SEA-LEVEL RISE
GUIDANCE FOR NEW JERSEY

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I. SUMMARY

As outlined in the New Jersey Scientific Report on Climate Change issued by the New Jersey Department of Environmental Protection (DEP) on June 30, 2020, New Jersey is already experiencing adverse impacts to public health, safety, and property due to climate change. From increasingly mild winters, more intense rainfall, chronic flooding, and increasing sea-level rise (SLR), the adverse effects of climate change will only increase in the years to come. The recommendations set forth here are specifically intended to aid decision-makers in planning, mitigating for, and adapting to SLR.

While there is no legitimate scientific dispute that global atmospheric warming, caused largely by human activities, is leading to significant changes in climate patterns, we must acknowledge that climate science is imperfect and evolving, and therefore carries some uncertainty. Yet, as New Jersey disproportionately experiences the adverse effects of climate change, and more rapidly than other areas around the globe, governments and institutions must not defer or delay action in pursuit of perfect information. The costs of inaction demand the development of adaptive climate change response strategies to ensure the continued protection of our people, property, economy, environment, and way of life, and which are grounded in the best available science.

DEP has determined that the best source of SLR science for New Jersey is the 2019 report of the Science and Technical Advisory Panel (STAP) convened by Rutgers University: New Jersey's Rising Seas and Changing Coastal Storms. The STAP, a diverse scientific panel representing numerous research universities, federal institutions, professional associations, and consulting firms with unparalleled collective expertise, has evaluated and synthesized current peer-reviewed science on SLR projections and changing coastal conditions specific to New Jersey. The 2019 STAP report, which updated an earlier 2016 version to include updated global ice melt data, includes SLR projection ranges for low, moderate, and high greenhouse gas emissions scenarios through 2150.

After analyzing the information presented in these reports, DEP recommends that decision-makers *utilize SLR projections from the 2019 STAP report based on a moderate greenhouse gas emissions scenario*.

In planning an activity, decision-makers should consider the expected life of an activity, their supporting systems, and services they provide when determining the planning horizon. Decision-makers should also consider the impact of today's decisions on future generations. DEP recommends decision-makers generally *utilize 2100 as a planning horizon*.

Once the planning horizon is identified, decision-makers must consider the potential consequences, likelihoods and responses of flooding to decision-makers and users to determine acceptable risk tolerance.

To ensure adequate protection against the worst of the likely range of SLR impacts, DEP recommends:

- *For residential, commercial, and most infrastructure activities, utilization of a SLR projection at the upper end of the likely range, reflecting a probability of SLR exceedance less than 17 percent;*
- *Where catastrophic consequences could result if structures or infrastructure were impacted by SLR, utilization of a high end SLR projection, reflecting a probability of SLR exceedance of less than 5 percent*.

  Catastrophic consequences include debilitating effects on security, public health, safety, essential government operations, emergency response, or economic or environmental systems.

While DEP acknowledges the need for adaptative management and regulatory flexibility that considers project purpose and need, siting limitations, technical feasibility, and other relevant constraints, DEP recommends the use of a set of principles to determine appropriate SLR projections across all levels of government, activities, and regions to standardize risk assessment and promote consistency. DEP recommends that decision-makers:

- determine future areas of vulnerability due to storm-induced flooding, *using the geographic extents of the sum of the SLR* *projections and the most current FEMA base flood elevations;*

- determine future coastal areas subject to permanent inundation that will render these areas difficult to inhabit, or to receive routine essential services without significant flood management projects, *using the SLR projections alone;*
- provide a margin of safety when determining structural heights in SLR-impacted areas, *adding a minimum of one foot of freeboard to the projected SLR*.

DEP will continue to update this guidance as necessary to ensure it continues to reflect the best available scientific information and SLR projections for the State of New Jersey.

The New Jersey Scientific Report on Climate Change is publicly available online at: https://www.nj.gov/dep/climatechange/.

The STAP report is publicly available online at: https://climatechange.rutgers.edu/images/STAP_FINAL_FINAL_12-4-19.pdf.

II. BACKGROUND

A. GLOBAL CLIMATE CHANGE

There is scientific consensus that the Earth's climate is warming and human activities, including the burning of fossil fuels, contribute significantly to the process. Since the late 19th century, the average global temperature has risen by 1.5°F and is driven primarily by increased anthropogenic inputs of carbon dioxide (CO_2) and other greenhouse gasses into the atmosphere since the onset of the industrial era.[1] Global temperatures are expected to continue to increase but the magnitude of that change will greatly depend on future greenhouse gas (GHG) emissions.

DEP recommends analysis of SLR in conjunction with a digital tool such as NJFloodMapper at https://www.njfloodmapper.org.

The Intergovernmental Panel on Climate Change (IPCC) relied on multiple scenarios of future atmospheric conditions to model climatic changes. The scenarios are referred to as Representative Concentration Pathways (RCP). The RCPs represent different climate futures depending on the amount of GHGs emitted. Under a low emissions scenario (RCP 2.6), where global GHG emissions are reduced in the latter part of the century, global temperatures are expected to rise 0.5 to 3.1°F but may increase up to 4.7 to 8.6°F under a high emissions scenario (RCP 8.5) through the end of the 21st century.[2] Locally, temperature changes will respond differently than the average global observation.

Because of this warming and other processes, global sea-level is rising. The 20th century global sea-level rise (SLR) rate is estimated at between 1.1 to 1.9 mm/yr.[3] However, SLR is not

[1] IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp. Available here.

[2] IPCC 2013

[3] As summarized in Horton, B.J., R.E. Kopp, A.J. Gardner, C.C. Hay, N.S. Kahn, K. Roy, and T.A.

consistent around the globe. The primary factors contributing to global SLR include thermal expansion of the oceans due to increased water temperatures and melting of land and sea ice (terrestrial glaciers and polar ice sheets). Additional factors influencing regional and local SLR include changes in ocean circulation, vertical land movement (subsidence due to natural sediment compaction and groundwater withdrawals), and isostatic rebound (adjustment of land surface to the loss of ice sheets at the end of the last ice age), as well as local coastal morphology.[4,5,6] A combination of these factors will dictate local or regional rates of SLR.

