
Photo Source: Tybee Island Fire

Flooding Dynamic Modeling Tools for Optimized Planning of Core MPO Transportation Infrastructure Systems

Chatham County – Savannah Metropolitan Planning Commission

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1. Executive Summary

The Flooding Dynamic Modeling Tools for Optimized Planning of CORE MPO Transportation Infrastructure Systems assess the vulnerability of the region's stormwater infrastructure and surface transportation network to present and future flooding. This assessment aimed to develop a tool for optimal planning and design of resilient and equitable transportation infrastructure systems.

An urban stormwater management model was developed for several watersheds that outfall into the Savannah River in the City of Savannah. The model examines the stormwater network's performance for the 10- and 25-year rainfall events and three sea level rise conditions (SLR) for 2050 and 2075 that range from 1.18 ft to 4.08 ft. The SLR scenarios follow the guidance of NOAA and the Georgia Coastal Resource Division (CRD) of the Department of Natural Resources (DNR). The results of the stormwater model illustrate the need for backflow preventers within the systems that drain toward the Savannah River. For example, in places such as the Bilbo Watershed, the coastal inundation can penetrate up to 3,300 feet inland through the pipe system when considering SLR projections. This further exacerbates the street inundation during a rainfall event. Therefore, future efforts should focus on more comprehensive flood studies to determine the extent of the compound flood impacts around the community.

A coastal tidal inundation model examined flooding due to astronomic tides and its impact on the region's transportation network. Tidal flooding was simulated for six SLR scenarios provided by the Georgia DNR CRD that range from 1.23 ft to 6.56 ft for 2050 – 2100. In addition to tidal flooding, the 1% (100-yr) and 0.2% (500-yr) annual exceedance probability (AEP) floods were derived from the US Army Corps of Engineers (USACE) South Atlantic Coastal Study (SACS). AEP is the probability of a given flood depth that is expected to be met or exceeded within any given year.

A recent lidar survey of coastal Georgia (2018-2019) provides the most accurate bare-earth elevations for the study region. Minimum elevations were extracted for each road segment centerline in the study area and compared to the astronomic tide and 1% and 0.2% AEP flooding scenarios. Each road segment was classified as none, moderate, or high vulnerability based on the depth of flooding across the centerline. For present day conditions, 141.7 miles in the study region are vulnerable to flooding and increase to over 1,000 miles for the 0.2% AEP. These Roadway Vulnerability Assessment results were integrated into an ESRI Online Dashboard to form a Project Prioritization Tool (http://www.gmcgis.com/mpo).

As vulnerabilities to transportation systems grow over time, it will increasingly be necessary to diversify the range of resources available to maintain necessary levels of service. Fortunately, a wider range of values can be addressed by focusing on natural and nature-based infrastructure systems as part of a broader concept of resilience planning. This allows project developers to layer diverse funding mechanisms that have yet to be considered. A spreadsheet was developed that lists numerous funding opportunities for the Chatham-Savannah Coastal Region (CORE) Metropolitan Planning Organization (MPO), particularly through natural and nature-based (NNBF) infrastructure. Recognizing the diversity of values that NNBF can support to enhance infrastructure resilience, the list of grants has been sorted into four categories of funding: Transportation, Environmental, Department of Defense, and State and Local Funding.

Integrating an assessment of the region's stormwater infrastructure vulnerability and the susceptibility of the surface transportation network to SLR and flooding into the standard procedures for planning future transportation-related projects, policies, and decision-making processes is imperative. Moreover, a comprehensive examination of NNBF as a flood mitigation measure should be conducted.

2. Introduction

2.1. Project Site Description

The CORE MPO contains Chatham County and portions of Effingham and Bryan Counties (Figure 1). The CORE MPO includes approximately 438 square miles of land and 213 square miles of open water. The area is marked by large areas of coastal marsh and barrier islands that buffer the open coast to the mainland. The Savannah River bounds the area to the north and the Ogeechee River to the south, along with a vast network of tidal creeks in between.

Chatham County has a population greater than 289,000, making it the most populous area outside the greater Atlanta metropolitan area. Rising sea levels and changes to extreme weather events threaten the transportation infrastructure, public health and safety, and quality of life within the CORE MPO planning area.

The University of Georgia developed this Project Prioritization Tool and associated Financial Stewardship and Resiliency Planning in partnership with Goodwyn Mills Cawood and Clearview Geographic. The vulnerability assessment covers the stormwater drainage infrastructure within the City of Savannah and astronomic and tidal flooding along the coastal region. Although stormwater drainage infrastructure was only assessed for part of the CORE MPO area, it is the project team's intention that the framework presented herein may be extended to other municipalities.

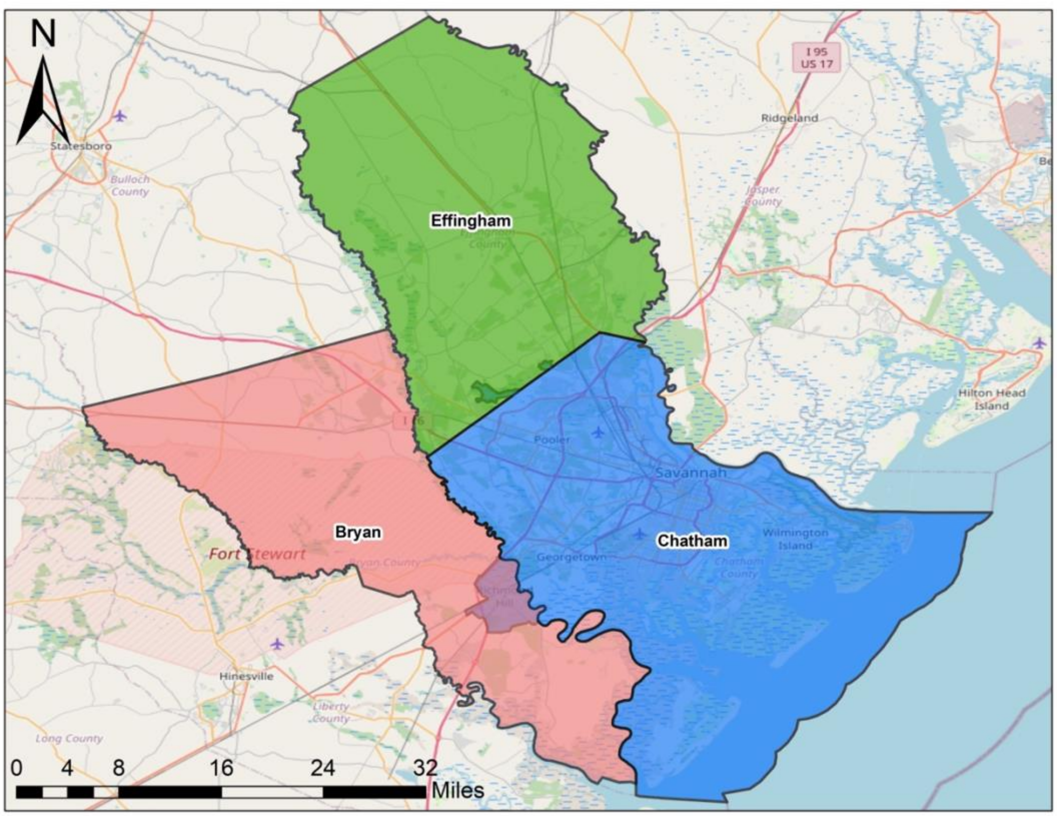

Figure 1. Chatham-Savannah MPO boundary.

2.2. Project Purpose

Building upon existing research and resiliency planning efforts in Chatham County, the primary purpose of this project will be to develop additional flood modeling and decision-planning tools that help target and prioritize projects and strategies aimed at mitigating the impacts of rainfall events and sea level rise on transportation infrastructure. Specifically, the project will build from the assessments conducted as part of the Chatham County Sea Level Rise Study to develop a Project Prioritization Tool that assists with optimizing the planning of new and existing transportation infrastructure to improve reliability and resiliency with additional consideration to economic constraints and social inequities. The tool will be designed to be utilized alongside an updated Road Vulnerability Assessment, which includes social vulnerability data, recent lidar, and integrates flooding data in a more comprehensive way to consider “compound” impacts of flooding that may impact the CORE MPO.

2.3. Project Scope

The Project Team formed for this study includes the University of Georgia (primary grant applicant), Goodwyn Mills & Cawood, and Clearview Geographic. The project team met regularly to discuss the project methods, progress, results, and deliverables. The project scope is summarized below.

Task 1: Project Management Plan (PMP)

The Project Team developed a PMP that described the study area and scope of services; and identified responsibilities of team members, task leaders, and communication protocols. The PMP also included a detailed project schedule with milestones and deliverables, including progress reports and meetings with the CORE MPO. As part of Task 1, UGA also created a stakeholder engagement process and developed a steering committee.

Task 2: Research, Modeling, and Data Analysis

The Project Team reviewed existing plans, tools, and data to identify additional information necessary to integrate “compound” flooding that considers sunny day flooding, storm surge, and select design rainfall events for the CORE MPO planning area. All models used the recent 2019 lidar data. Sunny-day flooding was assessed using sea level rise (SLR) projections. Additionally, rainfall-runoff was simulated using the Storm Water Management Model (SWMM). The sunny-day and coastal surge modeling was used to inform of roadway vulnerability to flooding under various scenarios. The SWMM modeling was used to examine flood depths at stormwater drainage points for various combinations of rainfall, tides, and SLR.

Task 3: Project Prioritization Tool

The Project Team developed an online ESRI Dashboard that integrates flood modeling, roadway vulnerability, and other GIS layers. The tool serves as a way to examine roadway transportation for future flood mitigation projects based on the vulnerability assessment.

Task 4: Financial Stewardship and Resiliency Planning

The Project Team identified funding opportunities for potential projects and mitigation measures and identified the next steps for updating the local standards to ensure that future road design projects affecting any part of the transportation network include SLR as a required design criterion.

2.4. Sea Level Rise Projections

The SLR scenarios used in this project employ the Georgia Department of Natural Resources (GA DNR) Coastal Resources Division (CRD) projections (Evans et al. 2020) and the NOAA intermediate scenario for 2050 (Sweet et al. 2022). A summary of the projections is shown in Table 1.

Table 1. SLR projections for Chatham County, GA as feet relative to 1992 mean sea level (MSL).

Year	CRD Low (ft)	CRD High (ft)	NOAA Intermediate (ft)
2050	1.23	2.18	1.18
2075	2.14	4.08	NA
2100	3.28	6.56	NA

3. Compound Flood Research & Modeling

3.1. 2019 Coastal Georgia Digital Elevation Model

Point cloud elevation data was acquired between November 27, 2018 and April 24, 2019 using a Leica ALS70-HP lidar sensor and a PAC750 outfitted with an Optech Galaxy Prime lidar system. Point cloud data accuracy was tested against a triangulation constructed from the lidar points in clear and open areas. The accuracy meets ASPRS standards for horizontal (+/- 95% confidence level) and vertical (10-cm RMSE) accuracy. The lidar point cloud was processed to extract bare-earth and ground points using GeoCue, TerraScan, and TerraModeler, visual inspection, and manual editing. A bare-earth and ground surface was created from the lidar point cloud with a grid spacing of 1 m in GeoTiff format. The elevation is in reference to the North American Vertical Datum of 1988, Geoid 12B. The final GeoTiff was masked to the MPO boundary (Figure 2).

3.2. Stormwater Modeling

3.2.1 Stormwater Management Model (SWMM)

The runoff quantification and hydrograph generation were assessed via modeling. For that, a Hydrologic and Hydraulic (H&H) model was built using the Storm Water Management Model (SWMM) (Rossman and Simon 2022). SWMM is a dynamic rainfall-runoff model capable of simulating single and continuous storm events. Additionally, this model is widely used in urban areas to assess the quantity and quality of the runoff (Rossman and Simon 2022). The inputs used for the H&H modeling are described in the following subsections.

Required input parameters for SWMM were related to the watersheds' area (e.g., percent imperviousness, slope, and infiltration) and conduit properties (e.g., invert elevations and cross-sectional area). The parameters related to the watersheds were calculated and gathered using ESRI ArcMap and WMS (Watershed Modeling System) software. Rainfall, rainfall excess, and flow routing were estimated using the dynamic wave routing model for each model simulation.

The properties of the watersheds used in SWMM required basin area (acres), a width of overland flow (feet), basin slope (%), impervious area coverage (%), a storm event with a certain duration and intensity, and the infiltration approach, in which the Curve Number (CN) method was selected.

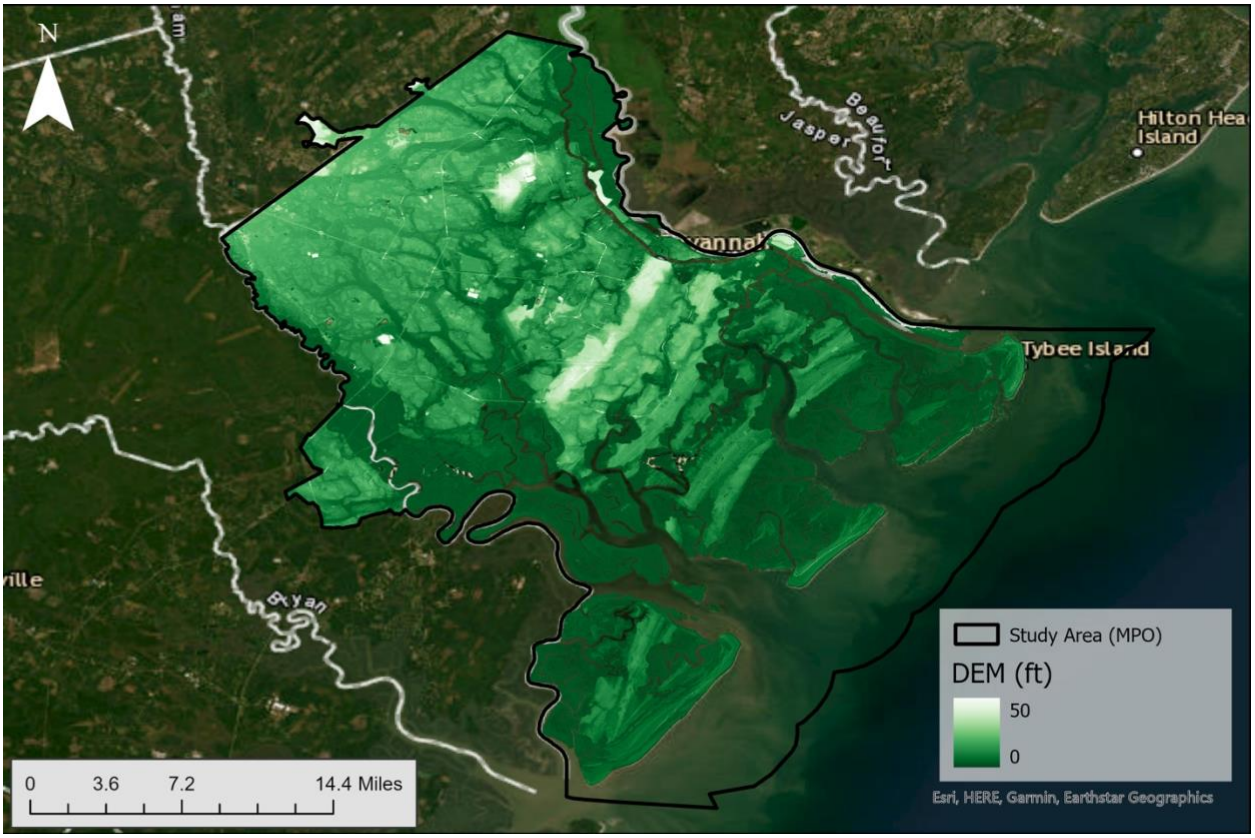

Figure 2. 2019 lidar-derived digital elevation model (2 ft horizontal resolution).

3.1.1.2 Data Collection

The stormwater drainage network in SWMM requires several parameters. The conduit properties for the system include the cross-sectional shape and area, conduit length, the invert elevations of the junction and outfall nodes, and the type of outfall for each sub-watershed. The conduits' cross-sectional shape and area were estimated in several ways. Geographical Information System (GIS) data provided by Savannah-Chatham County contained information on the system's dimensions and shapes of many conduits. Cross-separation areas were estimated using the DEM for conduits that were not measured (canals or ditches). The invert elevations of junction nodes and outfalls had to be approximated using invert extrapolation methods. For example, the neighboring inverts of nodes in the system were estimated from a known and accurate invert elevation at select nodes. This was achieved by considering the connecting conduits' known percentage slopes and lengths.

Since every watershed analyzed in this project drains into the Savannah River, the river's tides can influence the flow of runoff within the stormwater drainage system. To accurately simulate runoff flows with consideration to tidal influence, the tidal setting for each outfall node was selected in all models. The models created for the CORE MPO study are gravity-based conduit models. The stormwater conduit system in Savannah contains several pump stations that aid in moving runoff to prevent backups - however, information on pump data, such as the pump characteristic curve, was not available to the project team and was therefore not included in the analysis.

For the stormwater delineation, data from the city of Savanah and Chatham County were obtained in shapefile format from the GIS Savanah area office. These data include green infrastructure, stormwater canals, ditches, pipes, reservoirs, tide gate locations, roads, inlets, outfalls, manholes, urban drainage watersheds, and pump stations.

The final stormwater network is a combination of pipelines, canals, and ditches. All data were established to reference the vertical datum NAVD88. The stormwater pipeline shapefile includes bottom, top, and ground elevation data, pipe size, length, and location. However, most of the pipelines did not include the flow direction attribute. Therefore, pre-processing of the data was needed to delineate the sub-watersheds for the SWMM model.

3.2.2 Watershed Delineation and Stormwater Network Simplification

Six watersheds were considered for the SWMM modeling. The watersheds were selected based on data availability and location. The watersheds are in the most densely populated area of Savannah in Chatman County. These watersheds are Fell Street, Bilbo, Springfield North, Casey North, Casey South, and Placentia (Figure 3).

For the watershed delineation and pipe network simplification, reverse engineering was applied to simplify the stormwater network based on an empirical process that follows the steps shown in Figure 4. The data given include pipelines, canals, and ditches. However, the flow direction must also be established (Figure 5). The provided urban drainage watersheds were compared to hydrological watersheds (extracted from the DEM) for the area, and it was found that they differed. Therefore, the urban drainage watersheds were designed with additional topography variables considered. To create the stormwater network, different variables, such as pipe size and topography, were analyzed to determine the flow direction of each pipe. For example, pipes not connected to any other pipe with lengths less than 100 ft were deleted from the original file. As a result, a flow direction map was obtained, and with it, the simplification of watersheds into sub-watersheds.

The process of delineating sub-watersheds within a watershed is determined by topography, pipe size, and flow direction. After locating the outlets of each sub-watershed and identifying the main (bigger pipeline/ canal) where most of the pipelines drain to, the logical flow direction will follow topography from high elevations to low elevations and it is expected to match network capacity, therefore, bigger pipe size represents higher water storage capacity, helping to untangle the flow direction. However, there are specific cases where the flow direction follows a non-gravitational direction, for instance, where there are pumping stations, this was also considered for the reverse engineering process, the resulting stormwater simplification network is shown in Figure 6. This methodology was established to make the SWMM modeling easier, calculating flow discharges per sub-watershed, the final watersheds and sub-watersheds are shown in Figure 7.

SWMM only allows one conduit from a stormwater network to receive all runoff from an individual sub-watershed. This means that in the instance where multiple outlets exist, their impact on relieving runoff flows and properly distributing runoff is not accounted for. To account for the existence of multiple outlets, stormwater network outlets were given an equivalent pipe area. For many of the areas modeled, each watershed drains into a singular outflow with a cross-sectional pipe area equal to the sum of all mapped outflow cross-sections in the watershed. This also prevents one conduit from failing (flooding) from the massive influx of water it will receive, which is important when conducting a flood vulnerability assessment on the existing stormwater network.

3.2.3 Rainfall

Various rainfall intensity events were simulated in SWMM to produce runoff quantities. NOAA Atlas 14[1] data were collected in the Savannah Chatham County Area to establish appropriate rainfall quantities, specifically at the Savannah International Airport station (Station number 09-7847). Precipitation depths with a partial duration of 24 hours were selected. The quantile estimates of 10- and 25-year return periods were used for the model, each yielding 6.51 inches and 8.10 inches of rain, respectively. For every SWMM model in the study, a 48-hour simulation was performed that was divided into two periods - a 24-hour rainfall event followed by a dry period of 24 hours. In the first 24 hours of the simulation, each subwatershed received a certain intensity of precipitation that reached its maximum depth after 24 hours. For each model, Type 2 precipitation curves were input into SWMM, with the last value being the maximum depth for. In the last 24 hours of the simulation, each subwatershed received no rainfall. The purpose of this period is to account for precipitation lag time and acquire the peak flows recorded for each storm event.

