2015 NACCS-Derived Inundation Surfaces for Rhode Island Incorporating the Effects of Both Storm Surge and Tide

Purpose:

Impacts of recent coastal storms such as Superstorm Sandy (October 2012) reveal the need to address the vulnerability of populations, infrastructure, and resources at risk from storm surge throughout Rhode Island. The U.S. Army Corps of Engineers (USACE) completed the North Atlantic Comprehensive Study (NACCS) in 2015, which provides new tools and information to assess coastal storm and flood risks. Information from the NACCS was integrated into STORMTOOLS. These coastal inundation modeling results can be used by state government and local communities to identify storm surge flooding risks and develop adaptation strategies to reduce those risks now and into the future.

Objective:

The vision for STORMTOOLS is to provide access to a suite of high-resolution coastal planning tools (numerical models, etc.) that can be used to develop adaptation policies and actions to reduce storm surge vulnerability. The STORMTOOLS inundation mapping effort represents the first step in the development of an integrated toolset that includes the development of simplified flood maps for varying storm return periods and sea level rise scenarios, incorporating the effects of both storm surge and tide as derived from the NACCS.

These NACCS-derived flood surfaces correct major deficiencies with the widely used bath tub models by taking in to account the shape/orientation of the Narragansett Bay basin and the resulting funneling effects on water levels during storm events (Spaulding, 2014). From this work, two important points emerge:

1) Surge heights increase as one moves north from Newport to Providence; and

2) The relationship between water levels at Newport and Providence is predominantly linear.

Understanding this, as long as the water level is known at the Newport tide gauge, values can be interpolated for any location within the Bay. For a complete understanding of the theory, methods and limitations of this work, users should review both the Scaled Sea Level Rise Summary document and the draft report detailing the methodology employed for the Simplified Flood Inundation Mapping.

Table 1 lists the inundation surfaces developed as part of this work for multiple storm events and sea level rise (SLR) scenarios. In addition, inundation layers were generated for the 4 largest historic storms to impact the state and illustrate Rhode Island's current level of vulnerability if an event with a similar magnitude were to strike again today.

Table 1: Inundation layers available through STORMTOOLS

Storm Return Period	Sea Level Rise Scenarios (ft)
Nuisance Events	
1-Year	0, 1, 2, 3, 5, 7
2-Year	0, 1, 2, 3, 5, 7
3-Year	0, 1, 2, 3, 5, 7
5-Year	0, 1, 2, 3, 5, 7
10-Year	0, 1, 2, 3, 5, 7
Major Events	
25-Year	0, 1, 2, 3, 5, 7
50-Year	0, 1, 2, 3, 5, 7
100-Year	0, 1, 2, 3, 5, 7
500-Year	0
Historic Events	
Hurricane of 1938	0
Hurricane Carol (1954)	0
Hurricane Bob (1991)	0
Superstorm Sandy (2012)	0

Storm Return Period Analyses:

The North Atlantic Comprehensive Study (NACCS) performed simulations of 1050 synthetic tropical storms using a fully coupled ADCIRC/WAM/STWAVE with a very high resolution grid primarily covering the Mid Atlantic study area (Cialone, 2015). The grid resolution was as high as 50 m in flood inundated areas in Narragansett Bay and along the southern RI shoreline and associated coastal ponds. Simulations were performed for surge only and surge plus tidal cases. Model predictions were saved at 18,000 grid locations; 1000 in RI. Return period analyses were performed by USACE for each save point. Values for the mean and upper and lower 95% confidence intervals were provided.

In the present effort, the data from the NACCS RI save points were analysed and spatially scaled to develop a series of projected flood inundation surfaces for coastal RI (Table 2; Table 3). Mean projections were used for events with a return period of 10 years or less, while the upper 95% confidence interval (CI) values were applied to events with return periods 25 years and greater to provide an extra measure of protection. By their very nature, mean projections will be wrong 50% of the time. In adopting the 95% CI, planners can be 95% certain that storm surge inundation will not exceed the values contained within these surfaces. Details on the application and validation are provided in Spaulding et al (2015). Background information on the North Atlantic Coastal Comprehensive Study can be found in the documents: NACCS Resilient Adaptation to Increasing Risk and NACCS Flood Guidance.

