Indian River Lagoon

Outfall and Sea Level Rise Vulnerability Analysis

Prepared by: The East Central Florida Regional Planning Council

April 2016

TREASURE COAST TCRPC REGIONAL PLANNING COUNCIL
"Regionalism One Neighborhood AT A Time" • Est. 1976

EAST CENTRAL FLORIDA REGIONAL PLANNING COUNCIL EST.1962

Page intentionally left blank

Table of Contents

SECTION I: Introduction

This vulnerability analysis is part of a grant awarded by the Florida Department of Economic Opportunity to the East Central Florida Regional Planning Council and the Treasure Coast Regional Planning Council to continue the work done for an associated grant awarded in 2014. As part of the 2014-15 planning project, the ECFRPC collected data and mapped all outfalls within the Indian River Lagoon, its connected water bodies and primary canals that flow into the lagoon system. As part of the 2014 project, the planning team also collected data for water quality, outfall ownership, and other important information.

The 2015 grant aims to continue the work done during the 2014 planning cycle. This phase includes an update of all outfall-associated data (such as water quality) and an analysis to determine the effects of sea level rise on the outfalls within the lagoon system. This vulnerability analysis investigates those effects through a documented GIS analysis methodology. This analysis contains an overview of the effects of sea level rise within the 5-county study area which corresponds to an atlas developed to show the location of every outfall along the Indian River Lagoon. The atlas is a separate document, however the analysis provided in this document provides a qualitative and quantitative analysis of the atlas.

This document also contains county sea level rise inundation summaries, documentation of the planning process, a GIS methodology, a land inundation analysis and a summary and description of all outreach done to compile this data. All outreach was performed on the county level, allowing local level input in the modeling parameters.

The 2015 grant also includes an economic analysis, a maintenance plan, and a listing and analysis of stormwater management best practices. These analyses are intended to be utilized side-by-side in order to discover and prioritize future projects and mitigation efforts within the Indian River Lagoon system.

The maps in this report depict the final Indian River Lagoon system maps developed as part of this project, which include sea level rise projections for 2040, 2070 and 2100. Each map utilizes a different ‘rate curve’ as developed by the U.S. Army Corps of Engineers (ACOE); low, intermediate or high. This analysis utilizes these same metrics consistently throughout the study.

SECTION II: Planning Process

Outreach for this project incorporated the inclusion of County-level sea level rise planning decisions and horizons into a regional project providing a snapshot of the Indian River Lagoon system. This bottom-up approach allowed the regional project to include county-level nuances, making the project more applicable to each of the five counties studied. This was done by accounting for local lagoon and tidal trends via the data collected by the project team from county and jurisdiction staff. For consistency, all counties were modeled utilizing the U.S. Army Corps of Engineers sea level rise rate curves. This included running the model for the low, intermediate and high ACOE rate curves for each jurisdiction. The ACOE curves have been adopted by FDOT and UF for use in the FDOT Sea Level Scenario Sketch Planning Tool for statewide analysis, thus increasing statewide consistency. Decisions on datum – made by the county representatives based on their parameters – were derived from local oceanographic conditions.

All county representatives – which included emergency managers, environmental scientists, planners, and engineers – provided the East Central Florida Regional Planning Council with critical information regarding the modeling for their planning areas. The parameters that were decided upon by county officials included:

- **Tidal Datum (Atlantic):** The first water level at which the vertical rise will be applied. This figure is applicable to contiguous water features alongside the Atlantic Ocean.
- **Tidal Datum (Lagoon):** The second water level at which the vertical rise will be applied. This figure is applicable to contiguous water features alongside the lagoon system.
- **Planning Horizons (3):** The three years at which sea level rise is measured. All counties will utilize the 2040, 2070 and 2100 planning horizons.
- **Local Knowledge**: Qualitative information received from county and jurisdiction officials is included in the report.
- **Confirmation of Consistencies**: All counties were informed that the Army Corp of Engineers projections are modeled in the FDOT Sea Level Scenario Sketch Planning Tool as determined through the UF/FDOT modeling team.

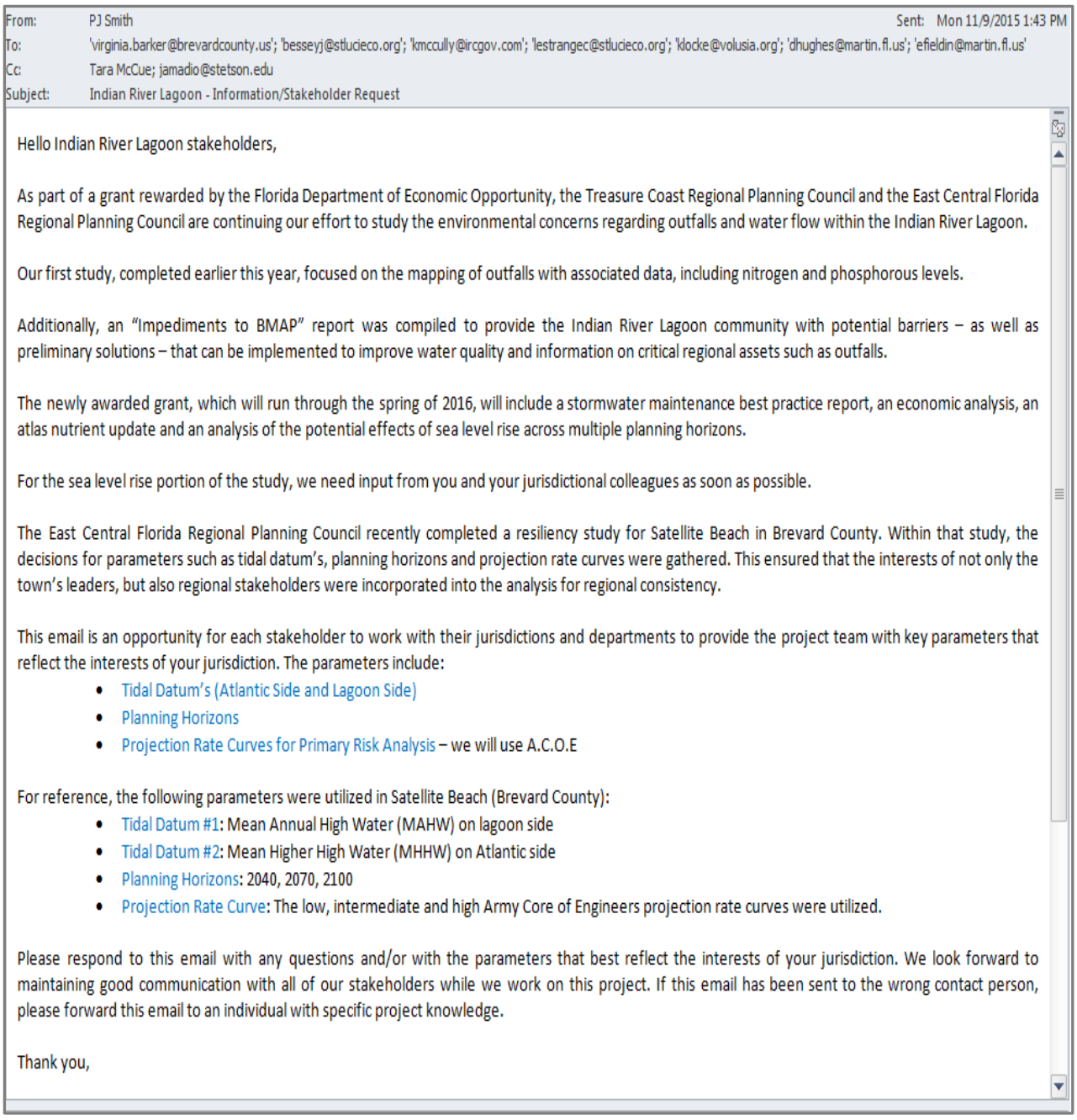
Coordination was conducted via email between the project team and each of the five counties. The Army Crop of Engineers (ACOE) low, intermediate and high rate curves were used to be consistent with other statewide efforts. The county coordination resulted in the following datum and planning horizons to be modeled.

Table 1: Jurisdictional Datum and Planning Horizons

Jurisdiction	Horizon 1	Horizon 2	Horizon 3	Lagoon Datum	Atlantic Datum	Rate Curve
Brevard County	2040	2070	2100	MHW	MHHW	A.C.O.E
Indian River County	2040	2060, 2070	2100	MHW	MHW	A.C.O.E
Martin County	2040	2070	2100	MHW	MHHW	A.C.O.E
St. Lucie County	2040	2070	2100	MHW	MHW	A.C.O.E
Volusia County	2040	2070	2100	MHW	MHHW	A.C.O.E

Outreach Email

The email depicted below was sent to representatives of the counties included in this report. For a correspondence listing, please contact the planning team at the East Central Florida Regional Planning Council.



From: PJ Smith Sent: Mon 11/9/2015 1:43 PM
To: 'virginia.barker@brevardcounty.us'; 'besseyj@stlucieco.org'; 'kmccully@ircgov.com'; 'lestrangec@stlucieco.org'; 'klocke@volusia.org'; 'dhughes@martin.fl.us'; 'efieldin@martin.fl.us'
Cc: Tara McCue; jamadio@stetson.edu
Subject: Indian River Lagoon - Information/Stakeholder Request

Hello Indian River Lagoon stakeholders,

As part of a grant rewarded by the Florida Department of Economic Opportunity, the Treasure Coast Regional Planning Council and the East Central Florida Regional Planning Council are continuing our effort to study the environmental concerns regarding outfalls and water flow within the Indian River Lagoon.

Our first study, completed earlier this year, focused on the mapping of outfalls with associated data, including nitrogen and phosphorous levels.

Additionally, an "Impediments to BMAP" report was compiled to provide the Indian River Lagoon community with potential barriers – as well as preliminary solutions – that can be implemented to improve water quality and information on critical regional assets such as outfalls.

The newly awarded grant, which will run through the spring of 2016, will include a stormwater maintenance best practice report, an economic analysis, an atlas nutrient update and an analysis of the potential effects of sea level rise across multiple planning horizons.

For the sea level rise portion of the study, we need input from you and your jurisdictional colleagues as soon as possible.

The East Central Florida Regional Planning Council recently completed a resiliency study for Satellite Beach in Brevard County. Within that study, the decisions for parameters such as tidal datum's, planning horizons and projection rate curves were gathered. This ensured that the interests of not only the town's leaders, but also regional stakeholders were incorporated into the analysis for regional consistency.

This email is an opportunity for each stakeholder to work with their jurisdictions and departments to provide the project team with key parameters that reflect the interests of your jurisdiction. The parameters include:

- Tidal Datum's (Atlantic Side and Lagoon Side)
- Planning Horizons
- Projection Rate Curves for Primary Risk Analysis – we will use A.C.O.E

For reference, the following parameters were utilized in Satellite Beach (Brevard County):

- Tidal Datum #1: Mean Annual High Water (MAHW) on lagoon side
- Tidal Datum #2: Mean Higher High Water (MHHW) on Atlantic side
- Planning Horizons: 2040, 2070, 2100
- Projection Rate Curve: The low, intermediate and high Army Core of Engineers projection rate curves were utilized.

Please respond to this email with any questions and/or with the parameters that best reflect the interests of your jurisdiction. We look forward to maintaining good communication with all of our stakeholders while we work on this project. If this email has been sent to the wrong contact person, please forward this email to an individual with specific project knowledge.

Thank you,

SECTION III: GIS Methodology

Two methodologies were utilized to complete the Sea Level Rise analysis for the Indian River Lagoon system. The University of Florida GeoPlan Center is responsible for FDOT Sea Level Scenario Sketch Planning Tool, which the ECFRPC utilized to model the sea level rise conditions. The ECFRPC combined these raw data layers using the specific methodology outlined below.

ECFRPC Methodology Report

The ECFRPC utilized the FDOT Sea Level Scenario Sketch Planning Tool plug-in to GIS to begin the process of creating highly customized sea level rise shapefiles for each of the five counties in the study area.

Per the decisions on datum (lagoon and ocean side) and planning horizons per jurisdiction as shown on page 5, each shapefile needed to be 'cut' to be customized to the local criteria and local oceanographic conditions. As explained in the planning process, these decisions were made by county and jurisdiction representatives.

After running the FDOT Sea Level Scenario Sketch Planning Tool in ArcGIS, the project team had a total of 90 shapefiles depicting sea level rise, a total of 18 per county. The shapefiles, by county, consisted of three planning horizons and three projection rate curves, which produced 9 shapefiles on both the Atlantic side and the lagoon side of the model.

It is important to note that the Atlantic coast sea level rise model results are only included in the lagoon analysis (in terms of vulnerability) if there are contiguous water bodies from the ocean side that come into direct contact with contiguous lagoon-side sea level rise areas. The contiguous oceanic sea level rise areas will be mapped; however they will not be analyzed as part of this analysis due to the focus of this report on the lagoon system.

Once all contiguous Atlantic-side sea level rise areas were identified, the next step was to remove all non-contiguous sea level rise areas from both models (oceanic and lagoon). This ensures that the sea level rise areas would rationally occur, as direct contact with the lagoon or the ocean is required for an area to be considered threatened by sea level rise.

Up to this point, the methodology steps depicted above have been completed 9 times for each county due to the three datum and three horizons for each county.

The next step in the process was to merge the final ocean-side shapefiles with the final lagoon-side shapefiles, by county. This resulted in a total of 45 shapefiles, or nine per county. These shapefiles are the final files that were overlaid with outfall locations.

It is important to note that, due to the custom datum by county, edges of sea level rise zones that are located along county lines may not match up geospatially.

The next step of the methodology was to incorporate data (or attributes) into the outfall file developed in 2014 to depict sea level rise components. This step also included the addition of updated water quality data and other attributes within the outfall shapefile.

As part of this step, nine attributes were created in the outfall shapefile. These attributes (or columns depicting data for outfall records) are utilized to describe the modeling parameters for each county model (datum and horizons), as well as the year of inundation under each of the three rate curves utilized.

The following fields were created. This listing also includes descriptions of each attribute.

- DATUM_ATL: This represents the datum used on Atlantic side, by jurisdiction. These values are also included on page 5 of this report.
- DATUM_LAG: This represents the datum used on lagoon side, by jurisdiction. These values are also included on page 5 of this report.
- HORIZONS: This represents the three planning horizons chosen by each county. These values are also included on page 5 of this document.
- COUNTY: This represents the county that each outfall lays within.
- LOW_INUND: This represents the horizon at which the outfall is projected to be inundated utilizing the A.C.O.E low rate curve.
- MED_INUND: This represents the horizon at which the outfall is projected to be inundated utilizing the A.C.O.E intermediate rate curve.
- HI_INUND: This represents the horizon at which the outfall is projected to be inundated utilizing the A.C.O.E high rate curve.
- USNG: This represents the USNG coordinate of each outfall identified.

Once these fields were created, a series of spatial cross-reference functions were run between the outfall data and the sea level rise data. Specifically, the project team utilized the “Select by Location” tool within ArcGIS.

Beginning with the most distant planning horizon, the process included a population of table rows when outfalls were ‘selected’ by the location query. The most distant planning horizon (2100) must be utilized first as part of this step because records that are within the 2040 planning horizon are also located within the 2070 and 2100 planning horizons. Thus, populating from the

2100 planning horizon first, followed by the 2070 and then the 2040 horizon will populate each field correctly.

Once a record is selected, this process step allows you to populate the field with the correct data. For example, under the "LOW_INUND" field, a proper data input could be '2070' if that is the projected inundation year. The number of outfall records selected using this process will naturally be reduced as the planning horizon shortens. This process step was used for all three rate curves, as is represented in the attributes listed on page 8.

The third and final step of this process was to populate the outfall table with updated water quality, ownership and other data. This step is identical to the second step in terms of a spatial reference. If an outfall is located within one Water Body ID Area (WBID), then the attributes of that WBID are included in the outfall table via the spatial cross-reference. Water Body ID Areas are updated annually (although not for all counties) and the data associated is managed by the Florida Department of Environmental Protection.

Qualitative data was also added to the outfall table in terms of ownership changes or comments from jurisdictions on specific outfall locations. Priorities identified in 2014 were also revisited by the planning team. Table 2 below is a summary table of the source data used in this analysis and the table update process.

Table 2: Datasets, Fields and Sources

Data Layer	Source(s)	Fields Used
Sea Level Rise	UF (2015); ECFRPC (2015)	All Fields
Water Body ID	Florida Department of Environmental Protection (2015)	TN, TP, WBID
Outfalls	ECFRPC (2015)	All Fields
Water Bodies	Florida Geographic Data Library (2015)	Descript
Counties	Florida Geographic Data Library (2015)	Name
Parcels	County Property Appraiser's Offices (2015)	DOR_Code; Assessed

All data utilized is the best available data at the time of the report. This has been confirmed, as the data collected came directly from each source during the project cycle
Parcel field names differed slightly between counties

Table 3: USACOE Inundation Projections

USACE Rate Curve	2040 - MHW	2070 - MHW	2100 - MHW	2040 - MHHW	2070 - MHHW	2100 - MHHW
Low	*19 Inches*	*22 Inches*	*25 Inches*	*24 Inches*	*26 Inches*	*29 Inches*
Intermediate	*22 Inches*	*28 Inches*	*37 Inches*	*26 Inches*	*33 Inches*	*42 Inches*
High	*30 Inches*	*49 Inches*	*77 Inches*	*34 Inches*	*54 Inches*	*81 Inches*

Source: US Army Corps of Engineers

UF GeoPlan Methodology Report (Sketch Tool)

Methods for Creating GIS Layers of Sea Level Rise Inundation on Indian River Lagoon

Crystal Goodison, University of Florida GeoPlan Center
Methodology effective September 2014

The project team worked with the University of Florida GeoPlan center in the development of ArcGIS shapefiles to utilize in this project. All mapping products developed by the GeoPlan team were utilized by the ECFRPC data team via the FDOT Sea Level Scenario Sketch Planning Tool, which is available through ArcGIS. This methodology describing the process utilized to guage sea level rise as determined by the US Army Corps of Engineers has been used for Satellite Beach, Florida. This methodology was replicated to the five-county study area.

The methodology and documentation of the University of Florida sea level rise project can be found at the link provided below:

ftp://ftp.sls.geoplan.ufl.edu/pub/sls/docs/FDOT_BDK75_977-63_Final_Technical_Report.pdf

Methods for Calculating Sea Level Rise on the Indian River Lagoon Using USACOE Methods

The U.S. Army Corp of Engineers (USACOE) methods were used to calculate the projected amount of relative sea level rise (SLR) on the Indian River Lagoon side of Satellite Beach. To calculate relative sea level rise, the following equation from the USACOE's SLC Curve Calculator was used (http://www.corpsclimate.us/ccaceslcurves.cfm), which is based on Engineer Circular EC 1165-2-212, Equation 2:

$$T(t) = (E+M)t + bt^2$$

Where:

T(t) = Total relative sea level rise at time "t"
E = Eustatic sea level change (mm/yr) 1.7mm – eustatic sea level change
M = Local subsidence or uplift rates (mm/yr) * taken from NOAA regional estimates - Estimating Local Vertical Land Motion from Long-term Tide Gauge Records
t = Time period (in years) between 1992 (Base Year) and year of interest
b = Coefficient of sea level rise
Historic (Low) - 0
Curve II (Intermediate) – 7.00 E-5 (0.00007)
Curve III (High) – 1.13E-4 (0.000113)

The following equation was used to calculate projected inundation on the land, incorporating starting water levels and the vertical adjustment to NAVD88 (the vertical datum of the Digital Elevation Model).

$$PI = SLCP_T + NAVD88_{diff} + TD$$

Where:

PI = Projected Inundation Level

$SLCP_T$ = the sea level change projection at time "T" (expressed in years) derived from USACOE equations (i.e. – amount of sea level rise)

$NAVD88_{diff}$ = the difference in reference height of the tide gauge level point between the NAVD88 and MWL (Local Buoy)

TD – Tidal Datum or Seasonal High Water Level

Average of Seasonal High Tide

For example, to calculate inundation at 2040 using the USACOE Intermediate projection, start with 6.84 inches calculated using USACOE Curve Calculator, then account for NAVD88 adjustment and tidal datum:

$$PI = SLCP_T + NAVD88_{diff} + TD$$

$$PI = 6.84 \text{ inches} + -7.44 \text{ inches} + 12 \text{ inches}$$

$$PI = 11.4 \text{ inches}$$

Methods for Creating GIS Layers SLR Inundation

The input Digital Elevation Model (DEM) used was from the Florida Geographic Data Library (FGDL) and compiled by the University of Florida GeoPlan Center: Florida Digital Elevation Model Mosaic (FGDL filename: FLIDAR_MOSAIC_IN). The DEM cell size (horizontal resolution) is 5.4 meters and the vertical units are inches.

Steps for Creating GIS Layers of Inundation using ArcGIS 10.1 SP1:

- Extracted study area boundary from FGDL Layer PAR_CITYLM_2011 (City Limits – Derived from Florida Parcel Data – 2011).
- Buffered outputs to county boundaries (5)
- Converted boundary to raster at 5.4m cell size to match DEM, set snap raster to DEM
- Clipped DEM to buffered Satellite Beach City Limits, and re-classed -1 values (representing water) to no data.
- Created bathtubs with SLR Calculator using SLR projected inundation amounts calculated with US Army Corps of Engineers methods.
- Ran Hydro-connectivity Model in ArcMap Model Builder. To delineate Oceans and Rivers for hydrologic connectivity – used data from Water Management District and DEM. Used the DEM to create a modified oceans and rivers layer to better represent the Indian River Lagoon shore. Our existing layer of oceans & rivers was created with Water Management District (WMD) data didn't line up exactly in some areas on the IRL side. If projected inundated area was adjacent to or overlapping with an area delineated as ocean or river, then that inundated area was kept in the output layer.
- Processed in raster environment. Exported to polygon feature classes in a File Geodatabase.

SECTION IV: Inundation Analyses

All outfalls identified within the 5-county study area were assessed according to the vulnerability posed by the low, intermediate and high Army Corps of Engineers projection rate curves for sea level rise. This section summarizes overall inundation rates, by county, and provides specific examples of vulnerable areas that could be addressed by local authorities for preventative measures. The table below depicts the number of outfalls inundated under each of the projection rate curves utilized. Brevard County and Indian River County outfalls, within the middle portion of the study area, are the most susceptible to sea level rise of the five counties studied in the near term (2040). As projection rate curves reach the years 2070 and 2100, Indian River County becomes the most susceptible county for outfalls, while Brevard, Volusia and St. Lucie counties see comparable inundation rates. Martin County outfalls are the least affected, but the vulnerability and risk posed are still severe.

Table 4: Inundation Summaries

Low USACOE Projection Curve Outfall Inundation Summary

County	Number of Outfalls	Inundated 2040 *(%)*	Inundated 2070 (%)	Inundated 2100 (%)
Volusia County	138	1 (0.7%)	2 (1.4%)	2 (1.4%)
Brevard County	1,132	83 (7.3%)	97 (8.6%)	106 (9.4%)
Indian River County	50	5 (10.0%)	7 (14.0%)	10 (20.0%)
St. Lucie County	411	5 (1.2%)	7 (1.7%)	8 (1.9%)
Martin County	339	28 (8.3%)	35 (10.3%)	39 (11.5%)
Total	**2,070**	**122** (5.9%)	**148** (7.1%)	**165** (8.0%)

Intermediate USACOE Projection Curve Outfall Inundation Summary

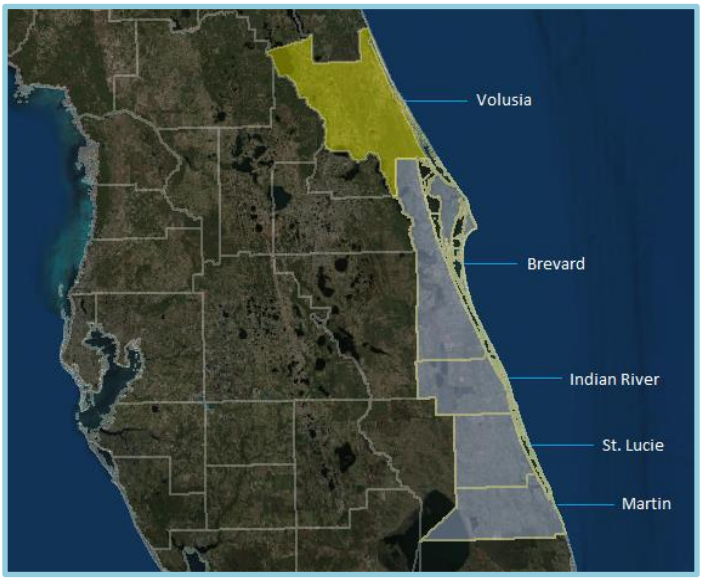
County	Number of Outfalls	Inundated 2040 *(%)*	Inundated 2070 (%)	Inundated 2100 (%)
Volusia County	138	2 (1.4%)	2 (1.4%)	11 (8.0%)
Brevard County	1,132	97 (8.6%)	122 (10.8%)	159 (14.0%)
Indian River County	50	7 (14.0%)	11 (22.0%)	17 (34.0%)
St. Lucie County	411	6 (1.5%)	11 (2.7%)	25 (6.1%)
Martin County	339	32 (9.4%)	43 (12.7%)	56 (16.5%)
Total	**2,070**	**144** (7.0%)	**189** (9.1%)	**268** (12.9%)

High USACOE Projection Curve Outfall Inundation Summary

County	Number of Outfalls	Inundated 2040 *(%)*	Inundated 2070 (%)	Inundated 2100 (%)
Volusia County	138	4 (2.9%)	19 (13.8%)	40 (29.0%)
Brevard County	1,132	126 (11.1%)	212 (18.7%)	355 (31.3%)
Indian River County	50	11 (22.0%)	22 (44.0%)	31 (62.0%)
St. Lucie County	411	11 (2.7%)	73 (17.8%)	154 (37.5%)
Martin County	339	44 (13.0%)	70 (20.6%)	92 (27.1%)
Total	**2,070**	**196** (9.5%)	**395** (19.1%)	**672** (32.5%)

Source(s): See provider information within attribute tables. Data provided by cities, counties, FDOT and state WMD's

Volusia County Vulnerability Analysis | *Outfall and Land Risk Summaries*



The vulnerability posed to Volusia County by sea level rise is severe, as 29.0% of the outfalls within the county would be inundated under the high projection rate curve for the year 2100. While that is the 'worst case' scenario, the threat would disrupt stormwater systems in the county. Volusia County is somewhat unique within the five-county study area, as there are significant inland threats posed to the far-western and southwestern portions of the county. Inland water systems, including the St. Johns River, are located along low-elevation floodplains and forest areas that would be completely inundated with certain sea level rise projections. In these areas, there is risk to populated areas. Stone Island, located in southwest Volusia County, is a flood-prone area already dealing with high water levels.

