New Jersey Fostering Regional Adaptation through Municipal Economic Scenarios (FRAMES)
Planning Inundation Levels – Technical Memo Summary

How Much Water Are We Planning For?

The NJ FRAMES project team will evaluate water levels of 3, 7, and 12 feet above Mean Higher High Water (MHHW)[1] to assess the people, places, and assets that flooding might affect now and in the future. The Rutgers FRAMES project team projected water levels associated with future events by adding 3 future projections of Regional Sea Level Rise (SLR) to NOAA's Annual Exceedance Probability (AEP)[2] levels and historic storm tide records using the Sandy Hook, NJ tide gauge through 2100.

Table 1. Water Levels above Current MHHW Assessed for NJ FRAMES Analyses (Sandy Hook, NJ)

	Water Level	What High Water Level Condition Does This Height Represent?	How does this water level relate to recent events at Sandy Hook?
Permanent Inundation	3 ft.	• An Annual (99% AEP) Flood in 2050 • Permanent Inundation (MHHW) under a High Emission Scenario in 2100	• In January 2017, a water level associated with a Nor'easter reached approximately 2.8 feet above MHHW.
Coastal Flooding	7 ft.	• A 100-Year (1% AEP) Flood today • A 10-Year (10% AEP) Flood under a High Emission Scenario in 2100 • An Annual (99% AEP) Flood under a low probability, high consequence High Emission Scenario in 2100	• Hurricane Sandy reached a water level of 8.3 feet above MHHW, slightly above this assessment.
Coastal Storm Flooding	12 ft.	• A 100-Year (1% AEP) Flood under a low probability, high consequence High Emission Scenario in 2100 • Hurricane Sandy under a High Emission Scenario in 2100	• The historical record for this tide gauge (i.e. since 1910) has never recorded a water level this high.

How Much Will Sea Levels Rise in New Jersey?

In 2016, a Science and Technical Advisory Panel (STAP) convened by Rutgers University on behalf of the New Jersey Climate Adaptation Alliance issued a report that provided future estimates for SLR and coastal storms in New Jersey (See Table 1)[3].

Table 2: Projected SLR for New Jersey (ft.)

	Central Estimate	'Likely' Range	1-in-20 Chance	1-in-200 Chance	1-in-1000 Chance
Year	*50% probability SLR meets or exceeds…*	*67% probability SLR is between…*	*5% probability SLR meets or exceeds…*	*0.5% probability SLR meets or exceeds…*	*0.1% probability SLR meets or exceeds…*
2030	0.8 ft	0.6 – 1.0 ft	1.1 ft	1.3 ft	1.5 ft
2050	1.4 ft	1.0 – 1.8 ft	2.0 ft	2.4 ft	2.8 ft
2100 Low emissions	2.3 ft	1.7 – 3.1 ft	3.8 ft	5.9 ft	8.3 ft
2100 High emissions	3.4 ft	2.4 – 4.5 ft	5.3 ft	7.2 ft	10 ft

Estimates are based on (Kopp et al., 2014). Columns correspond to different projection probabilities. For example, the 'Likely Range' column corresponds to the range between the 17th and 83rd percentile; consistent with the terms used by the Intergovernmental Panel on Climate Change (Mastrandrea et al., 2010). *All values are with respect to a 1991-2009 baseline. These results represent a single way of estimating the probability of different levels of SLR; alternative methods may yield higher or lower estimates of the probability of high-end outcomes.*

[1] Mean Higher High Water (MHHW) is the average of the higher high water height each tidal day observed over the National Tidal Datum Epoch.

[2] Annual Exceedance Probability (AEP) is defined by NOAA as probability associated with exceeding a given amount in any given year once or more than once. For example, on average, the 1% level will be exceeded in only one year per century. The 99% level will be exceeded in all but one year per century, although it could be exceeded more than once in other years.

[3] For more details about the Rutgers University report being used in the FRAMES project, see: www.njadapt.rutgers.edu/resources/nj-sea-level-rise-reports.

In addition to SLR projections, the STAP also provided guidance for the conditions that practitioners could evaluate to assess exposure:

1. **Use at least two SLR estimates** for each year of interest to assess exposure to a range of future flood conditions, with one being a sea-level rise estimate in the 'Likely' range, and one being a high-end estimate.
2. **Project water levels for at least three flooding conditions**: permanent inundation, tidal flooding, and coastal storms, by adding the SLR projection to current or historic water levels.

NJ FRAMES Exposure Assessment Planning Guidelines

To arrive at these water levels, the project team followed one of the recommended processes discussed by the STAP panel and supported by NOAA's "What Will Adaptation Cost" guide to coastal resilience planning (Figure 1).[4]

1: Select Appropriate Local Sea Level Rise Scenarios	2: Develop High-Water-Level Event Scenarios	3: Choose Water Levels for Assessment
• **Three SLR Scenarios** • Low Emissions Central Estimate - 2.3 Ft. SLR by 2100 • High Emissions Central Estimate - 3.4 Ft. SLR by 2100 • High Emissions 1-in-20 Chance Estimate - 5.3 Ft. SLR by 2100	• **Three flood conditions** • Inundation • Tidal / Nuisance Flooding • Extreme Coastal Flooding (Storms) • Use NOAA Extreme Water Levels and Historic Storms • Add sea level rise to water levels for chosen years	Select 3-4 water-levels that represent a low, medium, high, and perhaps catastrophic water-level. Project team consensus on 3 water levels based on group discussion and preliminary exposure assessment

