SLR Calculator:
Sea Level Rise (SLR) Inundation Surface Calculator
Add-in for ArcGIS Desktop 10.1

Florida Sea Level Scenario Sketch Planning Tool
Version 1.5.2, November 2014
University of Florida GeoPlan Center
http://sls.geoplan.ufl.edu

Contents

Please read these instructions carefully. Before using the SLR Calculator, it is recommended that you review the report entitled "Development of a Geographic Information System (GIS) Tool for the Preliminary Assessment of the Effects of Predicted Sea Level and Tidal Change on Transportation Infrastructure**"**, FDOT Contract # BDK75 977-63, available from the project website: http://sls.geoplan.ufl.edu/documents/.

1. Description

The Sea Level Rise (SLR) Inundation Surface Calculator assists users in creating GIS layers representing potentially inundation areas due to various sea level rise scenarios. The calculator uses the U.S. Army Corp of Engineers (USACE) sea level change projection methodology, as specified in Engineer Circular EC 1165-2-212, along with National Oceanic and Atmospheric Administration (NOAA) tide gauge data and sea level trends. For simplicity sake, this User Guide will refer to the calculator as the "SLR Calculator". The UF GeoPlan Center developed the SLR calculator with funding from the Florida Department of Transportation Office of Policy Planning. The SLR Calculator is part of the Florida Sea Level Scenario Sketch Planning Tool, which was created to facilitate the identification of transportation infrastructure potentially at risk from projected sea level changes.

The SLR calculator is an add-in for ArcGIS Desktop 10.1, which is required to run this tool, along with the Spatial Analyst extension. An add-in is a customized tool or toolbar that can be added to an ArcGIS for Desktop application (i.e. ArcMap, ArcCatalog, etc) to run custom GIS functions. Intermediate GIS expertise is recommended for using the SLR calculator. The add-in calls a python script, which processes the input and output parameters chosen.

1.1. What's New in Version 1.5.2

- Added input for DEM Vertical Units, which converts the vertical units (feet or meters) of the input DEM to inches to correspond with the USACE sea level rise projections, which are stored in inches for the SLR calculator. If the input DEM is inches, then no conversion will take place.
- Various bug fixes, including: "No bathtub" errors when running only the hydro-connectivity outputs; overwrite errors – if the output file name already exists, the calculator will now increment the file name with a unique ID.
- "Add to Map" function added in dialog after layers have been created.
- Some of the calculator inputs have been reordered.
- Vector (polygon) output added for bathtub model.

2. Software Requirements

ESRI ArcGIS Desktop 10.1, with Spatial Analyst

3. Data Inputs Included with Calculator

The SLR Calculator includes an embedded table of U.S. Army Corps of Engineers sea level change projections in inches and optionally, the calculator can be downloaded with or without a Digital Elevation Model (DEM). Hence, the SLR calculator can be used with no additional data inputs. Users do have the option of inputting their own DEM for processing inundation surfaces. The SLR calculator accepts DEM vertical units in inches, feet, or meters and in the calculator dialog, users must indicate the vertical units of the input DEM. If feet or meters are selected, the SLR calculator will convert from feet or meters to inches to correspond with the USACE sea level rise projections, which are stored in inches for the SLR calculator. If the input DEM is inches, then no conversion will take place.

3.1. USACE Sea Level Change Projections

The SLR calculator uses the U.S. Army Corps of Engineers (USACE) sea level change projection methodology, as specified in Engineer Circular EC 1165-2-212, along with National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services (COOPS) tide gauge data and sea level trends. Sea level rise projection values were compiled by the GeoPlan Center using the Excel version of the USACE Projection Curve Calculator (available at http://www.corpsclimate.us/ccaceslcurves.cfm). **The projection values used in the SLR Calculator are in inches.** Projection rates were calculated for three potential scenarios based on the rate of sea level change: "low" (historic/ linear); "medium" (intermediate/ Curve II) and "high" (Curve III). The historic projection is a linear rate of change assuming a continuation of rates of sea level change reported by NOAA. Intermediate and high projected rates were derived from scenarios originally developed by the NRC and modified by the USACE to account for the most recent IPCC projections and the local rate of vertical land movement (i.e. relative sea level rise).

