FLOOD VULNERABILITY ASSESSMENT:

The Flood Vulnerability chapter of the Resilience Plan offers a preliminary assessment of the current and future flood vulnerability of a variety of sectors in South Carolina.

DRAFT

Flood Vulnerability

Contents

Statement of Purpose

This draft chapter offers a preliminary assessment of the current and future flood vulnerability of a variety of sectors in South Carolina. The assessment is required by the South Carolina Disaster Relief and Resilience Act (DRRA), SC Code §48-62-10, et. Seq. The draft will be available for statewide review and the final version will be included in the full Strategic Statewide Resilience and Risk Reduction Plan.

Background

SC Office of Resilience

The South Carolina Office of Resilience (SCOR) exists to increase resilience to disasters and reduce or eliminate the long-term risk of loss of life, damage to and loss of property, and suffering and hardship, by lessening the impact future disasters. The Disaster Recovery Office, established by Executive Order 2016-13, was transferred and incorporated into SCOR by the Disaster Relief and Resilience Act (DRRA) (2020). The Office is led by Chief Resilience Officer Ben Duncan, who was appointed by Governor Henry McMaster in March 2021, and confirmed by the Senate in April 2021.

Strategic Statewide Resilience and Risk Reduction Plan

The DRRA directs SCOR to develop, implement and maintain the Strategic Statewide Resilience and Risk Reduction Plan (SSRRRP, Resilience Plan) and to coordinate statewide resilience and disaster recovery efforts including coordination with federal, state, and local governmental agencies, stakeholders, and nongovernmental entities. The Resilience Plan is intended to serve as a framework to guide state investment in flood mitigation projects and the adoption of programs and policies to protect the people and property of South Carolina from the damage and destruction of extreme weather events (SC Code §48-62-30).

Statewide Resilience Plan Advisory Committee

To aid in the development of the Resilience Plan and to coordinate efforts on a statewide level, the legislation created the Statewide Resilience Plan Advisory Committee, made up of state agencies, and directed SCOR to add members to the committee as deemed necessary and proper (SC Code §48-62-40). The following organizations participated in the Advisory Committee:

Table 1: Advisory Committee Members

SC Department of Natural Resources	SC Department of Insurance
SC Emergency Management Division	SC Department of Agriculture
SC Department of Health & Environmental Control	SC Department of Parks, Recreation and Tourism
SC Department of Commerce	SC Department of Transportation
South Carolina Department of Social Services	South Carolina Emergency Management Division
South Carolina Forestry Commission	South Carolina Law Enforcement Division
SC Sea Grant Consortium	South Carolina Office of Regulatory Staff, State Energy Office
SC Ports Authority	SC State Housing Finance and Development Authority
Center of Resilience Excellence SC (CORE SC)	City of Charleston Office of Resilience and Sustainability
The Pew Charitable Trusts	South Carolina Association of Counties
South Carolina Department of Labor, Licensing and Regulation	Municipal Association of South Carolina
US Army Corps of Engineers, Charleston District	University of South Carolina (HVRI)

Defining Resilience

Working with this committee, SCOR has adopted the following definition of resilience, guiding our work on the plan:

Resilience is the ability of communities, economies, and ecosystems within South Carolina to anticipate, absorb, recover and thrive when presented with environmental change and natural hazards.

Data, Development & Organization of this Chapter

In reference to the above definition, this chapter furthers the ability of organizations across the state to anticipate, by identifying current and future vulnerabilities. The data identification, collection and coordination of this chapter was done through subcommittees of the Statewide Resilience Plan Advisory Committee, focusing on the following sectors: environmental, economic, infrastructure, community services, cultural resources, and building codes and zoning.

Description of Flood Risk

Flooding has the potential to cause major damage to the communities, economies and ecosystems of South Carolina. South Carolina has 8 major watershed basins and hundreds of sub-basins, along with 2,876 statute miles of shoreline and 30,000 miles of rivers and streams (SCDNR, 2020; NOAA, 2016).

As of December 31, 2021, South Carolina ranks 5th in the nation for the number of National Flood Insurance Program (NFIP) policies in force, 202,098, a 4.1% decrease from 2020 (FEMA, 2021).

According to the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) Storm Event Database, there have been 733 reported flood events since 2000, with an estimated $201 million of property damage and 24 deaths, as seen in Table 2, (NOAA, 2021). The NCEI database property and crop damage estimates are best estimates at the time of publication of the event to the database** (NOAA, 2022). Thus, the damage estimates are not accurate based on what has been evaluated post publishment to the NCEI dataset.

Table 2: Flooding synopsis in South Carolina by type, from January 2000 to September 2021 (NOAA, 2021).
**Storm surge may be underrepresented because it is occurring in conjunction with other types of flooding.*

Event Type	Deaths	Injuries	Property Damage ($)**	Crop Damage ($)**	Event type Count
Coastal Flood	-	-	450,000	-	56
Flash Flood	22	39	163,908,390	24,879,720	470
Flood	2	1	37,430,500	5,009,600	195
Storm Surge/Tide*	-	-	-	-	12
Total	**24**	**40**	**201,788,890**	**29,889,320**	**733**

Physiography and River Basins

The United States Geological Survey (USGS) and South Carolina Department of Natural Resources (DNR) have mandates to study and describe the geologic, geomorphic, and hydrologic setting of South Carolina. Both have extensive descriptions of the hydrology and geology in the state that can be readily retrieved from the appropriate sources.

The state has three major geological provinces, the Blue Ridge, Piedmont, and Coastal Plain (Figure 1). The Blue Ridge is a small province in the western portion of the state that is identified by elevations ranging from 1,000 to 3,300 feet and high slope. The Piedmont is in the central western portion of the state that is 450 to 1,000 feet above sea level and is undulating terrains, albeit lower relief than the Blue Ridge and will have less energetic riverine flow. The Fall Line is the transitional boundary for the Coastal Plain, eastern portion of the state. The Coastal Plain is described by low slope, topographic relief between 0 to 450 feet above sea level.

South Carolina has 8 major rivers and their numerous large tributaries within the state, contain 30,000 miles of waterways that drain 20-million acres of land into the Atlantic Ocean. The major rivers and large tributaries are organized into eight major river basins: Broad, Catawba, Edisto, Pee Dee, Salkehatchie, Saluda, Santee, and Savannah (Figure 2). It should be noted that the hydrologic footprint extends beyond state boundaries, and includes those basins shared with neighboring states. Only three of the basins' drainage is exclusively in South Carolina, the other five drain areas within Georgia and North Carolina.

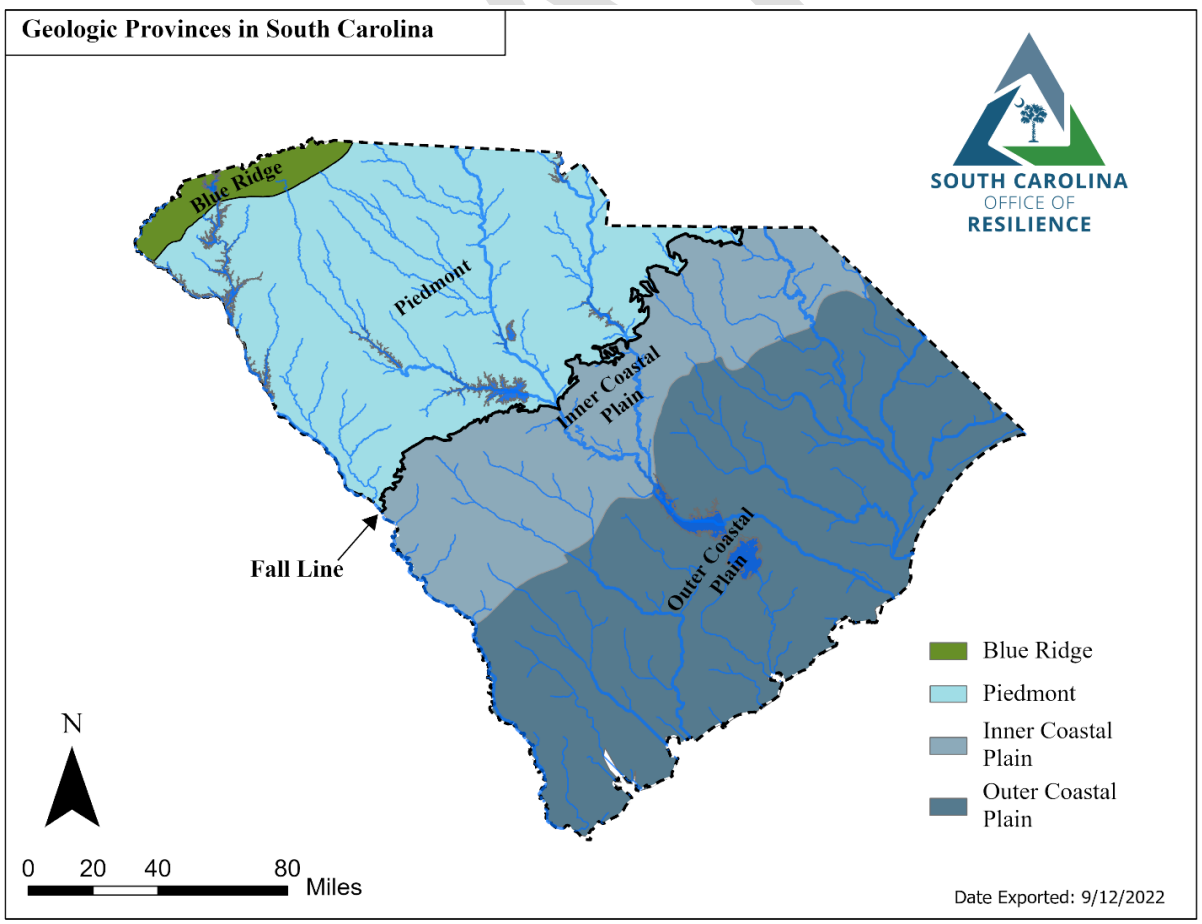


Figure 1: Physiographic Provinces of South Carolina (DNR)

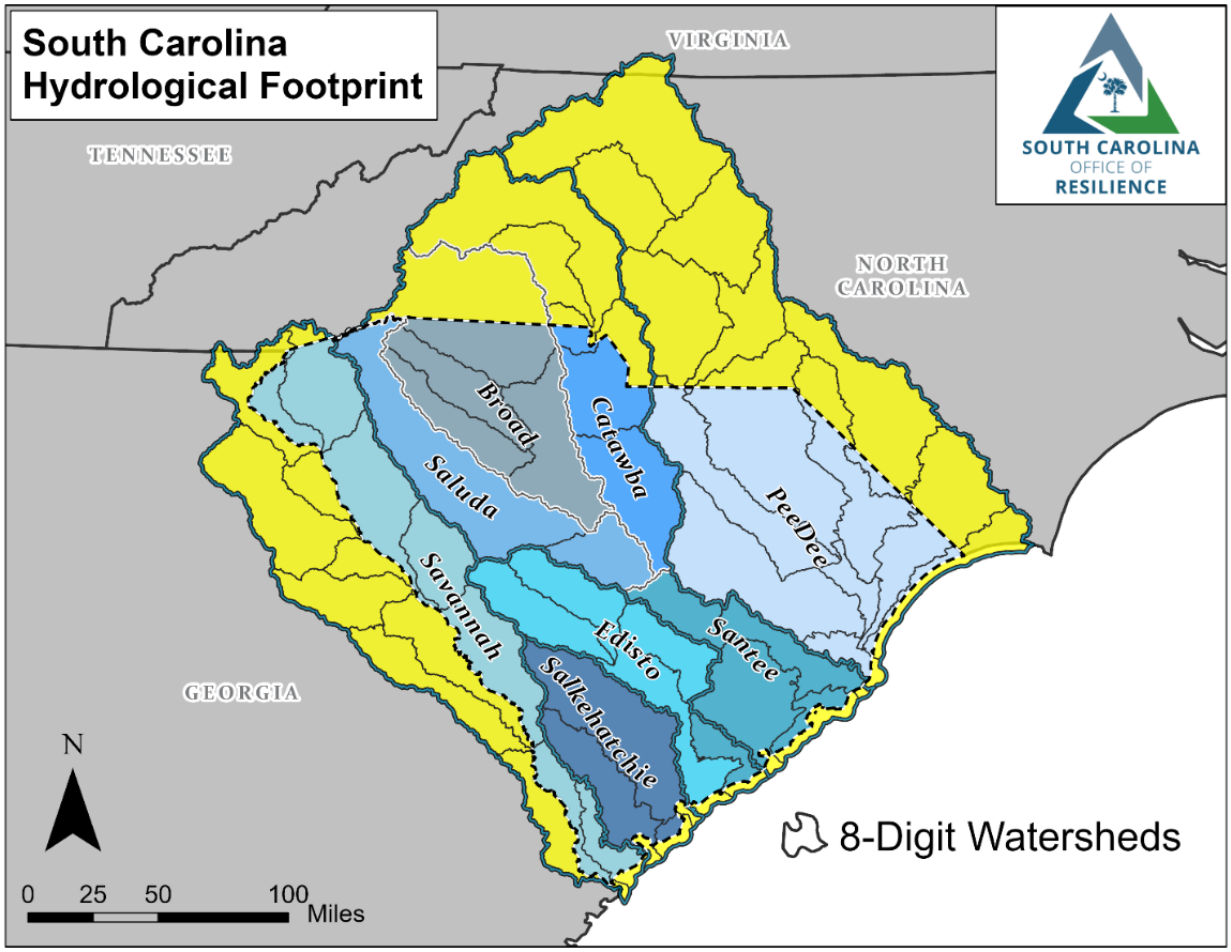


Figure 2: SCDHEC extended eight river basins of South Carolina, HUC 8 Basins

River Basins

Drainage basins are the geographical extent of land where the water will flow and drain into the rivers and tributaries. Basins and watersheds are identified by hydrologic unit codes (HUC), starting with a 2-digit code that designates region down to a subwatershed 12-digit HUC. At the HUC6 Basin designation, there are 4 basins in South Carolina. However, the South Carolina Department of Health and Environmental Control (DHEC) identifies 8 river basins, by splitting the Santee Basin that drains the central part of the state into 4 separate subbasins (Figure 2). South Carolina has 38 HUC8 subbasins, that are similar in scope as a county, and can make planning on a basin scale easier. The eight DHEC basins are described by DNR (DNR, 2013) and are summarized below and in Table 3.

Table 3: Basin Extents as described in (DNR, 2013)

Basin	Area (Square Miles)	Area in SC (Square Miles)	Percentage of Basin in SC	Percentage of SC Covered by Basin
Broad	5,308	3,794	71.5%	12.0%
Catawba	5,612	2,323	41.4%	7.3%
Edisto	3,607	3,607	100.0%	11.4%
Pee Dee	18,868	7,854	41.6%	24.8%
Salkehatchie	3,006	3,006	100.0%	9.5%
Saluda	3,213	3,212	100.0%	10.1%
Santee	2,950	2,950	100.0%	9.3%
Savannah	10,972	4,955	45.2%	15.6%

Edisto River Basin

The Edisto River basin is in south central South Carolina, including portions of Aiken, Bamberg, Barnwell, Berkeley, Calhoun, Charleston, Dorchester, Edgefield, Lexington, and Saluda Counties, and most of Colleton and Orangeburg Counties. The Edisto River basin is approximately 3,607 square miles and is wholly in South Carolina, covering about 11.4 percent of South Carolina (Table 3).

The Edisto River basin contains four major tributary streams: South Fork Edisto River, North Fork Edisto River, Edisto River, and Four Hole Swamp (DNR, 2013). The Edisto River basin reaches inland into the Coastal Plain region via the North Fork and South Fork. Four Hole Swamp is a blackwater river in the coastal zone and is a braided river system where the main channel is poorly defined. The low-lying nature of the Edisto River basin means that much of the basin is swamplands and becomes tidally influenced near the coast. The North Fork and South Fork of the Edisto River is primarily fed by groundwater discharge in the upper Coastal Plain region. This allows for consistent flows in drought times, as seen in 2011-2013.

Pee Dee River Basin

The Pee Dee River basin extends from a small section of Virginia, through North Carolina, enters South Carolina in the Northeast section of the state near the coastal plains and discharges into the Atlantic Ocean in Winyah Bay near Georgetown, SC and covers approximately 18,868 square miles (Table 3). In South Carolina, the Pee Dee Basin covers 7,854 square miles, or 24.8 percent of the state (Table 3), making it the largest basin in the State. The basin includes all or parts of 14 counties: Chesterfield, Clarendon, Darlington, Dillon, Florence, Georgetown, Horry, Kershaw, Lancaster, Lee, Marlboro, Marion, Sumter, and Williamsburg Counties (DNR, 2013). The Pee Dee River is the main river in the basin with major tributaries including the Little Pee Dee and Lynches Rivers. The majority of the basin (48.4 percent) is in North Carolina. In North Carolina, the Pee Dee River has six reservoirs with the last, Blewett Falls Lake, being near the South Carolina state border. In South Carolina, the Pee Dee River basin is free flowing and has four main tributaries: the Black, Little Pee Dee, Lynches, and Waccamaw Rivers.

The Black River is the southernmost river in the basin. It is a coastal river is bordered with extensive swamplands. Pocotaligo River, Scape Ore Swamp, Pudding Swamp, and Black Mingo

Creek are the tributaries that feed into the Black River and have poorly defined and meandering stream channels. The Black River outlets directly into the Winyah Bay.

The Little Pee Dee River and a major tributary, the Lumber River, have their headwaters in the Sandhills region of North Carolina. The Lumber River runs north to south and passes through Nichols, SC, which has experienced devastating flooding in the last few years and converges with the Little Pee Dee River soon after. The Little Pee Dee River flows through Dillion and Marion Counties and after the convergence with the Lumber River, flows through Horry County through Galivants Ferry and Aynor. The Little Pee Dee River converges with the Great Pee Dee at the border of Georgetown, Horry, and Marion counties.

The Lynches River system extends inland through Kershaw, Bishopville, Darlington, and Florence before converging with the Great Pee Dee River. The tributaries include the Little Lynches River, Bay Swamp, Lake Swamp, and Sparrow Swamp.

The Waccamaw River is the major coastal river in the Pee Dee River basin. The headwaters are in North Carolina at Lake Waccamaw and flows southward across Horry County, converging with the Intercoastal Waterway and Sampit River before out letting into Winyah Bay.

Salkehatchie River Basin

The Salkehatchie River basin consist of the Salkehatchie, Little Salkehatchie, Coosawhatchie, and Ashepoo Rivers. It is wholly contained within South Carolina and is approximately 3,006 square miles in area, covering about 9.5 percent of the South Carolina (Table 3). It includes parts of Aiken, Allendale, Bamberg, Barnwell, Beaufort, Colleton, Hampton, and Jasper Counties (DNR, 2013).

The Salkehatchie and Little Salkehatchie Rivers drain the tidally influenced Combahee River, while the Coosawhatchie River drains into the tidally influenced Broad River. The basin discharges into a tidal saltwater river that also receives drainage from surrounding marshlands and estuarine waters around St. Helena Sound and Port Royal Sound.

Santee River Basin

As noted above, DHEC splits the Santee Basin that drains the central part of the state into 4 separate subbasins, identifying the 3 sub-basins that flow into it: The Broad, Catawba, and Saluda. They are described individually below.

Broad River Basin

The Broad River basin is 5,308 square miles, with 3,794 square miles of it in South Carolina (Table 3) (DNR, 2013). It is in the northwestern part of the state sharing a section of the NC border. The Broad River's headwaters are in North Carolina and then flows into South Carolina where three major tributaries, the Pacolet, Tyger, and Enoree Rivers, converge into the main stem. Areas within Columbia, Gaffney, Greer, Spartanburg, Union, Winnsboro, and York are included within the basin. There are three reservoirs in the basin: Lake Monticello, Parr Shoals Reservoir, and Lake William C. Bowen.

Catawba River Basin

The Catawba basin has an orientation roughly North – South and matches the course of the Catawba-Wateree River from the North Carolina border south to the confluence with the Congaree River near Columbia, SC. The basin has an area of approximately 5,612 square miles,

with 2,323 square miles or 41.4 percent in the state of South Carolina and is 7.3 percent of the State's total area (Table 3) (DNR, 2013).

The Catawba and Wateree rivers are the major hydrologic features in the basin with several smaller tributaries that feed into these two rivers. The Catawba River's headwater and a majority of the river's watershed (58.6 percent) is in North Carolina. In the upper reaches, the tributaries include: Fishing Creek, Rocky Creek, Big Wateree Creek, Sugar Creek, and Cane Creek. The Catawba River flows into the Lake Wateree in Kershaw, Fairfield, and Lancaster counties. At the outlet of Lake Wateree, the Catawba River's name changes to the Wateree River. Below Lake Wateree, tributaries along Wateree River include: Spears Creek, Colonels Creek, and Swift Creek.

Within the Catawba River Basin, there are eleven hydroelectric reservoirs, six in North Carolina and five in South Carolina. All eleven reservoirs are owned and operated by Duke Energy. Due to this, the flow of the Catawba – Wateree River's is regulated and managed through releases and holding water. The tributaries are free flowing and are not dammed.

Lower Santee

The Lower Santee River basin is one of the smaller basins in South Carolina, covering only 2,950 square miles, about 9.3 percent of South Carolina (Table 3), covering portions of Berkeley, Calhoun, Charleston, Clarendon, Dorchester, Georgetown, Orangeburg, Sumter, and Williamsburg counties (DNR, 2013). The upper portion of the basin is formed at the confluence of the Congaree and Wateree Rivers that then flow into Lake Murray and subsequently Lake Moultrie. The coastal portion of the basin drains via the Ashley and Cooper Rivers into the Charleston Harbor. This section is tidally influenced and has a complex system of marshes and tidal creeks at the Atlantic Ocean.

Saluda River Basin

The Saluda River basin is in the western-central portion of the state. It is wholly within South Carolina and covers 3,212 square miles and 10.1 percent of South Carolina (Table 3). It originates in the Blue Ridge and Piedmont portion of South Carolina and flows northwest to southeast where it terminates at the convergence of the Catawba basin and it converts into the Santee River basin. The Saluda River Basin passes through Abbeville, Aiken, Anderson, Calhoun, Edgefield, Greenville, Greenwood, Lexington, Laurens, Newberry, Pickens, Richland, and Saluda Counties (DNR, 2013).

The northwestern part of the basin flows into Lake Greenwood and then Lake Murray with the tributaries of the Bush, Little, Little Saluda, Rabon and Reedy River feeding into the Saluda River as it passes through these reservoirs. Below Lake Murray, the Saluda converges with the Broad River and shortly forms into the Congaree River in Columbia. Along with these large rivers, Cedar Creek, Congaree Creek, Gills Creek, and Toms Creek feed into the Congaree River before its outlets into Lake Marion in the Santee River basin.

Savannah River Basin

The Savannah River basin follows the Savannah River that is the western border with Georgia. The basin is 10,972 square miles, with 15.6 percent, or 4,955 square miles (Table 3), in South Carolina. It passes though Abbeville, Anderson, Beaufort, Edgefield, Greenwood, Pickens,

Saluda, Aiken, Allendale, Barnwell, Hampton, Jasper, McCormick and Oconee Counties (DNR, 2013).

The Savannah River is the main river in the basin and is fed by Chattooga River, Twelvemile Creek, Rocky River, Little River, Stevens Creek, Horse Creek, Upper Three Runs Creek, and Lower Three Runs Creek on the South Carolina side. The Savannah River has five large reservoirs for hydroelectric power and has controlled discharges throughout the basin.

Soils & Land Cover

The way the water interacts with the soils, land covering, infrastructure, topography, etc. strongly influences how water flows and infiltrates into the ground.

Soils

For flooding purposes, the hydrologic soil group is used to describe how four different soil types transmit water through the soils. Soils are classified based on the components that makes up the material, including rock sediment and organic material. Organic material is often from the vegetation that grows, roots, or falls onto the ground and then decomposes and incorporates into the ground. The sediment components are comprised of eroded lithified rock that is classified into sizes as described by Wentworth (1922). In simple terms, the larger the grain size and voids between grains, the easier water will flow between the grains of sediment.

The four hydrologic soil groups are a continuum of the hydraulic conductivity labeled A-D (Natural Resources Conservation Service, 2009). Soil Group A have a high potential to absorb water and consist of 90 percent sand and gravel and 10 percent silts and clay. Group B soils also have relatively high transmissibility of water and consist of 50-90 percent sands and gravels and the other component being silts and clays. Group C contains 20-40 percent clay and less than 50 percent sand, with silty loams, sandy clay loam, clay loams; creating a moderately high runoff potential. Lastly, Group D soils contain greater than 40 percent clay and less than 50 percent sands.

South Carolina contains all four soils within the hydrologic boundaries (Figure 3). Group B and Group D soils are the most prevalent within the state. Group B and C soils are found mostly in the Upstate above the Fall Line covering 34.6 percent and 13.9 percent of the state respectively. Group A soils cover approximately 12.8 percent and are found primarily in the Midlands in the Sand Hill region of South Carolina. Knowing how the soils behave once flooding occurs allows for better planning. Group A soils are the best soils for allowing water to infiltrate into the ground, slowing and capturing potential floodwaters from storms. These areas are also associated with groundwater recharge zones that supply water to much of the Lowcountry across the state. The Lowcountry and small areas in the Upstate are mostly Group D soils and cover 38.7 percent of the state. Hydraulically saturated soils are placed in Group D independently of their composition.

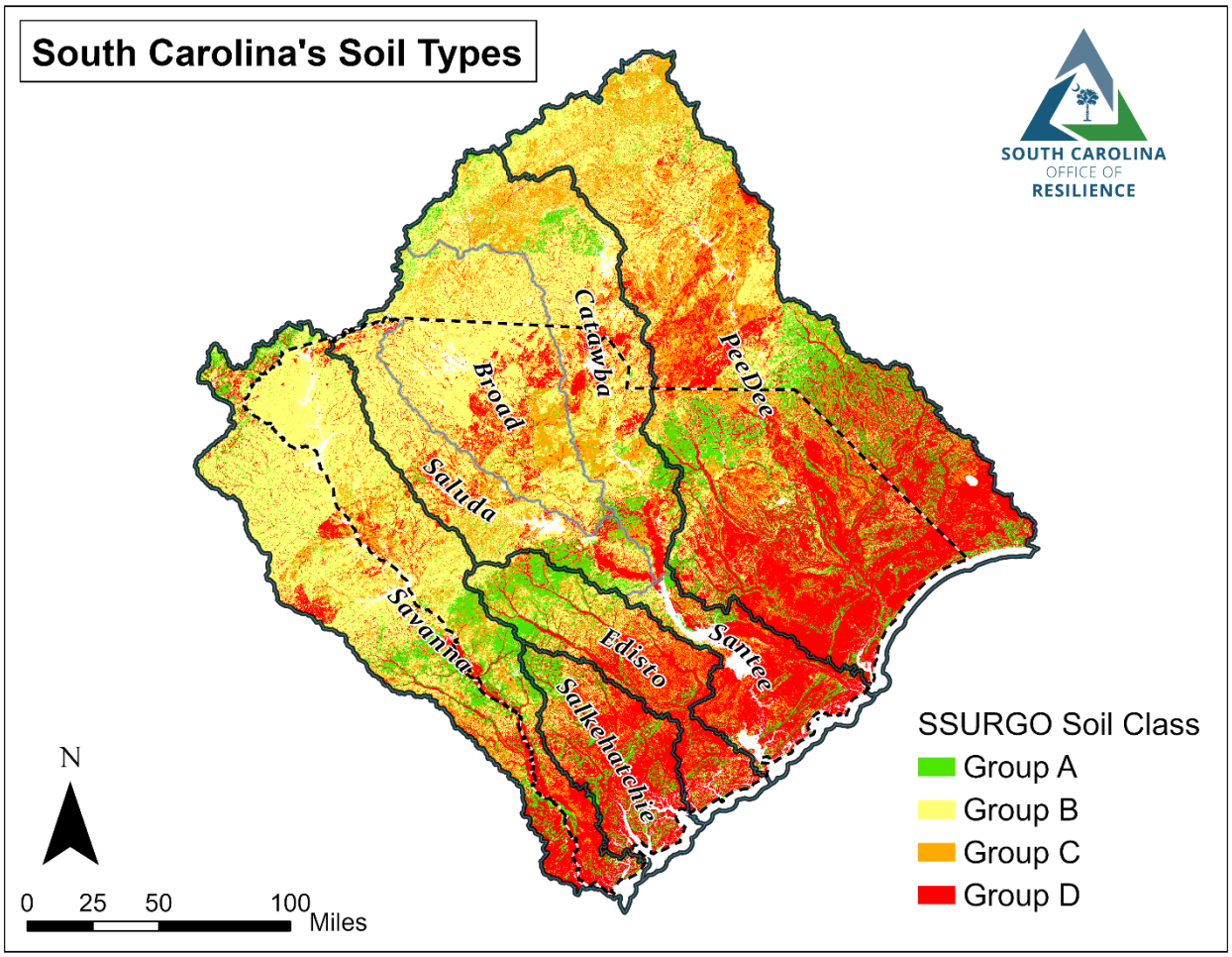


Figure 3: Hydraulic soil groups location in South Carolina.
**Group D soils include saturated soils (Group A-D, B-D, C-D) due to the inability to further drain water.*

Land Cover/Development

Along with the soils, land use also strongly influences where floodwaters flow. In natural, undeveloped areas like forest, wetlands, and grasslands, water is absorbed by the soils until saturation is reached and then overland flow of the waters occurs into waterways. Trees, shrubbery, and grasses slow the overland flows that eventually flows into the rivers, streams, and waterways. When these ecosystems are altered or changed, the capacity to store rainfall changes as well (Konrad, 2003). Urban and developed areas experience an increase in flooding as natural systems are changed into non-permeable surfaces. In South Carolina, roughly 23.2 percent of the land cover is wetlands and 46.2 percent is undeveloped forest, shrub, or grasslands, 15.4 percent is agriculture, and 11.5 percent is developed, as seen in Table 4 and Figure 4 (USGS, 2019). As urbanization continues, pluvial flooding will most likely increase, especially in areas with high topographic relief where water will flow quickly across steep surfaces with low porosity. In low lying regions of the state, Lowcountry and Pee Dee regions, where topographic relief is lower, water slows and fluvial flooding becomes more of an issue, the effects of urbanization move water into the waterways faster and removes that natural storage capabilities of the area to slow water down before it gets to the rivers.

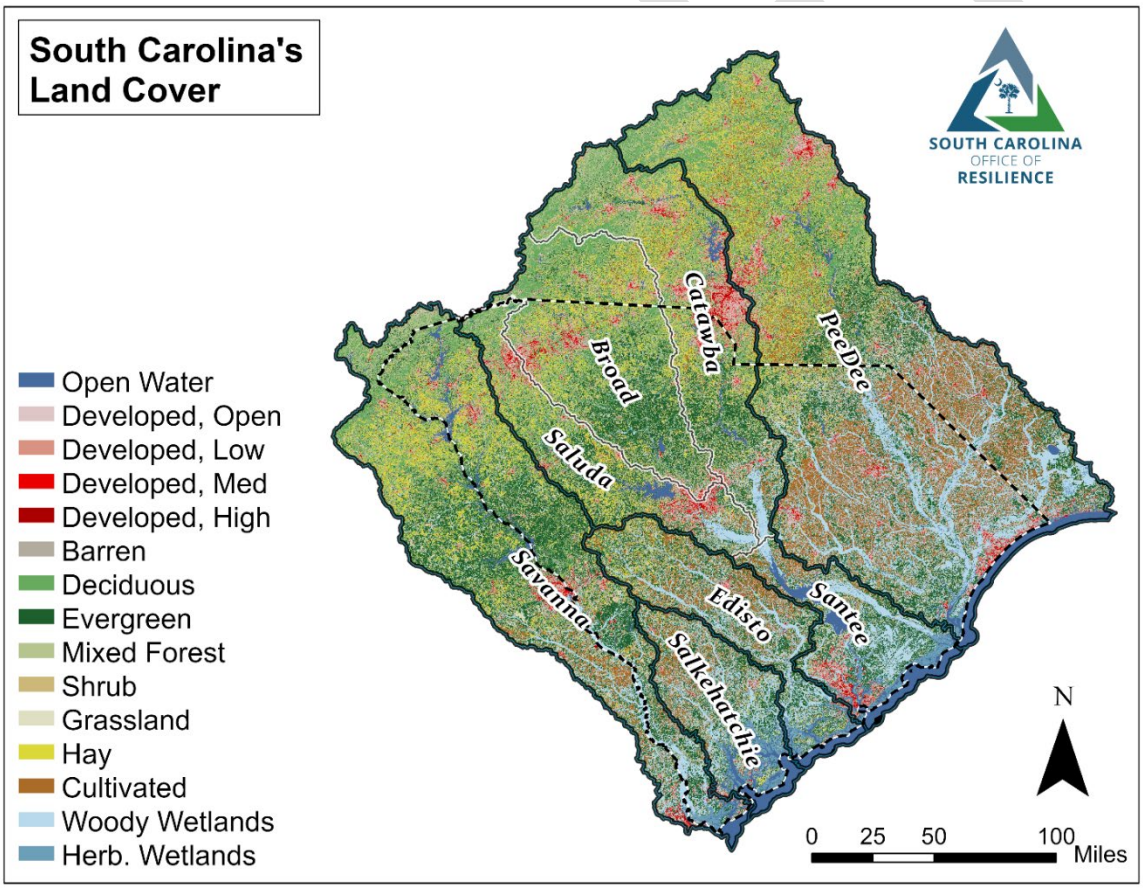


Figure 4: Land Cover in South Carolina (USGS, 2019)

Table 4: Percentage of land coverage by National Land Cover Dataset category in South Carolina (USGS, 2019)

NLCD Land Cover	Percent Area Coverage in SC (2019)
Open Water	3.5%
Developed, Open Space	6.0%
Developed, Low Intensity	3.5%
Developed, Medium Intensity	1.5%
Developed, High Intensity	0.5%
Barren Land	0.2%
Deciduous Forest	8.0%
Evergreen Forest	24.0%
Mixed Forest	5.6%
Shrub/Scrub	4.3%
Herbaceous	4.2%
Hay/Pasture	6.4%
Cultivated Crops	9.0%
Woody Wetlands	19.8%
Emergent Herbaceous Wetlands	3.4%

State Population Growth

South Carolina has experienced substantial population growth and its associated development. Between 2010 and 2020 alone, SC's population grew 10.7%, compared to a 7.4% nationwide increase, making South Carolina the 10th fastest-growing state in the nation (U.S. Census Bureau, 2021). Growth has continued during the COVID-19 pandemic. While many states saw decreases in population, SC saw a 1.4% increase in population between April 1, 2020 and July 1, 2021, the 5th highest in the nation (US Census Bureau, 2021). According to the South Carolina Revenue and Fiscal Affairs Office, this increasing trend is expected to continue, at least through 2035, when the statewide population is predicted to reach over 6.2 million people (2019) (Figure 5). The increasing population has important implications for planning for resilience.

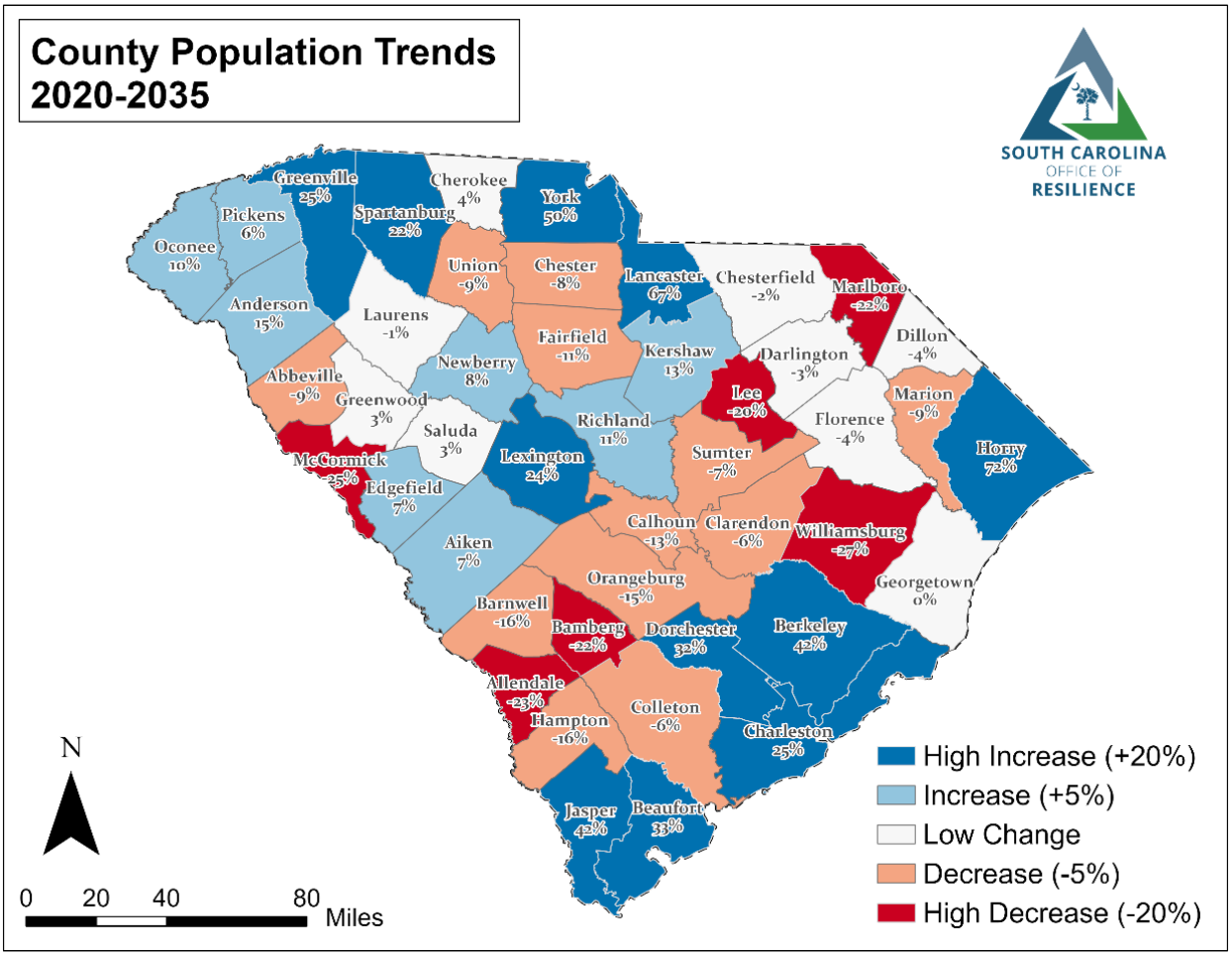


Figure 5: County Population Trend Projection 2020-2035 (SC Revenue and Fiscal Affairs Office, 2019)

Regional Population Trends

Population can also be described by comparing South Carolina's four regions: The Upstate, Midlands, Pee Dee and Lowcountry (Figure 6).

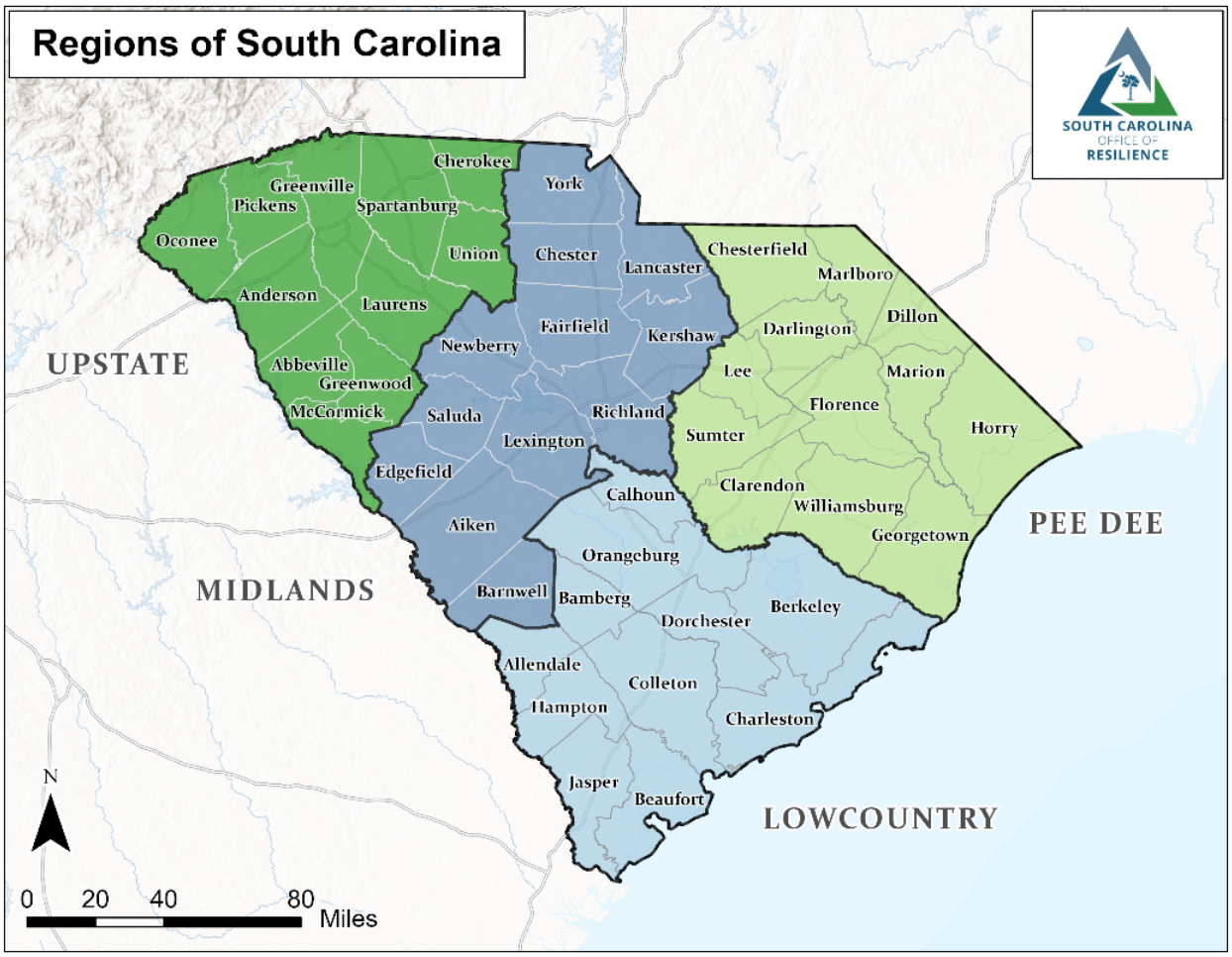


Figure 6 Four SC Regions

Upstate County Trends

The counties of the Upstate have seen rapid growth, especially since the 1990s, and are expected to see this growth accelerate in the next 15 years (Figure 7). Greenville is the region's most populous county, with Spartanburg, Anderson, and Pickens also seeing sustained growth. Meanwhile, other counties, such as McCormick, Abbeville and Union are expected to see their populations remain the same, as they have over the past few decades.

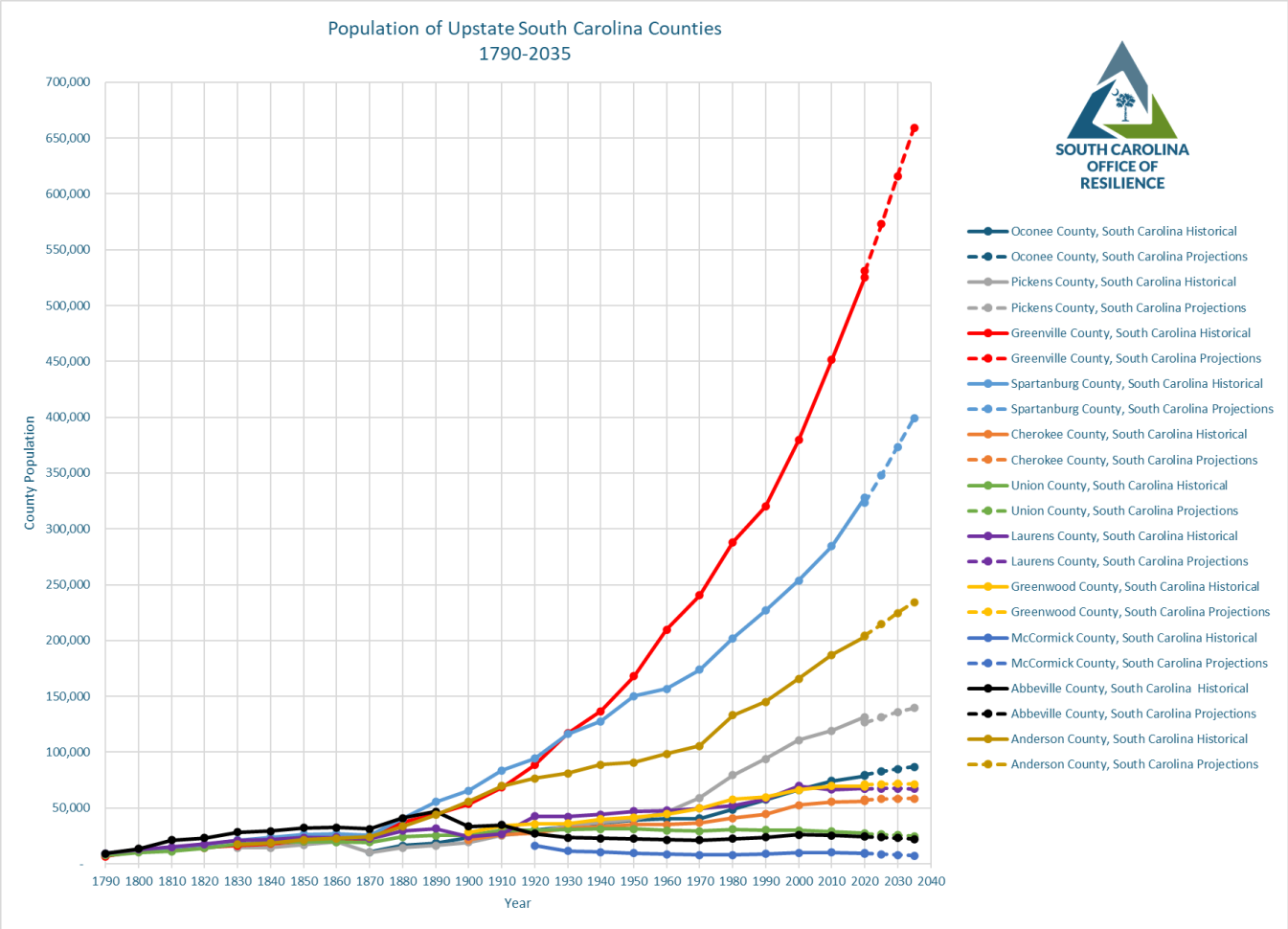


Figure 7: Upstate Population, 1790-2035 (SC Revenue and Fiscal Affairs Office, 2019; US Census Bureau, 2021)

Midlands County Trends

Population growth in the Midlands has been less linear than the Upstate, but similarly, there are several counties that stand out for their recent growth. Figure 8 show significant growth in Richland, York, Lexington and Lancaster counties. Particularly of note is that in the next 15 years, York's population is set to steeply increase, surpassing Lexington to become the region's second most populous county. Meanwhile, several other counties, such as Edgefield and Saluda, are expected to see stagnated growth.

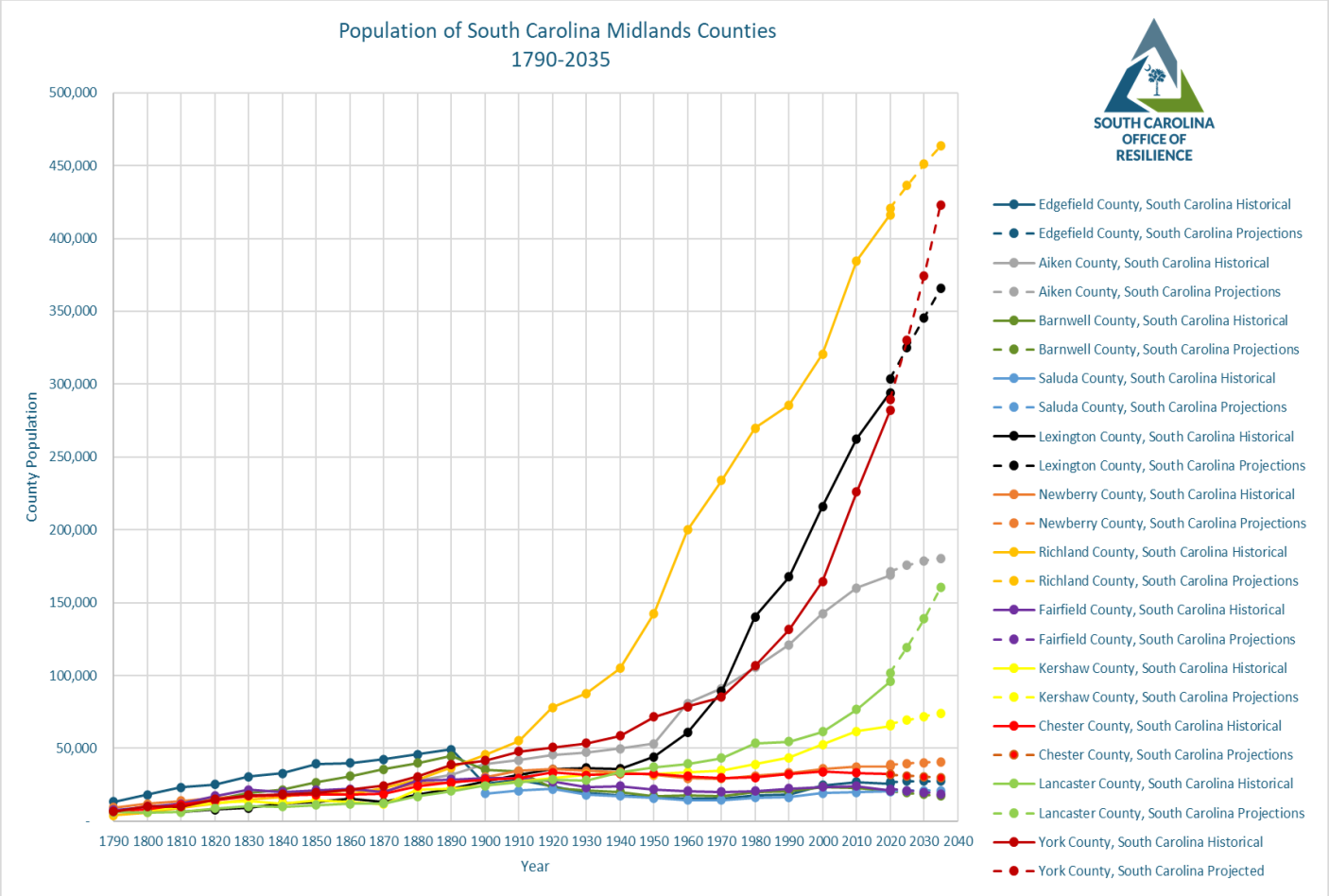


Figure 8: Midlands Population, 1790-2035 (SC Revenue and Fiscal Affairs Office, 2019; US Census Bureau, 2021)

Pee Dee County Trends

Unlike other regions, the Pee Dee only has one major population center, Horry County (Figure 9). In the 1980s, Horry surpassed Florence as the region's most populous county and has seen dramatic growth since. Particularly interesting is that Horry's County's 2020 population was much higher than even projected. Other counties in the region, such as Darlington and Sumter, are expected to see their populations begin to decrease in the coming years.