[1] https://hdsc.nws.noaa.gov/pfds/

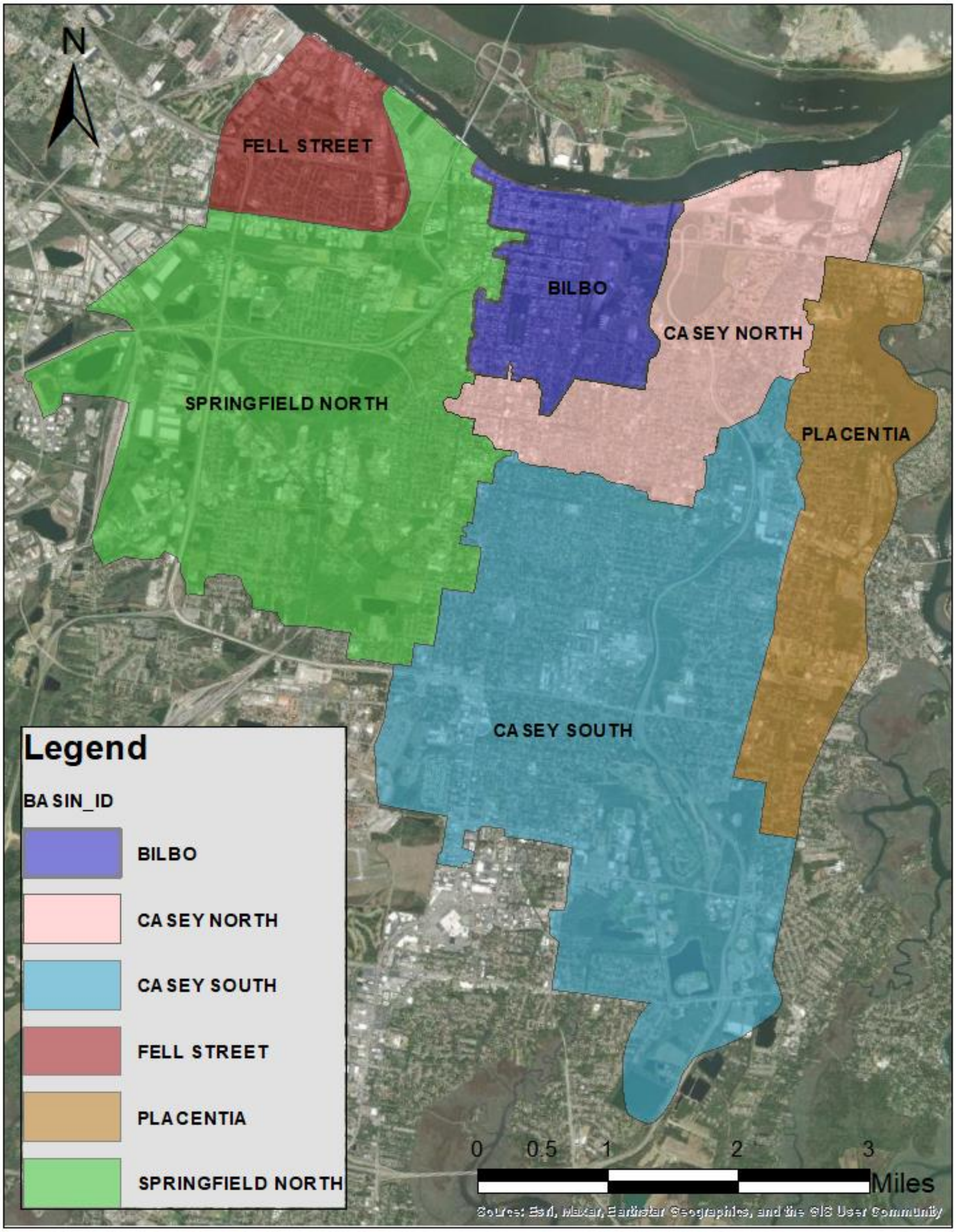

Figure 3. Selected urban drainage watersheds for SWMM modeling.

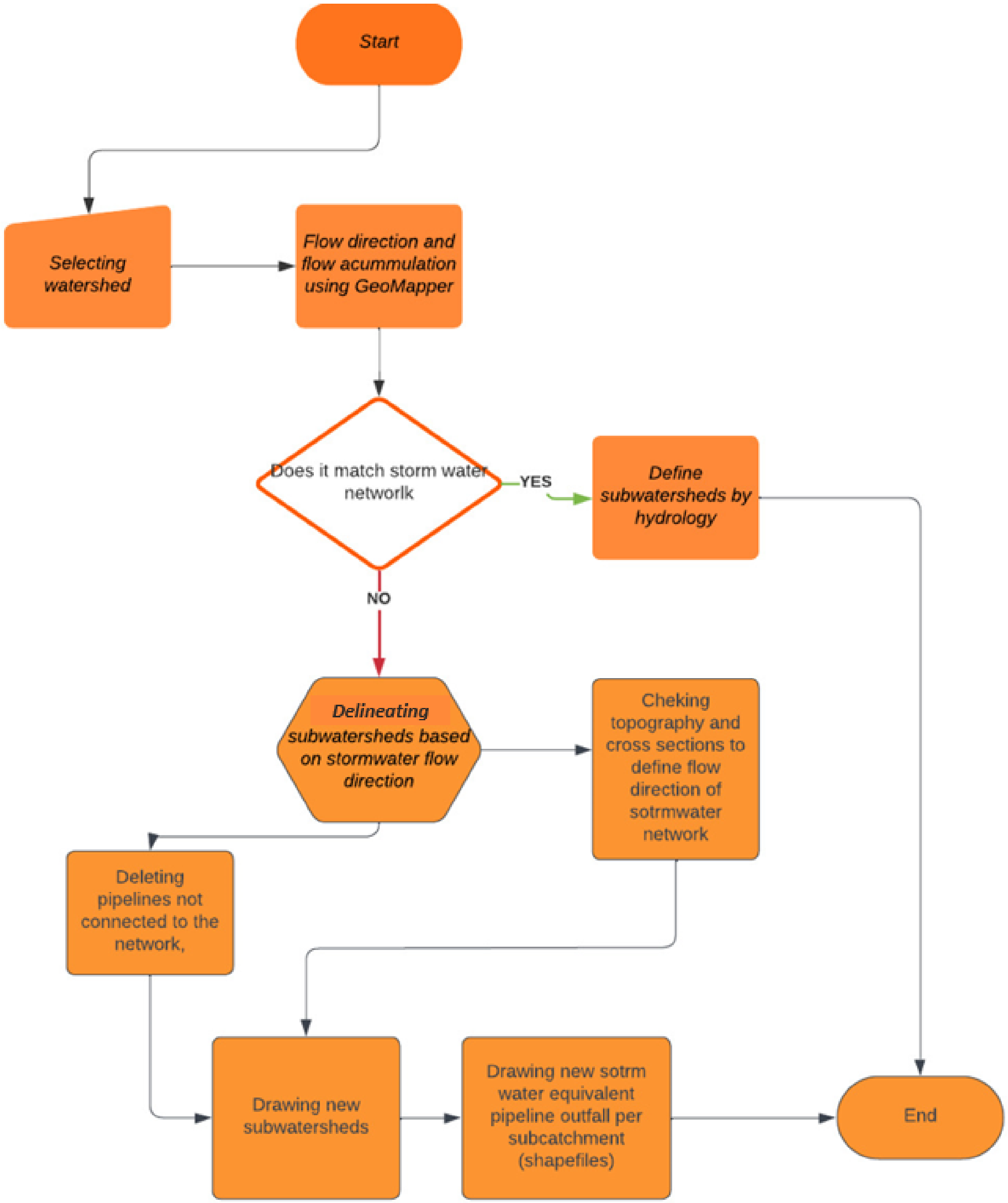

Figure 4. Reverse engineering steps to define sub-watersheds.

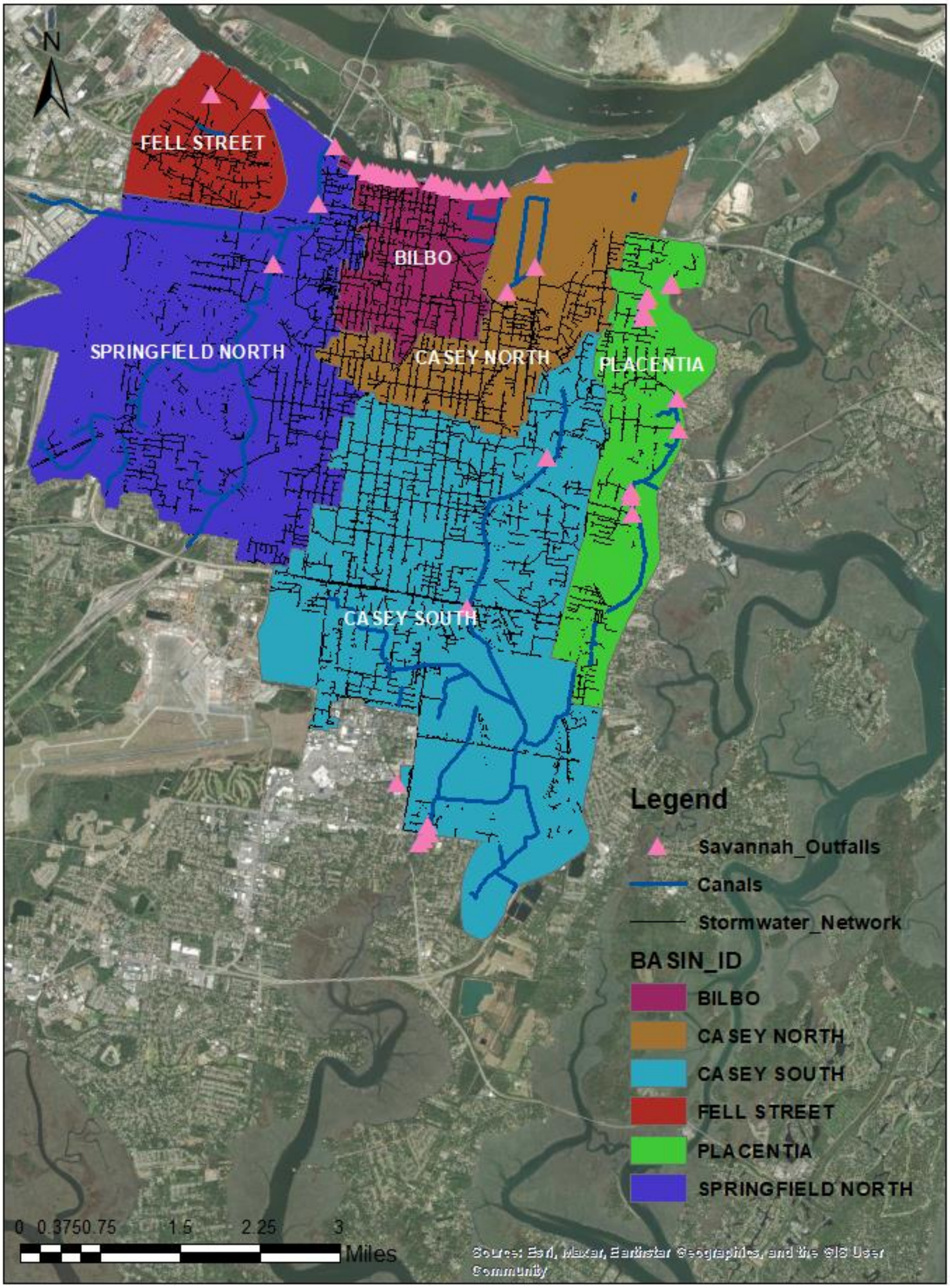

Figure 5. Provided stormwater network data and their urban drainage watersheds.

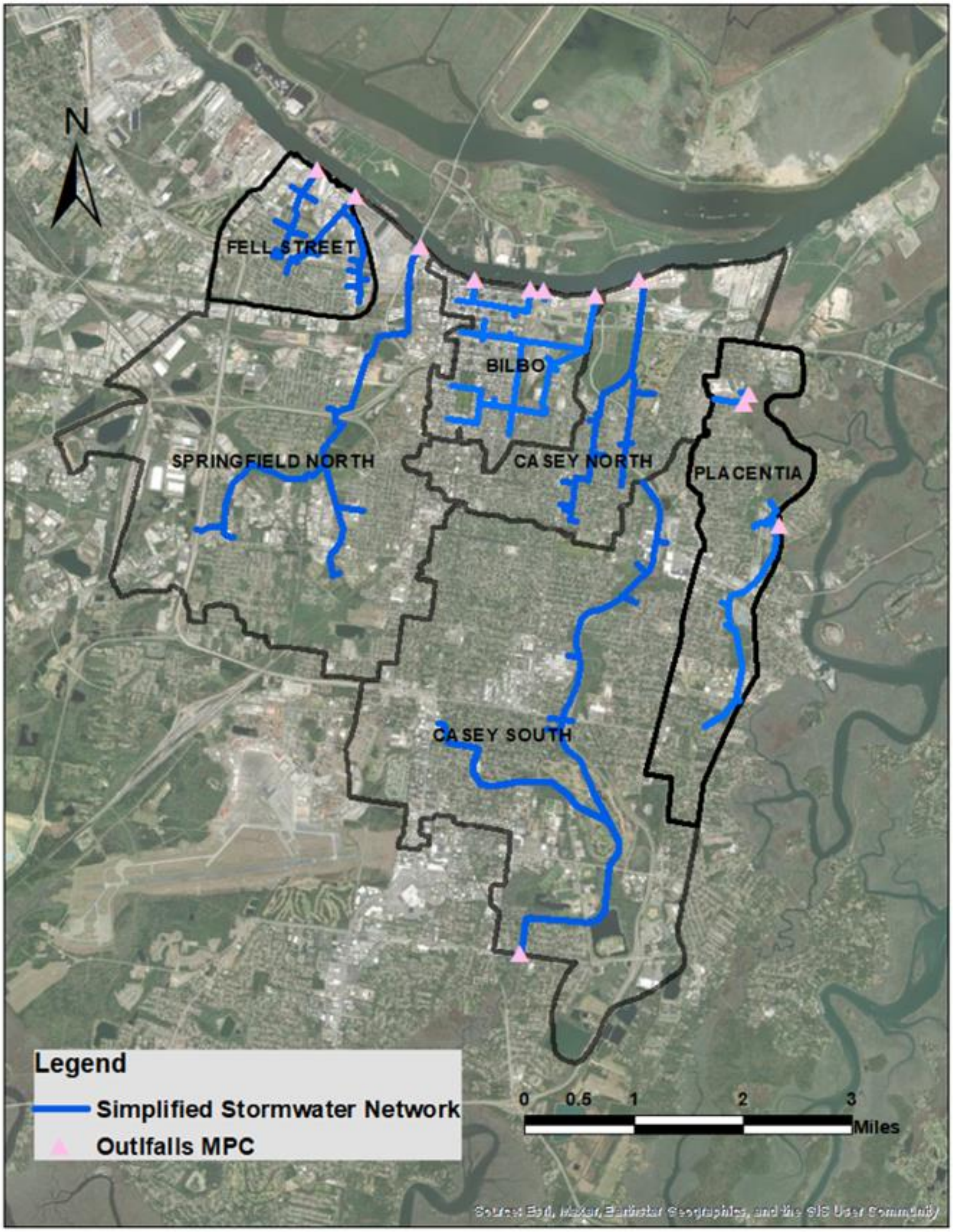

Figure 6. Final simplified stormwater network used in SWMM.

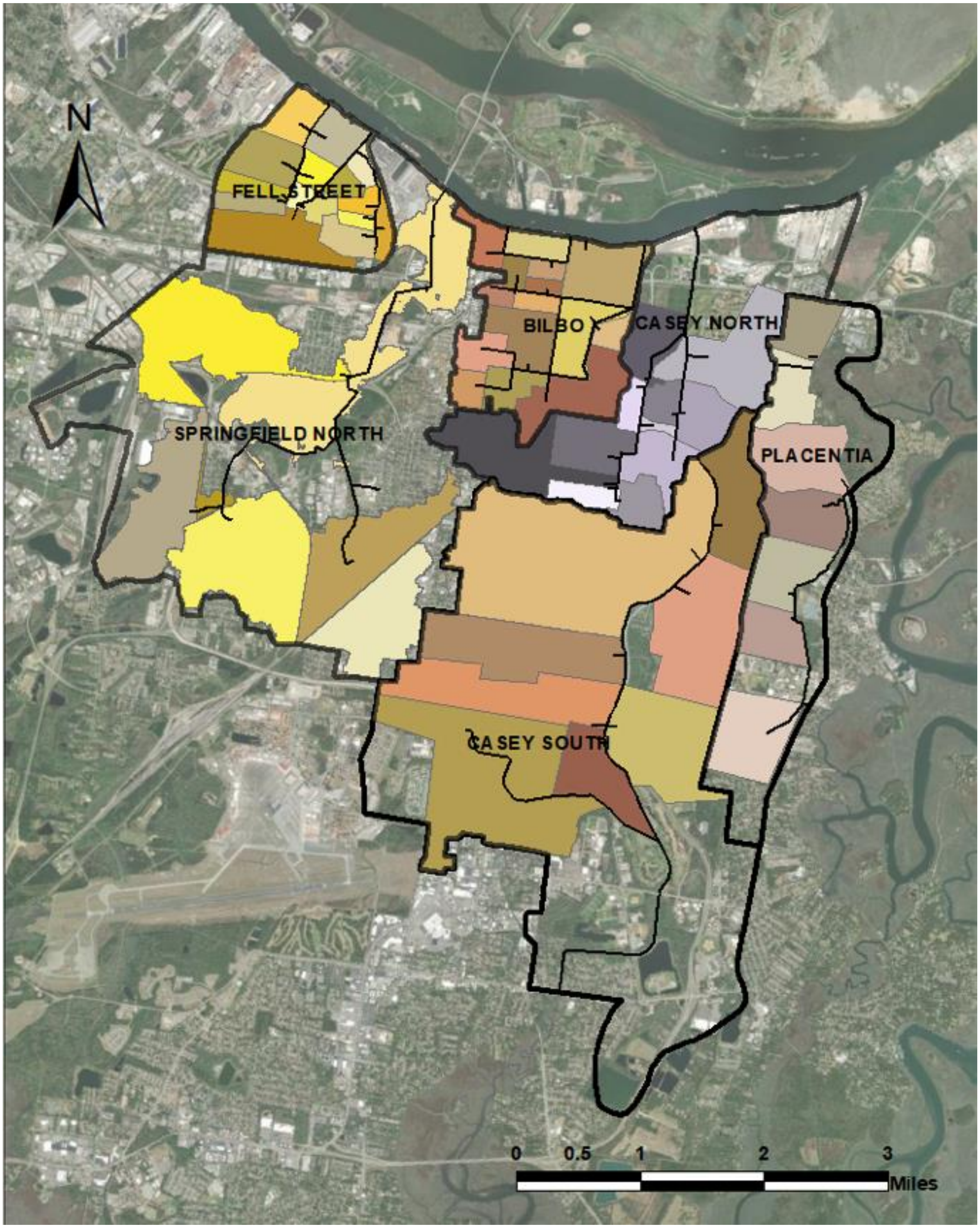

Figure 7. Final sub-watershed delineation per watershed.

3.2.4 Curve Number (CN) Estimation

The hydrological model used the CN method to determine the precipitation excess/loss. The CN was estimated based on the Land Use Land Cover (LULC) and soil type. LULC was gathered from the US Geological Survey's (USGS) Conterminous US Land Cover Projections (CONUS) model. This model is based on the United States Land Cover Projections developed by (Sohl et al. 2014). The model is a comprehensive overview of LULC of the US dating from 1992 to future predictions in 2100. There are different results of the model based on the International Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios (Sohl et al. 2014). For the SWMM study, scenario A1B was selected.

Initially, multiple SWMM models were going to be made of the same area with different LULC projections based on this data source. For example, models for 2022, 2050, and 2100 were planned to be made for each of the 6 drainage basins. However, when LULC data were collected for Fells Street and Bilbo, there was not a substantial change in land use for 2050 and 2100 when compared to 2022. This negligible change in land use carried over to every other basin as well. This is because every basin is already heavily urbanized and developed.

The soil type information required for the CN estimation corresponds to the hydrologic soil group, which was obtained from the web soil survey website of the Natural Resources Conservation Commission (NRCS)[2]. Most basins contained multiple soil types. In this case, the soil group that was least infiltrative (thus creating more runoff, typically soil type D) was assigned to each area to test the stormwater infrastructure under the worst infiltration conditions.

Table 2 shows the average values of curve numbers for all the watersheds analyzed. The values of CN estimated in the study area vary between 86 – 91, which is consistent with the soil coverage dominated for impervious areas.

Table 2. Average CN for each watershed.

Watershed	CN values
Springfield North	91.25
Casey North	90.76
Casey South	90.56
Fells Street	88.46
Bilbo	86.93
Placentia	86.20

3.2.5 Tailwater Conditions

The flooding and ebbing of the astronomical tides were considered throughout the SWMM simulations. As the astronomical tides flood, seawater enters the stormwater pipe outlet if the tide level is above the outfall elevation. This becomes worse as sea levels increase and seawater protrudes further inland. Typical conditions in this region include two flood and ebb events per lunar day (i.e., 24.83 hr), which is considered a semidiurnal tidal regime. Also, tidal ranges in the region are classified as mesotidal, with values ranging between 2 - 4 m. To quantify the tidal conditions within the study area, observed data were obtained from the Ft.

[2] https://websoilsurvey.nrcs.usda.gov/app/

Pulaski NOAA tide gauge (Station ID: 8670870[3]) located at the outlet of the Savannah River (Figure 8).

In addition to the tidal processes, different SLR projections were included in the climate change scenarios to be assessed by this study (Table 1). From NOAA, the intermediate SLR projections for the Southeast US in 2050, which projects an SLR of 1.18 ft, were considered. For the local source, two different SLR conditions were explored, CRD Low (2.14 ft) and CRD High (4.08 ft), both for 2075 projections.