For more information on the NOAA tide gauge data, see: http://tidesandcurrents.noaa.gov/. For more information on the USACE methodology and Engineer Circular EC 1165-2-212, see: http://www.corpsclimate.us/ccaceslcurves.cfm.

The embedded table of sea level change projections includes data for 14 Florida tide stations at decadal intervals from 2020 – 2100, three projection curves (low/ medium/ high), and five tidal datums. The sea level change projections were translated to the North American Vertical Datum of 1988 (NAVD88), using the correction unique to each tide station. In addition, the GeoPlan Center created sea level change projections for FDOT Districts using an area weighted mean method which averages data from multiple tide gauges (those gauges which are closest to the corresponding FDOT District). For more information on this process, see the final report entitled "Development of a Geographic Information System (GIS) Tool for the Preliminary

Assessment of the Effects of Predicted Sea Level and Tidal Change on Transportation Infrastructure**",** FDOT Contract # BDK75 977-63, available from the project website: http://sls.geoplan.ufl.edu/documents/

3.2. NOAA Tide Gauge Data

Data from fourteen NOAA Florida tide gauges were used. All of these gauges have long-term data records and most meet the 40-year minimum data record recommendation per the USACE guidance (2011, p. B-3). The 40-year period covers two tidal datum epochs which minimizes error in calculating mean sea level trends. An epoch spans a 19-year time period and is considered the official time range over which tide observations and mean values for datums are calculated. The current National Tidal Datum Epoch (NTDE) covers the time period 1983 to 2001.

NOAA Florida Tide Gauge Locations used in SLR Calculator

Station	Station ID	Latitude	Longitude	Year	Mean SLC trend (mm/yr)
Apalachicola	8728690	29° 43.6' N	84° 58.9' W	1967	1.38
Cedar Key	8727520	29° 8.1' N	83° 1.9' W	1914	1.8
Clearwater Beach	8726724	27° 58.7' N	82° 49.9' W	1973	2.43
Daytona Beach Shores[1]	8721120	29° 8.8' N	80° 57.8' W	1925	2.32
Fernandina Beach	8720030	30° 40.3' N	81° 27.9' W	1897	2.02
Fort Myers	8725520	26° 38.8' N	81° 52.2' W	1965	2.4
Key West	8724580	24° 33.3' N	81° 48.4' W	1913	2.24
Mayport	8720218	30° 23.8' N	81° 25.8' W	1928	2.29
Miami Beach[1]	8723170	25° 46.1' N	80° 7.9' W	1931	2.39
Naples	8725110	26° 7.9' N	81° 48.4' W	1965	2.02
Panama City	8729108	30° 9.1' N	85° 40.0' W	1973	0.75
Pensacola	8729840	30° 24.2' N	87° 12.6' W	1923	2.1
St. Petersburg	8726520	27° 45.6' N	82° 37.6' W	1947	2.36
Vaca Key	8723970	24° 42.7' N	81° 6.3' W	1971	2.78
[1]not currently in operation					

3.3. Digital Elevation Model (Option Download)

The SLR calculator can be downloaded with or without a Digital Elevation Model (DEM) dataset. Depending on the download package you selected, the zip included either a DEM for the entire State of Florida or a DEM clipped to one of the seven FDOT Districts.

The DEM was compiled by the UF GeoPlan Center by mosaicking the best available data from four different sources (including Lidar-derived elevation data for coastal areas) in order to get coverage for the State of Florida. The process steps are described in detail in the metadata included with the dataset. In addition, the DEM is available for download from the Florida Geographic Data Library via http://www.fgdl.org, under the "Elevation" theme, or by using the "DEM" keyword, with a filename that begins with “FLIDAR_MOSAIC”. DEMs are available with vertical units in inches, centimeters, feet and meters.