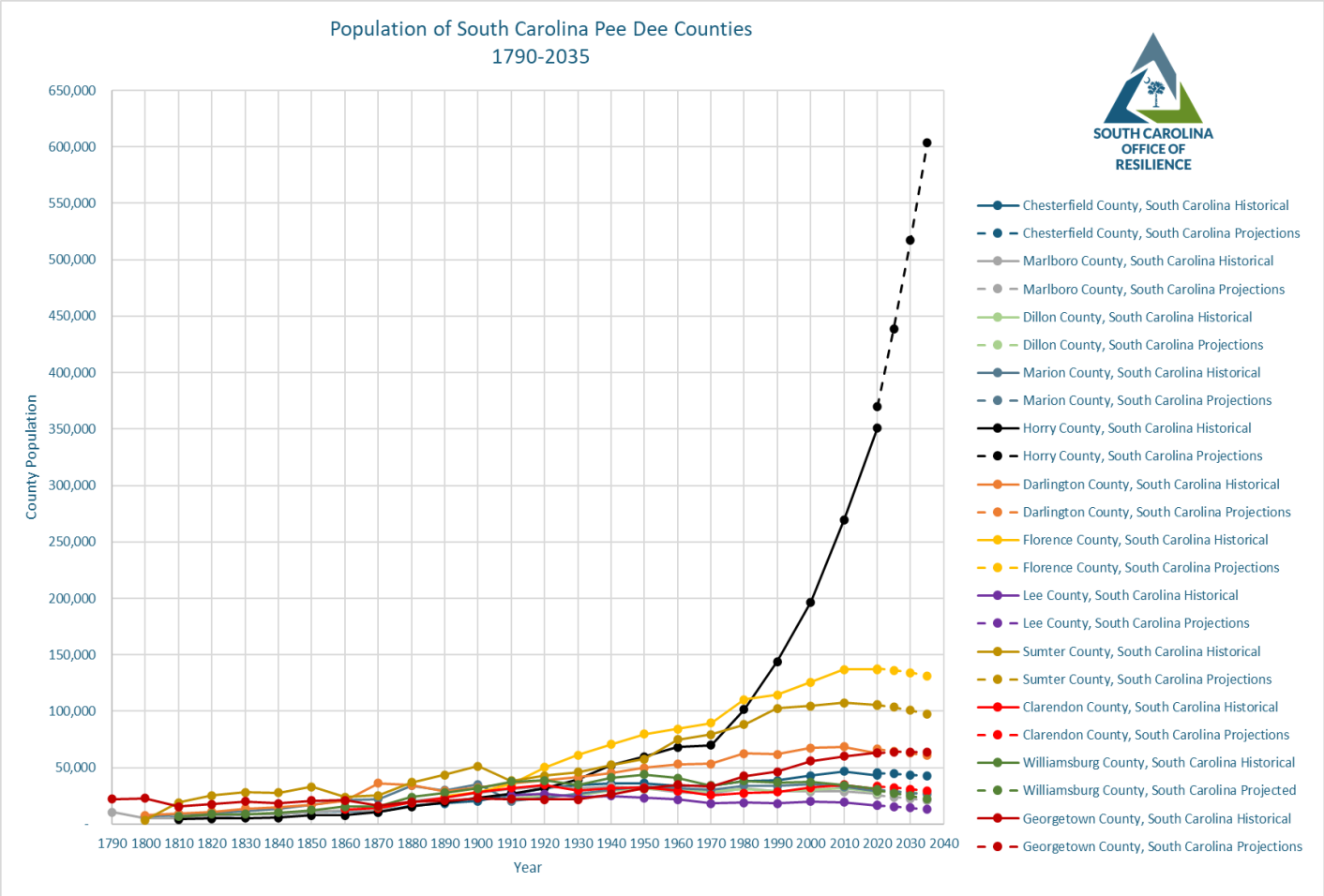


Figure 9: Pee Dee Population, 1790-2035 (SC Revenue and Fiscal Affairs Office, 2019; US Census Bureau, 2021)

Lowcountry County Trends

While Horry is the Pee Dee's major source of growth, in the Lowcountry region, Charleston County is seeing the most dramatic growth. Charleston County is expected to see its population hit half a million people by 2035 (Figure 10). However, Charleston is not alone in seeing growth; Berkley, Dorchester, and Beaufort counties are also seeing steep growth while Orangeburg County is expected to see a noticeable decrease in its population.

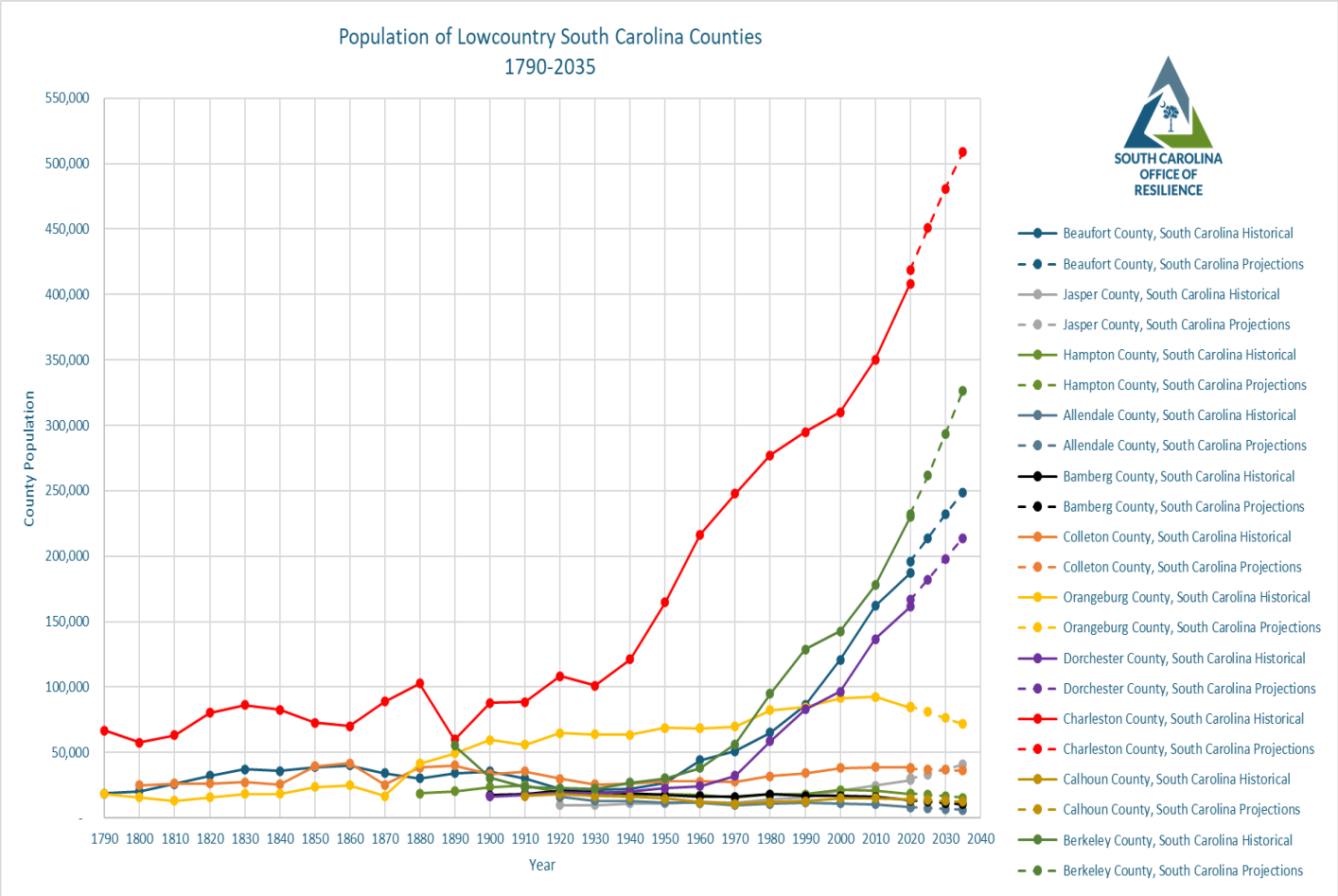


Figure 10: Lowcountry Population, 1790-2035 (SC Revenue and Fiscal Affairs Office, 2019; US Census Bureau, 2021)

Coastal Population Trends

In considering population growth's role in resilience, it is important to consider population trends in the counties historically most vulnerable to tropical storms and increased flooding due to sea level rise, those counties in the coastal zone: Beaufort, Berkeley, Charleston, Colleton, Dorchester, Georgetown, Horry & Jasper (SC Code § 48-39-10). Population growth in these counties means more people exposed to coastal flooding and tropical storms. Figure 11 below shows the share of the state's population living in these counties starting in 1790 and projected through 2035. In 1790, 43% of the state's population lived in these eight coastal counties. This is no surprise, as much of the population was still centered around the original colonial settlements such as Charleston, sustained by strong economic drivers such as the rice industry. As the cotton industry boomed in the upstate, the coastal zone's share of the statewide population decreased to just 15%. However, commercial and tourism growth along the coast has once again caused the share of the state's population living in the coastal zone to increase to nearly 30% (U.S. Census Bureau, 2021). This increasing trend is projected to continue to 32% by 2035, a level not seen since 1820 (SC Revenue and Fiscal Affairs Office, 2019). However, unlike in the 1820s, this time, 32% of the state's population will be over a million people.

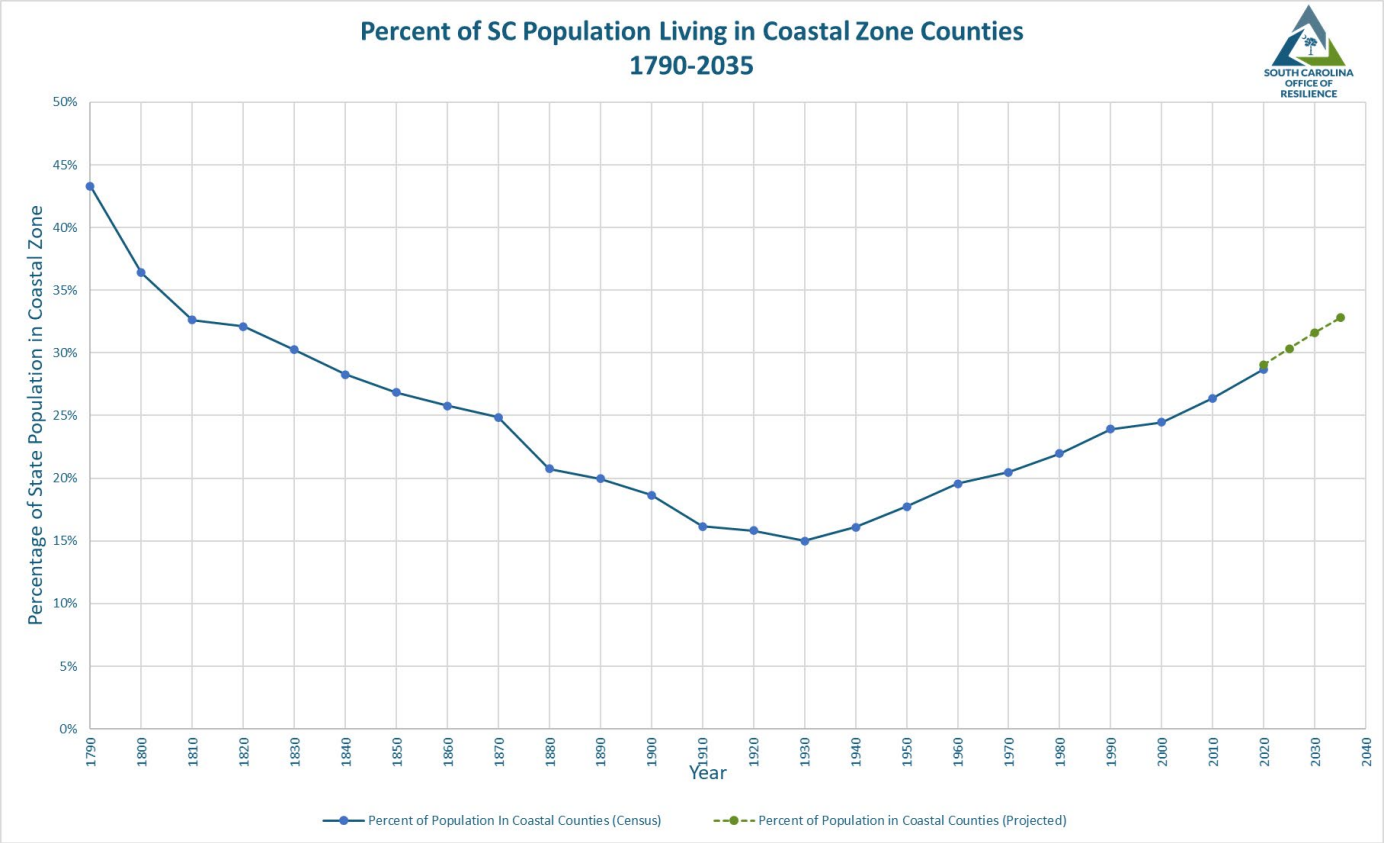


Figure 11: Percent of South Carolina Population living in the coastal zone counties 1790-2035 (SC Revenue and Fiscal Affairs Office, 2019; US Census Bureau, 2021)

Figure 12 provides a closer look at the population trend in each coastal zone county. Generally, most coastal counties have experienced continual growth since 1790, with some, such as Horry and Charleston, seeing exponential growth starting in the mid-twentieth century. In looking at the projected growth between 2020 and 2035, Horry County stands out, with expected growth from around 350,000 people to over 600,000 people, surpassing Charleston County, which has historically been the most populous county along the South Carolina coast. The only coastal county expected to see its population decrease in the next 15 years is Colleton (SC Revenue and Fiscal Affairs Office, 2019).

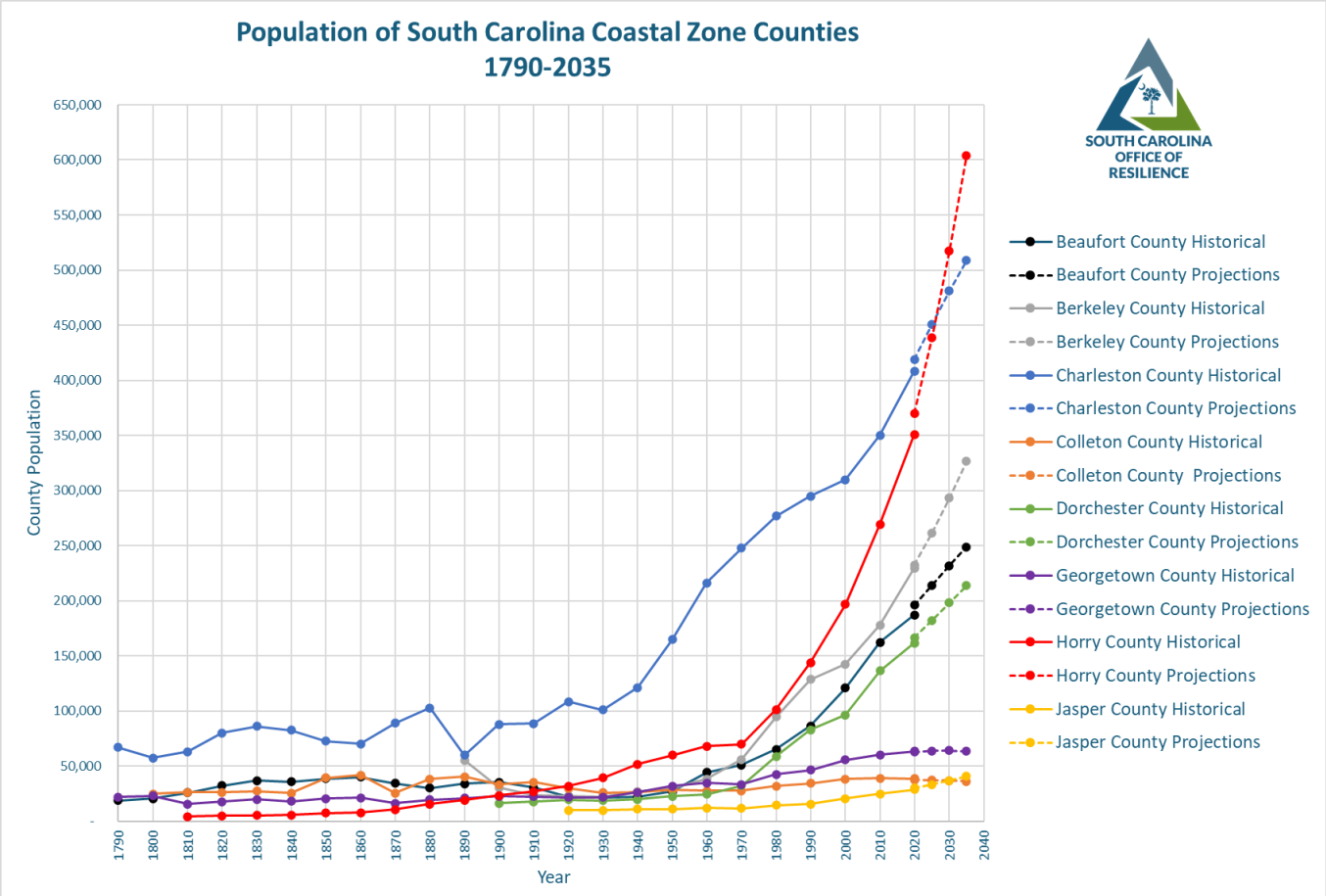


Figure 12: Population trends for the coastal zone counties in South Carolina 1790-2035 (SC Revenue and Fiscal Affairs Office, 2019; US Census Bureau, 2021)

Social Vulnerability

The sensitivity of this population to natural hazards and its ability to respond to and recover from the impacts of hazards can be described by measuring social vulnerability (Cutter & Finch, 2008). The Social Vulnerability Index (SoVI®), compiled and processed by the Hazards and Vulnerability Research Institute at the University of South Carolina (HVRI), measures the social vulnerability of counties in the United States, providing information on "where there is uneven capacity for preparedness and response and where resources might be used most effectively to reduce pre-existing vulnerability" using 29 socioeconomic variables (University of South Carolina). Total scores, percentiles, and Individual scores for each individual component are available to allow for specific analysis about what demographics drive local vulnerability.

Figure 13 shows SoVI® overlaid with the 2022 1% annual flood event as shown by the First Street model. Appendix A provides these maps by counties to identify areas with high social and physical vulnerability to flooding.

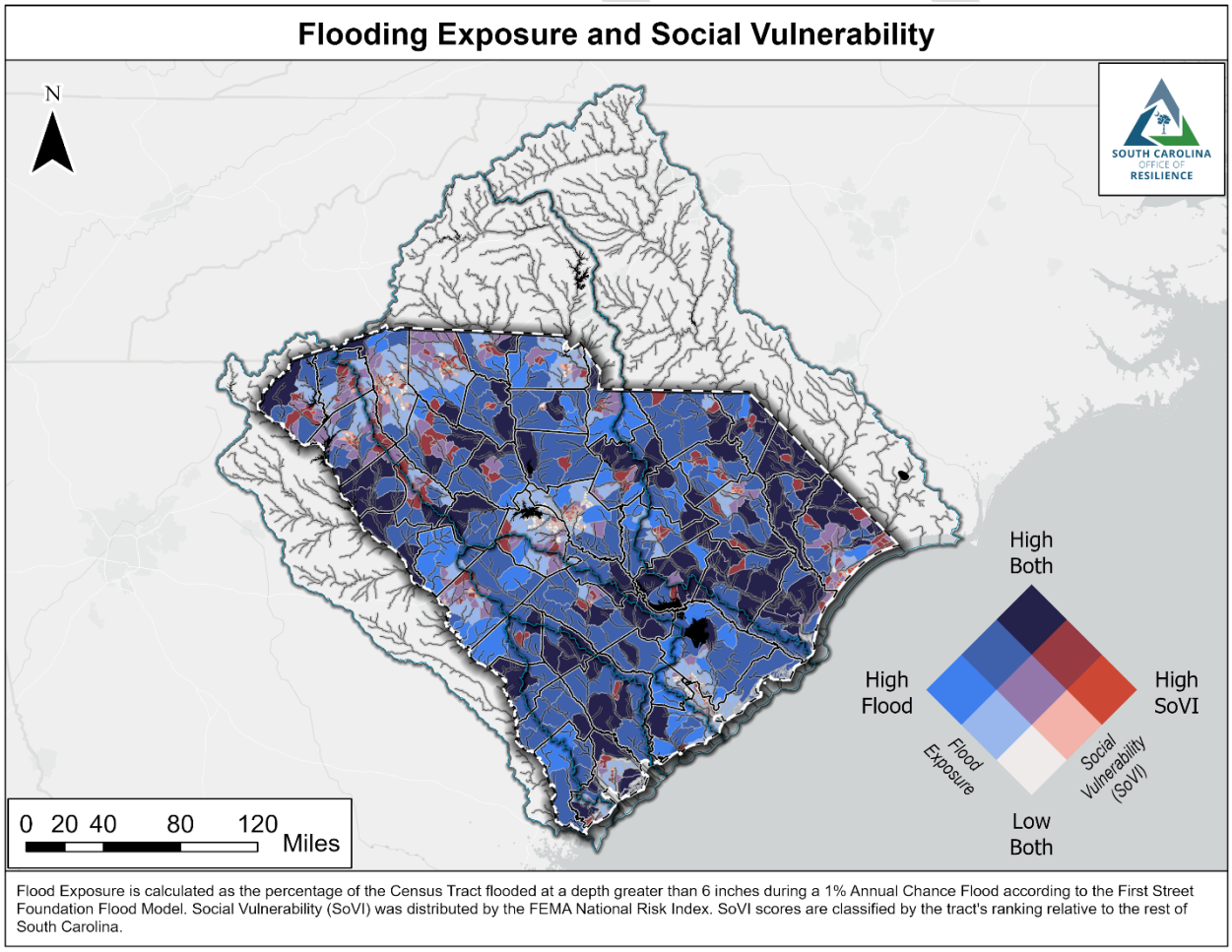


Figure 13 Flooding Exposure and Social Vulnerability. Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Recent Storm Events

Since 2015, there have been three federally declared natural disasters that have caused flooding in South Carolina. These storms caused debilitating damage throughout large sections of South Carolina. Water and wind-damage from these events caused homes to become unlivable. Those without the means to repair their homes were either forced to live in unsafe structures, relocate with relatives, or flee the disaster area. The damage continued to be felt by the local economy as businesses lost customers and local government tax revenues diminished. Some communities experienced damage from all three storms and are still struggling to recover and thrive years later.

October 2015 (Atmospheric River/ Hurricane Joaquin)

There was historic precipitation across the state from October 1st- 5th, 2015 associated with Hurricane Joaquin. As described by SC DNR Climatology Office, in late September and early October in 2015, Joaquin temporarily stalled off the coast of South Carolina due to a cold front crossing the state and a high-pressure system to the north (SCDNR, 2015). The interaction of these systems caused a large-scale flow of moist air over the Carolinas and record amounts of rain, with some areas receiving greater than 26 inches over the first week of October (SCDNR, 2015). The rain caused historic flooding across large portions the state, specifically in the midlands and coastal areas. During this event, an estimated $1.5 billion of property, infrastructure, and agricultural damage occurred, 36 regulated dams failed, and 19 fatalities occurred (NOAA, 2016). A more detailed report of this event by SCDNR Climatology Office can be found on their website.

October 2016 (Hurricane Matthew)

Hurricane Matthew made landfall near McClellanville, a small fishing community in Charleston County, as a category one hurricane on October 8, 2016. Hurricane Matthew moved slowly across the Carolinas coastline and upwards of 15 inches of rain occurred in the northeast South Carolina in close to a 12-hour period. This caused significant flash and riverine flooding in the Pee Dee River Basin and northeast South Carolina. During Hurricane Matthew, the Little Pee Dee River peak river level was at 17.1 ft at Galivant's Ferry and the Waccamaw River crested at 17.9 ft, both breaking records set in 1928 from the Okeechobee Hurricane (Weaver, 2016). Nichols, SC is located at the junction of the Little Pee Dee River and the Lumber River. During Hurricane Matthew, large amounts of water drained through these rivers and at the convergence caused significant flooding of the Town of Nichols, and although not directly in the path of Hurricane Matthew, the town lost 261 homes and almost 150 residents were rescued (Adcox, 2016; Edwards, 2020). A more detailed report of this event by SCDNR Climatology Office can be found on their website.

September 2018 (Hurricane Florence)

Hurricane Florence impacted the Carolinas on September 14th -16th and caused significant damage. Florence made landfall near Wrightsville Beach, NC and caused significant storm surge and historic rainfall in both North and South Carolina. More than 26 inches of rain fell in Loris, SC, setting a rainfall record (Stewart & Berg, 2019). Riverine flooding occurred in Chesterfield, Darlington, Dillon, Georgetown, Horry, and Marion Counties in South Carolina. In Conway, the

Waccamaw River crested at 22.1 ft and flooded close to 1,000 homes and businesses (NWC, 2018). The impacts of the hurricane and subsequent flooding is estimated to have caused 600 million dollars in property damage, evacuation of close to 500,000 people, and major damage to 550 homes (NOAA, 2021).

Flooding Types

Flooding is typically caused by excessive rain and insufficient drainage, including prolonged rain events or short intense rain, overflowing rivers, or dam or levee failure. South Carolina is vulnerable to several types of flooding events including river flooding (fluvial), overland flooding (pluvial), coastal flooding and even sunny day flooding.

Riverine (Fluvial)

Fluvial, or river, floods occur when the water level of the river overtops its banks or natural levees (Figure 14). Riverine flooding can be devastating because the rainfall or snowmelt needed to cause the flooding does not have to fall where the flooding occurs. Since 2000, there have been over 195 riverine floods that have been reported to the National Centers for Environmental Information database by local emergency managers, news reporters, and emergency responders (NOAA, 2021).

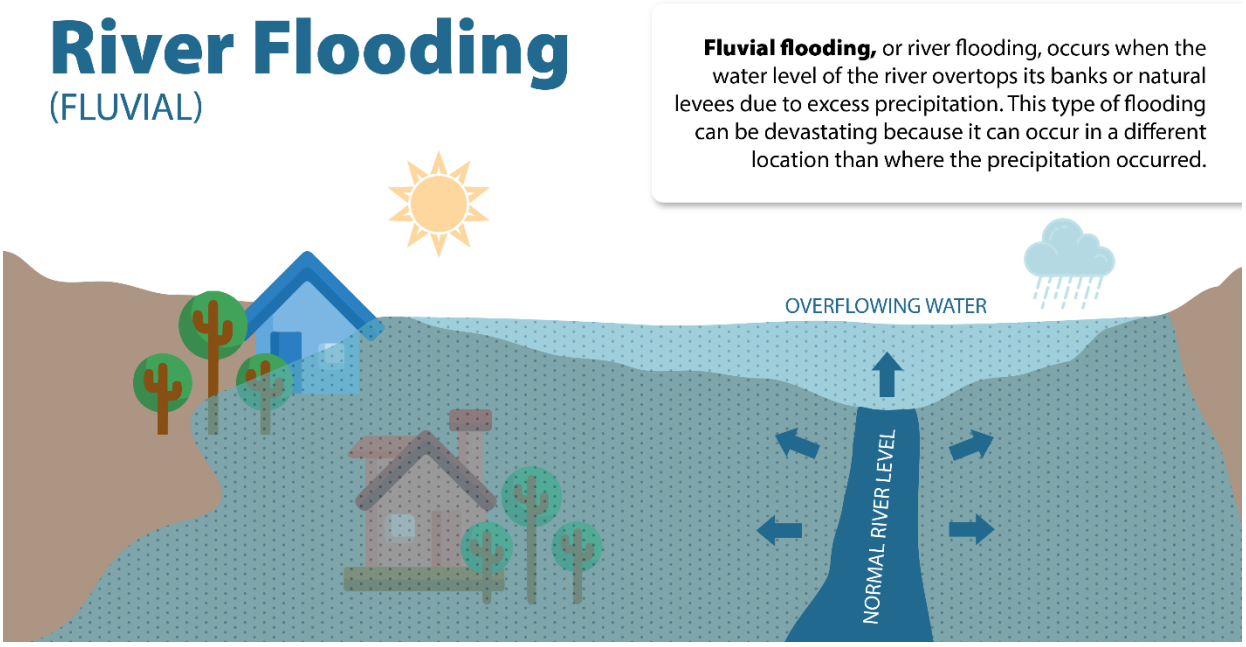


Figure 14: Fluvial Flooding

Pluvial

Pluvial flooding occurs when an extreme rainfall event creates a flood independent of an overflowing water body (Figure 15). Pluvial flooding occurs when there is inadequate drainage for the amount of rainfall that falls in a given area (Rosenzweig, et al., 2018). Pluvial flooding can be split into two different categories: flash flooding and surface water flooding.

Flash floods are defined by the National Weather Service as:

> "A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. Flash floods are usually characterized by raging torrents after heavy rains that rip through riverbeds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours of excessive rainfall. They can also occur even if no rain has fallen, for instance after a levee or dam has failed, or after a sudden release of water by a debris or ice jam" (NWS, n.d.).

This type of flooding is when rainfall flows over the surface of the landscape as it moves toward the established drainage system. When the amount of rain is higher than the capability of the drainage system to drain the water, the water floods at points where flow is restrained.

Surface water floods are specifically associated with urban environments and occur when there is insufficient drainage and the water discharges into the streets or surrounding structures (Zurich, 2020). Urbanization has been linked to an increase in flash flooding due to the increase in impermeable surfaces (Konrad, 2003). In South Carolina since 2000, there have been 440 flash flood events with a total estimated damage cost of over 163 million dollars and an estimated 25 million dollars of damage to agriculture, and 130 events with damage costing more than 10,000 dollars as recorded in NOAA's Storm Event Database (NOAA, 2021).

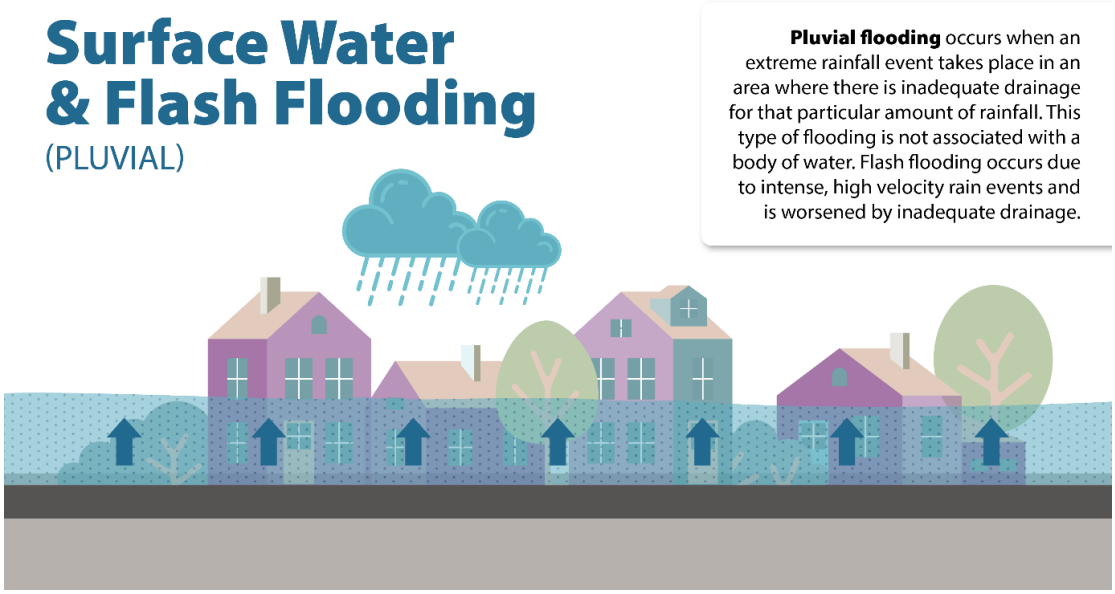


Figure 15: Pluvial Flooding

Coastal

The coastal system is complex and impacted by the interactions of inland flooding and marine processes. Coastal flooding can be caused by storm surge, high tides, compound and sea level rise and is amplified by onshore winds and by the gravitational pulls of the moon and sun on the earth.

Storm Surge

Storm surge flooding is often the greatest hazard during a hurricane and can be defined as a rise of water generated by a storm that is higher than the normal tides (Figure 16). There are two types of storm surge that hurricanes produce: wind-driven and pressure-driven. The strong winds of hurricanes disturb the water below and as the storm moves into shallower water, the vertical circulation in the water column that is caused loses depth and can increase in elevation, much like a tsunami (National Hurricane Center). Pressure-driven storm surge is less substantial than previously believed. It is formed by the low-pressure center of a hurricane and as the air travels upward, the water is siphoned into a bulge in a balance of vertical uplift from the wind and gravity. When the storm surge impacts land, it can push water up waterways, infrastructure, and onto the land over long periods of time and appears as a temporary increase in sea level. Since storm surge is independent of tides and waves, the flooding it causes can be additive in its risk and bring those tidal forces and wave actions into areas that do not normally feel the effects of them.

The 1989 landfall of Hurricane Hugo caused 13 impact fatalities (mostly drownings) and $8 to $10 billion in damages (NOAA, 1989; NOAA, 2021). Since the passage of Hugo, there has been a significant federal, state, and local investment in many coastal management policies (such as mandatory evacuation orders) and projects (such as beachfront flood mitigation) (SCDHEC, 2022). For example, over 60 million cubic yards of sand have been placed along South Carolina beaches and dunes over the last several decades (Elko, et al., 2021). These large-scale beach and dune restoration projects may have reduced flood risk along the South Carolina beachfront (Kana & Barrineau, 2021).

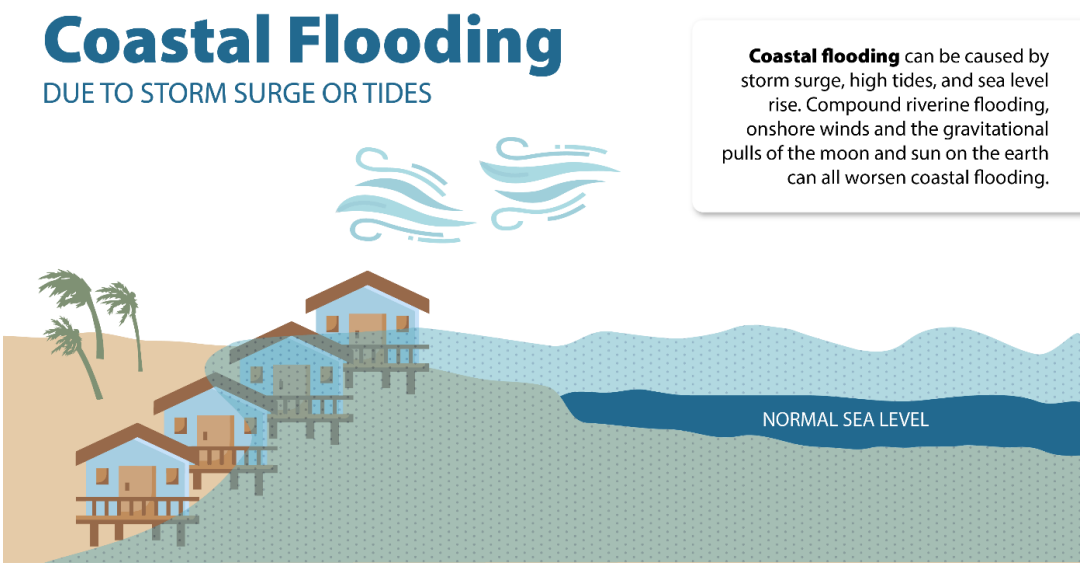


Figure 16: Coastal Flooding

Tidal Flooding

While coastal flooding caused by large events such as tropical storm surge receive a lot of attention, small changes in the system that are sustained can equally be as disruptive. Tidal flooding is low level inundation that disrupts daily activities, associated with high tides (Moftakhari, AghaKouchak, Sanders, Allaire, & Matthew, 2018). In low lying coastal areas, major damage is often associated with high tide flooding. High tide flooding has increased in the U.S. by about 50 percent in the last 20 years and 100% in the last 30 years (NOAA, 2021).

Spring tides occur when the moon orbit is in perigee or apogee (Figure 17). When the moon is in alignment with the earth and sun during the full or new moon, it has a greater gravitational effect on the tides. The moon's orbit around the earth is elliptical with the furthest point of the ellipse called Apogee and nearest point Perigee. As the Earth rotates around the sun, the moon's orbit changes in reference to the sun (Espenak & Meeus, 2006). When Perigee occurs with the Full or New Moon, about 6-8 times a year, higher than average spring tides flooding can occur (NOAA, 2021). These perigean spring tides, commonly referred to as king tides or spring tides, along with the increase of sea level, has started to regularly flood coastal roads and marshfront shorelines that have not historically been flooded regularly.

As sea level continues to increase along the South Carolina coastline (described in more detail in the next section), everyday occurrences such as high tides and coastal winds can cause flooding events. High tide flooding occurrence along estuarine or marshfront shorelines has increased due to the low-lying nature of the South Carolina coastline and increased development of coastal communities. Along with estuarine flooding events, higher tides also impact our beaches and dunes and may be causing additional erosion in these environments. This should be further studied to identify the extent of the impact.

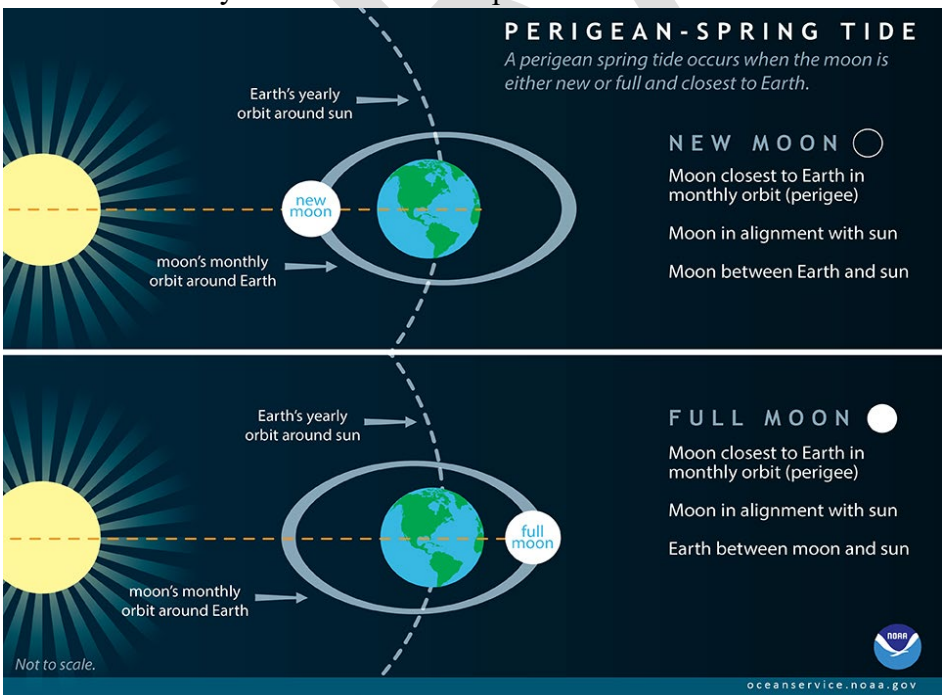


Figure 17: The moon's position within its orbit strongly influences gravitational pull on the Earth's tides (NOAA, 2021).

Compound Flooding

Compound flooding occurs when extreme tides, storm surge, pluvial or fluvial flooding combine in coastal areas (Wahl, 2017; Bevacqua, et al., 2020). Within coastal systems, flooding is rarely caused by a single driver (Wahl, 2017). The low-lying nature of South Carolina's coastlines means that flooding often compounds. This also makes cataloging the cause of impacts to a specific type of flooding difficult. In the National Center for Environmental Information database, storm surge and tides are not credited with any damage nor injury or deaths (NOAA, 2021). This may be because when recent storm surge occurs, there has also been pluvial or fluvial flooding that receives the credit in the National Centers for Environmental Information (NCEI) database (NOAA, 2021). It may also be attributed at least in part to large-scale beach and dune restoration projects that have reduced flood risk along the South Carolina beachfront (Kana & Barrineau, 2021).

Sea level Rise

The compound effects of these types of flooding will only be complicated by sea level rise. Climate model experts have developed a range of plausible future sea level rise scenarios, ranging from extreme, high, intermediate-high, intermediate, intermediate-low, and low (*Figure 18*). Sea level rise is not a new concept and has been observed in South Carolina with Charleston Harbor tidal gage since 1920, cataloging a rise of 10.9 inches since 1950 (South Carolina's Sea Level is Rising, 2022). Sweet et al. (2022) at NOAA project that sea level will continue to rise and have described six difference scenarios, extrapolation from observed tidal gages, low, intermediate-low, intermediate, intermediate-high, and high. The extrapolated observed tidal gage or present trajectory scenario calculates median sea level rise to be 16.14 inches (0.41 meters) by 2050, which falls between the intermediate (14.17 inches or 0.36 meters) and intermediate-high (16.93 inches or 0.43 meters) (*Figure 18*) (Sweet, et al., 2022). These scenarios support planning and decision-making in light of uncertainties regarding sea level rise risk. Higher-end projections represent scenarios in which South Carolina's sea levels rise precipitously while lower-end projections showcase more conservative sea level increases. Long-term planning, however, must consider a broad range of possible outcomes, including high-consequence, low-probability events.

During discussions with the Statewide Resilience Plan Advisory Committee, the consensus was that the intermediate to intermediate-high scenario should be considered in the development of South Carolina's Statewide Resilience Plan. SCOR is working with scientists at University of South Carolina, SCDNR Climatology Office, and Carolinas Integrated Sciences and Assessments (CISA) to generate a report on how NOAA, Sweet et al. (2022), and IPCC reports apply to South Carolina's regional sea level and how those reports compare to the long-term datasets that South Carolina has kept.

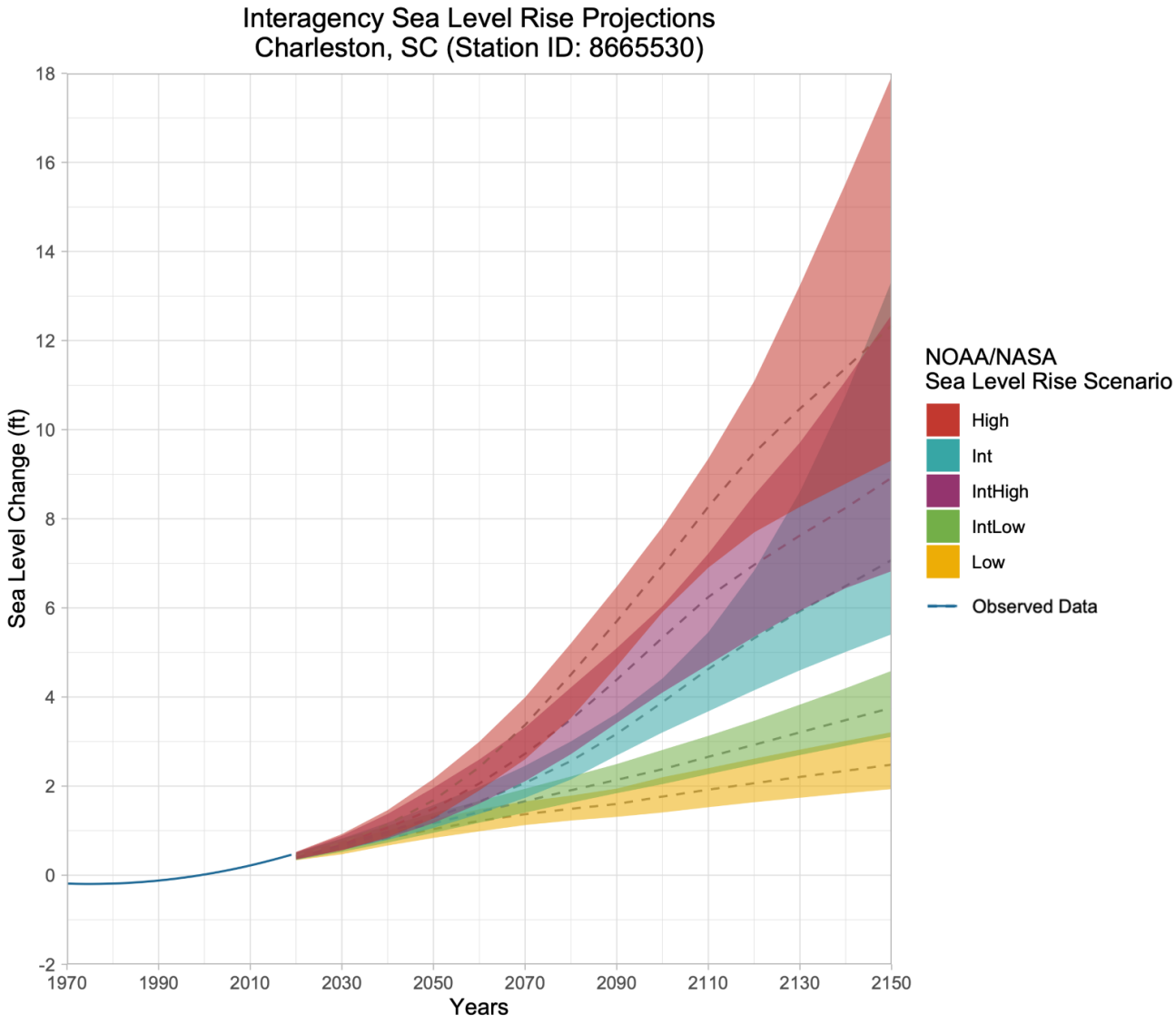


Figure 18: Sea level rise projections for Southeastern United States from NOAA's recent report (Sweet, et al., 2022). Edited from Sweet et al. (2022) Figure 2.3.

From historical records at the Charleston Harbor gauge, the total number of flood days increase has increased and an increase in "major" (8+ ft) flood events (*Figure 19* and *Figure 20*) (NWS, 2022). In fact, half of the top heights at the Charleston gauge have occurred since 2016, coinciding with tropical systems. However, as seen in the figures below, flood days are not limited to tropical system events. Most of the flooding days are a result of tidal flooding.

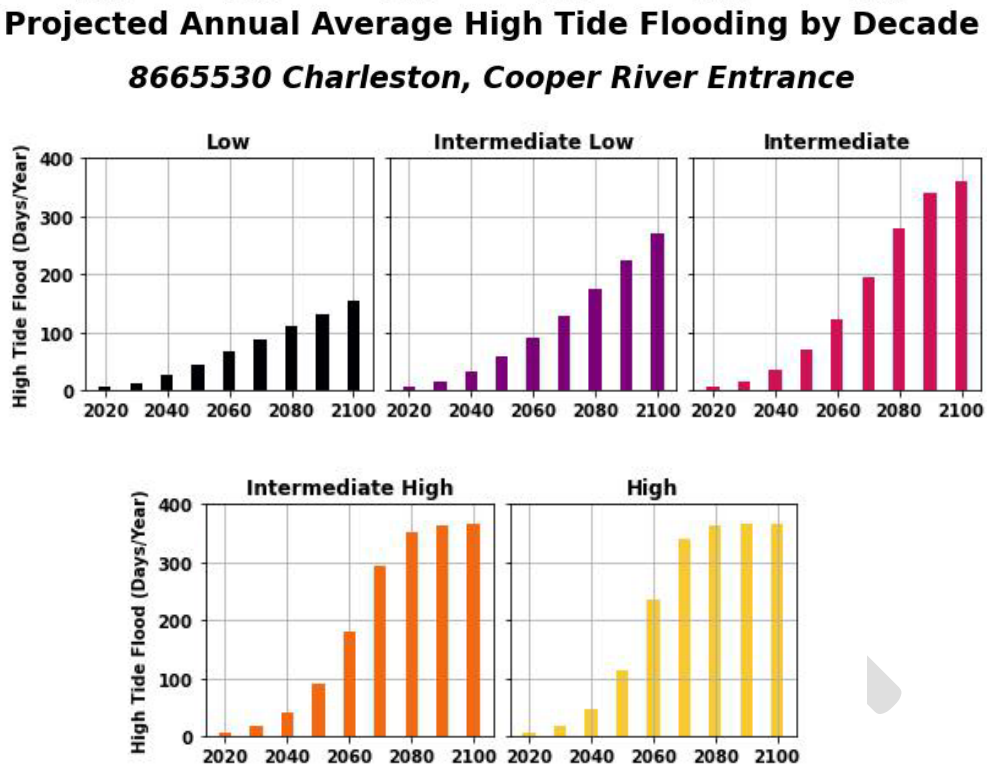


Figure 19: Total number of flood days at Charleston Harbor Gage, edited from (NOAA, 2022)

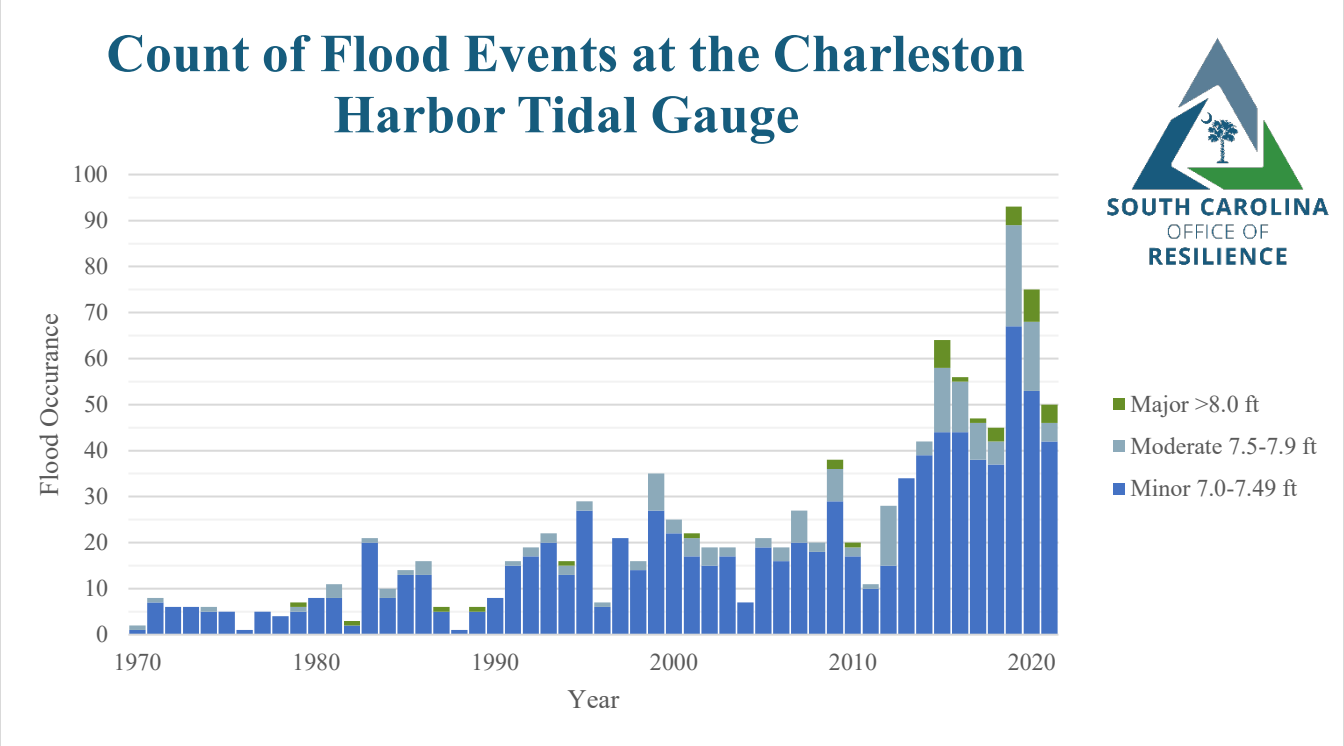


Figure 20: Number of flood events at Charleston Harbor gauge (NWS, 2022).