Outfall and Land Inundation | North to South | Medium Projection Curve Analysis

The northernmost area of the lagoon system in Volusia County is the Tomoka Basin, a large inlet area that contains six outfalls, two of which will be inundated in 2040 under the medium projection rate curve (all analysis within Section V will utilize this curve unless noted otherwise). While most of the lands enveloping this basin are projected to be inundated by 2040, there is no development in this area.

Moving southward to the Ormond Beach area, the immediate coastlines of the lagoon system are minimally affected by sea level rise. As so, the majority of the outfalls in this location show no risk out to the year 2100 under the medium projection curve. One outfall, located near Temple Beth Elementary School, is projected to be inundated by 2070. An outfall on Roberta Road also shows future inundation. The primary area of risk within Ormond Beach is an inland portion of the city that runs adjacent to the Tomoka River. Most critical facilities are spared in this area; however Ormond Beach Fire Station 93 and the public works building are threatened.

Holly Hill and Daytona Beach are much more susceptible to sea level rise from a development and outfall perspective, especially when compared to the northern portion of the county. The primary area where sea level rise becomes severe from a land and outfall perspective occurs where the Mason Avenue Bridge crosses the Halifax River. Inundation reaches as far as 0.25 miles inland in this area, and many outfalls in the vicinity will be inundated by 2040 according to projections.

Moving south to the 'downtown' Daytona Beach area, inundation stretches 0.1 to 0.3 miles inland, enveloping two outfalls within the 2070 year mark and threatening Daytona Beach City Hall, the Florida National Guard Outpost, as well as the main recreation and athletic attraction area adjacent to the Halifax River. Despite the significant vulnerability posed to the western

coastline of the Halifax River in Daytona Beach, the barrier islands are much less affected. Sea level rise, for the most part, extends a maximum of 100 feet into the islands. The only developments threatened in this area are properties or residences immediately adjacent to the lagoon. Inundation intrusion expands where the International Speedway crosses the river.

South Daytona and Daytona Beach Shores are similar in inundation levels to Daytona Beach. However, only one outfall in this area is threatened for inundation (at US 1 on the border of South Daytona and Port Orange). Western lagoon and eastern lagoon shores remained consistent with Daytona Beach.

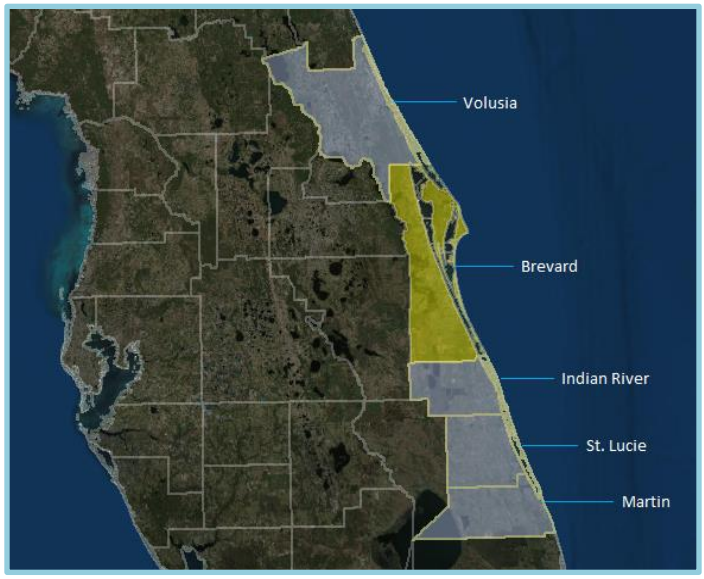
Vulnerability increases again where Dunlawton Avenue crosses the Halifax River in Port Orange. While inundation in this area – once again – is consistent with that of Daytona Beach, there are a number of critical facilities located in hazard zones in this area. A senior center, Port Orange Fire Station 71, as well the Riverview ALF are located in the hazard area. Moving southward to Ponce Inlet, where the Halifax River meets Ponce Inlet, sea level rise almost entirely covers the islands within the Halifax River by 2040 (medium curve). The Ponce Inlet Police Department is located directly adjacent to the end of the 2040 (medium curve) threat zone, and the outfall in this location is projected to be inundated by 2040. Most outfalls – however – are spared from hazard zones. This would otherwise seem unlikely given inundation levels in this area.

Moving south to New Smyrna Beach, inundation levels begin to subside with increased distance from Ponce Inlet. New Smyrna Beach Municipal Airport is surrounded by sea level rise hazard zones, and a sliver of the hazard zone extends into the terminal area (although not the runways). Once again, most of the outfalls in the northern New Smyrna Beach area are spared from the inundation zone.

Southward to Edgewater, the hazard zone mainly stretches into land that is currently swamp or mangrove environments. Outfalls in this area are completely spared under the medium projection rate curve. Oak Hill, Volusia County's southernmost coastal town, has a larger-than-average inundation level on the western side of the Indian River Lagoon system. Sea level rise stretches nearly 0.3 miles inland in this area and most of the hazard zone is within the 2040 horizon. This is due to a ridge located about a quarter of a mile inland that abruptly stops the sea level rise hazard zone.

The Canaveral National Seashore, an undeveloped stretch of barrier islands and inland conservation lands, is largely spared from sea level rise. However, there is no financial threat (outside of transportation infrastructure) in this area.

Brevard County Vulnerability Analysis | *Outfall and Land Risk Summaries*



Brevard is very susceptible to sea level rise, primarily in the short term. Much of Brevard County has a very low elevation, and thus the sea level rise impacts are more immediate and skew off over time to become comparable with the other counties in the study area. A significant area of vulnerability is the federally-owned area of Cape Canaveral, where inundation is almost complete in 2070 and 2100 projections. A second, but more invasive threat area is located along the east side of the Indian River Lagoon, facing the western intracoastal shores of communities such as Satellite Beach, Cocoa Beach and Cape Canaveral (proper). The barrier islands of Brevard County stretch nearly 70 miles, and a consistency among these islands is the threat from the intracoastal lagoon system.

Outfall and Land Inundation | North to South | Medium Projection Curve Analysis

The northernmost portion of Brevard County at the Canaveral National Seashore has a large volume of outfalls and severe inundation levels. While little development is located in this area, there is a serious short term (2040) threat posed to outfalls. Approximately 15 outfalls in the northernmost 12 miles of the county are projected to be inundated by the year 2040, and a few others are projected to be inundated between the 2070 and 2100 time frames. However, as was seen in Volusia County, the 2040 risk zone extends much farther inland than the 2070 and 2100 vulnerability zones due to an abrupt (although slight) change in elevation. Inland inundation (west of the lagoon system) varies in the northern portion of the county but is severe. Generally, inland inundation stretches approximately 0.5 to 1.0 miles inland in this location.

To the south, where federally-owned lands are located near Kennedy Space Center, is the most severely threatened piece of land along the entire east coast of the study area. Alongside the extremely large volume of outfalls that are projected to be inundated in this area (most by 2040 under the medium projection curve), the Kennedy Space Center and its assets are almost certain to be inundated – even with modest increases in water levels. This area includes a number of outfalls, but also includes critical transportation infrastructure such as bridges and a private railway that serves NASA. The only unaffected area of the federally-owned land in this locale is located to the east of the primary railway, accounting for less than one third of the entire width of these land masses from the Atlantic Ocean to the lagoon system.

To the west of the federally-owned land at Cape Canaveral is the city of Titusville, a heavily populated area with a number of stormwater outfalls. The downtown area of Titusville – where the A Max Brewer Memorial Parkway crosses the lagoon into Titusville – is unfortunately the

highest-risk area within the city. Sand Point Park, a major attraction for visitors, is projected to be inundated by 2040 under the medium projection rate curve projection. Many outfalls in the immediate area north and south of downtown Titusville are projected to be inundated by 2040.

To the south of Titusville is Merritt Island, where the largest volumes of outfalls within the study area are located. Merritt Island is affected on both its western and eastern shores, and a low-elevation area of the land mass within the middle of the peninsula is completely inundated under the 2040 medium rate model. This area is perhaps the most critical area of the lagoon system alongside the St. Lucie River in Martin County, as a large population, a large volume of outfalls, and a breadth of diverse critical facilities are located in this area. There is an increase in elevation on the shores to the west of Merritt Island, thus there is a much smaller amount of vulnerability in central Brevard County in this area. Priority for mitigating measures should be focused on Merritt Island proper, from the eastern and western borders to the center of the peninsula.

Moving to the east of Merritt Island is Port Canaveral and the City of Cape Canaveral. Consistent with most of the study area, sea level rise from the Atlantic side of the communities on the coast from this point southward to the end of the study area are mostly unaffected, as dune systems protect most areas with a consistent protective seal. However, consistent from this point of the study area southward is the increased impact to the barrier island systems from the west. Port Canaveral is minimally affected, although stormwater outfalls in the immediate proximity of the port are projected to be inundated by 2040 under the medium projection rate curve.

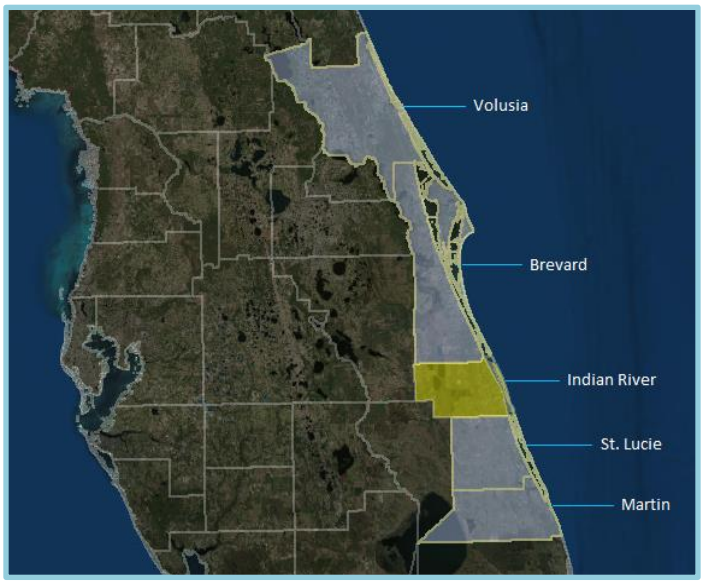
Cocoa Beach has considerable vulnerability to sea level rise on its western shores. Not only do sea level rise hazard zones stretch nearly to State Road A1A, a number of critical facilities are projected to be inundated by 2040. The Roosevelt K-8 School, Cocoa Beach High School, the Cocoa Beach Water Reclamation Plant and the Cocoa Beach Public Works Garage are all located within this hazard zone. There are no documented outfalls in this area.

Patrick Air Force Base and Satellite Beach, to the south of Cocoa Beach on the barrier islands, are also very susceptible to sea level rise. Consistent with most of the state, sea level rise is expected to creep in from the western shores. Inundation levels stretch approximately 0.2 to 0.4 miles inland from the west in these locations. Due to a large volume of highly-valued coastal residences in these areas, this is among the more highly vulnerable locations in the study area from a financial perspective for home owners.

As we move south to Indialantic, Melbourne Beach and Melbourne, the vulnerability to shores on both the barrier islands and the eastern shores of the 'mainland' is significantly reduced as compared to the Merritt Island, Satellite Beach and Patrick Air Force Base areas. Although there are a large number of outfalls located south of Melbourne – in Palm Bay – the vast majority are not modeled to be inundated by year 2100 under the medium projection curve. The majority of the vulnerable outfalls are located at the Turkey Creek inlet and the riverine system near Malabar and Palm Bay. Threatened critical facilities in the Turkey Creek area include two water treatment plants and aquifer utility sites. However, these facilities are only threatened as projected by the high projection rate curve.

Grant-Valkaria and areas to the south and east are also highly susceptible to sea level rise. Eight out of nine outfalls within a 1.5 mile radius of Grant Road are projected to be inundated by 2040.

Indian River County Vulnerability Analysis | *Outfall and Land Risk Summaries*



The Indian River Lagoon travels entirely through Indian River County; however this stretch of the lagoon is much narrower than the other counties within the study area. Like Brevard County, Indian River County is extremely susceptible to sea level rise during the 2040 time frame due to its low elevation. The entire coastline of the Indian River Lagoon – east and west – depicts a considerable encroachment of water on developed land. The western shores of the Indian River Lagoon have inundation stretching 0.25 to 0.75 miles inland, while the majority of the barrier islands would be inundated under 2100 high projection rate curves. Sebastian Inlet, located at the northernmost point of the county, is among the most susceptible areas in the region. By 2040, the surrounding beach and dune systems could be completely inundated, even when analyzing the low projection rate curve.

Outfall and Land Inundation | North to South | Medium Projection Curve Analysis

The northern most part of Indian River County is Sebastian Inlet and the town of Sebastian. The Sebastian River, which runs to the north of downtown Sebastian, has a number of inundated outfalls. The town is located on higher ground than other 'mainland' towns, and the effect on the coastline facing the lagoon system is minimal. However, two outfalls along the town of Sebastian coast are projected to be inundated by 2070. The primary inundation risk to the town occurs as the Sebastian River turns south, but development in this area is sparse. The same is true with Sebastian Inlet. While the inlet and its surrounding marshlands are projected to be almost completely inundated by 2070 under the medium projection rate curve, there is no substantial development in this area. However, an outfall located on the southern end of the inlet is projected to be inundated in 2070.

A general lack of development continues southward to the town of Orchid and the Pelican Island National Wildlife Refuge. However, the land to the west of the lagoon system to the south of 85th Street is susceptible to sea level rise reaching an average of 0.2 miles inland. There is a large amount of low density residential development in this area, contributing to perhaps the highest-risk area in Indian River County. Places of interest including three golf courses – Sandridge, Red Stick and Orchid Harbor – are located within the hazard zone. Once again, in this area a sudden increase in elevation ends the hazard zone but the 2040 zone encompasses most of the area projected to be affected by sea level rise. The primary areas affected include the coastal areas located approximately 1.5 miles to the northeast of and 1.5 miles to the southeast of the community of Gifford. Both of these areas include large swathes of residential development and are susceptible to financial and transportation infrastructure exposure.

The town of Indian River Shores, to the east of Gifford, is located on the barrier islands. While inundation travels well-into the land mass, most of the development within the town is located on higher ground. Residential development near Coconut Palm Road is susceptible to sea level rise as a result of waterfront properties; however the inundation typically does not pass through the first residential lot adjacent to the lagoon system.

Similar to the situation in Indian River Shores, the inundation levels in the area to the southeast of Gifford (along the western shores of the lagoon system) show high levels of inundation with little to no development present. One outfall in this area is projected to be inundated by rising seas by the year 2040 according to the medium projection rate curve trend. However, to the east of this area is the State Road 60 Bridge that travels over the lagoon system. This bridge has an outfall at its eastern terminus that is projected to be inundated by 2040 (medium curve). In addition, an outfall to the immediate southwest of this transportation network is to be inundated by 2070. The road itself, as it travels downward toward the mainland, may become susceptible to rising seas. This presents a challenge from a transportation infrastructure and access perspective.

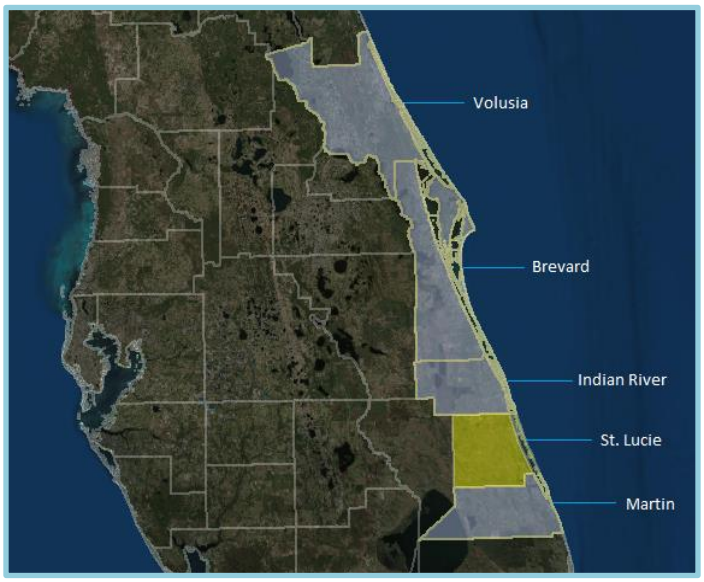
Moving south to Vero Beach, a large city straddling the lagoon system and fronting the Atlantic Ocean, there is little to no threat to development. Vero Beach is situated on higher lands, and thus the inundation does not go far inland. However, there are a number of canal-facing residences to the east of Miracle Mile Plaza that would be partially inundated by sea level rise in 2040, 2070 and 2100. However, outfalls in this residential area remain unaffected with the exception of one on the southern end of the canal adjacent to 30th street.

The Florida Ridge area, which is densely populated in pockets and marshland in others, would be highly susceptible to sea level rise if development were to occur within a quarter-mile of the lagoon system. Three outfalls in this area are inundated – all adjacent to the coastline – however most residential areas are spared from the hazard zone.

Areas to the east of the lagoon south of the 17th Street Bridge are almost entirely immune of sea level rise vulnerability. The primary concern in this area, like other areas, is a select number of residential properties adjacent to the lagoon system. Primarily located in canal communities, these properties could see rising water levels reach the structures situated on the lots.

The area adjacent to St. Lucie County includes large inundation swathes, however most development is located away from these zones. The primary vulnerability area is the residential community to the immediate north of the county boundary. The areas to the east of Round Island Park are undeveloped outside of a few Atlantic-facing properties.

St. Lucie County Vulnerability Analysis | *Outfall and Land Risk Summaries*



St. Lucie County has approximately 42 linear miles of coastline (combined, east and west) along the Indian River Lagoon and 21 miles of coast along the Atlantic Ocean. The lagoon is quite wide in this area, with an average width near 1.5 miles. Unlike other counties in the study area, St. Lucie County has a slight ridge located along the western shores of the Indian River Lagoon and inland inundation is almost nonexistent. However, the barrier islands are threatened by rising water levels from the Indian River Lagoon to the west. Vulnerability on the barrier islands is reduced due to the lack of substantial development adjacent to the lagoon system. In most cases, development along St. Lucie's barrier islands is located in uplands that are not within the primary risk zones.

Outfall and Land Inundation | North to South | Medium Projection Curve Analysis

Year 2100 sea level rise projections under the medium projection rate curve depict approximately 0.1 miles of infringing water along the western shore of the lagoon system in the northern portion of the county. This area is scarcely populated; however some homes are at risk. Avalon State Park, on the eastern side of the lagoon, also shows considerably inundation, primarily by 2040. Moving south, a small residential community anchored by Soveriegn Way is under extreme pressure by sea level rise by year 2040. Approximately half of the residential units in this location are within the hazard zone. Immediately to the south, Jack Island Preserve State Park and the Fort Pierce Inlet are projected to be severely inundated, but these areas are not populated. Developed land to the north of Fort Pierce Inlet is relatively safe from the effects of rising seas. However, some lots and a small number of homes along Marina Drive and Bimini Drive are projected to be partially inundated by year 2100. To the west of the inlet along the western shore of the lagoon system, inundation is light and does not reach the Florida East Coast Railway.

Causeway Island, which pinches the lagoon system just south of Fort Pierce Inlet, begins a long stretch of western lagoon shoreline along Fort Pierce that is almost entirely void of hazards to the west of South Indian River Drive. However, Causeway Island has nine outfalls that are projected to be inundated by the year 2070. This is likely due to the placement of the outfalls in hazard zones along with the high density of the outfalls in this location rather than a large amount of inundation to the land on Causeway Island.

To the immediate south of Causeway Island, Hutchinson Island has an unpopulated swamp area that will be almost completely inundated by 2040. Populated areas on this island are placed on higher ground and these areas are not expected to be inundated by 2100 under the medium

projection rate curve. Three outfalls are projected to be inundated on Hutchinson Island by 2070. Moving to the central and southern portions of Hutchinson Island, sea level rise inundates marshlands that account for approximately 85% of the width of this barrier island. To the immediate east of the Savannah Recreation Area across the lagoon system, two outfalls on Hutchinson Island are projected to be inundated by 2040. Hutchinson Island, however, is under a much different scenario than the western shores of the Indian River Lagoon.

The western shores of the lagoon system remain almost untouched by the effects of sea level rise through to the southern end of Fort Pierce, which reduces the financial, economic and societal risk of sea level rise greatly. This lack of inundation continues southward through the Savannah Recreational Area to Indian River Estates and White City, all the way to the border with Martin County. This marks a significant change from Volusia, Brevard and Indian River counties to the north, areas that face severe risk to sea level rise along its western lagoon shores.

It is clear that St. Lucie County is extremely protected from sea level rise on its western lagoon shores due to an increase in elevation that stretches 14 miles from Fort Pierce Inlet to the county boundary. As stated earlier, the Florida East Coast Railway is located almost adjacent to these shores. This extremely important cargo and passenger railway is a critical transportation network that connects goods and services from major hubs including Atlanta, Jacksonville and Orlando to Miami. The lack of inundation to this asset represents an extreme reduction in risk, as the surrounding areas are dense with business, industry and neighborhoods along the lagoon.

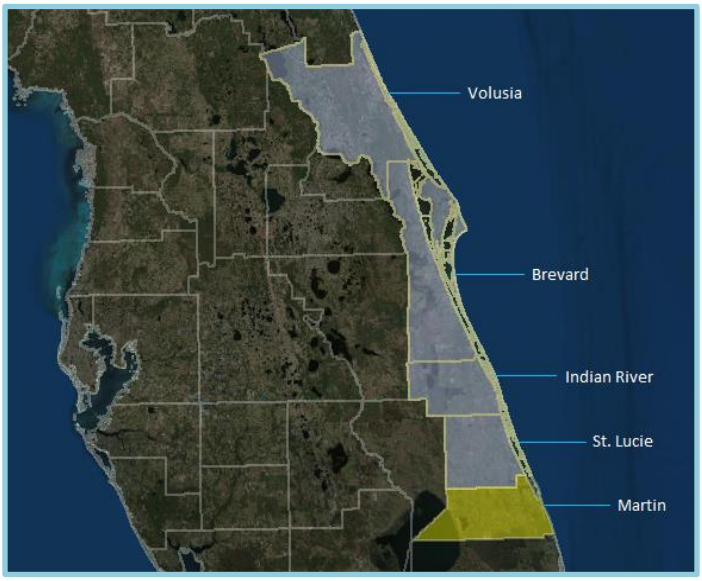
South Indian River Drive is the consistent stopping point for sea level rise along this stretch of coast and its maintenance will be critical moving forward. There is almost no development to the east of this roadway, making it the primary buffer between the ocean and the developed mainland.

While Hutchinson Island is very inundated to the southern boundary of the county, its population areas remain consistently untouched for the most part through the county. Sea level rise in this area primarily affects swamps and marshland. However, Island Dunes Country Club, near the border with Martin County, is projected to be nearly 40% inundated by 2040 utilizing the medium projection rate curves. To the south, at Nettles Island, most of the residential lots adjacent to canals or the lagoon system will be at least partially inundated by 2040 under these projections.

A separate, but critical threat to St. Lucie County occurs along the north fork of the St. Lucie River, which stretches approximately 16 miles into St. Lucie County from the south. This represents a large risk to the county, as the areas surrounding the river are densely populated. The river system has a buffer that – in some cases – stretches approximately 0.3 miles in each direction. This acts as a protective buffer to most of the densely populated areas surrounding the river. Port St. Lucie and White City are the most vulnerable cities within the county in terms of riverine flooding. High projection rate curve analysis confirms heightened risk to populations here.

Of the 166 outfalls located directly along the St. Lucie River in St. Lucie County, only four are projected to be inundated utilizing the medium projection rate curve. The high projection rate curve increases this number to 51, which begins to show the slight topographic conditions in this area that increase risk severely when transitioning from the medium curve to the high curve.

Martin County Vulnerability Analysis | *Outfall and Land Risk Summaries*



The southernmost county within the study area, Martin, includes 7 linear miles of the Indian River Lagoon system (or 14 miles of lagoon coastline). The lagoon system terminates at the St. Lucie Inlet and Port St. Lucie, where water from multiple Lake Okeechobee canals drains into. Moreover, the St. Lucie River extends northward and southward from the inlet and increases inland vulnerability to sea level rise. Unlike St. Lucie County, Martin County has a fair amount of development along the barrier island system. However, these barrier islands are located on higher land and thus are not severely susceptible. This is true on the western shores of the lagoon system as well. Most of the inundation within Martin County west of the Indian River Lagoon is located along the banks of the St. Lucie River.

Outfall and Land Inundation | North to South | Med-High Projection Curve Analysis

The St. Lucie Inlet and St. Lucie River, located at the northern extent of Martin County, is the primary risk area in the county. Regionally, the inlet and river system have the highest concentration of outfalls of all areas with the exception of Merritt Island in Brevard County. Jensen Beach, Ocean Breeze Park, Stuart, North River Shores, Palm City, Sewall's Point, as well as Port Salerno are located along this inlet-river system.

Ocean Breeze Park and Jensen Beach are located along the western shores of the Intracoastal Waterway system to the north of the St. Lucie River. Sea level rise is somewhat consistent along these shores with an average of 0.1 miles of inland inundation by 2100 under the high projection rate curve. 2 of the 21 outfalls located here are projected to be inundated by 2070 under the medium curve. Moreover, large portions of the Northeast Dixie Highway are projected to be inundated by 2100 under the high projection rate curve. This roadway serves as the main service road into Ocean Breeze Park and Jensen Beach from the south and is a critical piece of transportation infrastructure.

To the east of Jensen Beach and Ocean Breeze Park, the barrier island systems show high levels of inundation by the year 2040 but development is limited in this area. The primary concern for this section of the barrier island system is the projected inundation of A1A. From the northern boundary with St. Lucie County to the eventual crossing over the intracoastal system north of St. Lucie Inlet, the entire stretch of A1A is projected to be partially inundated under the medium projection rate curve. This represents a 4.2 mile stretch of the roadway with intermittent inundation. Of the 10 outfalls located along the barrier system, four are projected to be inundated by 2040. These outfalls are located less than a mile north of the St. Lucie Inlet.

On the northern bank of the St. Lucie River to the north of Stuart, the community of North River Shores is projected to be inundated from the south – primarily in developed areas – under the high projection rate curve. Neighborhoods located near the US1 crossing from the south are located within the primary hazard zone under this curve. Moreover, the Florida East Coast Railway – which is largely spared within the study area from sea level rise – is projected to be inundated along parts of a half-mile stretch (medium curve and high curve). This could have a severe impact on freight movement through the state of Florida. Of the 54 outfalls located along the northern shores of the St. Lucie River in Martin County, 9 are expected to be inundated by 2100 under the medium curve. Of those nine, four are projected to be inundated by 2040 and two by 2070. The difference between the medium curve and high curve in this area is significant.