4. Installing the Calculator

After downloading the calculator zip file, navigate to the location of the downloaded file. Then choose one of the following install methods:

4.1. Installation Using Auto ArcGIS Add-In Installation Utility

1. Unzip SLR_Calculator.Zip.
2. Double-click the SLR Calculator .esriaddin File
3. Start Arcmap
4. Add "SLR Toolbar" (Customize --> Toolbars --> Check "SLR ToolBar")
5. Click SLR Calculator button on toolbar to open application window

4.2. Installation - Manual

1. Unzip SLR_Calculator.Zip
2. Open ArcMap
3. Click "Customize" on menu bar
4. Click "Add-In Manager"
5. Select Options Tab
6. Click Add Folder "Add Folder" and browse to folder location of unzipped .esriaddin
7. Select Add-Ins Tab Choose SLR Surface Calculator and Click Customize
8. Check "SLR Toolbar" and Close
9. Click SLR Calculator button on toolbar to open application window

Important note: If you have installed a previous version of the calculator, use the Manual Installation Method (4.2). Once you open the Add-In Manager, delete the old SLR calculator add-in before installing the new one.

5. Using the Calculator

Six input parameters and two output parameters are required to run the calculator. The input parameters define the Sea Level Scenario(s) for which you are creating inundation layers. The output parameters define the file format and location of where to save the layers.

SLR Calculator Dialog Overview

Input Parameters

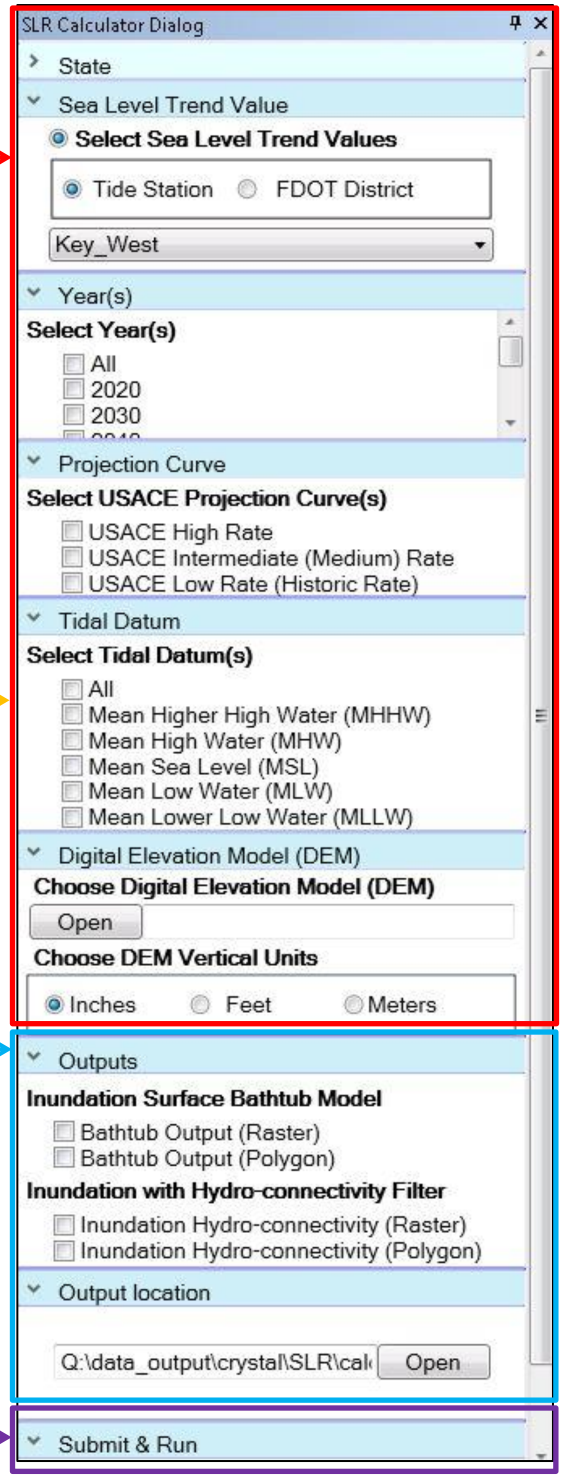
- State
- Sea Level Trend Value
- Year
- Projection Curve
- Tidal Datum
- Digital Elevation Model (DEM)

