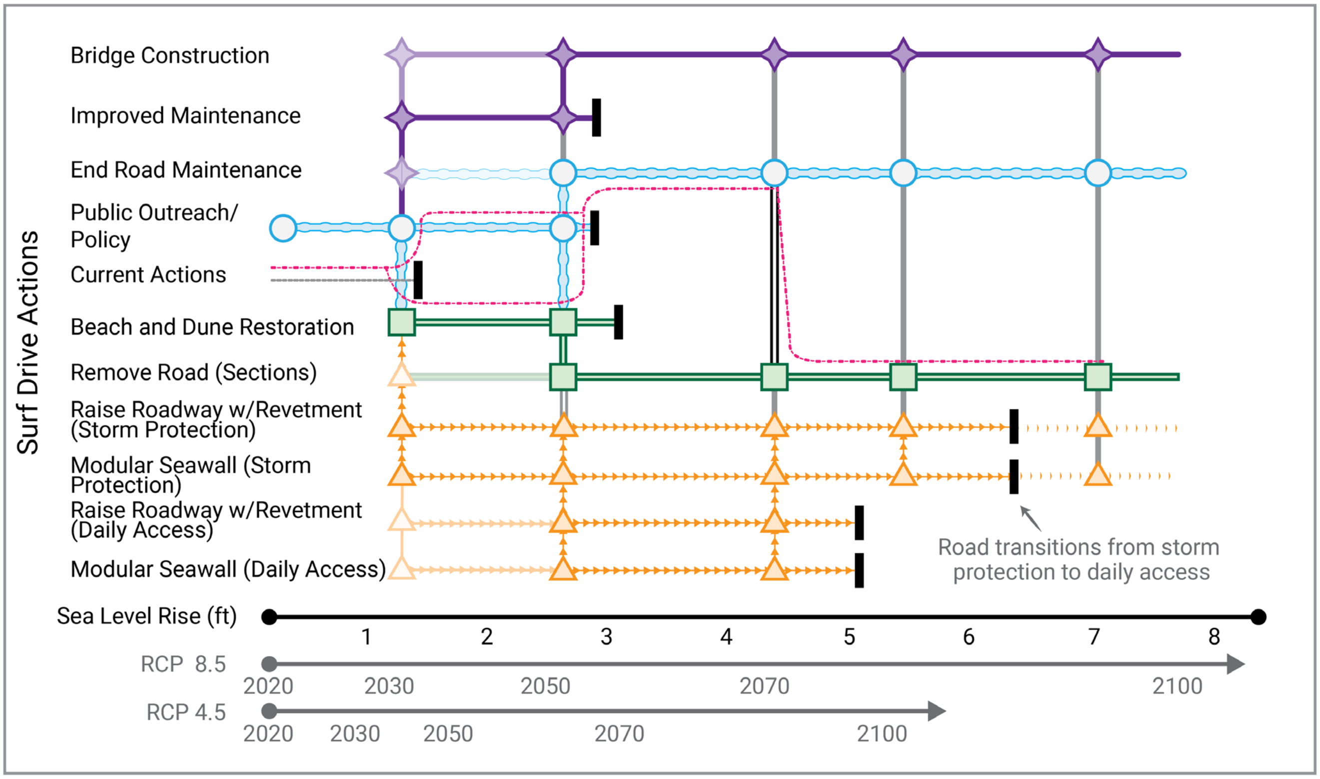
The adaptation pathways approach can be utilized for both near- and long-term planning, but planners may have different reasons for using it across different timescales. In the near term, it might be associated with needing to prioritize limited available funding, whereas in the long-term it can allow for flexibility in the face of uncertainty about how much sea level will rise.

The 2022 SLR scenarios can provide guidance on the amount of SLR to consider when constructing the adaptation pathways. Because of the nature of adaptation pathways, potential adaptation strategies should be evaluated across a range of potential SLR amounts, which can be determined by considering the range in the 2022 SLR scenarios across the planning timeline. Evaluating adaptation strategies against many SLR amounts can be expensive or time consuming, so it may make sense to choose fewer SLR amounts that cover a larger range of possible SLR amounts in both the near and long term.

In addition to providing a range of SLR amounts to consider, the 2022 SLR scenarios also provide an opportunity to assess feasibility of different management actions by evaluating *when* a particular SLR amount may be crossed. For example, a very expensive strategy associated with reducing risks associated with 3 feet of sea level change may not be as feasible if that change is likely to occur rapidly under multiple 2022 SLR scenarios. Expensive or highly intensive adaptation strategies require fiscal resources, consensus, and political will, which may take a great deal of time, more than is available.