A constant-amplitude, single-frequency tidal signal was used to represent the tidal flooding within the SWMM model. This tidal signal was applied at each stormwater outlet that empties into the Savannah River. A tidal resynthesis analysis of observed data was performed to determine the tidal amplitude for coastal Savannah during a full tidal cycle. The daily tidal amplitude was computed as one-half of the mean daily tide range. The average tide value was selected as the representative tidal amplitude for the compound flood event since it is the most frequent tidal water level. The average tide amplitude in this region is 3.84 ft and represents the US Southeast Atlantic mesotidal range, with a tidal range of 7.68 ft.

3.3. Coastal Tide and Surge Modeling

3.3.1 Astronomic Tide Flooding

Hydrodynamic simulations for astronomic tidal flooding were conducted using the depth-integrated version of the ADvanced CIRCulation (ADCIRC) code (Luettich and Westerink 2004). Simulations were conducted using the ADCIRC South Atlantic Coastal Study (SACS) Atlantic coast unstructured mesh (USACE 2022) (Figure 9). The mesh contains high resolution along the coast and describes the coastal marsh, tide creeks, and low-lying regions up to approximately the 35 ft elevation contour (Figure 10).

Numerical simulations were performed with astronomic tidal forcing along the open ocean boundary (60 deg. West Meridian) for 45 days. Astronomic tidal constituents used for the forcing were Q1, O1, P1, K1, N2, M2, S2, and K2. The simulations included a 10-day ramp to establish a dynamic equilibrium of the simulation. The peak tidal water levels were extracted from the remaining 35 days to obtain the maximum likely tidal-driven flooding. The simulations were performed for present-day sea level and six SLR scenarios established by the GA DNR (Table 1). SLR was included in the model simulations as an additional geoid offset, which provides improved hydrodynamics in contrast to bathtub SLR and GIS-based models (Bilskie et al. 2016).

Results for tidal flooding within the CORE MPO area are shown in Figure 11 - Figure 17.

[3] https://tidesandcurrents.noaa.gov/stationhome.html?id=8670870

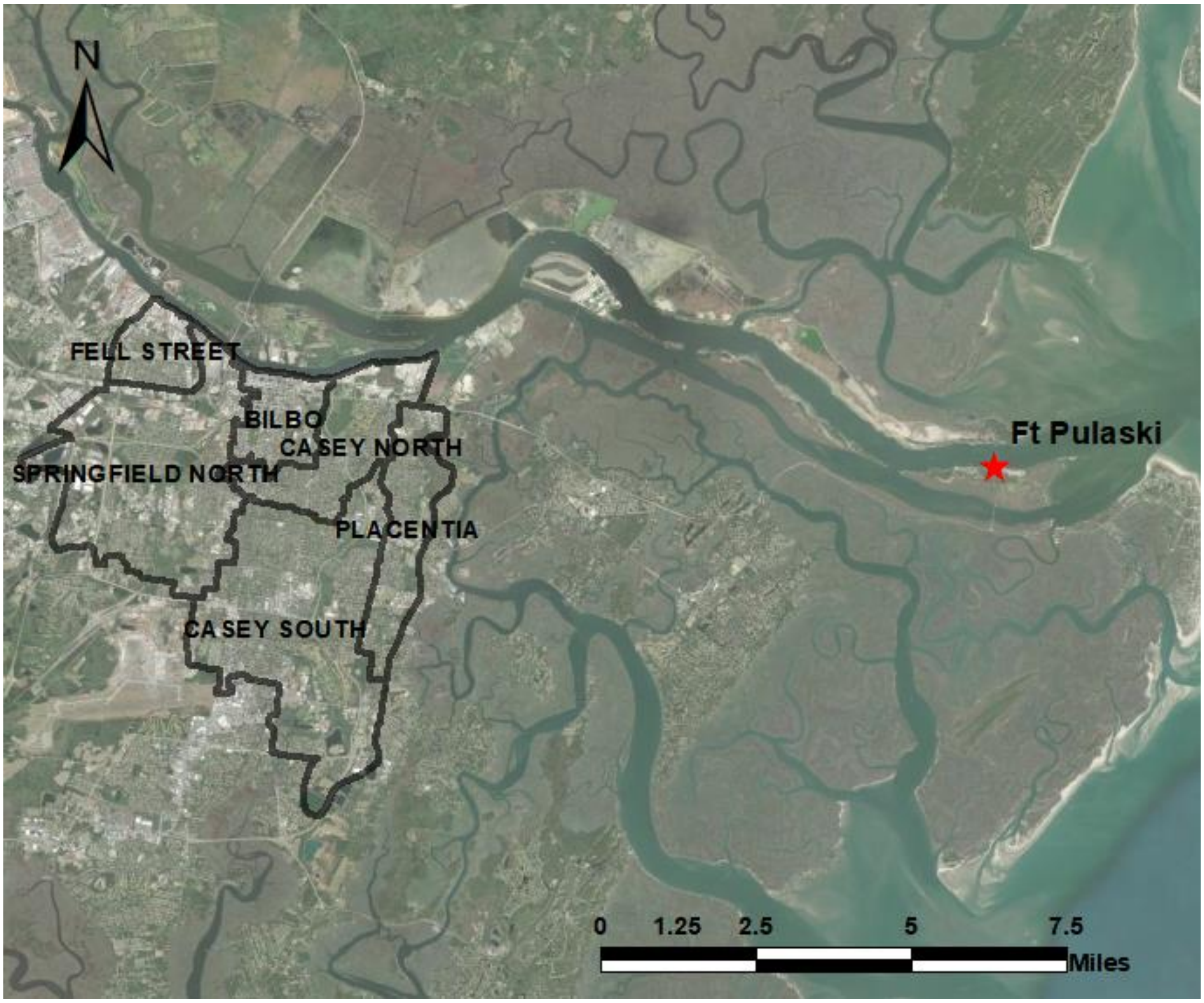

Figure 8. Fort Pulaski tide gauge location in reference to the SWMM watersheds.

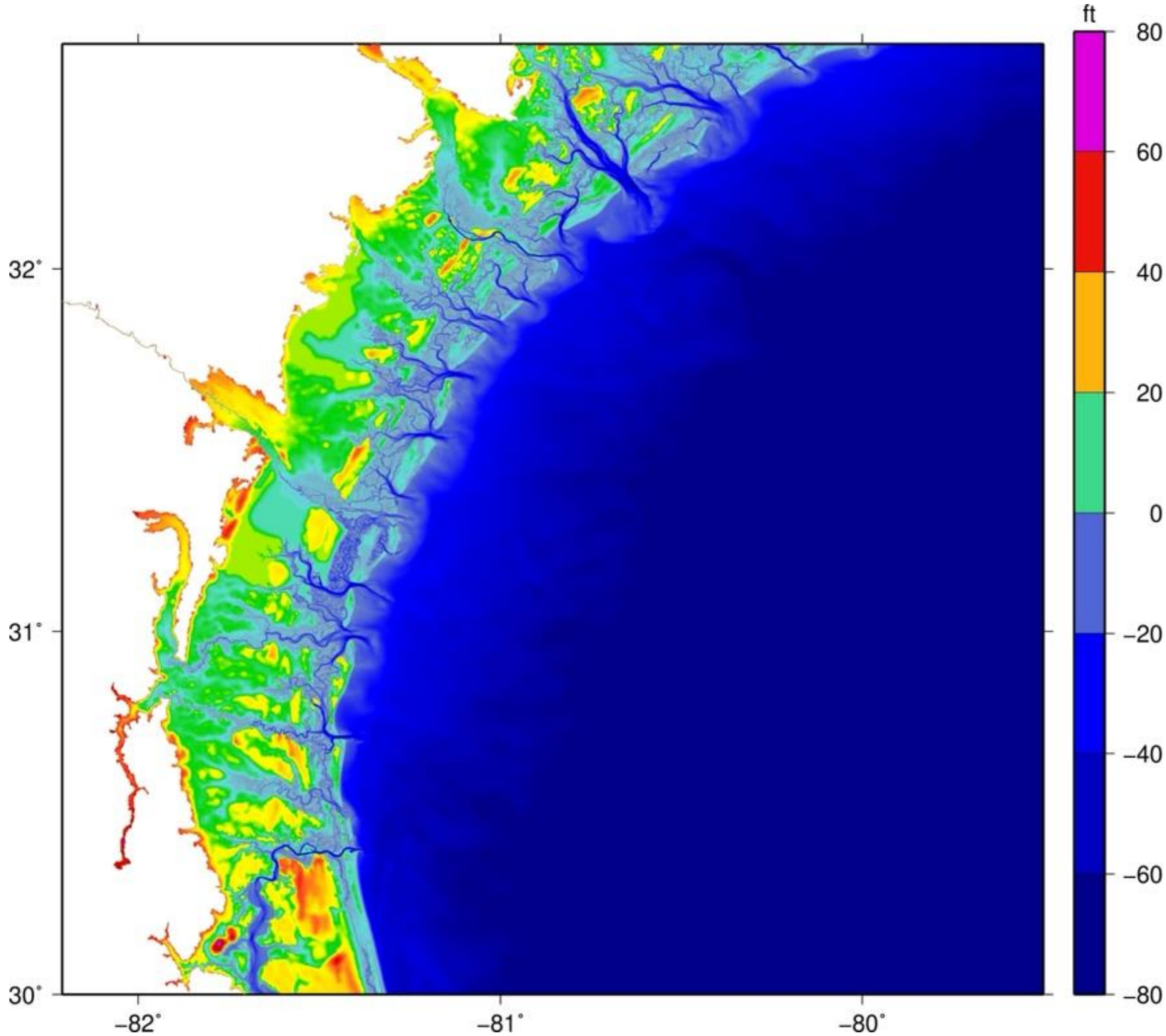

Figure 9. SACS ADCIRC east coast unstructured mesh topography/bathymetric (ft, NAVD88) for the southeast coast.

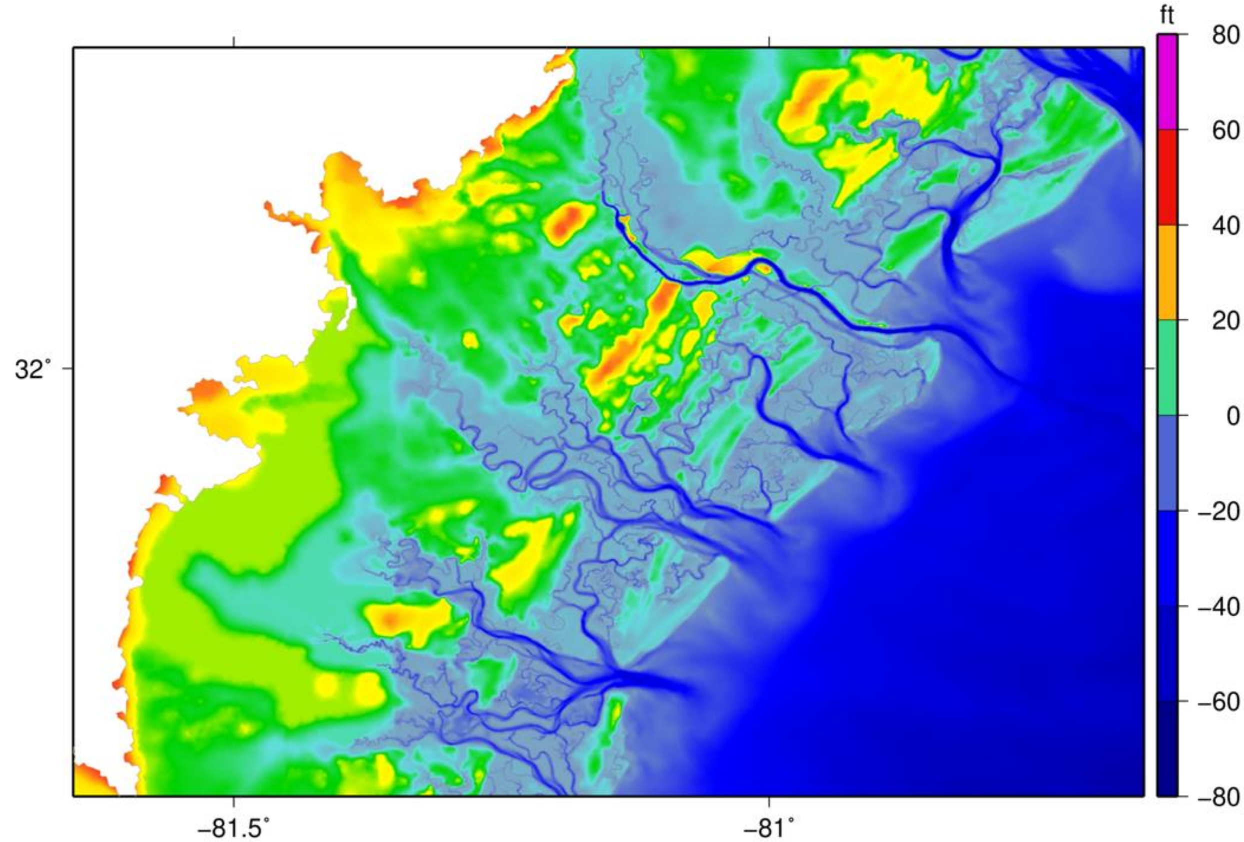

Figure 10. SACS ADCIRC east coast unstructured mesh topography/bathymetric (ft, NAVD88) shown for the northeast Georgia coast.

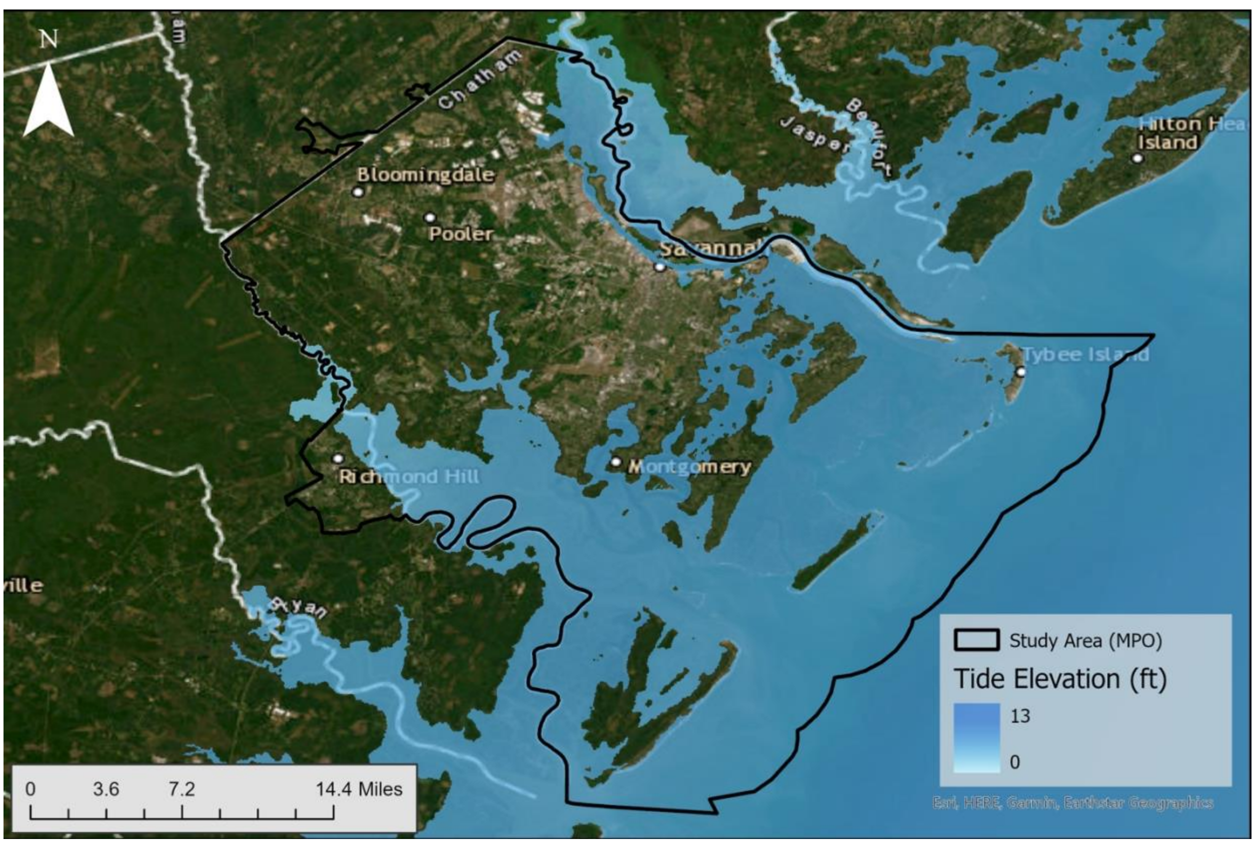

Figure 11. ADCIRC-derived tidal flooding conditions for 2020.

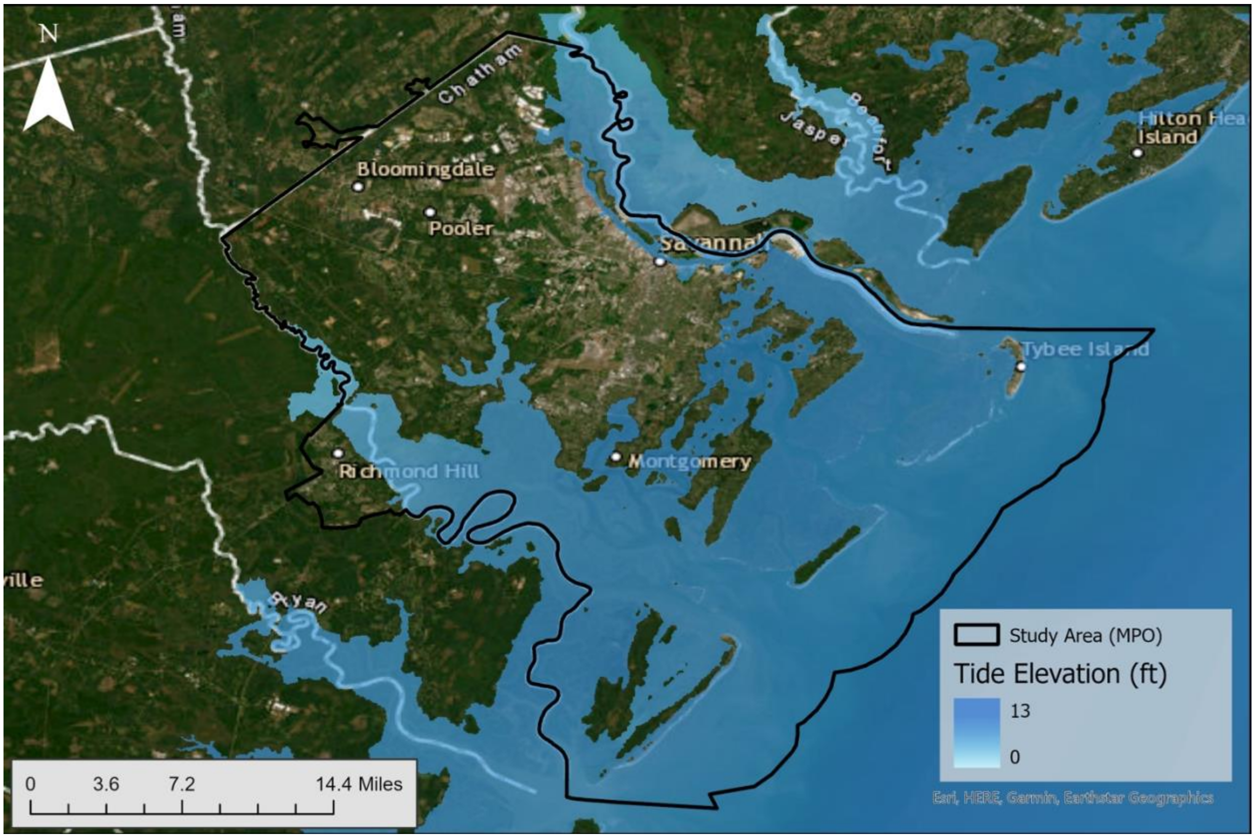

Figure 12. ADCIRC-derived tidal flooding conditions for 2050 under the low SLR projection (1.23 ft).