Click on the arrows to expand/ collapse details for each

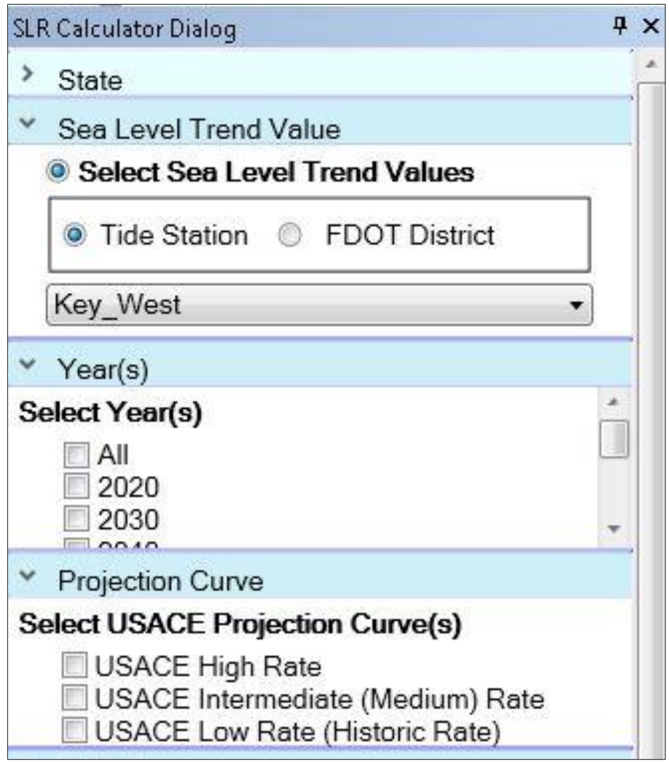
Output Parameters

- Model Outputs
- Output Location

Submit/ Run



5.1. Choosing Input Parameters (State, Sea Level Trend Value, Year, Projection Curve)



State:

Select the State in which you want to create inundation surfaces. This version of the calculator only includes data for Florida.

Sea Level Trend Value:

Tide Station: User has the option to choose one of 14 NOAA tide stations (located in Florida) in order to use the sea level trends and water levels associated with that specific tide station. Only one tide station can be chosen at a time. The 14 stations available have long-term data records.

FDOT District**:** District trend values were calculated using an average weighted mean (AWM) method for each FDOT District. The AWM method summarizes data from the tide stations closest to each FDOT District in order to give a consistent SLR value for that entire district's geographic area. For more information on these methods, see the report referenced in this document: "Development of a Geographic Information System (GIS) Tool for the Preliminary Assessment of the Effects of Predicted Sea Level and Tidal Change on Transportation Infrastructure**",** FDOT Contract # BDK75 977-63:

Year(s):

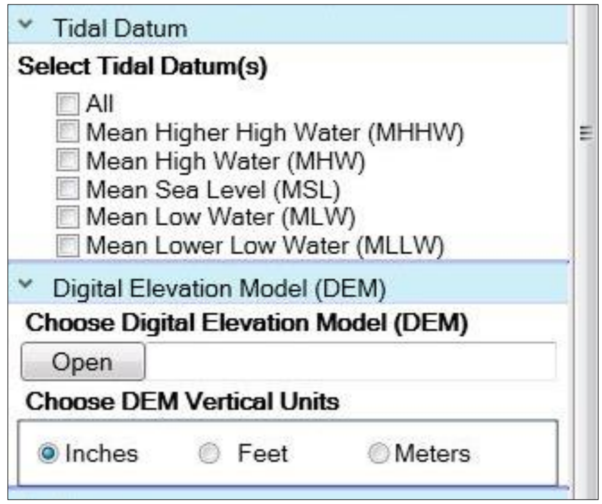
Select the time periods (decades) for which inundation surfaces will be created. Decades 2020 – 2100 are available. One or multiple years can be selected. The "All" checkbox will select all decades. For each decade selected, one layer will be created.