Example of Adaptation Pathways Application

The Town of Falmouth, Massachusetts, developed a coastal resilience plan based on the dynamic adaptation pathways approach to reduce flood vulnerabilities of specific assets (Town of Falmouth, 2020). This approach allowed flexibility in future adaptation pathways, with decision points and actions being triggered when specific amounts of SLR have been observed or certain functions are lost (*Figure 14*). An important component of the work in Falmouth was the integration of community outreach and engagement throughout the plan, as well as identifying how local land-use decisions, governance, and permitting may need to be revisited to support the long-term adaptation vision.



Pathway Scorecard

	Path Actions	Relative Costs	Target Effects	Side Effects
1.	Managed Retreat	+	Balances present uses with increased costs and risks in the future through a multi-phase retreat plan	Loss of Homes No Connection via Surf Dr. Loss of Accessible Beach
2.	Protection	+++++	Protects operational capacity of existing infrastructure and features	Loss of Accessible Beach Aesthetics/Visuals
3.	Natural Resources	+++	Preserves and enhances coastal and marine ecosystem functions	Loss of Homes No Connection via Surf Dr.
4.	Connection	++++++	Maintains important public access, utility connections, and transportation corridors	Loss of Homes
5.	Preferred	+++	Balances present uses with increased costs and risks in the future through a multi-phase retreat plan, while enhancing ecosystems	Loss of Home No Connection via Surf Dr.
6.		+++	Improved maintenance for short-term uses with a long-term focus on ecosystem restoration	Loss of Homes No Connection via Surf Dr.
7.		+++++	Coastal habitat restoration in the short-term, with protection of existing infrastructure in the long-term	Loss of Accessible Beach Aesthetics/Visuals

Figure 14. *A dynamic adaptation pathways example from a coastal resilience planning process focused on Surf Drive in Falmouth, Massachusetts. In the top panel, adaptation actions are identified and their feasibility is evaluated under different amounts of future sea level rise (black line with different timelines associated with emissions scenarios represented by gray arrows). The actions are categorized into four general themes: managed retreat, protection, natural resources, and connections. The bottom panel assesses these themes individually and in combination for cost, target effects, and side effects. These are presented as path actions and a preferred path is identified (dashed red line) that addresses many of the community priorities considered during the planning process. This is a detailed representation of a multifaceted process. Readers are encouraged to refer to source documents for a full description.*

5. I'VE MADE IT THIS FAR. WHAT DO I DO NOW?

A key message of the 2022 Sea Level Rise Technical Report is that the impacts of SLR are here, and are not a problem that can be pushed off to the next planning cycle, or on to the shoulders of future decision makers. This document, *Application Guide for the 2022 Sea Level Rise Technical Report* (Application Guide), is designed to assist decision makers and coastal professionals in the application and integration of the 2022 Sea Level Rise Technical Report into coastal planning and adaptation decisions. The considerations included in this guide can be daunting, though, if only because of their variety. The lessons in this guide are distilled from numerous case studies and specific examples from across the nation, and represent innovative thinking and planning occurring in neighborhoods, towns, and cities across the country. The people at the center of these processes struggled with many of the same questions that you may be facing: What approach should I use? What scenario should I plan with? The answers to those questions are not always easy to come by, but do not let them become an obstacle to getting started.

If you do find yourself ready to integrate SLR considerations into your coastal decision-making, there are numerous additional resources that can enrich your understanding of sea level science, the impacts of SLR, approaches for assessing SLR vulnerability, and adaptation options and strategies. To that end, we have compiled a set of suggested additional resources. This is by no means an exhaustive list; there are many other high quality and salient resources covering these topics. This list simply represents a collection the authors of this report have found to be helpful in their work.

Dig Into the 2022 Sea Level Rise Technical Report

- *Key Takeaway Messages* from the Technical Report
- *Frequently Asked Questions* for the 2022 Sea Level Rise Technical Report
- *2022 Sea Level Rise Technical Report*

Access Data from the 2022 Sea Level Rise Technical Report and Updated Tools

- Visualize community-level impacts from SLR and coastal flooding on *NOAA's Digital Coast Sea Level Rise Viewer*.
- Visualize the updated scenarios and the new extrapolated observations data, as well as download the data, for global, regional, or individual tide gauges on *NASA's Interagency Sea Level Rise Scenario Tool*.
- Generate reports with current and future flooding impacts on stormwater systems with *NOAA's Adapting Stormwater Management for Coastal Floods* tool.
- View accessible charts and graphs with sea level rise data for a specific coastal county on *NOAA's Coastal County Snapshot* tool.
- Access and download SLR observation data, trends, and projections at specific tide gauges on *NOAA's Sea Level Rise API URL Builder*.
- Download three data sets—Scenarios of Future Mean Sea Level (2000-2150); Extreme Water Levels (Tide Gauges); and Extreme Water Levels (Gridded)—from the 2022 Sea Level Rise Technical Report *data and tools* page.