B. CLIMATE CHANGE AND SLR IN NEW JERSEY

Certain adverse impacts of climate change, including temperature and SLR, are greater in New Jersey than in other areas around the world. In New Jersey, the average annual temperature has increased by about 3.5°F since the late 19th century[7] and is predicted to increase to 4.1 to 5.7°F by 2050.[8] The rate of SLR in the Northeast United States has been higher than the global rate over the last several decades and is expected to continue to be amplified. In New Jersey, sea levels at Atlantic City, Cape May, and Sandy Hook have risen at a rate of approximately 4 millimeters per year (mm/yr) (0.157 in/yr) since the beginning of the 20th century.[9,10] Pre-anthropogenic SLR in New Jersey was approximately 2 mm/yr (0.079 in/yr).[11,12] This suggests that anthropogenic (human) contributions to the current rate of rise have doubled the historic rate. There is uncertainty surrounding exactly why the rates in the Northeast and New Jersey are greater, but it may be in part due to changes in the Gulf Stream[13] and localized subsidence and continued geologic influences of isostatic rebound in the forebulge region, which only exacerbate SLR impacts attributable to GHG emissions. Regardless of the specific contributions of each factor, SLR presents a real, immediate and disproportionate threat to New Jersey.

C. NEED FOR NEW JERSEY TO ADDRESS SLR

Sea-level rise specifically threatens our residents, economy, natural resources, and wildlife who rely on our coastal zone. New Jersey's coastal zone is a significant population center, a critical element of the State's economy, and a hallmark of its culture. This makes New Jersey particularly susceptible to the adverse impacts of climate change, like SLR, which the State is experiencing at a worse degree than elsewhere in the world. At

Shaw. 2018. Mapping sea-level change in time, space, and probability. Annual Review of Environmental Resources. 43:481-521.

[4] Horton et al. 2018. Mapping sea-level change in time, space, and probability. Annual Review of Environmental Resources. 43:481-521

[5] Kopp, R.E., C. Andrews, A. Broccoli, A. Garner, D. Kreeger, R. Leichenko, N. Lin, C. Little, J.A. Miller, J.K. Miller, K.G. Miller, R. Moss, P. Orton, A. Parris, D. Robinson, W. Sweet, J. Walker, C.P. Weaver, K. White, M. Campo, M. Kaplan, J. Herb, and L. Auermuller. 2019a. New Jersey's Rising Seas and Changing Coastal Storms: Report of the 2019 Science and Technical Advisory Panel. Prepared for the New Jersey Department of Environmental Protection. Trenton, New Jersey. Available here.

[6] Miller, K.G., P.J. Sugarman, J.V. Browning, B.J. Horton, A. Stanley, A. Kahn, J. Uptegrove, M. Aucott. 2009. Sea-level rise in New Jersey over the past 5000 years: Implications to anthropogenic changes. Global and Planetary Change 66:10-18.

[7] Based on linear interpolation of average annual temperature provided by the NJ State Climatologist. Available here.

[8] Horton, R., D. Bader, Y. Kushnir, C. Little, R. Blake, and C. Rosenzweig. 2015. New York City Panel on Climate Change 2015 Report, Chapter 1: Climate observations and projections. Page 18-35 Building the Knowledge Base for Climate Resiliency. Annual of the New York Academy of Science. Available here.

[9] Kopp, K.E. 2013. Does the mid-Atlantic United States sea-level acceleration hot spot reflect ocean dynamic variability? Geophysical Research Letters 40:1-5.

[10] Data provided by NOAA. Available here.

[11] Miller et al. 2009.

[12] Stanley, Alissa, Kenneth Miller, and Peter Sugarman, 2004. Holocene Sea-level Rise in New Jersey: An Interim Report, DEP Grant Final Report, submitted to New Jersey Department of Environmental Protection Division of Science, Research & Technology. September 15, 2004.

[13] 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. Tech. Rep. NOS CO-OPS 083, Nat. Oceanic Atmos. Admin., US Dep. Comm. Available here.

risk are 1,800 miles of tidal shoreline including 126 miles along the Atlantic coast from Sandy Hook to Cape May), and over 4.6 million people living in 239 coastal communities, comprising more than half the current population of New Jersey. Almost two-thirds of our coastline is already at high or very high risk to coastal erosion and 98% of the coastline is projected at medium or very high risk to SLR. Over half a million acres of land are highly vulnerable to coastal hazards.[14]

Also at risk are approximately 579,000 acres of wetlands including 197,000 tidal flats and marshes, which provide necessary water quality, flood storage, and carbon sequestering benefits to the public. These risks extend to the wildlife and migratory birds who depend on the State's natural resources for food and shelter. For example, the State's coastal wetlands are an important stopover for approximately 1.5 million migratory birds and with intensifying storms and rising sea levels, tidal flats and marshes are at risk of becoming open water, jeopardizing the survival of migratory birds which depend on the tidal flats and marshes to feed and nest.

New Jersey's coastal resources are a vital part of the State's economy. The coastal zone is critical to many industries including, a $50 billion maritime industry which includes ports and terminals, cargo movement, boat manufacturing and sales, ferry operations, government services, marine trade, recreational and commercial boating, and maritime environmental resources. As home to the Port of New York and New Jersey, over $200 billion in cargo moves through the Port (estimates from 2016) each year.

Counties in the coastal zone are estimated to contribute $400 billion in annual economic output, $22 billion from tourism alone, which is more than half of total tourism dollars. In 2017, leisure, hospitality, and retail accounted for approximately $50 billion of the state's gross operating profit[15].

The adverse effects of SLR are magnified during storm events, increasing the severity of coastal flooding and erosion. For example, the storm surge produced by Superstorm Sandy reached 9-10 feet above normal levels in some coastal areas. The Sandy-imposed damage to the State reached an estimated $29.4 billion in repair, response and restoration costs. The storm also cost the State an estimated $11.7 billion in lost gross domestic product, including $950 million in tourism losses[16]. A recent study has attributed approximately $3.7 billion in damages in New Jersey as a result of human-caused SLR[17]. As a result of climate change, hurricane wind and flood damage will continue to grow and is projected to cost the State an estimated $1.3 to $3.1 billion in average annual state-wide losses by 2050[18].