Figure 21 combines the historical tidal floods in Charleston and pairs it with projected figures based on two scenarios higher and lower emission pathways. Current projections have tidal flooding in Charleston doubling to over 100 days a year by 2040 and up to 350 flooding days by 2100.

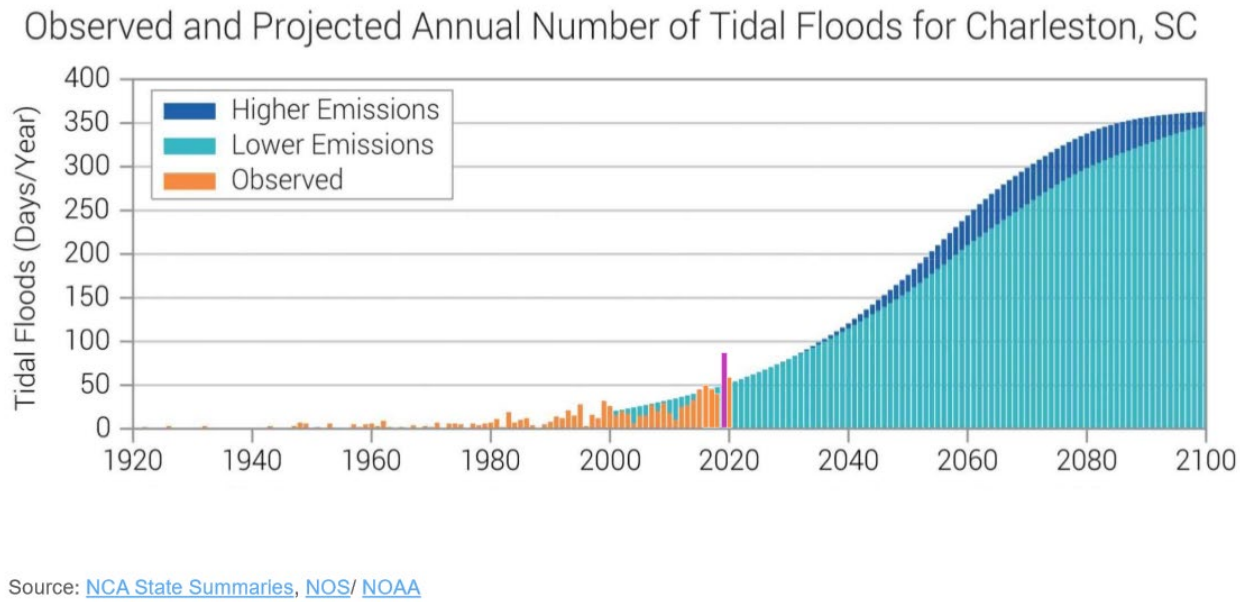


Figure 21: Observed and projected annual number of tidal floods for Charleston, SC.

In addition to the general flood risk from sea level rise, the projected trend will have wider reaching community effects, including erosion, a higher groundwater table, saltwater intrusion, corrosion of underground infrastructure, migration of salt marshes. One consequence of sea level rise is the impact to groundwater resources. The surficial – unconfined aquifer in the coastal region interacts directly with the sea water through tidal pumping through the unconsolidated sandy sediment that makes up the coastal areas in South Carolina. As sea level rises, the saltier ocean water layers under the fresh ground water due to density differences and as tides fluctuate, the water table will rise with the rising tide (Bowes, Sadler, Morsy, Behl, & Goodall, 2019; Cooper, 1964; Hoover, Odigie, Swarzenski, & Barnard, 2017; Plane, Hill, & May, 2019; Rotzoll & Fletcher, 2013). The rising of the water table also has detriments to pluvial flooding events due to the decreasing ability of the ground to absorb rainwater during a rain event. A secondary, non-flooding hazard associated with sea level rise is an increase in saltwater intrusion into coastal aquifers. Saltwater intrusion is not new to South Carolina, in the USGS Report 2009 – 5251 saltwater intrusion in Hilton Head Island has been observed since the 1970s and described and modeled in the report (Payne, 2010). Saltwater intrusion into freshwater aquifers impacts many coastal drinking water sources.

Dam Failure

The South Carolina Dams and Reservoirs Safety Act charges the DHEC with administration of a program to protect citizens' health, safety, and welfare by reducing the risk of failure of dams. Dams are regulated based on the height and/or amount of water impounded by the structure according to the following criteria:

- Measures 25 feet in height from the invert of the receiving stream or natural ground
- Capable of impounding 50-acre feet or more
- Smaller than either of the criteria above but failure of the dam would likely result in loss of human life, regardless of size

Dams regulated by the Department are classified based on the hazard brought about to life and property should the dam fail. Hazard classifications are high hazard, significant hazard, and low hazard, which are defined as:

Table 5: Dam Hazard Classifications (DHEC)

Hazard Classification	Classification Description
High Hazard (Class I)	Dam failure would likely result in loss of life or serious damage to home(s), industrial and commercial facilities, important public utilities, main highway(s) or railroads
Significant Hazard (Class II)	Dam failure wouldn't likely result in loss of life but may damage home(s) industrial and commercial facilities, secondary highway(s) or railroad(s) or interrupt the service of relatively important public utilities.
Low Hazard (Class III)	Dam failure may cause minimal property damage to others. Loss of life is not expected.

The regulations promulgated under authority of the act specify the process of obtaining permits for the construction of new dams and for the alteration, repair, or removal of existing dams. The regulations outline the procedures for inspection of regulated dams and issuance of maintenance/repair orders, as well as emergency orders in situations where there is imminent risk of dam failure which may impact life or property. Dam owners are responsible for maintain the structural integrity of their dams.

In 2015, 51 dams failed in the Midlands, Pee Dee and Lowcountry due to the historic rainfall and subsequent flooding caused by Hurricane Joaquin (SCDHEC, n.d.). Since 2015, all 652 high- and significant-hazard dams in the state have been assessed and the state has invested significant resources in the state's dam safety program (SCDHEC, n.d.). In 2018, the SC General Assembly directed SCDHEC to focus the resources of the department's Dams and Reservoirs Safety

Program on regulating the state's high and significant hazard dams only and reclassifying dams when the failure or improper operation of a dam will likely result in loss of human life, 2018 Joint Resolution 231 (S.1190). Considerable efforts and resources have been directed to activities to mitigate the risk of dam failure, and the resultant flooding that would ensue. These include:

- Development of an Emergency Action Plan (EAP) template to guide the actions of owners during a potential dam failure.
- Increased staffing to ensure that dams are properly classified and inspected in accordance with the regulations.
- Development of dam breach models for most regulated dams to assess potential impacts of dam failure. These are available on a dedicated agency web application.
- Procurement of communications tools, first CodeRed and now ReadyOps, to communicate with dam owners during extreme events
- Development of Screening Level Risk Analysis for High Hazard Dams to gain a more thorough understanding of the risk of dam failure
- Expansion of training and owner outreach initiatives to further the understanding of the responsibility dam owners play in maintaining their dam in a safe condition.
- Coordination with SCEMD to include a "Dams Annex" in the South Carolina Hazard Mitigation Plan.

Flood Modeling and Monitoring in South Carolina

Computer models are very useful tools that simplify and represent a complex system. With advancements in computer technology, models have gotten more accurate and faster, but have yet to account for every variable that influences a system. Models are built to answer the specific questions of the developer and are not always useful to guide decision makers on those question that are outside to the original intent of the model. In many cases, several models are consulted depending on the needs of decision makers. The following section looks at a few of the models currently used in South Carolina:

Table 6: Existing Models

Model	Source	Focus
SCDNR Floodplain Inundation Model (in development)	DNR	Vulnerability Assessment Emergency Management
SWAM (Surface Water Allocation Model)	DNR, SCDHEC	Surface Water Availability Withdrawals, Accounting
HEC-RAS 2D (Hydrologic Engineering Center's River Analysis System)	US Army Corps of Engineers	Flow Calculations Sediment, Water Quality
CHEOPS (Computer Hydro-Electric Operations and Planning Software)	HDR, Inc	Hydroelectric Systems
Storm Water Management Model (SWMM)	EPA	Drainage system modeling
NOAA Atlas 14	NOAA	Precipitation Frequency Estimates Infrastructure Design
Bridge Watch	SC DOT	Bridge Monitoring & Alerts
First Street Flood Model	First Street Foundation	Property Level Statistics Current & Future Hazards

SCDNR Floodplain Model

Post Hurricane Matthew in 2018, DNR identified the need for a floodplain inundation model for the state. They received some funding through the FEMA Flood Mitigation Program to start the process of building a model and were able to complete a model within the Pee Dee River basin and have now modeled approximately 25% of the state. This model has been used to assess the risk of flooding and to stage SCDNR Law Enforcement and State Law Enforcement Division search and rescue personnel during flood events. Other state agencies have also used this model before and during flood events to assess vulnerabilities of their respective assets during an event, such as SCDOT. The DNR Floodplain Model can be accessed in a limited capacity on their website, SC Flood Impact, and DNR currently seeks funding to complete the model statewide.

SWAM

In 2014, DNR and DHEC awarded CDM Smith a contract to create a Surface Water Allocation Model (SWAM) for the State's eight river basins. SWAM provides the State the computational

ability to quantify the surface water usage in the State's streams and rivers (SCDNR, 2022). The model identifies the unimpaired flow in the waterways and then subtracts out the DHEC permitted and registered withdrawers to calculate the permitted water availability (Clemson University, 2022). The model can calculate water availability over a variety of climate and water use scenarios (Westphal & Boyer, 2014). According to CDM Smith, SWAM is a water accounting tool and a what-if simulation model, but it is equally not a precipitation-runoff model, a hydraulic model, a water quality model, optimization, nor a groundwater flow model (Westphal & Boyer, 2014).

HEC-RAS 2D

The US Army Corps of Engineers (USACE) developed the Hydrologic Engineering Center's River Analysis System (HEC-RAS) to perform one-dimensional steady flow and one- and two-dimensional unsteady flow calculations, sediment transport / mobile bed computations, and water temperature / water quality modeling (USACE, 2022). SCDOT uses HEC-RAS to:

- Design of bridges and culverts (time saving since we do not have to create the stream hydraulic model).
- Verification of water elevations.
- Calibration of existing models.
- Analysis of existing structures capacity.

CHEOPS

The Computer Hydro-Electric Operations and Planning Software (CHEOPS) was developed by HDR, Inc. The model simulates the physical changes and operational constraints of hydroelectric systems. It is used by the Catawba-Wateree River Basin Council and Duke Energy to manage the reservoirs and dams in that basin (HDR, 2014).

SWMM

EPA's Storm Water Management Model (SWMM) is used for planning, analysis, and design related to stormwater runoff, combined and sanitary sewers, and other drainage systems. It can be used to predict runoff quantity and quality from drainage systems. SWMM was developed to help support local, state, and national stormwater management objectives to reduce runoff through infiltration and retention and help to reduce discharges that cause impairment of waterbodies (EPA, 2022).

NOAA Atlas 14

The NOAA Atlas 14 is a precipitation frequency estimation of 5-minutes through 60-day durations at average recurrence intervals of 1-year through 1,000-year (Bonnin, et al., 2006). This is simply that the amount of rain, at a particular location and a given duration can be calculated and represented. These curves are used by agencies and stakeholders to design infrastructure, environmental management, stormwater management, hydrologic studies, floodplain and watershed management, and many others. In South Carolina, the Atlas 14 curves were calculated and published in the early 2000s and was updated in 2006 (Bonnin, et al., 2006). SCOR and SCDOT have committed funds to update NOAA Atlas 14 Curves for the state. The project is expected to begin in Summer 2022 and be completed in two years.

BridgeWatch

BridgeWatch is a web-based monitoring software that allows SCDOT to predict, identify, prepare for, manage, and record potentially destructive environmental events. BridgeWatch is an application that centralizes and makes accessible all database and site information through an interactive web interface. In such manner, this application allows SCDOT to efficiently perform the following activities.

- Maintain Plan of Action and flood monitoring data for FHWA compliance.
- Monitor bridges over water and floodplains for rainfall and flow thresholds using radar and gage adjusted radar rainfall data, USGS gages, NWS rainfall predictions, and SLOSH and ADCRIC tidal surge predictions.
- Monitor bridges for seismic events using USGS data continuously.
- Analyze threshold alerts sent to SCDOT personnel for rainfall, riverine, tidal, and seismic events.
- Access real-time graphical display of geographic data, an inventory of structures being monitored, and the list of those structures experiencing their respective critical event.
- Prepare a watch list of structures identified for action according to user-defined protocols.

All the data is available on the BridgeWatch web-based software application, which can be accessed on computers and mobile devices.

First Street Foundation

First Street Foundation describes itself as:

> "A non-profit research and technology group dedicated to quantifying and communicating those risks by incorporating world class modeling techniques and analysis with the most up to date science available in order to simply, and effectively, inform Americans of their risk today and into the future from all environmental changes" (First Street Foundation, 2022).

The Foundation produces high resolution flood maps by modeling three main flood types (fluvial, pluvial, and coastal) in different modeling software with 3-meter digital elevation models (DEM) and then combining the flood type models to get a single coverage of flooding per scenario. The modeling software used is Fathom-US for fluvial, a proprietary model for pluvial that integrates the high-resolution DEMs with the NOAA Atlas 14 curves, while coastal flooding is modeled in multiple software packages due to the complexity of coastal modeling (GeoCLAW, ADCIRC, and SWAN). These are then historically validated to corroborate the models based on past events.

Property level statistics provide an estimated flood inundation level for various scenarios including low, medium, and high projections for flood probabilities 2-, 5-, 20-, 100-, and 500-year flood events, along with modeling the flood projections for 2022, 2037, and 2052. To model future climate scenarios, First Street identified that the IPCC RCP 4.5 carbon emission scenario is the median projection for future change. To calculate the property value, First Street uses ComeHome by HouseCanary's AVM (Automated Valuation Model), paired with parcel & building characteristic data from Lightbox.

As with any model, there is inherent error by the limited data available in the state. South Carolina does not keep a complete dataset of parcel statistics at the state level; thus, counties and municipalities hold this information in a non-standardized format. This data inconsistency will cause data gaps in the model and thus the assessment.

Vulnerability by Sector

First Street Foundation was identified as a partner to supply the data that will allow the South Carolina Office of Resilience to fulfill its mandate, providing modeled flood coverage, property level flood probability and estimated property value. First Street Foundation provides parcel level statistics that identify registered parcels across the state. If the parcel has a building on it, the first-floor elevation is used to determine flood inundation, and if not, the point of inundation evaluation is at the geometric center of the parcel. In the following analysis, parcel and property is used interchangeably. This data allows SCOR to not only identify properties that may currently flood, but also plan for potential flooding under various scenarios in the future.

In assessing vulnerability, the First Street flood maps pair well with the FEMA floodplain maps. When comparing the 100-year flood maps, the First Street high-resolution floodplain maps matchup and provide additional coverage in areas that have historically reported flooding that is not represented or underrepresented by the FEMA maps.

The First Street Foundation model described above served as the basis for quantifying the vulnerability of the assets below. The First Street 2022 and 2052 1% annual chance flooding event models were overlaid with data sets obtained from state partners and public sources.

Natural Systems Vulnerability

Forestry

South Carolina has approximately 12.9 million acres of forestland; 87% of the forests are privately owned (SCFC, 2021). Economic impact of forestry in SC is approximately $21.2 billion annually. The main impact from flooding on forest management is infrastructure damage, such as destruction of stream crossings on forest roads. Newly-planted tree seedlings occasionally succumb to flooding, but forest stands beyond seedlings should survive short-term flooding if they are not submerged for more than 7-10 days (SCFC, 2015).

Trees help reduce the impact of flooding through their interception of rainfall and softening of raindrop impact. Depending on species, a mature tree retains 20 to 30 percent of annual rainfall (Forest Service, 2020). Healthy forests help slow runoff from rain events in steep terrain, insulating creeks from scouring of the creek banks and beds. They ensure stable hydrology, low sedimentation rates, stable channels, moderate water temperatures (through shading), and woody debris for in-stream habitat. Trees and other vegetation store carbon, important for reducing the impacts of climate change.

Beaches

South Carolina's coastline measures 187 miles containing 98 miles of developed beaches (including public parks) and 89 miles of wilderness areas with limited public access. It should be noted that this figure does not include tidal shoreline, which totals 2876 miles. The beach/dune system provides the basis for a tourism industry that generates approximately two-thirds of South Carolina's annual tourism industry revenue (South Carolina Code §48-39-250, 2019), about $17 billion annually, and also serves as a front line of defense to coastal residents and businesses from wind, waves, and storm surge.

The main risk from flooding to South Carolina beaches is exacerbated erosion due to accelerating sea level rise. As noted in the Coastal Flooding section above, beach and dune

restoration (also known as nourishment) has reduced flood risk along much of the developed coastline but requires dedicated funding and planning to sustain. In policy, the Beachfront Management Reform Act of 2018 adopted a state policy of beach preservation. The Office of Coastal Resource Management of DHEC is currently convening The South Carolina Beach Preservation Stakeholder Workgroup to make recommendations on how to implement the state policy. SCOR is participating in this workgroup.

Salt Marshes

South Carolina is home to roughly 350,000 acres of saltmarsh, much of which is at risk from sea level rise and lack of management. Some sources estimate that 50% of the original salt marsh habitat in the U.S. has been lost due to human influence over the last century (Kennish, 2001). Globally, it is estimated that 85% of oyster reefs have been lost, with those remaining in poor condition (Beck, et al., 2011). Salt marshes provide essential habitat, wave attenuation, and water filtration. They provide a vital refuge, breeding grounds and food for fish, birds, and other wildlife, as well as a unique open space in a dense urban environment. South Carolina marshes provide public and commercial fishing/oystering opportunities, as well as other recreational opportunities like boating and bird watching. Recreational fishing is a $686 million annual industry (USFWS, 2014) in our state. In 2012, commercial fishermen in South Carolina landed 12.3 million pounds of finfish (2.4 million pounds) and shellfish (9.9 million pounds), earning $24 million in landing revenue (NMFS, 2014).

Salt marshes provide services for the state by reducing wave energy, absorbing flooding, and filtering debris and pollutants from the water. Yet despite decades of regulatory protection, salt marshes continue to be threatened by poor water quality, rising sea levels, encroaching development, illicit dumping, and erosion without adequate room for natural migration of marshes.

Wildlife

Threatened and Endangered Species

Numerous state and federally Threatened/Endangered species depend on South Carolina's undeveloped land for survival and recovery. Along the coast, birds are particularly vulnerable. Least Tern and Wilson's Plovers are both beach-nesting species that are State Threatened. Red Knot and Piping Plover are Federally Threatened & Endangered species that rely on South Carolina beaches as critical habitat throughout their life cycle (SCDNR, 2020). The recently listed Black Rail has seen greater than 90% population decline since the 1990s due to sea level rise and its associated nest flooding. In a recent study that made national headlines, 20,000 Whimbrel, almost 50% of the eastern population, were found to congregate on Deveaux Bank during spring migration (Weidensaul, 2021). Tidal marshes are vitally important feeding grounds for these species who breed in the Arctic tundra. Other shorebird species use Deveaux and other barrier islands for breeding. Protection of SC's beaches, marshes, maritime forests, and barrier islands is critical for the survival of multiple species of conservation concern and the buffering capacity of these landscapes.

Invasive Species

While threatened and endangered species are at additional risk due to flooding, several invasive species have been found to exacerbate flooding in addition to their negative impacts on people and ecosystems. Ineffective marsh protection and/or management, for example, can lead to the damage/destruction of native species that would otherwise provide important ecological benefits (from food sources to structural support to protect against flooding/storms), and the subsequent possible introduction or promotion of invasive species. Even native species can become invasive when predator-prey relationships become disrupted. Beavers can build dams that back up water, creating flooding. Marsh periwinkle feed on intertidal cordgrass, (*Spartina alterniflora*) and are preyed on by blue crab. However, if periwinkle become overpopulated, they can degrade their own habitat which also impacts the prevalence of economically important blue crab (*Calinectes sapidus*) (SCDNR, 2015). Many invasive species become introduced into new habitats as a direct result of flooding either through movements to avoid the floodwaters or by being carried by the floodwaters.

Phragmites australis: can invade freshwater marshes, outcompeting native vegetation and changing the organic composition of the ground cover. A once open marsh system may become too thick for birds and other wildlife to utilize effectively (K. Bradley, SCDNR Botanist, personal communication 2022).

Feral hogs: can trample cordgrass as they forage for ribbed mussels, disrupting the mutualistic relationship between the bivalve and the grass as well as damaging the marsh ecosystem (Hensel, et al., 2021). Feral swine routinely undermine the integrity of dikes and levees leading to costly repairs. Some repairs have been estimated in excess of $100,000 to replace a single water gate (N. Myers, USDA APHIS WS SC State Director, personal communication 2022). In inland areas, feral hogs can foul waterways with their wallows, spread disease, and destroy sensitive habitats. They are omnivorous and consume plant and animal matter, including rare and declining species of conservation concern (West, Cooper, & Armstrong, 2009).

Invasive zebra mussels (*Dreissena polymorpha*): have been known to block power intake pipes at power plants and water treatment facilities (Rosaen, Grover, & Spencer, 2016). Although not currently a problem in South Carolina, the potential impact they could have on storm water drainage pipe systems is obvious. Additionally, runoff volume can negatively impact the marsh ecosystem by increasing flow velocity and creating rapid salinity fluctuations (Blair, et al., 2013; Tweel, et al., 2015).

Wildlife Viewing, Hunting & Fishing

Wildlife and their associated habitat contribute to a significant portion of the state's economy. Fishing, hunting, and wildlife viewing contributes to almost $3 billion in economic value to South Carolina based on a 2017 study (Willis & Straka, 2017). This is largely due to the undeveloped wildlife habitat that our state continues to attract visitors from all over the world. More data can be found in the most recent report on SC's Ocean Economy (S.C. Sea Grant Consortium, 2020).

Hunting

Hunting of many species is popular in the state, including deer, alligator, bear, turkey, trapping & commercial fur, small game, feral hog, coyote armadillo, migratory bird, dove and waterfowl (eRegulations, 2022). Waterfowl hunting is particularly important to the state's economy. Although of anthropogenic origin, these impoundments have been a fixture on the landscape long enough to serve valuable ecosystem functions, including supporting wildlife and buffering the coast (Green, Carloss, Rader, & Brasher, n.d.). Coastal impoundments are managed wetlands that were former rice fields or built for protection of the coast from subsidence, high water levels, and high salinity. These areas are highly productive waterfowl and wading bird habitat and support a myriad of other wildlife species. Water levels are managed using gates and other water-control structures and pumps which replicate natural cycles. SCDNR publishes harvest reports, which identify the number of over 20 species of waterfowl and migratory birds taken (SCDNR, 2022). A 2001 report estimated $38 million was spent in SC by over 70,000 hunters on migratory bird hunting (IAFWA, 2002).

Fishing

During flood events, fish populations can be impacted by the degradation of water quality with the increase of turbidity and runoff from surrounding land (bacteria, fertilizers and other nutrients, heavy metals, hazardous material, auto fluids, trash, and many others) (Clemson, 2022). With the influx of pollutants like nutrients and fertilizers, algal blooms can occur and cause fish kills (die-offs) when the algae growth consumes the oxygen in the water column, thus decreasing the available oxygen that other organisms need to live (Florida Fish and Wildlife Conservation Commission, 2022). An additional source of oxygen demand placed on aquatic systems during and following flood events is the organic detritus that enters aquatic systems during and following flood events. As these materials breakdown the result can be oxygen depletions can stress aquatic organisms sometimes to the point of mortality.

An even greater concern associated with flooding of small impoundments or ponds is the loss of what may be non-native species into public waters that can contribute to adverse impacts on native biota from the introduction of non-native often invasive species. During flood events, smaller water bodies, like ponds, that are normally isolated from other water bodies can overflow and allow for stocked fish to escape into nearby streams and rivers or the reciprocal problem of the introduction of invasive species or other fish species that are not a part of the pond management plan (Clemson, 2022).

Mobile Homes

Mobile homes could be considered one of the most vulnerable residential building types. The mobile or manufactured homes built today must meet the same general requirements as stick built or conventional housing. These homes can be used with or without a permanent foundation but should be elevated and anchored to a permanent foundation to resist flooding, collapse, or lateral movement (FEMA, 2020). Therefore, the vulnerability of these homes can depend on their age and anchoring.

The vulnerability of mobile homes, and the recovery of those who live there, is complicated by common ownership in an arrangement where many residents own their individual homes but rent the land underneath (Rumbach, Sullivan, & Makarewicz, 2020). This often occurs in mobile home parks. While there is no statewide database of mobile homes, the Department of Homeland Security (DHS) maintains a database of mobile home parks, which represent communities where these homes are concentrated (Figure 33 & Figure 34).

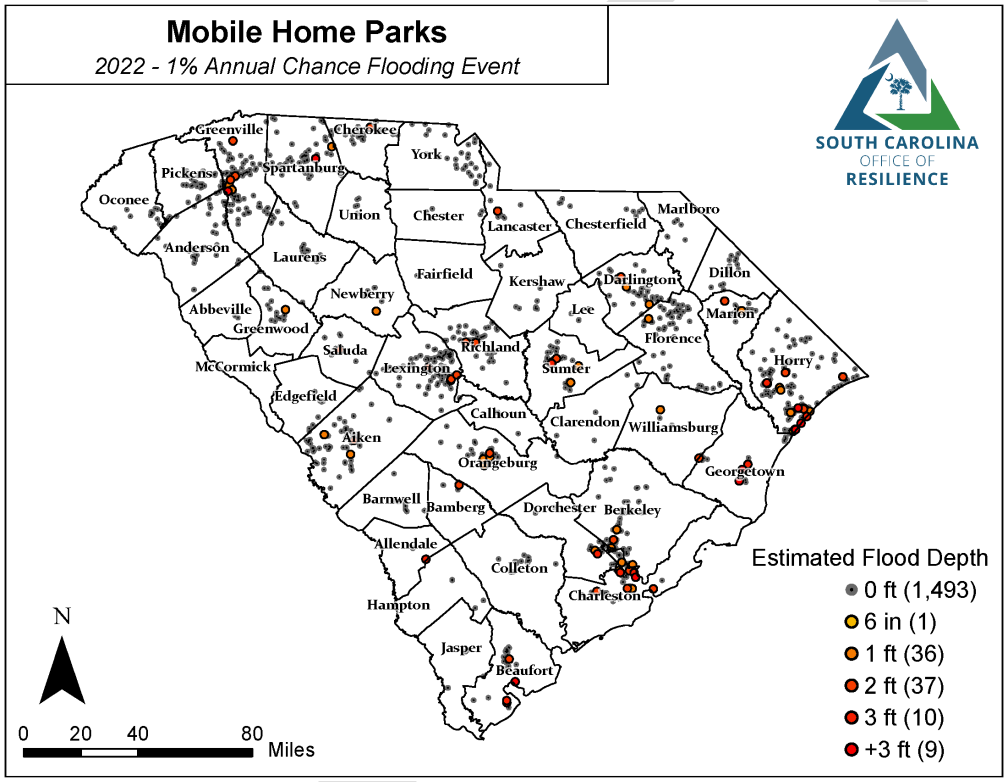


Figure 22: Estimated flooding of mobile home parks in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

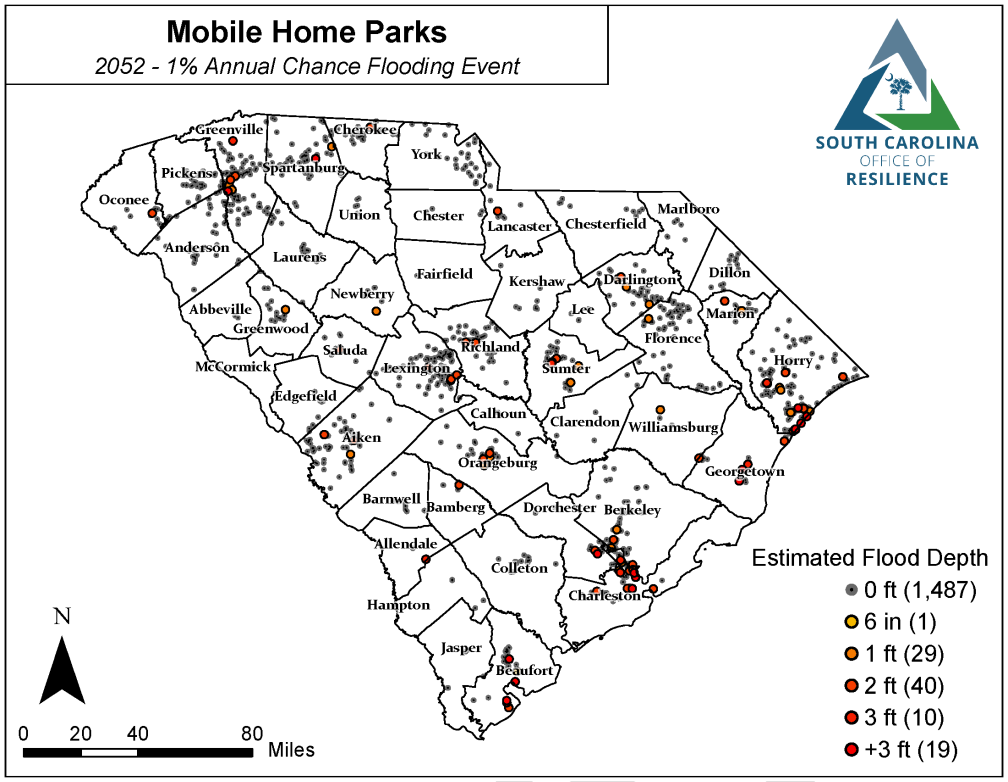


Figure 23: Estimated flooding of mobile home parks in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Commercial & Residential Properties

The parcel level data described above was used to quantify the vulnerability of individual properties across the state. The figures below show the location and number of parcels inundated greater than 6 inches, 1 foot, 2 feet, 3 feet and 6 feet in the 2022 (Table 7, Figure 22 - Figure 26) and 2052 (Table 8, Figure 27 - Figure 31) 1% annual chance flooding events. Appendix B, list estimated count of properties impacted of a 1% annual chance flooding event by county.

Table 7: Number of parcels estimated to see greater than 6 inches and greater than 6 feet of inundation in 1% annual chance flood event in 2022 and 2052 statewide. First Street Foundation identifies 2,334,328 parcels in South Carolina currently with their dataset.

Count of Potentially Inundated Parcels					
Year	>6 inches	>1 foot	>2 feet	>3 feet	>6 feet
2022	306,118	244,431	155,426	108,804	43,246
2052	340,901	277,224	187,682	141,585	63,762

Table 8: Statewide summary of commercial loss by inundation level for a 1% annual chance flood event in 2022 & 2052

Count of Potentially Inundated Commercial Parcels						
	2021			2051		
	Count	Total Loss ($)	Avg Days Loss	Count	Total Loss ($)	Avg Days Loss
>6 inches	8,838	1,869,247,287	68	10,707	2,342,389,629	75
>1 foot	6,801	1,725,887,130	78	8,536	2,195,073,643	85
>2 feet	4,304	1,355,536,642	99	6,089	1,869,013,394	102
>3 feet	2,884	1,069,844,028	113	4,448	1,583,387,349	113
>6 feet	1,312	540,956,282	142	2,012	852,832,771	140

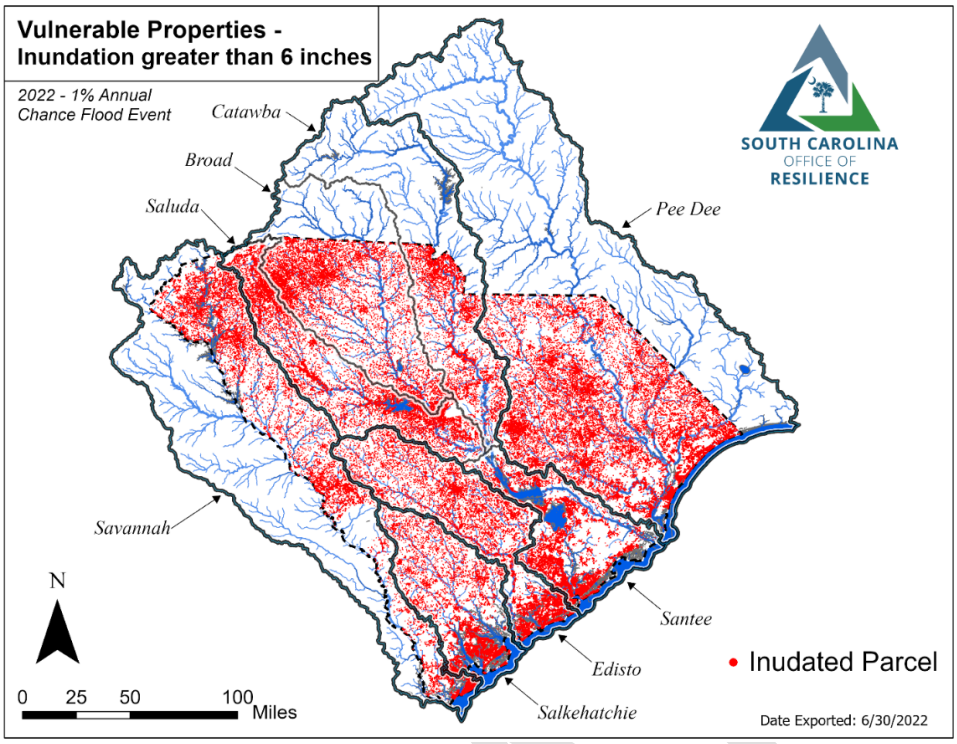


Figure 24 Properties estimated to be inundated greater than 6 inches in the 2022 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

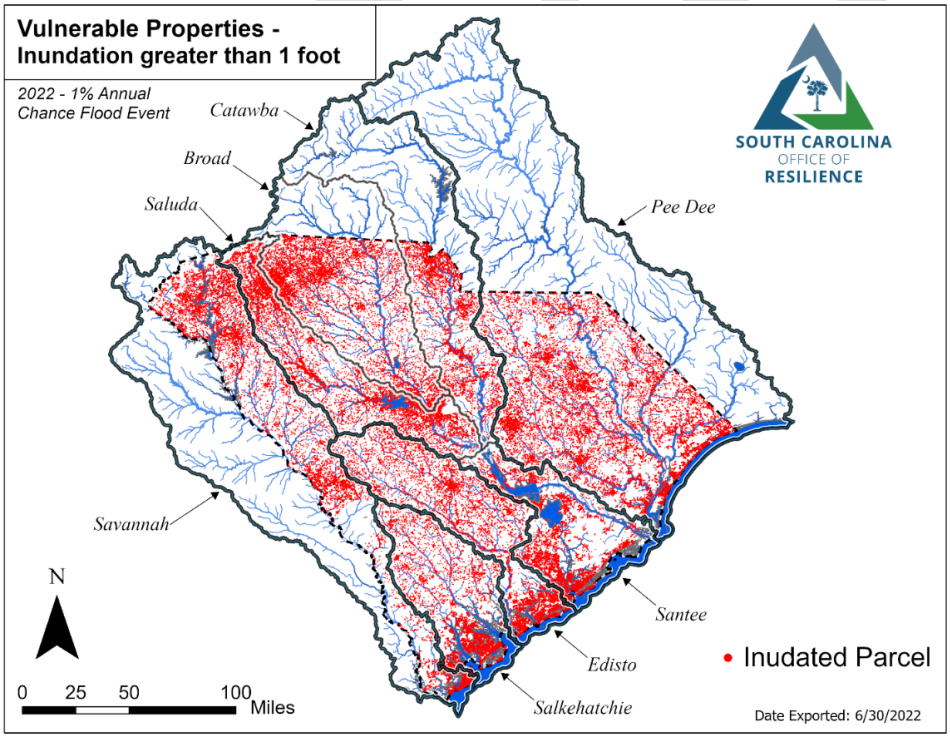


Figure 25 Properties estimated to be inundated greater than 1 foot in the 2022 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

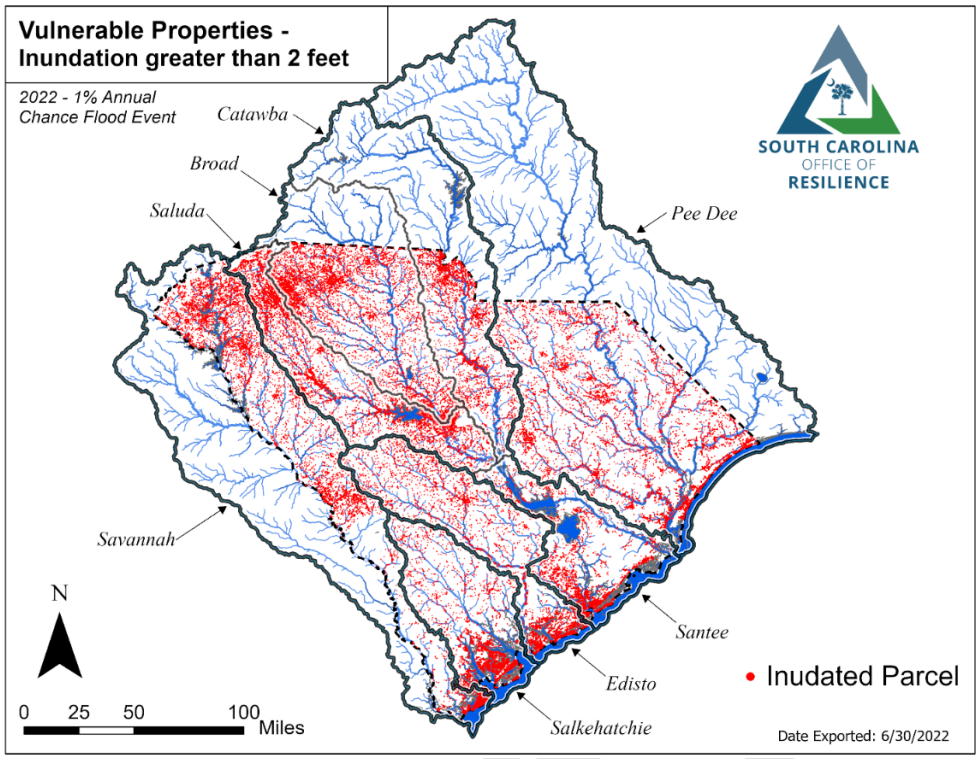


Figure 26 Properties estimated to be inundated greater than 2 feet in the 2022 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

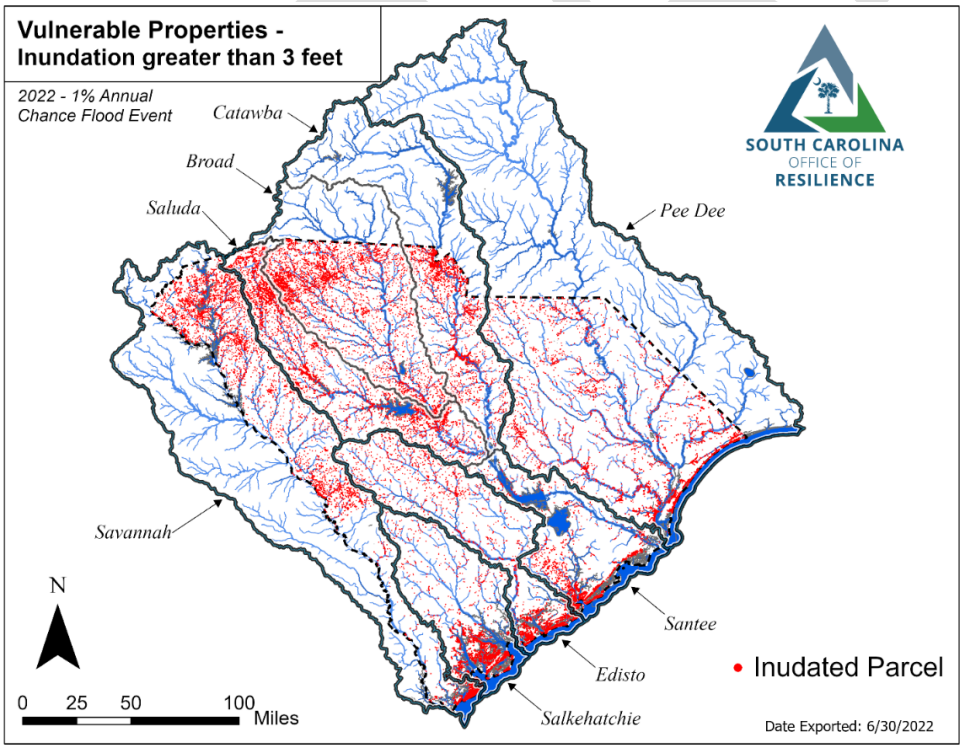


Figure 27 Properties estimated to be inundated greater than 3 feet in the 2022 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

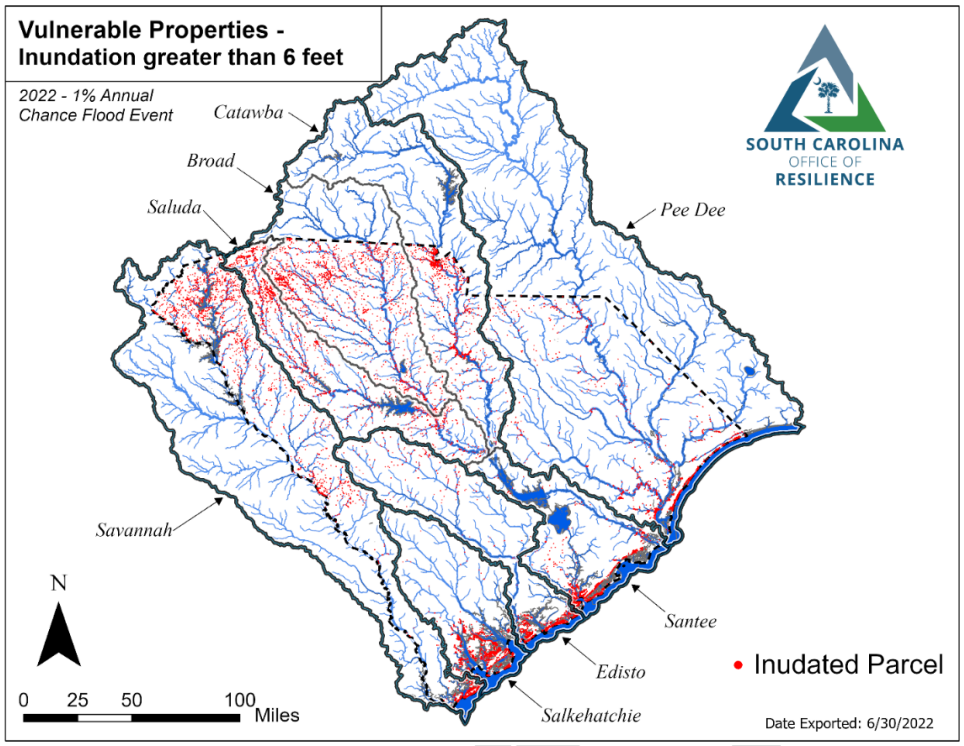


Figure 28 Properties estimated to be inundated greater than 6 feet in the 2022 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

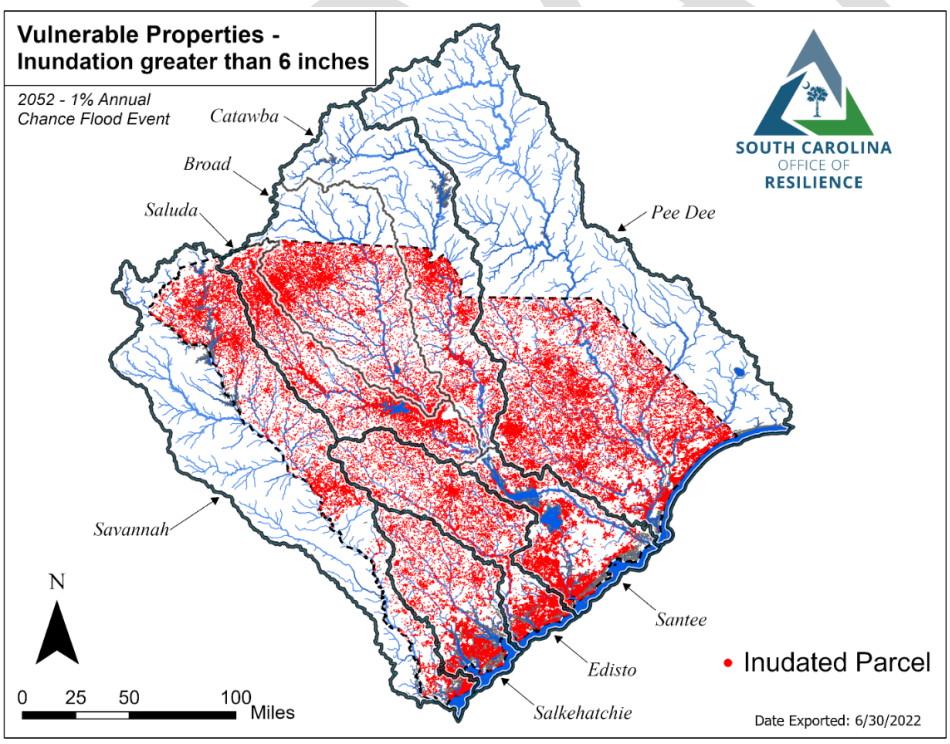


Figure 29 Properties estimated to be inundated greater than 6 inches in the 2052 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

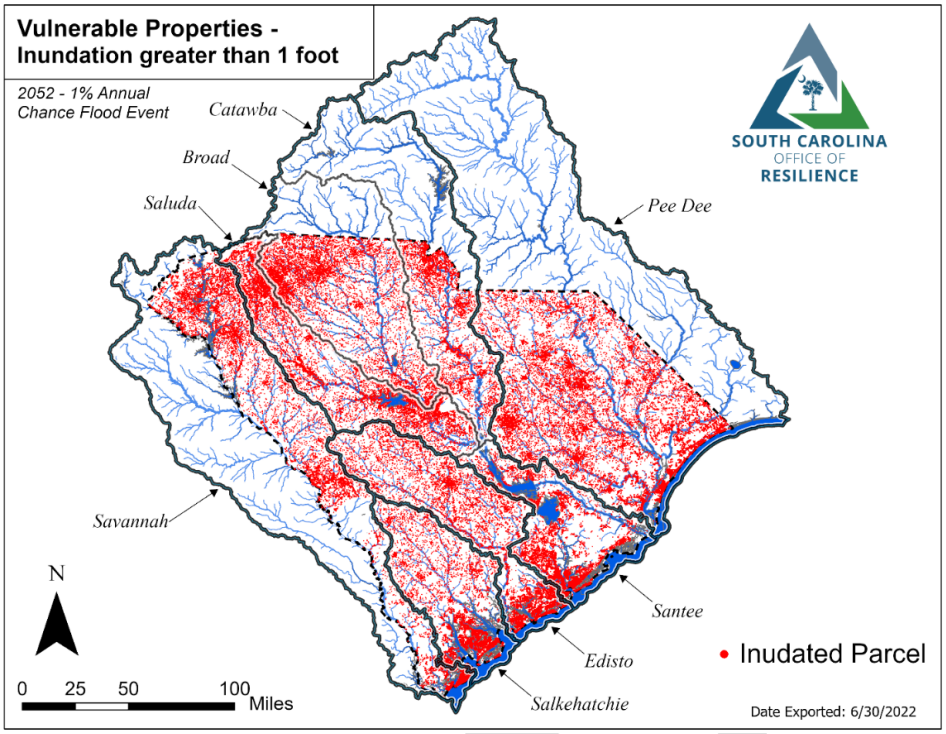


Figure 30 Properties estimated to be inundated greater than 1 foot in the 2052 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

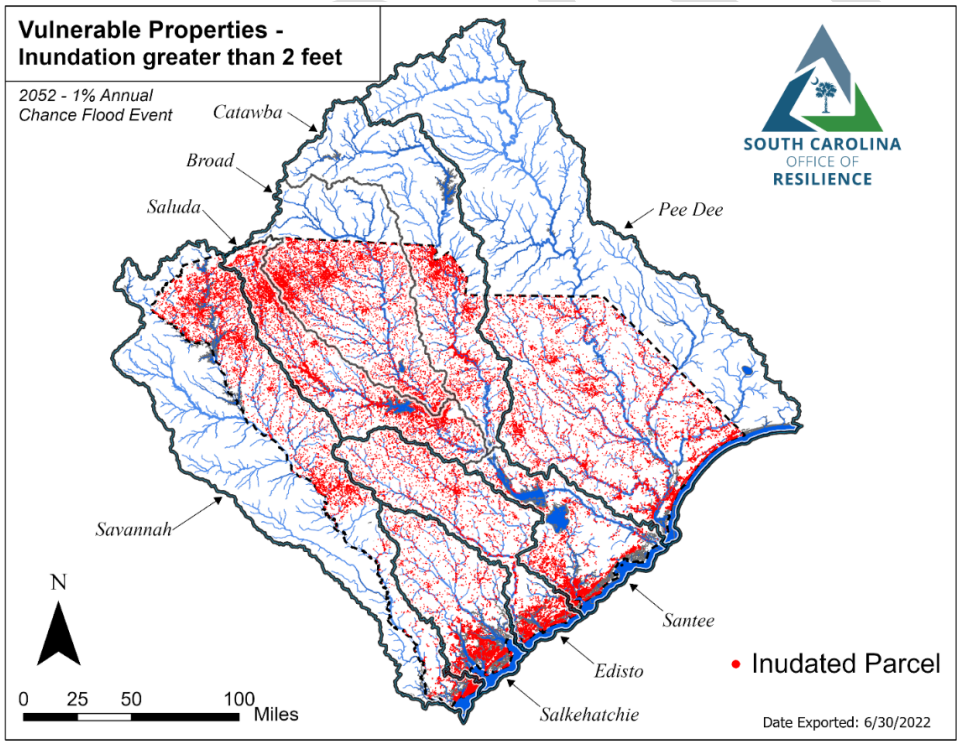


Figure 31 Properties estimated to be inundated greater than 2 feet in the 2052 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

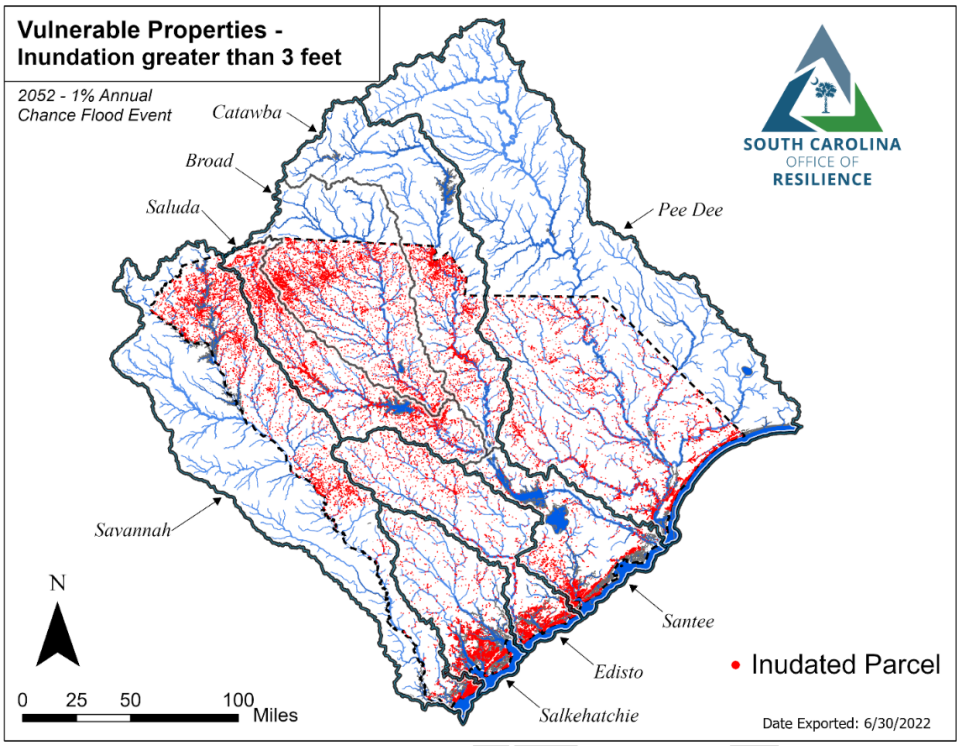


Figure 32 Properties estimated to be inundated greater than 3 feet in the 2052 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

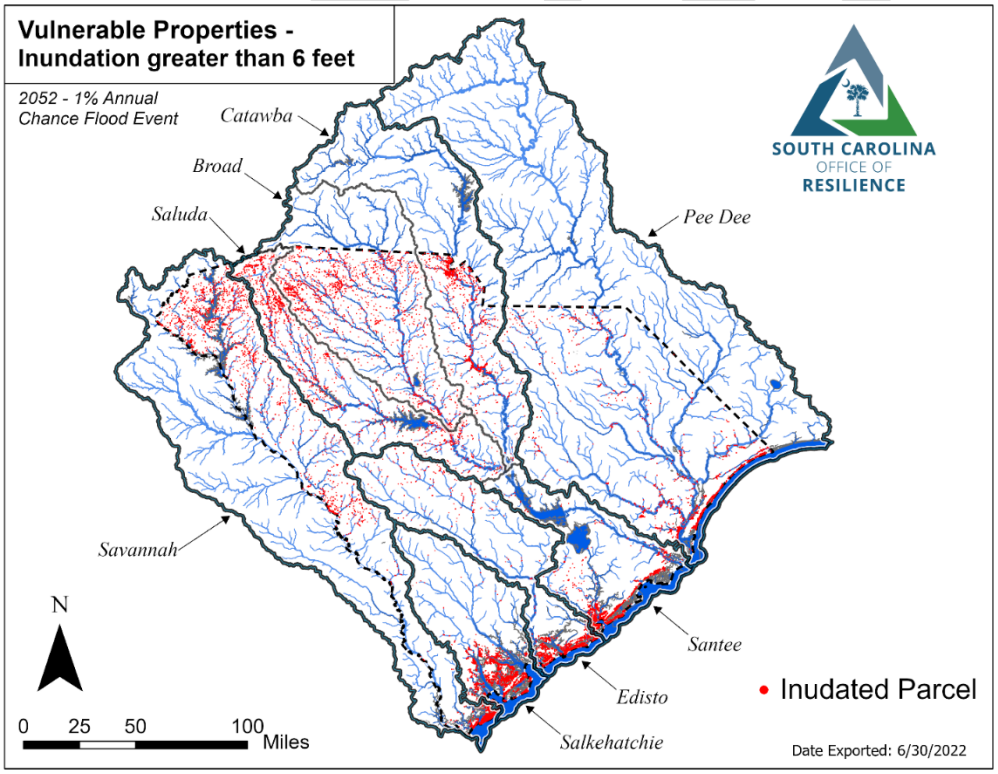
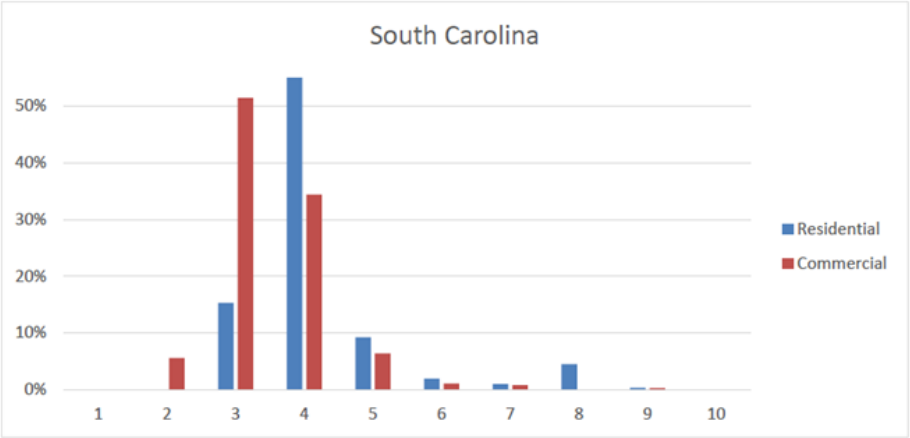


Figure 33 Properties estimated to be inundated greater than 6 feet in the 2052 1% annual chance flooding event. Flood risk data provided by the First Street Foundation Flood Risk Statistics, V2.0.