The northern shores of Stuart are largely protected by sea level rise with the exception of three linear stretches of inundation along the Krueger Creek, Poppolton Creek and Frazier Creek. These are highly developed areas with a mixture of uses. Of the 40 outfalls located along the coastlines of Snug Harbor and Stuart, only 1 is projected to be inundated by 2100. The Martin County Airport, located in this area, is mostly spared with the exception of a small amount of year 2100 inundation in the northeast section of the airport under the high curve. No runways are projected to be affected. However, to the southeast of the airport, the community of Port Salerno shows high inundation levels. A small inlet exacerbates sea level rise projections in this area.

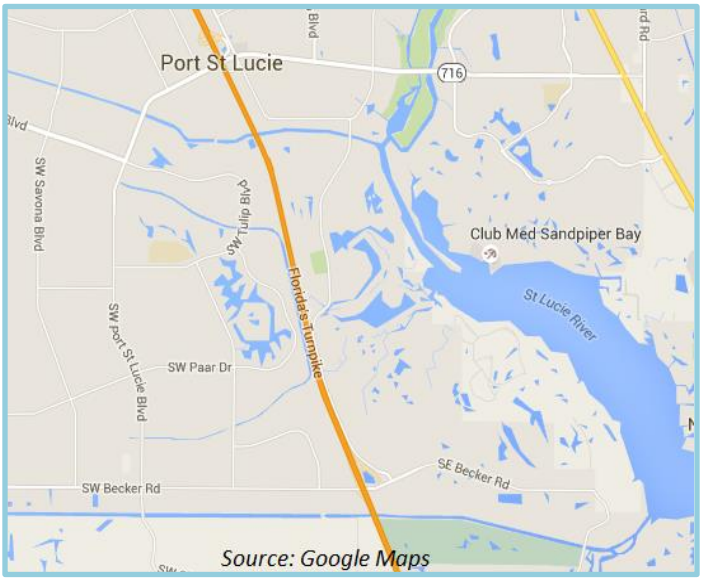
Palm City, to the west of Stuart, is an area that shows high levels of inundation by 2040. Of the locations along the St. Lucie River, this is perhaps the area with the densest concentration of outfalls. The Lighthouse Point community is projected to have severe inundation levels by 2100. This residential community is susceptible due to the canal systems that back residential lots alongside naturally low elevation. However, of the 33 outfalls in this location, only three are projected to be inundated by 2070 under the medium curve. The Palm Cove Golf Club – located to the west of Lighthouse Point, shows high levels of inundation by 2070 as well.

To the immediate south in Palm City, a high amount of inundation is present along the town's eastern shores with the south fork of the St. Lucie River. The south fork is surrounded by low-elevation lands, intensifying the effect of sea level rise. Of the 28 outfalls in this location, 7 are projected to be inundated by 2100. In addition, major roadway Martin Downs Boulevard is projected to be partially inundated by 2100. This would restrict access from Palm City to Stuart, as the Martin Downs Boulevard Bridge connecting the two is the only bridge in the vicinity. Five of the 26 outfalls in this area are projected to be inundated by 2070 (medium curve).

The south fork of the St. Lucie River continues well into the central portion of Martin County. There are 62 outfalls along the south fork, and 18 are projected to be inundated by 2100. Moreover, Southeast Cove Drive and the Kenner Highway are major transportation networks in this area showing sections of light inundation by 2100 under the medium and high curves.

The Intracoastal Waterway system between Jupiter Island and Hobe Sound is also a high risk hazard zone. Inundation stretches an average of approximately 0.2 miles inland under the high curve, inundating portions of golf courses and residential communities. There are 15 outfalls in this location, four of which are projected to be inundated by 2070.

Canal System Vulnerability Analysis | *Outfall and Canal Risk Summaries*



Lake Okechobee is located on higher land than the areas surrounding it, which requires mass-draining to the Atlantic Coastline through Martin and St. Lucie counties via canals. These canals, which also come from agricultural areas to the northeast of Lake Okeechobee, eventually drain into the St. Lucie River and St. Lucie Inlet. Located along primarily agricultural parcels of land, these canals are susceptible to chemical exposure, resulting in lower water quality within the canal systems. Elements including phosphorous and nitrogen are two of many chemicals that are typical of this type of adjacency. Suspended solids are also generated in these canals, which can reduce lighting to vegetation and wreak havoc on ecological systems. These canal systems are a hazard primarily due to potentially deteriorating water quality and could have negative impacts on property values as well as ecological and ecotourism-based assets along the St. Lucie River.

Outfall and Land Inundation | East to West | Medium Projection Curve Analysis

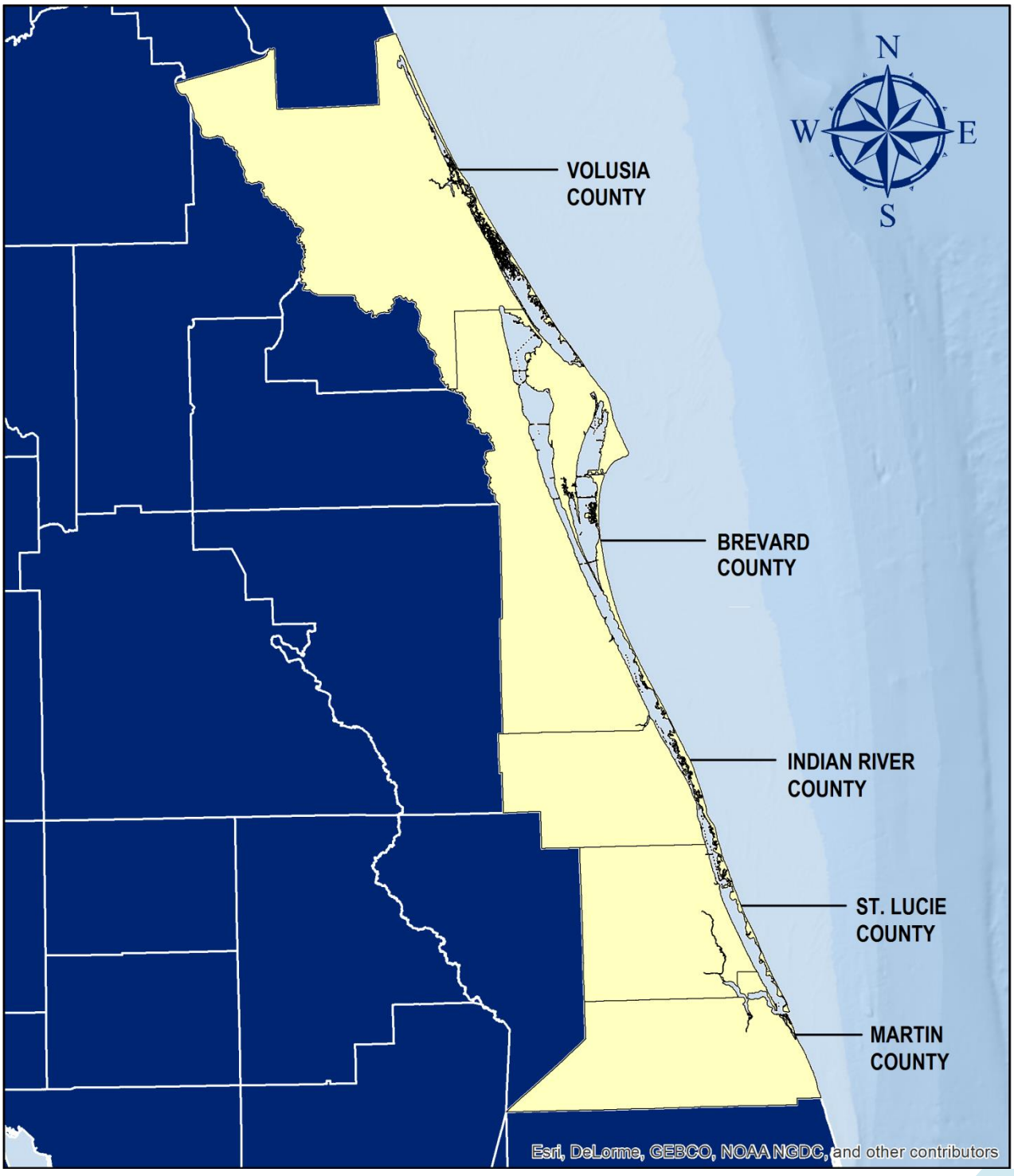
C-24 Canal: The C-24 Canal, also known as the Diversion Canal, traverses from agricultural and natural lands to the northeast of Lake Okeechobee into the northern fork of the St. Lucie River near Sandpiper Bay. While the southeastern portions of the canal travel through heavily populated residential areas, the portion of the canal that travels through St. Lucie County is located adjacent to agricultural parcels. Of the 29 outfalls located adjacent or in close proximity to this canal, none are expected to be inundated by 2100 under the medium curve. However, 6 are projected to be inundated under the high projection rate curve by 2100.

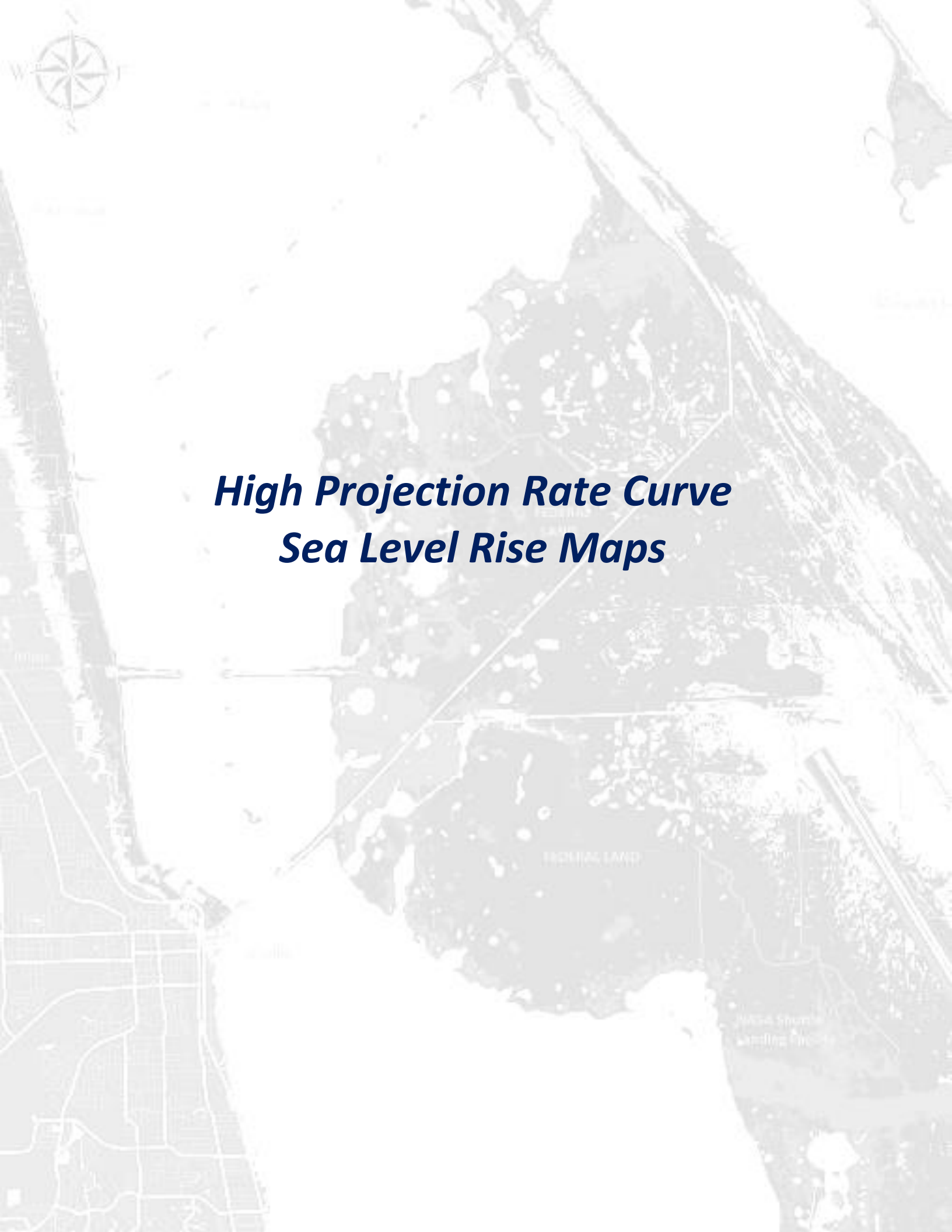
C-23 Canal: The C-23 Canal, located along the border of Martin and St. Lucie counties, drains into the central portion of the St. Lucie River. This canal begins to the northeast of Lake Okeechobee and contains a number of outfalls. However, sea level rise risk does not affect this canal system or the lands surrounding it. Of the 16 documented outfalls located along this canal, none are projected to be inundated under the medium or high projection rate curve in year 2100.

C-44 Canal: The C-44 Canal runs from Lake Okeechobee to the southern fork of the C-44 canal. The portion of the canal is largely unaffected by sea level rise, as all 17 outfalls in this area are safe by year 2100 under high projections. However, as the canal approaches the St. Lucie River the risk is heightened. In total, 11 out of 35 outfalls in this vicinity (some directly adjacent to the C-44 Canal, others in smaller connected riverine systems) are projected to be inundated by 2100 under the medium projection rate curve.

SECTION V: Study Area Maps

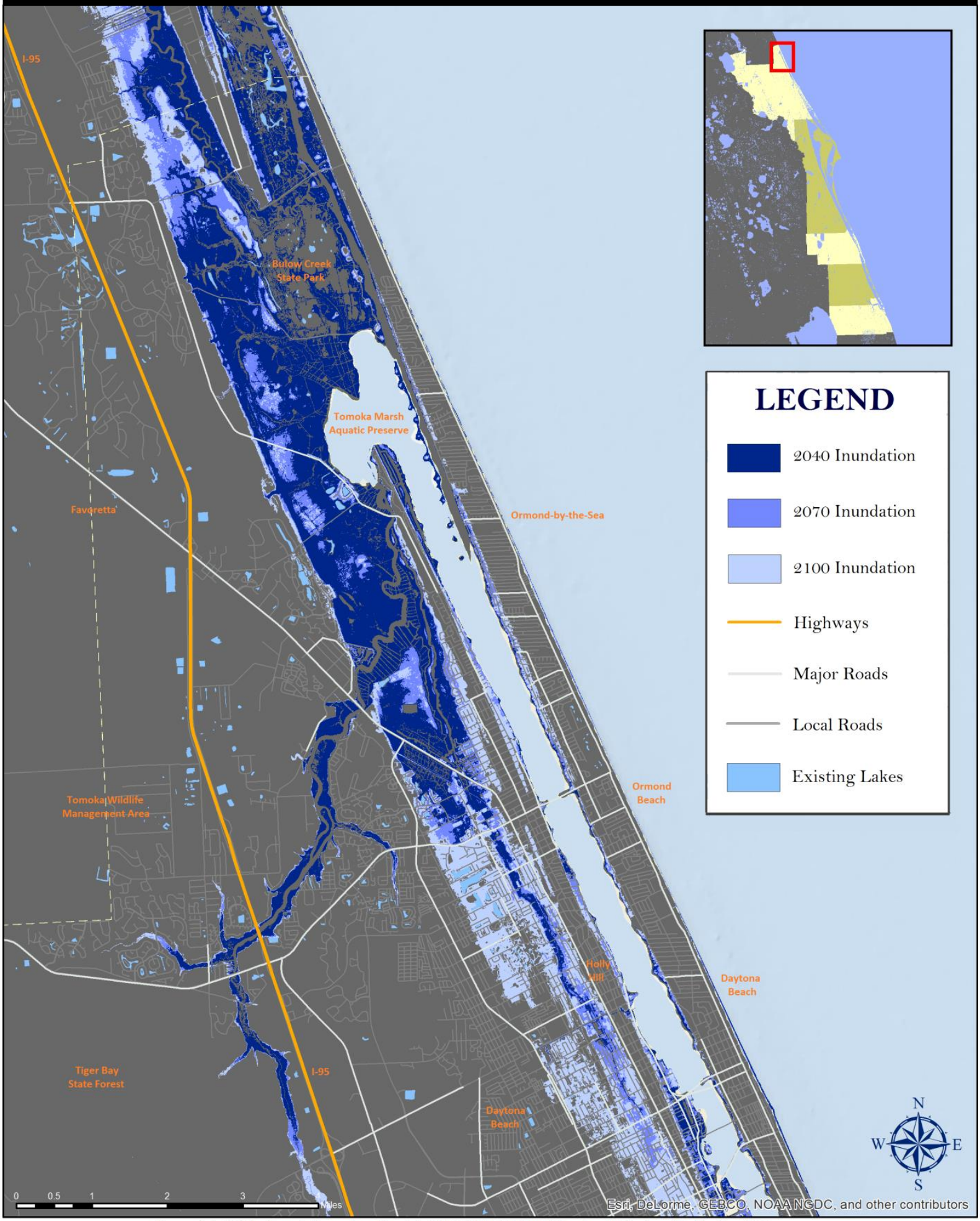
The maps on the following 36 pages depict modeled sea level rise inundation as estimated by the three U.S. Army Corps of Engineers projection rate curves. The study area is depicted below.





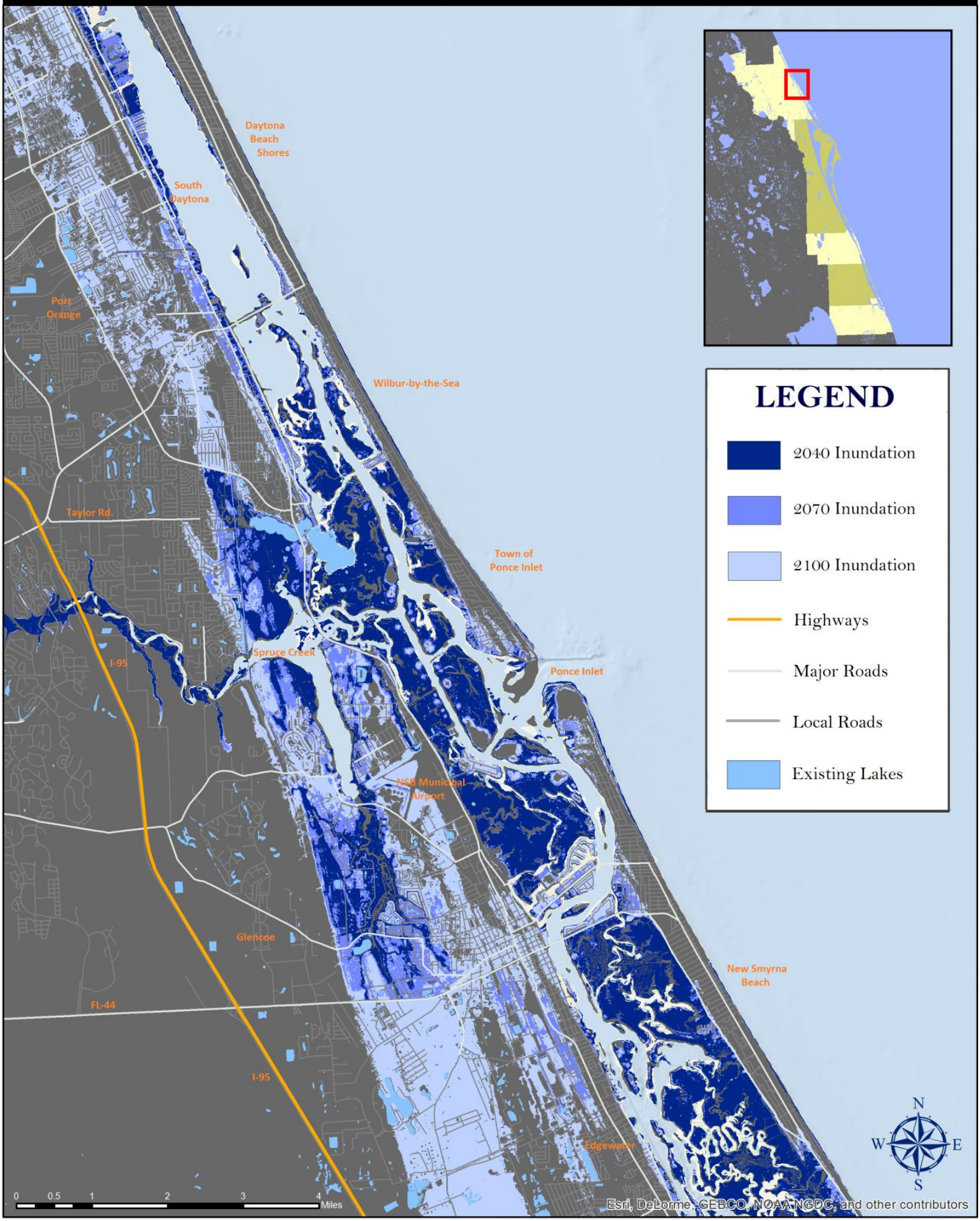
High Projection Rate Curve
Sea Level Rise Maps

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



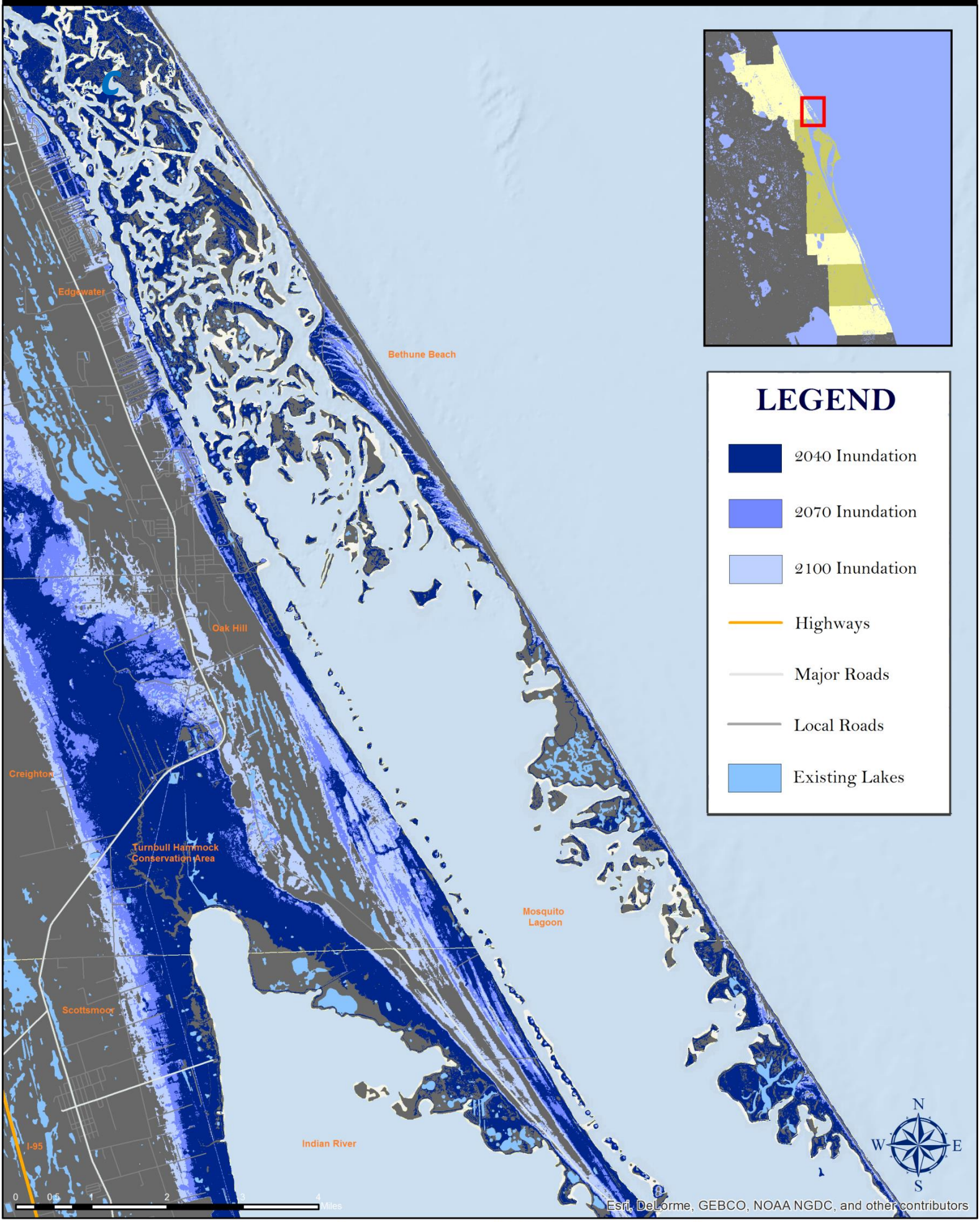
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