Given these current and increasing impacts from climate change, the State must take immediate and deliberate action to plan for and adapt to SLR to protect lives, natural resources, and assets.

[14] NJDEP. New Jersey Coastal Management Program Section 309 Assessment and Strategy 2021-2025. Trenton, NJ. Available here.

[15] NJOEM. 2019. 2019 New Jersey State Hazard Mitigation Plan. West Trenton, NJ. Available here.

[16] NJOEM. 2019.

[17] Economic Damages from Hurricane Sandy Attributable to Sea Level Rise Caused by Anthropogenic Climate Change, Nature Communications (18 May, 2021). Available here.

[18] Rhodium Group. 2019. New Jersey's Rising Coastal Risk. October 2019. Available here.

III. SEA-LEVEL RISE PROJECTIONS FOR NEW JERSEY

A. SELECTING THE SCIENTIFIC BASIS FOR SLR PROJECTIONS

DEP evaluated five sources of SLR projections to develop this guidance. Local estimates of sea-level rise (SLR) are available from the New Jersey Climate Adaptation Alliance (NJCAA), now known as the New Jersey Climate Change Alliance (NJ Climate Change Alliance) Science and Technical Advisory Panel (STAP)[19] convened by Rutgers University, the National Oceanic and Atmospheric Administration (NOAA),[20] and the US Army Corps of Engineers (USACE).[21] Additionally, projections outlined in the 4th National Climate Assessment[22] and the 5th Assessment Report of the IPCC[23] were reviewed. Each report uses a slightly different approach and thus offers different SLR projections by 2100. After careful deliberation, DEP determined that the New Jersey-specific focus of the STAP made its projections the most appropriate basis for this guidance.

The NJ Climate Change Alliance is a collective of organizations and individuals that seek to advance science-informed climate change strategies and policy at the state and local levels in New Jersey. The STAP was initially convened by Rutgers on behalf of the former NJCAA in response to a stakeholder engagement process between 2012 and 2014. The STAP consisted of 19 authors representing research universities, federal institutions, professional associations and consulting firms. The STAP used a rigorous collaborative approach to answer charge questions about the future of New Jersey's sea-level rise. STAP's mission was to help identify planning options for practitioners to enhance the resilience of New Jersey's people, places, and assets to regional SLR, coastal storms, and the resulting flood risk. The STAP identified and evaluated recent science on SLR projections and changing coastal storms, considered the implications for the practices and policies of local and regional stakeholders, and provided practical options for stakeholders to incorporate science into risk-based decision processes. After DEP determined to use the New Jersey-specific STAP projections, DEP requested Rutgers to reengage the STAP to update its 2016[24] report with state-of-the-art SLR projections based on the most recent science, specifically, including recent advancements in the understanding of the physical processes affecting the reduction of Arctic and Antarctic ice sheets.

In response, the STAP prepared a report which provides probabilistic-based projections specific to New Jersey with decadal estimates under high, moderate, and low emissions scenarios to 2150 based on the most current peer-reviewed science and understanding of Arctic and Antarctic ice-sheet conditions.[25] The high emissions scenario is consistent with the IPCC high emissions scenario (RCP8.5) and corresponds to an average global temperature increase of 9.8°F (5°C) by 2100.[26] The low emissions scenario assumes a 3.6°F (2°C) increase in average global temperature by 2100, a slightly higher benchmark than the RCP2.6 scenario. The moderate emissions scenario represents the midpoint of the high and low climate emission scenarios and generally corresponds to the warming expected under

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[19] Kopp, R.E., A. Broccoli, B. Horton, D. Kreeger, R. Leichenko, J.A. Miller, J.K. Miller, P. Orton, A. Parris, D. Robinson, C.P. Weaver, M. Campo, M. Kaplan, M. Buchanan, J. Herb, L. Auermuller and C. Andrews. 2016. Assessing New Jersey's Exposure to Sea-Level Rise and Coastal Storms: Report of the New Jersey Climate Adaptation Alliance Science and Technical Advisory Panel. Prepared for the New Jersey Climate Adaptation Alliance. New Brunswick, New Jersey. Available here.

[20] Sweet et al. 2017.

[21] US Army Corps of Engineers (USACE). 2013. Incorporating Sea-level Change in Civil Works Programs. ER 1100-2-8162. Washington, D.C.: USACE. Available here.

[22] USGCRP. 2017. Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp., doi: 10.7930/J0J964J6. Available here.

[23] IPCC. 2013.

[24] Kopp et al. 2016.

[25] Kopp et al. 2019a.

[26] Kopp et al. 2019a.

current international emissions policies, approximately 6.3°F (3.5°C) by the end of the century. Factors accounted for in relative sea-level changes in New Jersey include glacial isostatic adjustment, which is the ongoing movement of land once burdened by ice-age glaciers, sediment compaction, movement of land ice to the oceans, and dynamic sea level changes.

B. EXPLANATION OF THE STAP SLR PROJECTIONS

The STAP SLR projections are based on a probabilistic model that associates likelihood of occurrence of SLR heights and rates over time and are directly tied to a range of future emissions scenarios. For example, a 50% likelihood that the sea will rise to a particular level suggests that there is a 50% chance that SLR will meet or exceed a given level. Conversely, there is an equal chance that future SLR will fall somewhere below this given level. Notable, however, is the fact that SLR projections have tended towards the higher end of the likely range over time.

A likely range, consistent with definitions by the IPCC, is also presented. The likely range includes projections between the 17th and 83rd percentile and thus represents a 66% probability that future SLR will be within that range. The projections represent a 19-year average centered on the given year and are based on sea levels in the year 2000 and therefore already incorporate some of the rise included in these projections, approximately 0.2 feet through 2010.