Learn More About Sea Level Rise

- *Learning Module on Sea Level Rise* from NASA and NOAA
- *Coastal Inundation Resources* from NOAA's Digital Coast
- *Glossary of Sea Level Rise Terms* from Washington State and Washington Sea Grant
- *Glossary of Flood Terms* from University of Georgia and Georgia Sea Grant
- *Sea Level Change Portal* from NASA

Communicating Sea Level Rise

- *Videos on Sea Level Rise, Impacts, and Adaptation Case Studies* from the Resilience to Future Flooding Project
- *SLR Graphics Library* from the Resilience to Future Flooding Project

Learn More About Community Engagement

- *Toolkit on Equitable Adaptation: Legal and Policy* from Georgetown Climate Center
- *Framework on Community-Driven Climate Resilience Planning* from Movement Strategy Center (MSC) and the National Association of Climate Resilience Planners (NACRP)
- *Toolkit on Advancing Resistance and Resilience in Climate Change Adaptation* from the NAACP
- *Case Studies on Municipal Community-Driven Environmental and Racial Equity Committees* from the Urban Sustainability Directors Network Innovation Fund, Facilitating Power, MSC, and the NACRP

A Few Examples of SLR Planning

- Risk-Tolerance Approach
    - *Jackson County Utility Authority, Mississippi* (See Section 1.4)
- Scenario-Planning Approach
    - *Everglades, Florida*
    - *Humboldt Bay, Jacobs Avenue, California*
    - *Jamestown S'Klallam Tribe, Washington* (see pages 15-16)
    - *Metro Parks, Tacoma, Washington* (site design example)
    - *Monmouth County, New Jersey* (using total water levels)
    - *Tijuana River Valley, California*
    - Guide from U.S. Fish and Wildlife Service on *Considering Multiple Futures: Scenario Planning to Address Uncertainty in Natural Resource Conservation*
- Adaptation Pathways Approach
    - *Town of Falmouth, Massachusetts*

Training Resources

- *Training on sea level rise tools*, coastal inundation mapping, coastal adaptation, coastal flooding, coastal stormwater management, nature-based solutions, and more from NOAA's Digital Coast
- *Sea-Level Rise in the Classroom* Curriculum - targeted to support educating high school students but appropriate for older and more advanced audiences

Reports Cited

Fox-Kemper, B., H.T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S.S. Drijfhout, T.L. Edwards, N.R. Golledge, M. Hemer, R.E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I.S. Nurhati, L. Ruiz, J.-B. Sallée, A.B.A. Slangen, and Y. Yu, 2021: Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [MassonDelmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. *https://www.ipcc.ch/report/ar6/wg1/*

International Panel on Climate Change (IPCC), 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

Maine Climate Council (MCC) Scientific and Technical Subcommittee (STS), 2020. Scientific Assessment of Climate Change and Its Effects in Maine: A Report by the Scientific and Technical Subcommittee of the Maine Climate Council. Augusta, Maine. 370 pp. *http://climatecouncil.maine.gov/future/sites/maine.gov.future/files/inline-files/GOPIF_STS_REPORT_092320.pdf*

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas, 2017: Global and Regional Sea Level Rise Scenarios for the United States. NOAA Technical Report NOS CO-OPS 083. National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services, Silver Spring, MD, 75 pp. *https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf*

Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak, 2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. *https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf*

Town of Falmouth. (2020). Coastal Resiliency Planning for the Surf Drive Area. *https://www.falmouthma.gov/DocumentCenter/View/8286/Surf-Drive-DRAFT-Report*

6. APPENDIX A: DETERMINING HOW MUCH SEAS HAVE RISEN TO ADJUST SEA LEVEL RISE SCENARIOS

Consider the hypothetical question, “How much did sea level rise . . . in Washington, DC, between 1992 and 2020?” To answer this question, we can consider three published trend analyses that are all based on historic tide-gauge observations. First, the long-term linear rate can be obtained from NOAA’s *sea level trend database*. The reported value of 0.14 inch/year is based on water level observations from 1924 to 2020. When adjusted to a baseline year of 1992, the linear trend results in 3.8 inches of SLR from 1992 to 2020 (*Figure A-1*).