Building Codes

To look at the vulnerability of the buildings on these properties, the strength of our building codes and their enforcement can be investigated. FEMA Region 4's 2021 Building Code Adoption Tracking Fact Sheet gives South Carolina a grade of 91.5%, for adopting most recent International Codes without weakening of any resilience provisions, but states that the state is "not fully resistant because some jurisdictions with high flood risk do not participate in the NFIP" (FEMA, 2021). The Building Code Effectiveness Grading Schedule is designed to assess building codes and their enforcement, with an emphasis on requirements designed to mitigate natural hazard losses. This grading scale can be used to lower insurance costs, which produces an incentive to rigorously enforce codes. With a raw score up to 100, and a possible rating class between 1 (exemplary commitment of building code enforcement) and 10, South Carolina has an average score of 4 for both the residential and commercial code (Figure 32). Community officials can get their local scores by emailing BCEGS_info@verisk.com (Insurance Services Office).



State Average

	Score	Class
Commercial	75.12	4
Residential	68.41	4

Figure 34: Average BCEGS Score for South Carolina (Insurance Services Office)

Anthropogenic Systems Vulnerability

Water Supply

South Carolina DHEC Bureau of Water maintains an extensive dataset that includes the location of water suppliers in the state. Public water suppliers retrieve the water from two sources, surface water (lakes and rivers) and groundwater (via wells). Surface water intakes can be fixed pipes or soft hoses in the water source with the pump station nearby, with larger municipalities using canals to divert water or locate on a dam to ensure a stable water source. Water supply groundwater wells are more likely to be found in the coastal plain of South Carolina due to access to availability of productive aquifers. Pump station and well locations are reported to SCDHEC during the permitting and registration process. The figures below quantify the number of public water supply facilitates impacted by the 2020 (Figure 35) and 2050 (Figure 36) 1% annual chance flood events.

The Columbia Canal originally opened in 1824 as a transportation alternative to the railroads to connect the upstate to the port in Charleston. Later additions of water supply and power in the later 19th and early 20th century (Marsh, 2015). During the historic 2015 flooding in Columbia, a 60-foot wide breach, emptying the canal into the Congaree River, compromising the primary water supply to the roughly 400,000 people that rely on the canal for water (Underwood, 2021; Marsh, 2015). The City of Columbia, Columbia Water, and FEMA kicked off repairs of the canal, with agreements announced in 2020 and the construction stating in 2022 (Columbia Water, 2022; Underwood, 2021).

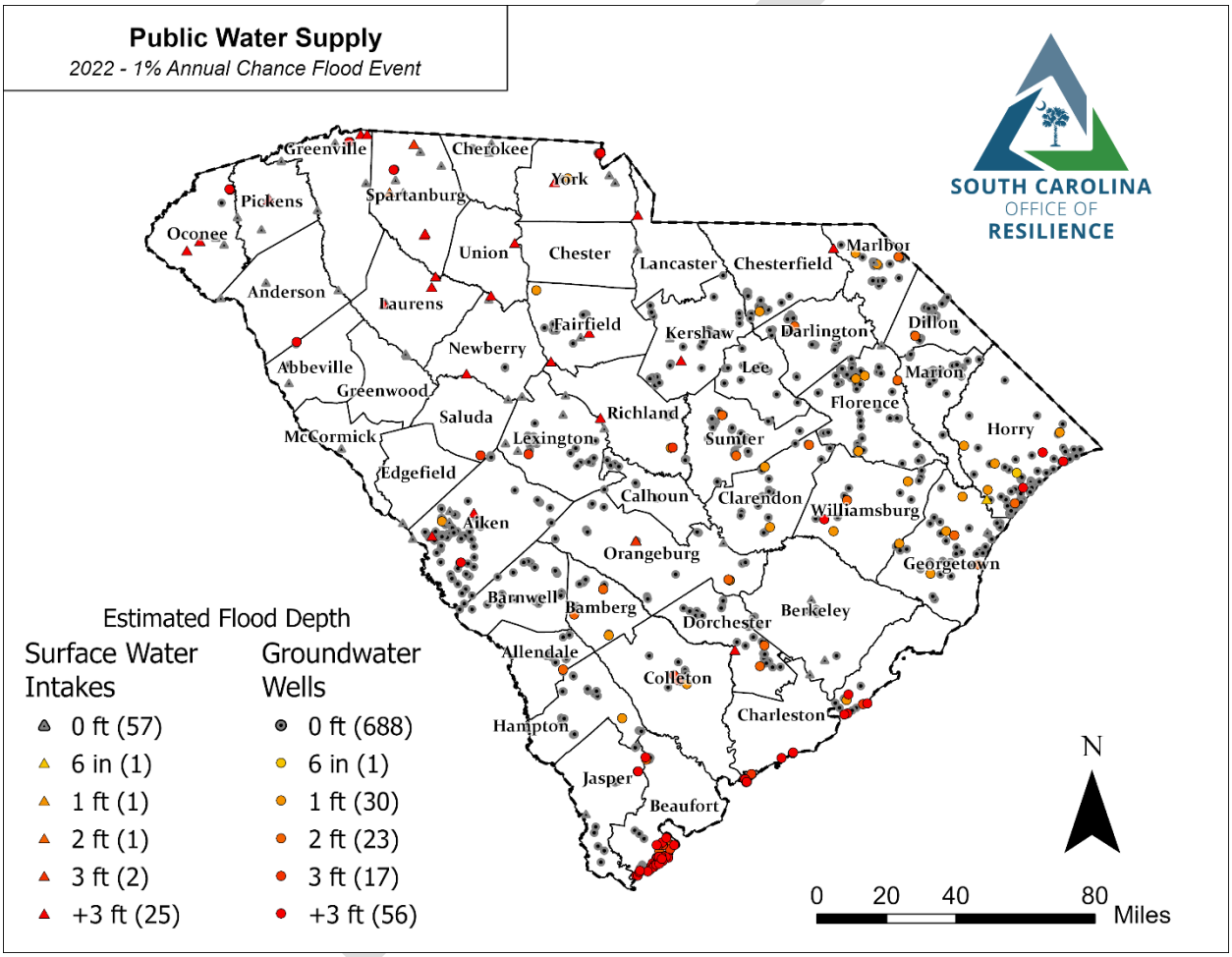


Figure 35: Estimated flooding of Public Water Supply in the 2022 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

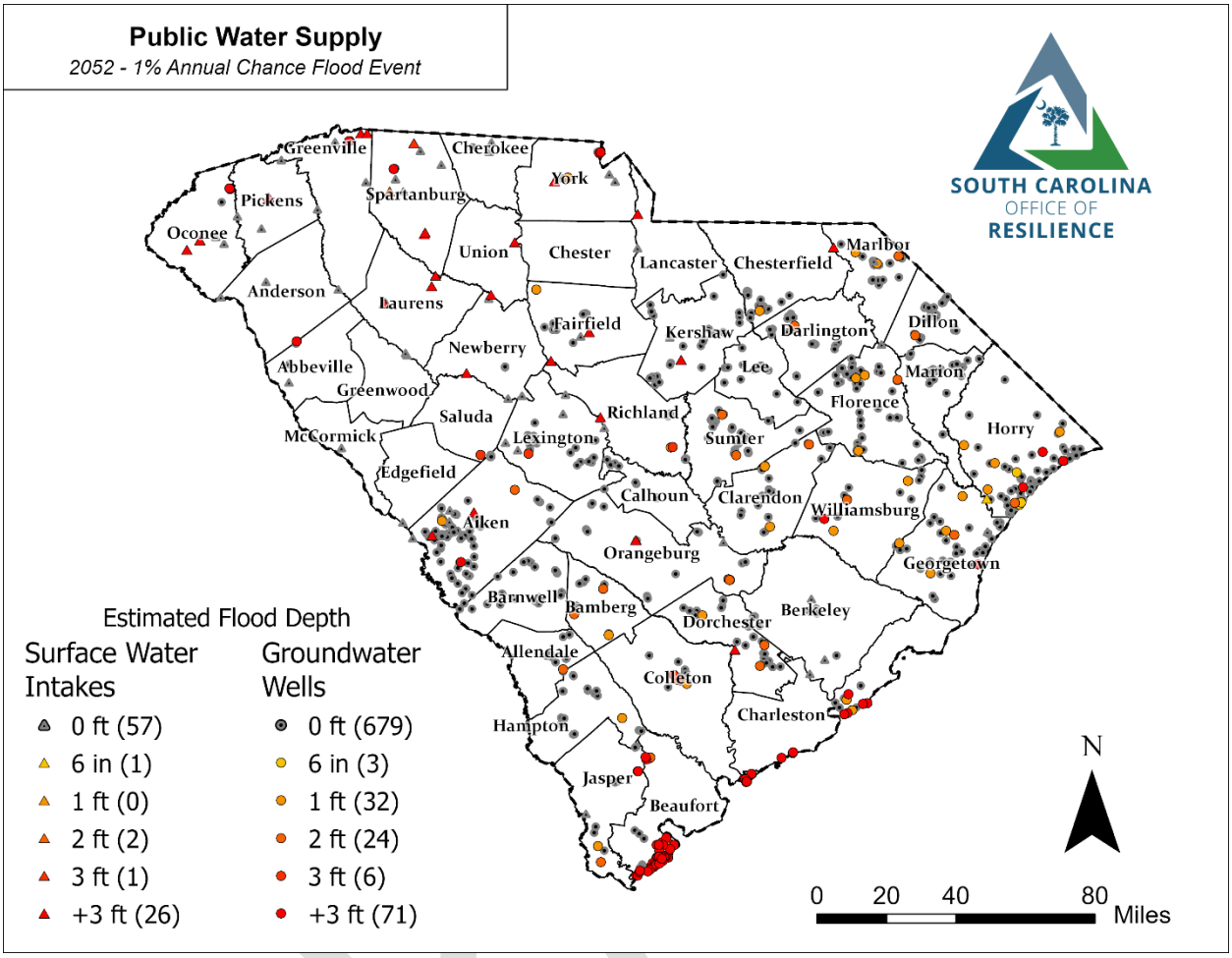


Figure 36: Estimated flooding of Public Water Supply in the 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Hazardous Waste Locations

Sewerage System Discharge

The National Pollutant Discharge Elimination System (NPDES) regulates potential discharge of pollutants into the waters across the nation and in South Carolina, is maintained by SCDHEC. Using the sewerage system user type in the NPDES permits, supplied by SCDHEC, the location of the discharge pipe can be used as a proxy for the potential flood vulnerability of the facility discharging the sewerage. The figures below quantify the number of public water supply facilitates impacted by the 2020 (Figure 37) and 2050 (Figure 38) 1% annual chance flood events.

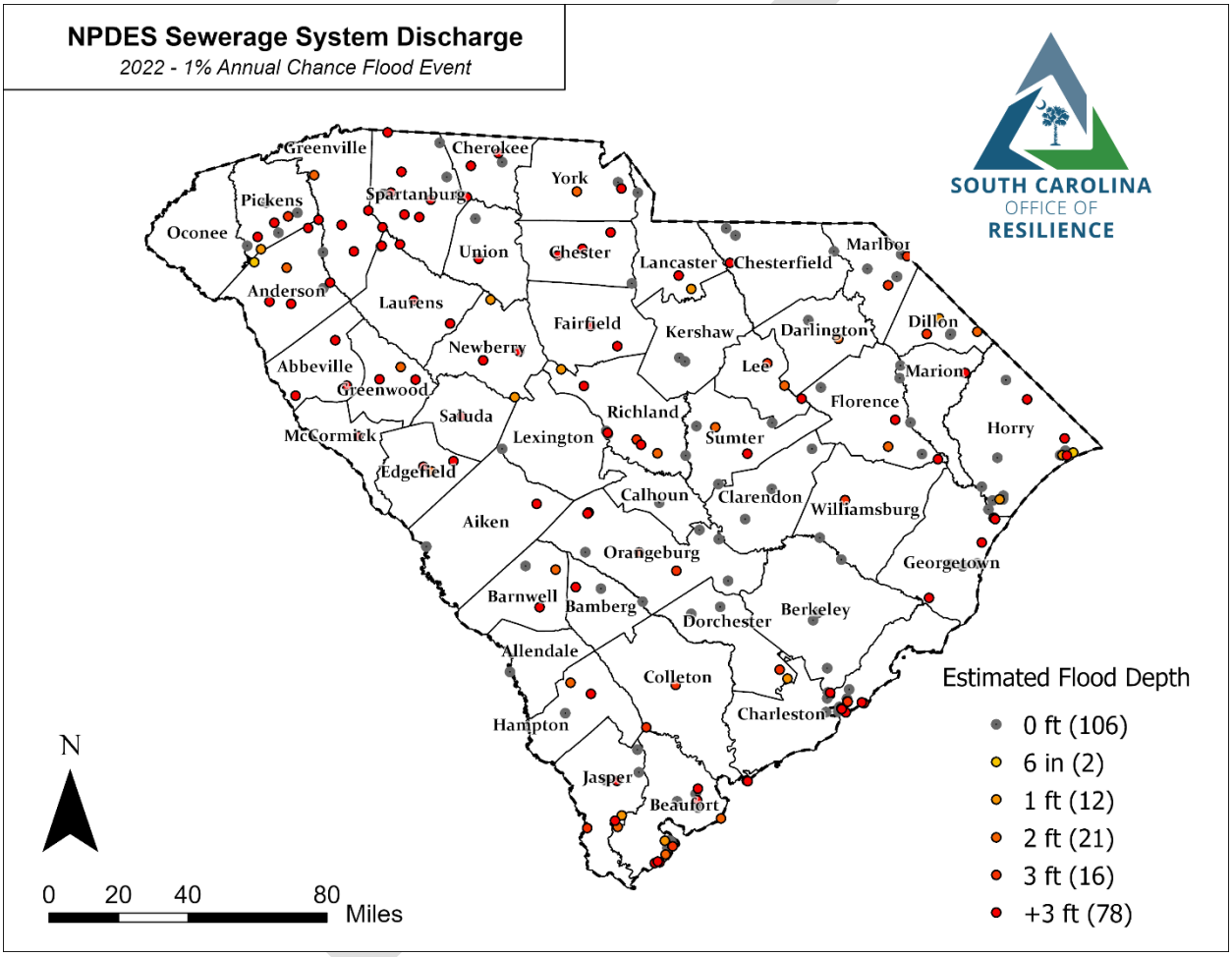


Figure 37: Estimated flooding of NPDES sewerage system discharge in the 2022 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

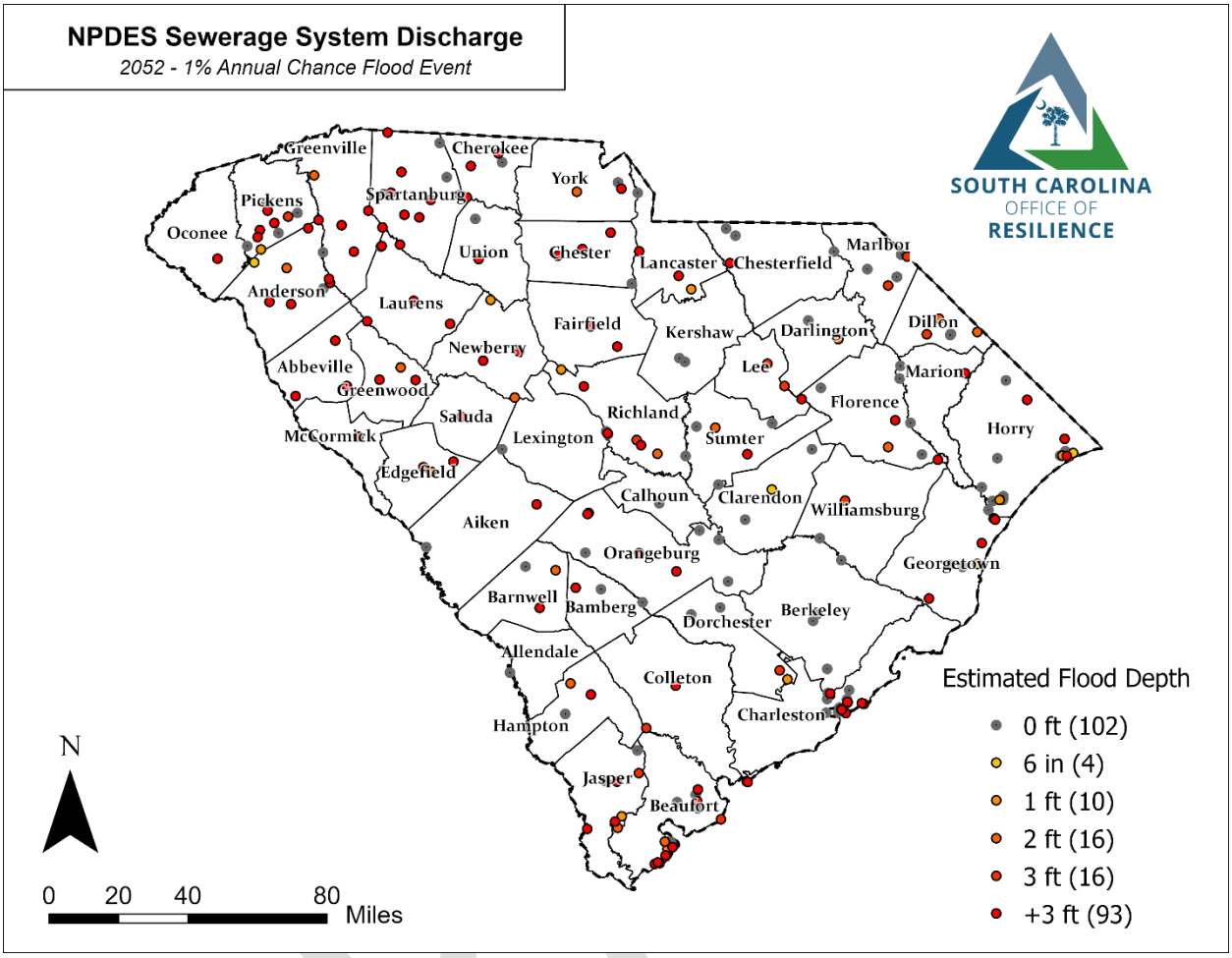


Figure 38: Estimated flooding of NPDES sewerage system discharge in the 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Dry Cleaners

Dry cleaners are included in the South Carolina Hazardous Waste Management Act, which defines a dry-cleaning facility as a professional commercial establishment for the purpose of cleaning clothing or other fabrics utilizing a process that involves the use of dry-cleaning solvent, which can contaminate water or soil if released. Despite containment measures, many small solvent releases occur during normal operations. SC environmental regulatory standards only allow a few parts per billion of the solvent to be present in the ground or groundwater under a facility (SC DHEC, n.d.). Contamination has the potential to be even more widespread if solvent comes in contact with flood water. The figures below show the estimated flooding of dry cleaners in the 2022 (Figure 39) and 2052 (Figure 40) 1% annual chance flooding event.

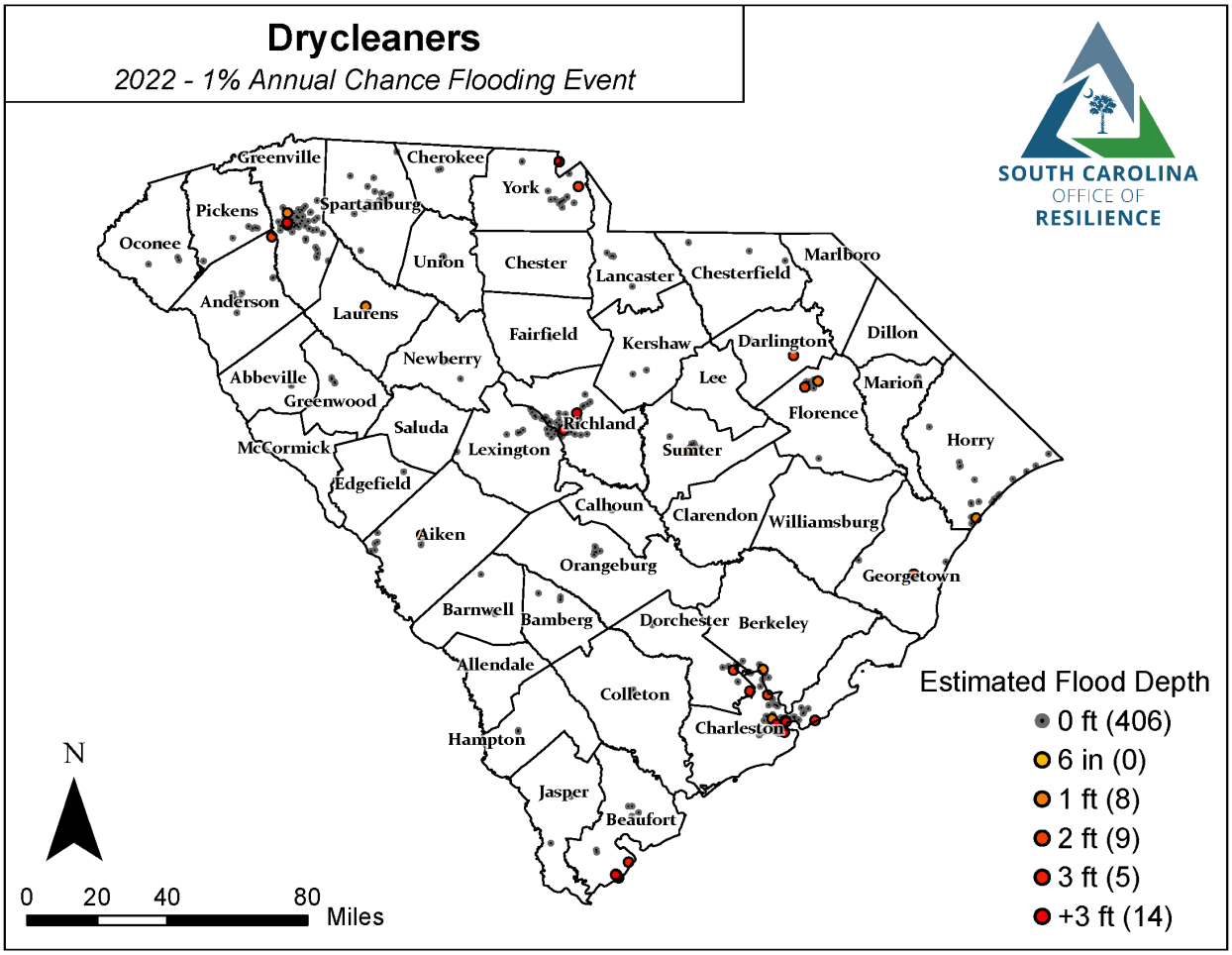


Figure 39 Estimated flooding of dry cleaners in the 2022 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

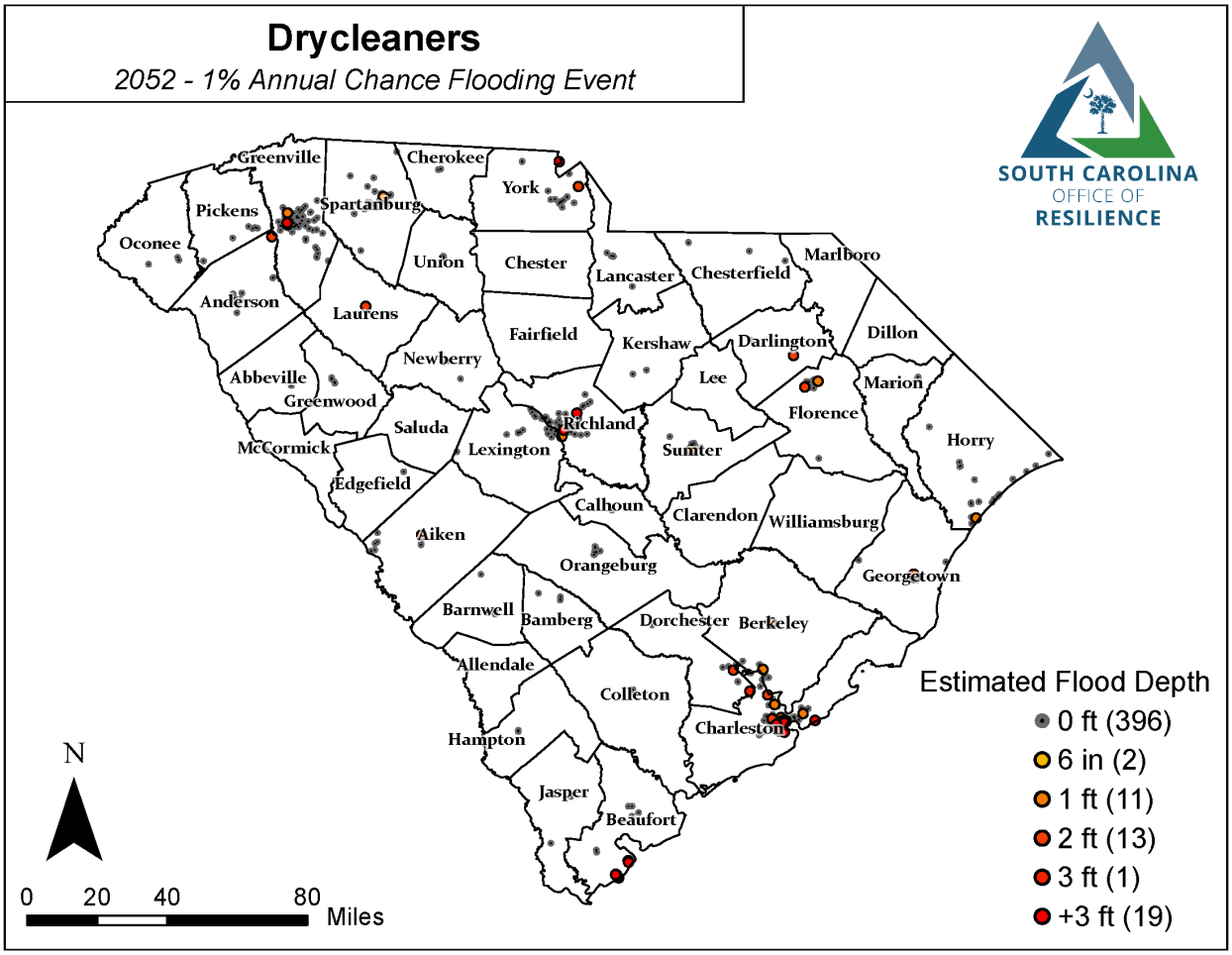


Figure 40 Estimated flooding of dry cleaners in the 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Mines

About 500 mines are actively operating, with permits through DHEC, following the SC Mining Act (1974). There are several types of surface mining done in the state including open pit mining of granite for instance, as well as strip mines for sand, clay and gravel, and sand dredging from river bottoms (DHEC, n.d.). Regulation 89-10 through 89-350 states that all overburden and spoil shall be placed so as not to result in deposits of sediment in streams, lakes or on adjacent property and that permanent overburden piles shall not be placed in or infringe on natural drainageways of floodways, and that temporary piles should not be placed there unless proper designs are utilized (DHEC, 2003). However, the figures below show that some mines may be impacted under the First Street current (2022) and future (2052) scenario outside of these floodways (Figure 41 and Figure 42).

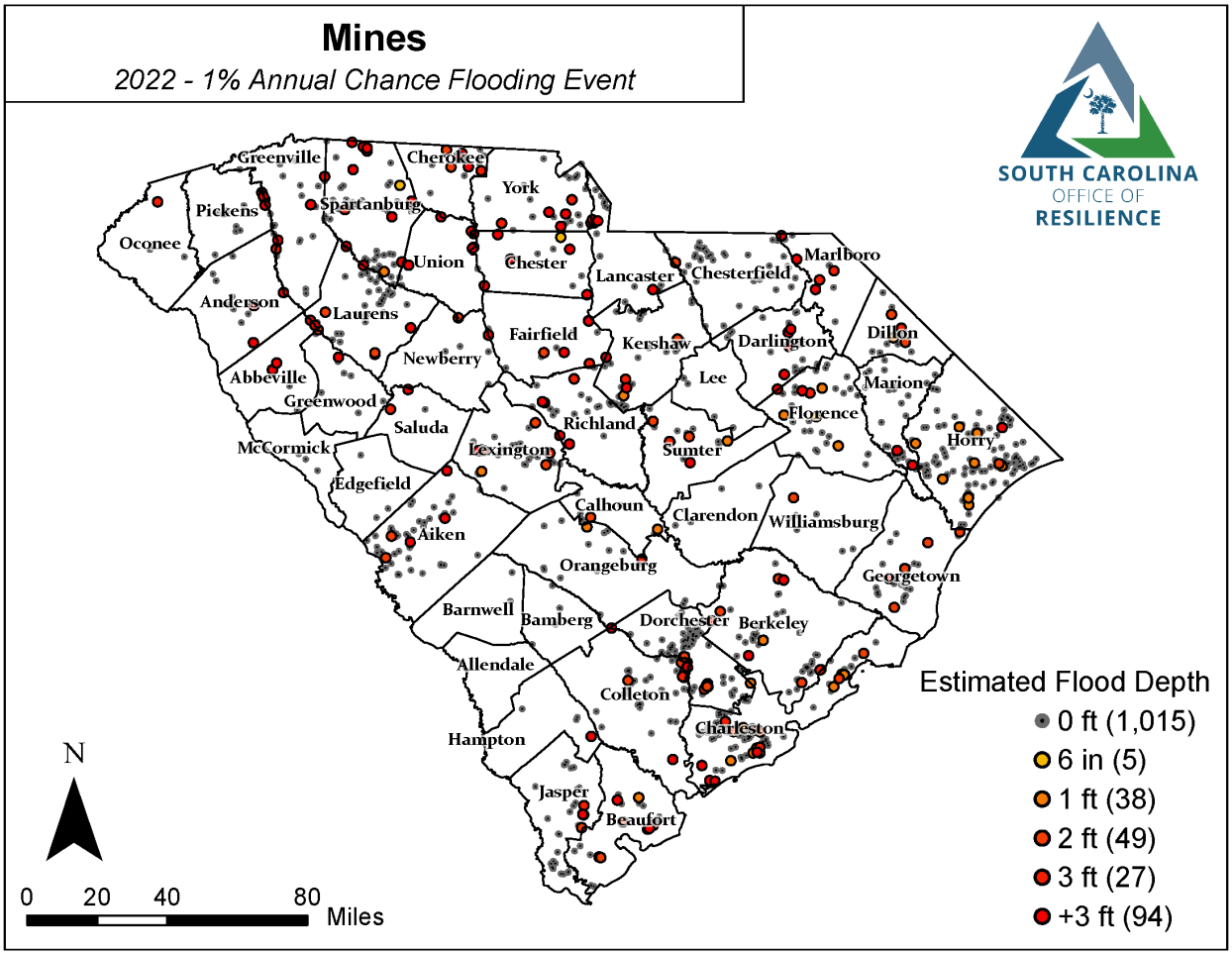


Figure 41 Estimated flooding of mines in the 2022 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

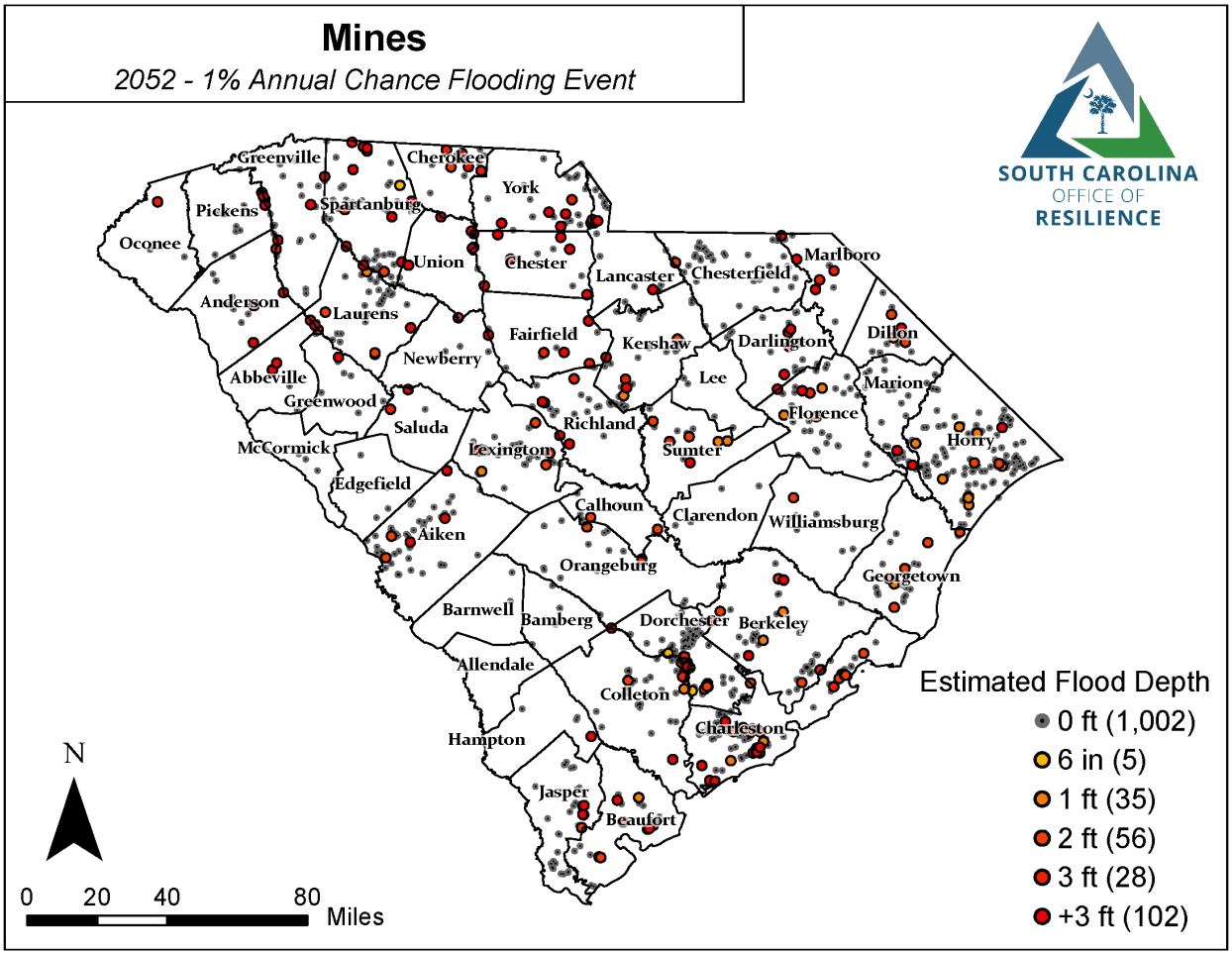


Figure 42 Estimated flooding of mines in the 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Solid Waste

The South Carolina Solid Waste Policy and Management Act defines a solid waste facility as all contiguous land, structures, other appurtenances, and improvements on the land used for treating, storing, or disposing of solid waste. A facility may consist of several treatment, storage, or disposal operational units such as landfills, surface impoundments, or a combination. Washout of solid waste and leachate by floodwater poses a hazard to human health and the environment. The South Carolina Solid Waste Policy and Management Act states that landfills shall not be located in the one-hundred-year floodplain unless it can be demonstrated "that engineering measures have been incorporated into the landfill design to ensure the landfill will not restrict flow of the one-hundred year base flood, reduce the temporary water storage capacity of the flood plain, or result in the washout of solid waste". Figure 43 and Figure 44 show the estimated flooding of solid waste landfills in 2022 and 2052 1% annual chance flooding event while Figure 45 and Figure 46 show the estimated flooding of all solid waste facilities.

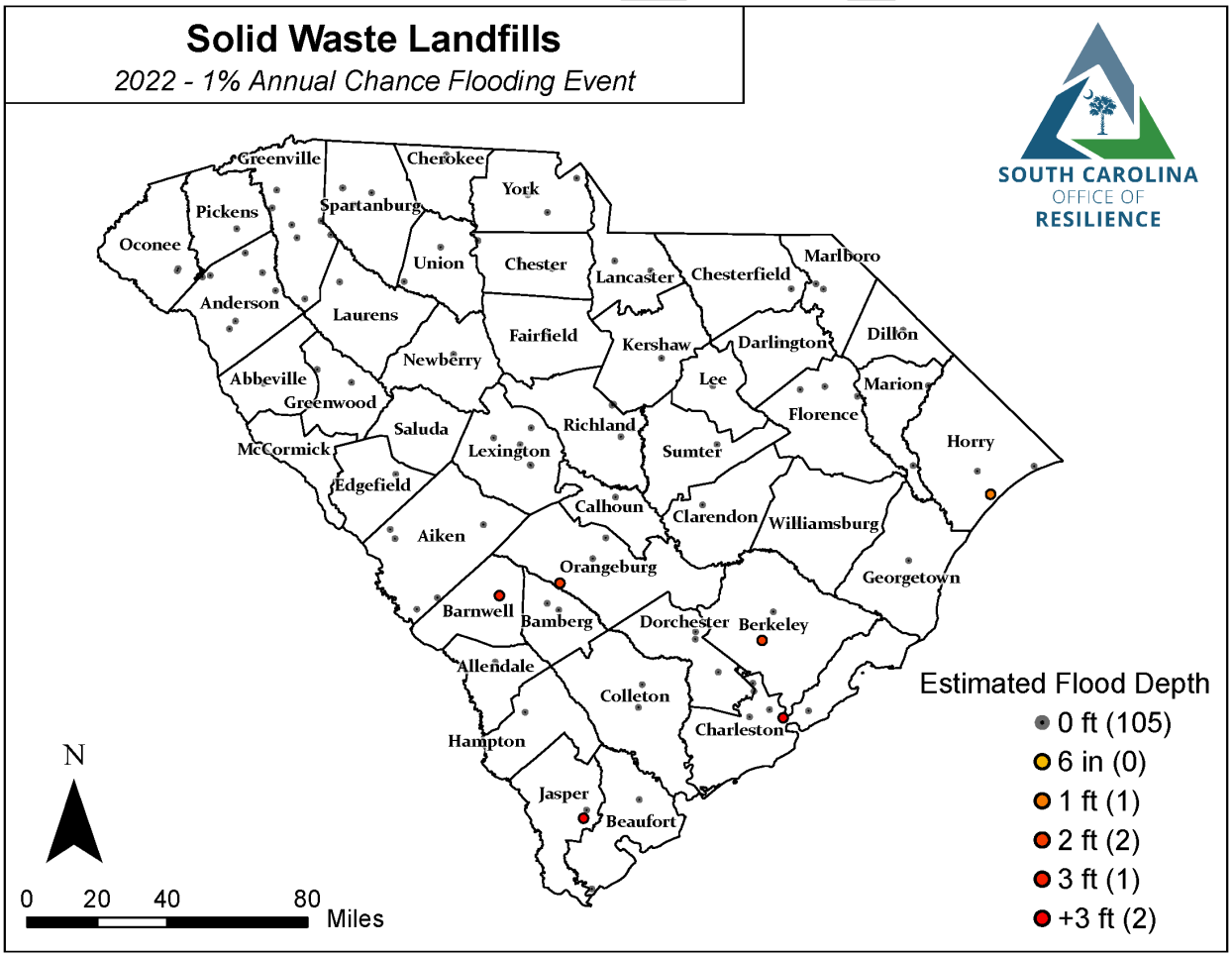


Figure 43: Estimated flooding of solid waste facilities in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

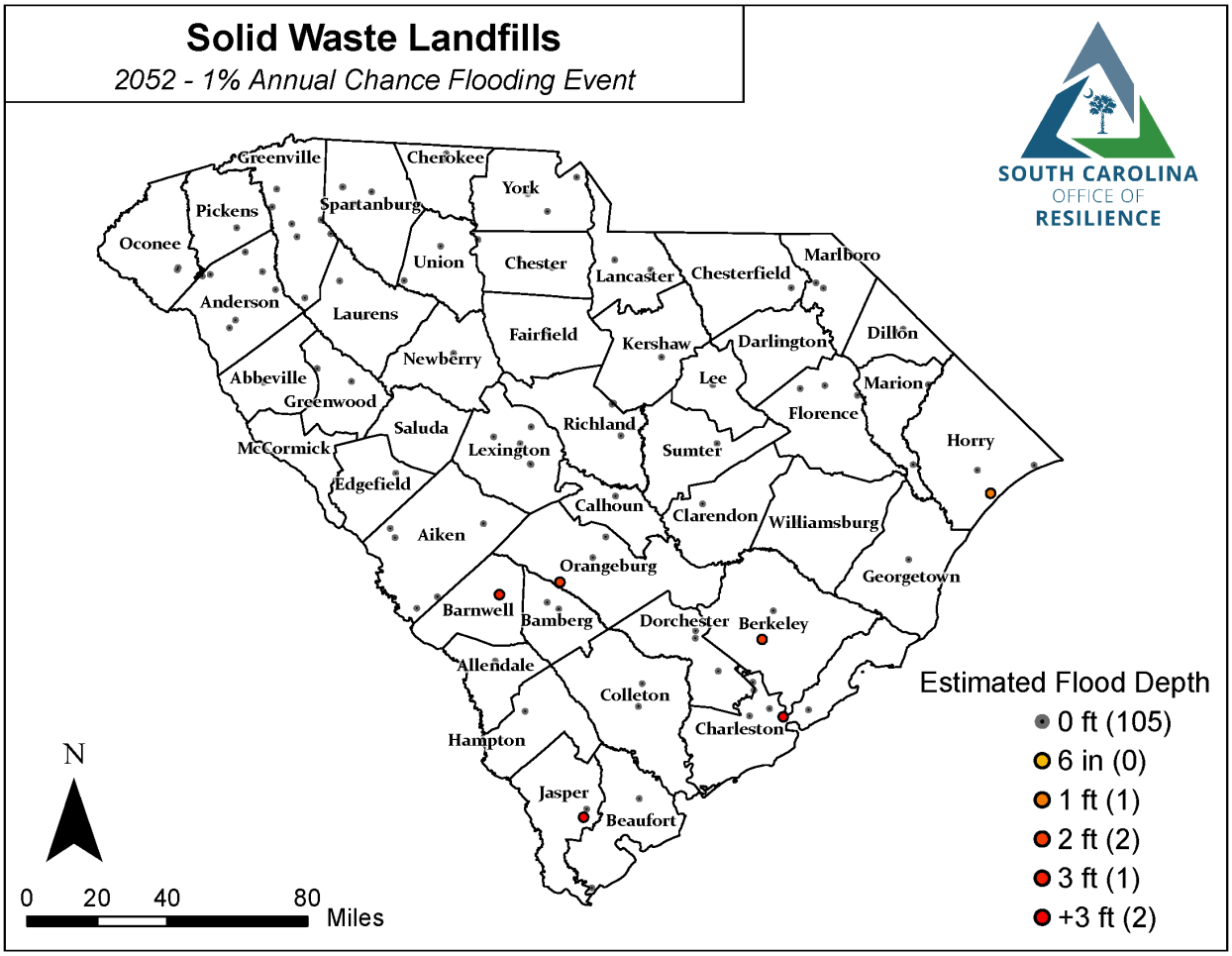


Figure 44: Estimated flooding of solid waste landfills in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

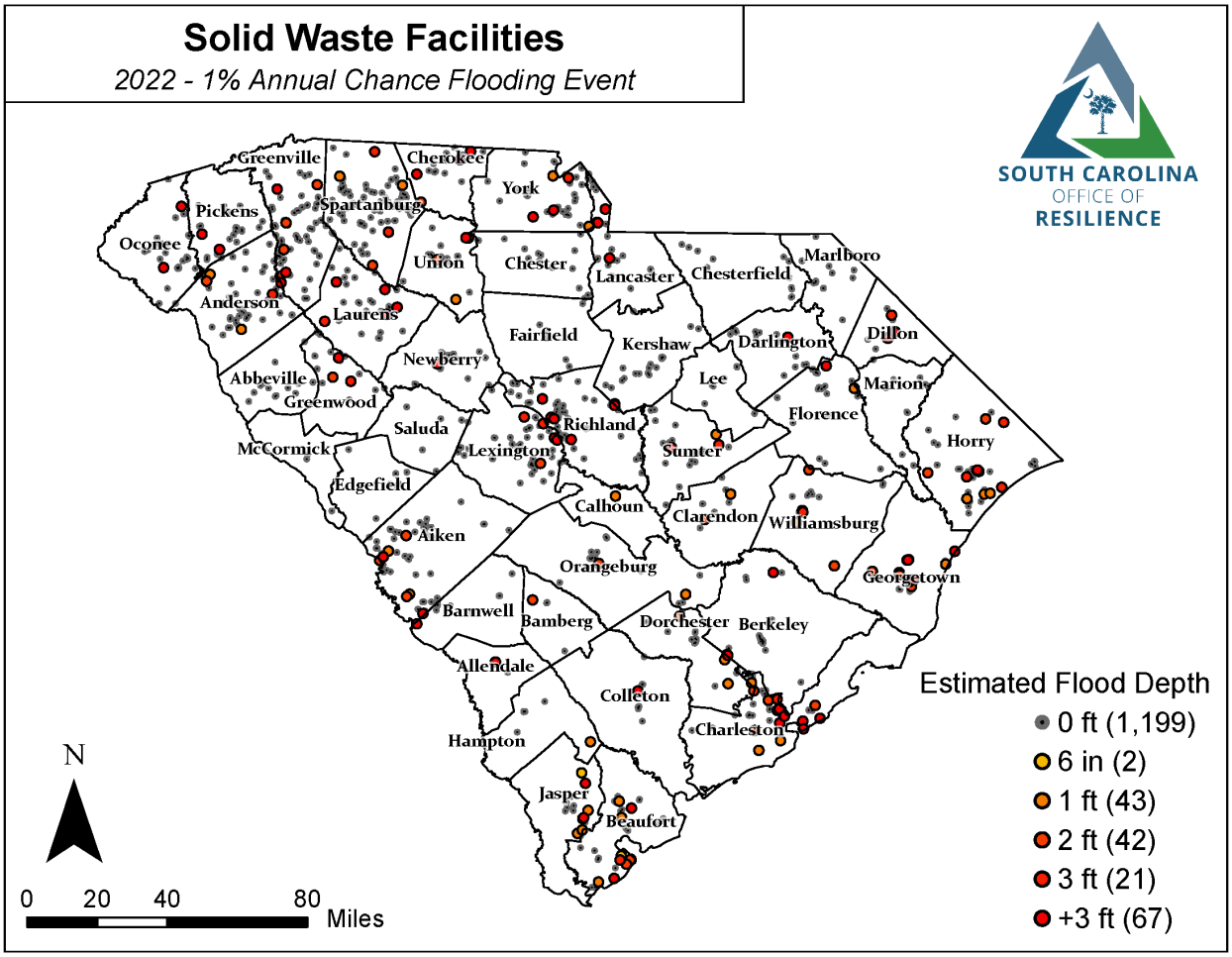


Figure 45 Estimated flooding of solid waste facilities in the 2022 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

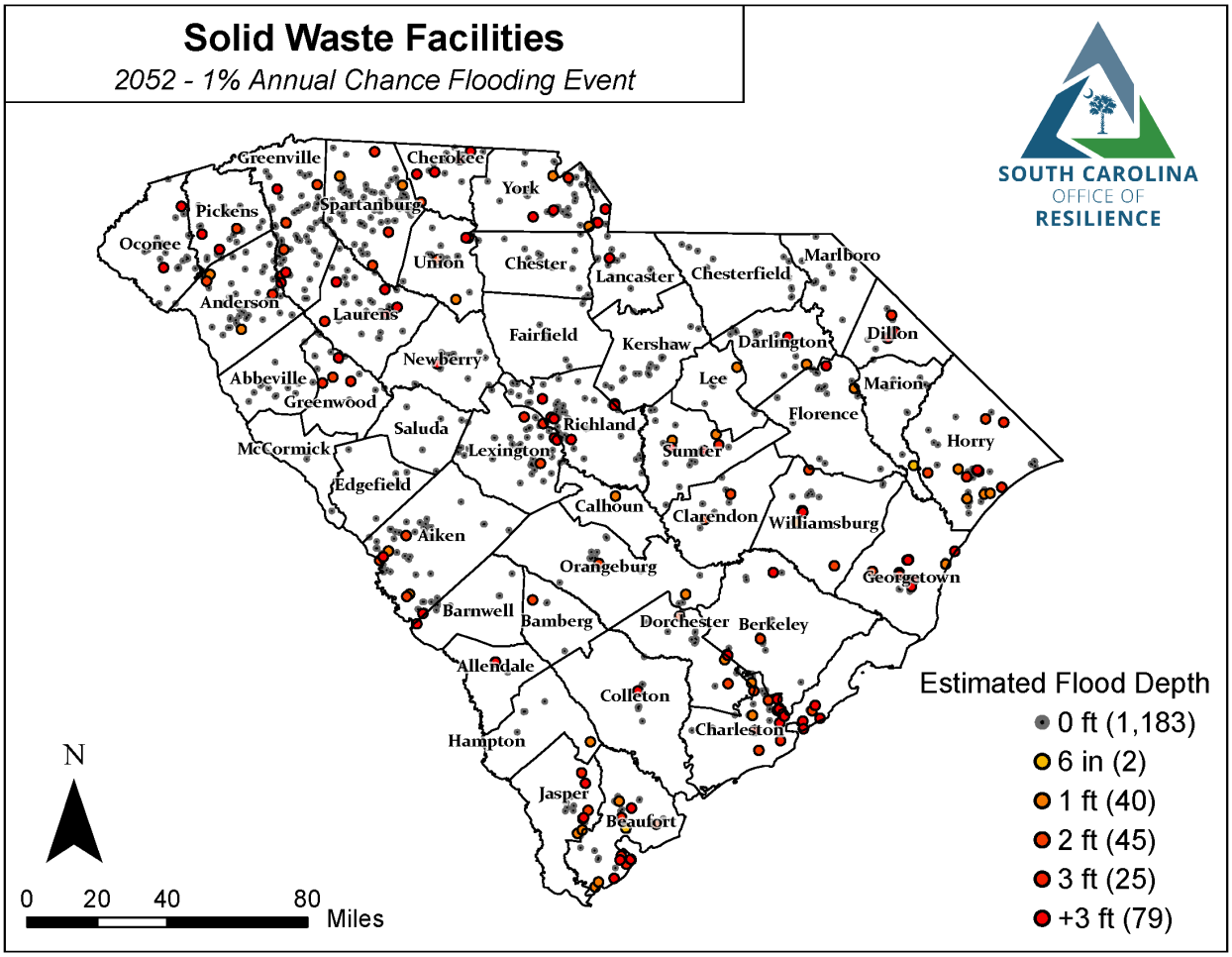


Figure 46 Estimated flooding of solid waste facilities in the 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

*Site Assessment, Re*mediation and Revitalization *(*SARR)

DHEC's Site Assessment, Remediation and Revitalization (SARR) Division manages the evaluation and restoration of sites where hazardous waste has polluted the environment. These sites include Brownfields, Superfund and State Voluntary Cleanup locations. According to preliminary data from DHEC, there are over 5800 sites across the state. Table 9 shows the estimated flood depth of these sites under both the 2022 and 2052 1% annual chance flooding event.