Table 2: NACCS Storm surge height vs return period for Newport, Rhode Island

NEWPORT
Storm surge height vs return period based on NACCS estimates
Save Point #7700
Latitude 41.50500
Longitude -71.32667

Return Period (yrs)	Surge Only: Mean (m)	Surge Only: Mean (ft)	Surge Only: Upper 95% Confidence (m)	Surge Only: Upper 95% Confidence (ft)	With Tide: Mean (m)	With Tide: Mean (ft)	With Tide: Upper 95% Confidence (m)	With Tide: Upper 95% Confidence (ft)
1	0.76	2.5	1.62	5.3	1.31	4.3	2.20	7.2
2	1.00	3.3	1.86	6.1	1.50	4.9	2.45	8.0
3*					1.58	5.2		
5	1.31	4.3	2.23	7.3	1.75	5.7	2.70	8.9
10	1.54	5.1	2.55	8.4	1.95	6.4	2.94	9.6
20	1.77	5.8	2.85	9.4	2.16	7.1	3.23	10.6
25*							3.30	10.8
50	2.10	6.9	3.24	10.6	2.47	8.1	3.62	11.9
100	2.42	7.9	3.58	11.7	2.76	9.1	3.93	12.9
200	2.76	9.1	3.92	12.9	3.09	10.1	4.26	14.0
500	3.19	10.5	4.35	14.3	3.52	11.5	4.70	15.4
1000	3.50	11.5	4.66	15.3	3.83	12.6	5.01	16.4
2000	3.77	12.4	4.93	16.2	4.11	13.5	5.29	17.4
5000	4.05	13.3	5.21	17.1	4.44	14.6	5.61	18.4
10000	4.24	13.9	5.40	17.7	4.65	15.3	5.82	19.1

* Denotes interpolated return period not available in NACCS Study.
Denotes water levels at Newport used for the return period analyses.

Table 3: Return period analysis and water level scaling between Newport, RI and Providence, RI.

Storm Return Period	Water Level at Newport (ft)	Up-Bay Scaling Factor
	Nuisance Events	
1-Year	4.3	1.30
3-Year	5.2	1.30
5-Year	5.7	1.30
10-Year	6.4	1.30
	Major Events	
25-Year	10.8	1.30
50-Year	11.9	1.30
100-Year	12.9	1.40
500-Year	15.4	1.44

Historic Events		
Hurricane of 1938	11.5	1.30
Hurricane Carol (1954)	8.8	1.56
Hurricane Bob (1991)	6.0	1.30
Superstorm Sandy (2012)	6.2	1.10

Sea Level Rise (SLR) Scenarios:

Figure 1 displays SLR projection curves at the Newport, RI tide gauge. While storms and the resulting impacts generally attract the most attention, these are episodic events - sporadic and of short duration. By contrast, the effects of SLR are regular, lasting and coincide with the daily tidal cycle. Table 4 lists SLR predictions at the Newport tide gauge based on NOAA's high rate curve estimates, and translates that information into associated planning horizons.