Second, the 2022 Sea Level Rise Technical Report provides regional offset values for three time periods: 1992-2000, 2000-2005, and 2005-2020 (see 2022 Sea Level Rise Technical Report, *Table A1.2*). These values were derived from the regional observation-based extrapolations and represent non-linear rates averaged throughout the entire Northeast region. When added together, the regional offsets result in 5.5 inches of SLR from 1992 to 2020.

Third, station-specific observation-based extrapolation data were obtained for the Washington, DC, tide gauge from the *NASA Interagency Sea Level Rise Scenario Tool.* The values for the 50th percentile of the observation extrapolation were obtained for the years 1992 and 2020, resulting in a total of 6.8 inches of change.

Table A-1. *Sea level rise in inches in Washington, DC from 1992-2020 determined using local and regional tide-gauge observations. Values are provided relative to the baseline year associated with the data source. The data are presented based on linear and non-linear models of sea level change.*

SLR Source	Trend Type	Period	1992	2000	2005	2020	Change
Local Observation-Based Extrapolation[1]	Non-linear	1970-2019	-1.2	0.0	1.1	5.6	**6.8**
Regional Observation-Based Extrapolation[2]	Non-linear	1970-2019	-2.0	-0.8	0.0	3.5	**5.5**
Local Linear Trend[3]	Linear	1924-2021	0.0	1.1	1.8	3.8	**3.8**

[1]Extrapolated observation for tide-gauge PSMSL ID *#360* from NASA Interagency SLR Scenario Tool

[2]Offset values for the Northeast region from *Table A1.2* in the 2022 SLR Technical Report

[3]Relative sea level trend data for Station ID *#8594900* from NOAA CO-OPS sea level trend database