To help understand the SLR projections, the following terms are important to understand. A *central estimate* represents a 50% probability that SLR will meet or exceed the given value in the given decade. For example, the central estimate for 2050 represents a 50% probability that SLR will meet or exceed 1.4 feet. The *likely range* represents a 66% probability that SLR is between a "*lower end*" and "*upper end*" at a given point in time. For example, the likely range for 2050 represents a 66% probability that SLR will be between 0.9 feet (lower end) and 2.1 feet (upper end). For the recommended planning horizon of 2100, the likely range represents a 66% probability that SLR will be between 2.0 feet (lower end) and 5.1 feet (upper end).

Additionally, the SLR projections through 2050 provided in the STAP report do not include low, moderate, or high emissions scenarios because differences in SLR projections between emissions scenarios are minor in the first half of the century where low emissions projections for 2050 are about 0.1 feet lower than high emissions projections. Therefore, differences in projections related to greenhouse gas emissions (high, moderate, and low emissions scenarios) are only germane for those decision-makers with planning horizons that extend beyond 2050. In short, the expected SLR of between 0.9 and 2.1 feet by 2050 is unavoidable.

Uncertainty is inherent to science. The IPCC has addressed the issues of the uncertainty that accompanies evolving science and projections stating that "…the governance of these deep uncertainties…rests on three pillars: precaution, risk hedging, and crisis prevention and management." Furthermore, the IPCC authors state "in addition to that uncertainty/risk dimension, there is also a time dimension of precaution: the precautionary principle recognizes that policy action should not always wait for scientific certainty[27]." The approach recommended herein, therefore, is to use the best available science for decision making to protect public health and safety (see Core Principle 1 below). DEP considers the 2019 STAP report the best available science. Still, the aggregation of many environmental and climatic factors to project future conditions, as done with STAP, will by design include uncertainty. The STAP report addresses uncertainty by accounting for a number of possible factors within the projections. The result is an effective and usable range of projections.

[27] USGCRP. 2017.

IV. SEA-LEVEL RISE GUIDANCE FOR DECISION MAKERS

This guidance provides a method for the instrumentalities of New Jersey state and local government, as well as private entities and individuals, to utilize SLR projections in their decision-making. This guidance assumes that, when informed by likely future risks to assets and social systems, public and private sector actors will make decisions based on risk tolerance. Risk tolerance in this context refers to a decision-maker's level of comfort with the consequences of sea-level rise (SLR) and associated hazards, including the potential for mitigating such consequences in planning exercises and project siting, design, and development.

The SLR values in **Table 1** and **Figure 1** represent projections for a moderate emissions scenario made by the STAP.[28]

A. CORE PRINCIPLES

DEP recommends adherence to the following principles for incorporating SLR projections into decision-making. Considering SLR necessarily entails understanding of permanent inundation as well as chronic inundation, *i.e.*, the future extent, frequency, and depth of routine flooding.

1. Prioritize public health, safety, and welfare.

Decision-makers should use a precautionary approach when planning for future conditions, prioritizing public health, safety, and welfare over other considerations, including short term financial considerations. Criticality, risk tolerance, extent, and the direct, indirect, and cumulative impacts of SLR and flooding to communities and natural resources should be considered and evaluated for proposed activities.

2. Use the best available science to guide decision-making.

The best available science evolves over time. To that end, current SLR projections will be updated regularly. Further, SLR projections do not account for fluvial flooding, changes to rainfall patterns, coastal storms, or the potential strength or frequency of such events. The impacts of these events will increase with SLR. SLR will also result in other previously unseen affects, such as the migration of the extent of tidal influence (i.e., head-of tide) and the boundary of the resources which are held in trust for public.

3. Maximize protection of coastal resources, including natural resources, public access, and recreation.

The preservation, conservation, protection, and restoration of coastal resources should be prioritized when considering the impacts of SLR. Particularly in view of the risks to coastal resources from SLR, regional and cumulative impacts to coastal resources should be considered in planning and development. Impacts to coastal resources should be avoided to the maximum extent practicable. This includes impacts to natural resources such as wetlands and other protected areas, as well as impacts to recreational features and the public's access thereto. The prospect of off-site mitigation for impacts to coastal resources should be viewed as a last resort in the event of impacts that cannot be avoided or minimized to the fullest extent possible.

4. Minimize SLR impacts through planning.

Strategies to avoid, protect from, or adapt to SLR should be routinely considered. Where new development or activities are considered, the avoidance of impacts from SLR should be a paramount consideration. Local conditions and context of the activities should be considered. For example, the presence of preexisting contamination, vulnerable populations, or erosion rates may impact the design of a proposed activity. Similarly, the impacts on the service area of new/updated infrastructure should also be considered.

5. Maximize coordination and public education and participation.

Coordination amongst all levels of government, education and outreach to the public, including risk assessment and disclosure, and maximum participation of the public, stakeholders, and local and elected officials will result in better decisions.

[28] Kopp et al. 2019a.

B. SLR PROJECTION RECOMMENDATIONS

1. Plan for a moderate emissions scenario.

The SLR projection recommendations in this guidance are based on a moderate emissions scenario which is consistent with current global climate policies and corresponds with the 5.4°F (3°C) temperature trajectory many scientists believe we are heading toward and offers flexibility if some global policies are reversed.[29,30,31] The high emissions scenario was not used because of the strong likelihood that it does not align with assumed future emissions forecasts. The STAP high emissions scenario, which closely follows the RCP8.5, represents the 90th percentile of all baseline scenarios, or the most unlikely outcomes. Models based on it will likely overpredict future conditions, whether that be temperature, precipitation, or sea levels. Similarly, the low emissions scenario was developed to emphasize very low future emissions. Such low emissions are not likely to be achieved even with current mitigation policies. Therefore, any climatic projections based on this low emissions scenario will most likely underestimate the conditions we are likely to experience.[32]

2. Identify the planning horizon based on expected life of an activity.

This guidance recommends identification of a planning horizon that accounts for the impact of decisions on future generations by considering the siting of structures, as well as the expected life of an activity, supporting systems, and services provided. Decisions regarding the siting and construction of residential and commercial structures, roadways, and water and energy infrastructure will impact New Jersey residents for the life of those structures and beyond, because of the need to maintain, repair, or upgrade those structures. For example, siting decisions regarding energy infrastructure at the New Jersey coast made in 1911 impacted communities nearly a century later during and after Superstorm Sandy[33].