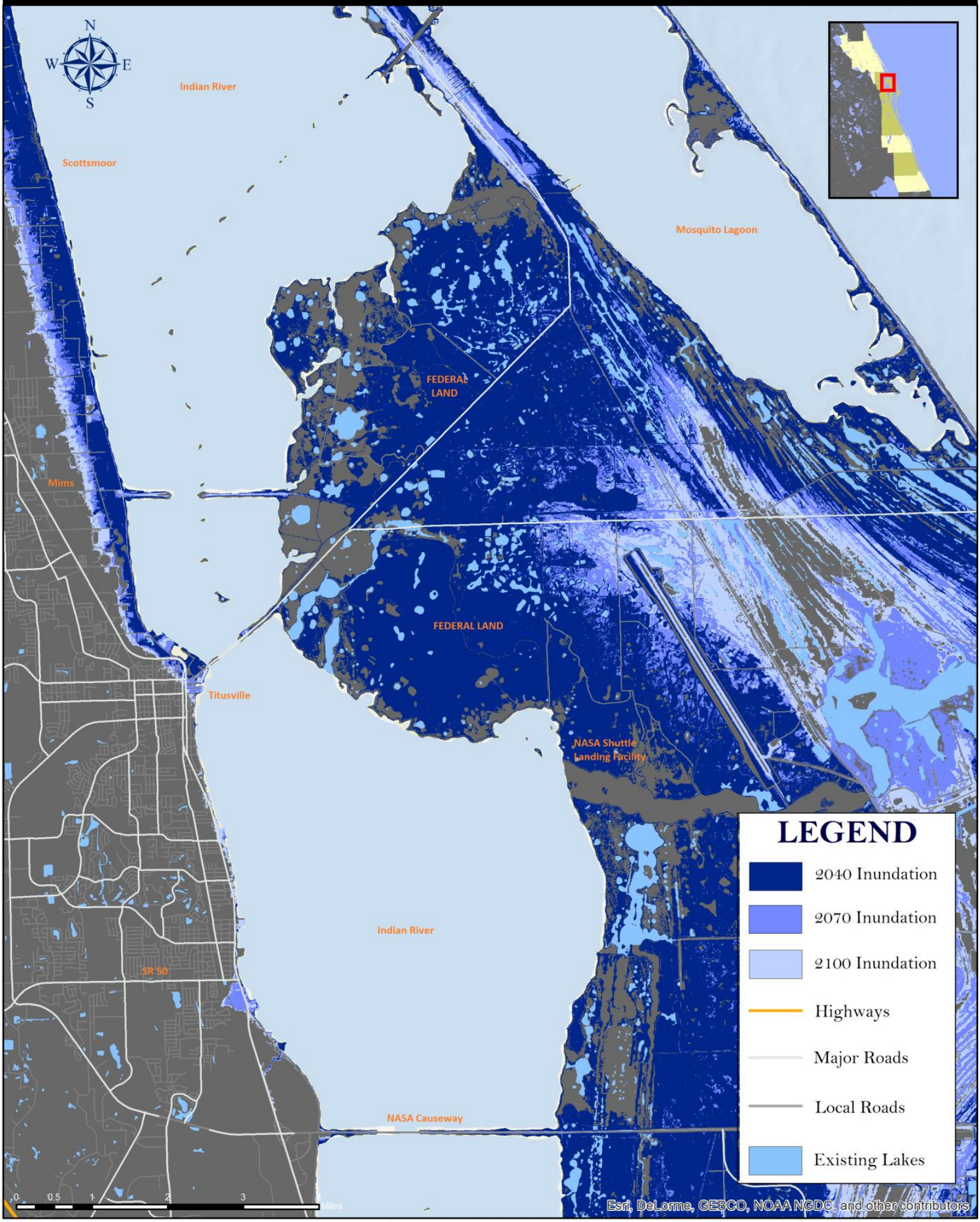
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



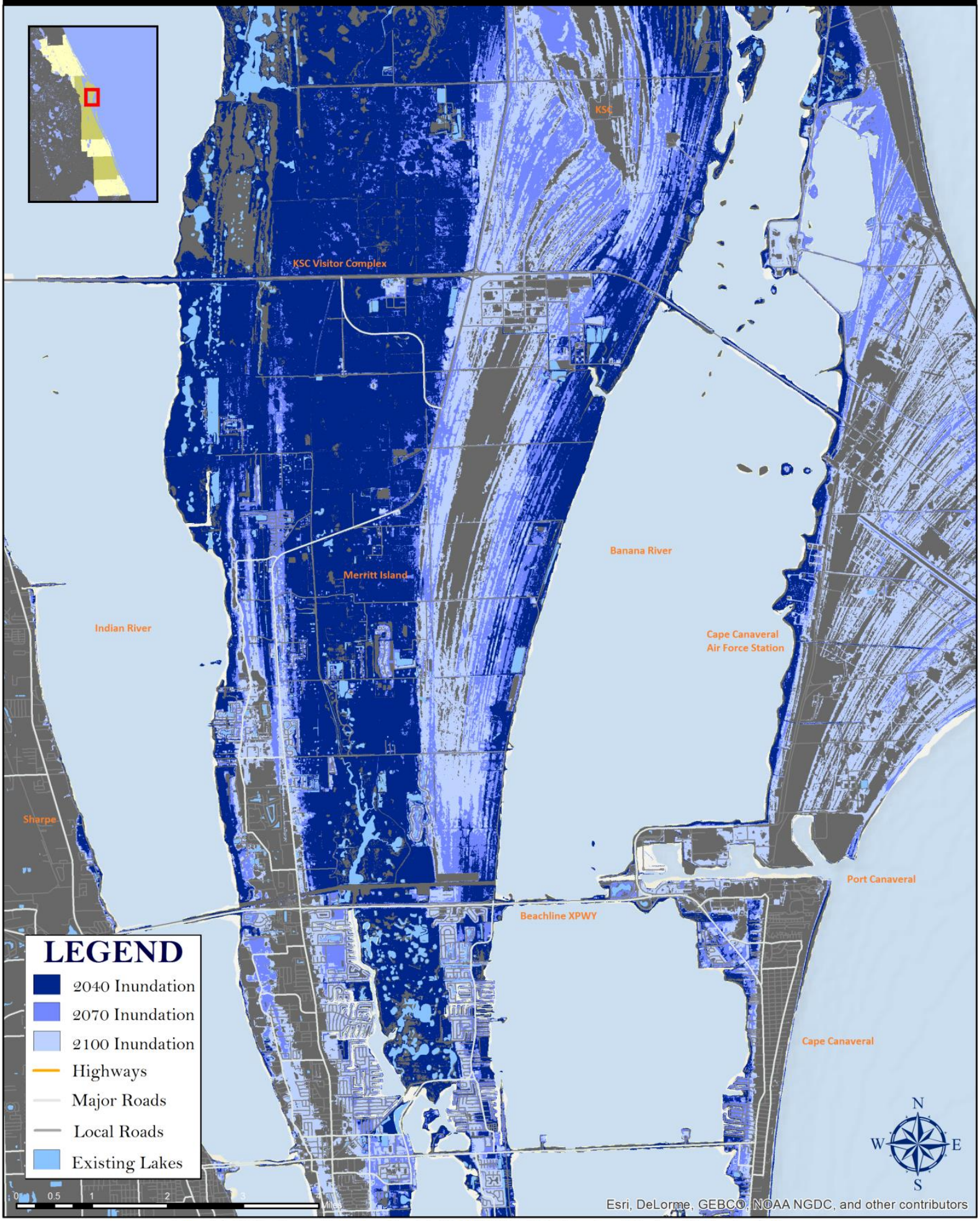
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



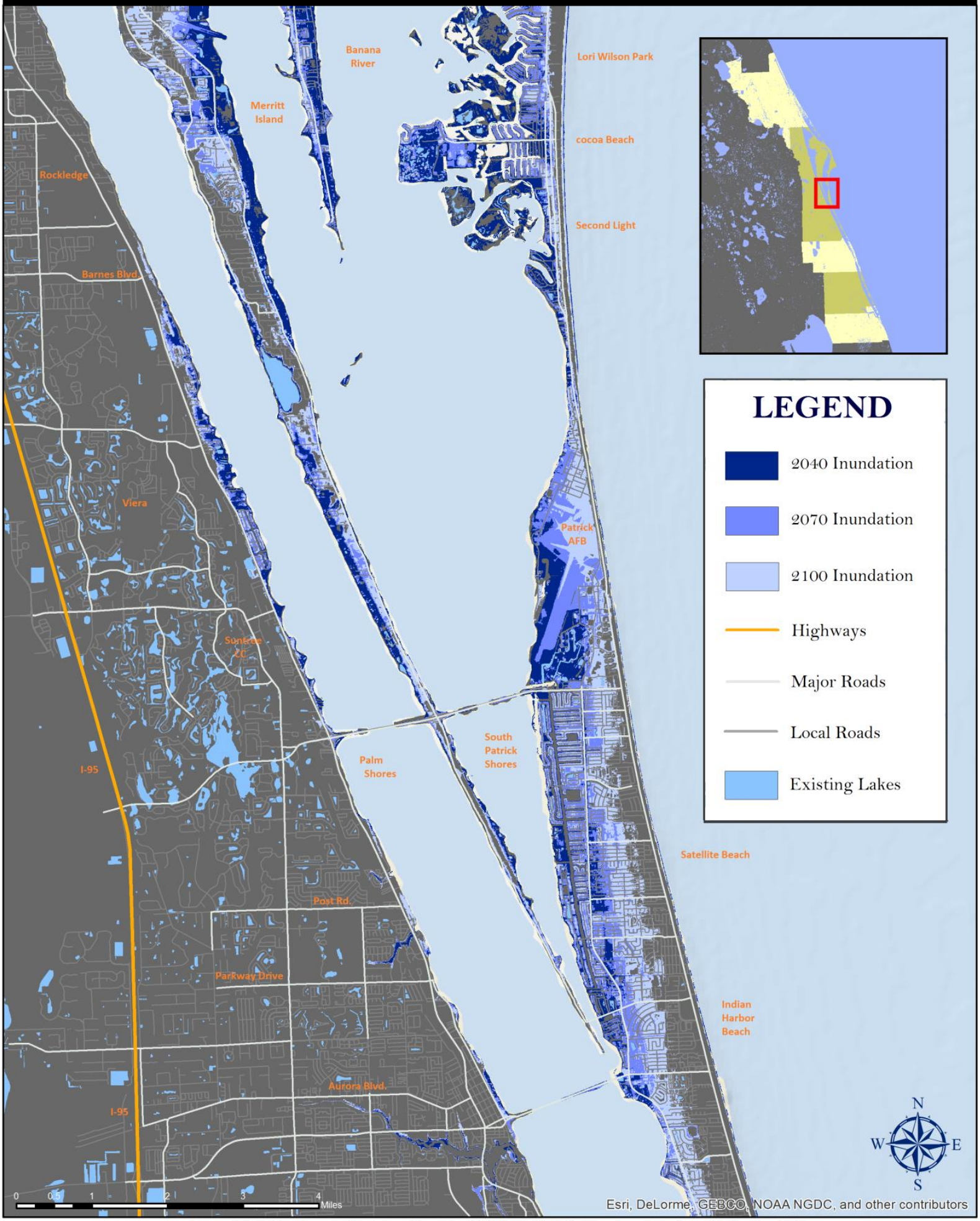
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



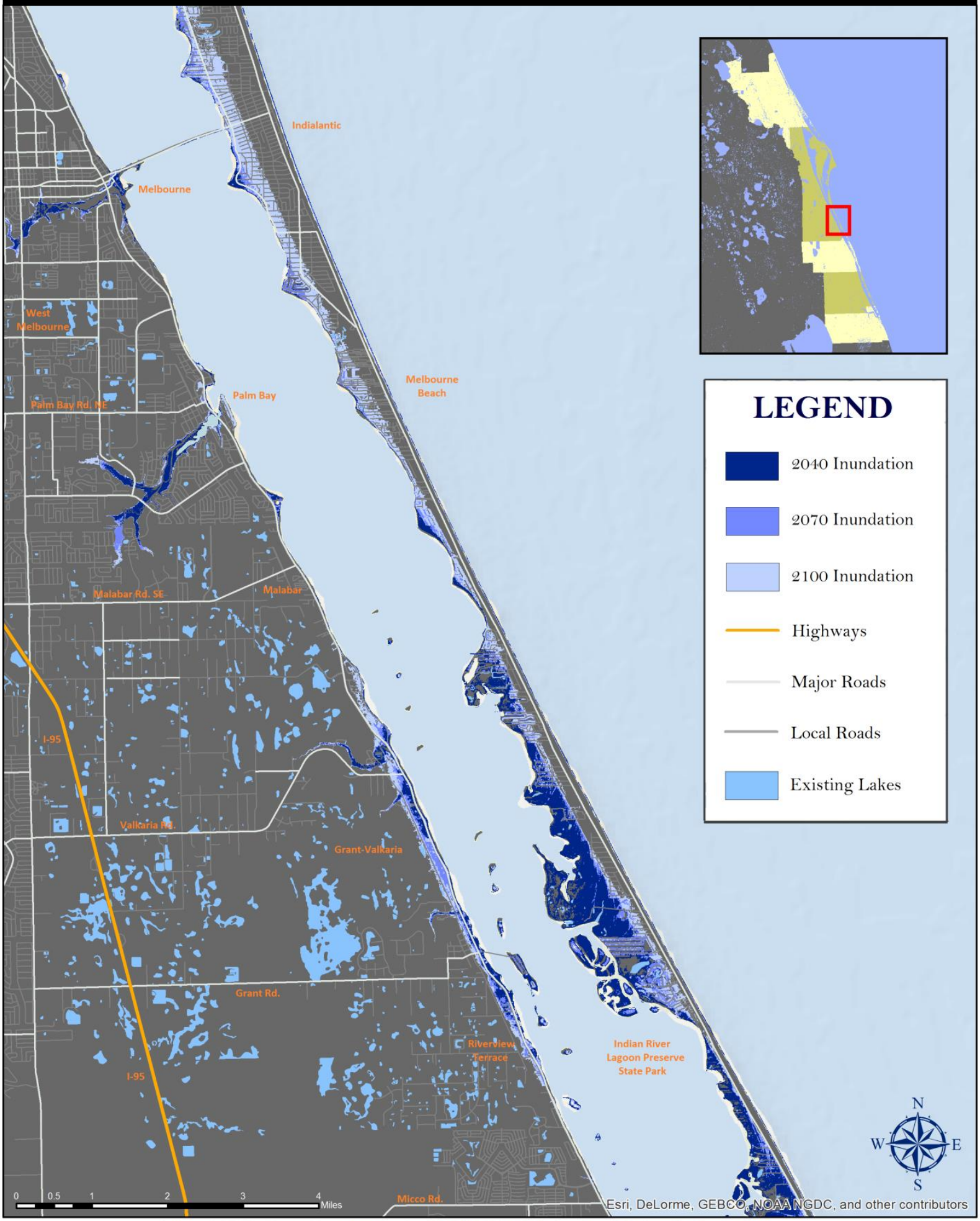
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



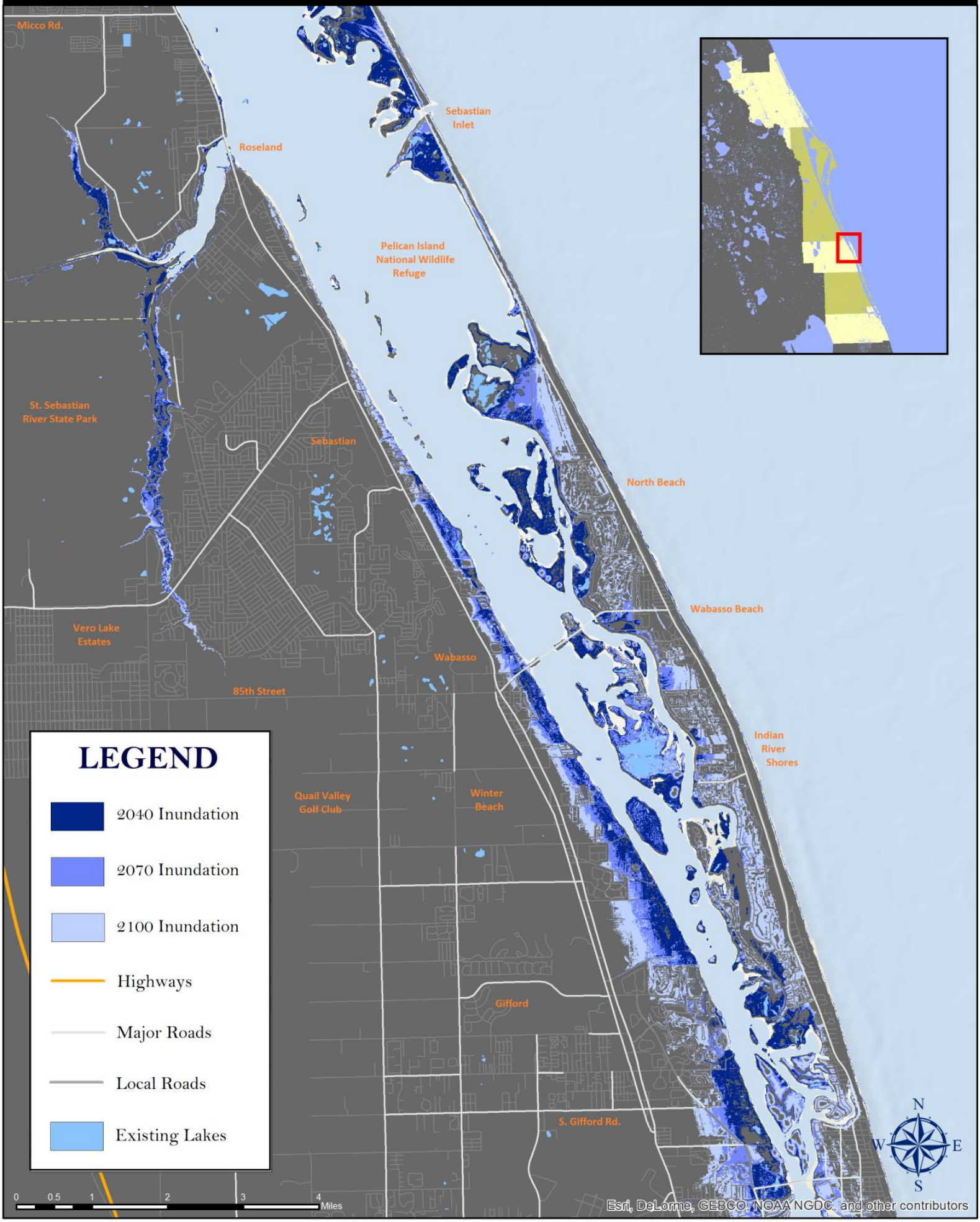
LEGEND

- 2040 Inundation
- 2070 Inundation
- 2100 Inundation
- Highways
- Major Roads
- Local Roads
- Existing Lakes

N
W E
S

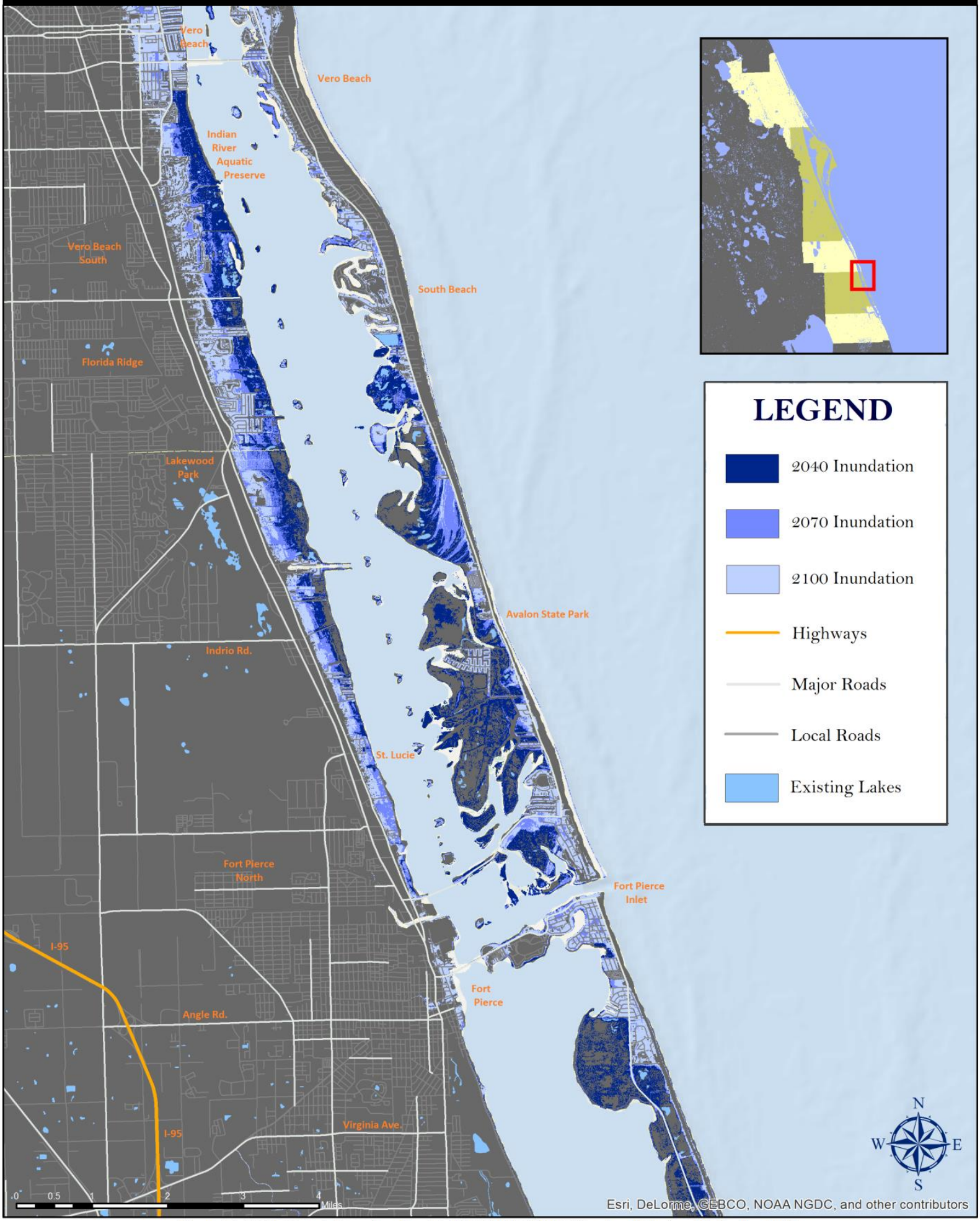
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve



Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve

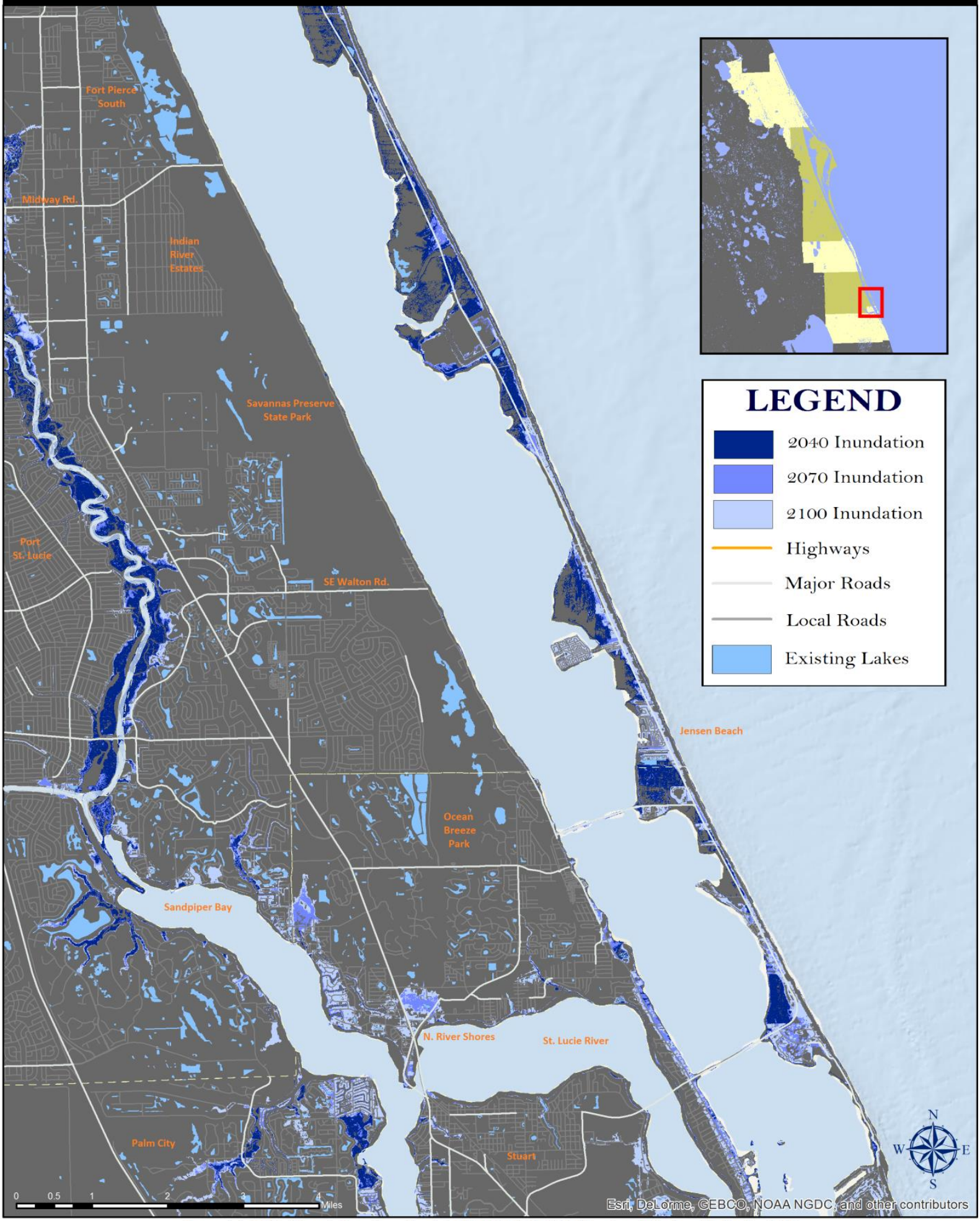


LEGEND

- 2040 Inundation
- 2070 Inundation
- 2100 Inundation
- Highways
- Major Roads
- Local Roads
- Existing Lakes

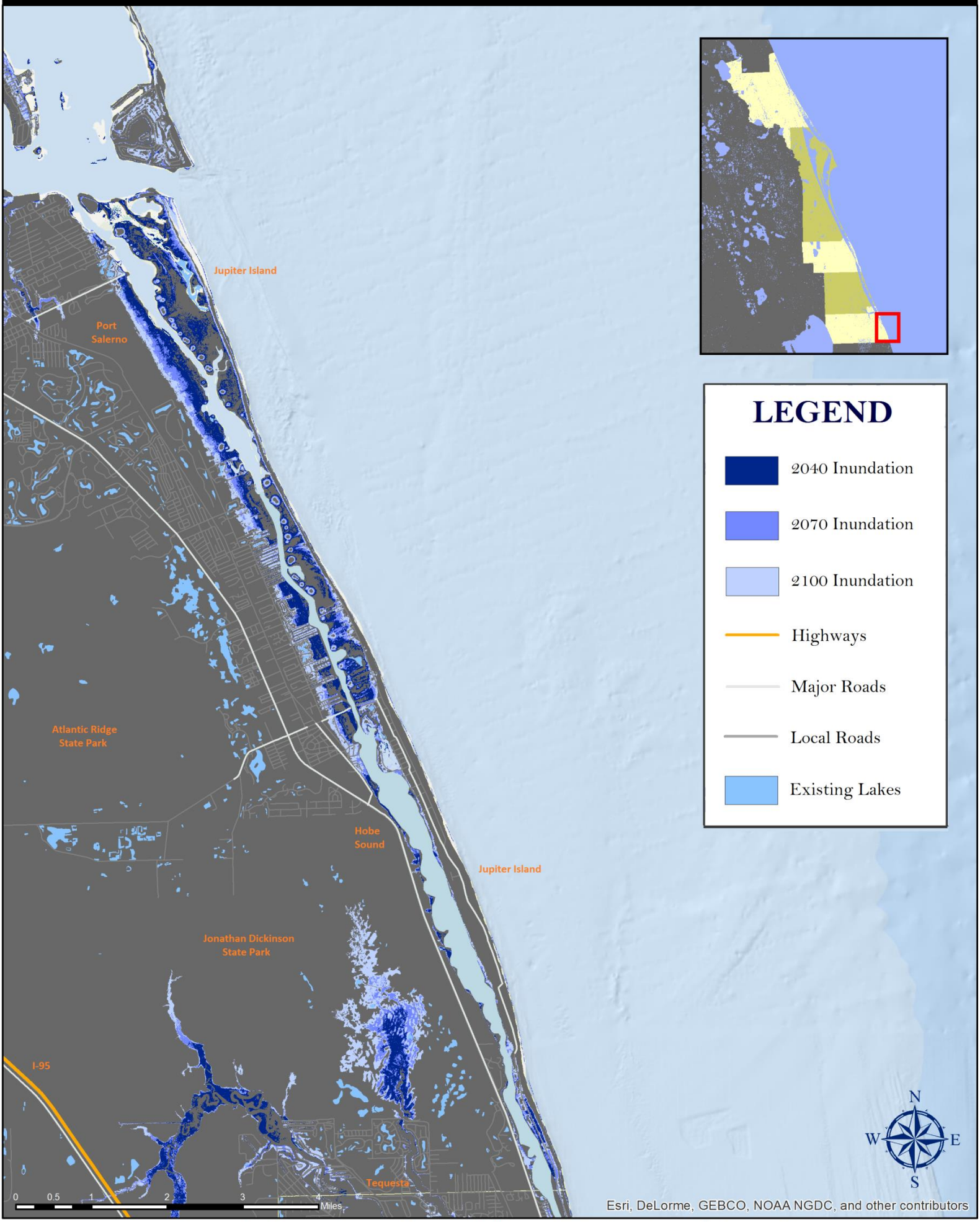
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve

