

# METHOD DESCRIPTION



## Detailed Method for Mapping Sea Level Rise Inundation

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NOAA Office for Coastal Management  
(843) 740-1200  
*coast.noaa.gov*

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### Introduction

This document describes the mapping process used by the NOAA Office for Coastal Management to map sea level rise inundation for the Sea Level Rise Viewer. Generally, this process can be described as a modified bathtub approach that attempts to account for local and regional tidal variability and hydrological connectivity.

### Goals of Mapping

- Use best publically available and accessible elevation data
- Map literature-supported levels of sea level rise
- Map sea level rise on top of mean higher high water (MHHW)
- Incorporate local and regional tidal variation of MHHW for each area
- Evaluate inundation for hydrological connectivity
- Preserve hydrologically unconnected areas greater than one acre in size, but display separately from hydrologically connected inundation

### Caveats and Assumptions

- These data are 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 and assumes present conditions will persist, which will not be the case.
- The digital elevation model used to map sea level rise does not incorporate a detailed pipe network analysis, or engineering grade hydrologic analysis (for example, culverts and ditches may not be incorporated resulting in incorrectly mapped areas). Therefore, hydrologically unconnected areas of inundation are still displayed, though symbolized differently than hydrologically connected inundation.

## Tidal Surface Creation

To incorporate tidal variability within an area when mapping sea level rise, a “modeled” surface (or raster) is needed that represents this variability. In addition, this surface must be represented in the same vertical datum as the elevation data, which is typically the orthometric datum of NAVD88 (North American Vertical Datum of 1988). Once created, this surface can be used as a current conditions surface upon which sea level rise can be added.

Currently, there are two primary ways this surface can be created. The first and simpler approach is to interpolate a surface using tide gauges and their associated vertical datum conversions. The second and more accurate approach is to use NOAA’s vertical datum conversion software, VDatum (<http://vdatum.noaa.gov>), which was used by the NOAA Office for Coastal Management. Each process is described below.

### Tide Gage Approach

- Use <http://tidesandcurrents.noaa.gov> to determine which tide gauges are available within the area.
- Select tide gauges where the tidal-to-orthometric-datum relationship or conversion has been calculated.
- Create a point shapefile of the selected tide gauges using their latitude and longitude information and the datum conversion factor/number.
- Interpolate a raster (inverse distance weighted, or IDW; natural neighbor) for the area using the point shapefile.

#### Considerations

- Include enough tide gauges so that the interpolated surface covers the area of interest.
- Use a raster resolution that will capture the tidal variability for the area: 500 meters (m) or more, up to 3 kilometers (km).

### VDatum Approach

- Create a grid of points; this can be generated in a number of ways including converting raster cells to points [Raster to Point]. Point spacing should be on the order of 500 m (1500 feet); smaller grids will increase the size of the file but add very little real improvement. Points should be set to have an elevation of zero.
- Use VDatum\* to convert the gridded points to the chosen tidal datum (MHHW). VDatum will only assign values to the points within its model extents; this means inland points will not typically have a real elevation number and will be assigned a -9999 value. Defining the elevation of the inland points is an extra step covered under “Extension of VDatum Water Surface Inland” below.
- Process parameters and steps within VDatum
  1. Select area of interest from drop-down menu in VDatum.
  2. Define **Datum Information** parameters:
    - Input Vertical Datum: Desired Tidal Datum (MHHW)
    - Output Vertical Datum: Datum of Digital Elevation Model (NAVD88)

3. Input File: X,Y,Z data reflecting points with elevation set to zero.
  4. Output file: X,Y,Z data will reflect points with elevations representing the offset between datums.
- Create a triangulated irregular network (TIN) or interpolated surface (IDW, natural neighbor) from the output points. This is the MHHW water surface in NAVD88 values.
  - In most cases, the VDatum water surface will stop near the shoreline; if the area of analysis extends significantly far inland (e.g., Florida Everglades), then the water surface will need to be extended inland.

\*For a detailed guide to using VDatum, visit <https://vdatum.noaa.gov/docs/userguide.html>.