Decision-makers should be realistic about the expected life of an activity, not just the design life. For example, it is insufficient to plan as though the life of a single-family home is 30 years (the length of a typical mortgage) when housing units in New Jersey last significantly longer. In 2019, approximately 25% of housing units in New Jersey were over 70 years old (built before 1950) and over 50% were over 50 years old (build before 1970)[34]. Similarly, while the design life of a bridge may be 50 years, the Federal Highway Administration notes that the average age of bridges in New Jersey is 55 years old. Of the 10 most heavily traveled New Jersey bridges that need structural repairs, all were built in 1970 or earlier, and 7 were built prior to 1940.[35]

Additionally, consideration of associated risk over the suggested planning horizon is necessary because the construction of structures in risk-prone areas leads to related and supporting development and infrastructure, resulting in a strong preference to continue to rebuild and protect structures that are increasingly vulnerable and with actions that are increasingly costly. Risk is therefore not reflected. Recent observations suggest that subsidized coastal protection and infrastructure development in exposed areas inflate property values, in turn stimulating further housing and infrastructure development, and thus an associated migration toward the coast[36].

DEP recommends a planning horizon of 2100 as a reasonable projection that encapsulates those

[29] Hausfather, Z. and G. P. Peters. 2020. Emissions – the "business as usual" story is misleading. Nature. 577:618-620.

[30] The CMIP6 landscape. 2019. Nature Climate Change. 9:727. Available here.

[31] Burgess, M.G., J. Ritchie, J. Shapland, and R. Pielke Jr. 2021. IPCC baseline scenarios have over-projected CO2 emissions and economic growth. Environmental Research Letters. 014016.

[32] Van Vuuren, D.P., Edmonds, J., Kainuma, M. et al. 2011. The representative concentration pathways: an overview. Climatic Change 109:5-31.

[33] Kopp, R. E., Gilmore, E. A., Little, C. M., Lorenzo-Trueba, J., Ramenzoni, V. C., & Sweet, W. V. 2019b. Usable science for managing the risks of sea-level rise. Earth's Future 7:1235-1269. Available here.

[34] Available here.

[35] Available here.

[36] Kopp et al. 2019b.

considerations recognizing that the impact of some activities may fall before or after 2100.

3. Consider the relative risk tolerance of an activity.

To ensure that activities are sufficiently protective of public health, safety, and welfare and to plan for and protect future and existing assets, the risk tolerance of an activity should determine the appropriate SLR projection. By assessing the risk tolerance of an activity, we can plan accordingly depending on how consequential the loss would be if the activity is impacted by SLR. For example:

(a) activities with the least risk tolerance should plan for the high end projection

The high end SLR projection reflects a 5% chance of being met or exceeded. These activities are those that the damage or loss of which would have a catastrophic impact or debilitating effect on security, public health, safety, essential government operations, emergency response, or economic or environmental systems and therefore requires the highest level of protection.

Examples of these types of activities include power plants, certain water supply facilities, fuel and chemical storage and processing facilities, or nuclear energy or storage facilities.

(b) activities with less risk tolerance should plan for the upper end of the likely range

The upper end of the likely range SLR projection reflects a 17% chance of being met or exceeded. These activities include those that the damage or loss of which would adversely affect household or community stability; would result in significant investment loss; adversely impact sensitive or socially vulnerable populations; with limited flexibility for adaptation; or have other large social, environmental, or economic impacts.

Examples of these types of activities include most activities including single and multi-family residential structures, commercial developments, most energy transmission and water treatment infrastructure, evacuation routes and bridges, hospitals, or public transit facilities.

(c) special considerations for activities with a high risk tolerance

Certain activities with a high risk tolerance may not need to be planned to the SLR projections listed above. These activities include those that the damage or loss of which would have a limited impact on health and safety; limited consequence to social, environmental, or economic systems; or those with opportunity for adaptation.

Examples of these types of activities include parks and open space, natural and nature-based projects, or marinas. These activities could plan for 2.0 feet of SLR, which is likely unavoidable, and which would be consistent with the likely range of projections between 2050 and 2100:

- the upper end of the likely range in 2050 is 2.1 feet;
- the central estimate in 2070 is 2.2 feet;
- the lower end of the likely range in 2100 is 2.0 feet.

4. The geographic area where these SLR projections are considered should be expanded to the extent of the one-percent storm (100-year storm) base flood elevation plus 5.1 feet of sea-level rise.

5.1 feet of SLR corresponds to the 17% chance of being met or exceeded in 2100. The addition of 5.1 feet of SLR to the geographic extent of the one-percent storm base flood elevation will allow for the appropriate and reasonable inclusion of future coastal hazard areas in decision-making.

5. When determining structural heights in SLR-impacted areas, add one foot of freeboard to the projected SLR to provide a margin of safety.