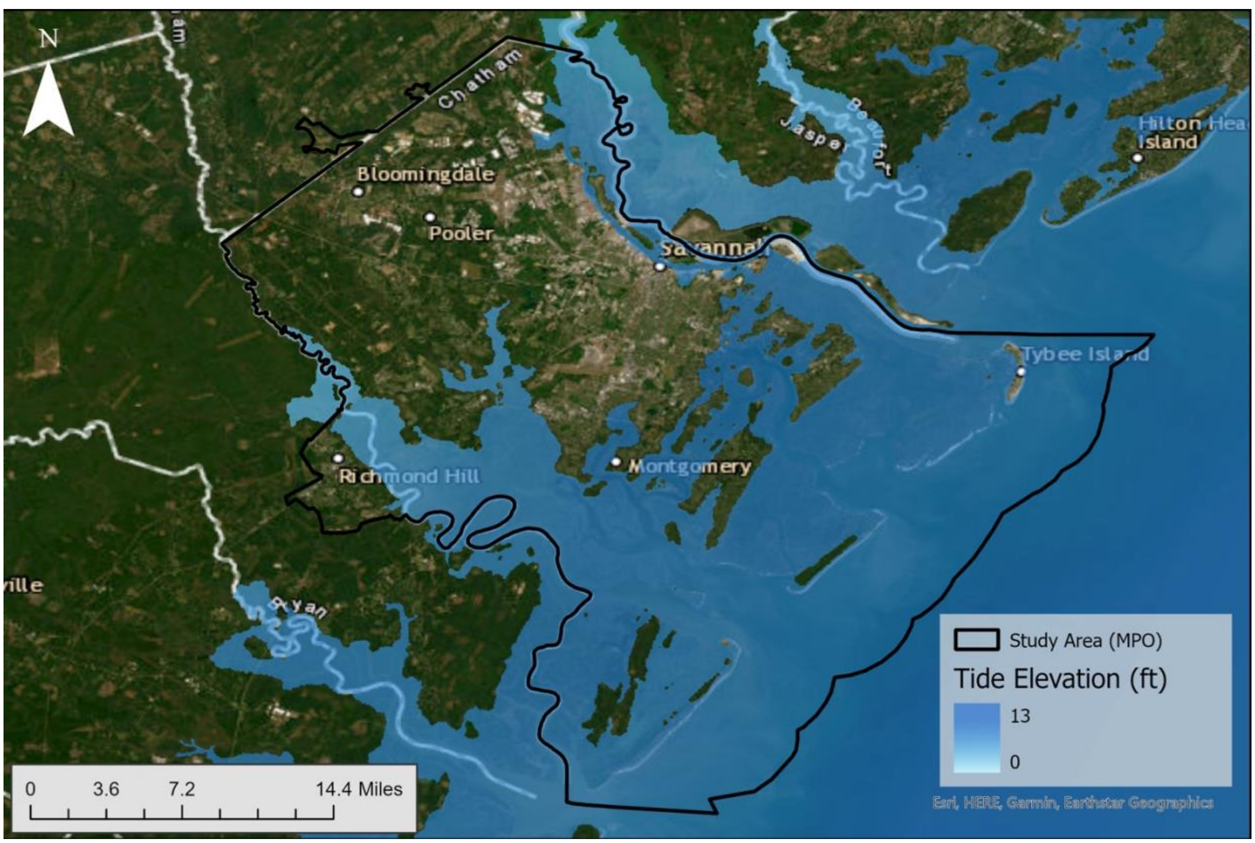

Figure 13. ADCIRC-derived tidal flooding conditions for 2050 under the high SLR projection (2.18 ft).

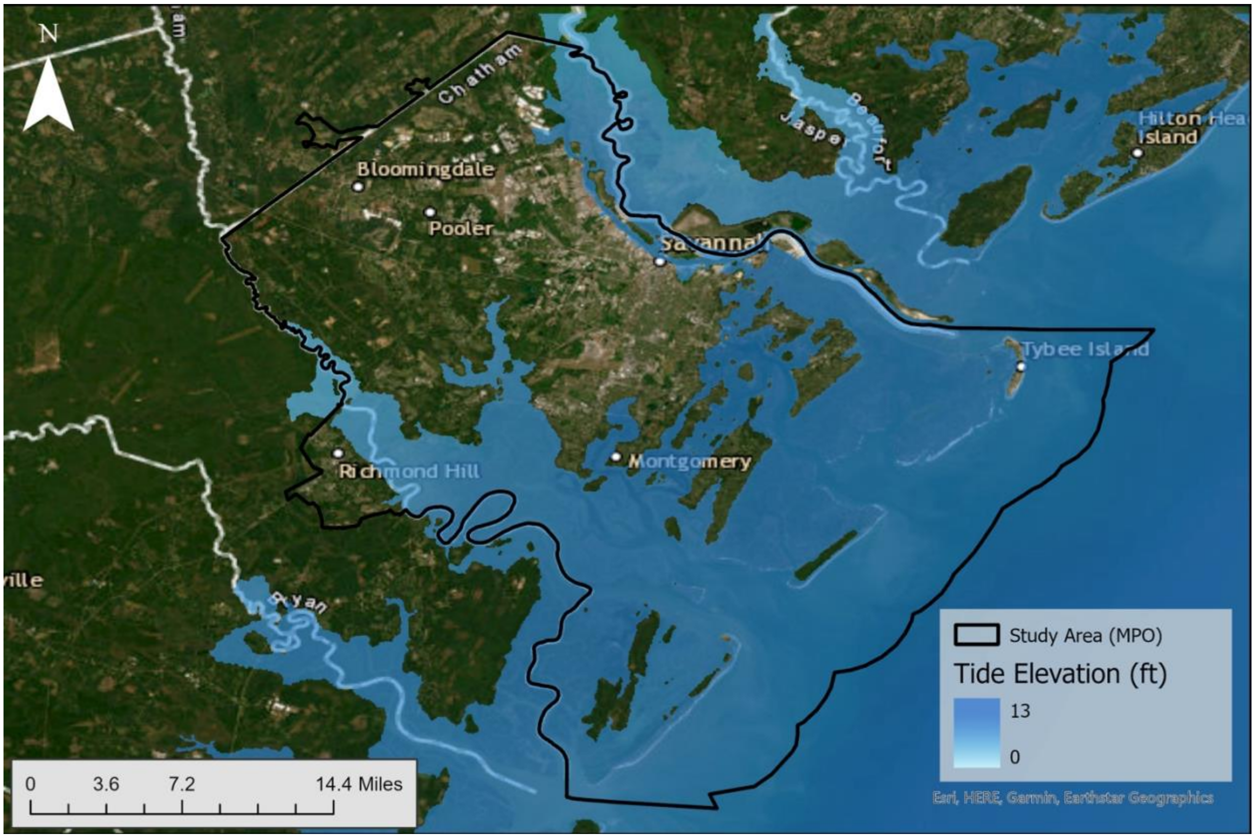

Figure 14. ADCIRC-derived tidal flooding conditions for 2075 under the low SLR projection (2.14 ft).

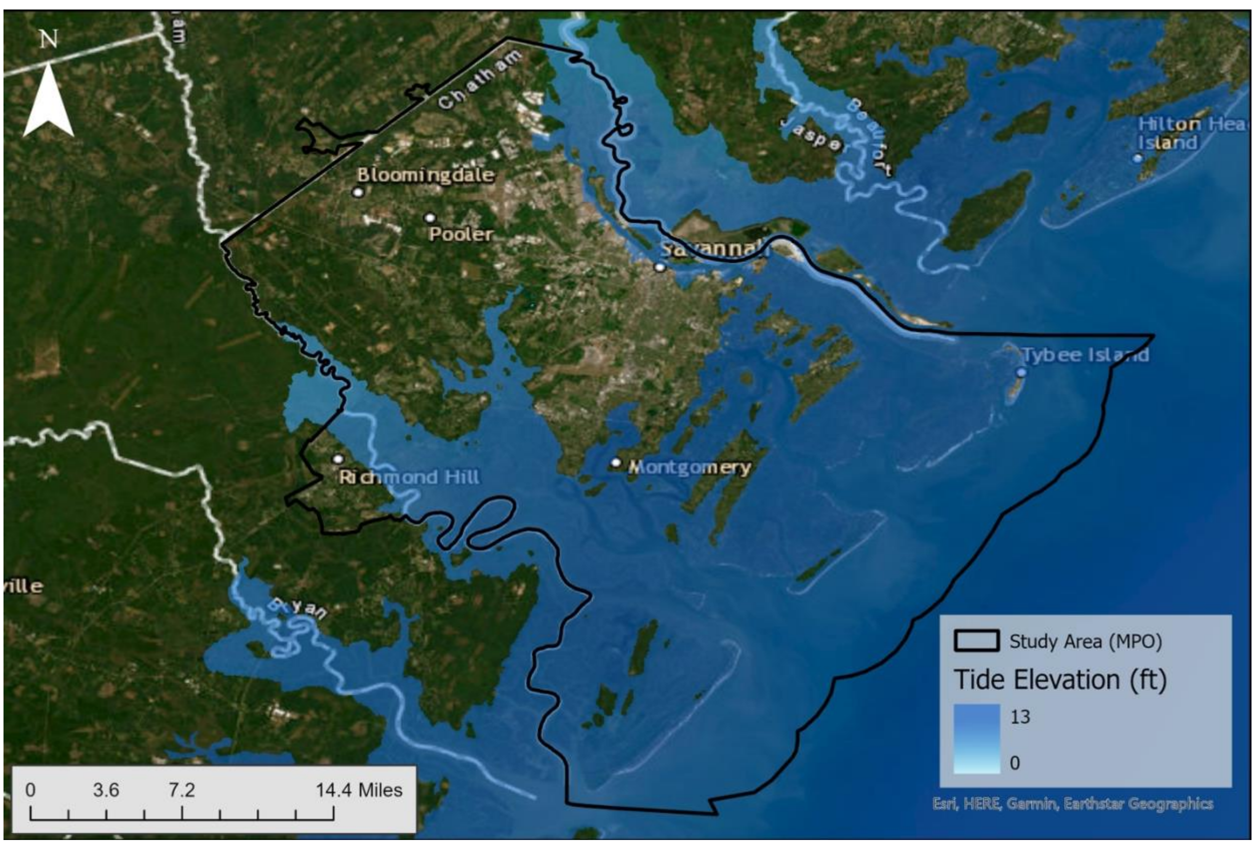

Figure 15. ADCIRC-derived tidal flooding conditions for 2075 under the high SLR projection (4.08 ft).

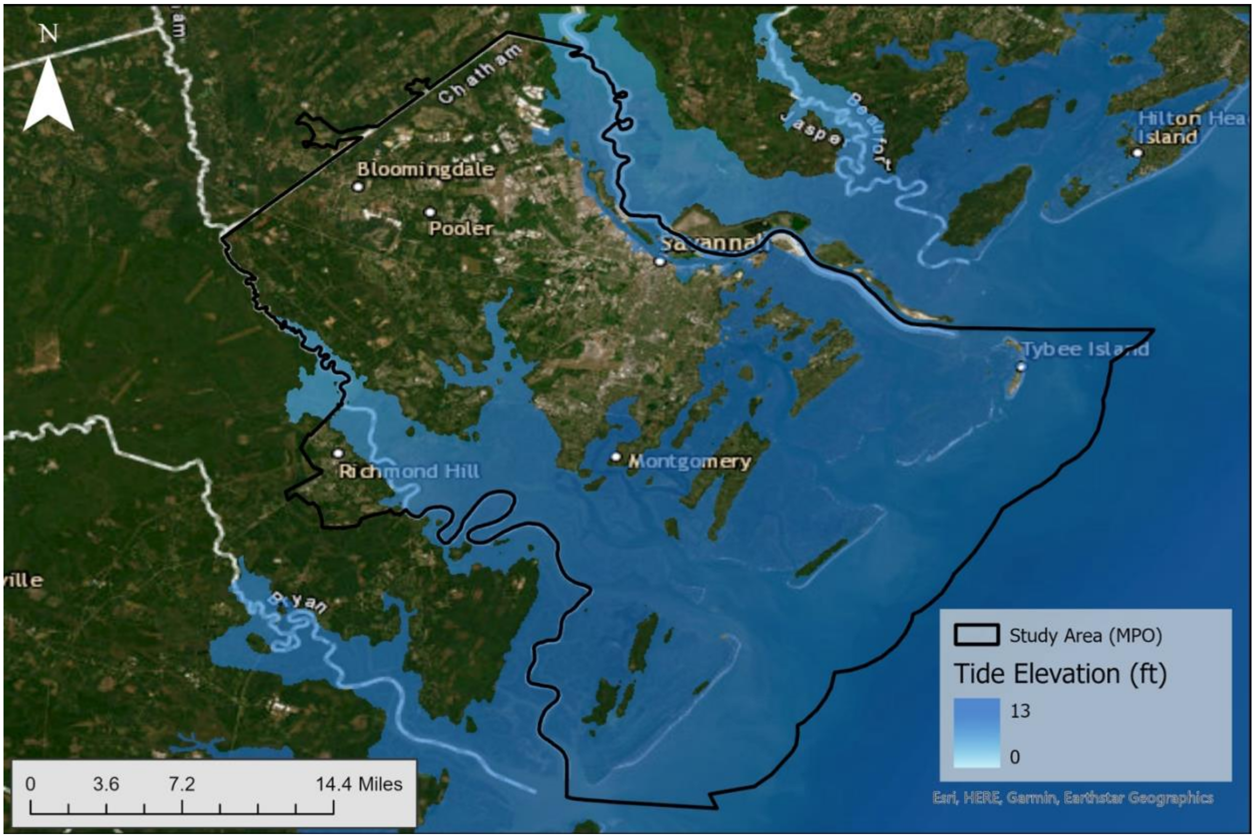

Figure 16. ADCIRC-derived tidal flooding conditions for 2100 under the low SLR projection (3.28 ft).

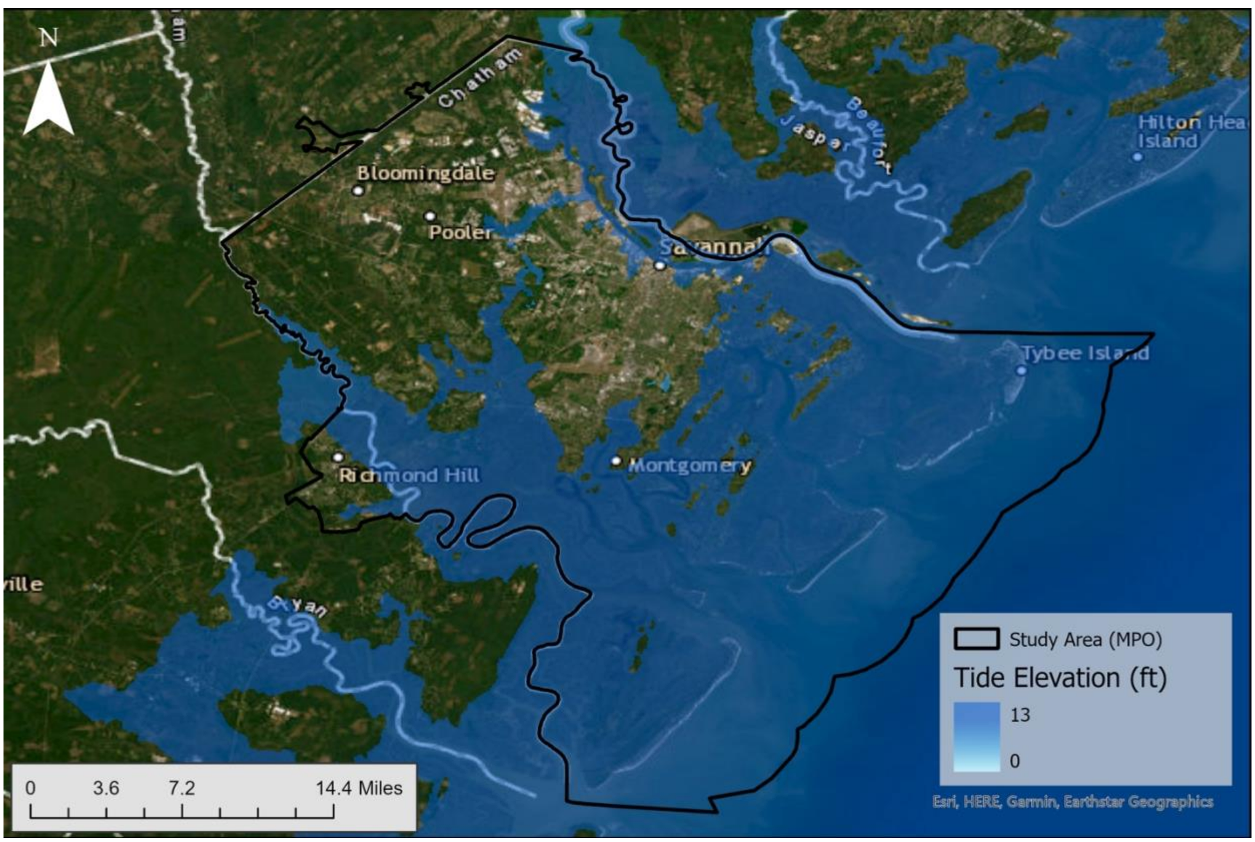

Figure 17. ADCIRC-derived tidal flooding conditions for 2100 under the high SLR projection (6.56 ft).

3.3.2 Storm Surge - 1% and 0.2% Annual Exceedance Probability (AEP)

The 1% and 0.2% AEP coastal flood events were taken from the SACS study (USACE 2022). The data were downloaded from the Coastal Hazards System Portal (v2.0)[4]. A water depth raster was created using the available data points (nodes) from the SACS study for both AEP datasets. Inverse Distance Weighted (IDW) was used to create a stillwater depth raster, which was masked to the CORE MPO boundary. Depth values that were 0.2 ft or less were removed from the dataset to limit interpolation errors along the raster edge. Lastly, the raster was masked to only land areas using the 2019 lidar-derived DEM. Figure 18 and Figure 19 present the 1% and 0.2% AEP for the CORE MPO region.

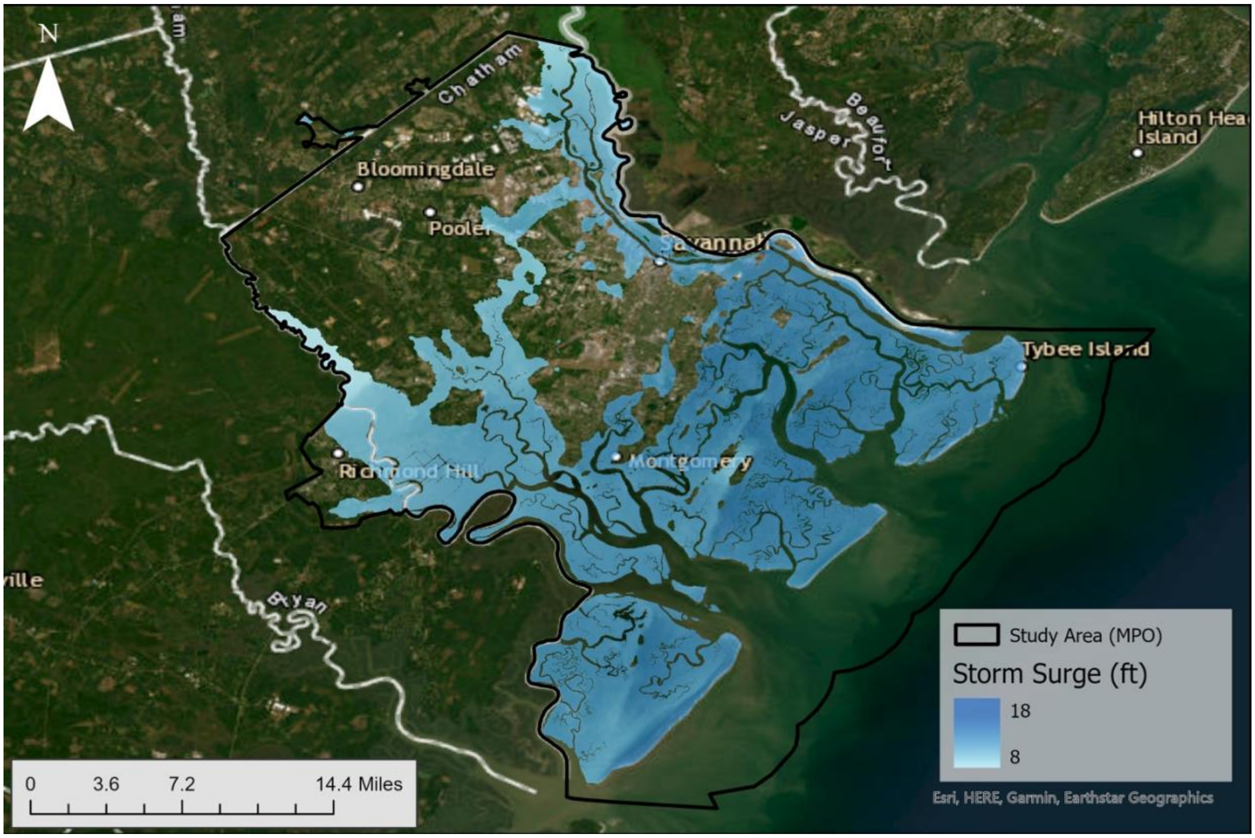

Figure 18. SACS-derived 1% AEP (100-yr return period) flood surface above NAVD88.