Projection Curve:

Select USACE Projection Curve to use for inundation calculation. One or multiple curves can be selected. For each curve selected, one layer will be created.

- USACE High Rate
- USACE Intermediate (Medium) Rate
- USACE Low Rate (Historic Linear Rate)

5.2. Choosing Input Parameters (Tidal Datum, Digital Elevation Model)



Tidal Datum:

Select the tidal datum(s) which to add the projected sea level change. The tidal datum values are utilized as constant offsets to the sea level change projections calculated for each rate and time period. For each datum selected, one layer will be created.

- Mean Higher High Water (MHHW): The average of the higher high water height of each tidal day observed over the NTDE.
- Mean High Water (MHW): The average of all the high water heights observed over the NTDE.
- Mean Sea Level (MSL): The arithmetic mean of hourly heights observed over the NTDE.
- Mean Low Water (MLW): The average of all the low water heights observed over the NTDE.
- Mean Lower Low Water (MLLW): The average of the lower low water height of each tidal day observed over the NTDE.

For more information on tidal datums, refer to NOAA's website:
http://tidesandcurrents.noaa.gov/datum_options.html

Digital Elevation Model (DEM)

Select a Digital Elevation Model from which to create the inundation surfaces. As discussed in Section 3 of this Guide, this calculator can be downloaded with or without a Digital Elevation Model (DEM) dataset. Depending on the download package selected, the zip included either a DEM for the entire State of Florida or a DEM clipped to one of the seven FDOT Districts.

To choose the DEM included with your download: navigate to the location where you saved the Add-in Zip file. There you will find the "DEM" folder, in which a File Geodatabase (FGDB) with the DEM raster will be located. Select the DEM raster within the FGDB.

The SLR calculator accepts DEM vertical units in inches, feet, or meters, and in the calculator dialog, users must indicate the vertical units of the input DEM. If feet or meters are selected, the SLR calculator will convert from feet or meters to inches to correspond with the USACE sea level rise projections, which are stored in inches for the SLR calculator. If the input DEM is inches, then no conversion will take place.

Important Note: The DEM determines the spatial extent of the output inundation layers

5.3. Choosing Output Parameters

The output parameters define the inundation models to be created and the file format (raster or vector) and location of the output layers. The inundation models include (1) a bathtub model of inundation and (2) an enhanced inundation model with a hydro-connectivity filter applied. The bathtub method identifies all inland areas with an elevation below that of the SLR projection value as potentially inundated areas due to sea level rise.

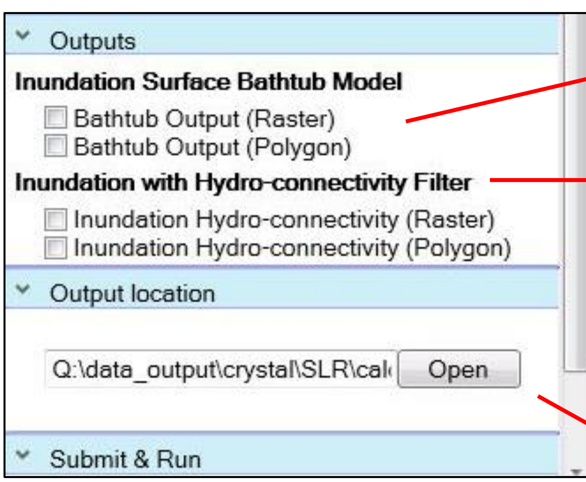
The hydrologic connectivity filter attempts to refine the bathtub method by evaluating the relationship of the potentially inundated areas to oceans and connected waterways. The result of the filter is to remove isolated areas, which were identified in the bathtub model but are not as likely to be inundated due to their isolation from the ocean or gulf. For more information and technical methods, please see the final report referenced in this guide.