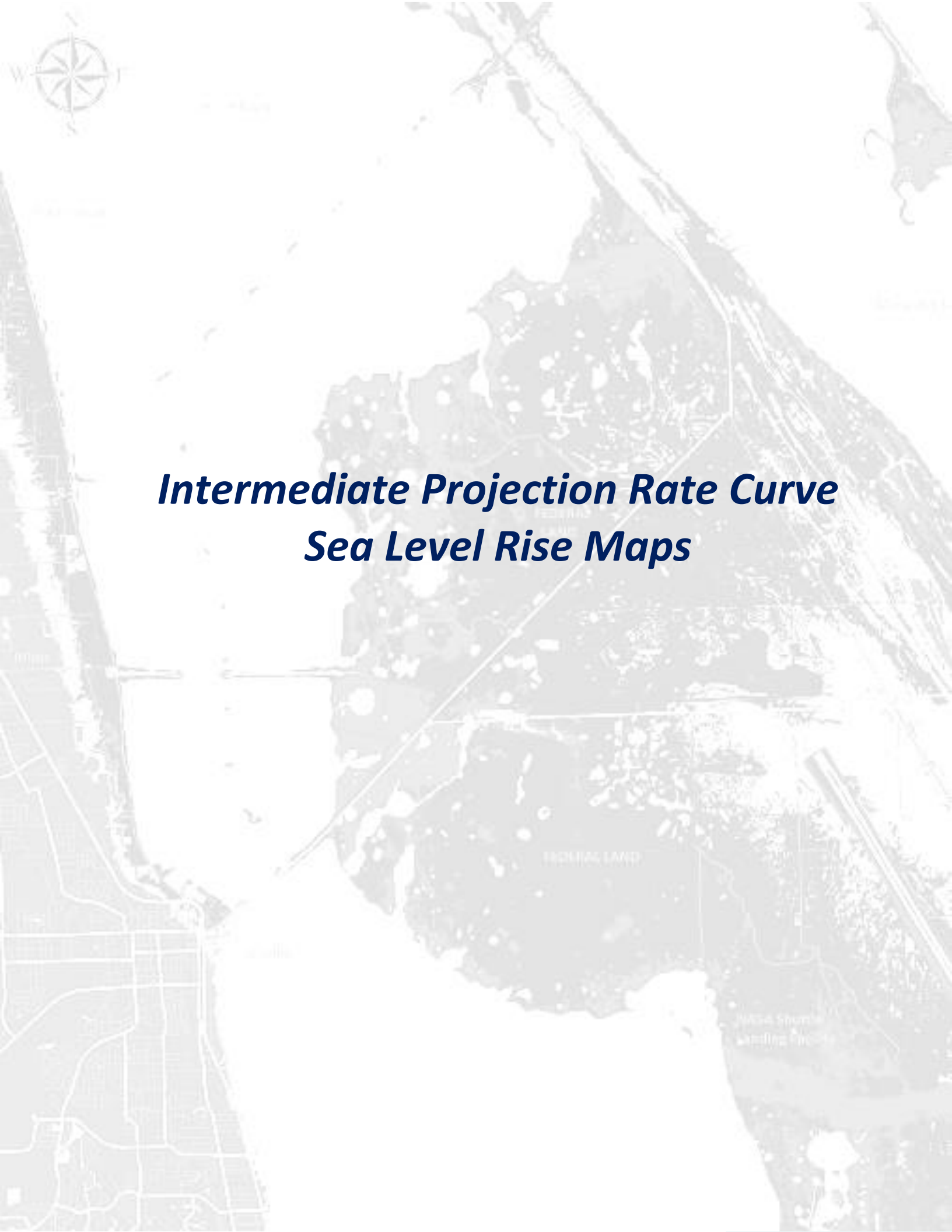


Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | High Curve

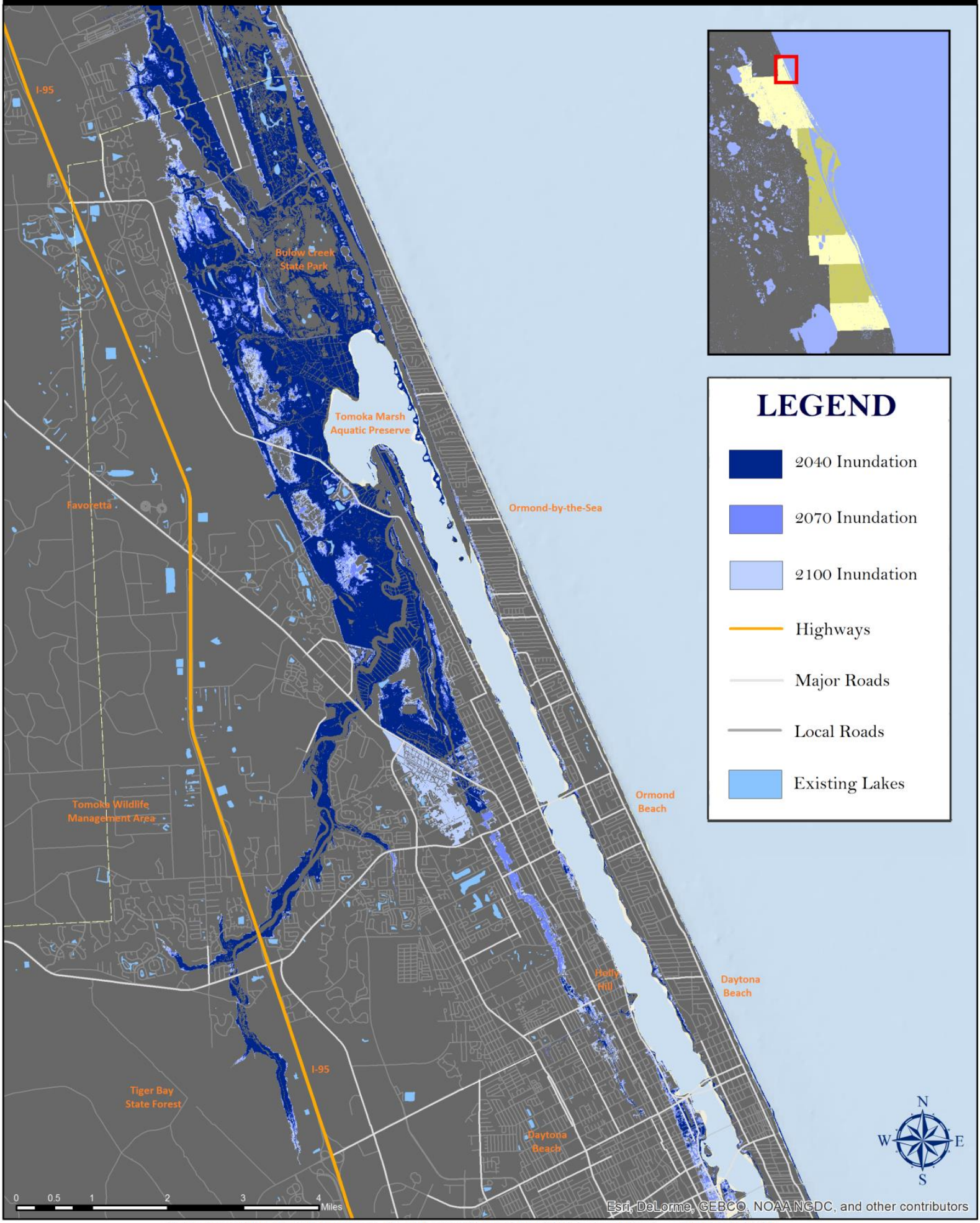


Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015



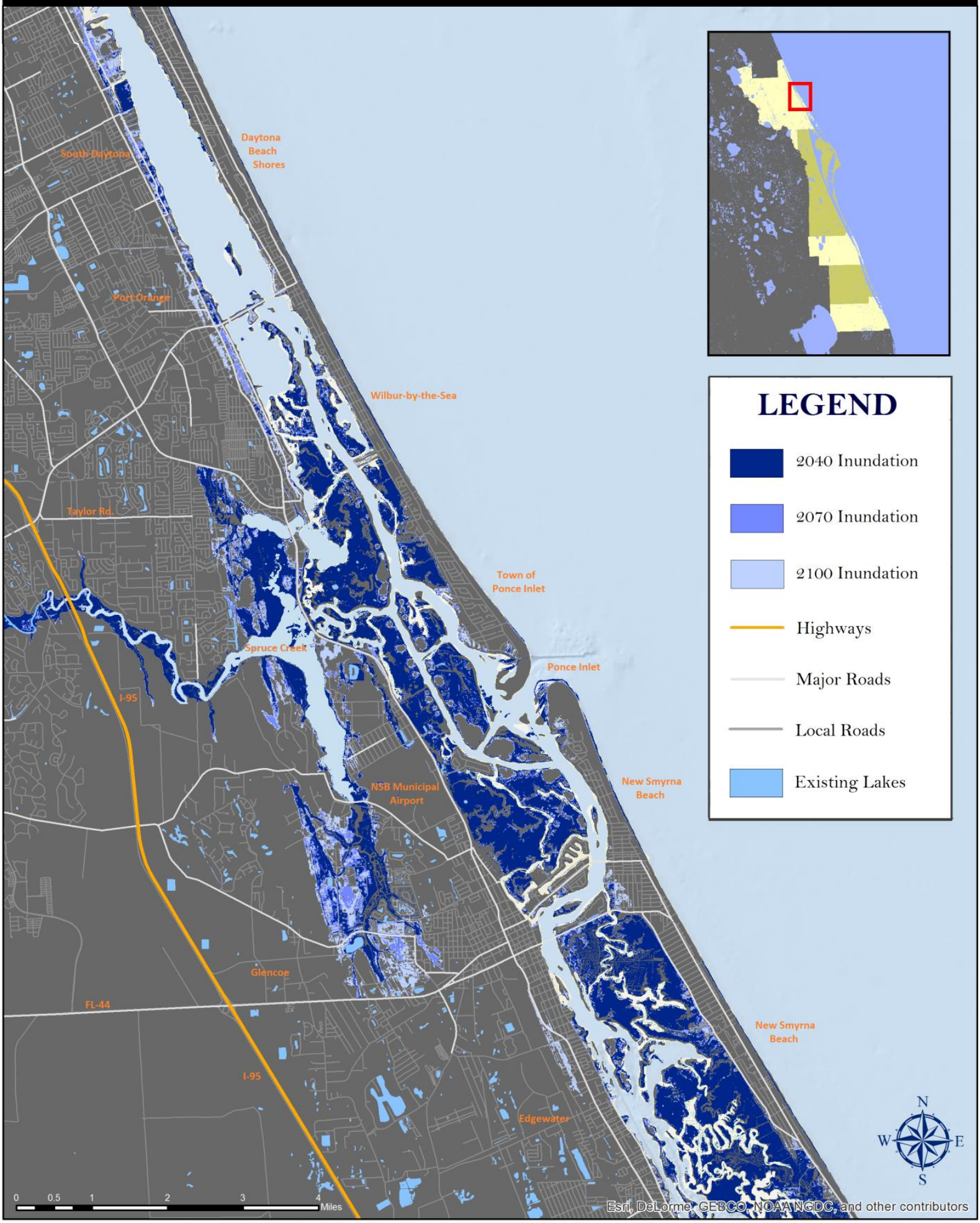
Intermediate Projection Rate Curve Sea Level Rise Maps

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



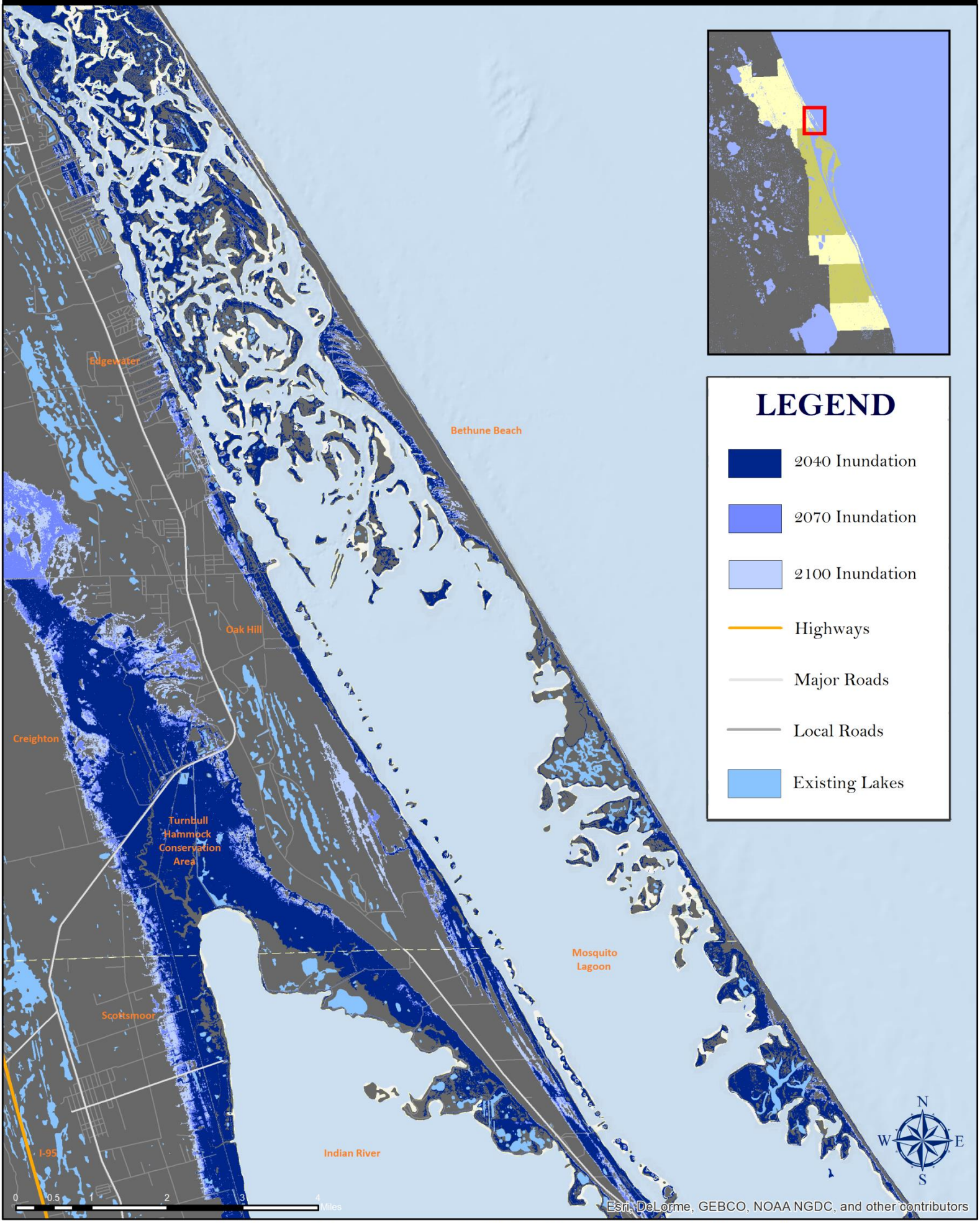
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



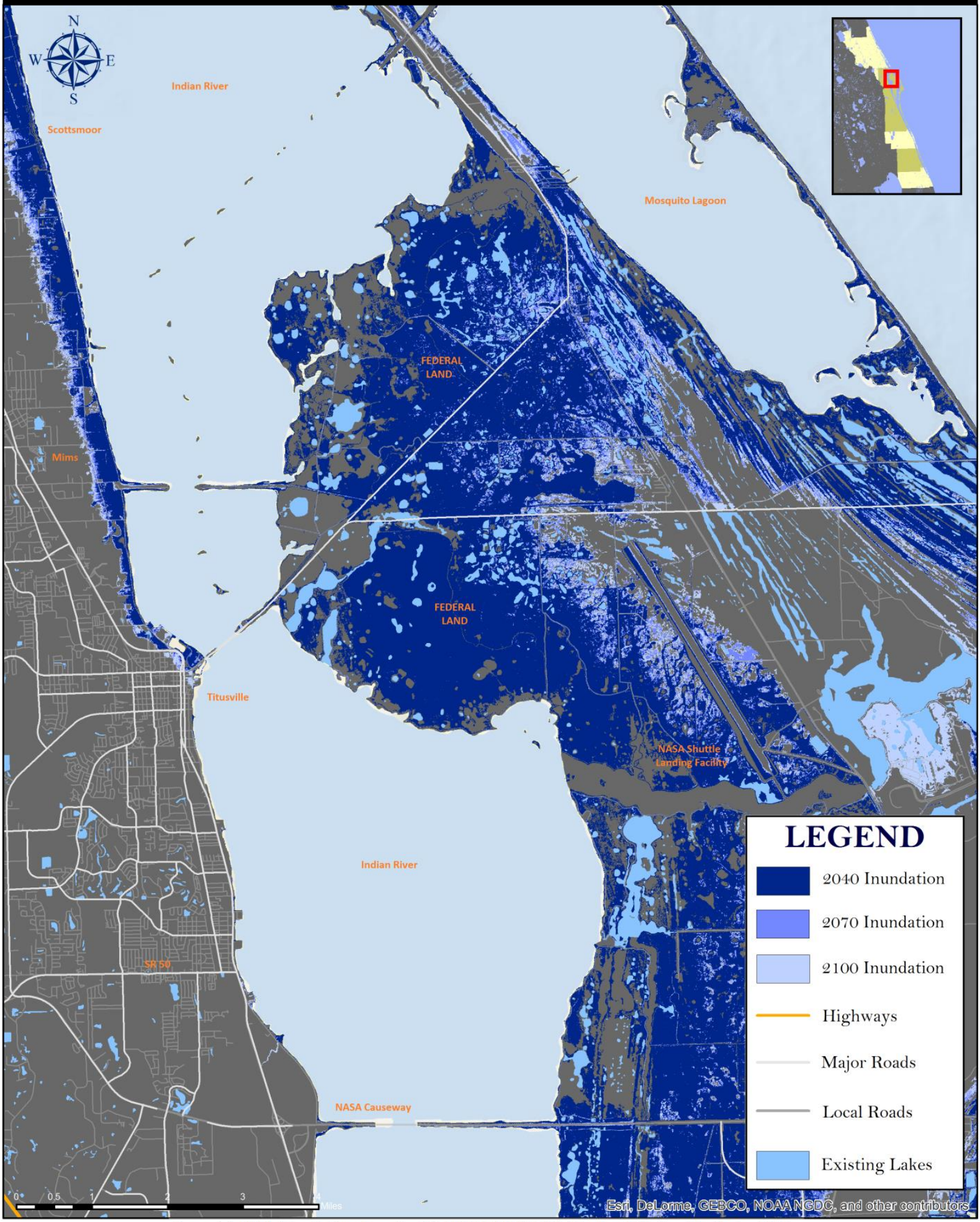
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



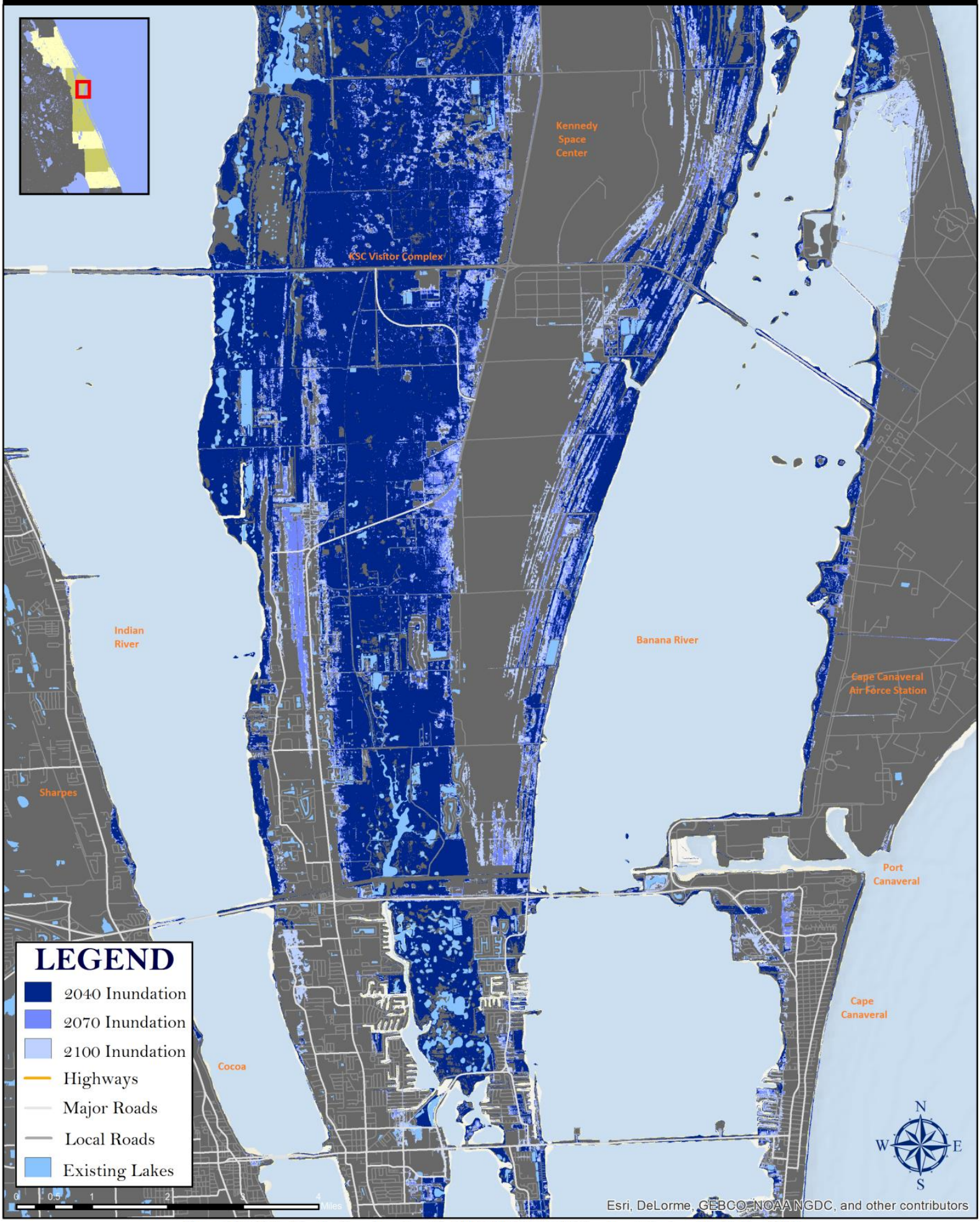
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



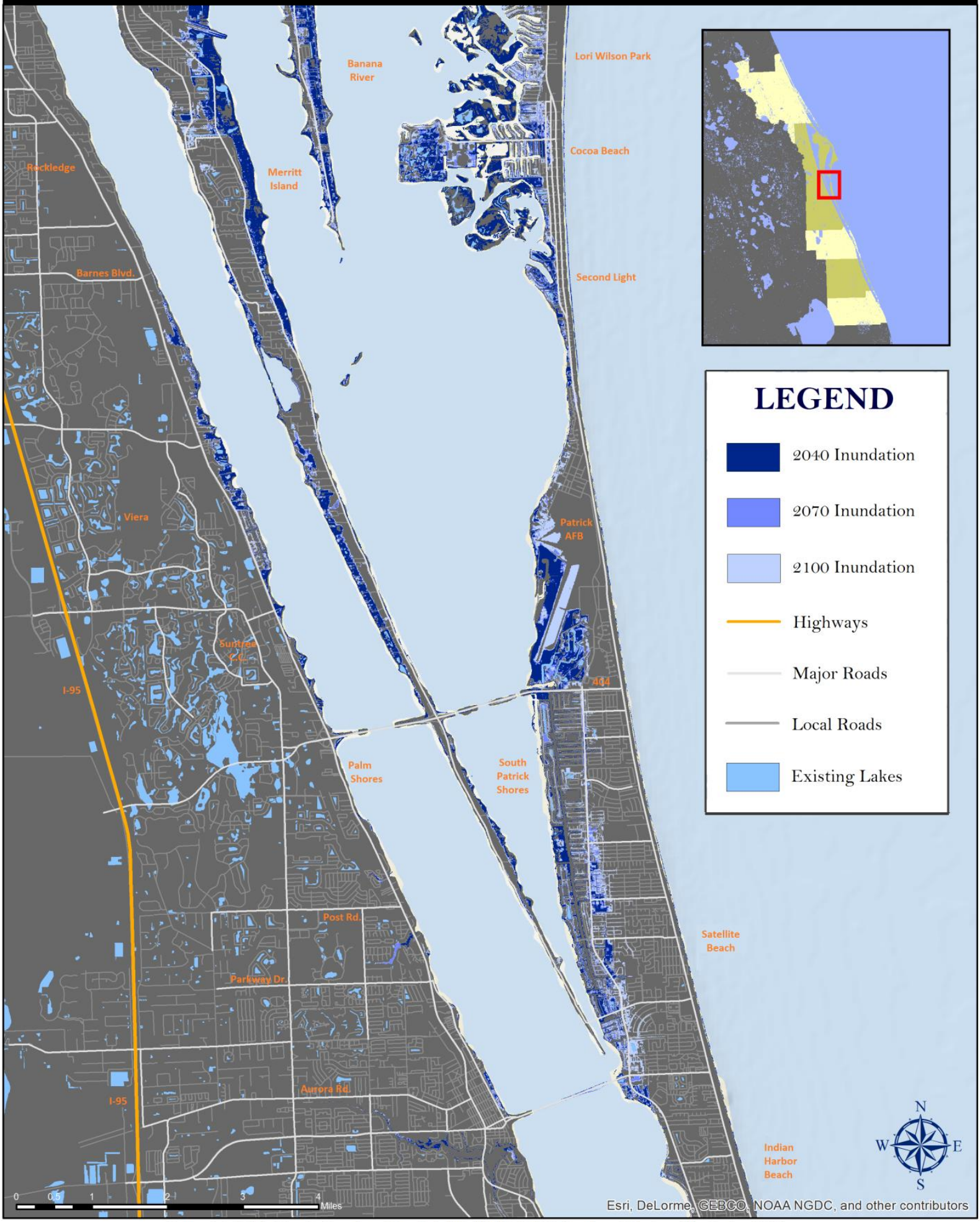
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