Table 9 Estimated flooding of DHEC Site Assessment, Remediation and Revitalization sites in the 2022 & 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Estimated Flood Depth	2022 1% Annual Flooding Event Number of Sites	2052 1% Annual Flooding Event Number of Sites
0 ft	5529	5482
6 inches	15	14
1 ft	46	53
2 ft	86	92
3 ft	44	46
+3 ft	139	172

TSD (Treatment, Storage and Disposal)

DHEC permits active treatment, storage and disposal facilities as authorized by the federal Resource Conservation and Recovery Act, which established a process for treating, transporting, storing and disposing of hazardous waste (DHEC, n.d.). The figures below show the estimated flooding of these facilities in 2022 (Figure 47) and 2052 (Figure 48) 1% annual chance flooding event.

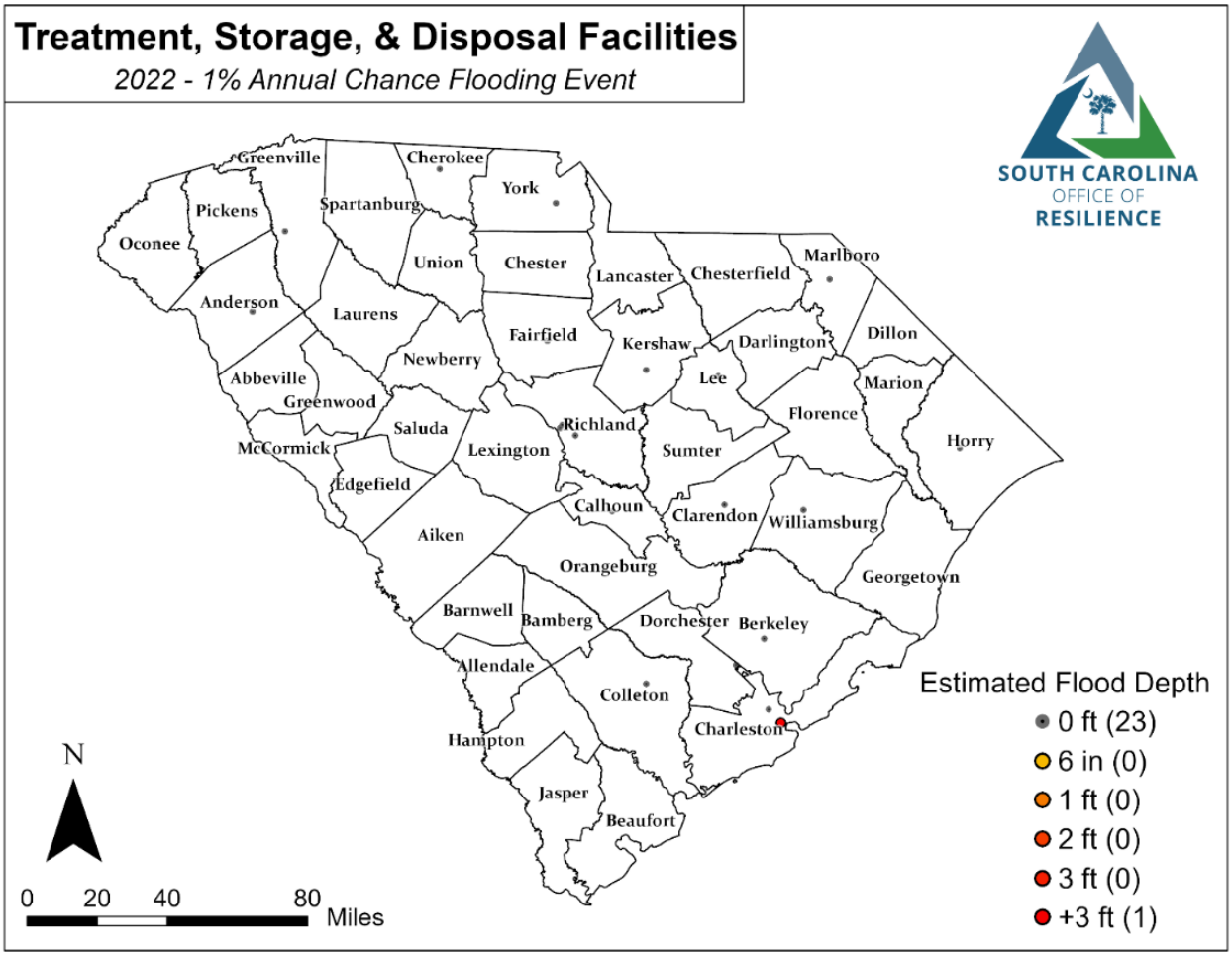


Figure 47 Estimated flooding of Treatment, Storage and Disposal Facilities in the 2022 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

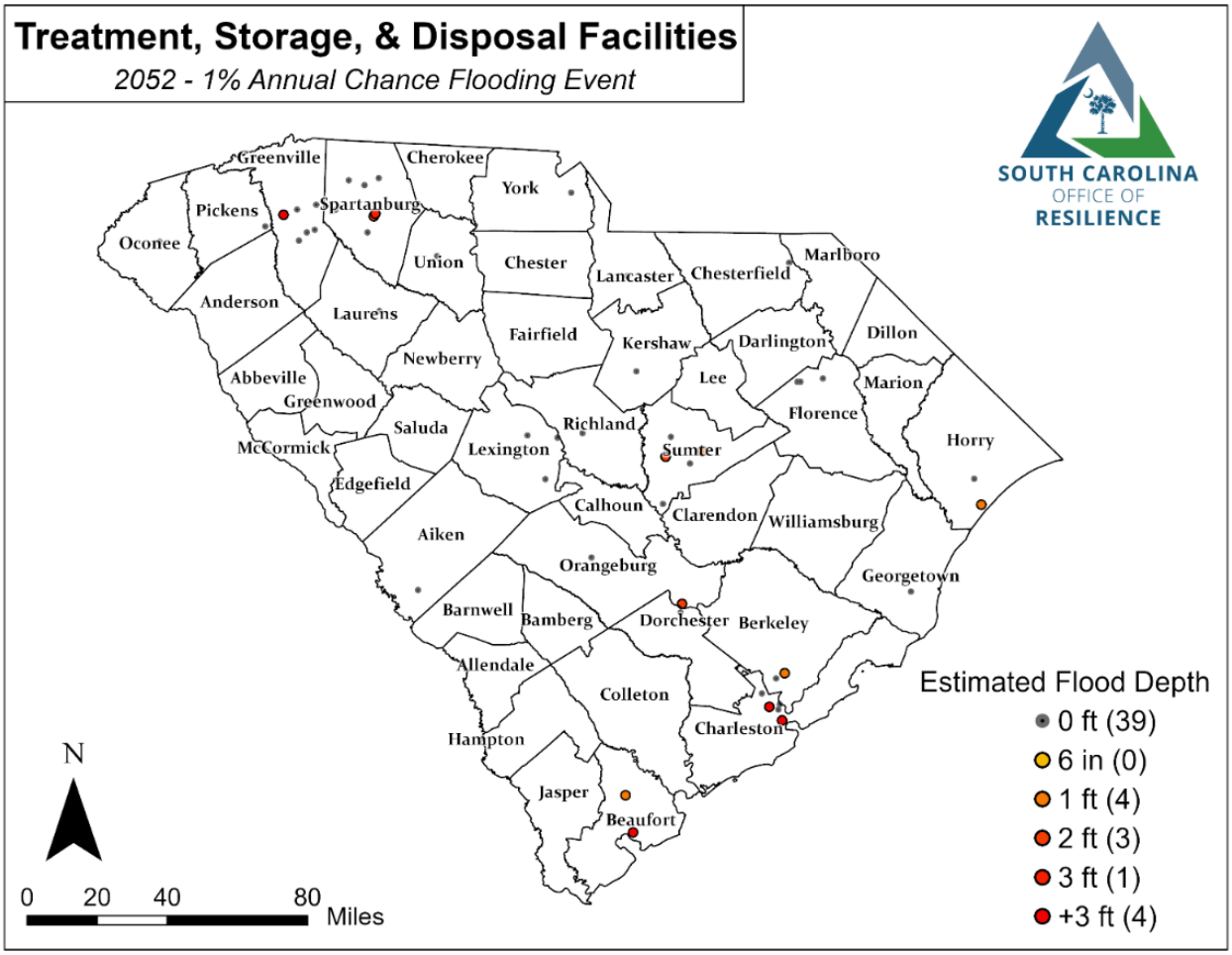


Figure 48 Estimated flooding of Treatment, Storage and Disposal Facilities in the 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

*U*nderground Storage Tanks (UST)

Underground storage tanks are used across the state to store vital fuel like gasoline but pose a risk if not properly contained. Regulation 61-92, Underground Storage Tank Control Regulations (SC DHEC), defines underground storage tanks as any single or combination of tanks, including underground pipes connected to it, which is used to contain an accumulation of regulated substance, and the volume of which is ten percent or more beneath the surface of the ground. The EPA Underground Storage Tank Flood Guide describes the effects flooding can have on underground storage tanks such buoyancy, erosion and scour, and product displacement and outlines action to decrease risks to the system and environment. Preliminary data from DHEC shows over 17,000 underground storage tanks across the state, with Table 10 showing the estimated flood depths under both the 2022 and 2052 1% annual chance flooding event.

Table 10 Estimated flooding of Underground Storage Tanks in the 2022 & 2052 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Estimated Flood Depth	2022 1% Annual Flooding Event Number of Sites	2052 1% Annual Flooding Event Number of Sites
0 ft	16099	15856
6 inches	31	38
1 ft	301	344
2 ft	381	401
3 ft	202	215
+3 ft	400	560

Cultural Resources

South Carolina's history is rich with the diversity of communities that trace their roots to the landscape. While the Catawba Indian Nation is the only resident federally recognized Indian tribe in the state, South Carolina recognizes an additional nine tribes and 4 recognized tribal groups (South Carolina Commission for Minority Affairs, 2022). Additionally, there are several traditional communities that warrant special considerations given their cultural significance, such as the Gullah/Geechee. Historically, these groups and their resilience have been encumbered for a multitude of reasons, while cultural representatives can help give insight to the specific threats experienced in their communities and possibilities that resilience planning may provide to solidify their continuing traditions.

Many cultural resources are intangible, such as local trade and craft skills, scholarship, and feelings of community connectivity by residents. However, museum collections, libraries, archives, and historic sites and landscapes can be utilized as a tangible way to study and analyze the vulnerability of these resources.

Unfortunately, these locations of interest are increasingly threatened both by development and by climate-driven changes, especially in coastal zones (Dawson, Hambly, Kelley, Lees, & Miller, 2020). However, in the United States, no such laws compel consideration of or provide funding for archaeological sites that are increasingly threatened by environmental processes that lead to site destruction. In the Southeastern United States alone, approximately 19,676 known recorded archaeological sites (e.g., archaeological sites, historical cemeteries, shipwrecks, and historical structures) are at risk of damage or destruction due to forces related to sea level rise given 1m increase in global mean sea level (Anderson, et al., 2012). Many additional archaeological sites will be lost before they are discovered. These sites are damaged most severely by the persistent wave and tidal energies generating erosion that precedes permanent sea level rise.

Regarding tangible collections, heritage custodians are overburdened and focused on triage and mitigating active instances of damage and loss rather than planning for the long-term needs of collections. According to the 2014 Heritage Health Information Survey (HHIS) conducted by the Institute of Museum and Library Services (IMLS), 76% of organizations do not have *both* a written institutional emergency plan and staff trained to carry that plan out - a statistic that was unimproved from the 2004 HHIS (Institute of Museum and Library Services, 2019). As a result, time and resources are directed to mitigating internal impacts on collections such as improper packaging and storage, obsolete and out-of-date equipment, water damage, and pest infestations rather than looking toward future impacts. The potential impact of future climate conditions on tangible collections has not been thoroughly investigated beyond the monetary impact of rising temperatures, humidity, and natural weather events on collection storage environments and the acknowledgement that most collections are greatly unprepared to respond to any emergency (International Institute for Conservation of Historic and Artistic Work, 2008).

Of primary concern is the lack of up-to-date documentation and assessments of State cultural assets. Over half of collecting organizations nationally have not completed a condition assessment of their collection, and nearly all do not regularly assess the entire collection (Institute of Museum and Library Services, 2019). Furthermore, volunteer-run sites and assets

not listed on any official registers will easily slip through the cracks. The level of preparedness was demonstrably worse for small collections compared to large ones with greater resources at their disposal. The State of South Carolina almost certainly has a far greater number of small- and medium- sized institutions than is represented in this survey.

Archsite, The South Carolina Institute for Archeology and Anthropology (SCIAA) and the South Carolina Department of Archives and History's online cultural resources information system, is used in the maps below to show physical vulnerability to cultural resources. ArchSite contains over 37,000 properties throughout the state, 2,114 of which are currently either individually eligible or listed on the National Register of Historic Places (ArchSite). In the following maps, this data is not represented by individual points to protect the security of the site while allowing for statewide analysis.

South Carolina has 1,595 listings in the National Register of Historic Places including 197 historic districts. Since one listing can include multiple buildings and sites, it is estimated 12,000 to 15,000 properties are included in the National Register. Charleston County has the most listings followed by Richland, Greenville, Beaufort, Spartanburg, Lexington, York, and Darlington counties. Counties with fewer than 10 listings are Barnwell, Chesterfield, Clarendon, and Edgefield. Figure 49, Figure 50, Figure 51 and Figure 52 display the number of sites or structures within a local watershed (at the HUC-10 level) that will be impacted by a 1% annual chance flooding event.

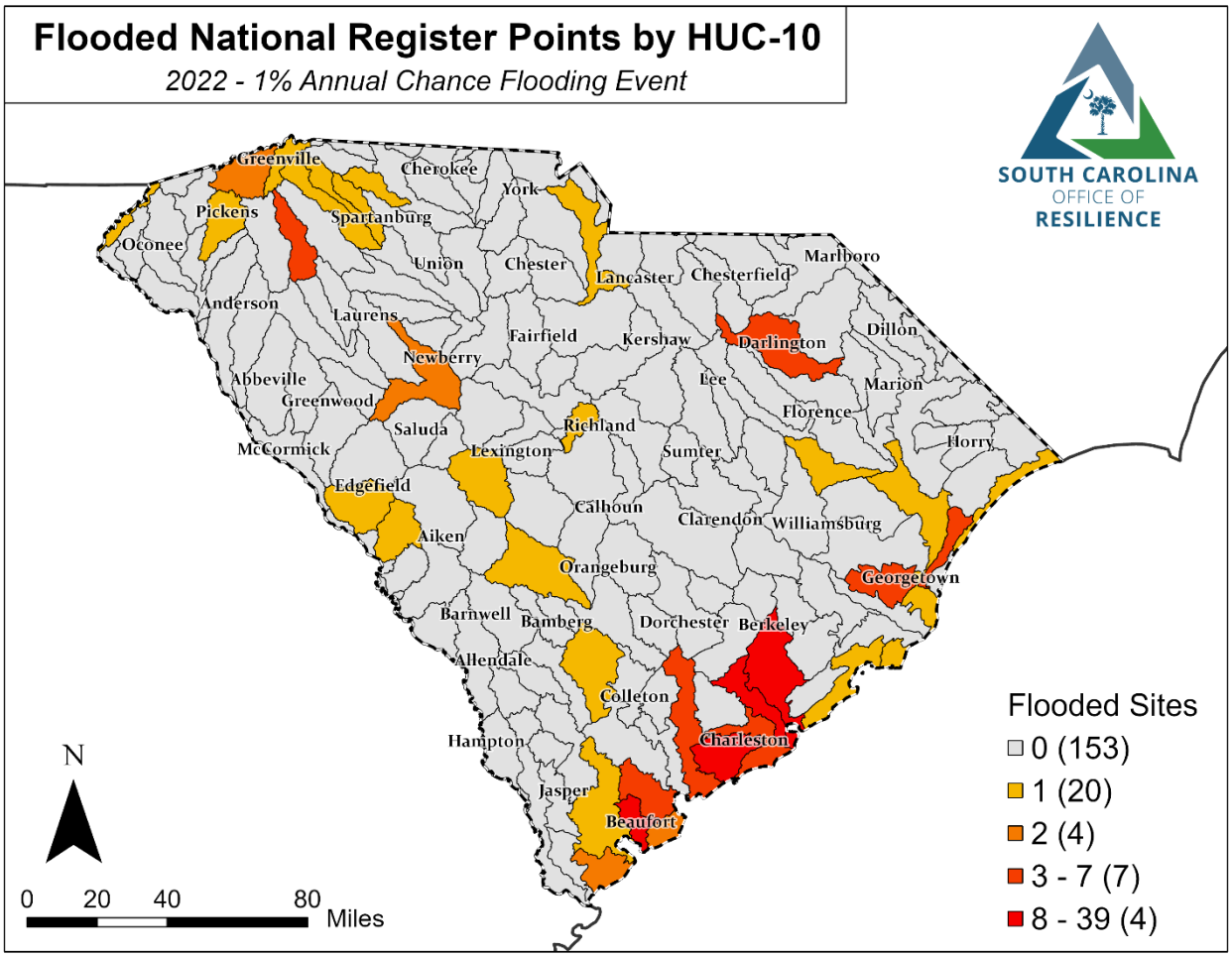


Figure 49 Estimated flooding of National Register Locations in the 2022 1% annual chance flooding event by local watershed (HUC-10) (ArchSite). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

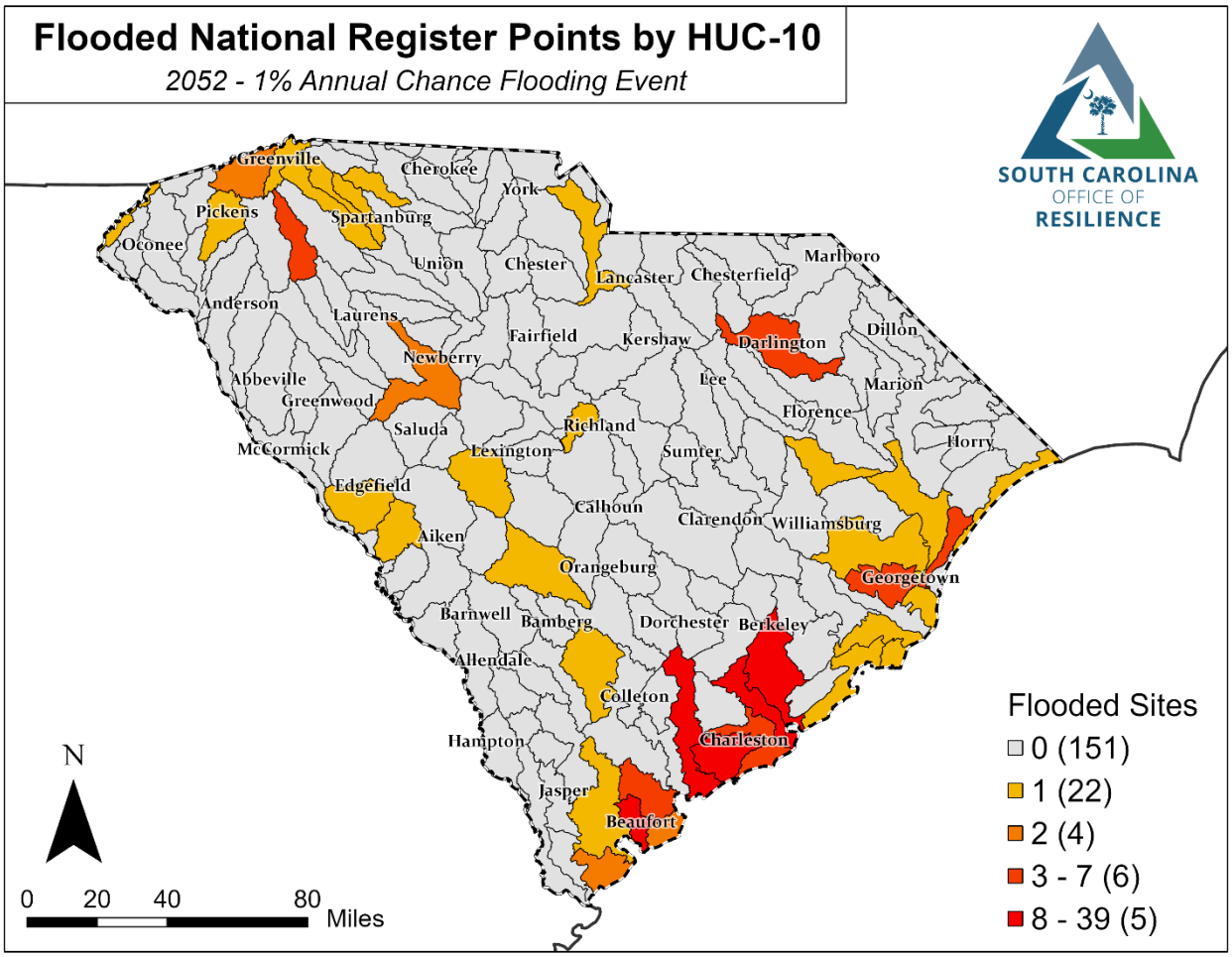


Figure 50 Estimated flooding of National Register Locations in the 2052 1% annual chance flooding event by local watershed (HUC-10) (ArchSite). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

In addition to these national register listings, 76 South Carolina properties are recognized as National Historic Landmarks (NHLs), including four historic districts - Beaufort, Charleston, Graniteville in Aiken County, and Penn School on St. Helena Island. Of the NHLs, 42 are in Charleston County and the remainder are scattered across the state.

The number of these properties continues to grow. Over 82,000 properties have been recorded by surveys of historic properties since the early 1970s. Over the past decade an average of 1,800 properties were added annually to the Statewide Survey collection that is maintained by the SC Department of Archives and History (SCDAH). Nearly 34,000 archaeological sites are in the state archaeological site files maintained by the SC Institute for Archaeology and Anthropology (SCIAA). Over the past decade, almost 700 new sites were added to the inventory annually, primarily through cultural resources surveys to comply with federal and state laws. Counties with the most recorded sites include Beaufort, Berkeley, Charleston, and McCormick, each with over 2,000 sites.

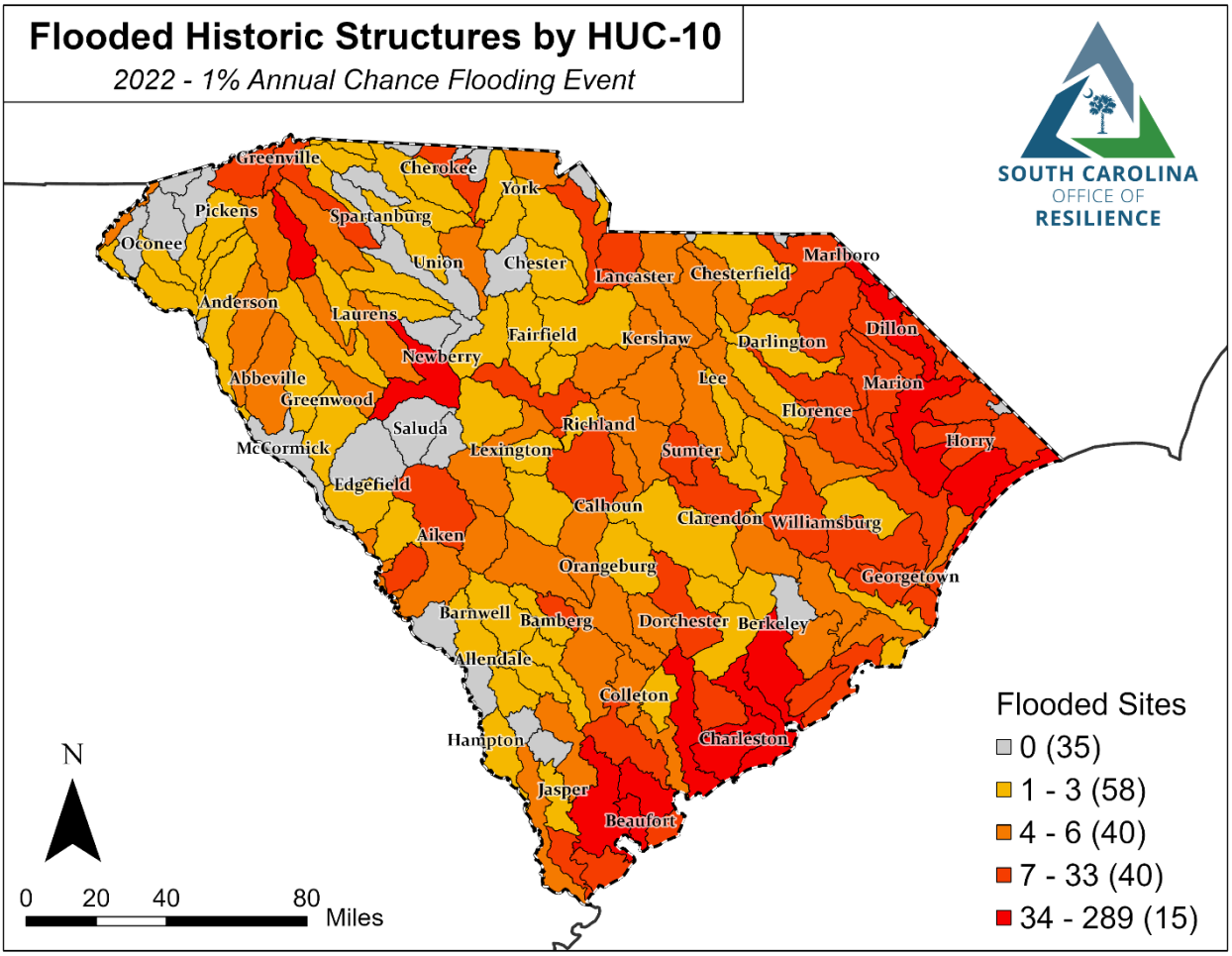


Figure 51 Estimated flooding of Historic Structures in the 2022 1% annual chance flooding event by local watershed (HUC-10)(ArchSite). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

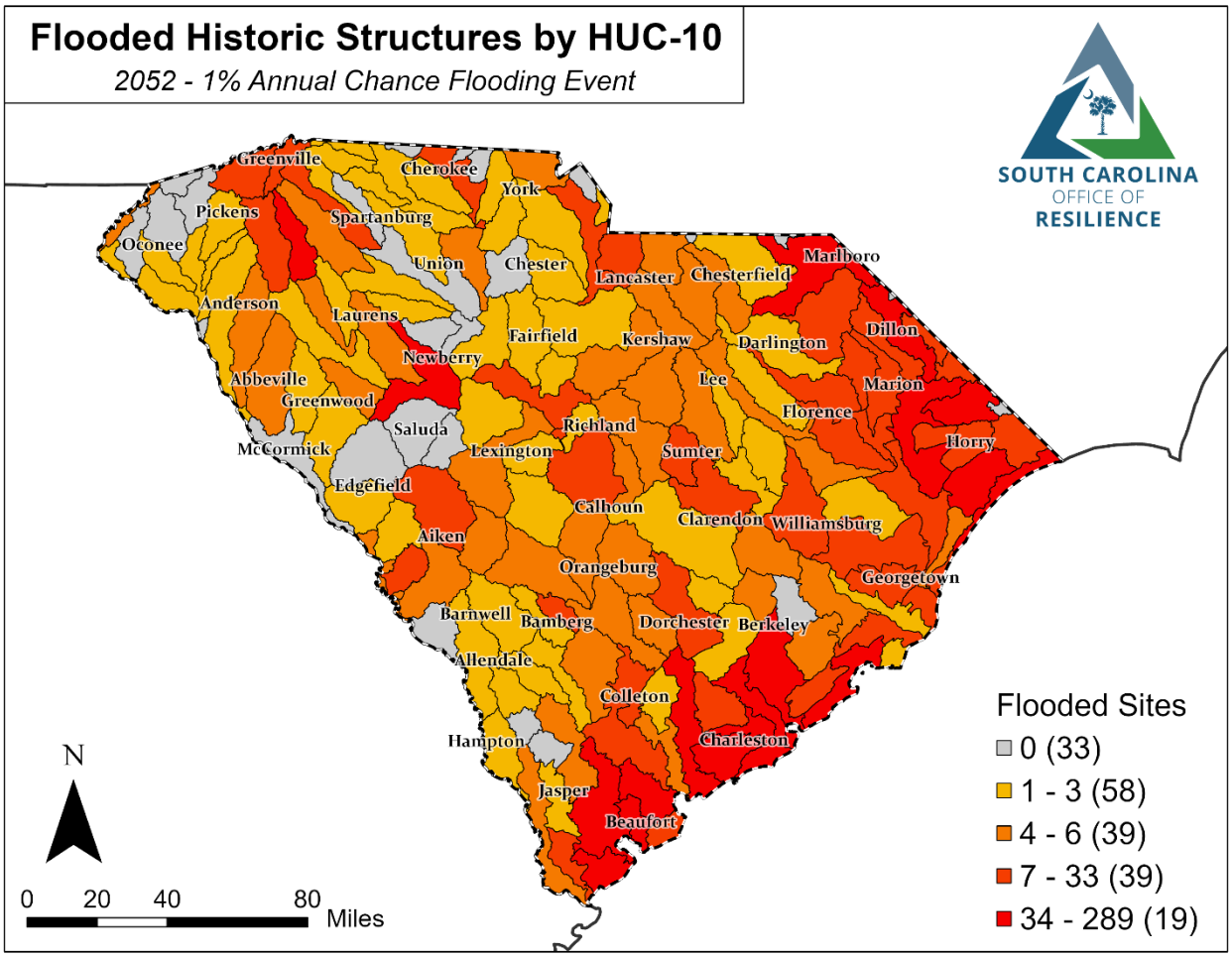


Figure 52 Estimated flooding of Historical Structures in the 2052 1% annual chance flooding event by local watershed (HUC-10) (ArchSite). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

In addition to these sites, South Carolina maintains 269 Cultural Institutions dedicated to the state's history and heritage (Smithsonian Institute). These museums, historical societies, and parks serve as hubs for local recovered materials and narratives. Although there exists a catalogue of these institutions, the artifacts, and resources that each of these facilities house is unclear. In the event of a flood threatening a facility, the materials it houses would be jeopardized without adequate hazard mitigation measures.

Community Services

Military

South Carolina's military community provides critical strategic value to our nation's defense. All five services have a significant presence in our state, leading to synergy and mission support. Our location on the East Coast is advantageous for deployment to the Middle East, South and Central America, Africa, and Europe, as well as to Military Operating Areas (MOAs) offshore. Each base supports multiple defense missions that contribute to defense readiness, training and homeland security (SC Department of Veterans' Affairs, n.d.). Many of these installations are located in the highly vulnerable coastal area, as seen in Figure 53.

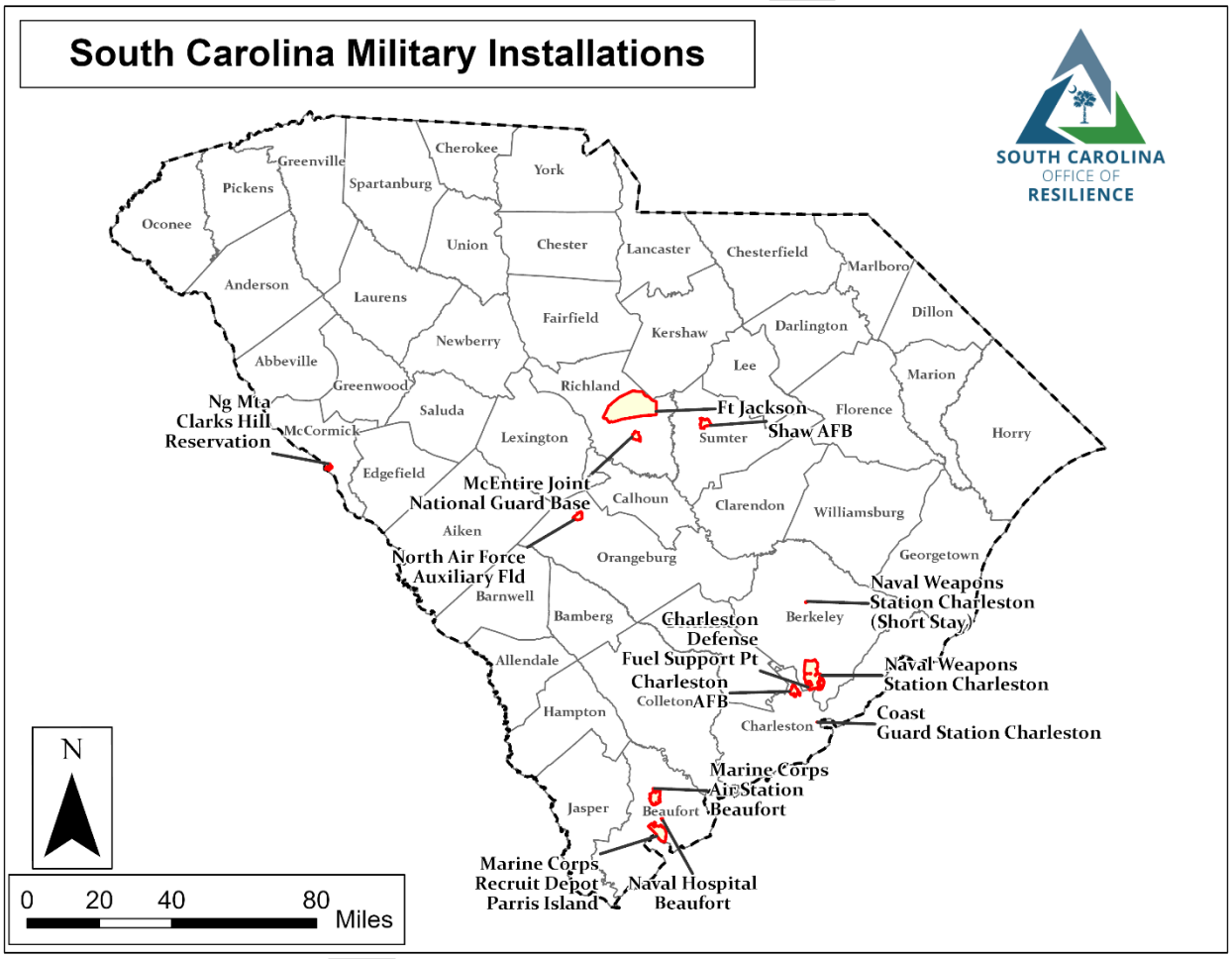


Figure 53 South Carolina Military Installations

Public Safety

State Level

State level law enforcement in South Carolina is split across several agencies. The Department of Public Safety and the State Law Enforcement Division (SLED) act in coordination with local and federal entities. On any given day, services provided include crime investigation, emergency response, intelligence gathering, protective services, and highway patrol. In times of emergency, personnel and resources are deployed preemptively to provide support functions to the afflicted areas.

The SC Criminal Justice Academy (SCCJA) is responsible for all mandated basic law enforcement, basic detention and basic telecommunications training in South Carolina. The Academy is one of the last few centralized law enforcement academies in the nation, thus providing full training continuity to every law enforcement officer in the state (includes over 300 law enforcement agencies). In addition, the SCCJA serves as a housing / operational staging point during emergencies for agencies such as FEMA, National Guard, Emergency Rescue Teams, and deployment teams.

The South Carolina Department of Probation, Parole and Pardon Services (PPP) is an accredited law enforcement agency that is charged with the community supervision of offenders placed on probation by the court and paroled by the State Board of Paroles and Pardons. The Department is committed to the use of innovative, cost-effective strategies proven to reduce new crime and new victimization in South Carolina. PPP is currently divided into 5 Regions and has offices in all 46 counties to better serve the State of South Carolina. PPP provides assistance and staffing for Emergency Support Function-13 security missions, hurricane evacuations, and other natural disaster assistance when called upon.

Local Law Enforcement

While the above state agencies support local law enforcement agencies, initial response depends on county, city, and town law enforcement agencies. The figures below quantify the number of local law enforcement facilitates impacted by the 2020 (Figure 54) and 2050 (Figure 55) 1% annual chance flood events.

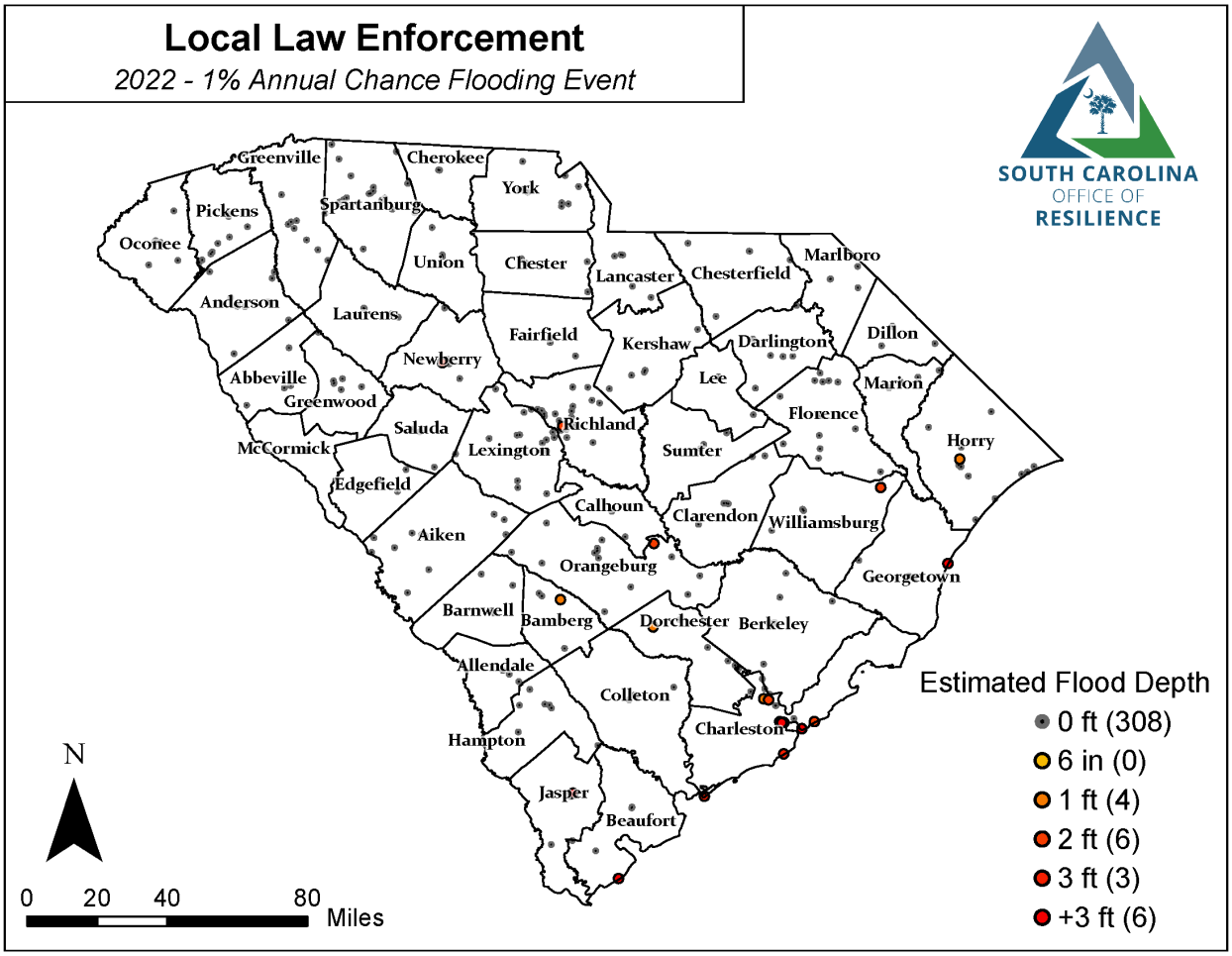


Figure 54: Estimated flooding of local law enforcement agencies in the 2022 1% annual chance flooding event (SLED). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

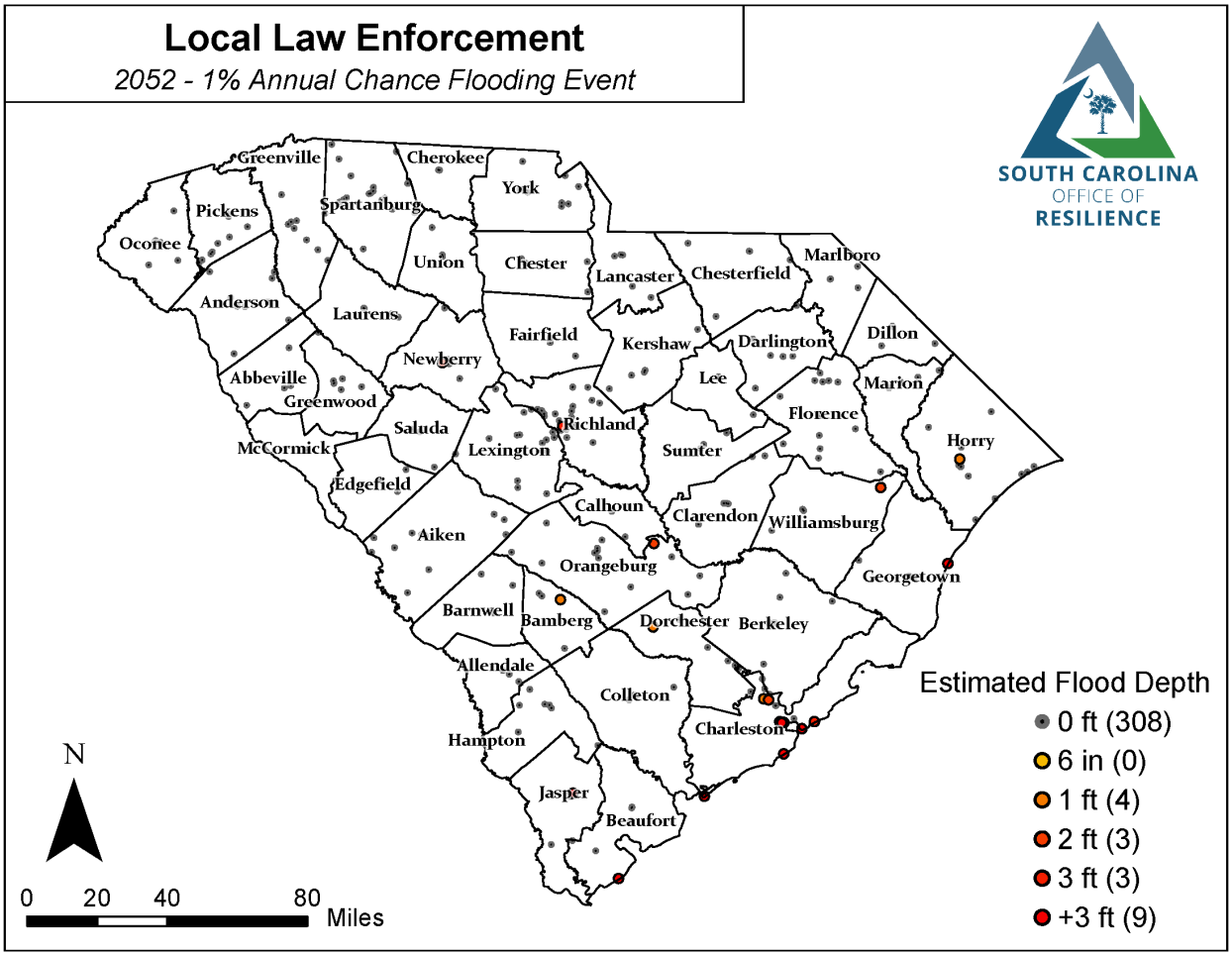


Figure 55: Estimated flooding of local law enforcement agencies in the 2052 1% annual chance flooding event (SLED). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Detention Centers

A dataset by SLED identifies 84 detention centers across the state, which includes county, state federal, and juvenile facilities. One of the most studied and pressing issues that these detention centers and the SC Department of Corrections face during flooding events is the need to evacuate large numbers of people from the facility. The figures below quantify the impact by the 2022 (Figure 56) and 2052 (Figure 57) 1% annual chance flood events.