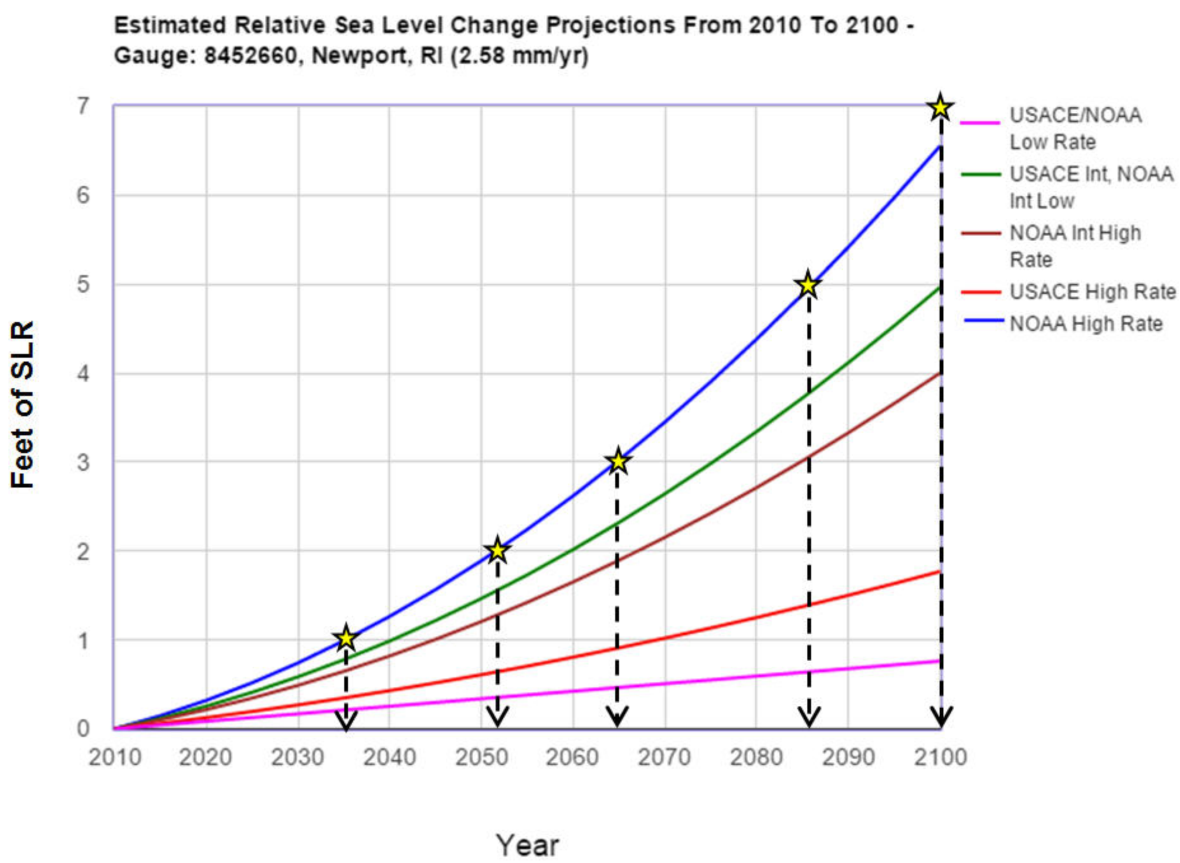

Figure 1: Sea level rise prediction curves for Newport, RI. Sea Level Change Curve Calculator, US Army Corps of Engineers: http://www.corpsclimate.us/ccaceslcurves.cfm

Table 4: Sea Level Rise prediction and planning horizons

SLR Scenario (ft)	Projected Year	Planning Horizon
0	Current	Current
1	2035	25-Year
2	2055	45-Year
3	2065	55-Year
5	2085	75-Year
7	2100	100-Year

Data Sources:

- Topographic data were derived from detailed LiDAR data collected as part of the 2011 Northeast LiDAR Project and are available from the Rhode Island Geographic Information System (RIGIS) website: http://www.edc.uri.edu/rigis/data/data.aspx?ISO=elevation
- Near-shore bathymetric soundings were compiled from multiple sources including the U.S. Army Corps of Engineers (JALBTCX 2007, 2010) and the National Ocean Service (NOS). NOS Hydrographic Survey data are accessible through the National Geophysical Data Center's data portal: http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html
- Conversion of elevation between vertical datums (MHHW, MLW, NAVD88, etc.) was accomplished using the NOAA VDatum vertical transformation software. http://vdatum.noaa.gov/
- Water level vs return period (mean and upper and lower 95% confidence limit values) from NACCS save point station at Newport, RI (# 7700).
- SLR curves and planning horizons were derived using the U.S. Army Corps of Engineers Sea Level Change Curve Calculator: http://www.corpsclimate.us/ccaceslcurves.cfm