Figure 1. How to Estimate Future Flood Exposure

The NJ FRAMES project team used three SLR scenarios to establish reasonable boundaries for future scenarios. The lower bound of the emission scenarios reflect estimates that are reasonable under a low-emissions future in which global emissions are substantially reduced (2.3 ft. by 2100). The upper bound scenario (i.e. the high-end estimate) represents a 1-in-20 chance (5% probability) that SLR will meet or exceed 5.3 ft. by 2100. The project team then calculated the resulting water levels above MHHW using NOAA's AEP levels and historic storm tide records using the Sandy Hook, NJ tide gauge. The calculations are summarized in Table 3.

The NJ FRAMES project team selected from among the water levels between 1 and 14 feet above MHHW through a deliberative process among team members[5]. Water levels of 3, 7, and 12 feet above Mean Higher High Water (MHHW) were selected in order to allow for a balanced assessment of near-term and long-term risks across the three flood conditions for assessment. While the chosen water levels reflect the height of SLR, we will also consider the rate of SLR for those assets that are most sensitive at lower water levels, such as coastal wetlands with emergent marsh species. Lower water levels (1 or 2 feet) may be of particular concern for these ecological systems, therefore the project team will also include maps assessing marsh migration indices and other indicators of ecological resilience.

[4] You can find a copy of the "What Will Adaptation Cost" document at: https://coast.noaa.gov/data/digitalcoast/pdf/adaptation-report.pdf
[5] For a detailed discussion of the deliberations, please refer to the technical memo at: http://www.nj.gov/dep/oclup/docs/njframes-tech-memo.pdf

Table 3: Sandy Hook, NJ - Water Levels Above Current MHHW for Exposure Assessment

		Rounded Water Level	What High Water Level Condition Does This Height Represent?
Permanent Inundation (MHHW)		1 ft.	• 2030 Permanent Inundation - LE/HE – 0.8ft • 2030 Permanent Inundation - 1-in-20 chance HE – 1.1ft • 2050 Permanent Inundation - LE/HE - 1.4ft • Nuisance Flood Level - 1.48 ft. (NOAA National Weather Service)
	Coastal Flooding (Annual flood (99% Chance Flood), 10-year flood (10% Chance Flood)	2 ft.	• Current Annual Flood - 1.6ft • 2030 Annual Flood -LE/HE - 2.4ft • 2050 Permanent Inundation - 1-in-20 chance HE – 2ft • 2100 Permanent Inundation – - LE - 2.3ft
		3 ft.	• 2030 Annual Flood - 1-in-20 chance HE – 2.7ft • 2050 Annual Flood - LE/HE - 3.0ft • 2100 Permanent Inundation – HE - 3.4ft
		4 ft.	• Current 10% Chance Flood – 3.9ft • 2050 Annual Flood - 1-in-20 chance HE – 3.6ft • 2100 Annual Flood - LE - 3.9ft
		5 ft.	• 2030 10% Chance Flood - 1-in-20 chance HE – 5.0ft • 2050 10% Chance Flood – LE/HE - 5.3ft • 2100 Permanent Inundation - 1-in-20 chance HE – 5.3ft • 2100 Annual Flood - HE - 5.0ft
		6 ft.	• 2050 10% Chance Flood - 1-in-20 chance HE – 5.9ft • 2100 10% Chance Flood - LE - 6.2ft
	Coastal Strom Related Flooding (100-year flood (1% AEP), Hurricane Sandy)	7 ft.	• Current 100 Year Flood – 6.7ft • 2100 10% Chance Flood – HE - 7.3ft • 2100 Annual Flood - 1-in-20 chance HE – 6.9ft
		8 ft.	• Observed Hurricane Sandy water level – 8.3ft • 2030 1% Chance Flood - 1-in-20 chance HE – 7.8ft • 2050 1% Chance Flood – LE -/HE - 8.1ft
		9 ft.	• 2030 Hurricane Sandy water level -LE/HE - 9.1ft • 2050 1% Chance Flood - 1-in-20 chance HE– 8.7ft • 2100 10% Chance Flood 1-in-20 chance HE – 9.2ft • 2100 1% Chance Flood with LE - 9ft
		10 ft.	• 2050 Hurricane Sandy water level - LE /HE – 9.7ft • 2050 Hurricane Sandy water level - 1-in-20 chance HE – 10.3ft • 2100 1% Chance Flood with HE – 10.1ft
		11 ft.	• 2100 Hurricane Sandy water level - LE – 10.6ft
		12 ft.	• 2100 1% Chance Flood - 1-in-20 chance HE – 12ft. • 2100 Hurricane Sandy water level - HE – 11.7ft
		13 ft.	• N/A
		14 ft.	• 2100 Hurricane Sandy water level - 1-in-20 chance HE – 13.6ft

Notes: Blue = Permanent Inundation Range / Orange = Flood Range / Green = Coastal Storm Range. HE = High Emissions. LE = Low Emissions. 1-in-20 Chance Estimate = High Emissions Estimate.