[4] https://data-sacs.opendata.arcgis.com/pages/coastal-hazards-system

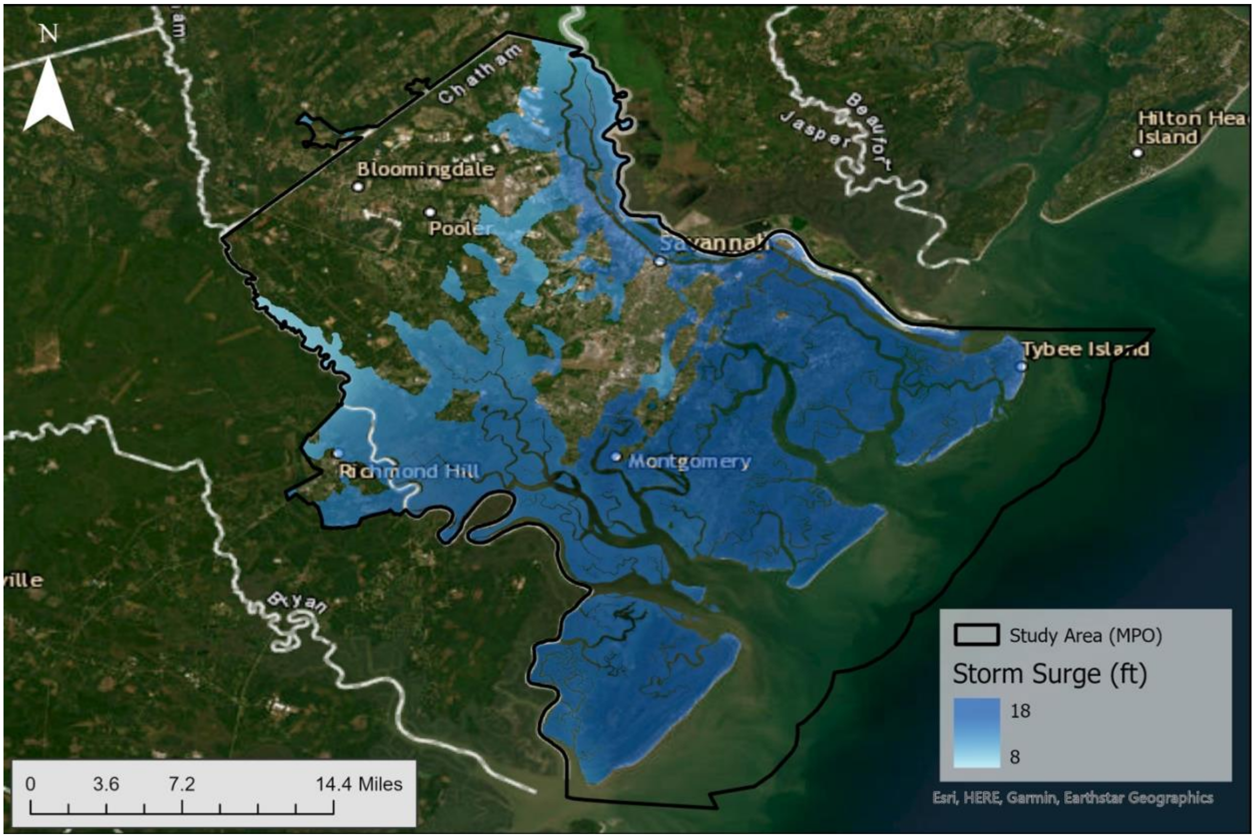

Figure 19. SACS-derived 0.2% AEP (500-yr return period) flood surface above NAVD88.

4. Roadway Vulnerability Assessment

4.1. Derivation of Road Segment Elevation and “Depth Above Road” Dataset

Bare earth land elevation from the 2019 Georgia lidar-derived DEM was used to assign elevation to individual roadway segments (Figure 21). Elevation was assigned to the road segments using the “Add Surface Information” tool in ESRI ArcGIS Pro. Each road segment was assigned an attribute of the minimum elevation based on the 2019 lidar data in feet referenced to the NAVD88 vertical datum (Figure 22).

Similarly, peak water surface elevations were assigned to each road segment from each tidal scenario (present-day, low, and high SLR scenarios for 2050, 2075, and 2100), and the 1% and 0.2% AEP stillwater floodplains. The Depth of flooding Above the Road (DAR) was computed by comparing the road segment's minimum elevation to the maximum water level for each scenario (Figure 20). Depths were computed by subtracting the water level from the elevation. When the maximum water level was above the minimum road elevation, the DAR was positive, meaning the road would likely be flooded and was assigned high vulnerability. In areas with flooding present but not above the road elevation, flooding could still impact the road through wave actions and other concerns. Roads where the water overlapped and had a DAR value between -3 and 0, meaning the water elevation was less than 3 feet lower than the road elevation, were classified with moderate vulnerability. Areas where the water does not overlap with the road and areas where the DAR was less than -3 were assigned a low vulnerability.

Table 3 shows the total length of roadway for each flooding scenario and vulnerability category and Figure 23 - Figure 31 show spatial maps of the resulting roadway vulnerability for each tide and AEP scenario.

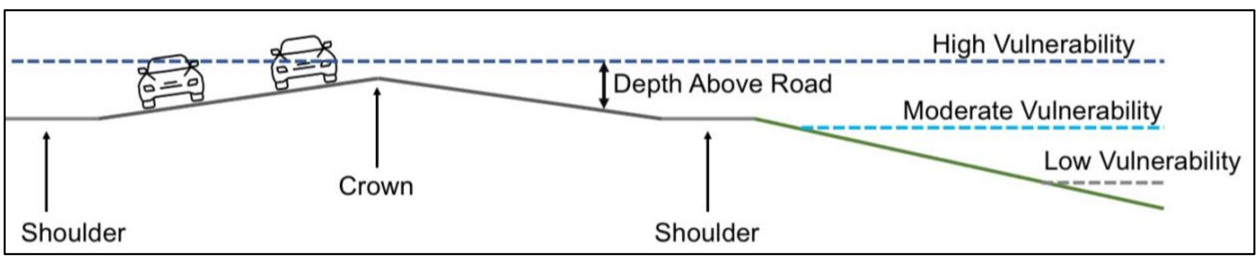

Figure 20. Sketch of depth above round and vulnerability classification.

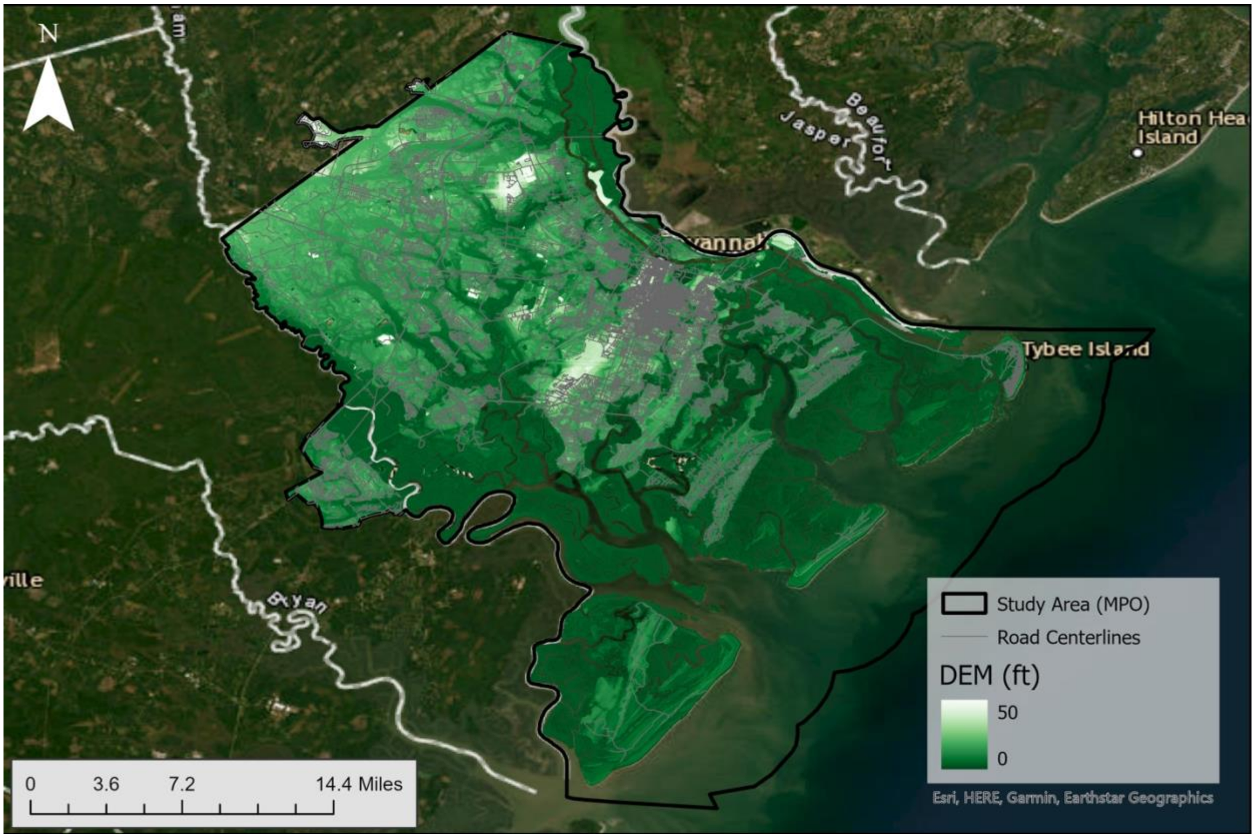

Figure 21. 2019 lidar-derived digital elevation model and road centerlines.

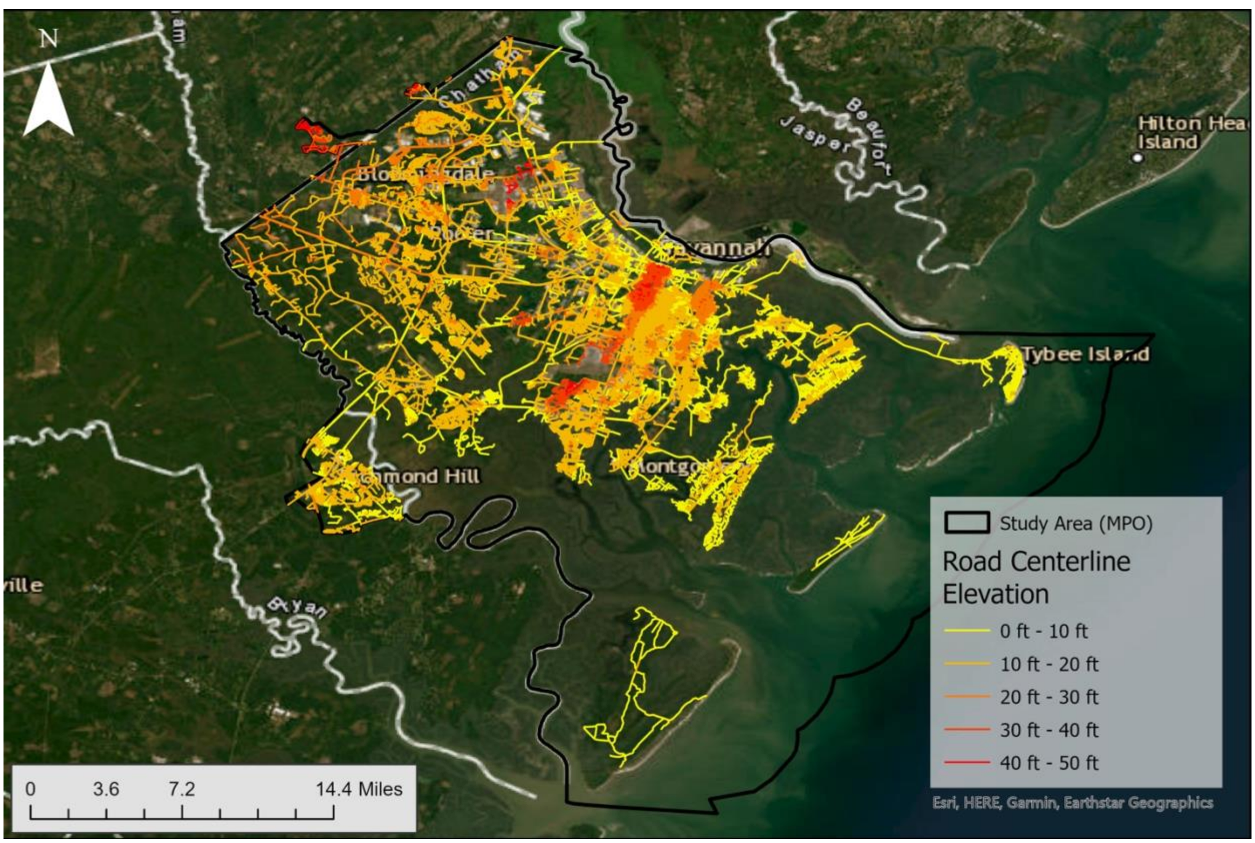

Figure 22. Road segments as described by elevation above NAVD88.

Table 3. Miles of effected roadway for each flooding scenario.

Scenario	Moderate Vulnerability (miles)	High Vulnerability (miles)	Total (miles)
Present-Day Tides	50.7	91.0	141.7
Tides 2050 DNR Low (1.23 ft)	47.5	151.0	198.5
Tides 2050 DNR High (2.18 ft)	40.8	202.5	243.3
Tides 2075 DNR Low (2.14 ft)	42.0	199.4	241.4
Tides 2075 DNR High (4.08 ft)	40.3	318.5	358.9
Tides 2100 DNR Low (3.28 ft)	35.2	274.8	309.9
Tides 2100 DNR High (6.56 ft)	44.1	523.5	567.5
0.1% AEP	73.3	638.9	712.2
0.2% AEP	116.2	948.8	1,065.0

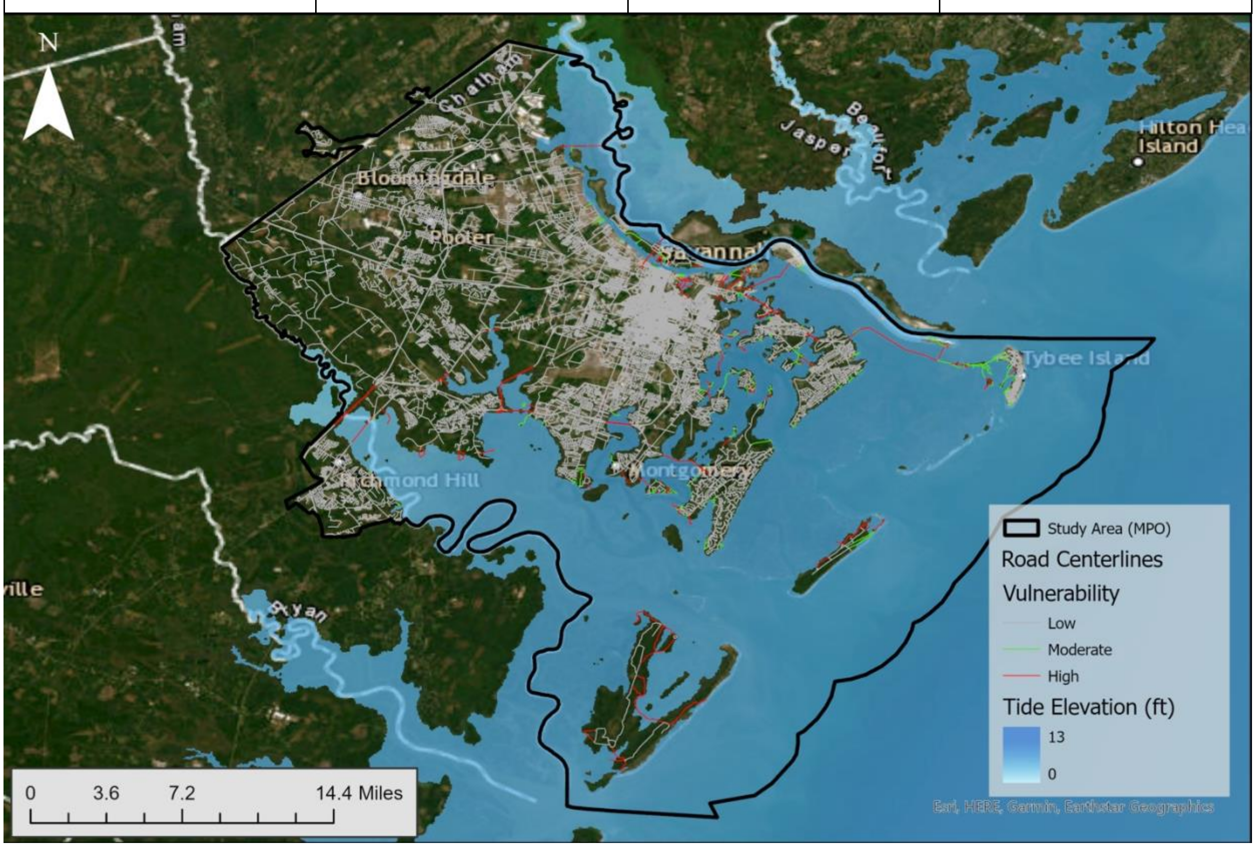

Figure 23. Roadway vulnerability and tidal flooding extent for present-day.

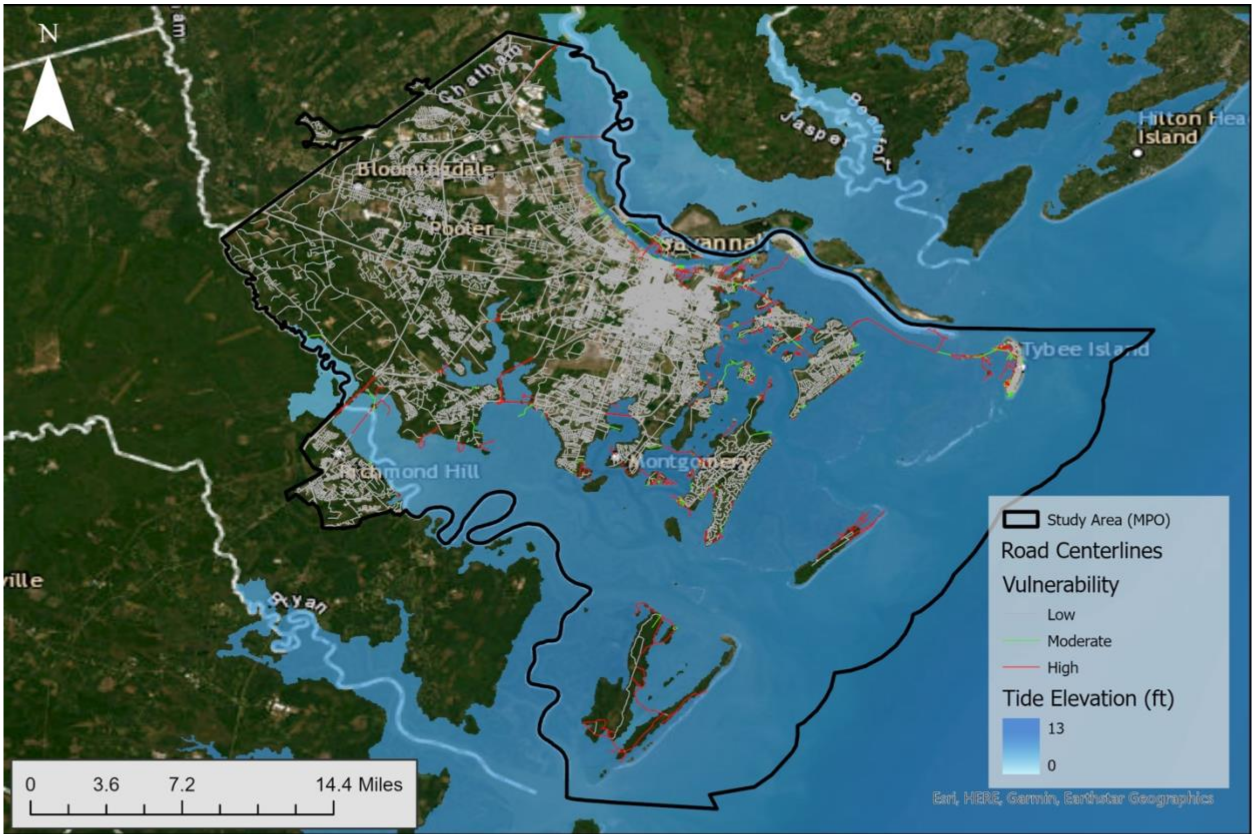

Figure 24. Roadway vulnerability and tidal flooding extent for 2050 under the low SLR projection (1.23 ft).

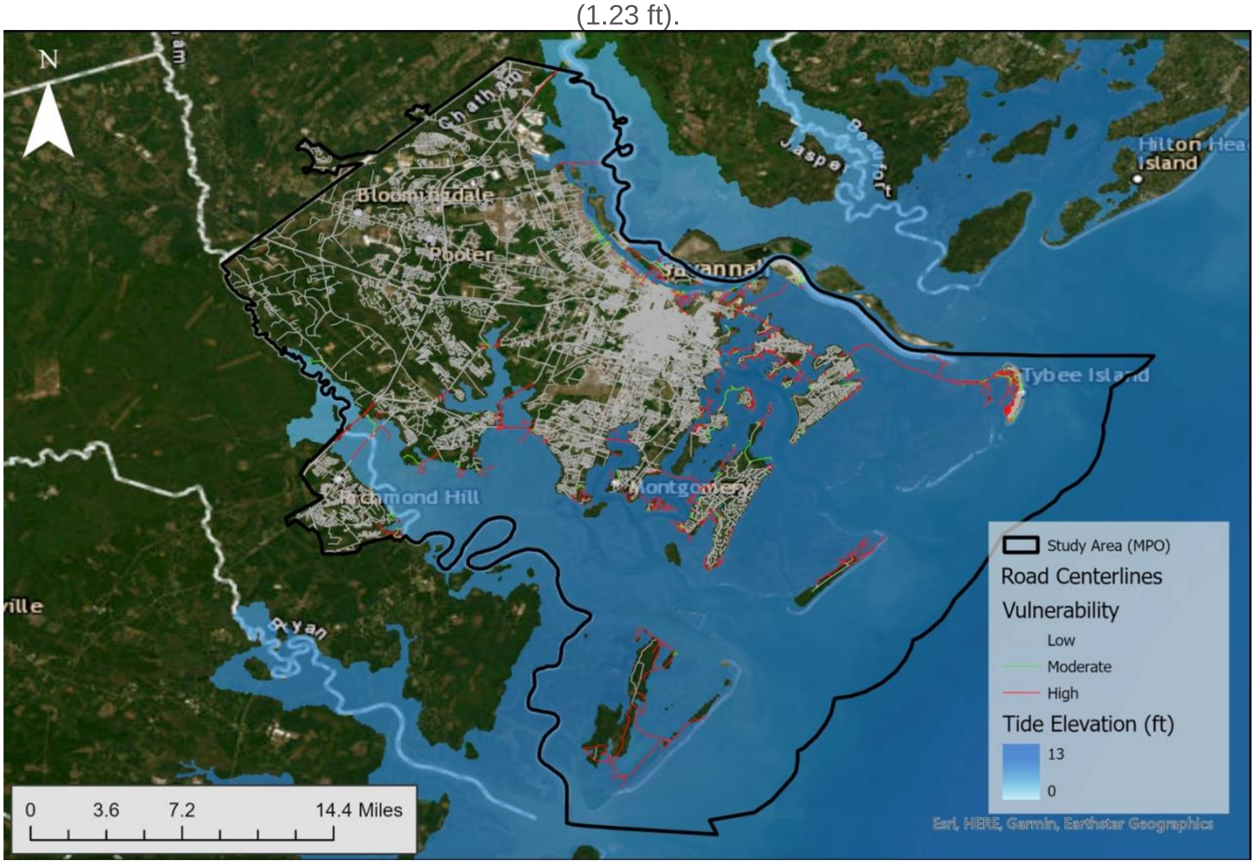

Figure 25. Roadway vulnerability and tidal flooding extent for 2050 under the high SLR projection (2.18 ft).