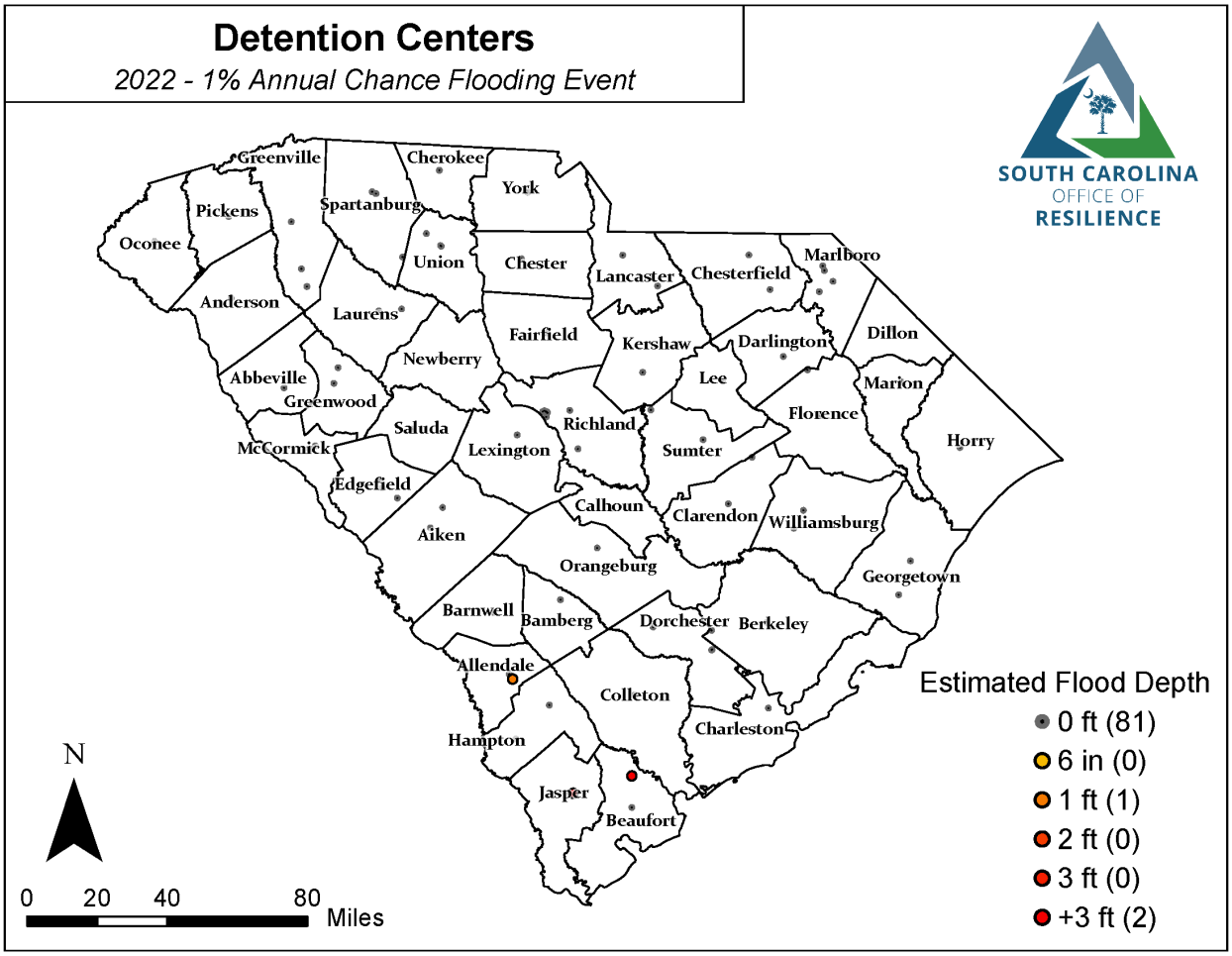


Figure 56: Estimated flooding of detention centers in the 2022 1% annual chance flooding event (SLED). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

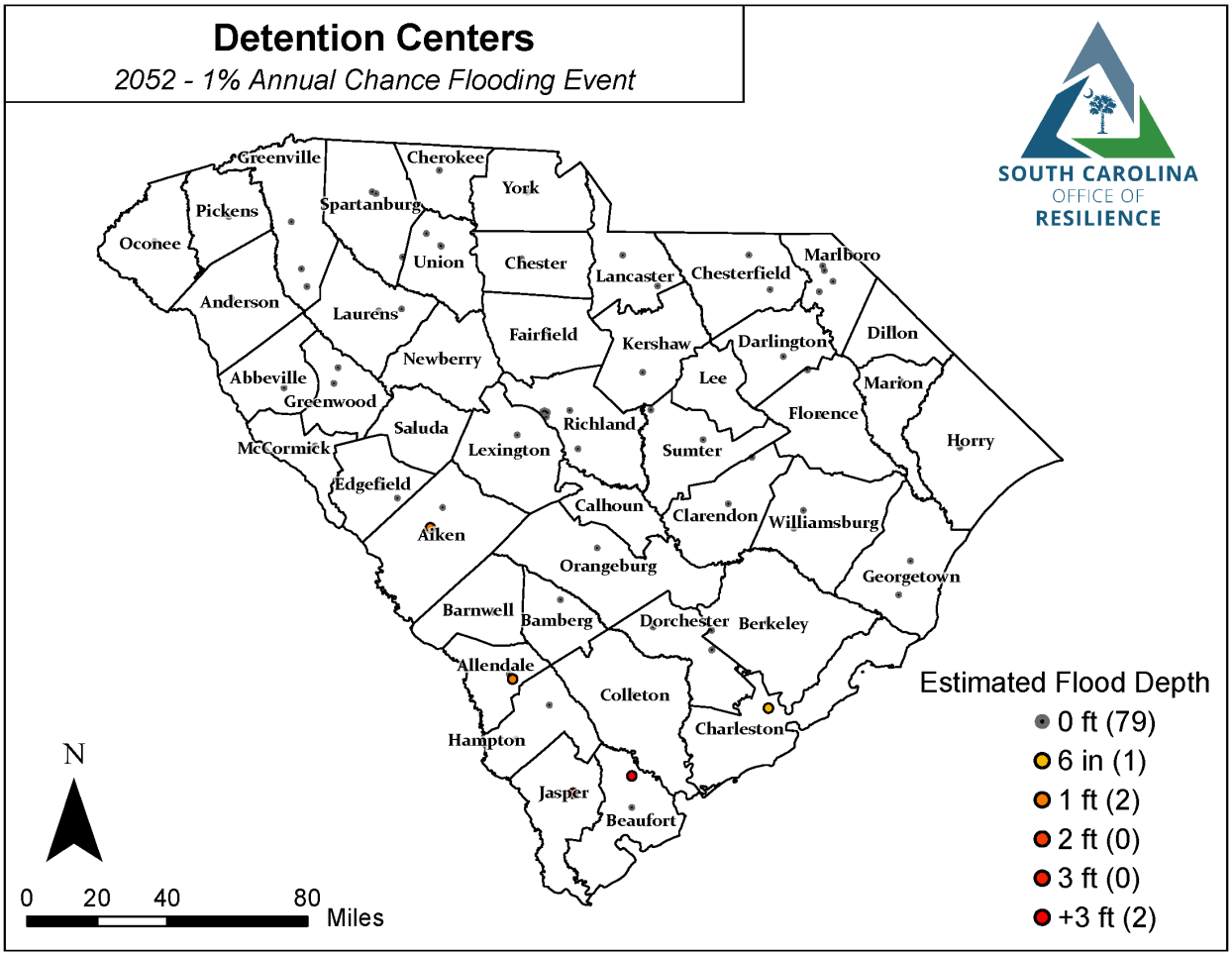


Figure 57: Estimated flooding of detention centers in the 2052 1% annual chance flooding event (SLED). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Fire Stations

Fire stations provide response to a variety of incidents, disasters and situations. The public relies heavily on first responders during daily emergencies, and even more during disasters, when there is an even greater need for assistance. Flooding can create dangerous barriers for fire personnel to get to the needed locations. The figures below quantify the potential impact of the 2022 (Figure 58) and 2052 (Figure 59) 1% annual chance flood events. The data points include manned fire stations and buildings from which a fire response occurs, such as volunteer fire department buildings, and includes both private and governmental entities.

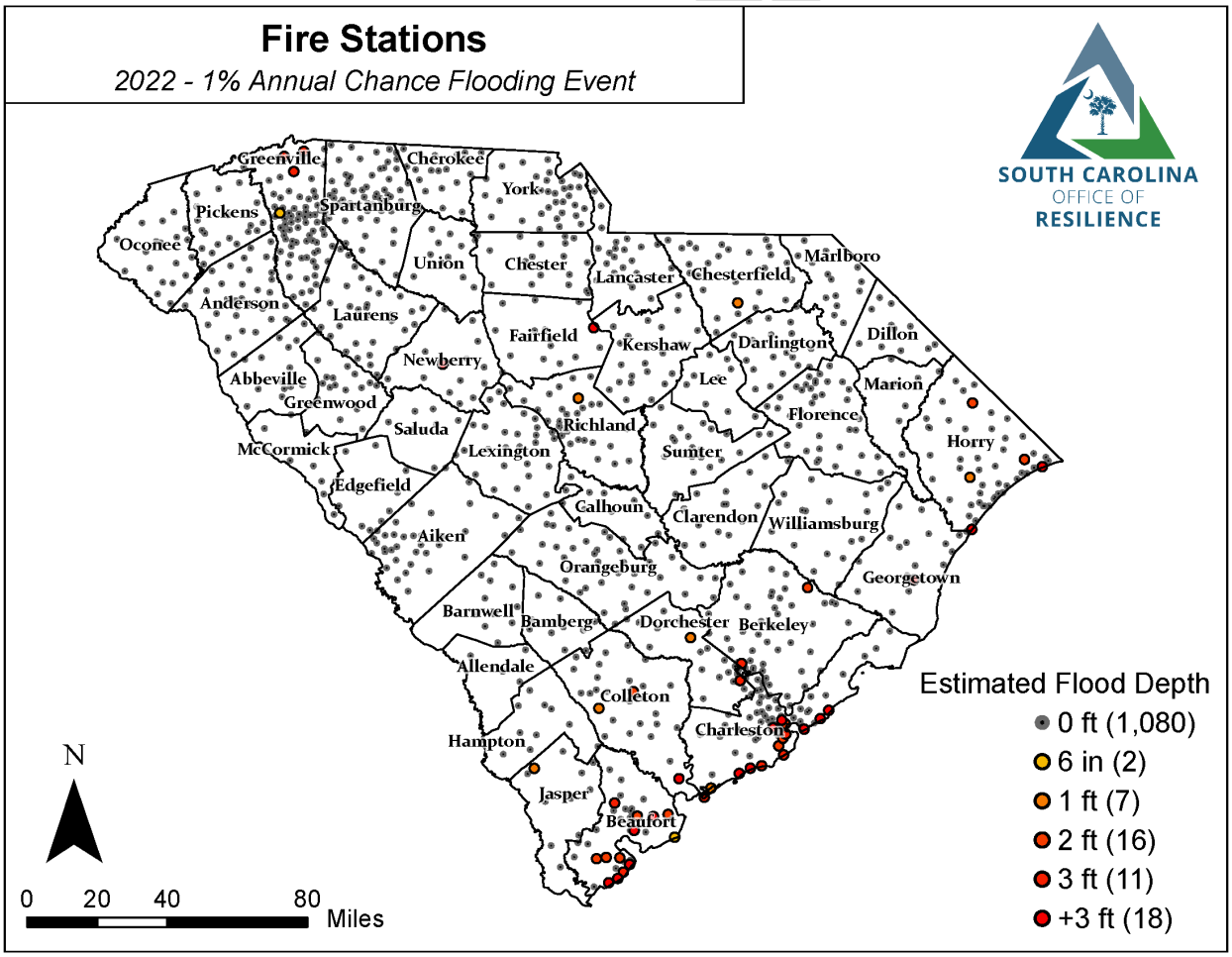


Figure 58: Estimated flooding of fire stations in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

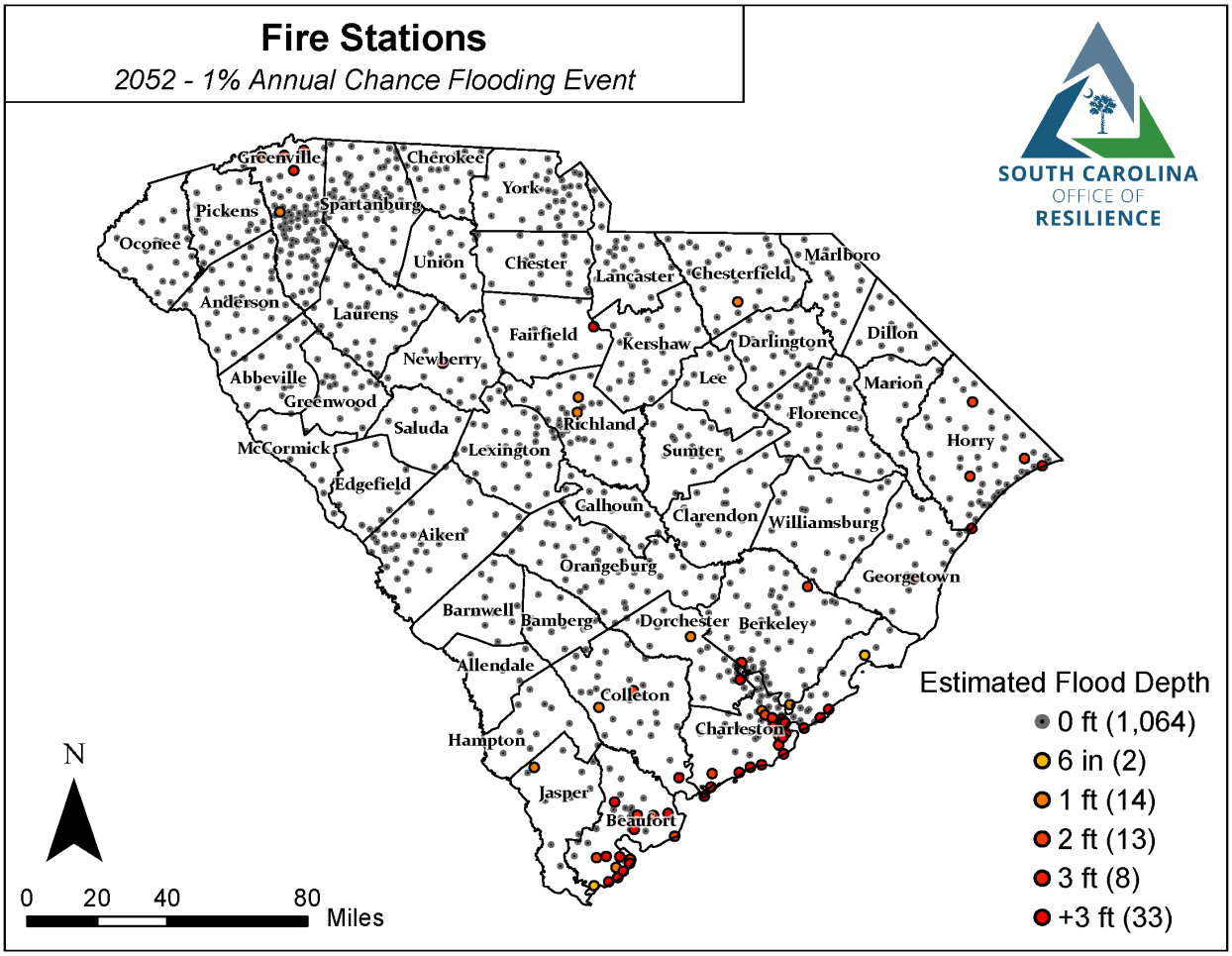


Figure 59: Estimated flooding of fire stations in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

EMS

Like fire stations, EMS stations and personnel are needed daily, but in increased demand leading up to, during and after a disaster. There are an increased number of calls to respond to, and more barriers to arriving on the scene. The figures below quantify the impact by the 2020 (Figure 60) and 2050 (Figure 61) 1% annual chance flood events on these stations.

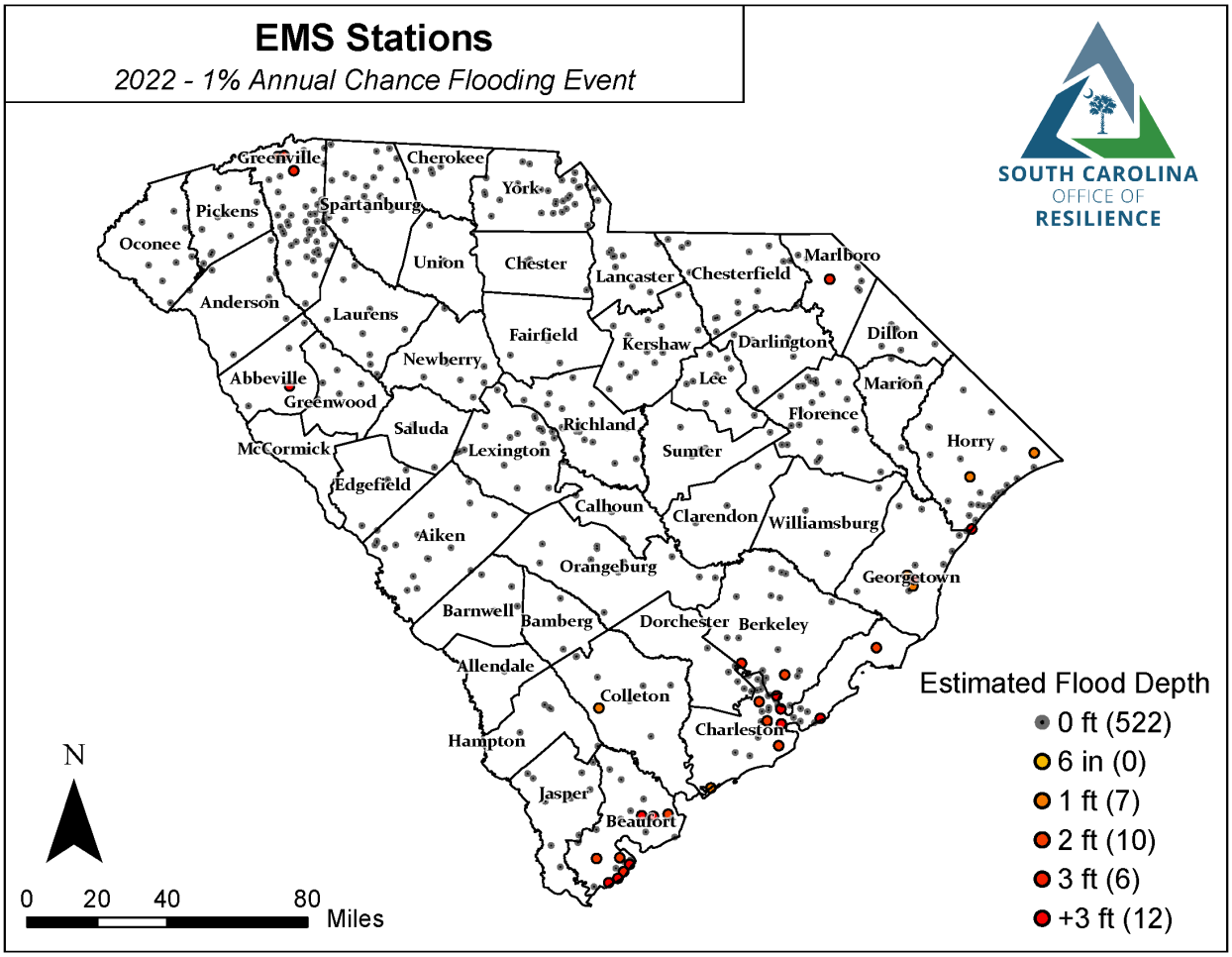


Figure 60: Estimated flooding of EMS stations in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

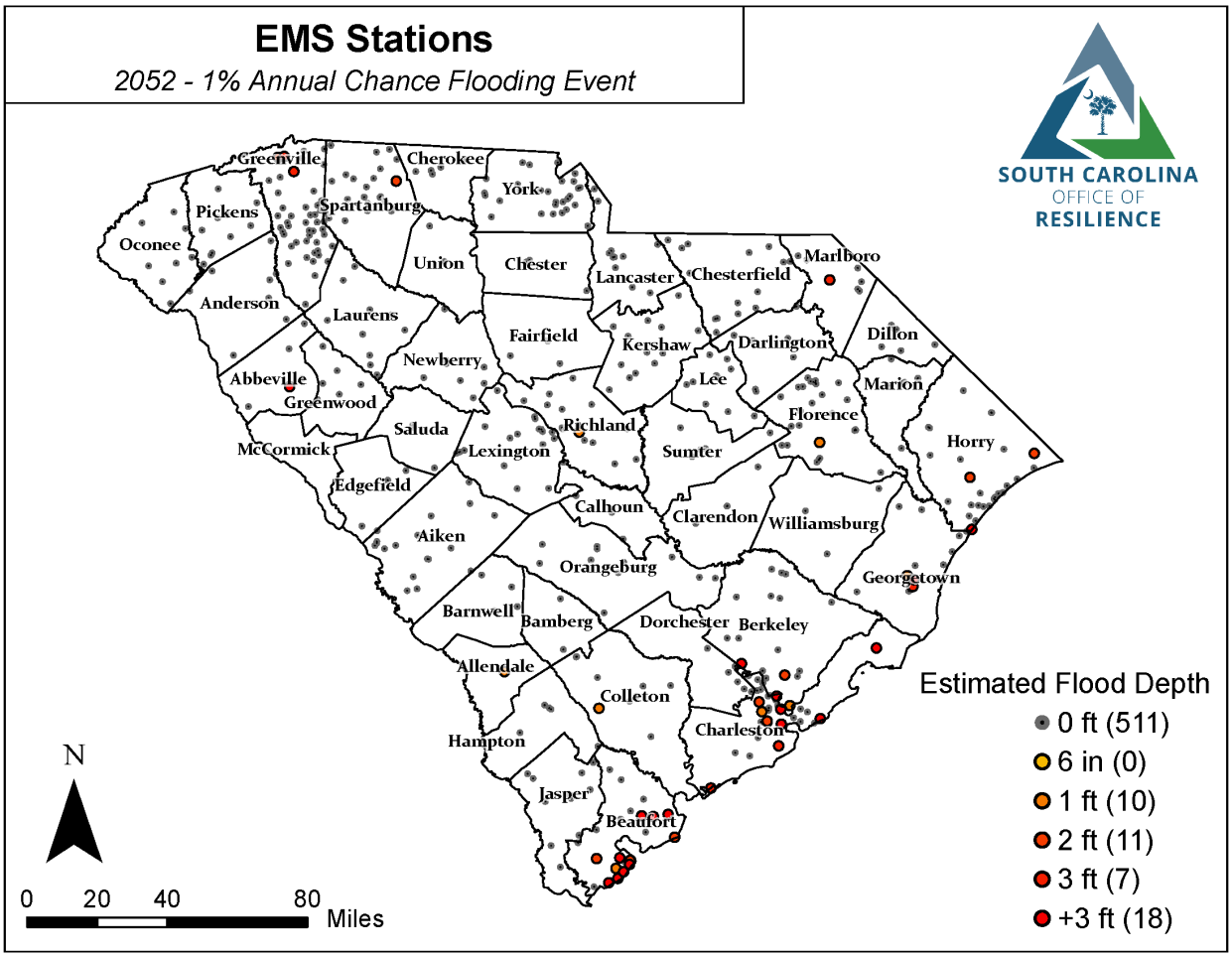


Figure 61: Estimated flooding of EMS stations in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Education

In addition to the initial impact of flooding on schools, floods have the potential to force schools to close for long periods of time, disrupting student learning.

K-12

According to the South Carolina Department of Education's Active Student Headcounts, there are 777,111 students enrolled South Carolina public schools (South Carolina Department of Education, 2022).It has been found that the damage public schools face due to flooding is compounded by their age and condition, with more than half of the nation's public schools being built in the last century, and not built to withstand such hazards (The Pew Charitable Trusts, 2017). While the maps below quantify the impact by the 2022 (Figure 62) and 2052 (Figure 63) 1% annual chance flood events, they do not consider these factors. Additionally, there are nearly 300 private K-12 schools across the state, those are shown in Figure 64 and Figure 65.

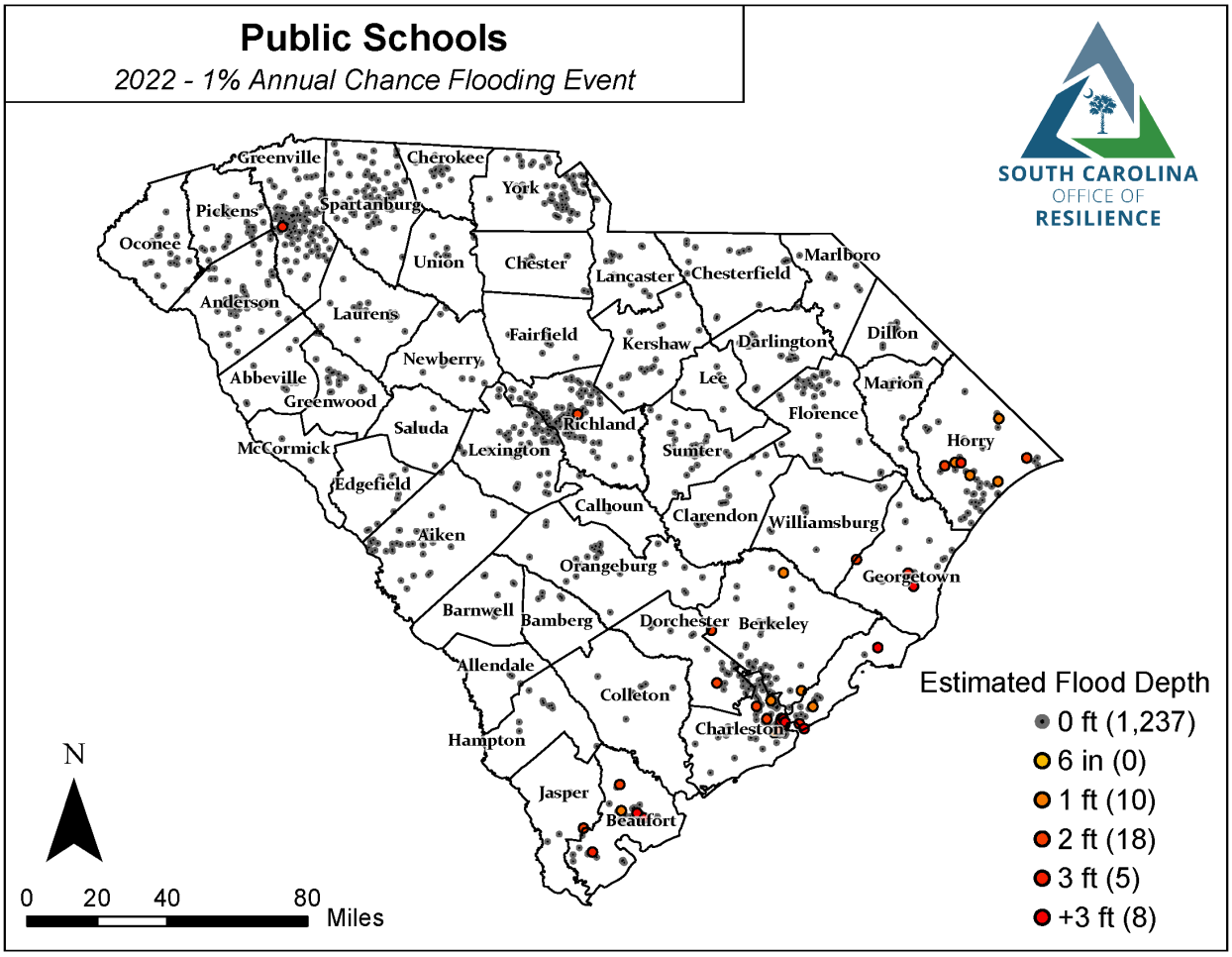


Figure 62: Estimated flooding of public schools in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

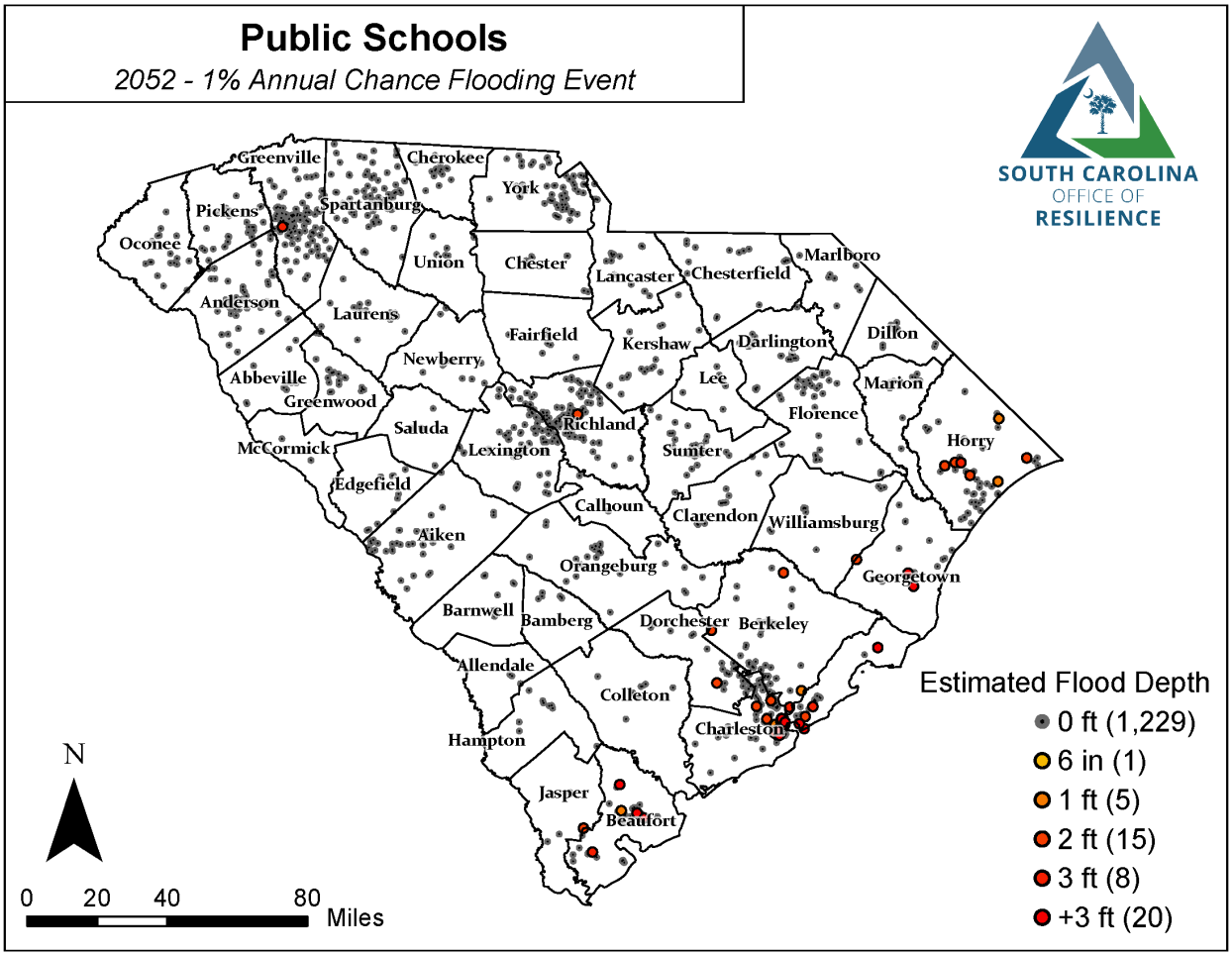


Figure 63: Estimated flooding of public schools in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

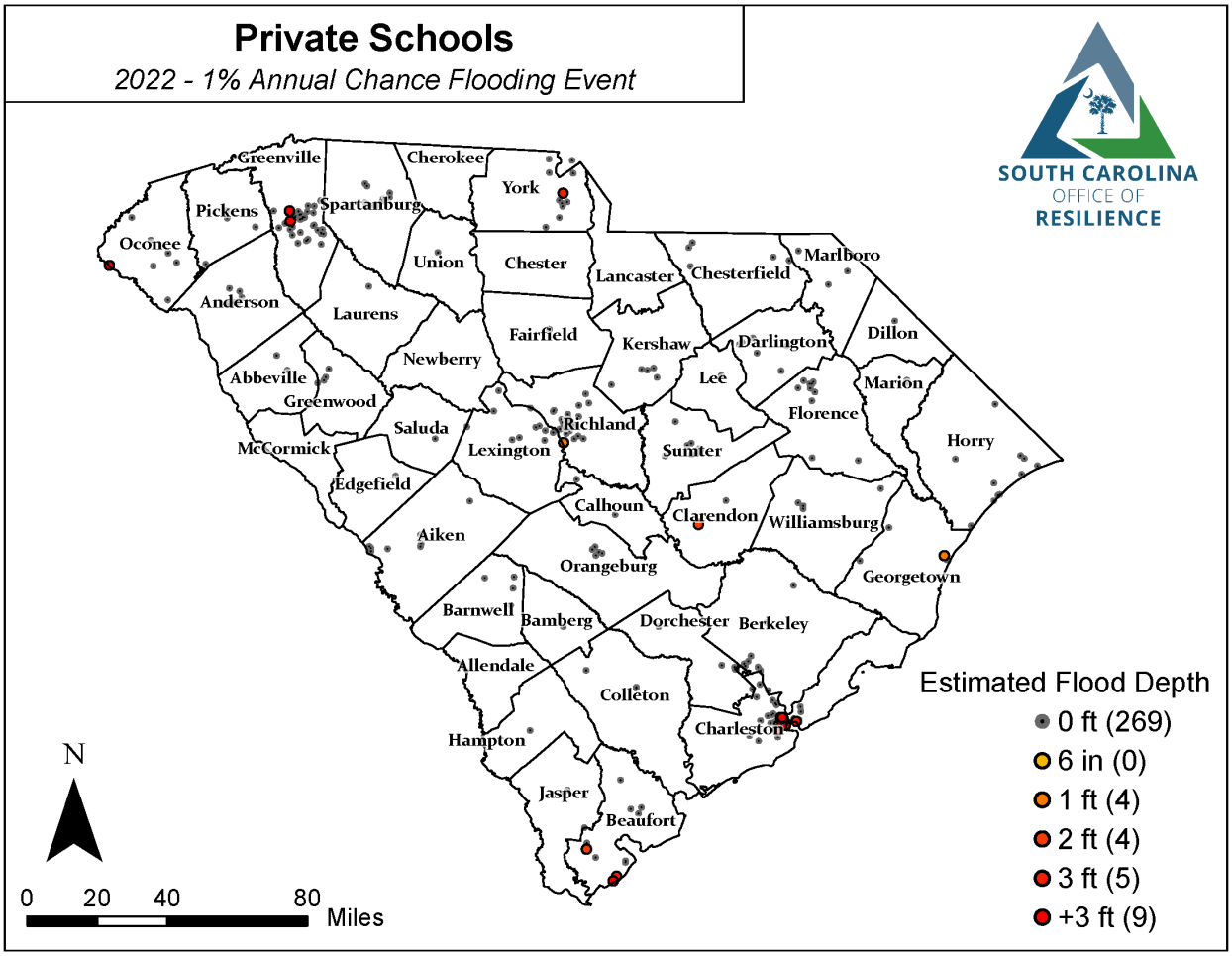


Figure 64: Estimated flooding of private schools in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

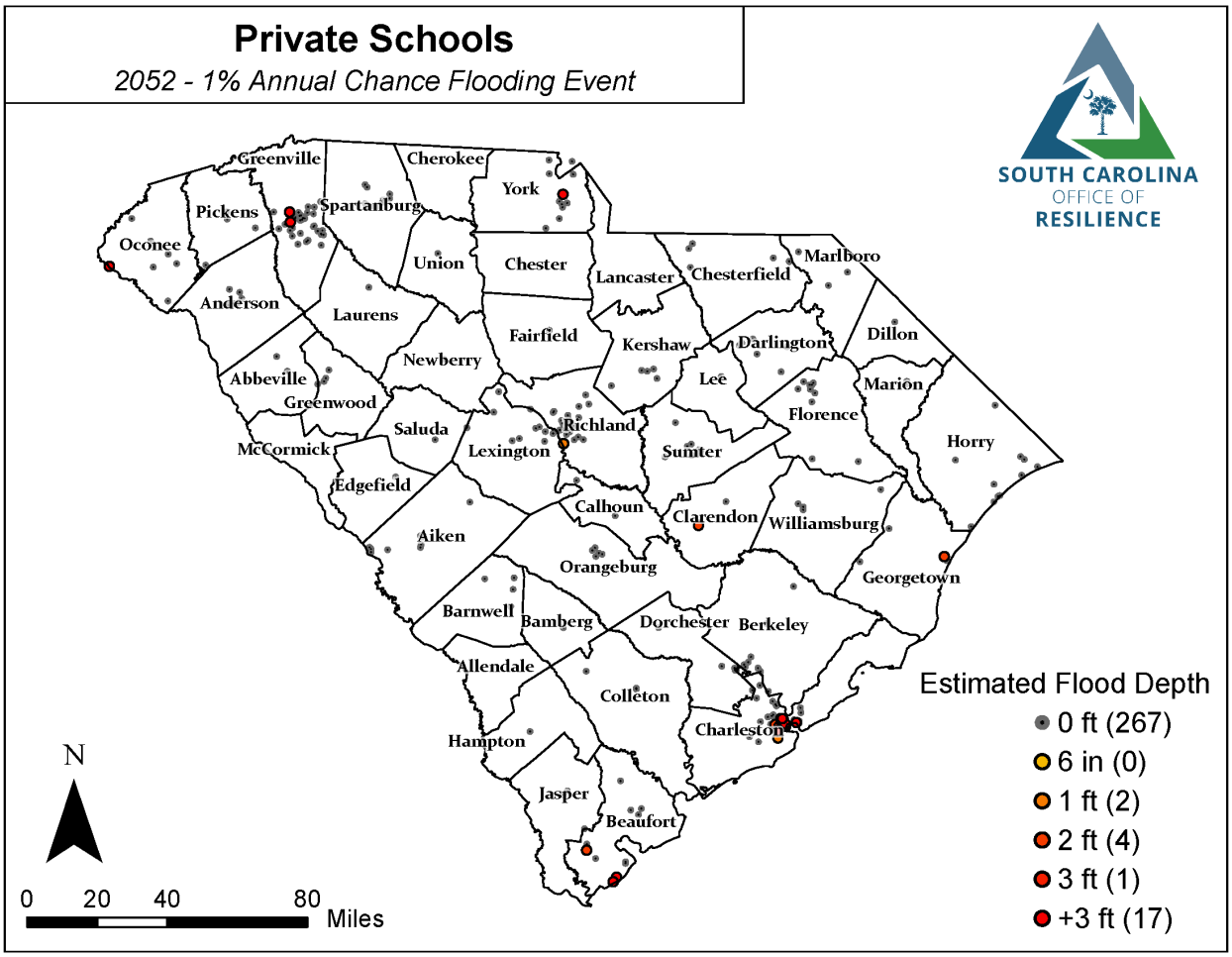


Figure 65: Estimated flooding of private schools in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Higher Education

There are 33 public colleges and universities as well as 25 independent institutions in South Carolina. In Fall 2020, these institutions enrolled 229,781 students, 69.8% of which were full-time students. In the previous school year (2019-2020), these institutions awarded 52,670 degrees, 49.4% of which were bachelor's degrees. This is a 14.5% increase over total degrees awarded in the 2010-2011 school year. In terms of physical vulnerability, public institutions alone have a building footprint of over 36 million square feet of usable space across the state, 28% of which is instructional space. 10% of all public campus buildings are over 99 years old, while over 40% of buildings are over 50 years old. From an economic perspective, public and private institutions employ nearly 16,000 faculty members, 48% full-time (SC Commission on Higher Education, 2021). Additionally, if you include other kinds of post-secondary education schools, such as cosmetology and barber schools and trade schools, the count comes to over a hundred institutions. The figures below quantify the impact by the 2022 (Figure 65) and 2052 (Figure 66) 1% annual chance flood events on these institutions. This data set does not include online colleges.

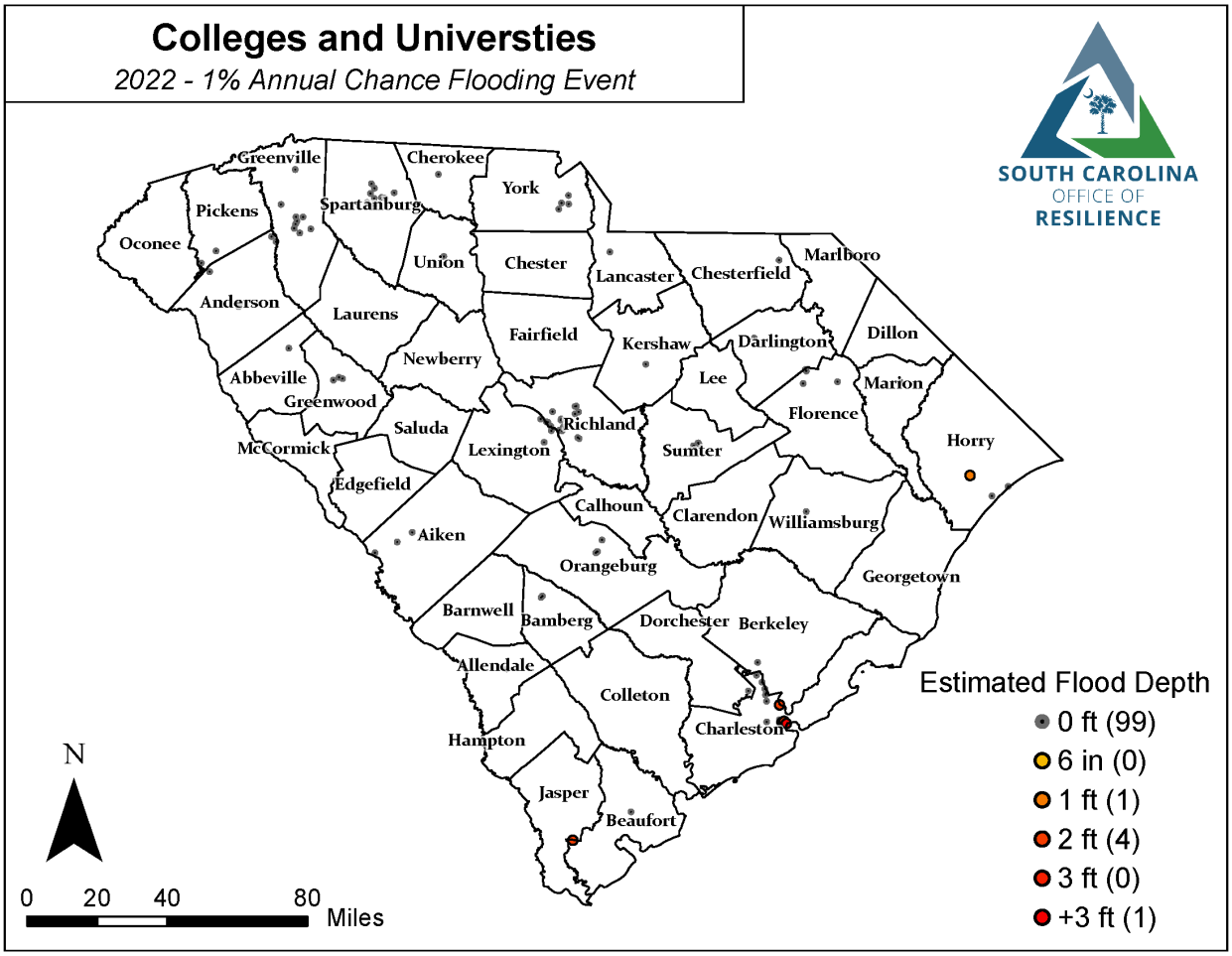


Figure 66: Estimated flooding of colleges and universities in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

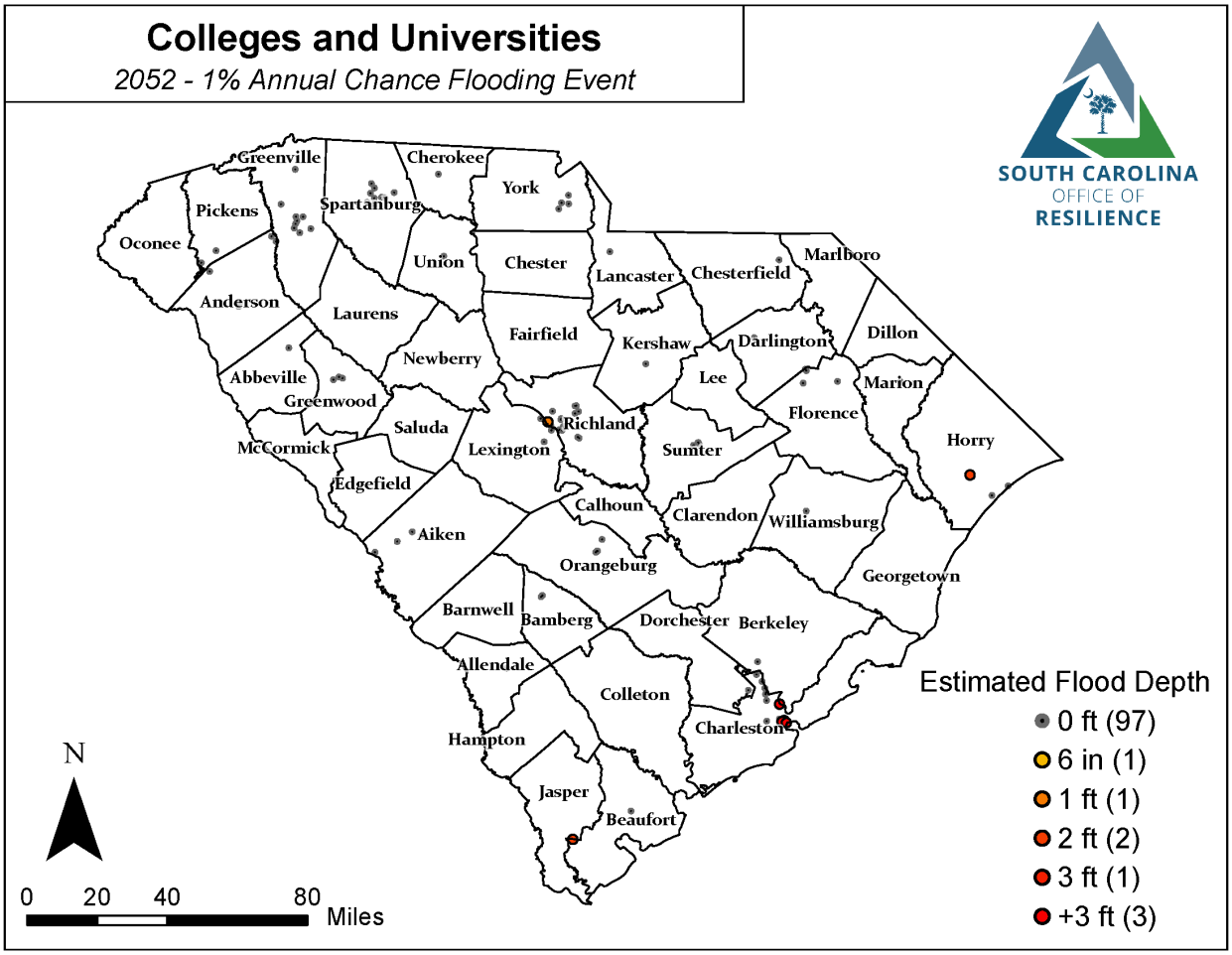


Figure 67: Estimated flooding of colleges and universities in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Public Health

Public Health Facilities

DHEC's Bureau of Health Facility Licensing (BHFL) regulates health care facilities and providers, enforcing standards, inspections, and licenses for nursing homes, hospices, home health agencies, ambulatory surgical centers, adult day cares and renal dialysis centers that provide essential health services. Those facilities are included in Figure 68 and Figure 69 below.