Geospatial Reference:

Coordinate System: RI Stateplane
Horizontal Units: Feet
Horizontal Datum: NAD83
Vertical Units: Feet
Vertical Datum: NAVD88

Data Distribution Format:

All in inundation surfaces are distributed it both raster and vector forms. While very similar, each format is best suited for particular uses:

Raster Datasets-

- There are 2 datasets for each storm event/ SLR scenario – 1 that shows the extent and depth of flooding, and 1 that shows adjacent low lying areas greater than 1 acre that may or may not be flooded. Both datasets should be viewed together to provide a complete picture of projected impacts for each scenario. Inundation surfaces display both the extent and maximum depth of water predicted for each event. Low lying areas do not have associated water depths, they are merely using to highlight areas of possible concern that require additional investigation.
- These data are best used to visualize projected water depths.

Vector/Polygon Datasets-

- Vector datasets are very similar to their raster counterparts but have been smoothed slightly to reduce the number of polygons created and minimize the "salt and pepper" effect that occurs when converting raster data to vector data.
- The flood extent polygons and the adjacent low lying areas have been combined into a single dataset. Use the "**CLASS**" attribute within the data table to indicate which areas are "Inundated" or "Low lying".
- These data are best use when only the flood extent is of importance or when users would like to perform other spatial analyses such as selecting other features that might be impacted; i.e. how many homes and businesses are potentially affected by a 100-year storm event if there were 7 feet of sea level rise?

Data Application:

Putting these data to work requires three steps:

1. Identify the planning horizon
2. Choose an appropriate SLR scenario
3. Select a storm event

For example – A community is looking to reduce their vulnerability to major storm events by updating their comprehensive plan to account for sea level rise. So, following the 3-steps outlined above:

a) What is the planning horizon? 25 Years
b) Which SLR scenario is most appropriate? 1-Foot (according to the *NOAA High Rate* SLR curve in Figure 1).
c) What level of storm protection is most important to my community? A 100-year event, or 1% chance.

Gather the appropriate data – In this case it would be the 100yr, SLR 7 suite of information.

Limitations:

Following the NOAA Inundation Mapping protocol (NOAA, 2012), limitations of the results include:

- These data are primarily for planning, educational, and awareness purposes only and should not be used for site-specific analysis, navigation, or permitting.
- The mapping does not incorporate future changes in coastal geomorphology (coastal erosion) and assumes present conditions (no adjustments for climate change) will persist, which will not be the case.
- The digital elevation model used to map sea level rise and flooding does not incorporate a detailed hydro-connectivity analysis, or engineering grade hydrologic analysis. Therefore, hydrologically unconnected areas of inundation are still displayed if they are in close proximity to flooded areas, though symbolized differently (noted as *low lying*) than hydrologically connected inundation. These areas require additional on-site screening to determine if flooding will occur.
- The digital elevation model used for the analyses represents the best available topographic/bathymetric available for RI. However, these data are only an approximation of the true landscape and artifacts within the data might indicate areas of flooding where none will actually occur. Local knowledge and experience must be used be used to inform any additional analysis or decision-making based upon these data.

Disclaimers:

The user should recognize that these maps are based on models that estimate coastal inundation. The maps maybe inaccurate or contain errors or omissions. The Rhode Island Geographic Information System (RIGIS) and the University of RI, Environmental Data Center (EDC), which serves these maps, does not guarantee the accuracy or reliability of the data generated from this service. The user assumes full responsibility for the risks and damages that might result from using these maps or the underlying data. These maps are not flood insurance rate maps and should not be used in place of them. Official FEMA Flood Insurance Rate Maps for RI are provided at http://www.riema.ri.gov/prevention/floods/mapping.php.

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Project Credits:

- Federal Emergency management Agency

- National Oceanographic and Atmospheric Administration
- RI Coastal Resources Management Council
- URI Coastal Resources Center
- URI Environmental Data Center
- URI Ocean Engineering
- U.S. Army Corps of Engineers

References:

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