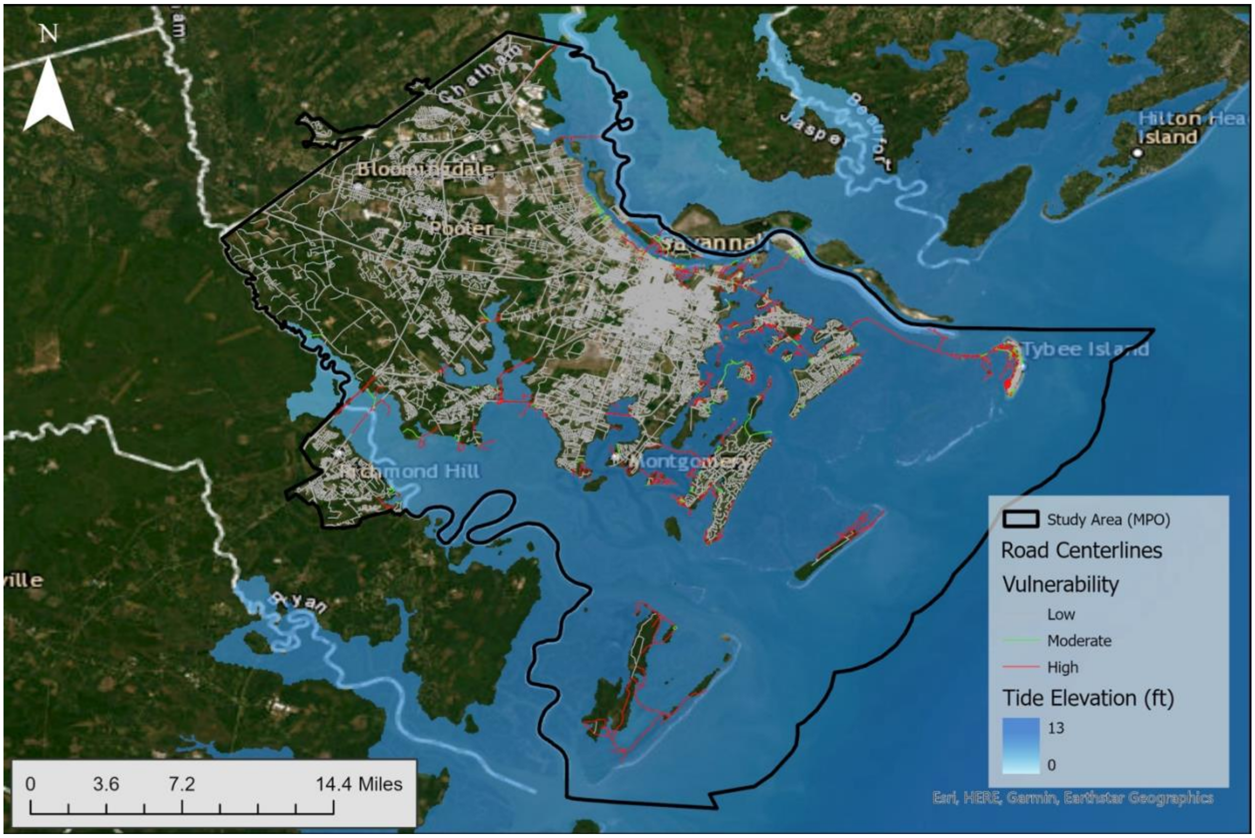

Figure 26. Roadway vulnerability and tidal flooding extent for 2075 under the low SLR projection (2.14 ft).

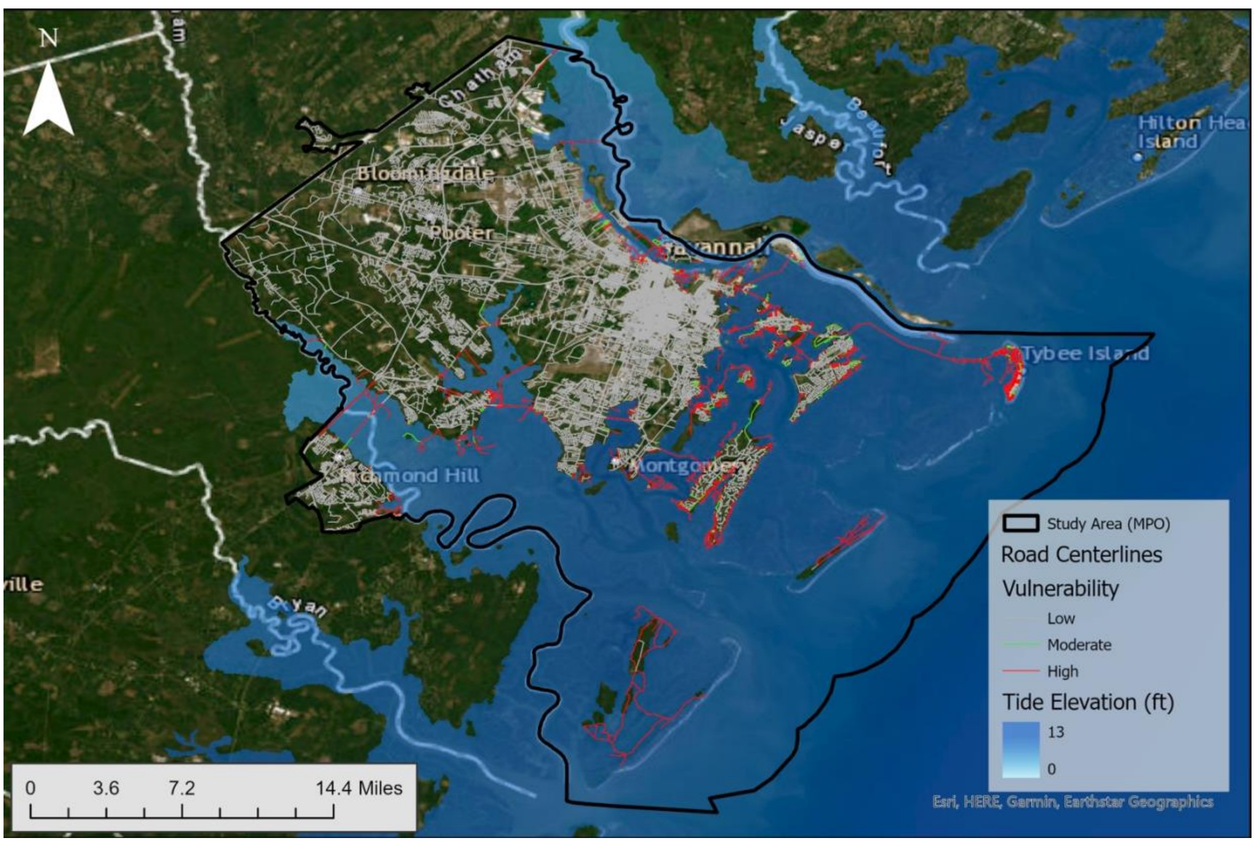

Figure 27. Roadway vulnerability and tidal flooding extent for 2075 under the high SLR projection (4.08 ft).

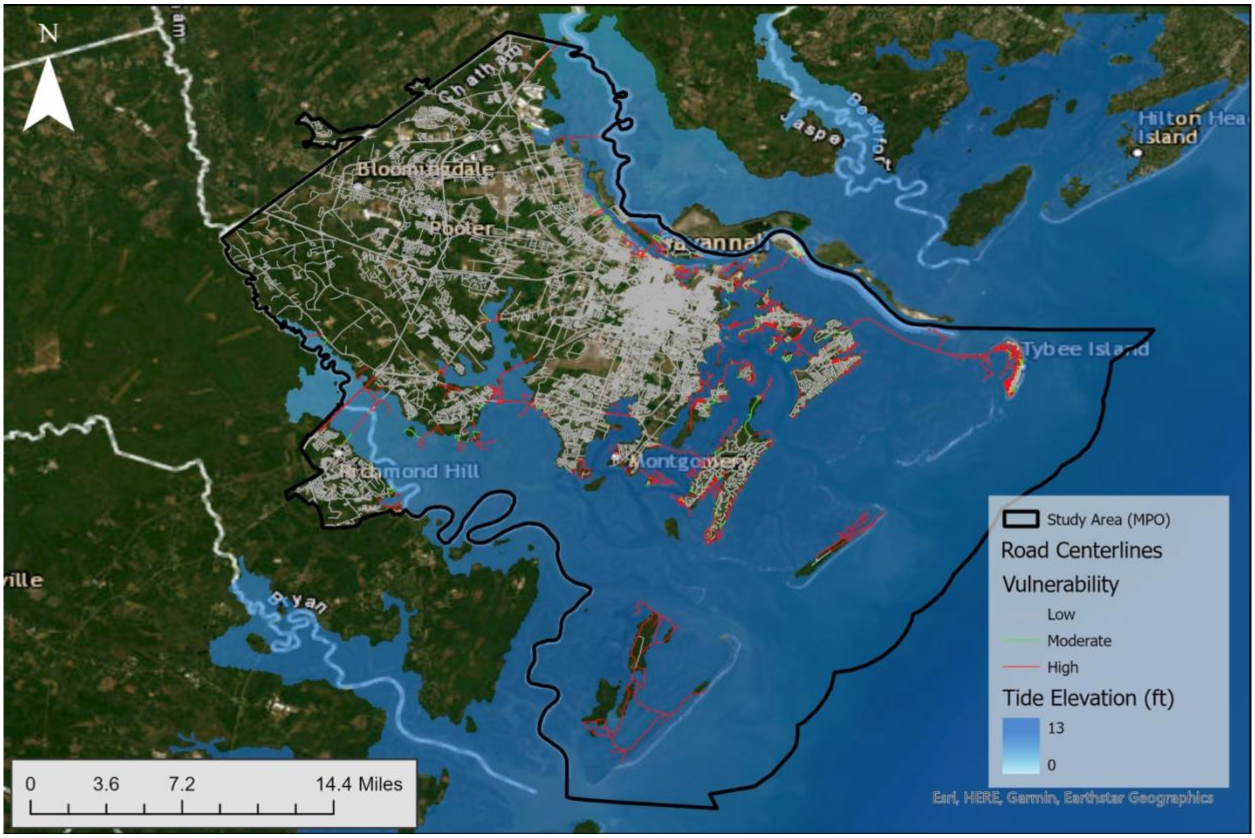

Figure 28. Roadway vulnerability and tidal flooding extent for 2100 under the low SLR projection (3.28 ft).

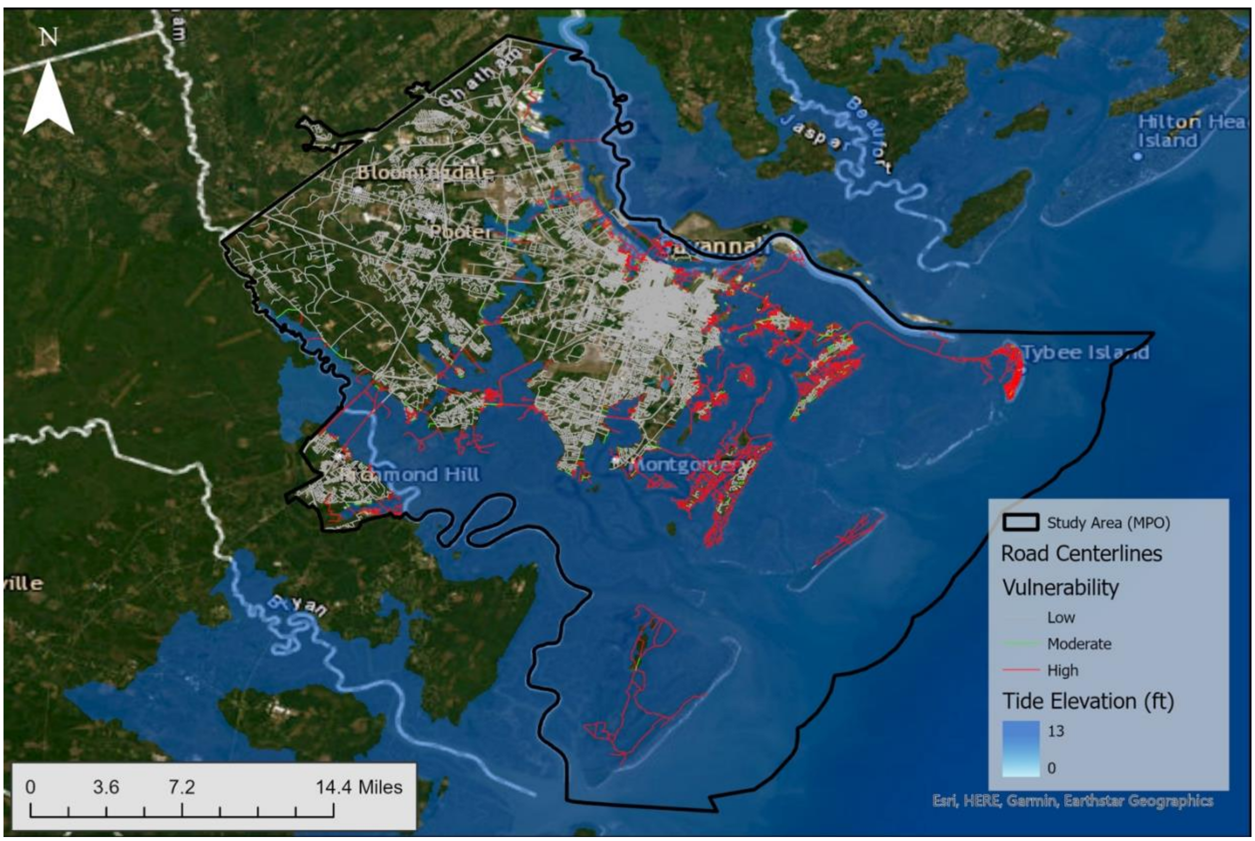

Figure 29. Roadway vulnerability and tidal flooding extent for 2100 under the high SLR projection (6.56 ft).

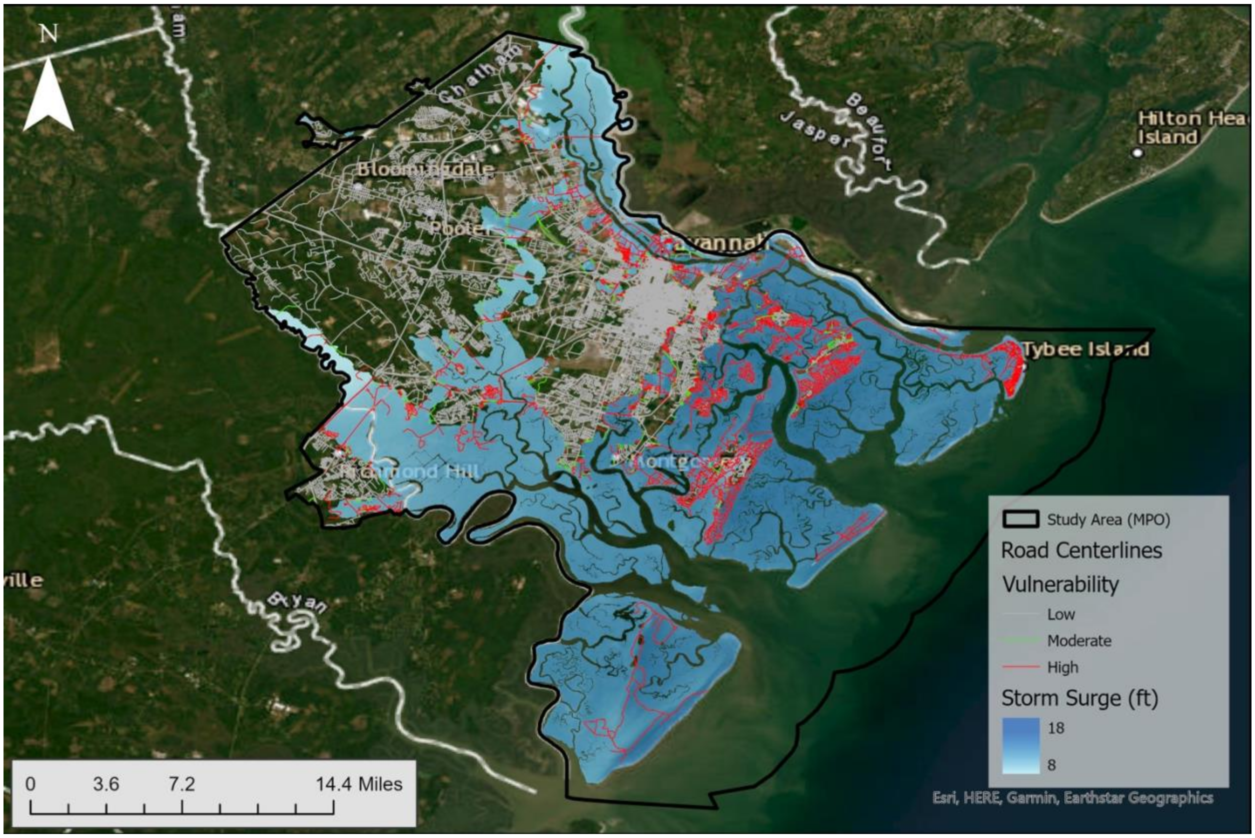

Figure 30. Roadway vulnerability and 1% AEP (100-yr return period) flooding extent.

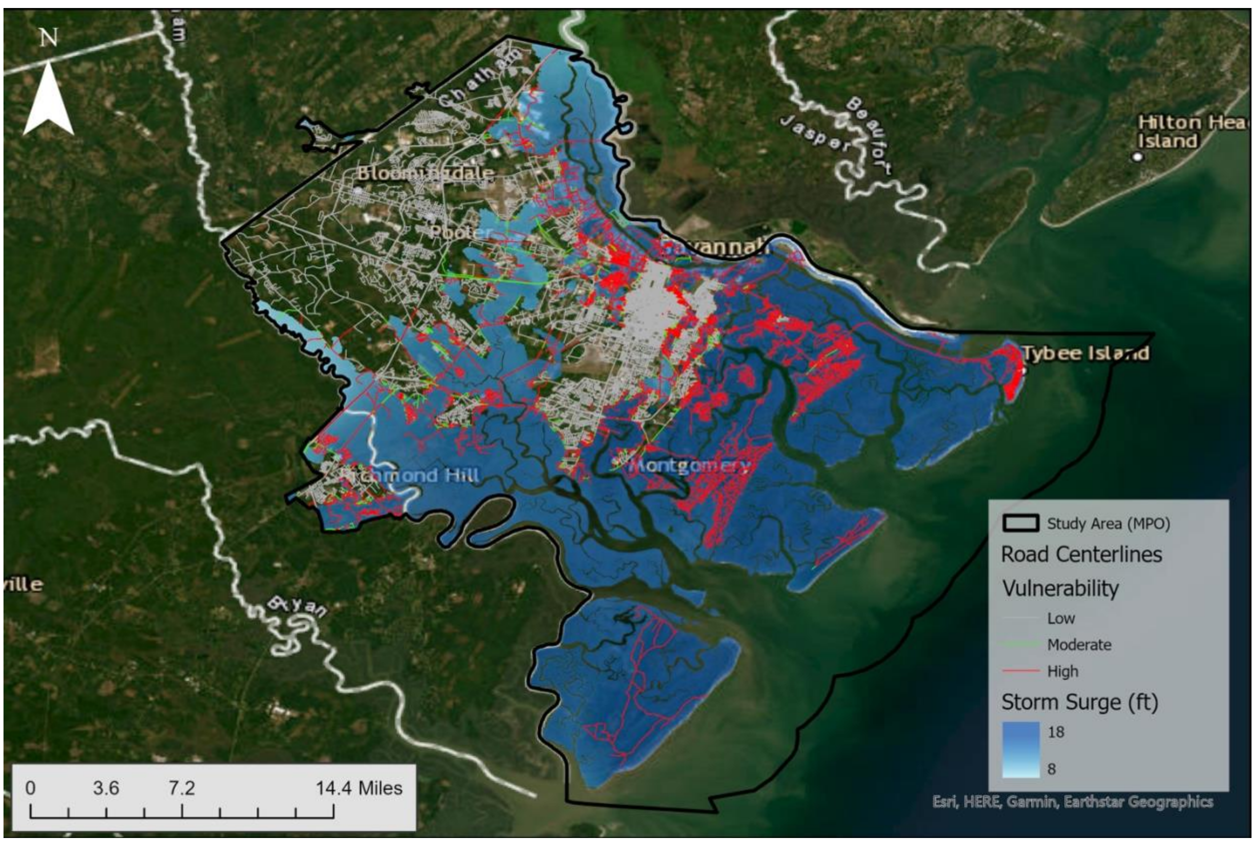

Figure 31. Roadway vulnerability and 0.2% AEP (500-yr return period) flooding extent.