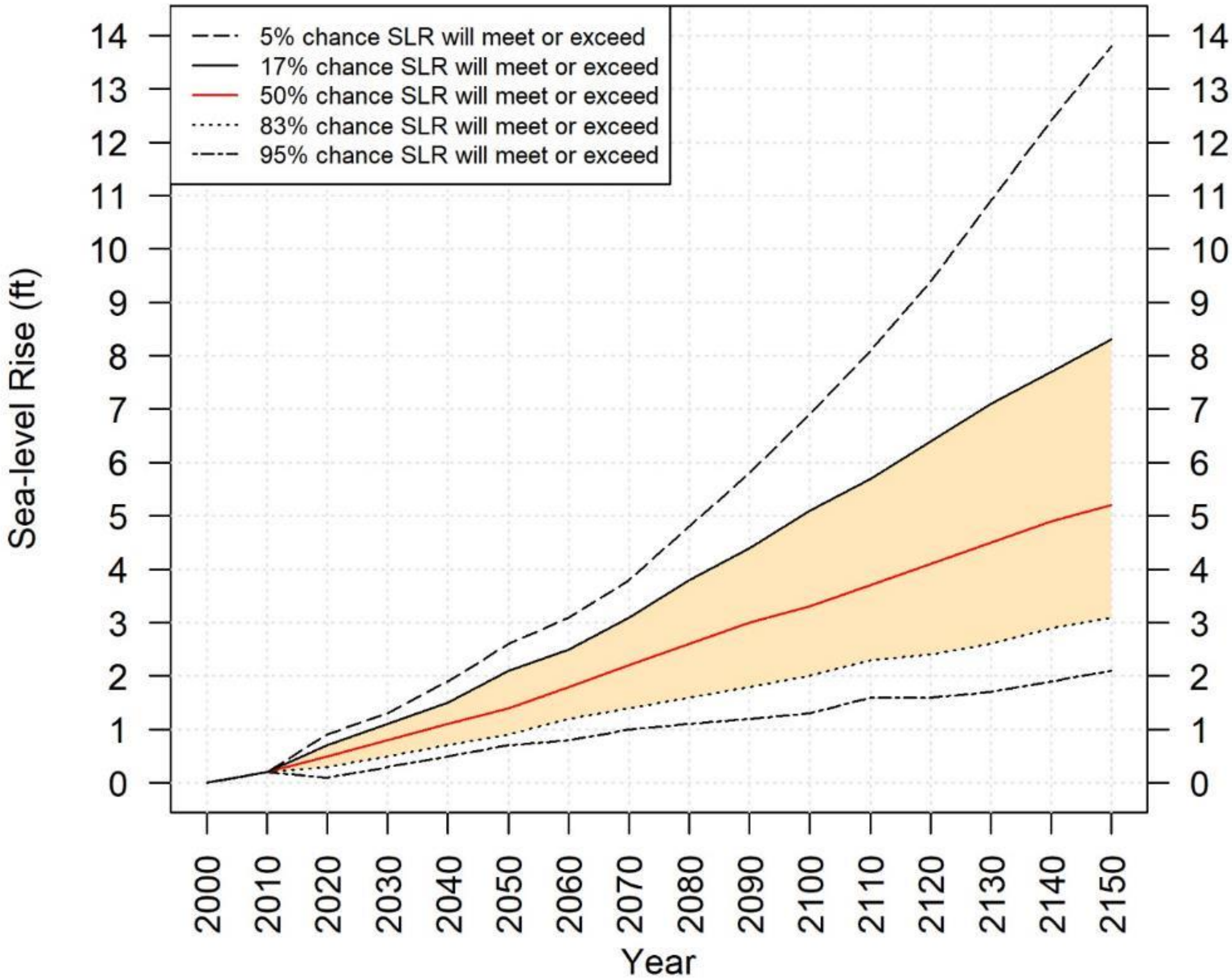
Having a margin of safety for buildings is crucial. If the lowest floor of a building is impacted by even a few inches more of flooding than expected, the building can experience costly damage, possibly long-term loss, and possibly endanger its occupants. By adding one foot of freeboard, the bottom of the floor joist in most buildings would lie above the flood elevation, further protecting the building from unexpected flood events. In most cases, the additional up-front cost of incorporating additional freeboard during a building's initial construction is nominal and is generally recouped within several years due to flood insurance savings alone.

Table 1. Table 1. SLR projections in feet for New Jersey from 2000 to 2150 under a moderate emissions scenario. The likely range represents the range of levels between which there is 66% chance that sea-level rise will occur (Kopp et al. 2019a). The "upper end of the likely range" is the column labeled "Less than a 17% chance SLR exceeds." The "central estimate" is the column labeled "~50% chance SLR exceeds." The "lower end of the likely range" is the column labeled "Greater than an 83% chance SLR exceeds" See Section B for recommendations on the use of the ranges presented in this table.

Year	Low End	At least a 66% chance between			High End
	Greater than a 95% chance SLR exceeds	*Greater than an 83% chance SLR exceeds*	*~50% chance SLR exceeds*	*Less than a 17% chance SLR exceeds*	*Less than a 5% chance SLR exceeds*
2000			0		
2010			0.2 ft		
2020	0.1 ft	0.3 ft	0.5 ft	0.7 ft	0.9 ft
2030	0.3 ft	0.5 ft	0.8 ft	1.1 ft	1.3 ft
2040	0.5 ft	0.7 ft	1.1 ft	1.5 ft	1.9 ft
2050	0.7 ft	0.9 ft	1.4 ft	2.1 ft	2.6 ft
2060	0.8 ft	1.2 ft	1.8 ft	2.5 ft	3.1 ft
2070	1.0 ft	1.4 ft	2.2 ft	3.1 ft	3.8 ft
2080	1.1 ft	1.6 ft	2.6 ft	3.8 ft	4.8 ft
2090	1.2 ft	1.8 ft	3.0 ft	4.4 ft	5.8 ft
2100	1.3 ft	2.0 ft	3.3 ft	5.1 ft	6.9 ft
2110	1.6 ft	2.3 ft	3.7 ft	5.7 ft	8.1 ft
2120	1.6 ft	2.4 ft	4.1 ft	6.4 ft	9.4 ft
2130	1.7 ft	2.6 ft	4.5 ft	7.1 ft	10.9 ft
2140	1.9 ft	2.9 ft	4.9 ft	7.7 ft	12.4 ft
2150	2.1 ft	3.1 ft	5.2 ft	8.3 ft	13.8 ft

Notes: All values are 19-year means and are measured with respect to a 1991-2009 baseline. Projections are 19-year averages based on Kopp et al. (2014), Rasmussen et al. (2018), and Bamber et al. (2019). Moderate emissions are interpolated between the high and low emissions scenarios. Rows correspond to different projection probabilities. For example, the 'Likely Range' rows correspond to at least a 2-in-3 (66-100% chance) chance of sea-level rise from the relevant projections considered, consistent with the terms used by the Intergovernmental Panel on Climate Change (Mastrandrea et al., 2010). Note alternative methods may yield higher or lower estimates of the chances of low-end and high-end outcomes.