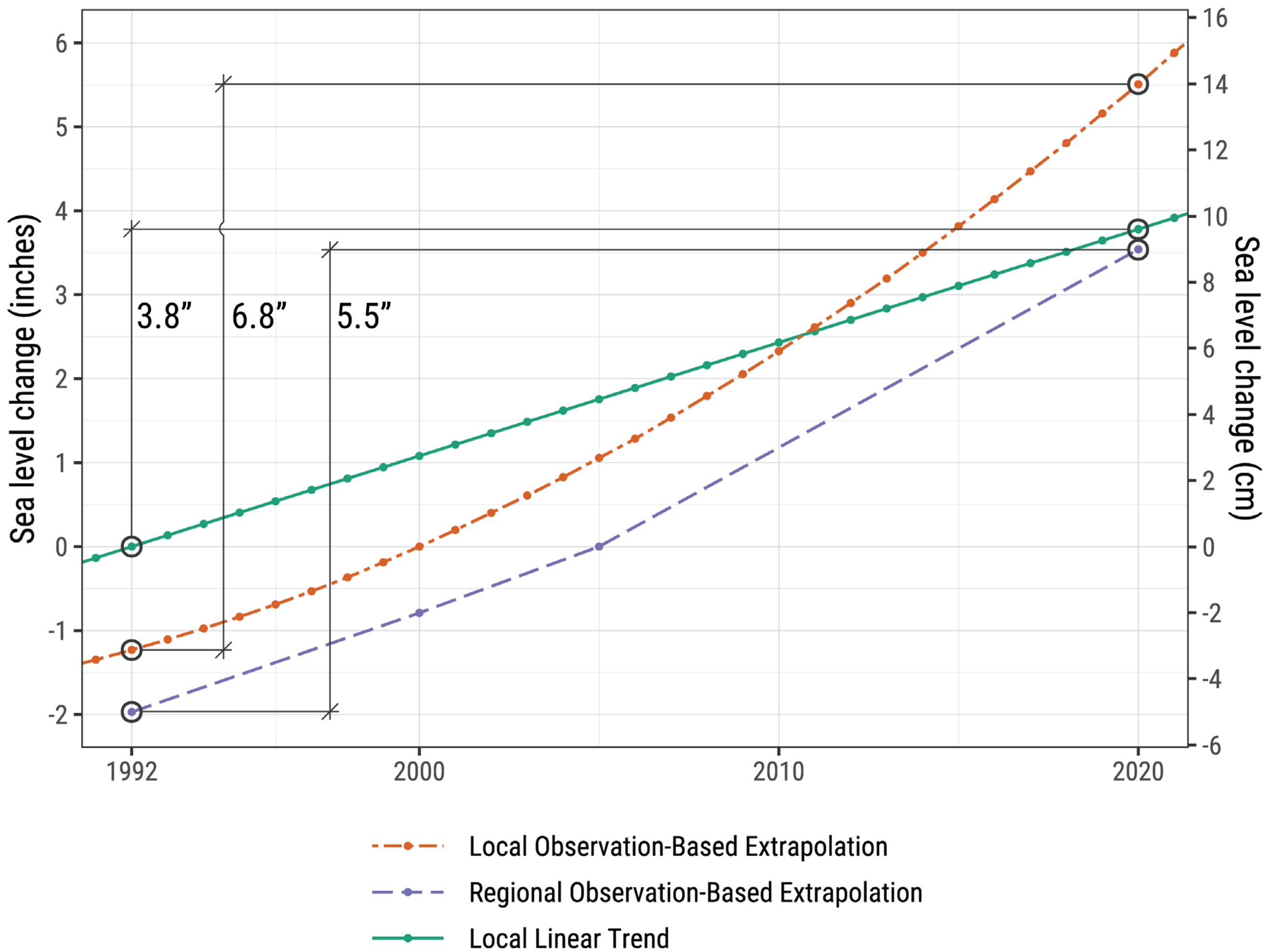


Figure A-1. *Three characterizations of historic sea level change at the Washington, DC, tide gauge: the long-term linear rate of change based on data from 1924 to 2021, the non-linear trend fit to observed water levels from 1970 to 2020, and the non-linear trend built from the 1970-2020 tide-gauge trends throughout the Northeast region. Relative differences in sea level for 1992-2020 are annotated.*

The data available through the NASA tool include annual values from 1970 to 2020, thus making it possible to calculate change between other years based on non-linear trend information (values for years 2000 and 2005 are included in the table for completeness).

Answering the question, “How much did sea levels rise between 1992 and 2020 in Washington, DC?” is not straightforward. The data presented here indicate that a linear approximation of SLR in Washington, DC, likely underestimates the true amount observed. Each of these methods includes associated uncertainty based on the lengths of the observed records and computation methods used. It can be said that seas have risen around half a foot in Washington, DC, between 1992 and 2020.

7. ACKNOWLEDGMENTS

2022 Sea Level Rise Technical Report Authors

This document would not have been possible without both the advancements in science presented in the 2022 Sea Level Rise Technical Report nor the patience and dedication of the following 2022 Sea Level Rise Technical Report authors. Benjamin Hamlington, NASA Jet Propulsion Laboratory, California Institute of Technology; Chris Weaver, U.S. Environmental Protection Agency; Mark Osler, NOAA National Ocean Service; Patrick Barnard, U.S. Geological Survey; William Sweet, NOAA National Ocean Service. These authors spent countless hours ensuring that the content herein was accurate, working with us over language nuance so that the content was clear and correct.

External Reviewers

Our external reviewers spanned a variety of sectors and perspectives. Because of their time and thoughtful input, this document is better able to meet the needs of many more who may be attempting to address rising seas. Our external reviewers all took time to not only read and review, but to provide essential suggestions to enhance the entire document.

Abby Sullivan, Senior Advisor for Climate Science and Risk Communication, Philadelphia Office of Sustainability

Brad Romine, Coastal Resilience Extension Specialist, Hawai‘i Sea Grant / Deputy Director, Pacific Islands Climate Adaptation Science Center University Consortium

Cirse Gonzalez, Coastal Training Program Coordinator, Chesapeake Bay National Estuarine Research Reserve in Virginia

David Behar, Climate Program Director, San Francisco Public Utilities Commission

Harriett Morgan, Climate Coordinator, Washington Department of Fish and Wildlife

Jayantha Obeysekera, Director, Sea Level Solutions Center, Research Professor, Institute of Environment, Florida International University

Jennifer Kline, Coastal Hazards Specialist, Georgia Coastal Management Program, Coastal Resources Division, Georgia Department of Natural Resources

Kelley Anderson Tagarino, American Samoa Extension Agent, Hawai‘i Sea Grant and American Samoa Community College

Maya Haden, Coastal Adaptation Program Leader, Point Blue Conservation Science

Nathalie DiGeronimo, Resilience Project Manager, New Hampshire Department of Environmental Services Coastal Program

Peter Slovinsky, Marine Geologist, Maine Geological Survey

Shannon Hulst, Floodplain Specialist, Deputy Director / Floodplain Specialist, Cape Cod Cooperative Extension and Woods Hole Sea Grant

Wes Shaw, Blue Urchin LLC, and Lead Coastal Consultant to the FEMA Community Rating System

Whitney Gray, Florida Program Manager, Resilience, Michael Baker International

MASGP-22-028
SGEB 88