Both the bathtub inundation model and the enhanced inundation model with the hydro-connectivity filter can be saved as a raster or as a vector ArcGIS polygon feature class.

<u>Important Note:</u> Output data layers can currently only be saved to a File Geodatabase (FGDB).

Outputs & Output Location

The outputs parameters define the output models to be created and the location where to save the inundation layers. All layers are saved as feature classes in a File Geodatabase. One or multiple output types can be selected.



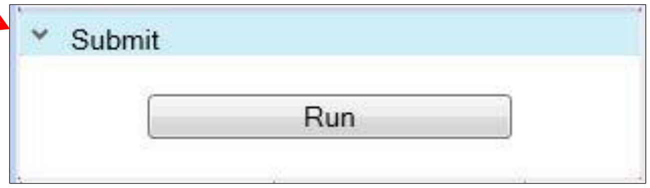
Check for creation of bathtub inundation surface model in raster or vector (polygon) format. Both outputs can be chosen.

Check for creation of inundation model with hydro-connectivity filter in raster or vector (polygon) format. Both outputs can be chosen.

Navigate to the File Geodatabase in which to save the output inundation layers or use the dialog to create an output File Geodatabase.

5.4. Running the Calculator

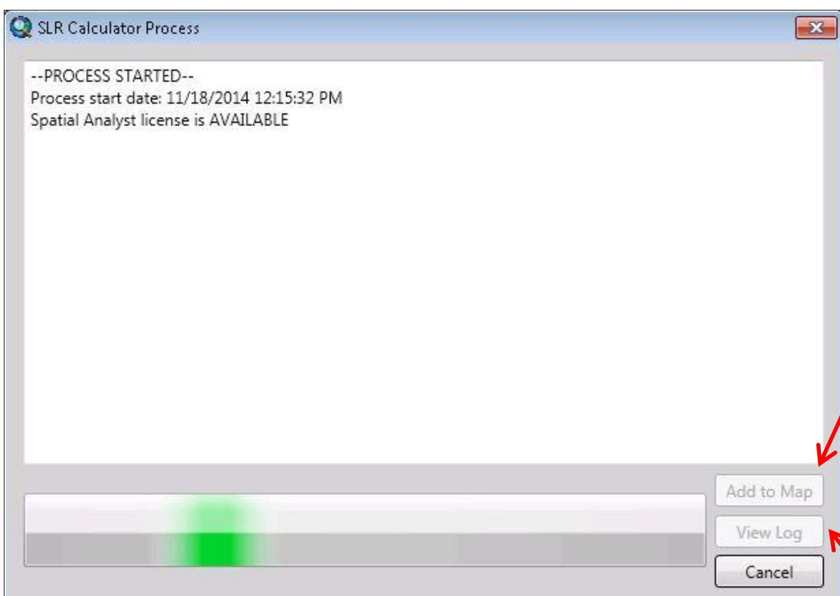
Once the input and output parameters have been selected, the SLR calculator is ready to run. Simply hit the "Run" button at the very bottom under the Submit section. You may need to click on the arrow to the left of "Submit" to expand the window and reveal the Run button.



5.4.1. Progress Dialog Window & Logging

Shortly after the calculator is submitted, a progress dialog window will open to show the progress. Please be patient, the process will take some time to complete, depending on the parameters chosen, the geographic extent of the input DEM, and the specifications of your computer (RAM, CPU, etc). If you want to cancel the process, simply hit the "Cancel" button.

Both the progress dialog window and the log file will display the process start time, the process end time, and the elapsed running time. Taking note of these times and the parameters chosen can help you plan for future iterations of the calculator.



Add to Map: This button is greyed out (disabled) while processed are running. Once processes are complete, the button will enable and allow the user to add the calculator output layers to the current map session.

View Log: A log file is created the first time the calculator is run. The log is appended for subsequent runs. If the log is opened before the process is complete, it will need to be reloaded to see the complete details of the log.