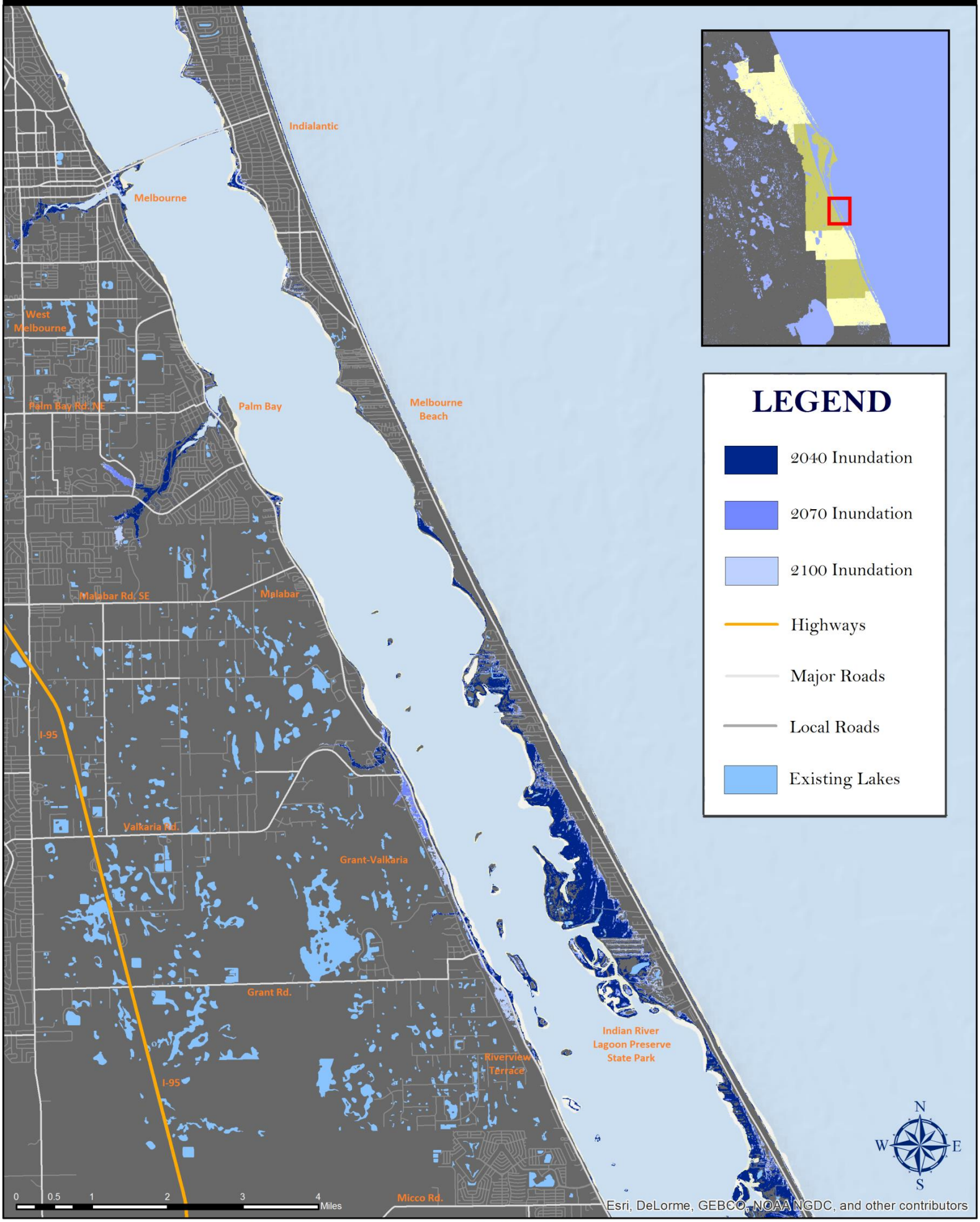
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve

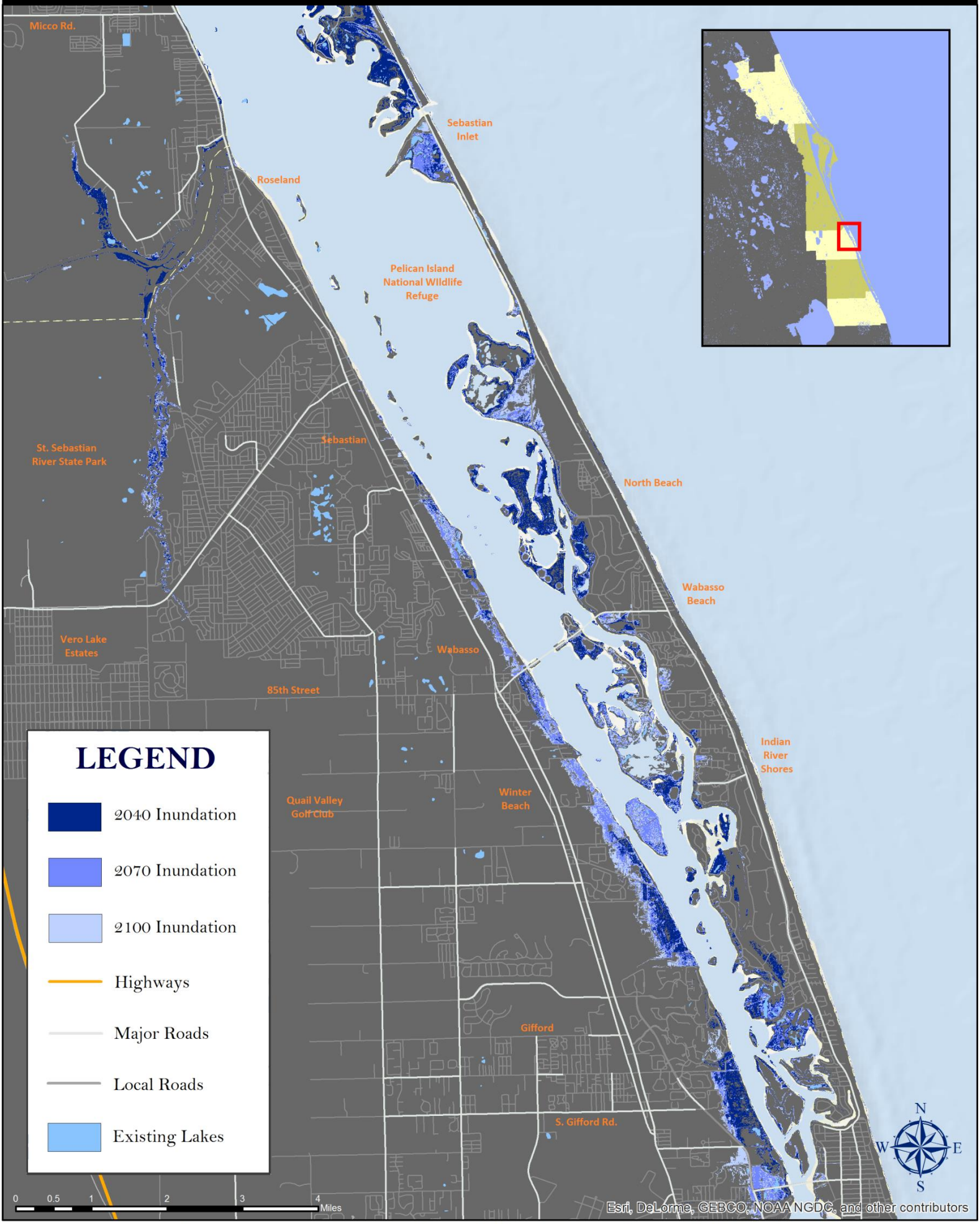


LEGEND

- 2040 Inundation
- 2070 Inundation
- 2100 Inundation
- Highways
- Major Roads
- Local Roads
- Existing Lakes

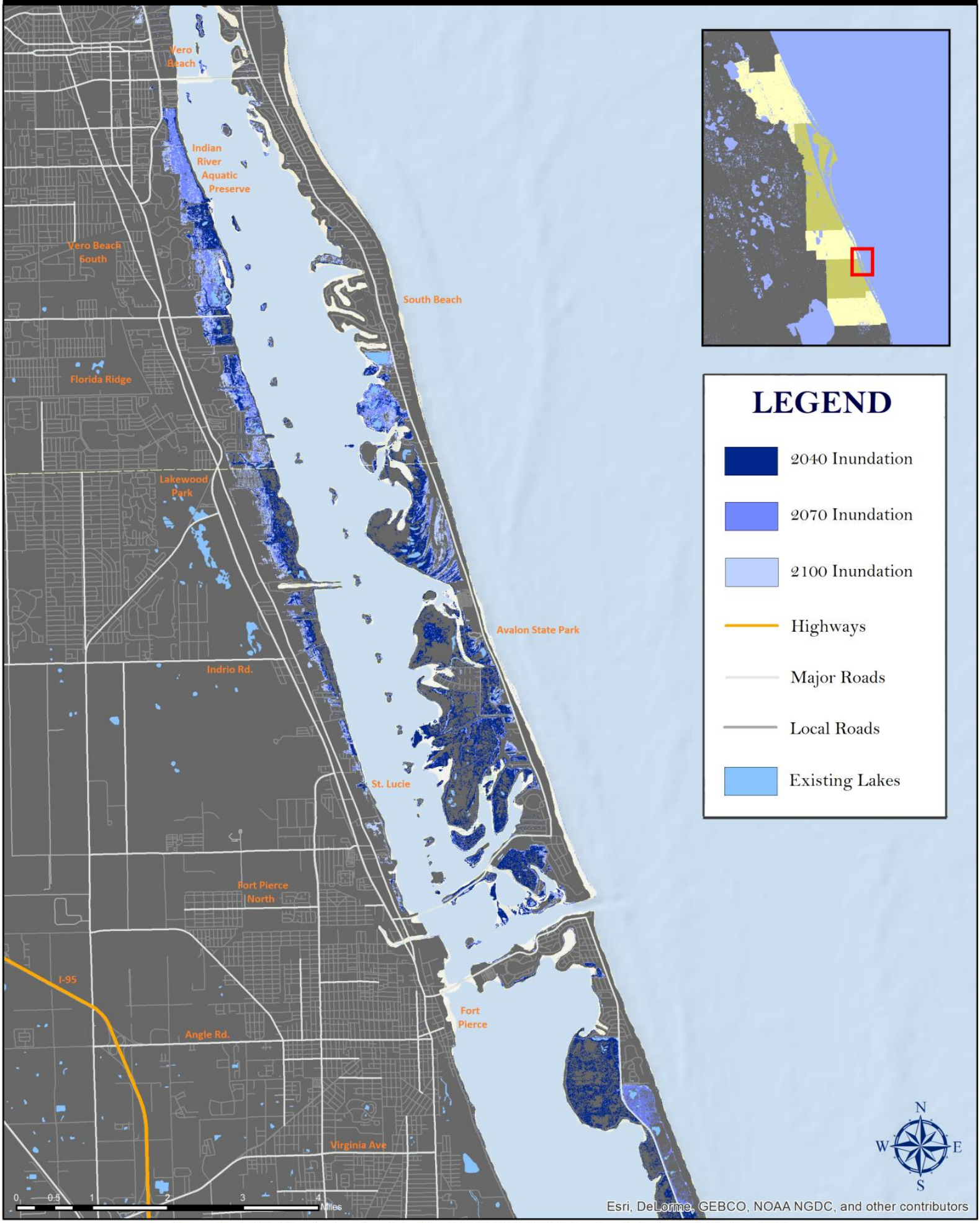
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



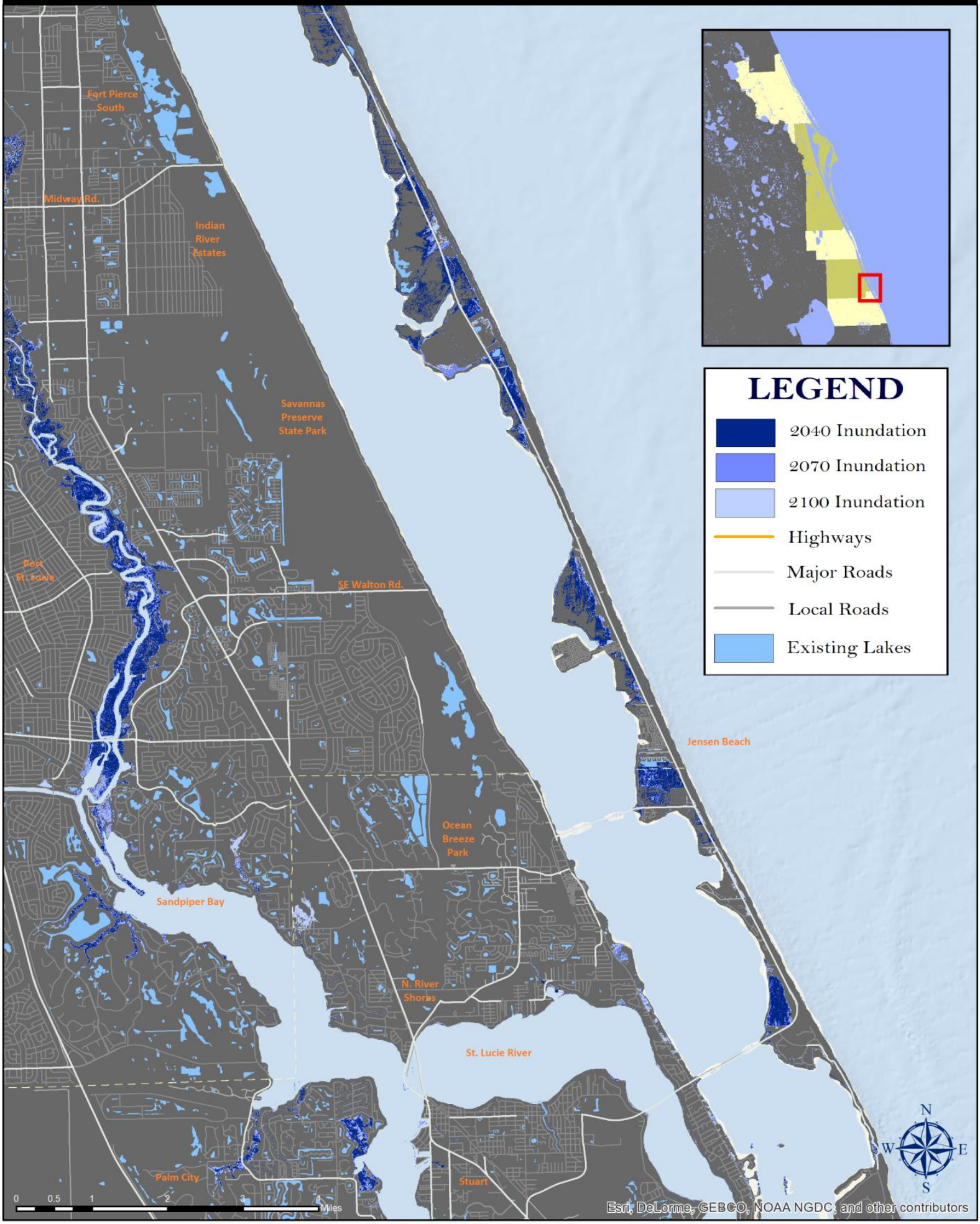
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve



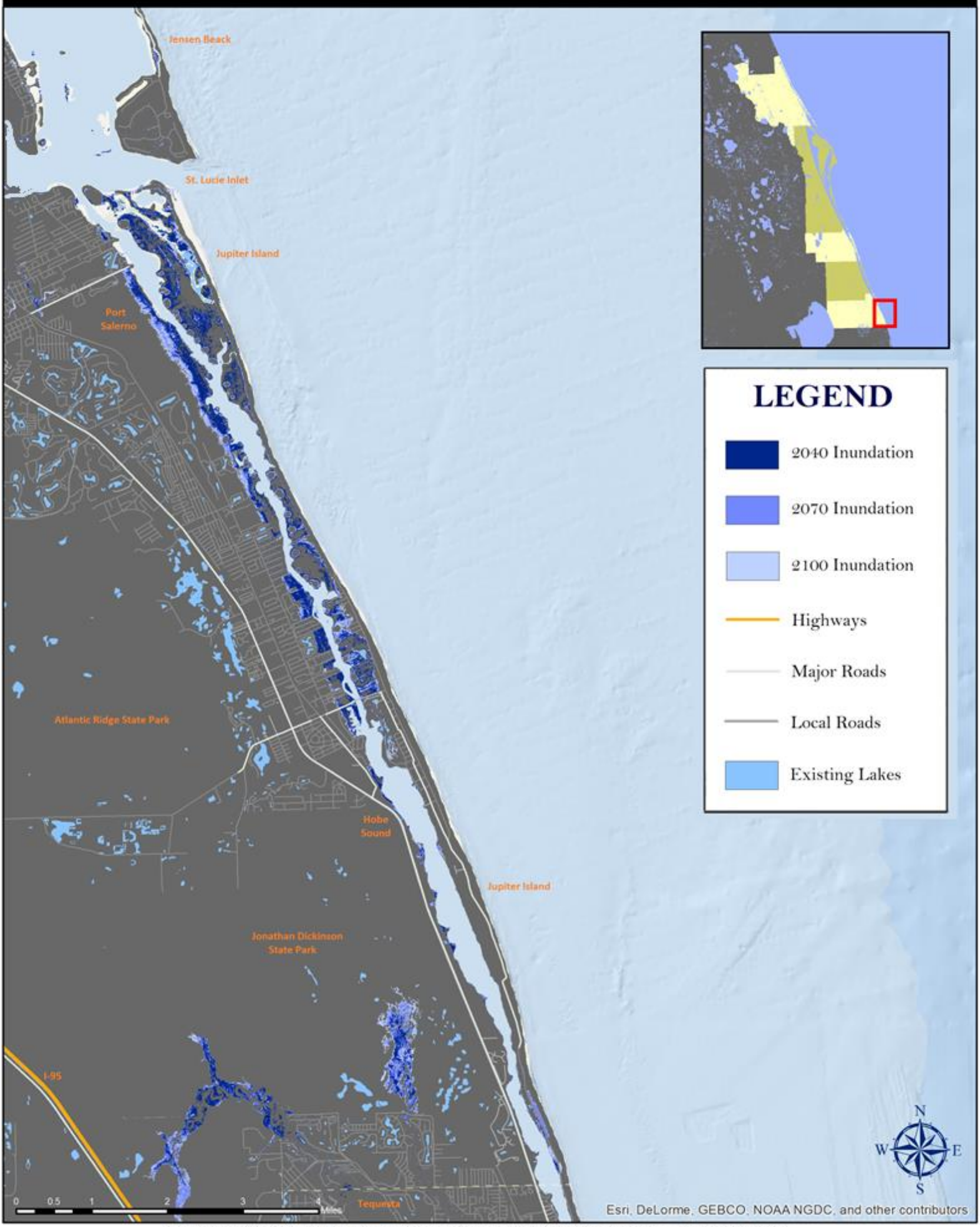
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve

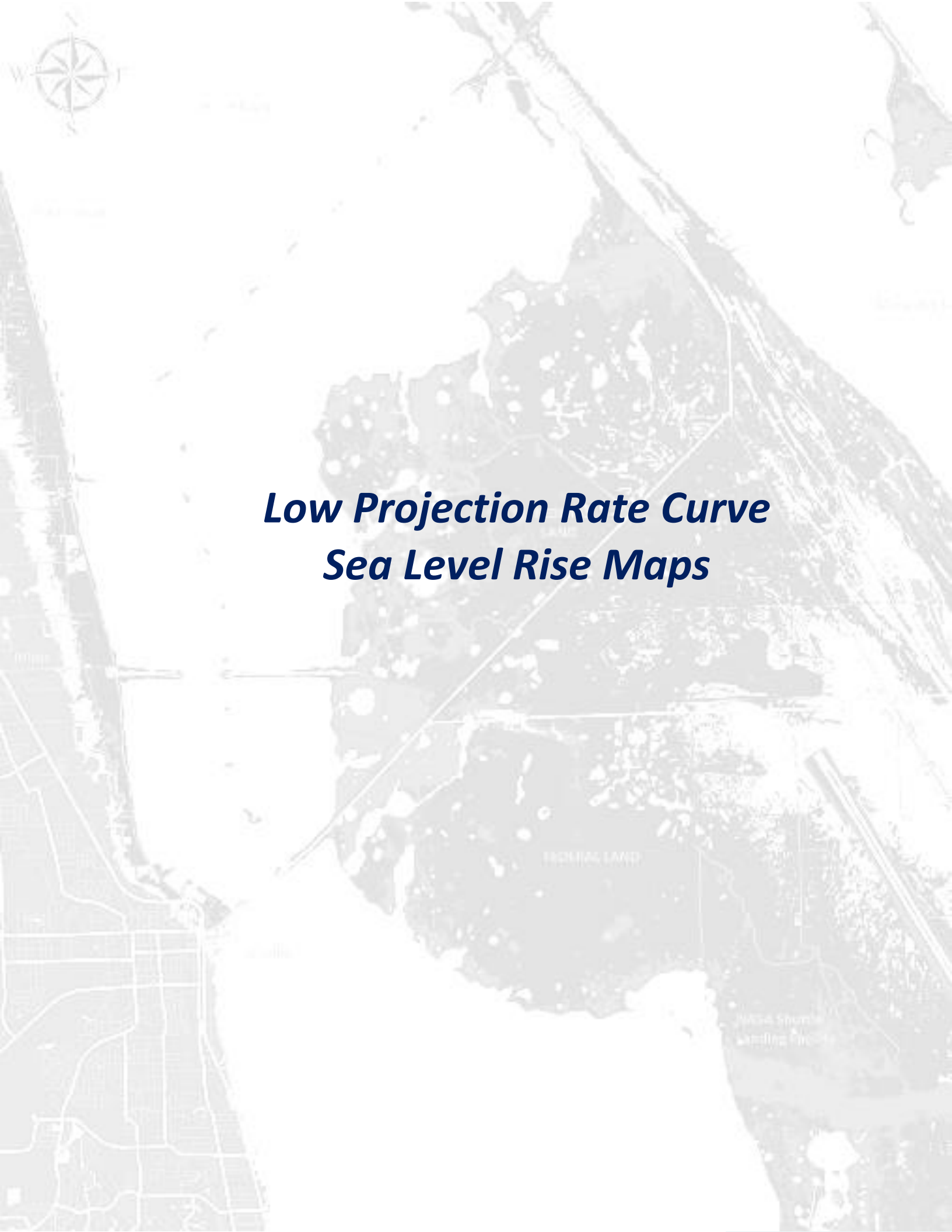


Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Intermediate Curve

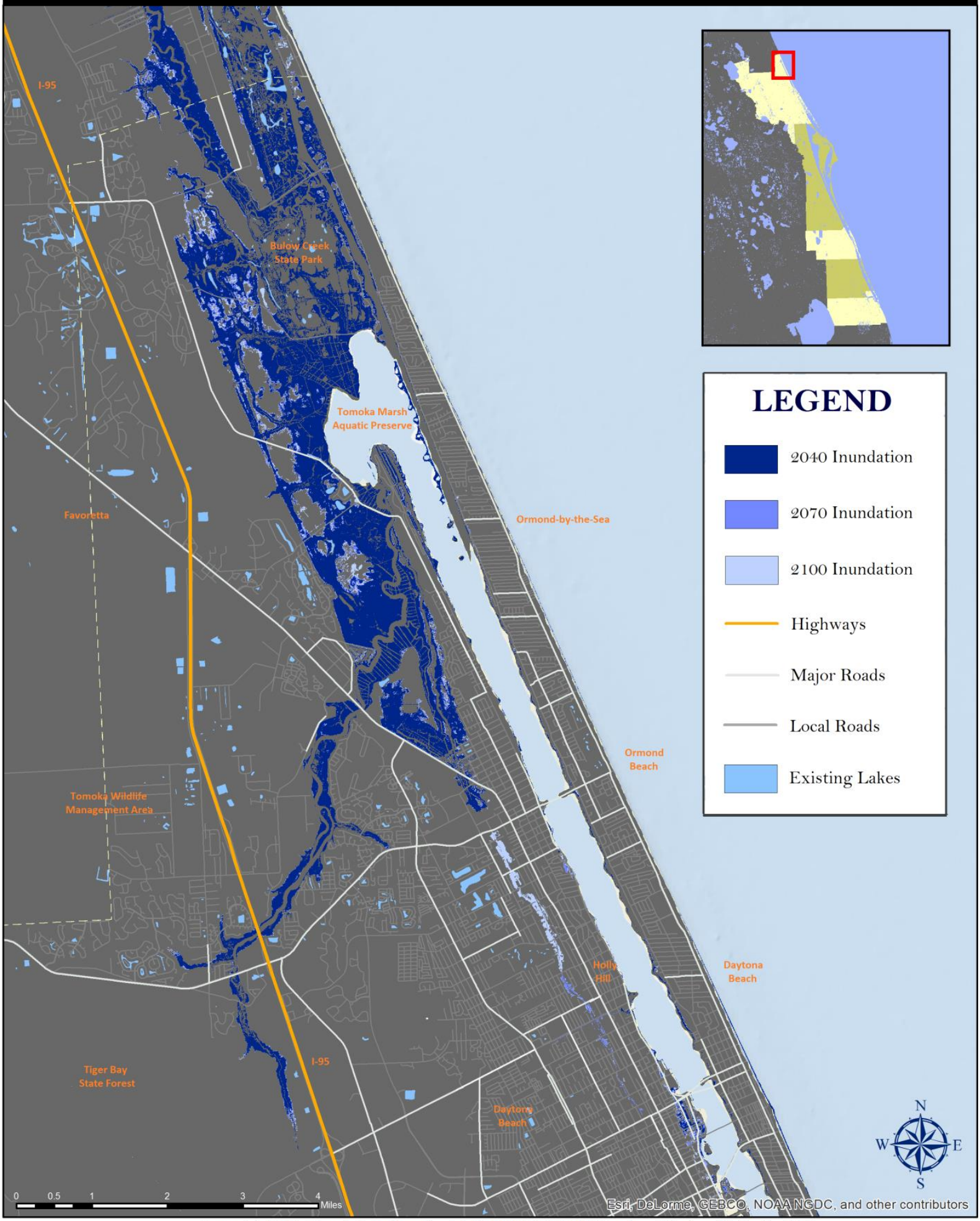


Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015



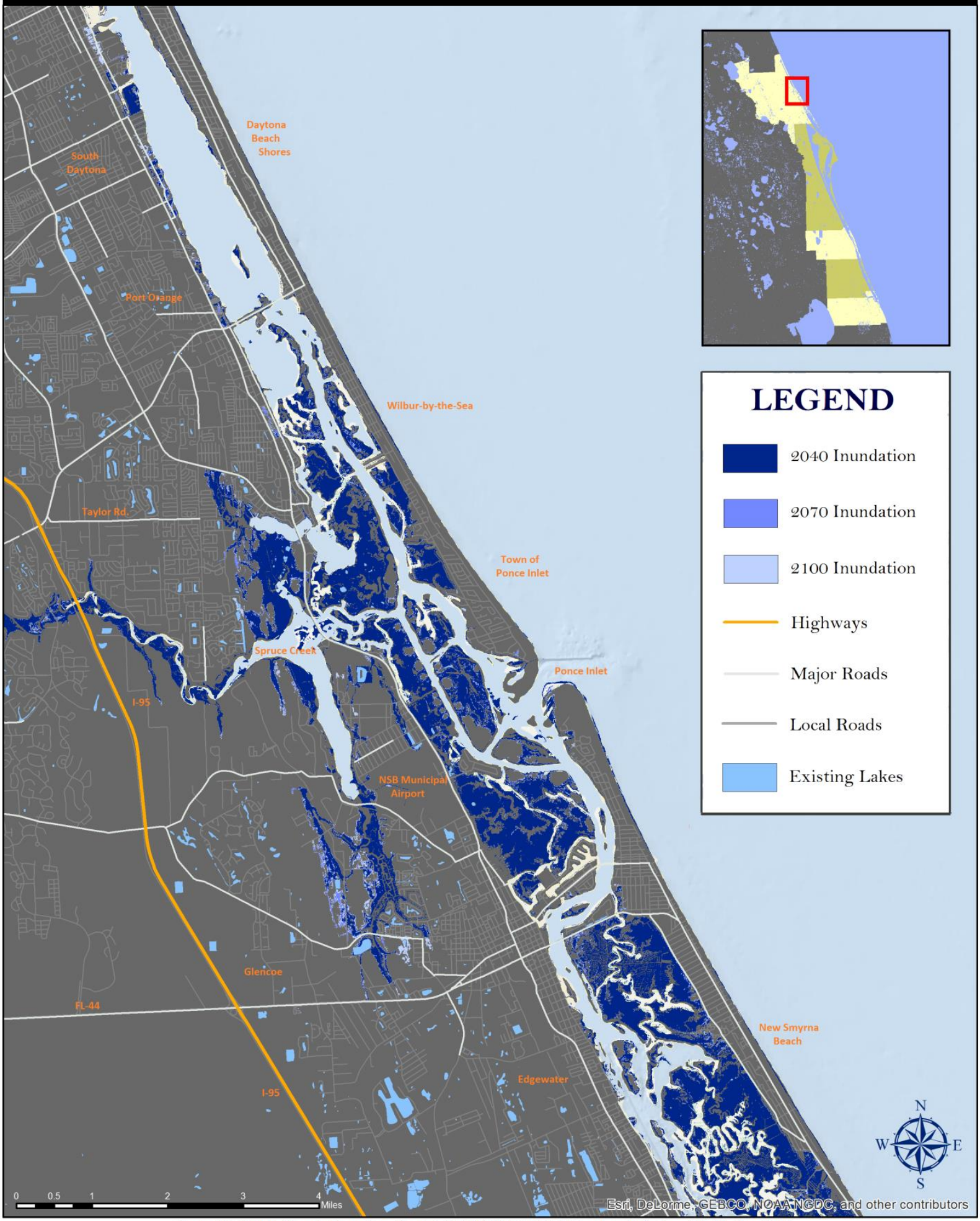
Low Projection Rate Curve
Sea Level Rise Maps

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



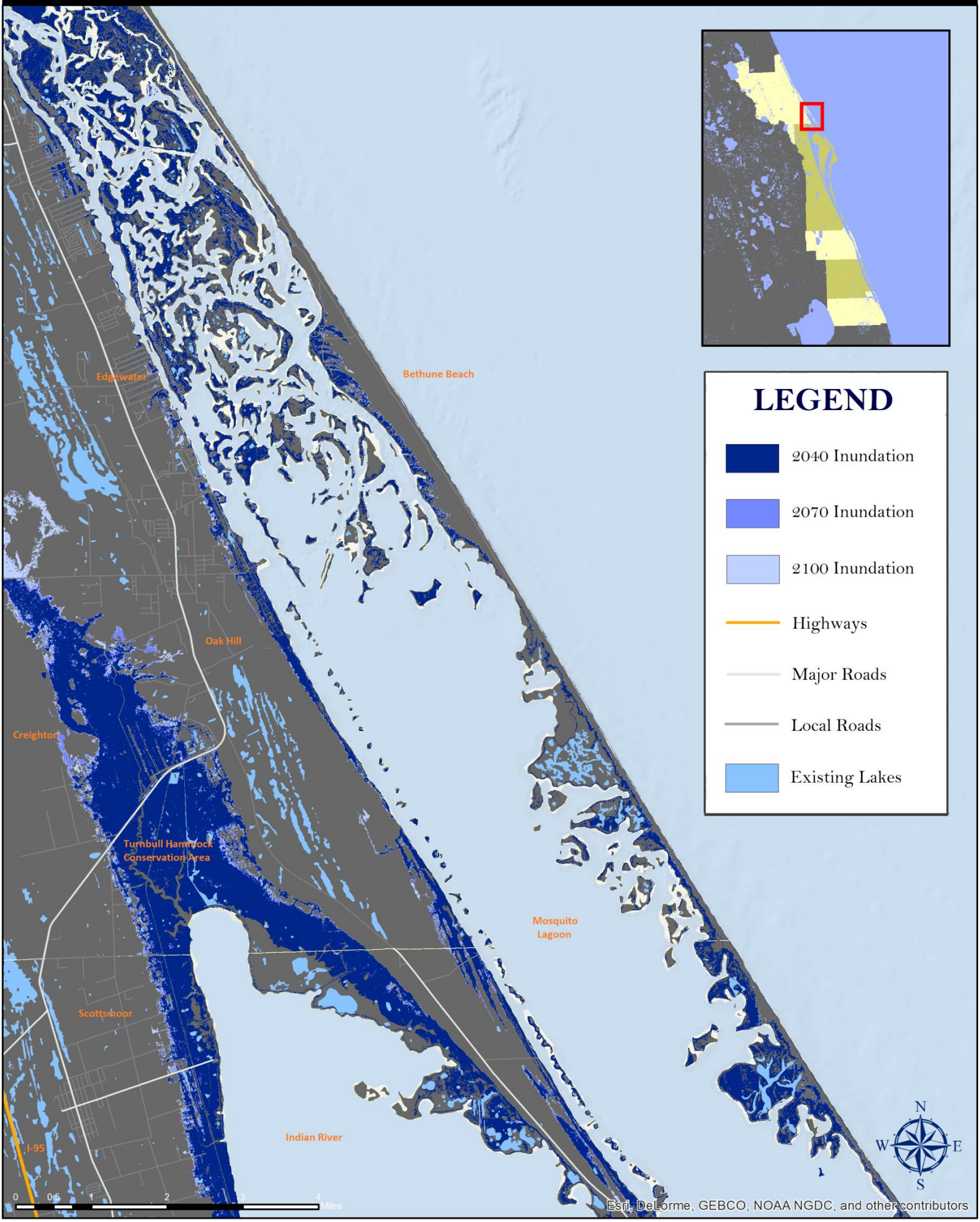
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



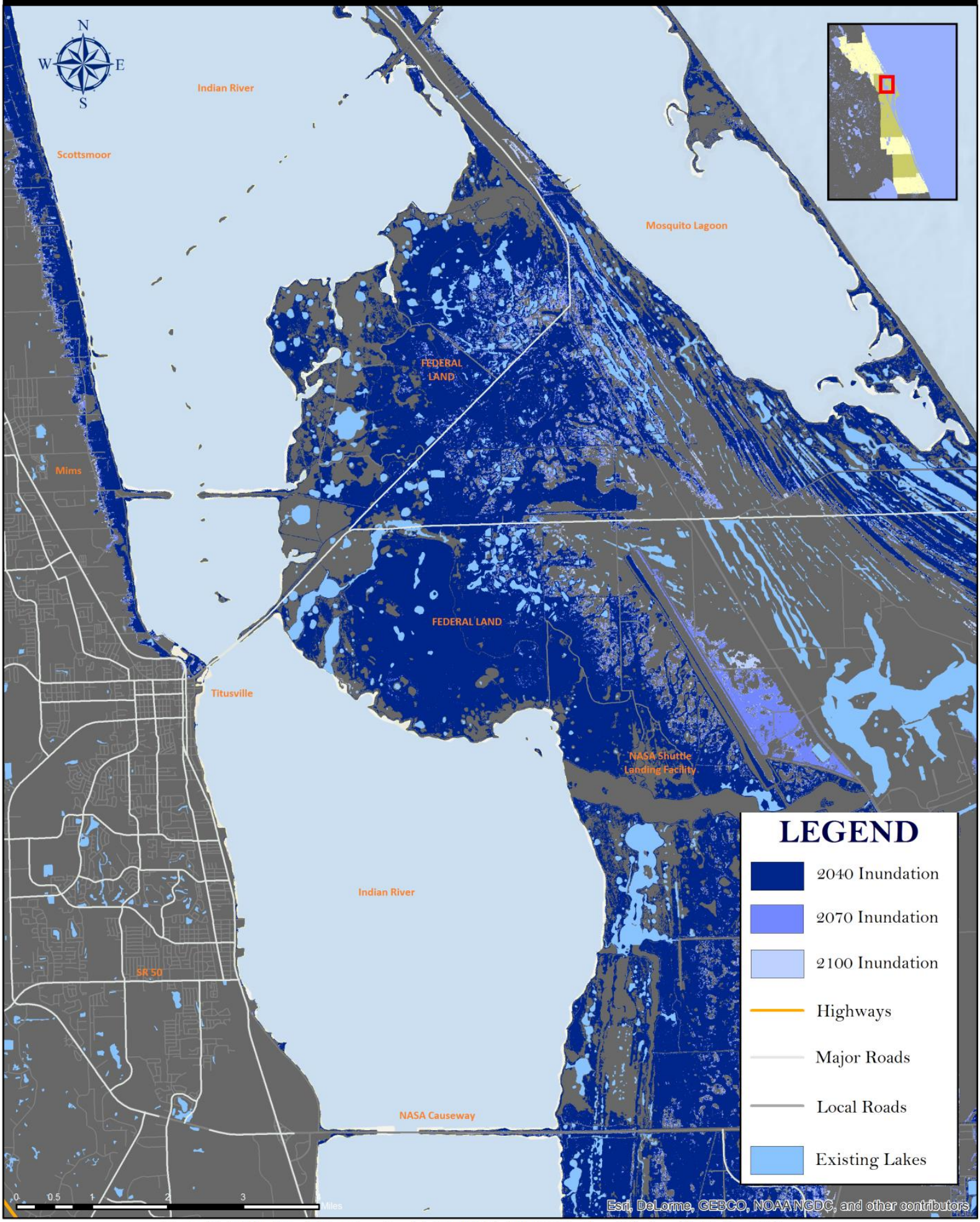
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



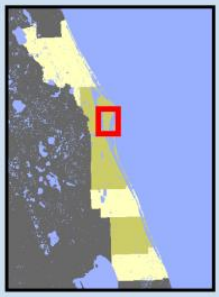
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



Kennedy Space Center

KSC Visitor Complex

Merritt Island

Banana River

Indian River

Cape Canaveral Air Force Station

Sharpes

Port Canaveral

Beachline XPWY

Cape Canaveral

Cocoa

LEGEND

- 2040 Inundation
- 2070 Inundation
- 2100 Inundation
- Highways
- Major Roads
- Local Roads
- Existing Lakes

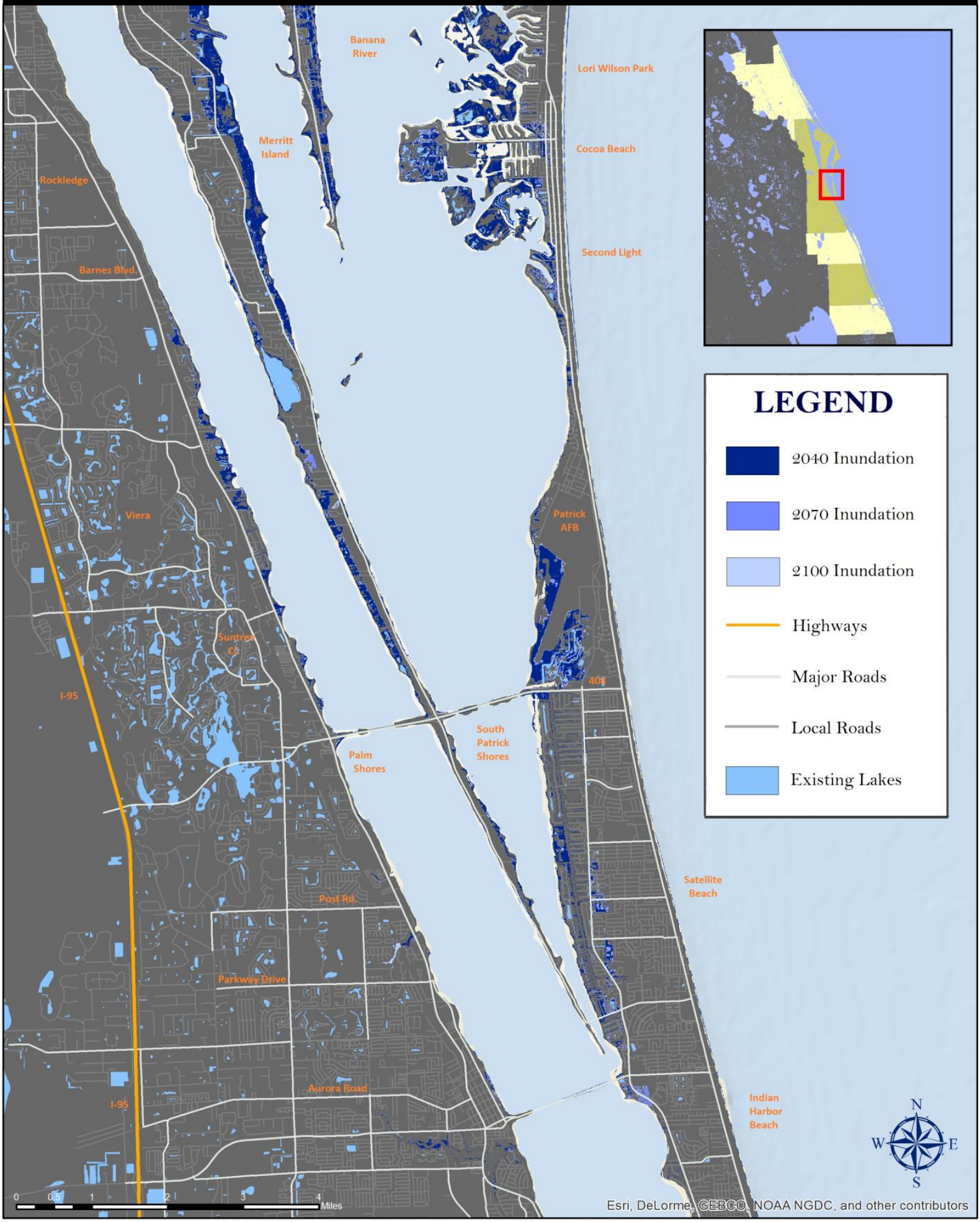
0 0.5 1 2 Miles

N W E S

Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

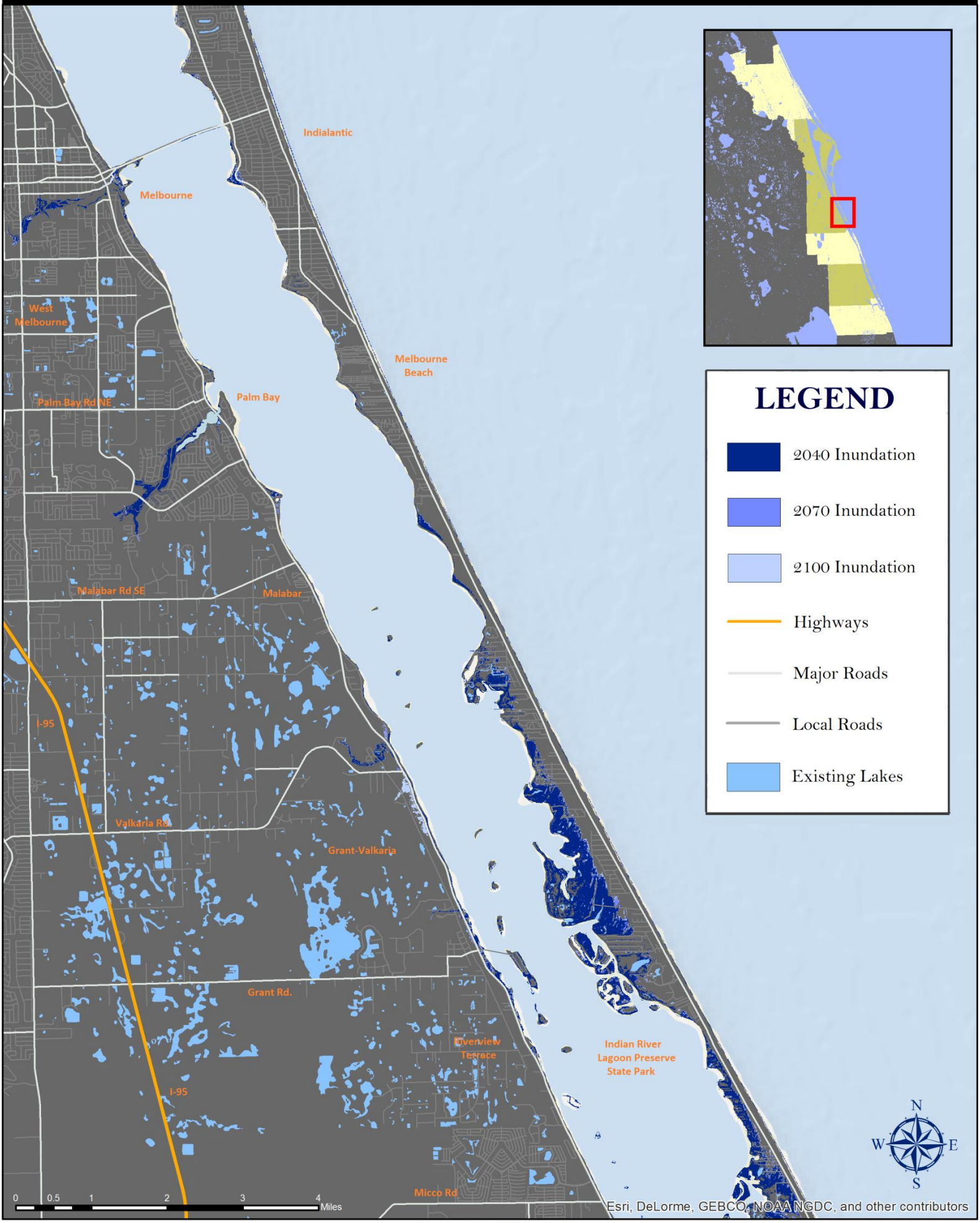
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve

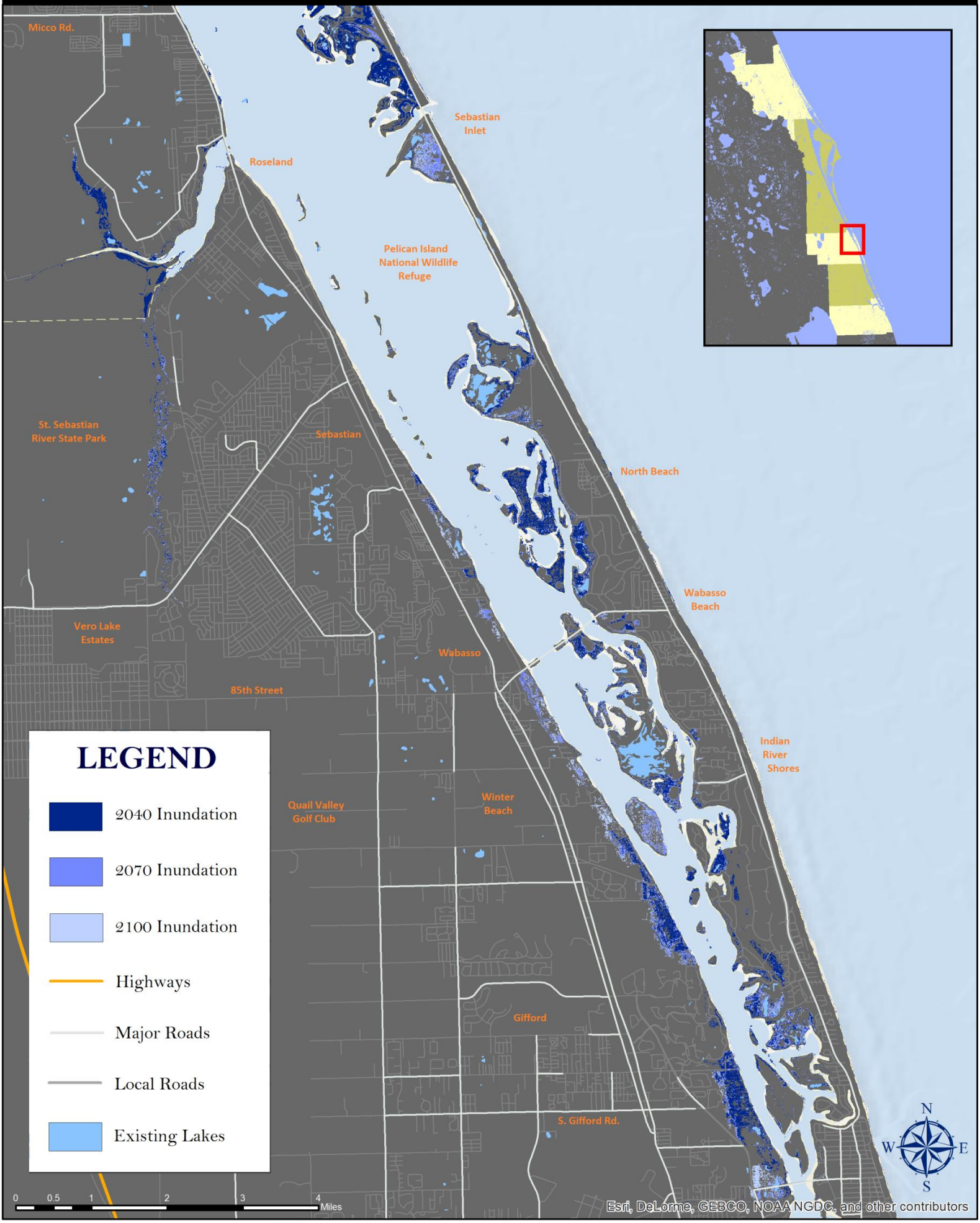


LEGEND

- 2040 Inundation
- 2070 Inundation
- 2100 Inundation
- Highways
- Major Roads
- Local Roads
- Existing Lakes

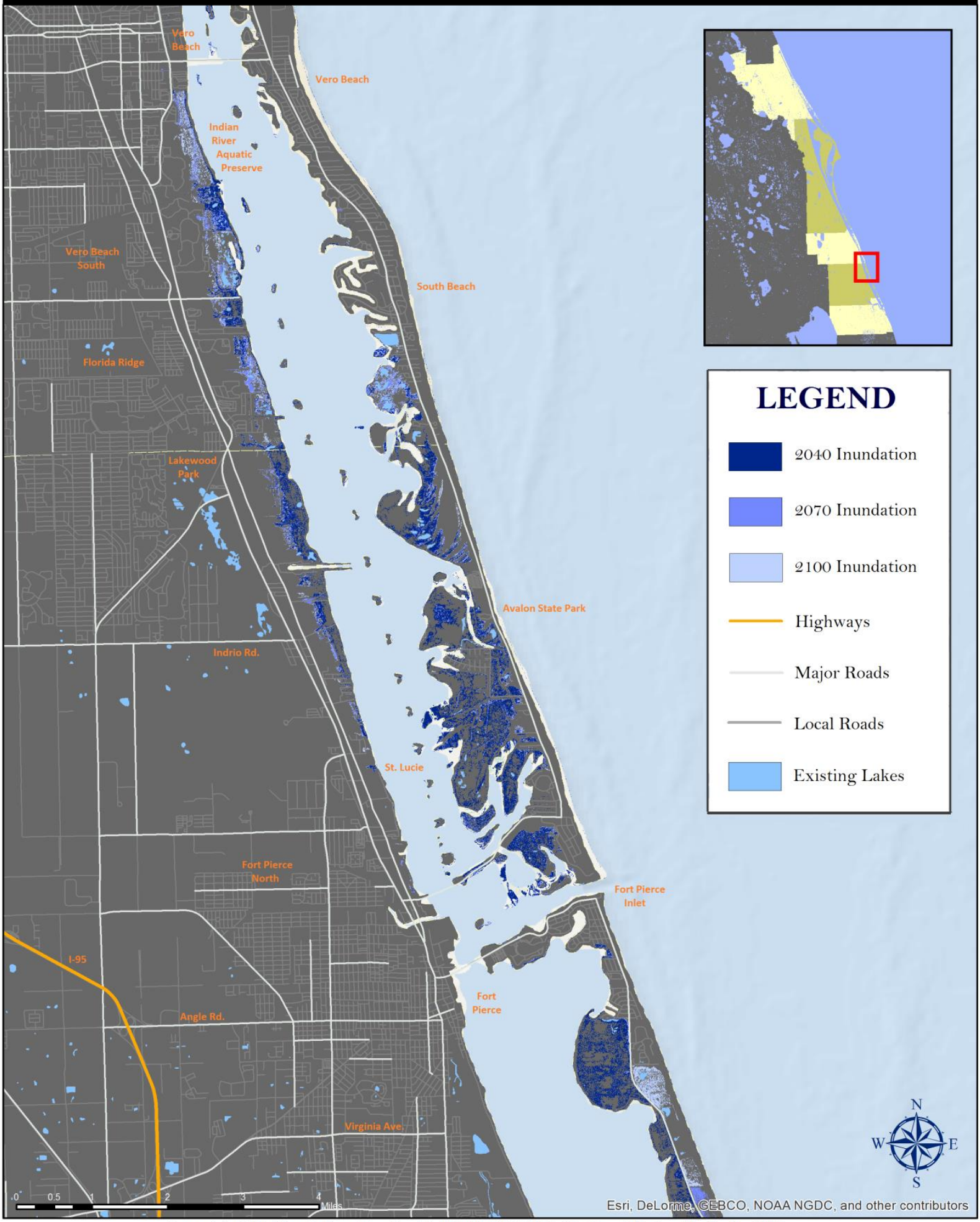
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