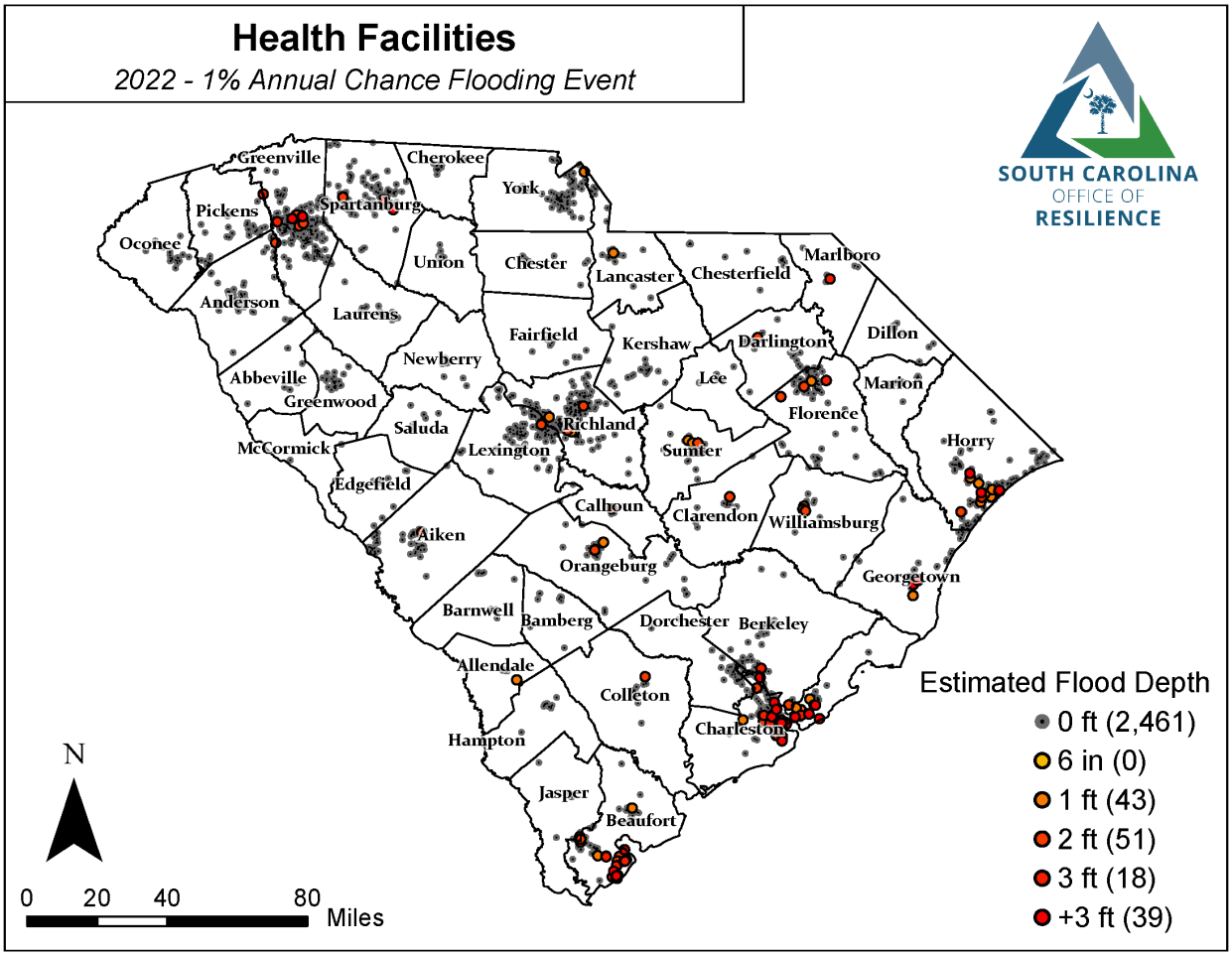


Figure 68: Estimated flooding of health facilities in the 2022 1% annual chance flooding event (DHEC). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

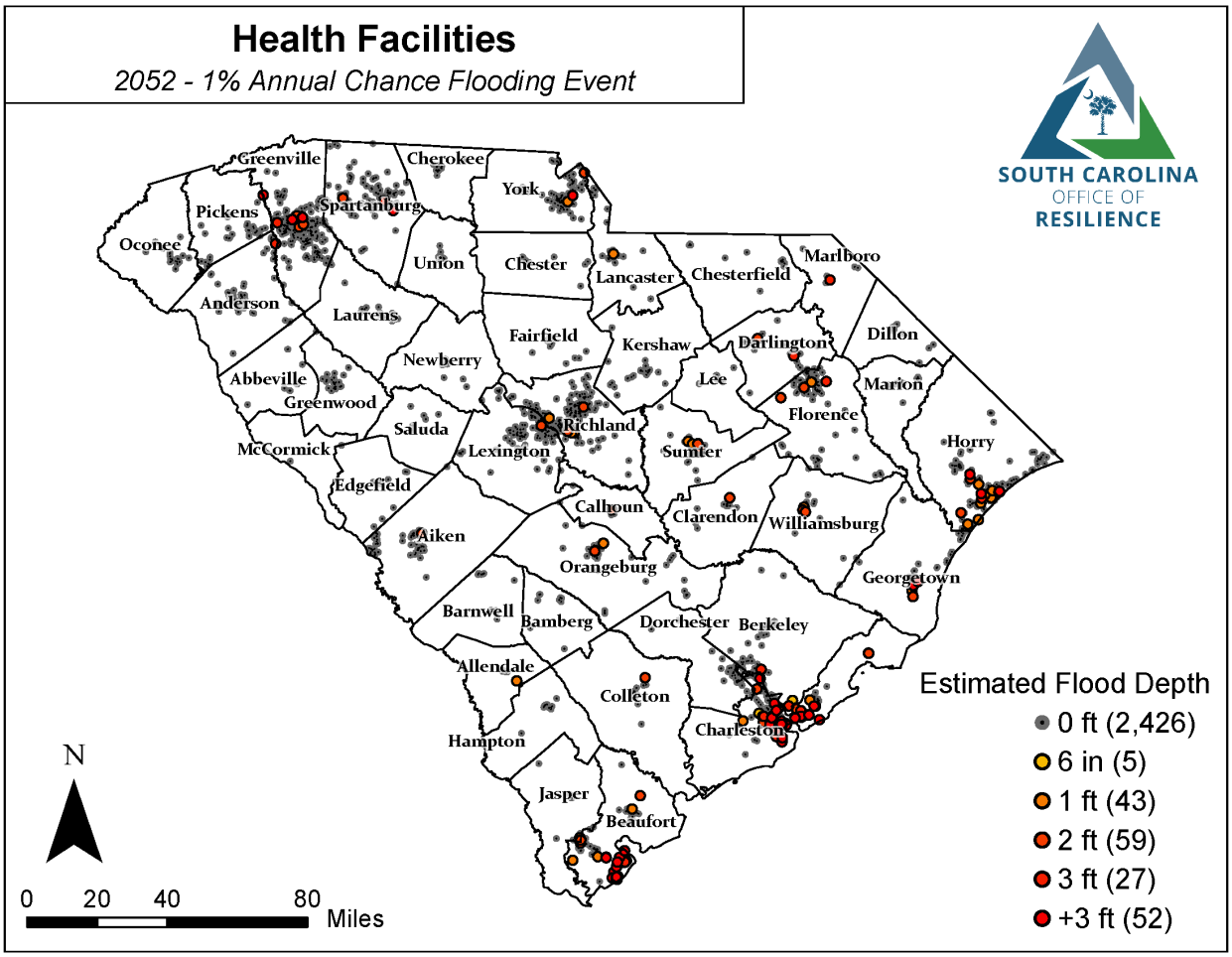


Figure 69: Estimated flooding of health facilities in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Hospitals

Across the state, there are over 100 hospitals. In addition to the physical vulnerabilities of these facilities, environmental changes and natural hazards can increase the demand for medical care, whether from the stress of increasing temperatures or immediate injuries from natural hazards. Hospitals can experience increased demand and continue to be essential leading up to, during, and in the short and long term after an event. In the time leading up to an event, especially in the case of evacuations, there can be increased traffic accidents. During and immediately after an event, those who cannot or do not leave may be trapped and in need of medical care. Road detours and closures before and during an event can limit access to hospitals for both patients and staff. Medical conditions that require hospital care may intensify as event effects linger. A common issue is carbon-monoxide poisoning related to the use of gas-powered generators (SC Sea Grant Consortium, 2019). The figures below quantify the impact by the 2022 (Figure 70) and 2052 (Figure 71) 1% annual chance flood events on these facilities. The dataset includes everything from children, chronic disease, critical access, general acute care, long term care, military, psychiatric, rehabilitation, special and women's hospitals.

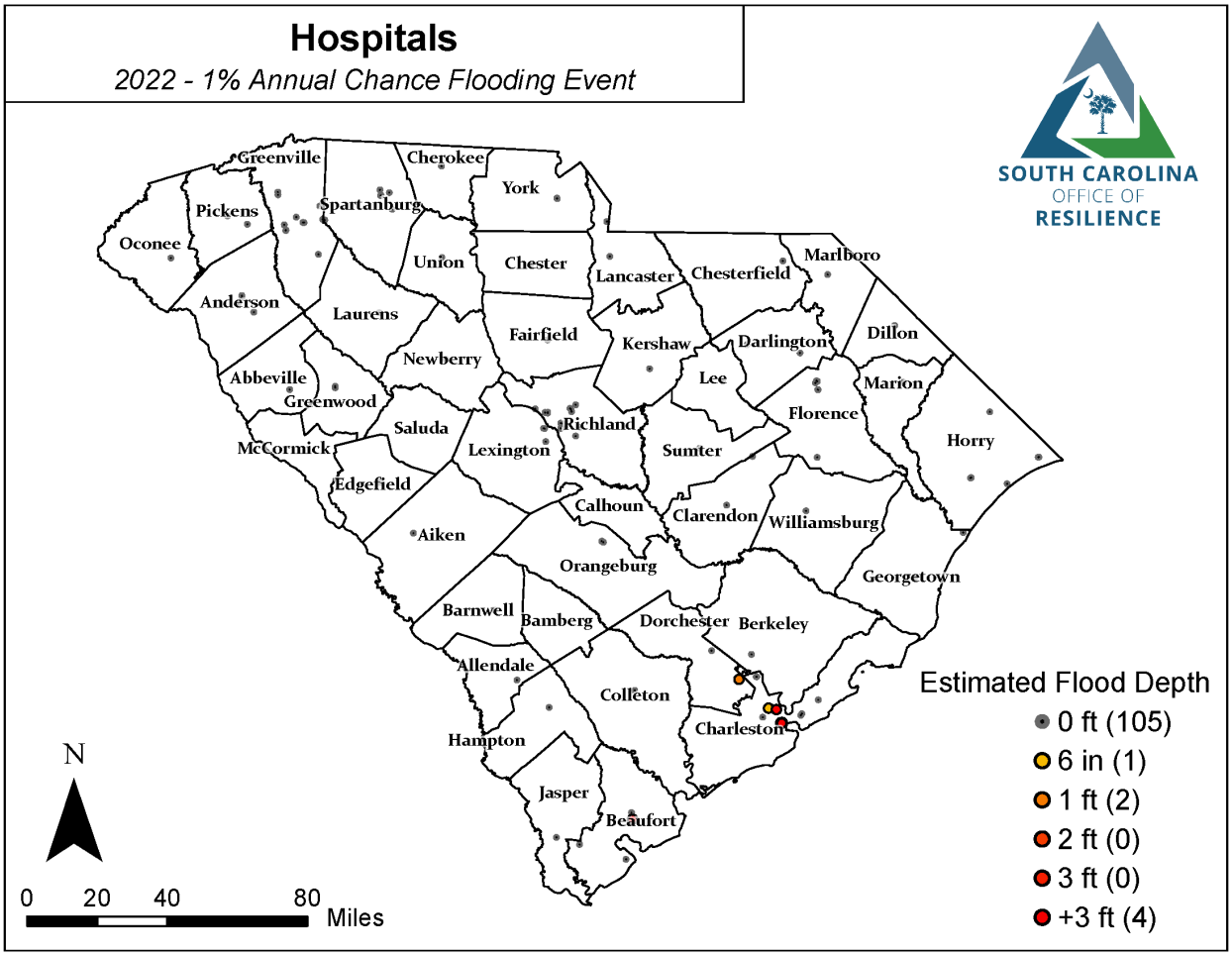


Figure 70: Estimated flooding of hospitals in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

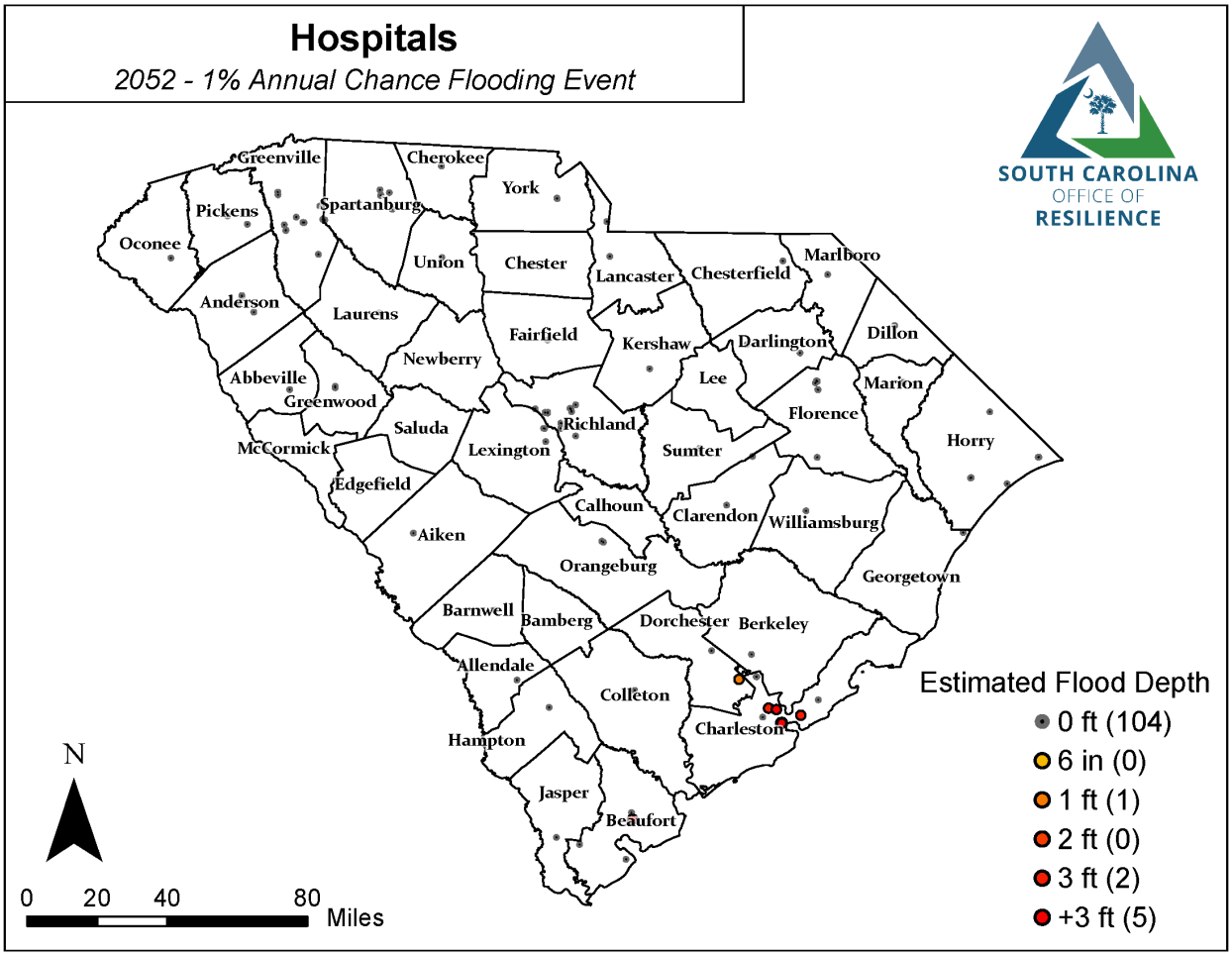


Figure 71: Estimated Flooding of hospitals in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Nursing Homes

Nursing homes have similar vulnerabilities when it comes to needed medical care of its residents, but the residential nature of these facilities have the potential to impact their residents in the long term, requiring them to find other homes to live in and the loss of personal belongings. The figures below quantify the impact by the 2022 (Figure 72) and 2052 (Figure 73) 1% annual chance flood events on these facilities. This database from DHS includes facilities that house older adults and assisted care facilities.

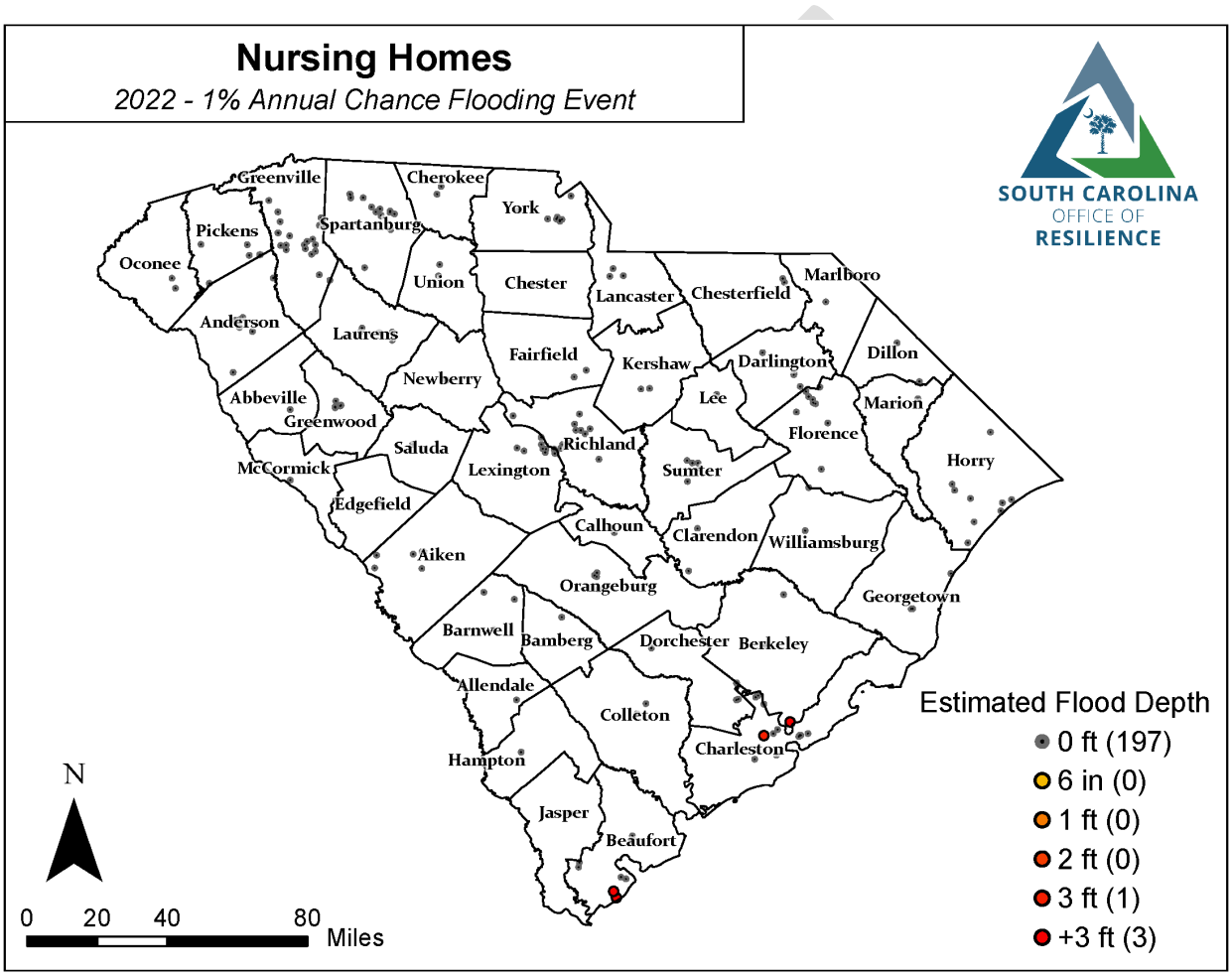


Figure 72: Estimated flooding of nursing homes in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

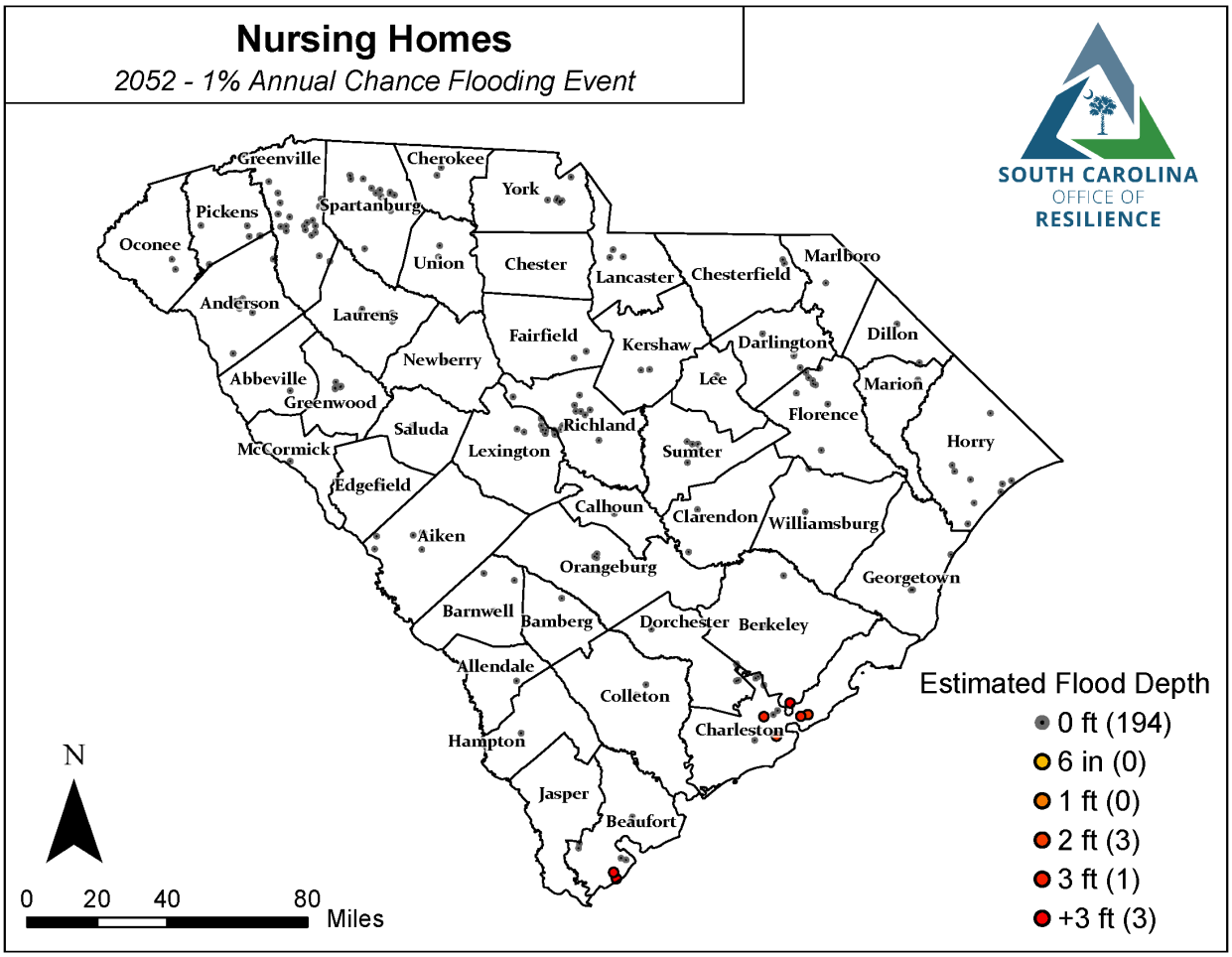


Figure 73: Estimated flooding of nursing homes in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Mental Health Facilities

According to the South Carolina Behavioral Health 2021 Progress Report, nearly a fifth of South Carolinians live with mental illness, with 18.3% reporting a diagnosable mental, behavioral or mental disorder in 2018 as reported by Mental Health America (South Carolina Institute of Medicine & Public Health, 2021).

There are 79 facilities operated by the South Carolina Department of Mental Health (DMH), helping individuals with addiction, Anxiety, Attention Deficit Disorder (ADD), behavioral problems, Bipolar Disorder, Depression, Oppositional Defiant Disorder (ODD), suicide risk, thought disorders, and trauma. This includes 3 hospitals, 4 nursing homes, 16 Community Mental Health Centers, and 43 Mental Health Clinics. The vulnerability of these programs is not isolated to the physical facilities but incorporates the mental health professionals and the patient's access to these locations. Flooding may create accessibility issues, as well as serve as a traumatic event, spurring the need for more mental healthcare in its wake. The figures below quantify the impact by the 2022 (Figure 74) and 2052 (Figure 75) 1% annual chance flood events on these facilities.

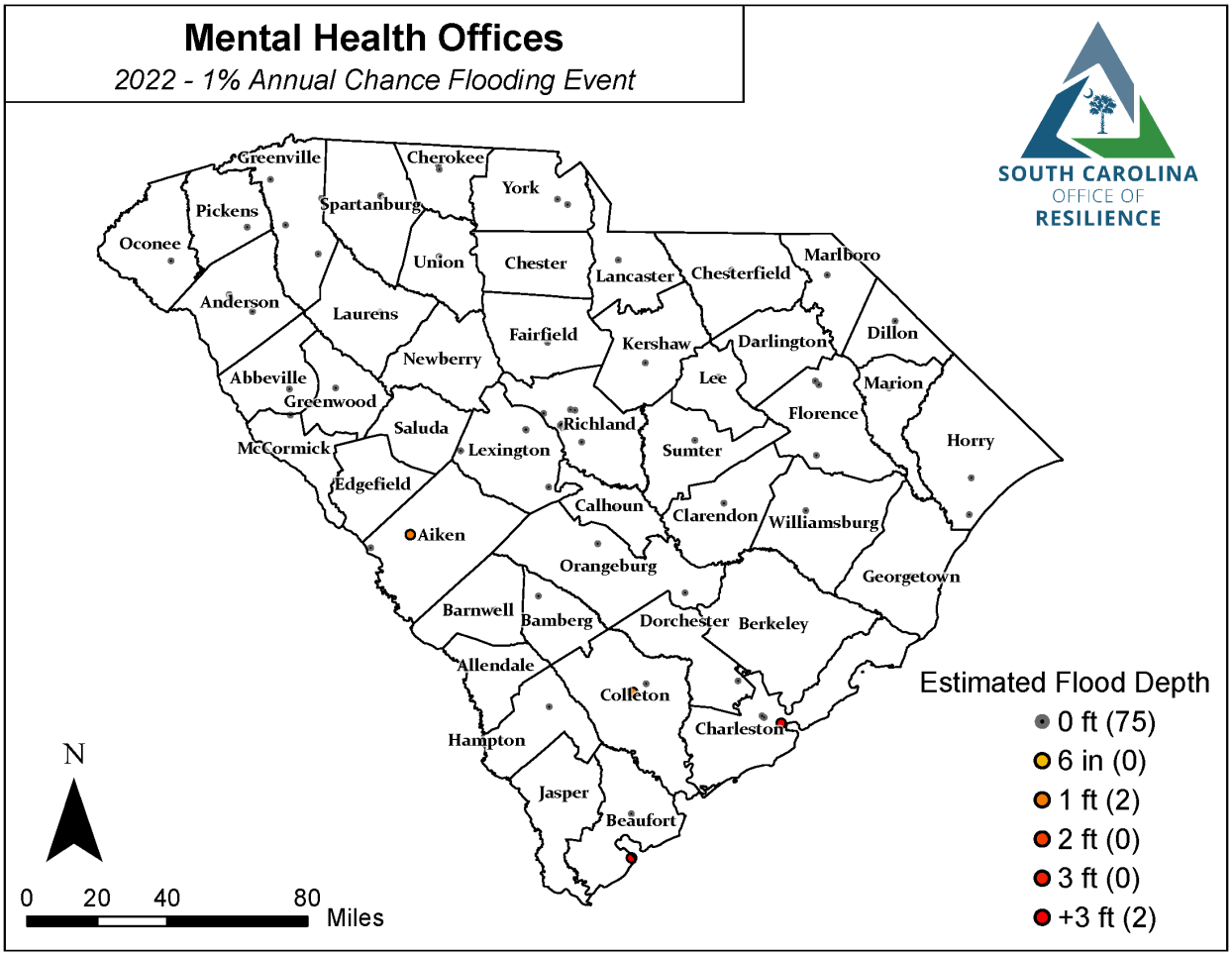


Figure 74: Estimated flooding of mental health offices in the 2022 1% annual chance flooding event (DMH). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

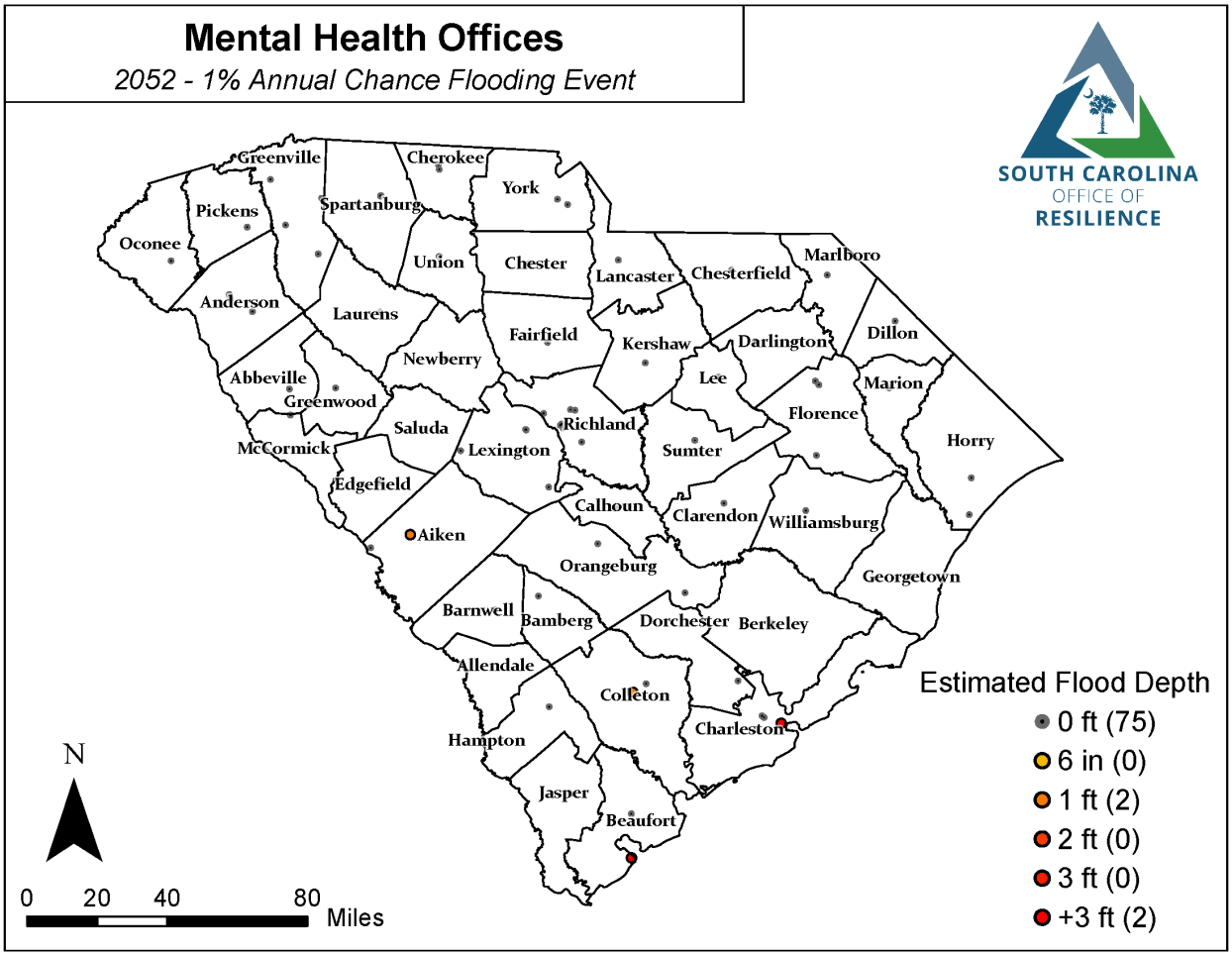


Figure 75: Estimated flooding of mental health offices in the 2052 1% annual chance flooding event (DMH). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Dialysis Clinics

A flood has the potential to become a kidney failure disaster: an event that places large numbers of patients treated with maintenance dialysis or individuals with a recent onset of acute kidney injury at risk due to lack of access to dialysis care. Dialysis treatment requires specialized equipment, power and high-quality water, all things that may be compromised during a flood event. Dialysis clinics close ahead of or in response to flooding events. Even if clinics are able to operate, access can be limited after an event, leading to increased demand at accessible clinics (Lempert & Kopp, 2013). The figures below quantify the estimated flooding of these centers by the 2022 (Figure 76) and 2052 (Figure 77) 1% annual chance flood events on these facilities.

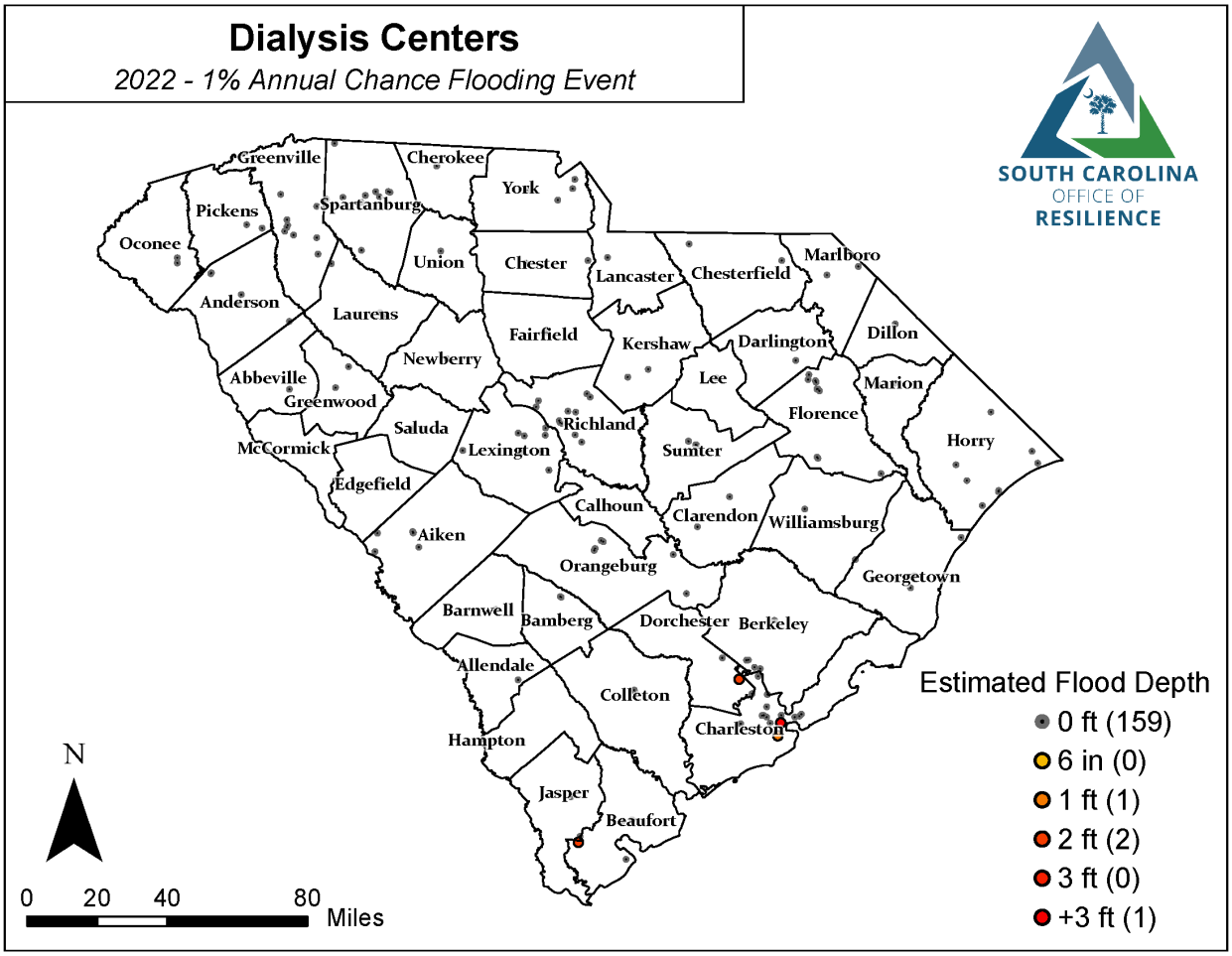


Figure 76: Estimated flooding of dialysis centers in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

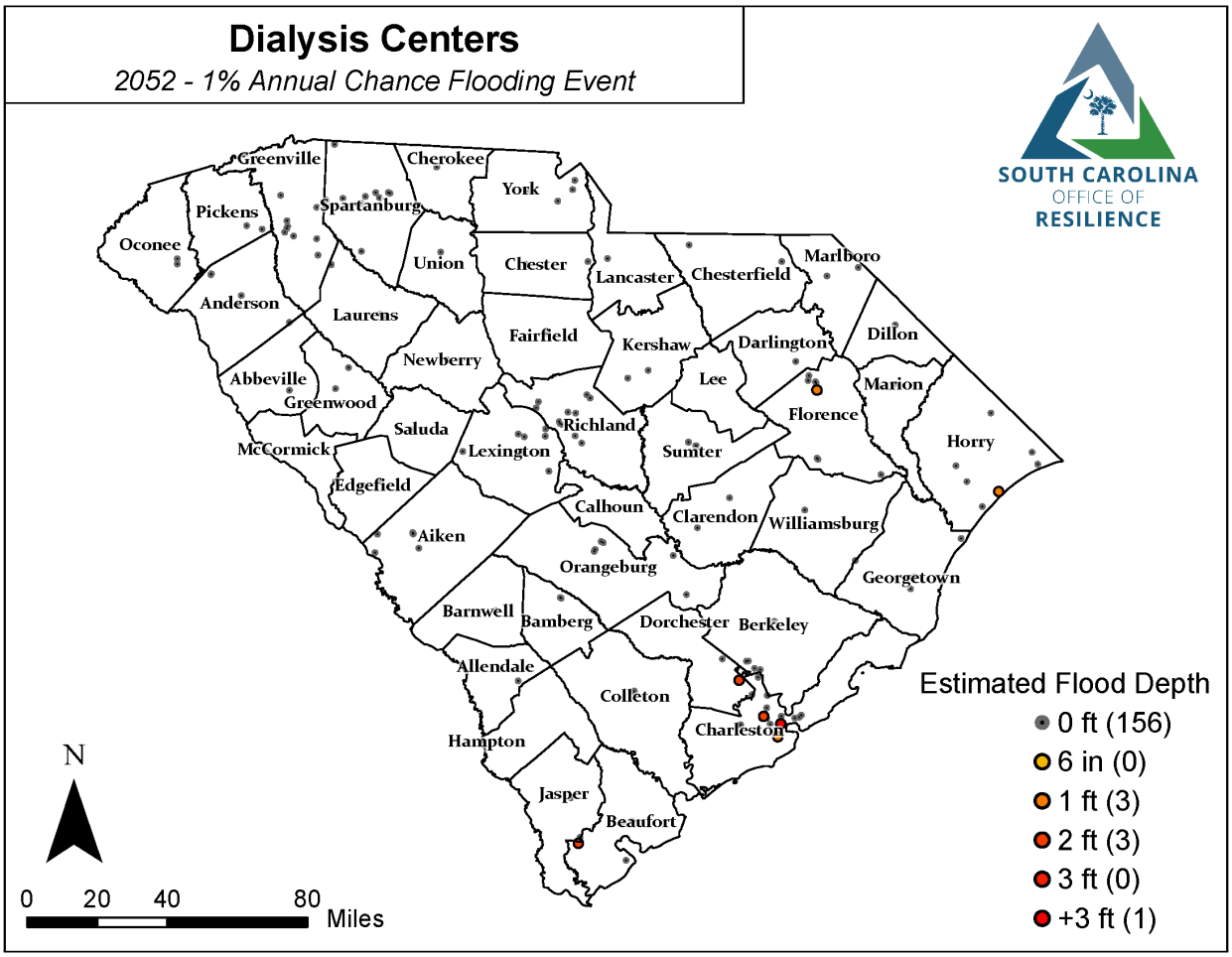


Figure 77: Estimated flooding of dialysis centers in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Pharmacies

People need access to their prescription medication to maintain continuity of care leading up to, during and after an event. Approximately half of all Americans live with a chronic disease that requires prescription medications. Evacuations and preparation can increase demand for pharmacy services and medication doses. After an event, pharmacies may be closed for extended periods of time or have supply chain issues. A study of Hurricane Florence found that pharmacy function along the North Carolina and South Carolina coast was "suboptimal" (Sharpe & Clennon, 2020). The figures below show the estimated flooding of pharmacies in 2022 (Figure 78) and 2052 (Figure 79) 1% annual chance flooding event.

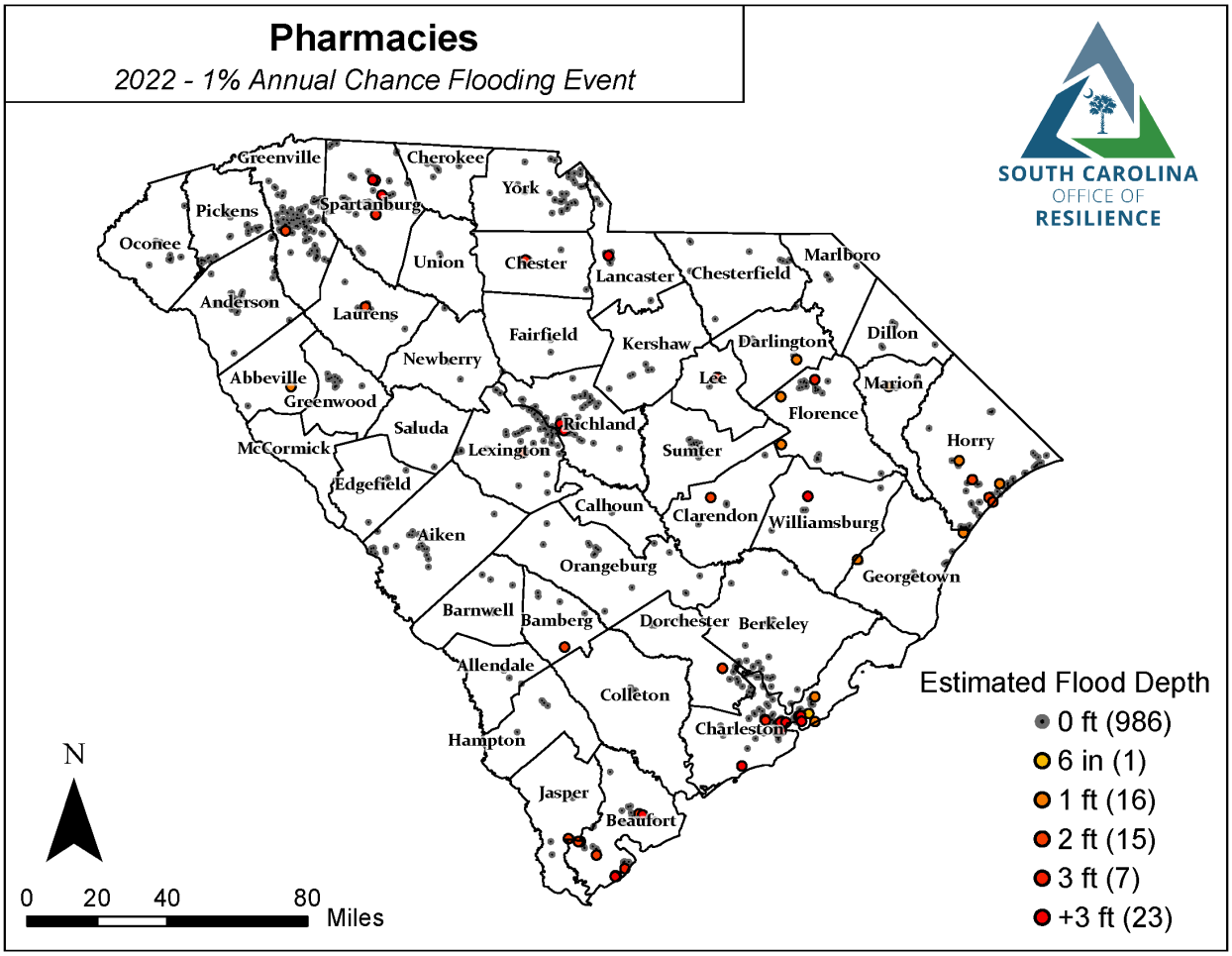


Figure 78 Estimated flooding of pharmacies in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

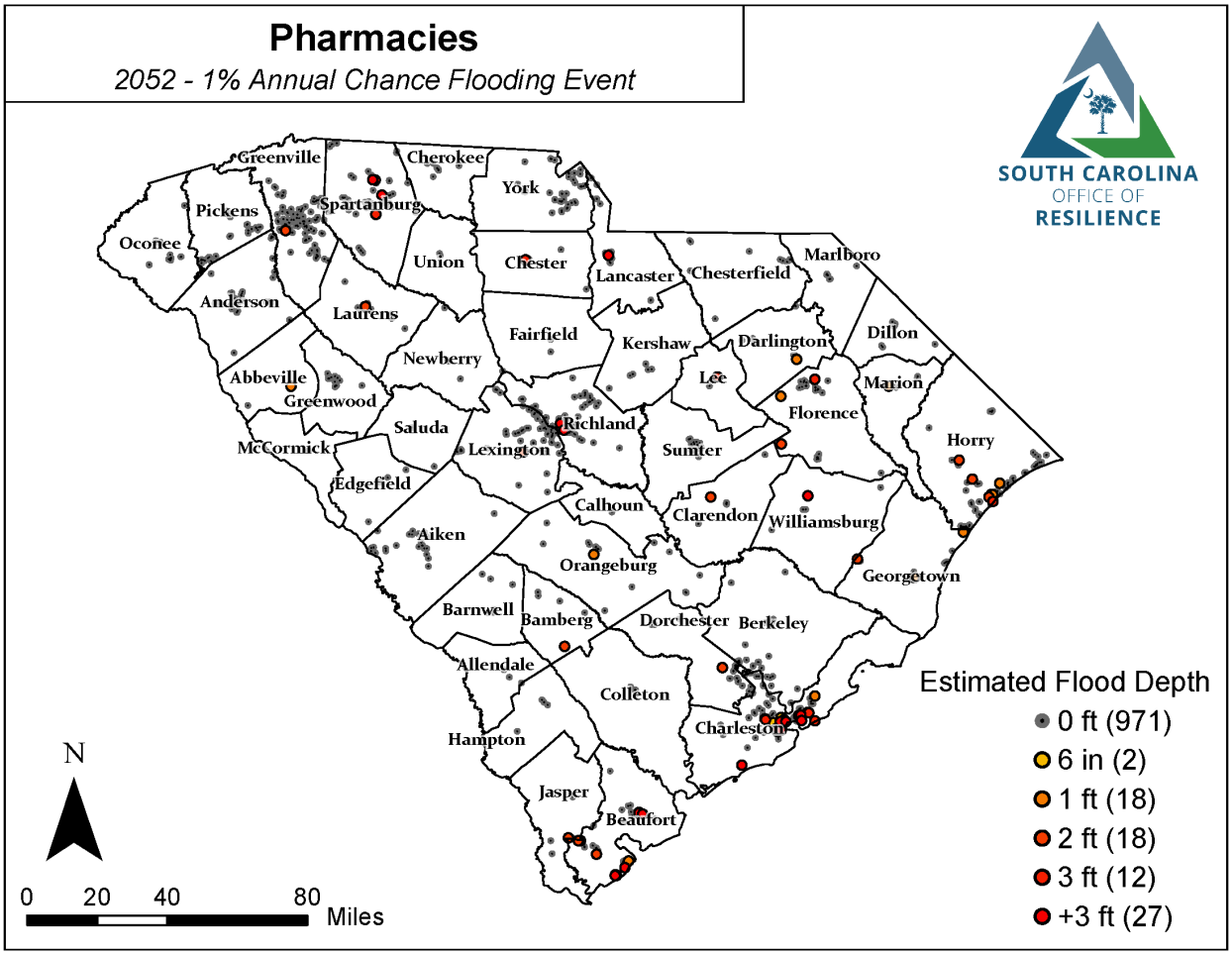


Figure 79 Estimated flooding of pharmacies in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Telehealth

In addition to these in-person service facilities, telehealth visits also gained momentum during the COVID-19 pandemic, with authorizations for the use of federal funds to expand telehealth. The SC Telehealth Alliance Strategic Plan seeks to continue this expansion; however, a potential barrier is the lack of broadband service across the state. Nearly 435,000 people across the state either have no internet service provider available or have internet service that is not capable of person-to-person telehealth visits (South Carolina Telehealth Alliance).

Health and Human Services

The SC Department of Health and Human Services administers a variety of program related to health-related services. The largest of which is Medicaid, but also includes Community Long Term Care, Telehealth, and BabyNet. The Department maintains offices in counties across the state to administer Medicaid and other programs listed below.

Medicaid

Medicaid in South Carolina is operated by the Department of Health and Human Services (DHHS) and supports 1 in 4 South Carolinians. The program serves to expand medical coverage to those with certain income thresholds as well as pregnant women and newborns, the elderly, the blind, the disabled, and those who may be in a nursing home or hospital for extended periods of time. The DHHS maintains offices in every county that serve as enrollment centers for Medicaid.

Community Long Term Care

In addition to administering the Medicaid program of South Carolina, the Department of Health and Human Services (DHHS) is responsible for Community Long Term Care (CLTC) program, which provides in-home services Medicaid-eligible people to those who want to remain living at home but need special services to make that a healthy possibility. CLTC services are available for persons age 18 years or older who are unable to perform activities of daily living such as bathing, dressing, and toileting due to illness or disability. In order to meet the qualifications to enroll into the Community Choices waiver the individual must meet the same level of care that is needed to enter a nursing facility (SC Department of Health and Human Services, n.d.).

There are 14 CLTC enrollment offices throughout the state, but the major vulnerability lies with connecting health providers with those residents who depend on them, as well as making sure that the patient's residence is safe in times of flooding.

BabyNet

The Department of Health and Human Services (DHHS) administers the BabyNet program, which connects children and youths with developmental delays or disabilities to care programs for early intervention, special education, and related programs. There are 14 offices throughout the state where children can be referred and enrolled to the program.

The maps below show the vulnerability of these offices to flooding in the 2022 (Figure 80) and 2052 (Figure 81) 1% annual chance flood event.