4.2. Project Prioritization Tool

The ***Vulnerability Assessment Dashboard*** (http://www.gmcgis.com/mpo) was developed by the University of Georgia and Goodwyn Mills Cawood in partnership with the MPO to assist with optimizing the planning of new and existing infrastructure to improve reliability and resiliency with additional consideration to economic constraints and social inequities. The purpose of this application is to provide decision makers and other interested parties with the ability to interact with the data produced as a part of this project in a manner that traditional methods do not offer. The application has been structured to allow data to be viewed over the entire project area or by areas of interest. Road vulnerability based on the DAR has been generalized in this application with all segments being assigned a value of low, moderate, or high.

The application contains additional data layers to allow for additional analysis. Known place names, critical facilities, road centerlines, and municipal boundaries have been included to provide more specific information. Social vulnerabilities such as race & ethnic minority status, household characteristics, socio-economic status, and housing type & transportation have also been included and can be overlaid for further analysis.

This section provides some general guidance for getting started with the dashboard. To begin, select a place or area of interest from the menu at the screen's top right corner. By default, the information is displayed for the MPO project area as a whole. When selected as an area, the interactive map will zoom to the selected area. The interactive map also contains a search tool that can be used to locate a specific address. Additional layers and basemaps can also be toggled on and off using the tools and options in the map's top right corner. Tabs across the bottom offer the opportunity to view additional information about the selected or the project area. The charts show mileage within the selected area that would be flooded during each DNR scenario. Additional interactive maps directly illustrate the impacts of high- and Low-sea level rise scenarios. Specific road segments can also be searched and viewed using the table list on the left.

The dashboard can be used by decision makers to assist with current and future project planning. By incorporating environmental and social vulnerabilities into the planning process, informed decisions can be made to benefit all citizens within the community.

5. Social Vulnerability and Transportation Resilience Planning

5.1. Social Vulnerability and Resilience

“Resilience” is a broad concept that is applied in many different contexts. In infrastructure planning, it is generally defined as a system’s capacity to absorb disturbance and re-organize into a fully functioning system (Norris et al. 2008). This includes the ability to withstand negative impacts without affecting the functions of the system and the capacity to restore affected systems quickly and efficiently. The concept of “vulnerability” goes hand-in-hand with the idea of resilience as it reflects the same concept from the perspective of the impacted system or an affected group or population. Vulnerability describes the likelihood that an event will cause damages or disruptions from some external shock and limits the capacity to recover from such a shock. In general, enhancing the resilience of a system such as a road network involves enhancing those characteristics of that system that enhance its resilient characteristics, e.g., in the context of flooding, engineers could use more durable materials to increase the pavement’s ability to resist damage or use readily available materials to increase its capacity to be repaired quickly. Resilience can also be enhanced by reducing the system’s vulnerability, e.g., reducing the likelihood that a flood event will impact a road by elevating it or by enhancing the affected population’s ability to adapt to the impacted system.

Much of the research and investment into improving infrastructure resilience has focused on building more robust infrastructure components and systems to withstand larger and more powerful disturbances. However, the characteristics of the local population and the makeup of their community significantly impact their relative vulnerability. This is often referred to as a population’s “social vulnerability.”[5] Research indicates that socially vulnerable people are often less prepared for potential disasters and more likely to experience adverse effects during a disaster (Lehnert et al. 2020). To enhance community resilience, it is not enough just to look at the physical features of a community’s natural and built environment, but planners must also consider the social vulnerability of the people who live there or are part of the larger community is a critical aspect of the overall resilience of the community.

For instance, in thinking about the resilience in the transportation context, it would be important to consider the neighborhoods with high concentrations of residents who are elderly or disabled as these groups may have more challenges evacuating in an emergency because they are unable to drive or are in assisted living facilities. Similarly, the mobility of households in areas with limited access to personal automobiles should also be a factor. In more densely populated areas, traffic congestion may present added difficulties for evacuation when compared with less dense areas, and the means of communication need to be tailored to the language needs and technological capacities of specific audiences in the community. For example, directions and warnings must be issued in multiple languages in many areas, and younger audiences may not watch broadcast television, and older audiences may not see social media posts.

[5] *See* FEMA Nation Risk Index, “Social vulnerability,” *available at:* https://hazards.fema.gov/nri/social-vulnerability. (Social Vulnerability is the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood.)

5.1.1 Social Vulnerability Index (SVI)

One of the primary tools used to evaluate the relative social vulnerability of different communities is the Social Vulnerability Index (SVI), produced by the Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (CDC/ATSDR)[6]. The SVI is a relative measure of vulnerability calculated using a variety of population characteristics derived from the U.S. Census. SVI is based on 16 factors (Table 4) including unemployment, racial and ethnic minority status, disability, and more. The 16 SVI variables are grouped into four thematic categories: Socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation. It is calculated at both the county scale and at the census tract level. Census tracts are geographic designations created by the U.S. Census Bureau that have generally comparable populations designed to enable researchers to tease out variations in population demographics at a scale smaller than a city or county by large enough to prevent the identification of individuals. It is generally the smallest geography for which much of the U.S. Census Bureau's data are publicly available. Table 4 shows the factors used in the most recent SVI analysis. CDC's SVI is widely recognized as a useful tool for examining community-scale vulnerability.

Social vulnerability, as captured in SVI data, intersects with hazards in many ways. For instance, factors such as low-income or high poverty rate can relate to an individual's ability to prepare, evacuate, and mitigate risks of harm or damage. Coupled with housing data, the factors may also indicate an increased likelihood to live in substandard housing that is more likely to be damaged, and it may indicate a reduced financial ability to make repairs after an event. Factors such as the lack of health insurance can indicate poorer health. Age factors such as the proportion of the population in the "65 and older" or "17 and younger" age groups may indicate larger numbers of people unable to care for themselves and less independently mobile. Communities with low proficiency in English are less likely to understand and follow preventative directions or evacuation plans. Housing and transportation factors are particularly important, in terms of evacuation. People living in apartments or group quarters such as nursing facilities or college dorms, with high population density, face increasing vulnerability when evacuation is needed due to overcrowding. SVI data reflecting low automobile ownership rates indicate potential problems for people who do not own a car or who live in rural areas without access to evacuation routes. While many of the SVI variables track the material consequences of historic and structural racism, particularly in the socioeconomic, housing type, and transportation categories, the inclusion of racial and ethnic "minority" status have significant implications for vulnerability. Those who identify as African American, Native American, Asian, Pacific Islander, and Hispanic add nuance to the analysis and serve as an additive factor in relation to the broad set of vulnerability factors that are also attached to racial and ethnic identity over time.

Table 4. CDC SVI variables used. CDC utilized data from the American Community Survey.

Socioeconomic Status	Below 150% Poverty
	Unemployed

[6] More information about the SVI is available on the CDC ATSDR website, where and SVI viewer, community maps, and SVI data downloads are available. *See*: https://www.atsdr.cdc.gov/placeandhealth/svi/index.html.

	Housing Cost Burden
	No High School Diploma
	No Health Insurance
Household Characteristics	Aged 65 & Older
	Aged 17 & Younger
	Civilian with a Disability
	Single-Parent Household
	English Language Proficiency
Racial & Ethnic Minority Status	Hispanic or Latino (of any race) Black or African American, Not Hispanic or Latino Asian, Not Hispanic or Latino American Indian or Alaska Native, Not Hispanic or Latino Native Hawaiian or Pacific Islander, Not Hispanic or Latino Two or More Races, Not Hispanic or Latino Other Races, Not Hispanic or Latino
Housing Type & Transportation	Multi-Unit Structures
	Mobile Homes
	Crowding
	No Vehicle
	Group Quarters

Adapted from:
https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/pdf/SVI2020Documentation_08.05.22.pdf

5.1.2 SVI and Flood Risk to the Chatham County–Savannah Regional Transportation System

To better understand how social vulnerability factors impact, we compared the relative vulnerability of the region, as determined by the SVI, to the rest of the state (Figure 32). Effingham County, northwest of Savannah, and Bryan County, to the west, are classified as having a relatively low social vulnerability, meaning that the populations in those counties are more likely to be able to withstand and recover from a disaster or other external shock with fewer long-term negative consequences than people residing in other areas. However, Savannah and Chatham County are shown to have a medium-high vulnerability, which means that in addition to being more likely to experience a natural disaster, particularly from flooding, residents there are less able to withstand and recover from the shock effectively. To the extent data at this scale can inform investment decisions, it does highlight that risks and resilience are distributed in different jurisdictions. While this does not directly inform any particular decision, this is an important fact to recognize in allocating resources to minimize the future negative impacts of flooding and bolstering the resilience of the transportation network.

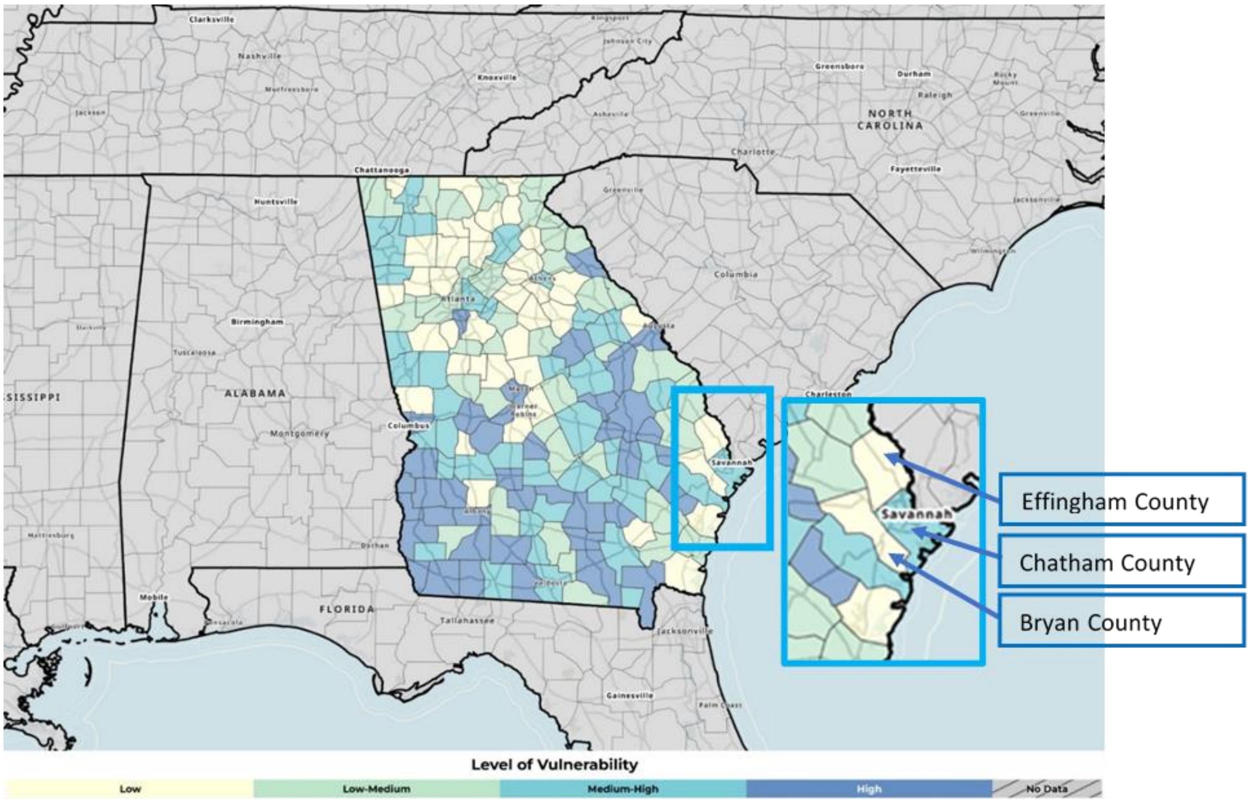

Figure 32. Relative state-level SVI for each Georgia County.

At a more local scale, transportation in the Chatham County–Savannah region is managed by a network of local governments that include the county government and eight cities, along with federal and state departments of transportation. Much of the planning for this transportation network is centralized in the regional Coastal Regional Metropolitan Planning Organization (CORE MPO), which provides a forum for local decision-making regarding the use of federal transportation funds in the region. The boundaries of the CORE MPO also include portions of Effingham and Bryan Counties as they are part of Savannah's census determined "urbanized area". The CORE MPO Board sets regional, long-term transportation policy; prioritizes projects; and approves the long-range plan, short-range TIP, and other required documents. Therefore, much of the discussion for long-term resilience planning is based around the MPO boundary.

To examine the relevance of the relative social vulnerability across the CORE MPO area, we examined the SVI statistics for the census tracts across the counties that comprise the MPO boundary (Figure 33) and show their relation to roadway vulnerabilities (Figure 34). The main SVI drivers in these areas relate to the socioeconomic status, housing type, and transportation categories, where most of the high and intermediate SVI areas subsist under the poverty line, suffer from high unemployment, live in crowded areas, and lack access to a vehicle. In Chatham County, high SVI is also driven by a significant number of residents in group quarters such as hospitals and schools and by a high percentage of residents who are racial or ethnic “minorities” and have low English proficiency.

From a public policy standpoint, it is important to recognize the implications of the fact that this map and the underlying SVI data result from a myriad of public policy and private individual decisions made over years, decades, and sometimes even centuries. The variables that inform SVI are influenced by public policies and private choices going back decades or even centuries. In planning for future resilience, particularly in directing investments, there may be opportunities to ameliorate some of the disproportionate impacts based on social, demographic, and economic factors. Conversely, it is also possible that infrastructure investments and other resilience decisions can reinforce many of the factors that drive the disproportionate vulnerabilities and deepen them – thus, considering community features like those highlighted in the SVI is critical to advance resilience effectively, ensure infrastructure funds are effectively and efficiently spent, and build strong communities in the face of growing threats.

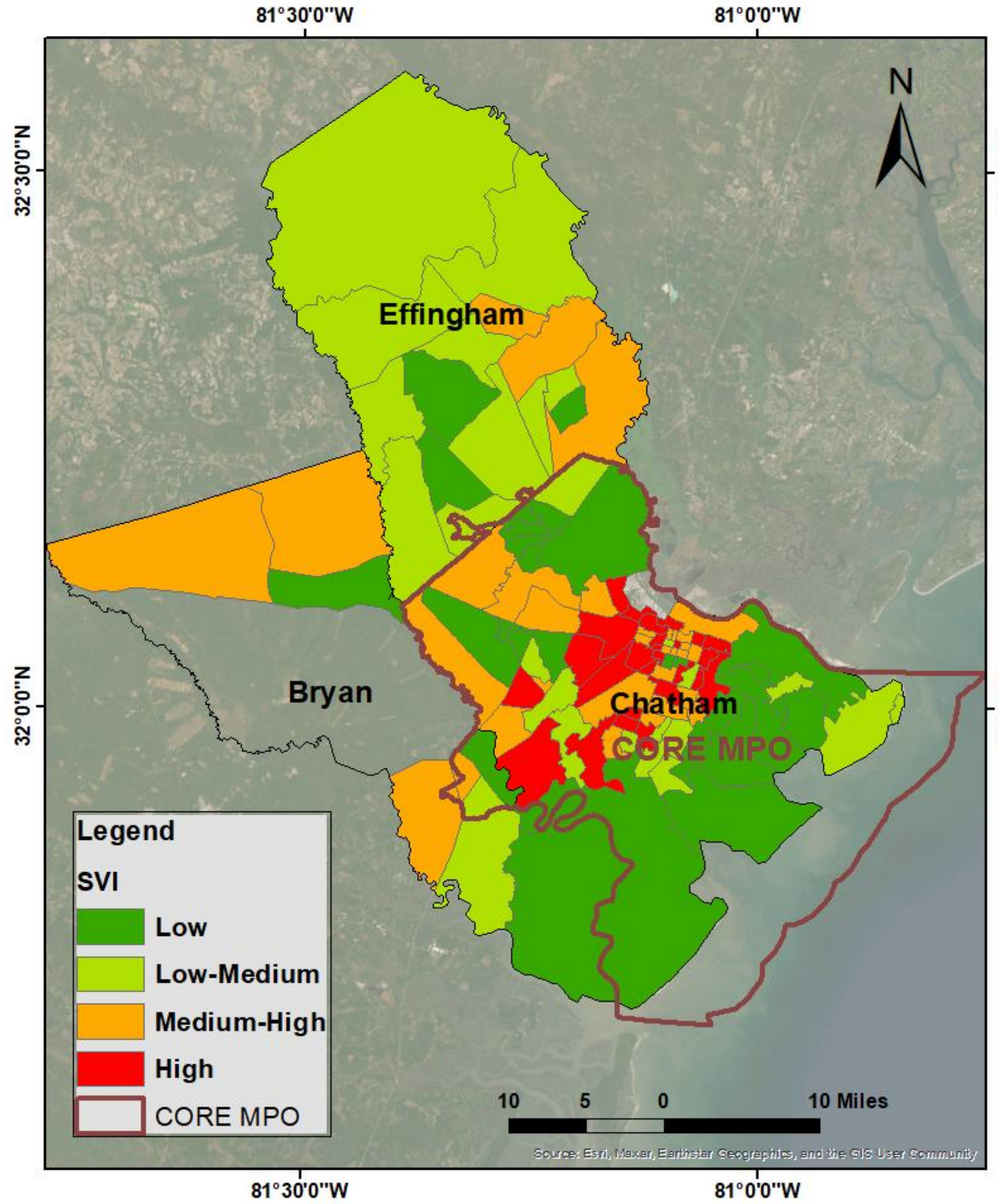

Figure 33. Relative SVI for the CORE MPO region.

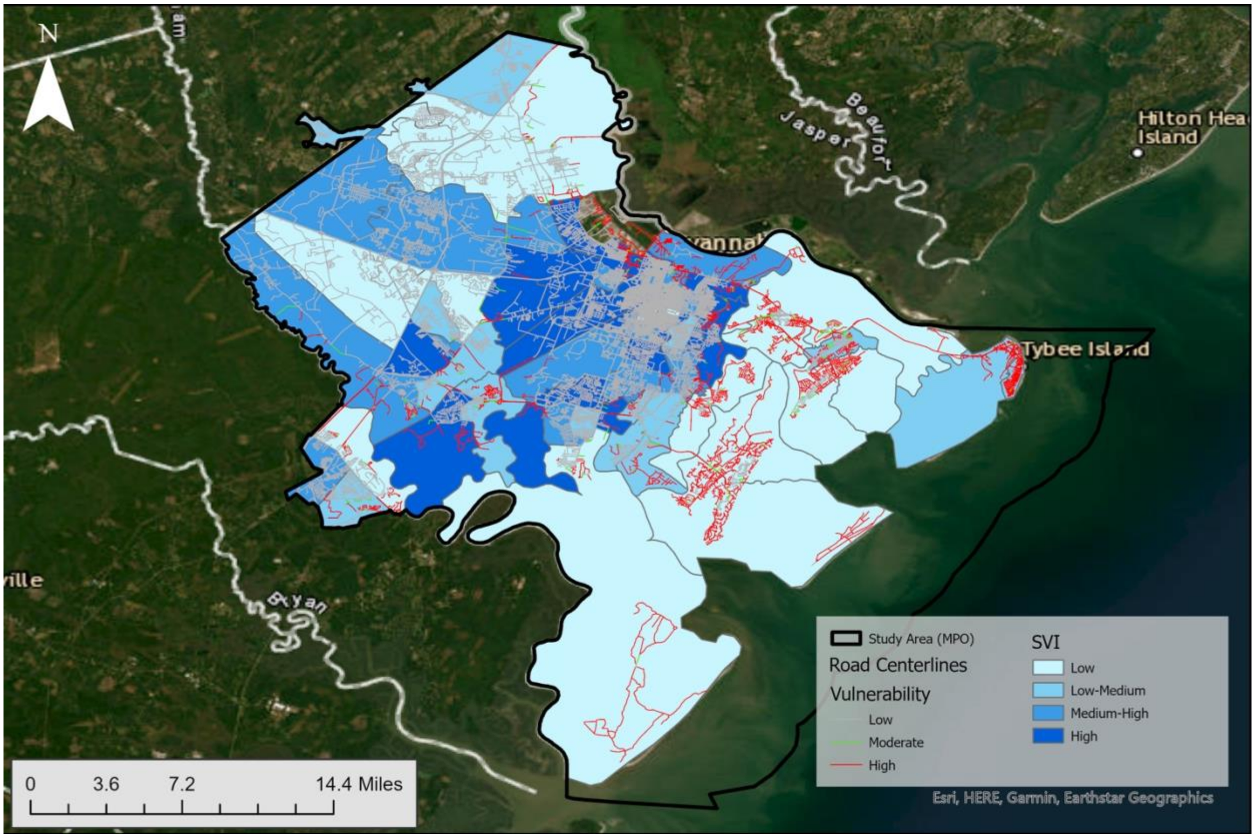

Figure 34. Relative SVI for the CORE MPO region and roadway vulnerability for the 2100 High SLR scenario.