Progress Dialog: The green arrow at the bottom will display as long as processes are running. The process is complete when the green arrow stops AND the dialog says: --PROCESS COMPLETE--

5.4.2. Naming Convention of Output Layers

Output inundation layers will be named according to the input and output parameters chosen in the calculator. The parameters will be abbreviated and separated by underscores. No spaces are allowed in the output file names.

Output File Naming Convention is as follows:
{STATION or DISTRICT}_{YEAR}_{PROJECTION_CURVE}_{DATUM}_{OUTPUT TYPE}

Where:

- **STATION or DISTRICT:** Tide Station or FDOT District (1-7) chosen for sea level trend value.
- **YEAR:** Decade chosen (2020, 2030, 2040, 2050, 2060, 2070, 2080, 2090 or 2100)
- **PROJECTION CURVE:** USACE Projection Curve chosen
    - H = USACE High Rate
    - M = USACE Intermediate (Medium) Rate
    - L = USACE Low Rate (Historic Rate)
- **DATUM:** Tidal Datum chosen
    - MHHW - Mean Higher High Water
    - MHW - Mean High Water
    - MSL - Mean Sea Level
    - MLW - Mean Low Water
    - MLLW - Mean Lower Low Water
- **OUTPUT TYPE:**
    - Bathtub – Bathtub inundation model – Raster File Format
    - HC – Enhanced inundation model with hydro-connectivity filter

Example filenames of output layers:

Filename	Input Parameters Chosen
KeyWest_2060_M_MHHW_Bathtub	• Key West tide gauge/ sea level trend • USACE Medium Projection Curve • Mean Higher High Water (MHHW) tidal datum • Projection year – 2060 • Bathtub Model, raster feature class
Naples_2040_H_MSL_Bathtub_Polygon	• Naples tide gauge/ sea level trend • USACE High Projection Curve • Mean Sea Level (MSL) tidal datum • Projection year – 2040 • Bathtub model, vector feature class
DISTRICT1_2040_H_MHW_HC	• FDOT District 1 sea level trend • USACE High Projection Curve • Projection year – 2040 • Mean High Water (MHW) tidal datum • Hydro-connectivity model output, **raster** feature class

DISTRICT1_2040_H_MHW_HC_Polygon	• FDOT District 1 sea level trend • USACE High Projection Curve • Projection year – 2040 • Mean High Water (MHW) tidal datum • Hydro-connectivity model output, **vector** feature class

6. Tips & Tricks

- When processing large amounts of data, the calculator may fail due to memory limitations. Close other intensive applications during processing, or try processing a smaller geographic area.
- The spatial extent of the output inundation layer is dependent upon the input DEM selected. The larger the geographic extent of the DEM, the longer calculator processing will take to complete. If you are working with an area that is smaller than the State of Florida or FDOT District, it is recommended that you clip the DEM to your area of interest to speed up processing time.
- While each input and output parameter is required for the calculator to run, choosing multiple selections (eg. Multiple years, datums, curves) could cause the calculator to take longer to complete.
- Use the log file to see if there were any errors in the process
- If you experience error messages with the calculator, please alert the GeoPlan team at: sls@geoplan.ufl.edu

7. Documents & Resources

Florida Sea Level Scenario Sketch Planning Tool – project website: http://sls.geoplan.ufl.edu

Final Report under which this calculator was developed: "Development of a Geographic Information System (GIS) Tool for the Preliminary Assessment of the Effects of Predicted Sea Level and Tidal Change on Transportation Infrastructure**"**, FDOT Contract # BDK75 977-63: ftp://ftp.sls.geoplan.ufl.edu/pub/sls/docs/FDOT_BDK75_977-63_Final_Technical_Report.pdf

Final Report also available via the project website at: http://sls.geoplan.ufl.edu/documents

NOAA COOPS tide gauge data: http://tidesandcurrents.noaa.gov/.

USACE methodology and Engineer Circular EC 1165-2-212: http://www.corpsclimate.us/ccaceslcurves.cfm