Figure 1. Diagram of sea-level rise projections curve under moderate emissions scenario SLR projections for New Jersey from 2000 to 2150 under the moderate emissions scenario. The likely range (colored area) represents the range of projections between which there is a 66% chance that sea-level rise will occur. This figure is adopted from values presented in Table 1. (Kopp et al. 2019a)



C. ADAPTIVE MANAGEMENT & FLEXIBILITY

The recommendations in this guidance are intended to facilitate minimum protections from future inundation risks in tidally-flowed areas. However, DEP acknowledges that adaptative management and flexibility in the application of this guidance may be necessary due to activity type, siting limitations, technical feasibility, and other relevant constraints. For example, historic property rehabilitation and natural resource restoration activities (which are vital to restore and enhance ecological function, promote carbon sequestration, and provide shorter-term storm protection and community resilience benefits), may not lend themselves to implementation of SLR projections as readily as new building or infrastructure projects. Variables specific to the location of an activity must also be considered. For example, the presence of preexisting contamination, vulnerable populations, or erosion rates may impact the design of a proposed activity.

In settings where SLR projections cannot be implemented at the start of an activity, adoption of an adaptative management plan that sequences the deployment of resilience measures could be considered. For example, construction of a sea wall to address a lower, interim, SLR projection could be built wide enough to allow for additional height to be added at a later date. This approach would include identification of pre-determined threshold events, which, if triggered, would cause planned adaptation actions to take place. The trigger events should reflect an activity's risk tolerance, local conditions, and adaptation goal. Adaptive strategies can be immediate or planned to occur to manage future risk and uncertainty. However, it is vital that enforceable mechanisms are in place to ensure that future measures are implemented, and that this approach is not used to avoid addressing SLR risk. Using the previous sea wall example, an enforceable mechanism may be requirement of financial assurance to address future conditions. Consideration of this approach may not be appropriate in all circumstances or programs.

The risks of SLR and other adverse climate change impacts require planning and decision-making informed by a long-term perspective. While adaptive management and flexibility may be necessary to address SLR in some circumstances, DEP cautions use of solutions that could undermine long-term climate resilience, such as an over-reliance of imported fill material. Actions that serve to postpone rather than confront SLR risk may carry a significantly higher cost to public health, safety, and welfare.

D. RECOMMENDED METHOD FOR DETERMINING AN APPROPRIATE SLR PROJECTION FOR AN ACTIVITY

This guidance provides the following step-by-step method to identify the appropriate SLR projection for an activity, as illustrated in Figure 2.

1. Evaluate the impact if the activity is damaged, destroyed, or lost.

The first step is evaluating the risk tolerance of the activity consistent with Section IV.B. of this guidance.

2. Identify appropriate SLR projection(s).

Once the risk tolerance of the activity is determined, the appropriate SLR projection should be identified consistent with Section IV.B. of this guidance.

3. Identify inundation and projected sea-level depth at activity location as appropriate.

Identify the location of the activity on maps that identify or otherwise incorporate the appropriate SLR projection, noting the depth of water. DEP recommends using the mapping tools available at www.NJFloodMapper.org.

4. Address the depth of inundation and frequency of nuisance flooding within its design.

Evaluate the depth of inundation and frequency of flooding as part of its design and explain why the location is appropriate.

Consider the impact of inundation to the operation and service area of the activity and whether the service area or area of impact includes sensitive or vulnerable populations.

Consider whether the activity is appropriate for that location. For example, a flood mitigation project may need to be located within an area of inundation to make other assets more resilient.

5. Evaluate the impacts of nuisance flooding, storm events and other hazards on top of SLR and require mitigation as appropriate.

Consider whether to evaluate other types of flooding including increased nuisance flooding, storm surge, and fluvial flooding. In addition to more areas being permanently inundated, coastal storms are expected to be more damaging, rainfall events are expected to be more intense, and nuisance flooding is expected to occur more frequently. These types of hazards will require different resilience strategies and should be evaluated in conjunction with SLR, along with appropriate mitigation measures.

6. If appropriate, consider a more detailed process/analysis for activities unable to address SLR.

If an activity that will be impacted by SLR cannot adequately address the depth and frequency of inundation, consider whether an alternatives analysis is appropriate. Do not rely on other actions not part of the immediate activity to address inundation (e.g., identification of a flood mitigation project a that is planned but not constructed).

Considerations for an alternatives analysis could include:

a. Alternative locations and designs
b. The public need for and benefit of the activity
c. Adaptive management plans that sequence deployment of resilience measures
d. Hardships on the property owner
e. Use of a lower SLR projection, consistent with the core principles provided in Section IV.A. of this guidance with implementation of appropriate design measures where below SLR recommendations.

7. Evaluate consistency and coordination concerns.

To increase uniformity and standardize risk evaluation, efforts led by or under the authority of multiple agencies and levels of government should use the same SLR projections to achieve consistency across specific activities and regions. Cross-jurisdictional decisions should also prioritize implementation of consistent or complementary adaptation strategies.

Consider the impacts on other assets in the surrounding area and how those impacts may affect a specific decision. For example, if the service area of a proposed facility will be inundated in 25 years, the decision-makers should consider whether such an investment is fiscally-responsible, whether that information requires modifications to the design of the activity, or whether additional efforts to address the resiliency of the service area are needed first.

8. Finalize design criteria and/or appropriate management strategies.

Finalize the design and appropriate management strategies consistent with the information provided in this guidance and the method outlined above.