#### *Extension of VDatum Water Surface Inland*

- **Transect Method** – create cross-shore (perpendicular to shoreline) transects that extend inland just past the area of analysis. Transect spacing and locations are at the discretion of the user but should capture the variation in tidal surface; more complex tidal areas will require more transects than simple tidal regimes. Using the water surface elevations along the transect, extend the general tidal trends inland and assign values (substitute transect values for -9999 values) to the grid points nearest the transect's path – here again, the number of points along the transect are at the discretion of the user and may depend on local variations in the tidal surface elevations. Generate a new surface from the combined VDatum (original values) and transect-generated points.
- **Interpolation Method** – in some cases an interpolated surface can be used instead of the transect method. These cases include areas where valid VDatum points exist on several sides of the area of interest (i.e., not a straight stretch of shoreline). For these areas, a natural neighbor algorithm is a good place to start. This will generate a fairly smooth surface. To create a more generalized surface, a 1<sup>st</sup> or 2<sup>nd</sup> order trend surface can be calculated.

#### *Considerations*

- Make the initial raster large enough to cover the area of interest.
- Use a raster resolution that will capture the tidal variability for the area: 500 m or more, up to 3 km.

## **Detailed Mapping Process**

This process is based on and describes tools and inputs in ESRI's ArcGIS software. Specifically, this process is intended for ArcGIS 10.3.1 and requires the Spatial Analyst extension.

### **Inputs**

- Digital elevation model (DEM)
- Tidal surface in NAVD88 values
- Sea level rise values

## Process

1. Add desired sea level rise (SLR) amount to tidal surface grid.  
Spatial Analyst > Math > Plus
  - Input raster or constant value 1 = tidal surface
  - Input raster or constant value 2 = SLR amount
  - Output raster = surface\_x (where “x” is the SLR amount)
2. Subtract DEM values from water surface to derive initial inundation depth grid.  
Spatial Analyst > Single Output Map Algebra
  - Map Algebra expression:  $\text{con}(\text{DEM} \leq \text{surface\_x}, \text{surface\_x} - \text{DEM})$
  - Output raster = depth\_x
3. In preparation for evaluating connectivity, create single value DEM to show inundation extent.  
Spatial Analyst > Single Output Map Algebra
  - Map Algebra expression:  $\text{con}(\text{DEM} \leq \text{surface\_x}, 1)$
  - Output raster = single\_x<sup>4</sup>.
4. Evaluate connectivity of extent raster.  
Spatial Analyst > Generalization > Region Group
  - Input raster = single\_x
  - Number of neighbors to use = 8
  - Zone grouping method = Within
  - Output raster = clumped\_x
5. Extract connected inundation surface to be used as a mask for the original depth grid.  
Spatial Analyst > Extraction > Extract by Attributes
  - Input raster = clumped\_x
  - Where clause: “Count” = maximum value<sup>1</sup>
  - Output raster = connect\_x
6. Derive low-lying areas greater than an acre.  
Spatial Analyst > Extraction > Extract by Attributes
  - Input raster = clumped\_x
  - Where clause: “Count” > 40<sup>2</sup>
  - Output raster = lowlying\_x
7. Create depth grid for connected areas.  
Spatial Analyst > Extraction > Extract by Mask
  - Input raster = depth\_x
  - Input raster or feature mask data = connect\_x
  - Output raster = con\_depth\_x

*Optional visualization method to show only impact on land.<sup>3</sup>*

1. Spatial Analyst > Reclass > Reclassify
  - Input raster = connect\_0
  - Reclass field = Value
  - Value becomes NoData
  - NoData becomes 1
  - Output raster = mask

2. Spatial Analyst > Extraction > Extract by Mask
  - Input Raster = con\_depth\_x
  - Input raster or feature mask data = mask
  - Output raster = extract\_x

**Notes:**

<sup>1</sup> Maximum Value is obtained by clicking **Get Unique Values** within the SQL Query Builder; this value represents connected inundation from the open ocean. Some instances may require the user to select more than one Maximum Value depending on the data.

<sup>2</sup> The value of 40 is based on the use of 10 m grid cells;  $1 \text{ acre} = 4046.85 \text{ m}^2$ ,  $4046.85 \text{ m}^2 / 100 \text{ m}^2 = 40.46$ ; this value may change depending on the resolution of the DEM.

<sup>3</sup> This process must first be executed using data reflecting “current” conditions (i.e. SLR = 0); the mask based upon the “0 SLR” is then used to obtain raster reflecting different levels of sea level rise.