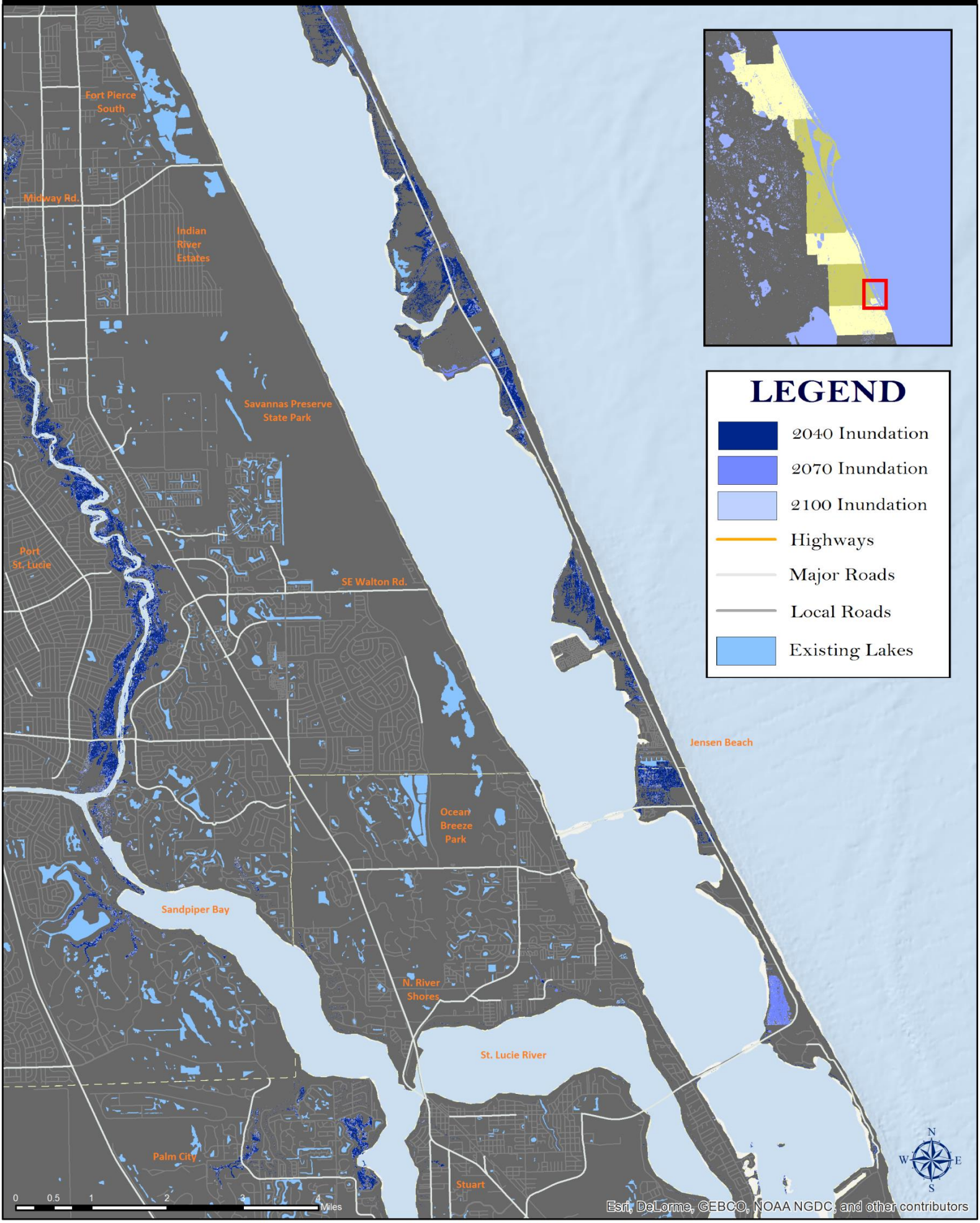
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



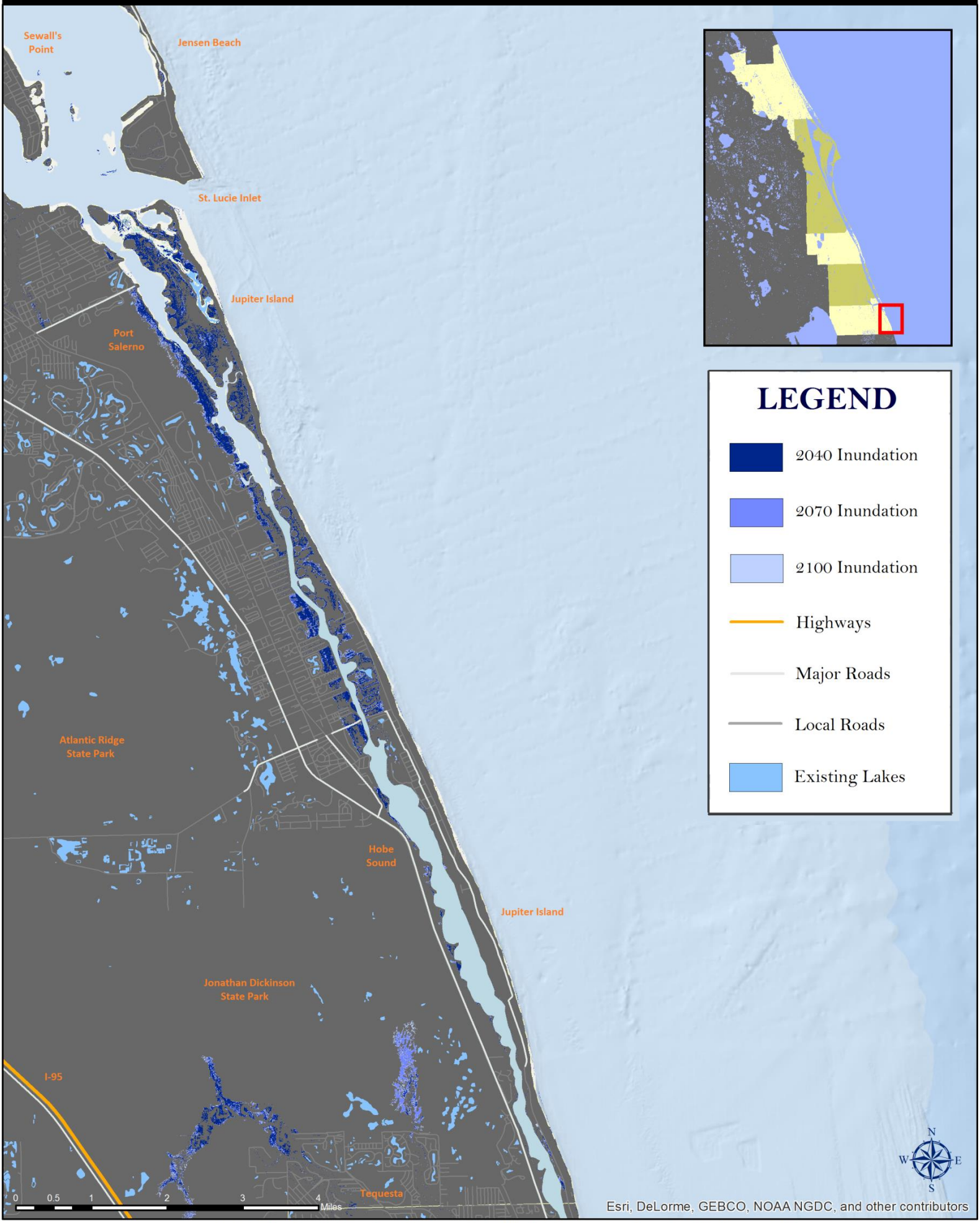
Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015

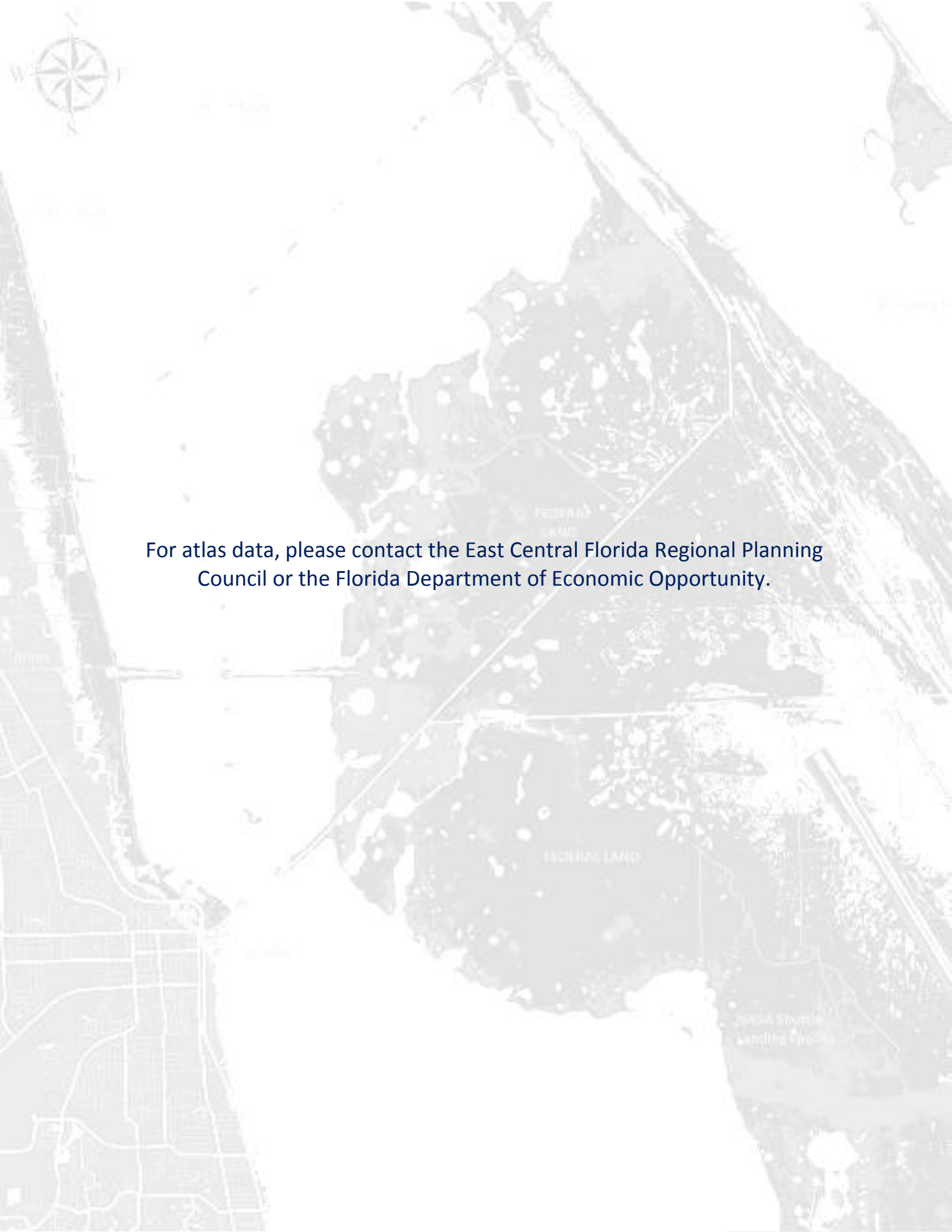
Sea Level Rise Inundation | U.S. Army Corps of Engineers Projections | Low Curve



LEGEND

- 2040 Inundation
- 2070 Inundation
- 2100 Inundation
- Highways
- Major Roads
- Local Roads
- Existing Lakes

Source(s): FGDL (County Boundary, Roads); FDOT/UF/ECFRPC (Sea Level Rise) --- All effective 2015



For atlas data, please contact the East Central Florida Regional Planning Council or the Florida Department of Economic Opportunity.

SECTION VI: Maintenance Information

Brevard County

The Brevard County Public Works Department is responsible for all stormwater and outfall-related activities within the county[22]. Within Public Works, it is the specific objective of the Road and Bridge Maintenance Division to maintain all outfall infrastructure located alongside the county's transportation system[22]. The county has a voluminous amount of documentation that outlines maintenance best practices, outfall projects and overall stormwater initiatives that are to be worked on over the ensuing years. The county's Stormwater Management Criteria is perhaps the most detailed in terms of outfall maintenance and is provided at the following link[23]: http://www.brevardcounty.us/docs/default-source/natural-resources-documents/stormwater-management-criteria.pdf?sfvrsn=0. This document provides regulations and practices concerning private lot drainage, conveyance facility design standards, design-storm based regulations for outfalls (based on 25 year storm), as well as structures that are required to have an outfall present [23]. Types of maintenance activities are also included, alongside specific design criteria that is regulated and requires outfall maintenance by the county[23]. Because a majority of the outfalls within the county are owned by FDOT, correspondence between the city and the department are critical, as standards must be maintained by both the county and the Florida Department of Transportation. A complete priority project listing showing the priority and approximate timeline of stormwater improvement projects is available in the Project Initiatives portion of the Brevard County Local Mitigation Strategy.

City of Cape Canaveral

The Public Works Services Department of the City of Cape Canaveral handles all outfall maintenance and repair alongside broader stormwater maintenance issues[16]. Within Public Works, the Infrastructure Maintenance Division maintains all outfalls owned by the city[17]. The city has two full time maintenance specialists and three full time maintenance workers that are responsible for these duties and has an on-call service for residents to report incidents involving all stormwater-related issues[17]. The Stormwater Administration Division is also a portion of the Public Works Department and is responsible for policy creation and stormwater best practices. This includes the implementation of monitoring processes, the enforcement of regulations, runoff control and documentation and education of the public[17]. The Stormwater Administration Division works alongside the Infrastructure Maintenance Division to maintain outfalls. Specific projects under consideration by the city can be viewed in the county's Local Mitigation Strategy, which is linked to the Brevard County section above.

Florida Department of Transportation

The Florida Department of Transportation owns a large number of outfalls along transportation networks across the state of Florida. In September 2012, FDOT released the Florida Department of Transportation Statewide Stormwater Management Plan, which outlines best practices for maintaining stormwater assets, including outfalls[24]. Standards and practices within this manual

concerning outfall upkeep, repair and replacement have been adopted statewide and are similar to many county and city-level practices[24]. The department has a unique strategy toward outfall maintenance, as these improvements often parlay with road maintenance projects and new FDOT roadways that are under construction[24]. The department has also adopted Maintenance Frequencies on all stormwater assets to ensure that they function properly and are not harming the environment due to what could be considered controllable factors. This table is located on page 16 of the FDOT 2012 Stormwater Management Plan at the link provided below[24]: http://www.dot.state.fl.us/statemaintenanceoffice/FDOTStormWaterMgmtPlan2012.pdf. The department also has a drainage manual concerning other best practices specific to drainage.

Indian River County

As is the case with other counties, Indian River Counties has multiple divisions under the Public Works Department that deal with the maintenance and procedures concerning outfalls and stormwater systems[27]. These divisions include the Engineering Division, responsible for design standards; the Road and Bridge Division, which is responsible for infrastructure surrounding county roadways; and finally, the Stormwater Division, which deals with runoff, pollutant removal systems, NPDES permitting and other environmental health issues[27]. The Indian River County 2030 Comprehensive Plan Stormwater Management Sub-Element outlines specific policies related to maintenance, design standards and other best practices and is available at the following link[28]: http://www.irccdd.com/Planning_Division/CP/Drafts/DRAFT_Stormwater.pdf. A second and more specific document that outlines all stormwater projects within the county and all of its jurisdictions is the Indian River County Local Mitigation Strategy. The county also lists current projects that are currently ongoing or those that have recently been completed at the following link[29]: http://www.ircgov.com/Departments/Public_Works/Index.htm. This listing includes a range of projects, including nutrient removal, capital improvements to stormwater infrastructure, drainage and other stormwater-related tasks.

Martin County

The Martin County Engineering, Field Operations and Stormwater Divisions are responsible for regular maintenance on Martin County outfalls and baffle boxes. This job includes the removal of sand and debris, cleaning and filter replacement. This cleaning typically occurs once a year for each outfall, per James Gordon with the county engineering division, and regular inspection occurs roughly three times per year at a cost of approximately $45. Vactor truck cleaning costs approximately $130, while an annual filter replacement costs approximately $765 with all costs built in. The Martin County Local Mitigation Strategy contains a listing of all stormwater and outfall projects that are active or planned within the county and all of its jurisdictions, which provides a comprehensive look into the current initiatives and priorities of the entire county, including stormwater projects and outfall maintenance[9]. These projects reference the policies within the county Comprehensive Plan that enforces their inclusion on the county initiatives listing[9]. This listing of projects is provided at the following link to the county Local Mitigation Strategy: http://mitigationguide.org/wp-content/uploads/2013/05/FL_MartinCo.pdf. Timeline of projects are based on the priority set within the plan. The county also has Stormwater Management and Flood Protection Standards, a listing of directives that enforce maintenance

practices and set standards for the design of insfrastructure[10]. These practices can be found at the following link: https://www.martin.fl.us/resources/stormwater-management-and-flood-protection-standards. One specific directive within the standards includes Section 1.2 C, which says "lots less than two acres shall slope towards streets or other adequate outfalls"[10]. Section 1.4 2D also includes specific outfall language.

City of Palm Bay

The City of Palm Bay's Stormwater Division (within the Public Works Department) handles all outfall-related issues within the county[18]. The Stormwater Division is responsible for education, permitting, maintenance and repair, the reporting of illicit discharge from outfalls and nonpoint source management (also known as watershed management) [18]. The service area of the department can be viewed at the following link, which is provided on the city website[19]: http://www.palmbayflorida.org/home/showdocument?id=2196. The city also has a guidebook that provides best practices as well as permitting and new construction procedures as they relate to stormwater maintenance[20]. A complete listing of projects under consideration by the city is included within the Brevard County Local Mitigation Strategy, a link to which is provided above.

City of Port St. Lucie

The Drainage Division, a section of the Public Works Department, handles all outfall maintenance for city-owned outfalls, swales and swale right of way[1]. The city also provides up to date status reports of drainage maintenance within the county, the link to which is provided within the source documentation portion of this report[2]. The city also trains employees on best practices, ensures that construction sites are in compliance, tests water quality and has mapped the drainage system[3]. City canals are also maintained by the Drainage Division[3]. A listing of projects under consideration by the city can be viewed in the county Local Mitigation Strategy.

Town of Sewall's Point

The town's Building and Facilities Department is responsible for all maintenance, repair and correspondence with county and statewide agencies concerning all stormwater systems, including outfalls[21]. All capital improvement projects are also under the Building and Facilities Department. Since the town is small compared to others within the study area, the number of outfalls maintained by the town is a fairly small proportion of the total number of outfalls within the town. FDOT and the county are responsible for a number of the outfalls within the jurisdictional boundary. For a complete listing of projects that are either in the planned, funded or ongoing stage within the town, refer to the Martin County Local Mitigation Strategy.

St. Lucie County

Outfall maintenance is handled by the Water Quality Division, the Road and Bridge Division and the Engineering Division, which are sections of the county's Public Works Department[4]. The 1997 Stormwater Management Program was created to determine needs and logistics[5], and the county's Comprehensive Plan Infrastructure Element details county best practices and areas of concern[6]. Specific policies within the Comprehensive Plan require the county to maintain level of service standards for sanitary sewer (85% of potable water LOS), require economic feasibility of

projects, and reference the Reclaimed Water Master Plan for specific site types[6]. The county has a construction crew that maintains drainage and provides retrofits and unclogs swales. The Road and Bridge Division has specific maintenance tasks alongside roads and bridges, which includes over 1,100 miles of swales[8]. A list of stormwater maintenance and other related projects can be viewed at the following link[7]: http://www.stlucieco.gov/departments-services/a-z/public-works/engineering-division.

City of Titusville

The City of Titusville Public Works Department is responsible for the maintenance of all city-owned outfalls. Through the Public Works Department, the Stormwater Utility Division is responsible for implementing capital improvement projects involving outfalls[14]. The City keeps a listing of stormwater projects (independent but inclusive of projects included in the Brevard County Local Mitigation Strategy) that includes the scope of the project and estimated repair or construction costs. Activities include drainage improvements, pipe and outfall replacement, pipe and outfall improvement, swale installation, pipe lining and projects to mitigate the effects of flooding[14]. A listing of these projects can be found at the following link to the city website: http://www.titusville.com/Page.asp?NavID=2034. Other tasks of the city are included at the following link: http://www.titusville.com/Files/CH35%20ART%20III.pdf[15].

Volusia County

The Volusia County Public Works Department is responsible for the maintenance of all county-owned outfalls within the county. The county takes a two-pronged approach to stormwater and outfall maintenance. The Water Resources and Utilities Division implements engineering services and treats and disposes of wastewater on a case by case basis[11]. This includes an emergency repair service hotline that the county has set up[11]. The second force behind the maintenance and provision of stormwater outfalls is the Road and Bridge Division, which implements the county's Stormwater Management Program[12]. The stormwater management program is intended to improve the water quality of stormwater runoff by the implementation of capital improvements[12]. These capital improvement projects are listed and prioritized within the county's Local Mitigation Strategy and covers all jurisdictions within the county boundary[13]. Maintenance operations of the Stormwater Management Program include the removal of sediment and debris, weed control, and the inspection of stormwater infrastructure. A listing of current stormwater initiatives to be completed by the Drainage Task Team, independent but inclusive of the Local Mitigation Strategy initiatives projects, is included at the following link: http://www.volusia.org/core/fileparse.php/4761/urlt/Drainage.pdf.

Water Management Districts

The St. Johns River Water Management District and the South Florida Water Management District also maintain outfalls within the state of Florida. These agencies have procedures in place that guide best practices for maintenance. The St. Johns River Water Management District has a Management and Storage of Surface Waters (MSSW) Handbook located at the following link[26]: http://www.dep.state.fl.us/water/mines/docs/sjmssw.pdf. Additionally, the South Florida Water Management District has a similar document, located at the link provided below[27]: http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/swerp_applicants_handbook_vol_ii.pdf.

SECTION VII: Planning Team Contacts

Director of Planning
Tara McCue
tara@ecfrpc.org

Senior GIS Analyst
PJ Smith
pjsmith@ecfrpc.org

GIS Analyst
Jordan Jamadio
jamadio@stetson.edu

Published May 2016
East Central Florida Regional Planning Council
309 Cranes Roost Boulevard
Altamonte Springs, FL 32701
(407) 262-7772

SECTION VIII: Source Documentation

1 – City of Port St. Lucie: http://www.cityofpsl.com/public-works/drainage_maintenance.html

2 – City of Port St. Lucie: http://www.cityofpsl.com/public-works/pdf/LinerMaintenanceStatusMaps.pdf

3 – City of Port St. Lucie: http://cityofpsl.com/npdes/index.html

4 – St. Lucie County: http://www.stlucieco.gov/departments-services/a-z/public-works

5 – St. Lucie County: http://www.stlucieco.gov/departments-services/a-z/public-works/stormwater-water-quality-division

6 – St. Lucie County: http://www.cityofpsl.com/planning-zoning/pdf/comprehensive_plan/infrastructure_element.pdf

7 – St. Lucie County: http://www.stlucieco.gov/departments-services/a-z/public-works/engineering-division

8 – St. Lucie County: http://www.stlucieco.gov/departments-services/a-z/public-works/road-and-bridge-division

9 – Martin County: http://mitigationguide.org/wp-content/uploads/2013/05/FL_MartinCo.pdf

10 – Martin County: https://www.martin.fl.us/resources/stormwater-management-and-flood-protection-standards

11 – Volusia County: http://www.volusia.org/services/public-works/water-resources-and-utilities/index.stml

12 – Volusia County: http://www.volusia.org/services/public-works/road-and-bridge/stormwater-management-program.stml

13 – Volusia County: http://216.157.37.6/emergency/Volusia-County-LMS-2015.pdf

14 – City of Titusville: http://www.titusville.com/Page.asp?NavID=2034

15 – City of Titusville: http://www.titusville.com/Files/CH35%20ART%20III.pdf

16 – City of Cape Canaveral: http://www.cityofcapecanaveral.org/public_works

17 – City of Cape Canaveral: http://www.cityofcapecanaveral.org/index.asp?SEC=69382D46-AF50-4607-A7E9-515272835ED3&Type=B_BASIC

18 – City of Palm Bay: http://www.palmbayflorida.org/government/departments/public-works

19 – City of Palm Bay: http://www.palmbayflorida.org/home/showdocument?id=2196

20 – City of Palm Bay: http://www.palmbayflorida.org/home/showdocument?id=8184

21 – Town of Sewall's Point: http://sewallspoint.org/building-dept/

22 – Brevard County: http://www.brevardcounty.us/publicworks

23 – Brevard County: http://www.brevardcounty.us/docs/default-source/natural-resources-documents/stormwater-management-criteria.pdf?sfvrsn=0

24 – Florida DOT: http://www.dot.state.fl.us/statemaintenanceoffice/FDOTStormWaterMgmtPlan2012.pdf

25 – Florida DOT: http://www.dot.state.fl.us/rddesign/Drainage/files/DrainageManual.pdf

26 – SJRWMD: http://www.dep.state.fl.us/water/mines/docs/sjmssw.pdf

27 – Indian River County: http://www.ircgov.com/Departments/Public_Works/Index.htm

28 – Indian River County: http://www.irccdd.com/Planning_Division/CP/Drafts/DRAFT_Stormwater.pdf

29 – Indian River County: http://www.ircgov.com/Departments/Public_Works/Index.htm