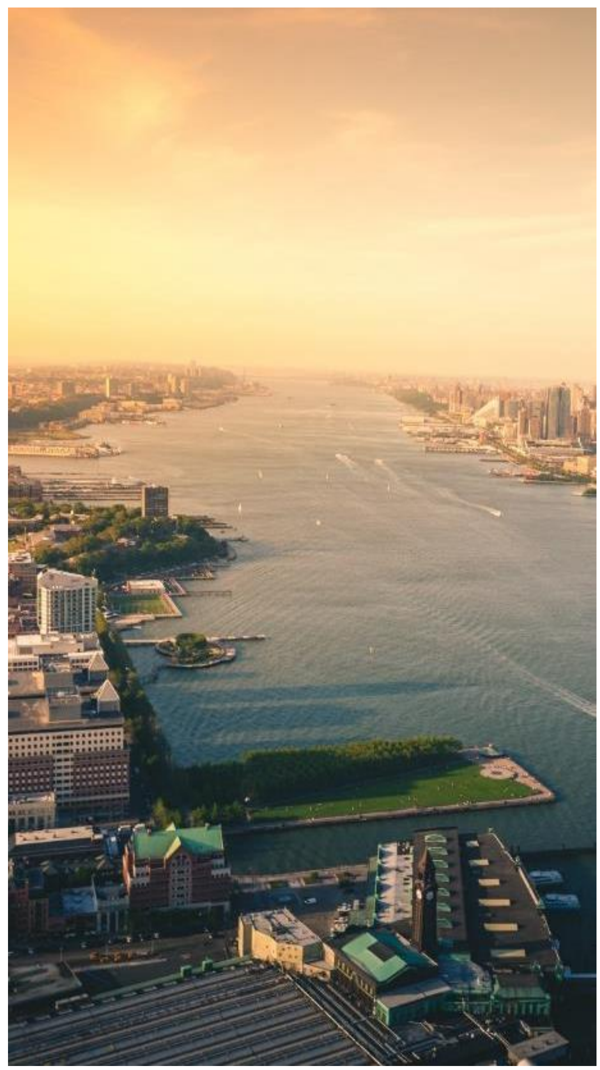
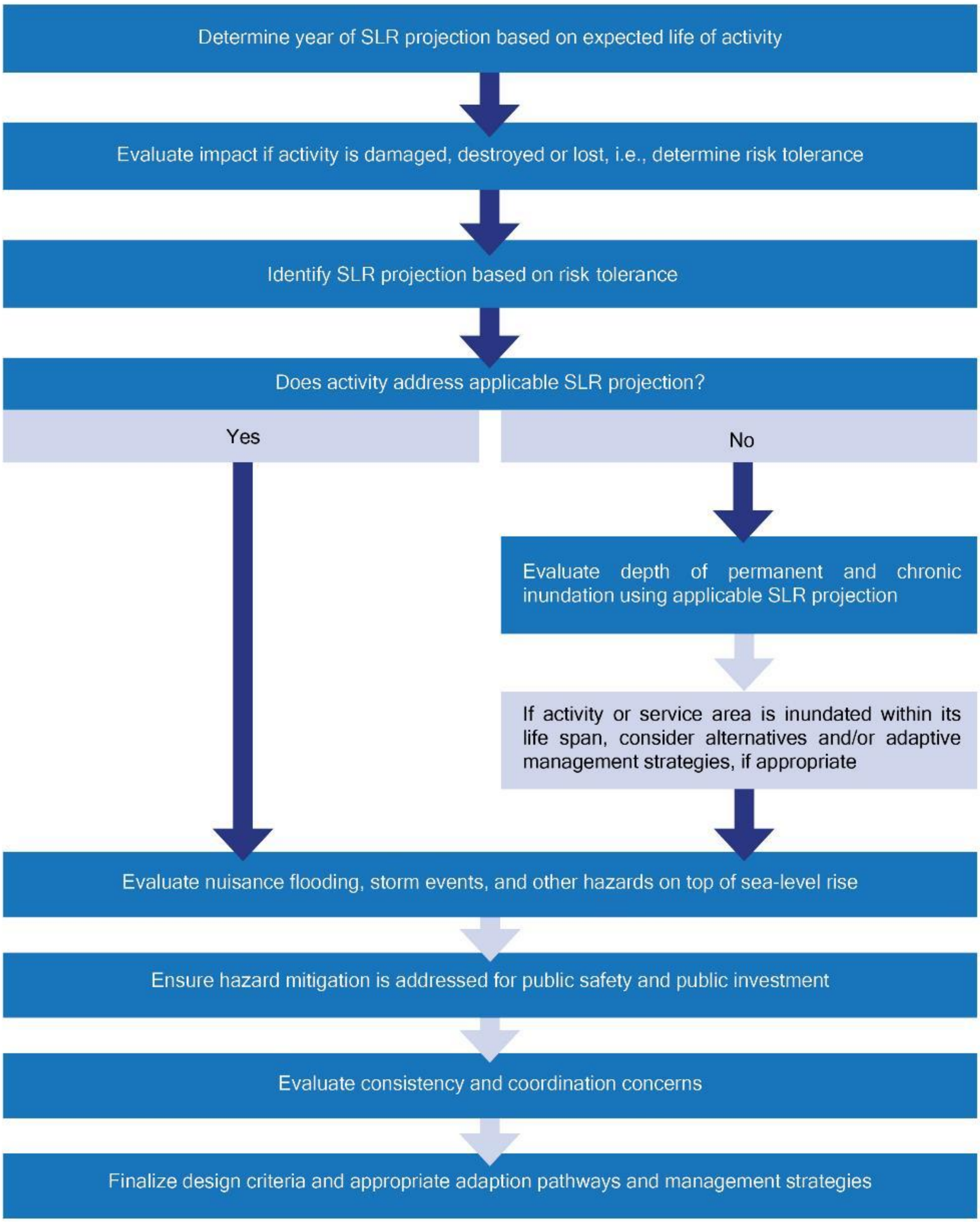


Figure 2. Diagram of method to determine appropriate SLR projection for an activity



V. USING THIS GUIDANCE

This guidance assumes that, when informed by likely future risks to assets and social systems, public and private sector actors will make decisions based on risk tolerance. Given the risks that sea-level rise (SLR) and other adverse climate change impacts pose to New Jersey, this guidance provides a method that the instrumentalities of New Jersey state and local governments, as well as private entities and individuals, to utilize SLR projections in their decision-making.

Decision-makers should consider their goals and obligations in determining how to incorporate and implement this guidance. Difficult questions will materialize during implementation of this guidance. However, by evaluating the expected life span, potential impacts, and adaptive capacity of an activity in view of the risks of SLR, decision-makers can guard against investments in high-risk activities while ensuring that viable activities are sufficiently protective of public health, safety, and welfare.

SEA-LEVEL RISE
GUIDANCE FOR NEW JERSEY

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