5.2. Project Prioritization and Next Steps

The Roadway Vulnerability Assessment developed as part of this project integrates multiple data sources onto a usable platform that identifies road segments vulnerable to flooding based on present and future tidal conditions. This tool provides invaluable information to inform planning for road improvements that will reduce future disruptions from flooding. Identifying these segments can inform the direction of resources to areas that need to be prioritized for maintenance and enhancement to avoid the impacts of increased flooding. Integrating this measure of the physical vulnerability of roads with the CDC's SVI data ties it to some of the best data available on the social and demographic aspects of the populations potentially affected by flooding. By prioritizing the temporal proximity of impacts with a measure of the potential extent of community impacts, this assessment tool provides a more robust basis for decision-making and planning.

Future steps to integrate the data available through the Roadway Vulnerability Assessment should include defining specific resilience metrics the road network needs to achieve. This can be framed in terms of the number of impacted road segments or miles of impacted road, or it can be communicated in terms of system disruption. Framing the challenge of improving system resilience as a matter of levels of service would provide greater flexibility and innovation in developing plans and adaptation measures to address system threats. Identifying this type of resilience goal will allow tools such as this vulnerability assessment to be more than just informative by creating a pathway for the products it can generate to be incorporated into planning and other operational documents.

Future work to integrate network analyses, assessments of the extent of system disruptions from flooding, and expanding the breadth of data incorporated into this analysis will also expand the potential applications for building local resilience.

5.3. Financial Stewardship

As vulnerabilities to transportation systems grow over time, it will increasingly be necessary to diversify the range of resources available to maintain necessary levels of service. Fortunately, a wider range of values can be addressed by focusing on natural and nature-based infrastructure systems as part of a broader concept of resilience planning. This allows project developers to layer diverse funding mechanisms that might have yet to be considered.

The attached spreadsheet (Table 5) identifies numerous funding opportunities for the CORE MPO planning area that can support enhancements to the local transportation network, particularly through natural and nature-based infrastructure features. Recognizing the diversity of values that nature-based features can support to enhance infrastructure resilience, the list of grants has been sorted into four categories of funding: Transportation, Environmental, Department of Defense, and State and Local Funding. While many grants have some overlap between multiple of the three categories, organizing the grants into the three categories helps identify the “main” purpose of the grant versus the residual benefits that projects funded by the grant will likely bring. Each spreadsheet entry identifies the name of the grant, the purpose, the agency responsible for the grant, the eligibility requirements, and timelines (as available) for each grant.

5.3.1 Transportation

Grants identified as transportation grants primarily serve to repair, maintain, and/or construct transportation projects to reduce or mitigate the negative impacts of climate change on transportation infrastructure within proposed areas. Projects under this category focus on roads, bridges, culverts, weirs, and other transportation-related infrastructure. Additionally, many grants allow or encourage incorporating natural and nature-based features. Grants cover modeling, design, planning, and implementation of the projects.

5.3.2 Environmental

Grants identified under the Environment category primarily serve to protect, preserve, or restore natural systems or geographies (wetlands, forests, riparian and coastal habitats) or protect terrestrial or aquatic wildlife. Many of these grants will have secondary benefits to communities and infrastructure in the proposed region. Still, the purpose of the grant focuses on preventing damage to ecosystems from the effects of climate change. Projects under this category include climate change strategy development; enhancement, restoration, and habitat protection; and other projects focusing on preserving wildlife or the natural ecosystem affected by climate change.

5.3.3 Department of Defense

While more limited, the Department of Defense grants support to communities and community infrastructure adjacent to military installations. These grants serve a dual purpose of supporting quality of life defense communities off installation while enhancing military value to the area and installation resilience. These grants include opportunities for communities to partner with local installations to support organizing, planning, and implementing projects to support the sustainability of installations.

5.3.4 State and Local Funding

Local governments in Georgia are empowered to enact special purpose sales taxes, known as Special Purpose Local Option Sales Tax (SPLOST) and Transportation-SPLOST, which are common means of raising funds to support projects in this area. Additionally, funds are available yearly through the Georgia Outdoor Stewardship program to support state lands, wildlife management, and to protect conservation lands.

Table 5. CORE MPO funding opportunities.

Grant/ Program Name	Categories of Funding	Agency	State/ Federal	Purpose	Eligibility	Deadline	Additional Comments	Grant No./Link
Defense Community Infrastructure Program	DoD	Readiness and Environmental Protection Initiative (REPI)/ Office of Local Defense Community Cooperation (OLDCC)	Federal	The Defense Community Infrastructure Program (DCIP) addresses deficiencies in community infrastructure, supportive of a military installation, to enhance military value, installation resilience, and military family quality of life.	State and local governments. Projects owned by not-for-profit, member-owned utility services are eligible, and these utilities may partner with a state or local government as a subrecipient.	Closed this year, will open for 2024 in March-April		https://oldcc.gov/defense-community-infrastructure-program-dcip
Installation Resilience Program	DoD	REPI - OLDCC	Federal	The OLDCC's Installation Resilience program presents states and communities with the opportunity to partner with their local installations and the Military Services to support the organizing, planning, and implementation actions necessary to foster, protect, and enhance the sustainability of installations. It merges previous installation resilience and compatible use (formerly a Joint Land Use Study) elements into one broader program continuum.	States, counties, municipalities, other political subdivisions of a state; special purpose units of a state or local government; other instrumentalities of a state or local government;	Each year (typically in Spring); closed this year. Recommendations typically come from Installation Commanders		https://oldcc.gov/our-programs/installation-resilience

Continuing Authorities Program	DoD	US Army Corps of Engineers	Federal	CAP is a group of nine legislative authorities under which the USACE can plan, design, and implement certain types of water resources projects without congressional authorization. Can do projects for: emergency streambank and shoreline protection; beach erosision and hurricane and storm damage reduction; regional sediment management and beneficial use of dredged material; aquatic ecosystem restoration	States, local governments, and agencies	doesnt look like this runs on a fiscal year timeline, it looks like you just apply to the CAP program if you have a project?		https://www.nae.usace.army.mil/missions/public-services/continuing-authorities-program/
Fish and Wildlife Service Coastal Program	Environmental	US Fish and Wildlife Service (USFWF)	Federal	The U.S. Fish and Wildlife Service (Service) Coastal Program is a voluntary, community-based program that provides technical and financial assistance through cooperative agreements to coastal communities, conservation partners, and landowners to restore and protect fish and wildlife habitat on public and private lands.	State and Local Governments, Public and State institutions of higher learning, nonprofits, individuals	Sep 30th, 2023		F23AS00032 - 2023 Coastal Program
Coastal Habitat Restoration and Resilience Grants for Tribes and Underserved communities	Environmental	National Oceanic and Atmospheric Administration (NOAA)	Federal	The principal objective of this funding opportunity is to support opportunities...underserved communities to meaningfully engage in coastal habitat restoration activities. NOAA anticipates up to $45 million will be available under this opportunity...Strengthening coastal resilience means preparing and adapting coastal communities to mitigate the impacts of and more quickly recover after extreme events such as hurricanes, coastal storms, flooding, and sea level rise.	underserved community, or entities that partner with tribes, tribal entities, and/or underserved communities such as institutions of higher education, non-profit organizations, commercial (for profit) organizations, U.S. territories, and state, local, and Native American and Alaska Native tribal governments.	Dec 19th, 2023		https://www.fisheries.noaa.gov/grant/coastal-habitat-restoration-and-resilience-grants-tribes-and-underserved-communities

CZM Habitat Protection and Restoration Bipartisan Infrastructure Law (BIL) Competition	Environmental	NOAA	Federal	Projects must be within the coastal zone management boundary or coastal watershed county. Eligible project types include: habitat restoration; habitat restoration planning, engineering, and design; ecosystem conservation; and program capacity support.	The Georgia Coastal Zone Management Program would be primary applicant, but funding could be passed to other partners through them.	Dec 19th, 2023		NOAA-NMFS-HCPO-2023-2008173
National Oceans and Coastal Security Fund	Environmental	NOAA	Federal	National Coastal Resilience Fund (NCRF) restores, increases and strengthens natural infrastructure to protect communities while also enhancing habitats for fish and wildlife. Emphasis on natural and nature based features.	non-profits orgs, state and territorial government agencies, local governments, municippal governments, education institutions.	Currently 2023 funding is closed, but allocted $492 million over 5 years.	Projects "in the vicinity of" a DoD installation can qualify for up to $15 million of matching funds.	https://www.noaa.gov/infrastructure-law/infrastructure-law-climate-ready-coasts/national-oceans-and-coastal-security-fund
Transformational Habitat Restoration and Coastal Resilience Grants	Environmental	NOAA	Federal	The principal objective of this solicitation is to support transformational habitat restoration projects that restore marine, estuarine, coastal, or Great Lakes ecosystems, using approaches that enhance community and ecosystem resilience to climate hazards.	higher education, non-profits, commercial (for profit) organizations, U.S. territories, and state, local, and tribal governments	Nov 17th, 2023	This my be a stretch if the focus is on infrastructure, not super clear if that would fit under this; would probably need some creative writing	
National Coastal Resilience Fund	Environmental	NFWF	Federal	The National Coastal Resilience Fund supports the implementation of nature-based solutions to enhance the resilience of coastal communities and ecosystems to these threats. We strategically invest in projects that construct or restore coastal habitats that increase the capacity of communities and habitats to withstand and recover from disruptions and adapt to changing environmental conditions. (Heavy focus on nature based solutions)	State, political subdivision of a Sate, public transit agency or authority, metropolitan planning organization			https://www.nfwf.org/programs/national-coastal-resilience-fund

Climate Resilience Regional Challenge	Environmental	NOAA	Federal	Supports grants for projects that build the resilience of coastal communities to extreme weather and impacts of climate change (sea level rise and drought) - two tracks; 1) regional collaborative building and strategy development (initiate new or advance existing partnerships and move coastal communities closer to action) 2) implementation of resilience and adaptation actions (fund projects to implement coordinated adaptation efforts)	Coastal states, counties, cities, or other political subdivisions of a coastal state or territory, institutions of higher education, non profit orgs	Closed this year, will likely also open sometime next year (application deadline for 2023 was end of august)		https://www.coast.noaa.gov/funding/ira/resilience-challenge/
North American Wetlands Conservations Grants: US Standard	Environmental	USFWF	Federal	Grants program to support furthering goals of the North American Wetlands Conservation Act; focus is on enhancement/restoration/protection of wetlands for the benefit of all weltands-associated migratory birds		Closed in July this year, expected to open early next year	grant matching requirements	https://www.fws.gov/service/north-american-wetlands-conservation-act-nawca-grants-us-standard
America the Beautiful Challenge	Environmental	NFWF	Federal	America the Beautiful Challenge funding allows applicants to implement landscape-level proposals that address conservation and public access needs. Projects create cumulative benefits for fish and wildlife, provide carbon sequestration and storage benefits, engage with and benefit underserved communities, support community access to nature, and help safeguard ecosystems through conservation and resilience-focused and nature-based solutions.	State government agencies, territories of the United States, Non-profit 501(c) organizations, local governments, municipal governments, Indian Tribes, and educational institutions.			https://www.nfwf.org/programs/america-beautiful-challenge

Building Resilient Infrastructure and Communities Program	Environmental	FEMA	Federal	BRIC program supports staes and local communities to undertake hazard mitigation projects to reduce the risks from disasters and natural hazards. Supports projects designed to increase resilience and public safety; reduce injuries and loss of life; and reduce damage and destruction to property, critical services, facilities, and infrastructure	States	Looks like they didn't do this in 2023 but in the few years before they had applicants and funding? Not sure if this is still going.		https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities
Flood Mitigation Assistance	Environmental	Federal Emergency Management Agency (FEMA)	Federal	provides fundign for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the national flood insurance program; can support community flood mitigation projects, individual flood imitgation projects, provide project scoping and technical assistance as well as flood hazard mitigation planning	state and local governments	Nothing posted for next year, but normally opens at the end of September for the next year fiscal year with apps due at the end of january.		https://www.fema.gov/grants/mitigation/floods
Hazard Mitigation Grant Program	Environmental	FEMA	Federal	provides funding to state, local, tribal, and territorial governments to support hazard mitigation planning and mitigation activities to reduce future disaster losses in their communities.	State governments (local governments apply through the states; local governments can apply on behalf of private businesses/landowners)		Requires FEMA approved hazard mitigation plan	https://www.fema.gov/grants/mitigation/hazard-mitigation
Longleaf Landscape Stewardship Fund	Environmental	NFWF	Federal	If there is a longleaf pine population that will be effected in this area, can receive grant money for "enhancing, establishing, and maintaining longleaf pine and/or bottomland hardwood forests"	state and local governments and agencies, municipal governments	Closed this year, has opened in February for that year in the past		https://www.nfwf.org/programs/forestland-stewards/longleaf-landscape-stewardship-fund
National Coastal Wetlands Conservation Grants Program	Environmental	USFWF	Federal	provides funding for the restoration, enhancement, or management of coastal wetlands ecosystems.	coastal state governments and agencies	Yearly, closed this year but should open in January for 2024 (due dates are in June)		https://www.fws.gov/coastal/coastalgrants/

Section 319 Nonpoint Source Grant Program	Environmental	Environmental Protection Agency (EPA)	Federal	Section 319 Nonpoint source Grant Program provides funding for implementing activities that restore impaired waters or protect unimpaired and high quality waters.	States, territories, tribes			https://www.epa.gov/nps/contacts-nonpoint-source-nps-pollution-programs
Watershed and Flood Prevention Operations Program	Environmental	US Department of Agriculture (USDA)	Federal	Program offers financial and technical assistance for watershed protection, water quality improvements, erosion and sediment control, and habitat enhancement	County agencies, soil and water conservation districts, flood prevention and flood control districts, or other subunits of state geovernments with authority and capcity to carry out, operate, and maintain installed works of improvement	continuous application cycle		https://www.nrcs.usda.gov/programs-initiatives/watershed-and-flood-prevention-operations-wfpo-program
Environmental Justice Collaborative Problem-Solving (EJCPS)	Environmental	EPA	Federal	Program provides financial assistance to organizations working to address local environmental or public health issues in their communities. The program assists recipients in building collaborative partnerships with other stakeholders (e.g., local businesses and industry, local government, medical service providers, academia, etc.) to develop solutions to environmental or public health issue(s) at the community level.	A community-based nonprofit organization or a partnership of community-based nonprofit organizations are eligible for funding.	Applications are due annually in April		https://www.epa.gov/environmentaljustice/environmental-justice-collaborative-problem-solving-cooperative-agreement-5
Emergency Coastal Resilience Fund	Environmental	NFWF	Federal	prioritizes nature-based restoration projects that achieve dual program goals: (1) the project benefits coastal communities by reducing impact of future storms and other natural hazards to properties, community infrastructure, assets of economic importance, and health and safety assets; and (2) enhances ecological integrity and ecosystem functionality to enhance fish and wildlife habitat.	states, units of local government political subdivisions of states, special purpose district or public authoirty with transportation function, metropolitican planning orgs	periodic program that is active only with supplemental disaster appropriation, application cycles and details are subject to change.		https://www.nfwf.org/programs/emergency-coastal-resilience-fund

Wetland Reserve Easement	Environmental	USDA	Federal	Part of Agricultural Easement Program, provides financial and technical assistance to help conserve wetlands and their related benefits.	Individuals, state and local governments	apply anytime through local USDA service center		https://www.nrcs.usda.gov/programs-initiatives/wre-wetland-reserve-easements
Five Star Wetland and Urban Waters Restoration Program	Environmental	NFWF	Federal	joint collaboration between the National Fish and Wildlife Federation, EPA, and USDA and provides financial assistance to grassroots partnerships for wetland, forest, riparian and coastal habitat restoration, stormwater management, outreach and stewardship with a particular focus on water quality, watersheds and the habitats they support.	State and Local Governements, acadmeic institutions, and non-profits	due in january annually		https://www.epa.gov/wetlands/5-star-wetland-and-urban-waters-restoration-grants
Georgia Outdoor Stewardship Program	Environmental	GA Dep. Of Natural Resources	State	dispersed for the purpose of providing stewardship to state parks; state lands and wildlife management areas; to support local parks and trails; and to protect critical conservation lands	local governments, recreation authorities, state agencies and NGOs with conservation core mission	Pre-application closes Oct 13		https://gadnr.org/gosp
Special Purpose Local Option Sales Tax	N/A	Local Government	State	Special Purpose Local Option Sales Tax (SPLOST) - 1% sales tax that is used to fund "capital outlay projects" and authorized by County Board of commissioners and enacated through voter referendum. Capital Outlay Projects --> major, permanent, or long lived improvements or betterments...include, but not limited to, roads, streets, bridges and their improvements/imrpovement of surface-water drainage/culvert repairs/other repairs necessary for preservation and may include storm-water drainage projects. Can be used to repair roads/streets				

				damaged or destroyed by natural disaster.				
Transportation - Special Purpose Local Option Sales Tax	N/A	Local Government	State	T-SPLOST - can be an additional tax on top of the SPLOST, up to 1% additional for the purpose of supporting transporation projects (roads, bridges, etc) and can be used for improvement/repair				
Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Grants	Transportation	US Department of Transportation (USDOT)	Federal	Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Grants are for surface transporatation infrastructure projects that will improve: safety; environmental sustainability; quality of life; mobility and community connectivity; economic competitivenes and opportunity including tourism; state of good repair; partnership and collaboration; and innovaction.	States and the District of Columbia; any territory or possession of the United States; a unit of local government; a public agency or publicly chartered authority established by one or more States; a special purpose district or public authority with a transportation function, including a port authority	FY 2023 applications are done, but Raise Grant funds will be dispersed yearly until 2027		https://www.transportation.gov/sites/dot.gov/files/2023-02/RAISE%202023%20NOFO%20Amendment2.pdf

SMART Grants - Justice40	Transportation	USDOT	Federal	Strengthening Mobility and Revolutionizing Transporation (SMART) -> awarded to conduct demonstration projects focused on advanced smart city or community technologies and systems to improve transportation efficiency and safety. SMART Equity and Justice40 Initiative -> "The Department seeks to award projects...that will create proportional impacts to all populations in a project area, remove trnsportation-related disparities to all populations in a project area.."	State, political subdivision of a Sate, public transit agency or authority, metropolitan planning organization	Sep 29th, 2023		
Promoting Resliient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Discretionary Grants Program	Transportation	National Wildlife Federation (NWF)	Federal	PROTECT Discretionary Grants Program funds projects on a competitive basis that address the climate crisis by improving the resilience of the surface transportation system, including highways, public transportation, ports, and intercity passenger rail. Nature-based solutions, such as protective wetland buffers and culverts, are eligible for this program. The Program also seeks to award projects that will increase equitable access to project benefits.	State and local governments, metropolitan planning organizations, special purpose districts or public authorities with a transportaiton function			https://www.fhwa.dot.gov/bipartisan-infrastructure-law/promote.cfm
Promoting Resliient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Program	Transportation	NWF	Federal	Same purpose as the PROTECT Discretionary Grants program (under PROTECT umbrella). The PROTECT Formula Program is designed for State agencies to help communities and first responders prepare for natural disasters and extreme weather intensified by climate change. Nature-based solutions, such as protective wetland buffers and culverts, are eligible for this program.	States and State Agencies			https://www.fhwa.dot.gov/bipartisan-infrastructure-law/protect_fact_sheet.cfm

National Culvert Removal, Replacement & Restoration Grants	Transportation	USDOT	Federal	An annual competitive grant program that awards funding for projects to replace, remove, and repair culverts or weirs in a way that meaningfully improves or restores fish passage for anadromous fish (fish born in freshwater who spend most of their lives in saltwater and return to freshwater to spawn, such as salmon) and increases culvert and weir resilience to increased flooding events due to the impacts of climate change on weather and precipitation.	States and Municipalities	Apps due annually in February		https://www.fhwa.dot.gov/engineering/hydraulics/culverthyd/aquatic/culvertaop.cfm
Neighborhood Access and Equity Program	Transportation	USDOT	Federal	Provides grants to help reconnect neighborhood divided by infrastructure through localy tailored projects and additionally aims to mitigate or remediate negative impacts on human and natural environment.	states, units of local government political subdivisions of states, special purpose district or public authoirty with transportation function, metropolitican planning orgs	Apps due annually at the end of September, NOFO published around July		https://www.transportation.gov/grants/rcnprogram
Surface Transportation Block Grant Program (STBG)	Transportation	USDOT	Federal	provides flexible funding that may be used by states and localities to best address their transportation needs. Natural infrastructure projects are an eligible use of funds. States may transfer 50% of their technical assistance funds from their STBG funds to provide technical assistance for PROTECT grants.	States and Local Governments	applications are due in either the 1st or 2nd quarter of each fiscal year, determined by State		https://www.fhwa.dot.gov/specialfunding/stp/

Reconnecting Communtiies Pilot Program (RCP Program)	Transportation	USDOT	Federal	planning and construction grants are available under the RCP program to address infrastructure barriers, reconnect communities, and improve quality of life. Eligible projects can include high-quality public transportation and infrastructure removal. Natural infrastructure, like linear parks and trails, roadway redesigns, complete street conversions, and main street revitalization, also qualify for funding.	States and local governments, Metropolitan planning orgs, non-profit orgs	due in October annually		https://www.transportation.gov/grants/rcnprogram
Water Infrastructure Finance and Innovation Act (WIFIA)	Transportation	EPA	Federal	designed to fast-track water, wastewater, and stormwater infrastructure funding by providing long-term, low-cost, supplemental credit assistance in the form of direct loans or loan guarantees.	Local, state, tribal, and federal government entities are all eligible recipients, including partnerships and joint ventures	submit letter of interest to EPA, considered on rolling basis		https://www.epa.gov/wifia/what-wifia

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