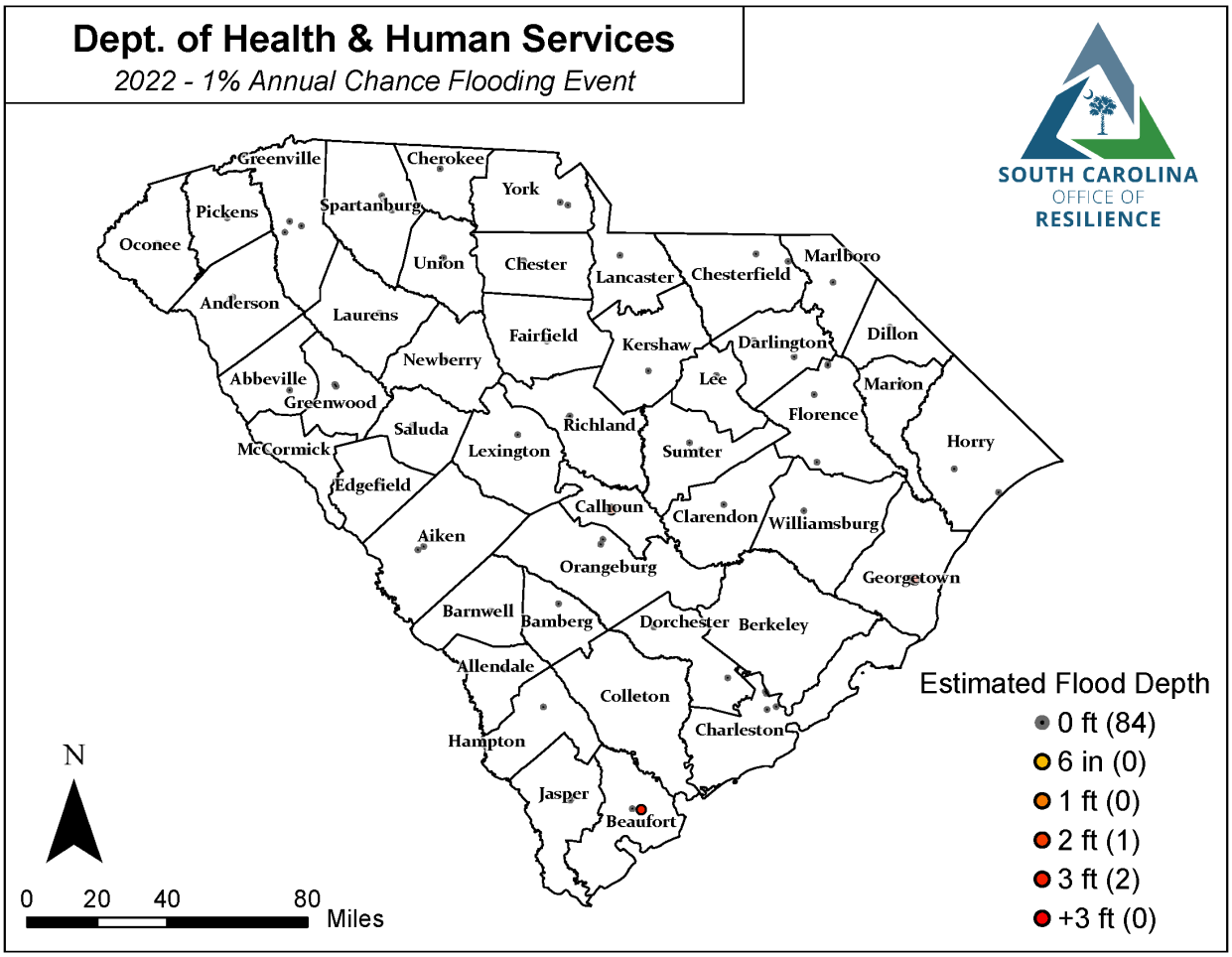


Figure 80: Estimated flooding of Department of Health and Human Services' offices in the 2022 1% annual chance flooding event (DHHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

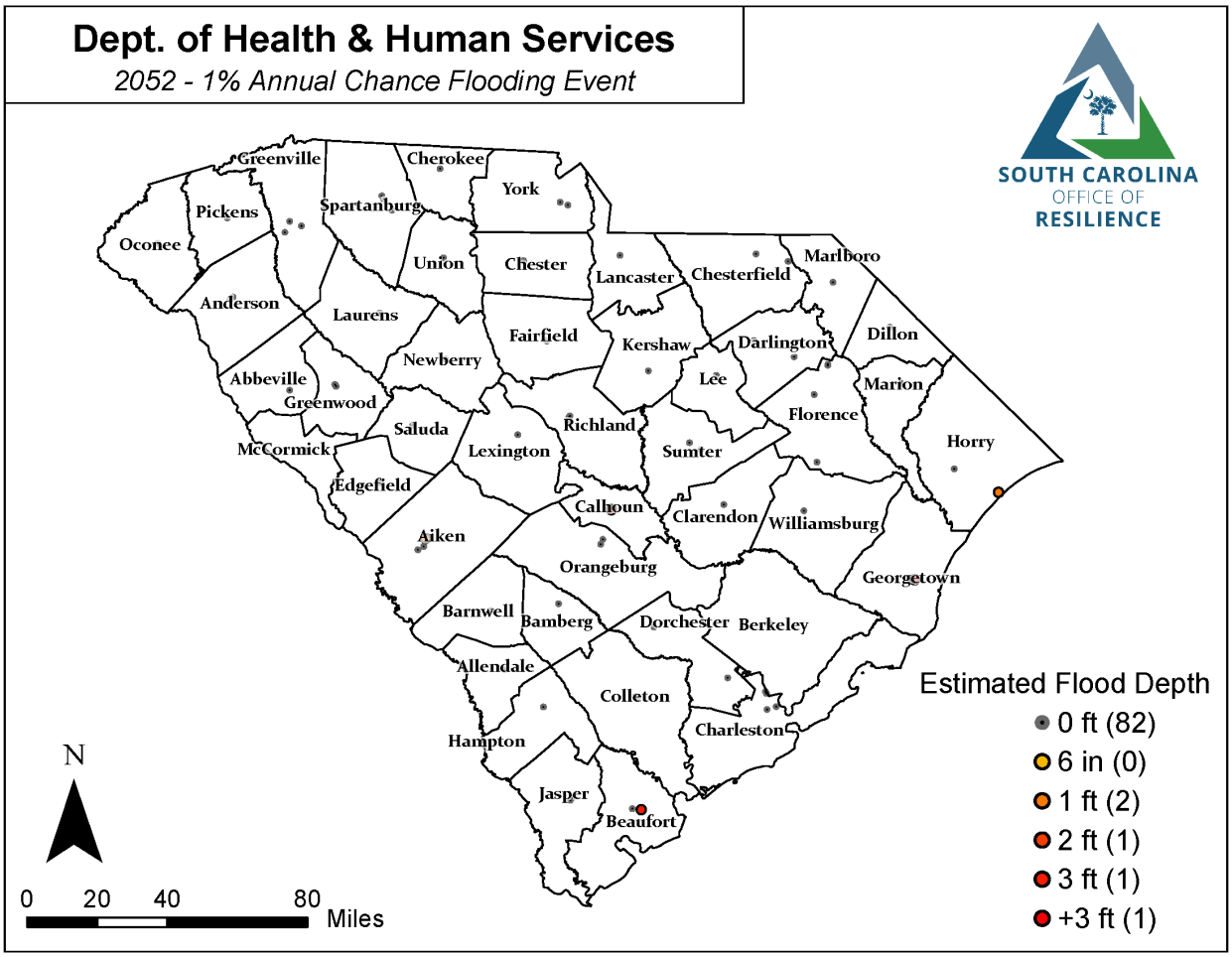


Figure 81: Estimated flooding of Department of Health and Human Services' offices in the 2052 1% annual chance flooding event (DHHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Social Services

The South Carolina Department of Social Services (DSS) hosts a diverse array of programs including Child Protective Services (CPS), foster care / adoption, Temporary Assistance for Needy Families (TANF), Supplemental Nutrition Assistance Program (SNAP), work programs, early care and education, adult advocacy, and child support services. These programs directly impact 1 in 6 South Carolinians and are based in every county in the state. Regarding flooding, DSS operates Disaster Supplemental Nutritional Program (D-SNAP) and maintains evacuation plans for all of its licensed facilities. Similar to other community services the vulnerability is not held completely by the physical locations, it lies with the access of providers and constituents to the services they rely on.

The maps below show the vulnerability of those childcare facilities licensed by DSS to flooding in the 2022 (Figure 82) and 2052 (Figure 83) 1% annual chance flood event.

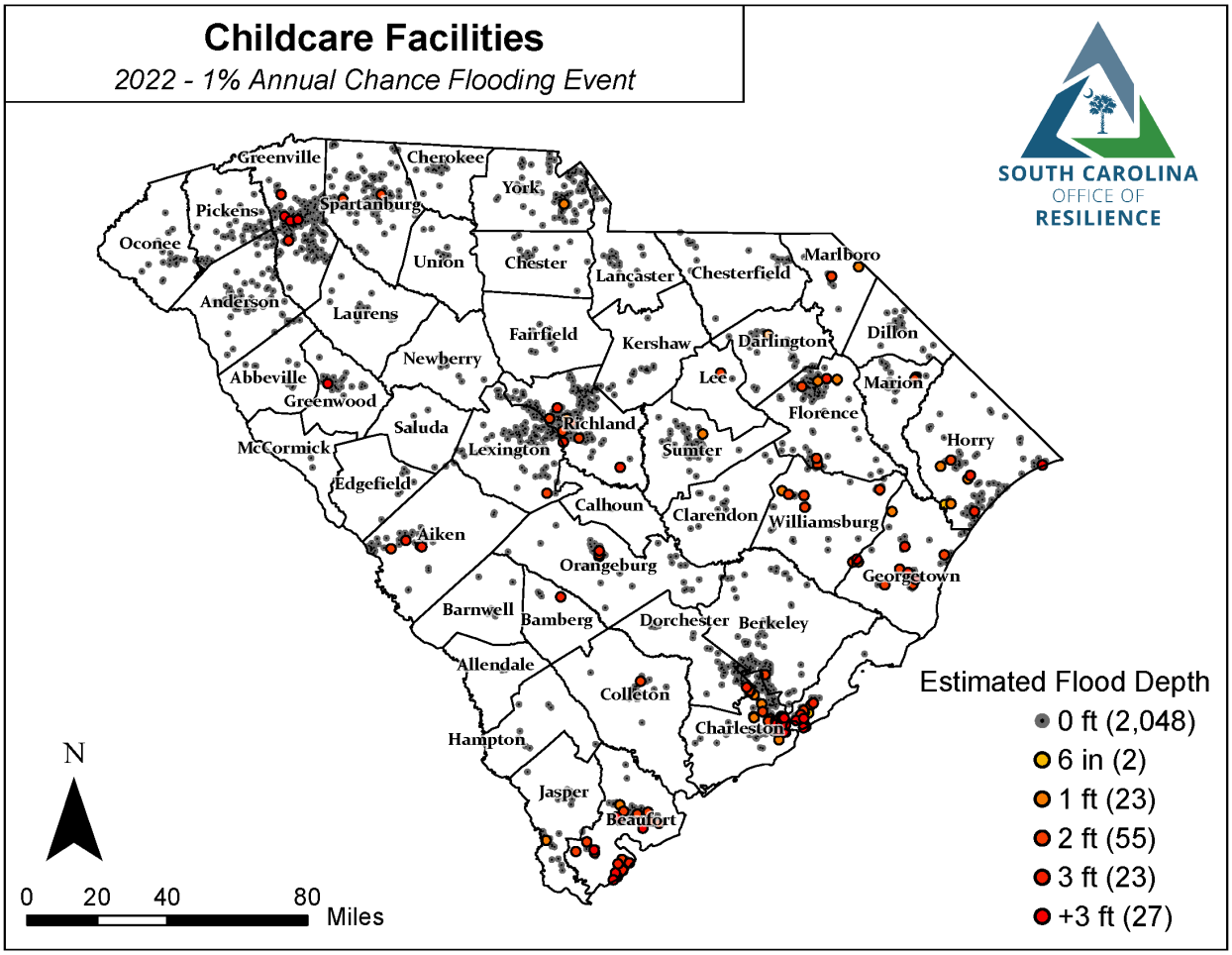


Figure 82 Estimated flooding Childcare Facilities in the 2022 1% annual chance flooding event (DSS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

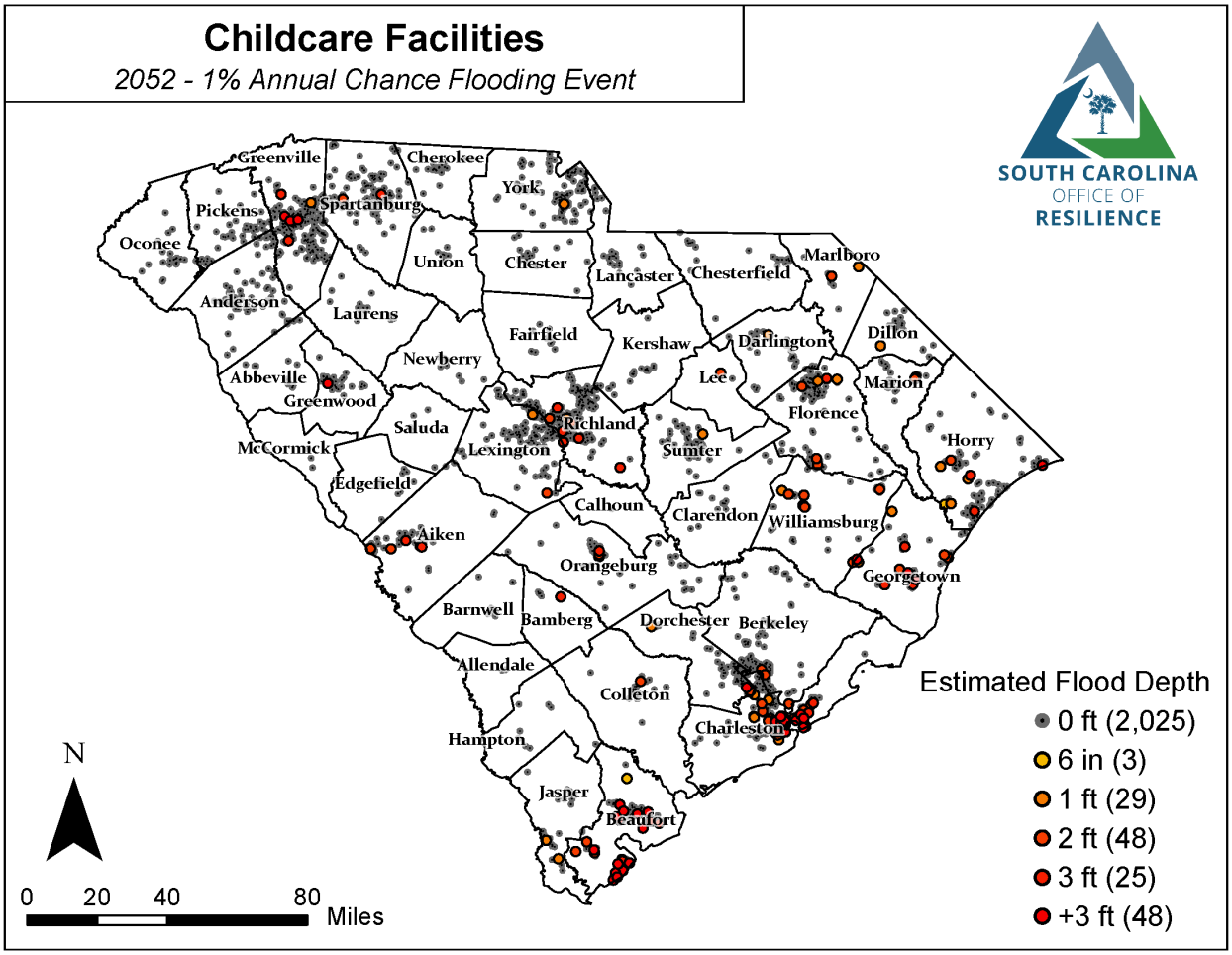


Figure 83 Estimated flooding Childcare Facilities in the 2052 1% annual chance flooding event (DSS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Veteran's Affairs

The South Carolina Department of Veteran's Affairs (DVA) coordinates county level Veteran's Affairs offices, places in the community where veterans can access benefits. The DVA assists veterans with employment, healthcare, suicide prevention, and education and have facilities across the state. The maps below show the vulnerability of these facilities to flooding in the 2022 (Figure 84) and 2052 (Figure 85) 1% annual chance flood event.

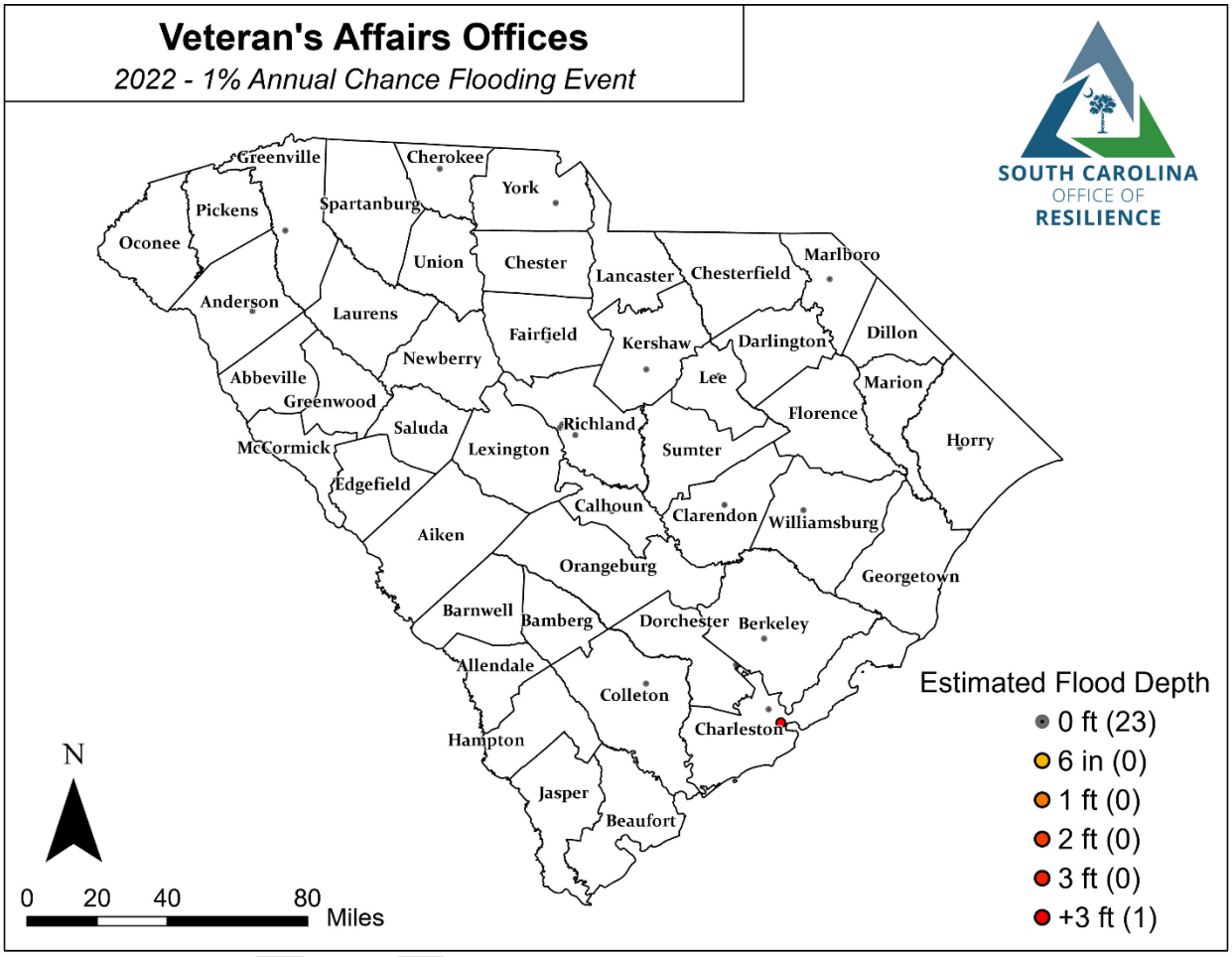


Figure 84: Estimated flooding of Veteran Affairs facilities in the 2022 1% annual chance flooding event (DVA). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

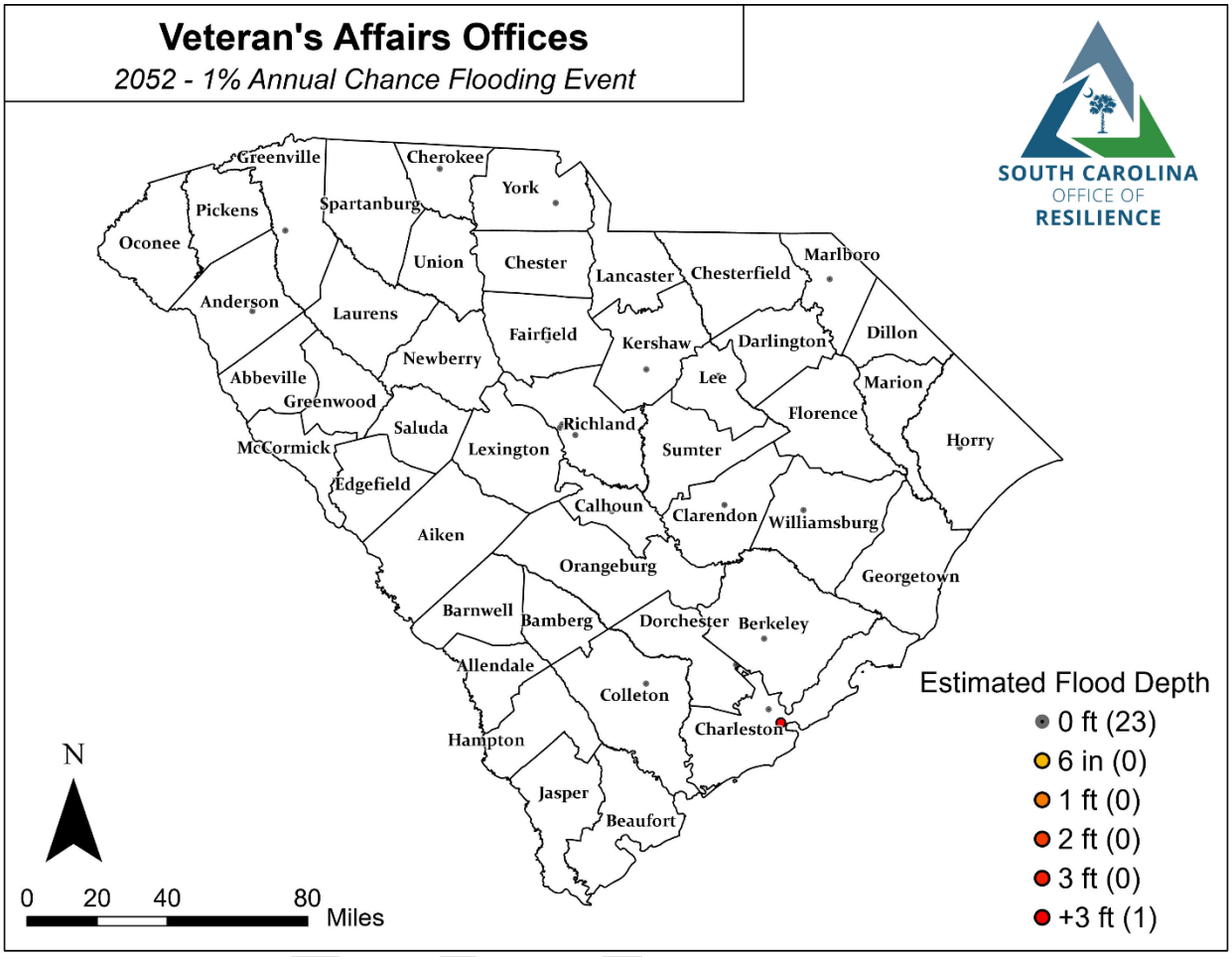


Figure 85: Estimated flooding of Veteran Affairs facilities in the 2052 1% annual chance flooding event (DVA). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Places of Worship

There are nearly 6,000 places of worship across the State. After a disaster, these places and their communities provide essential support such as the collection, storing and distribution of supplies, acting as a shelter, and supporting other community needs. The maps below show the vulnerability of these places of worship to flooding in the 2022 (Figure 86) and 2052 (Figure 87) 1% annual chance flood event.

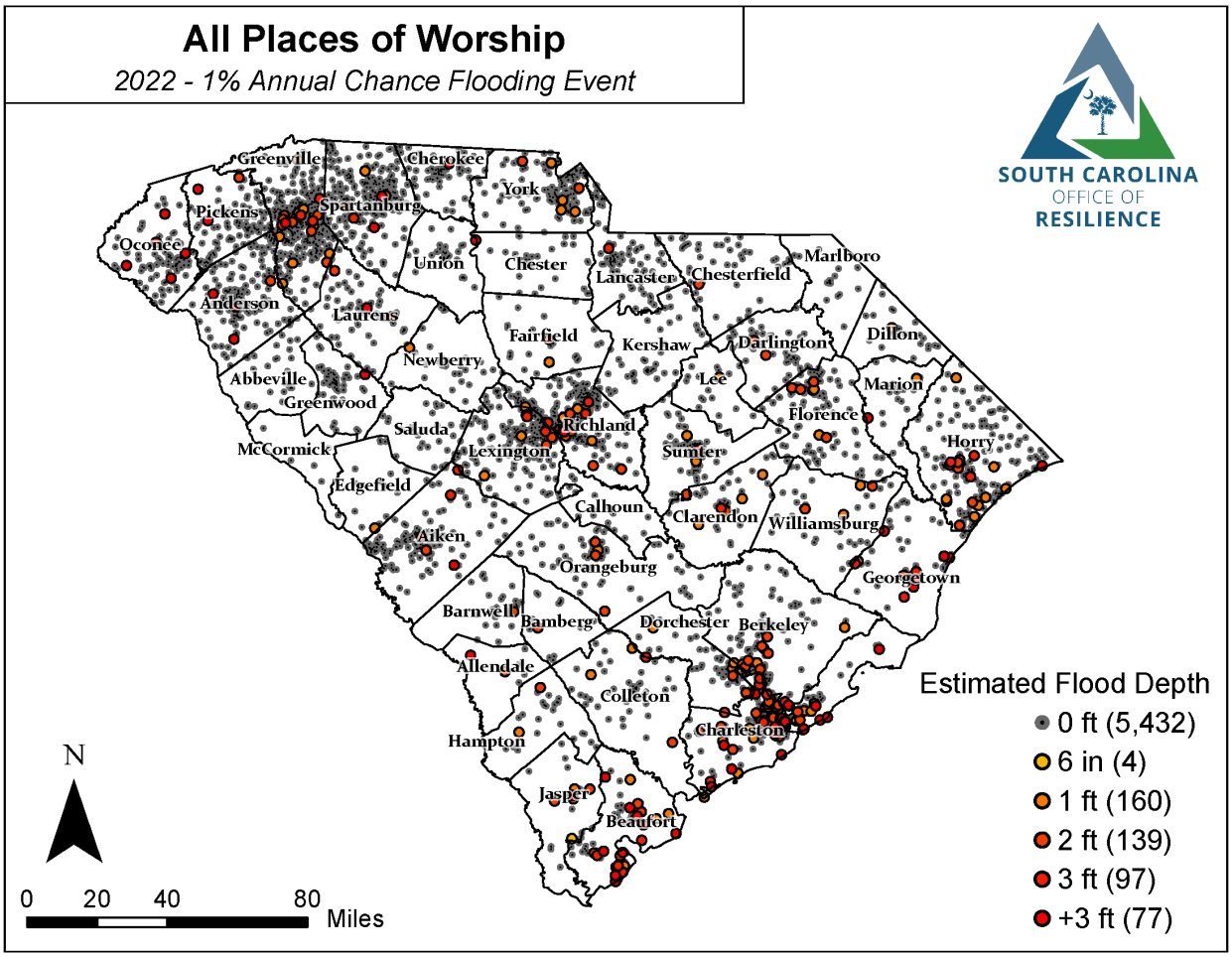


Figure 86: Estimated flooding of places of worship in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

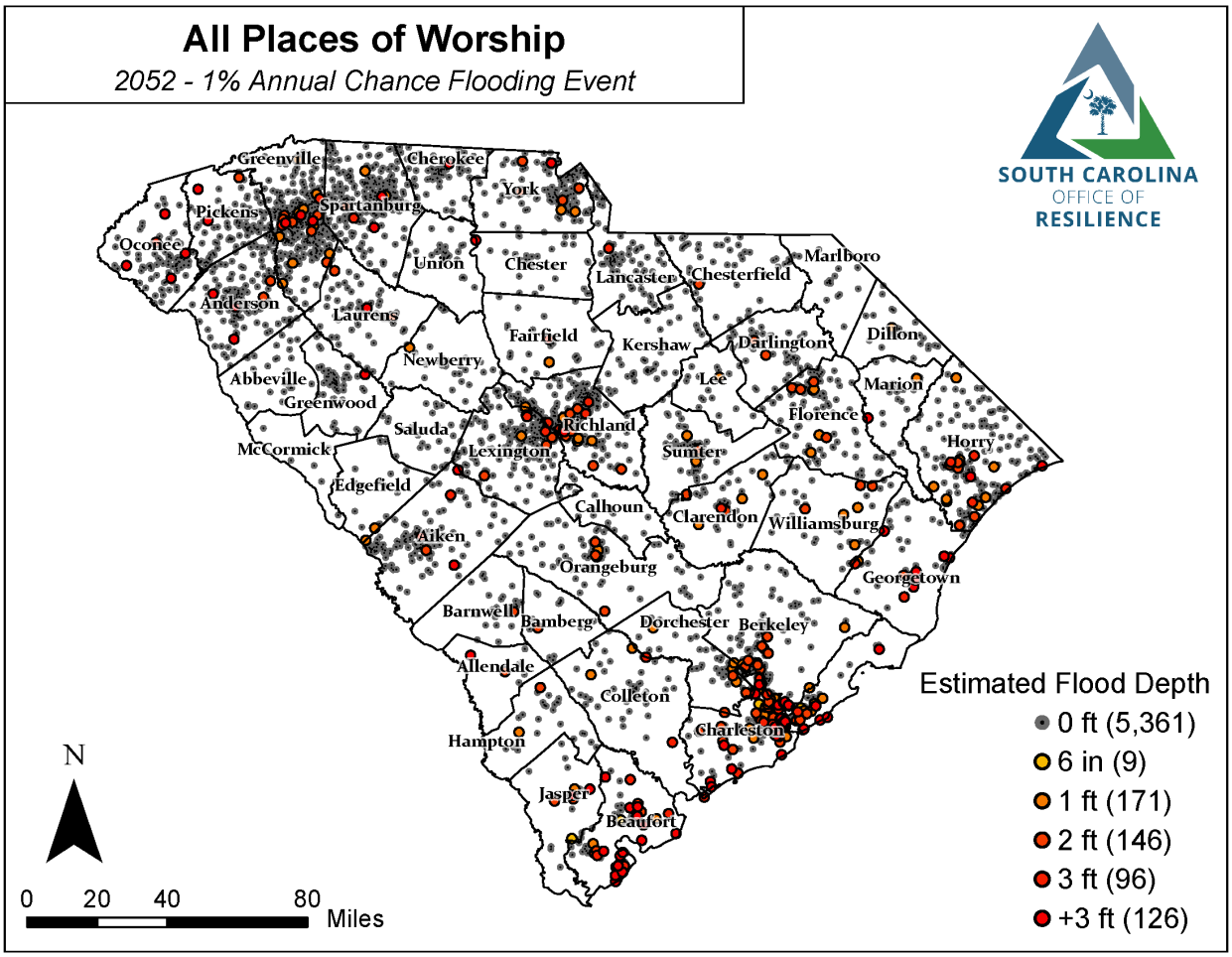


Figure 87: Estimated flooding of places of worship in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Infrastructure

Roads & Bridges

In South Carolina there are over 60,000 public road miles. SCDOT maintains over 41,000 miles of those roadways as well as more than 8,400 bridges, with the fourth largest state-maintained highway system in the nation (SCDOT, 2022). In many ways, the vulnerability of roads and bridges determines much of the vulnerability of all sectors listed in this chapter. All the facilities listed here require access. Additionally, roads and bridges are essential to evacuation and response, and for the delivery of longer-term recovery resources.

Air Facilities

There are 51 public general aviation and six commercial airports across the state. These airports employ 122,759 people, with an annual payroll of $4.8 billion. Additionally, they generate $16.3 billion in annual economic activity. This figure includes the economic impact of Boeing, which has a large presence in Charleston, the location of final assembly for the Boeing 787 Dreamliner (South Carolina Aeronautics Commission, 2018). The maps below show the vulnerability of these places of worship to flooding in the 2022 (Figure 88) and 2052 (Figure 89) 1% annual chance flood event.

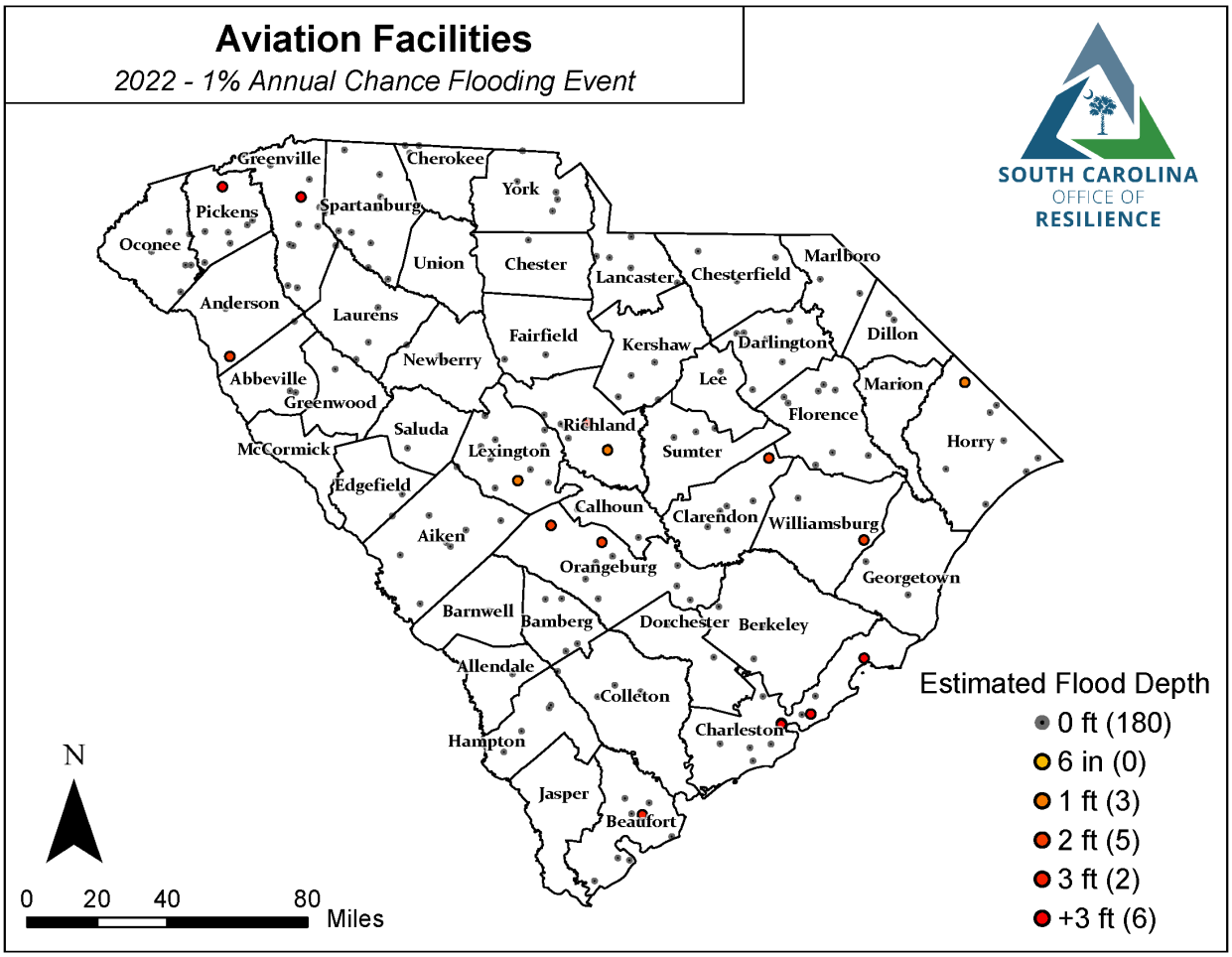


Figure 88: Estimated flooding of aviation facilities in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

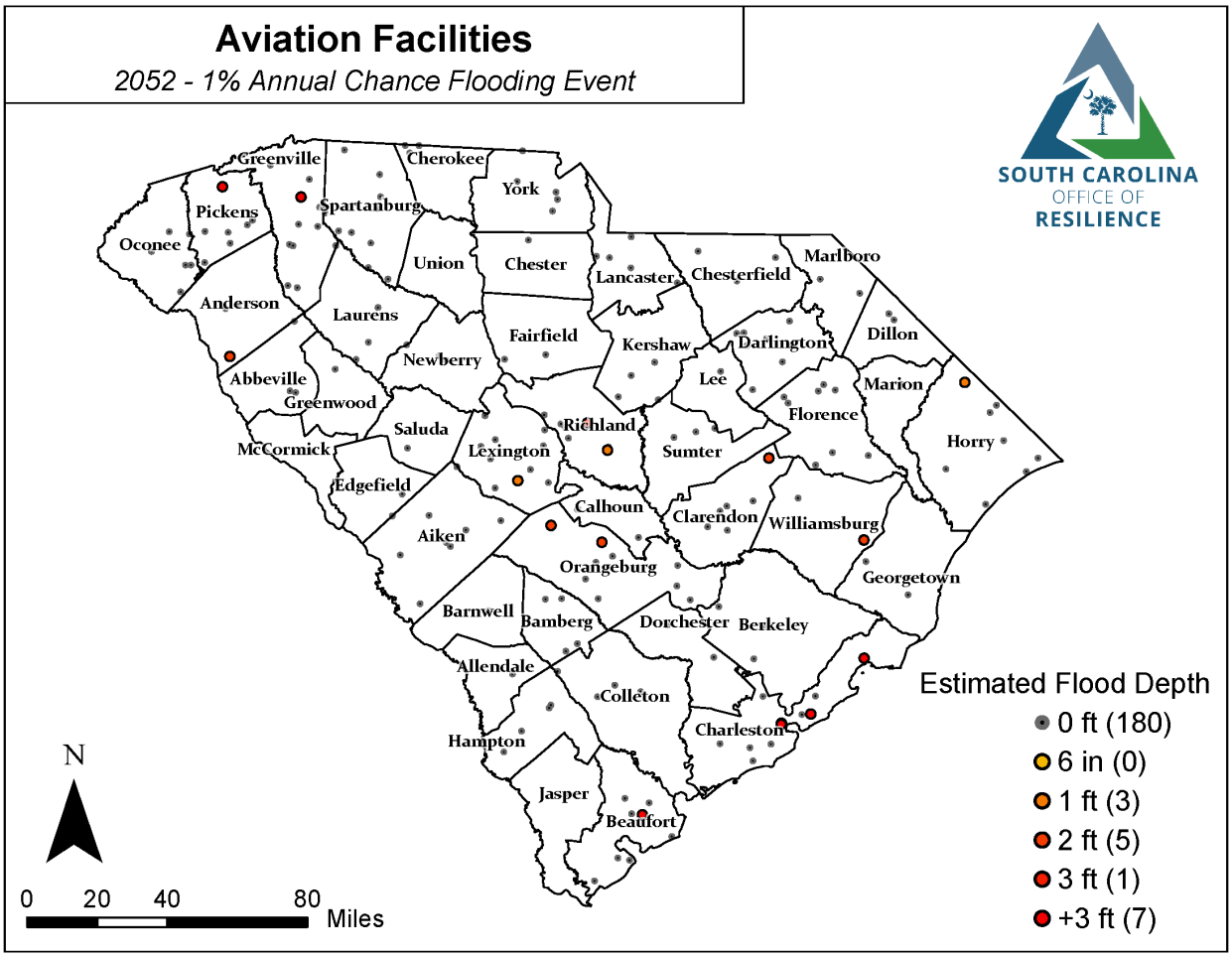


Figure 89: Estimated flooding of aviation facilities in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Ports

South Carolina Ports Authority owns and operates the Port of Charleston, Port of Georgetown, Inland Port Greer and Inland Port Dillon, ensuring the efficient movement of cargo between South Carolina and global markets, generating a $63.4 billion economic impact on South Carolina each year (South Carolina Ports Authority, n.d.).

Sea level rise poses risk to ports across US because mitigation measures are capital intensive. Ports plan for sea level rise contingencies, but the effects of storm surges and flooding could extend to complementary supply chain infrastructure on the landside and transportation sector. In the event of a massive hurricane or other disaster that leaves roads impassible, Ports would likely be a vital resource for delivery of supplies and movement of goods. Interruption of supply chain can be disastrous. Port equipment could be damaged along with cargo. Hurricanes could cause shipping channels and berths to shoal in from increased sediment load. ‘

Historically, our wharves have gotten progressively higher in elevation, and sea level rise is factored into Ports Authority’s design. However, older terminals have much older wharf structures that are more vulnerable to storm surge and sea level rise.

Rail

Rail freight is essential to the state’s economy by providing efficient transportation of raw materials and goods for industries and businesses located here, as well as a distribution channel for products exported to other states and countries. Rail services are provided by 11 railroads, including two Class I railroads (CSXT and Norfolk Southern). Palmetto Railways, a branch of the South Carolina Department of Commerce, operates four railroad subdivisions. Additionally, Amtrak provides passenger service in South Carolina, with four Amtrak services passing through the state: Silver Star – New York/Tampa/Miami via Columbia, Silver Meteor – New York/Miami via Charleston, Palmetto – New York/Savannah via Charleston, and Crescent – New York/New Orleans via Greenville, with 11 stations in the state (South Carolina Department of Transportation, 2020).

Electric Power Generation and Distribution

Electric Generation

Electric power systems are particularly vulnerable to flooding. Electric generation and distribution require a complex system of power plants, substations, transmission lines, and other critical infrastructure that make up the power grid (Kern & Miranda, 2021).

Power plants are all the land and land rights, structures and improvements, boiler or reactor vessel equipment, engines and engine-driven generators, turbo generator units, accessory electric equipment, and miscellaneous power plant equipment are group together for each individual facility. The maps below show the vulnerability of these power plants to flooding in the 2022 (Figure 90) and 2052 (Figure 91) 1% annual chance flood event. This list includes hydroelectric dams, fossil fuel, nuclear, solar, wind, geothermal, and biomass (DHS).

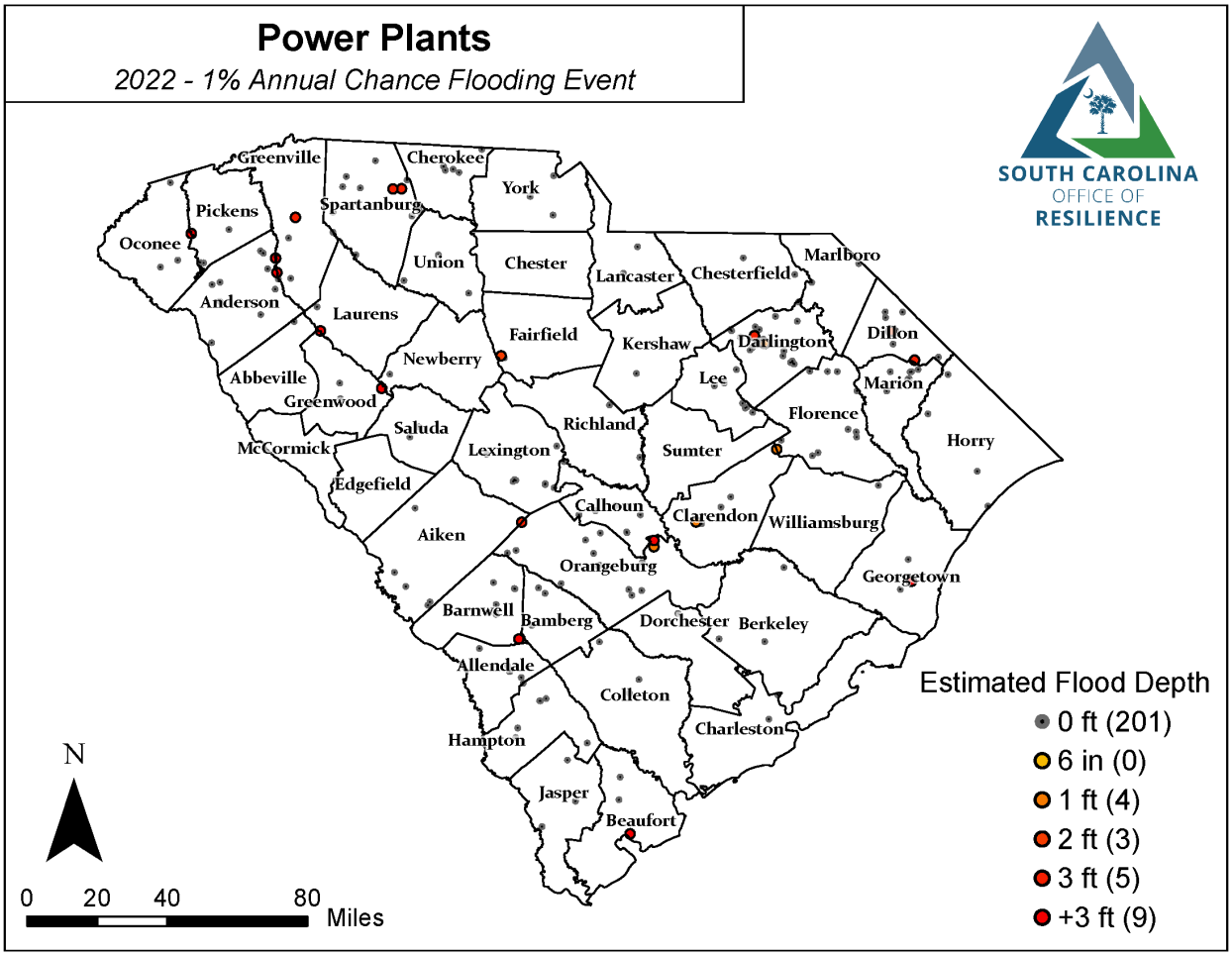


Figure 90: Estimated flooding of power plants in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

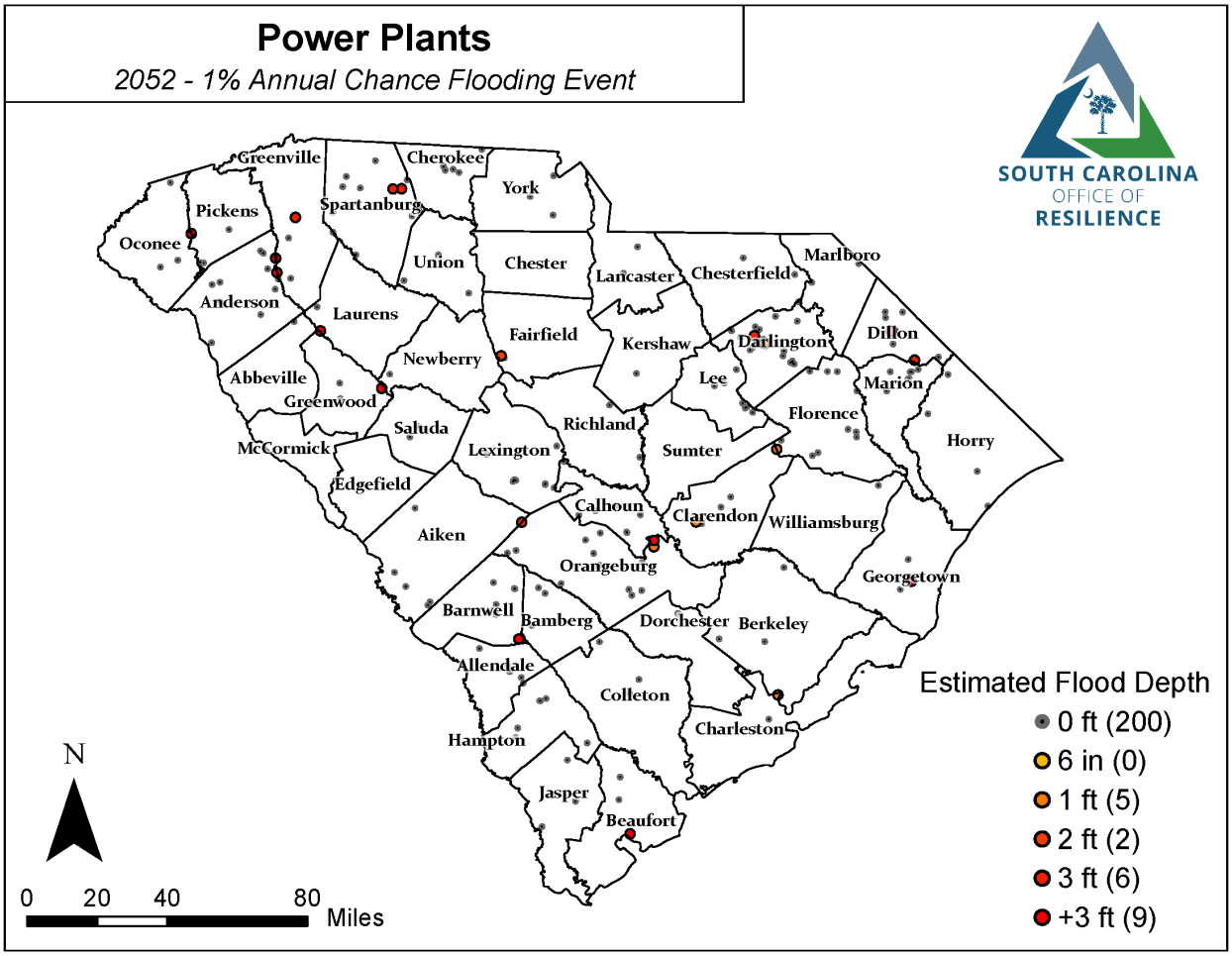


Figure 91: Estimated flooding of power plants in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Substations

Electric power substation facilities and equipment that switch, transform, or regulate electric power at voltages equal to, or greater than, 69 kilovolts, allowing for export onto the wider state grid and for distribution into homes and businesses (DHS). Repairing flooded substation can take much longer to repair than distribution lines because of the time needed to allow waters to recede (Kern & Miranda, 2021). The maps below show the vulnerability of these substations to flooding in the 2022 (Figure 92) and 2052 (Figure 93) 1% annual chance flood event.

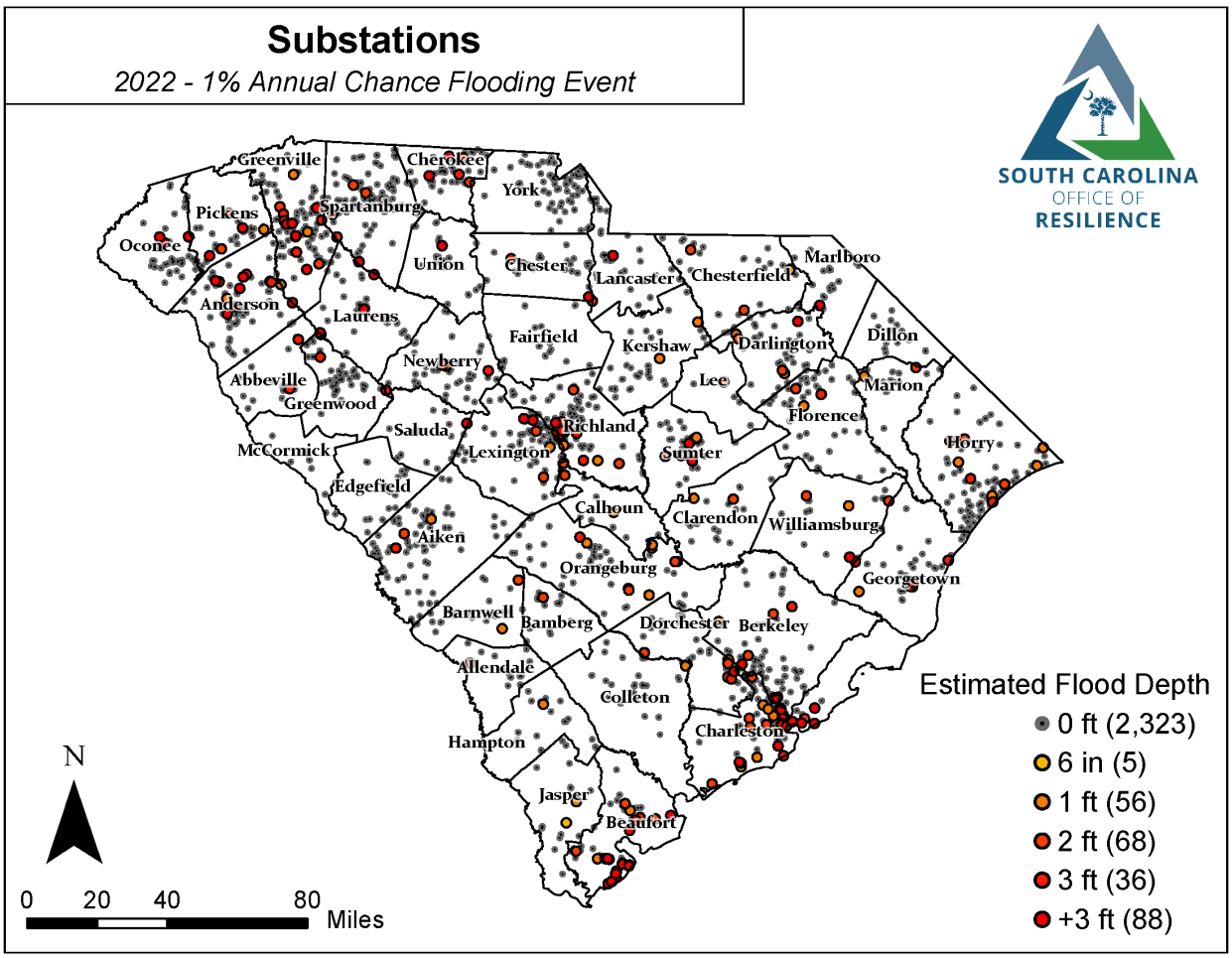


Figure 92: Estimated flooding of power substations in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

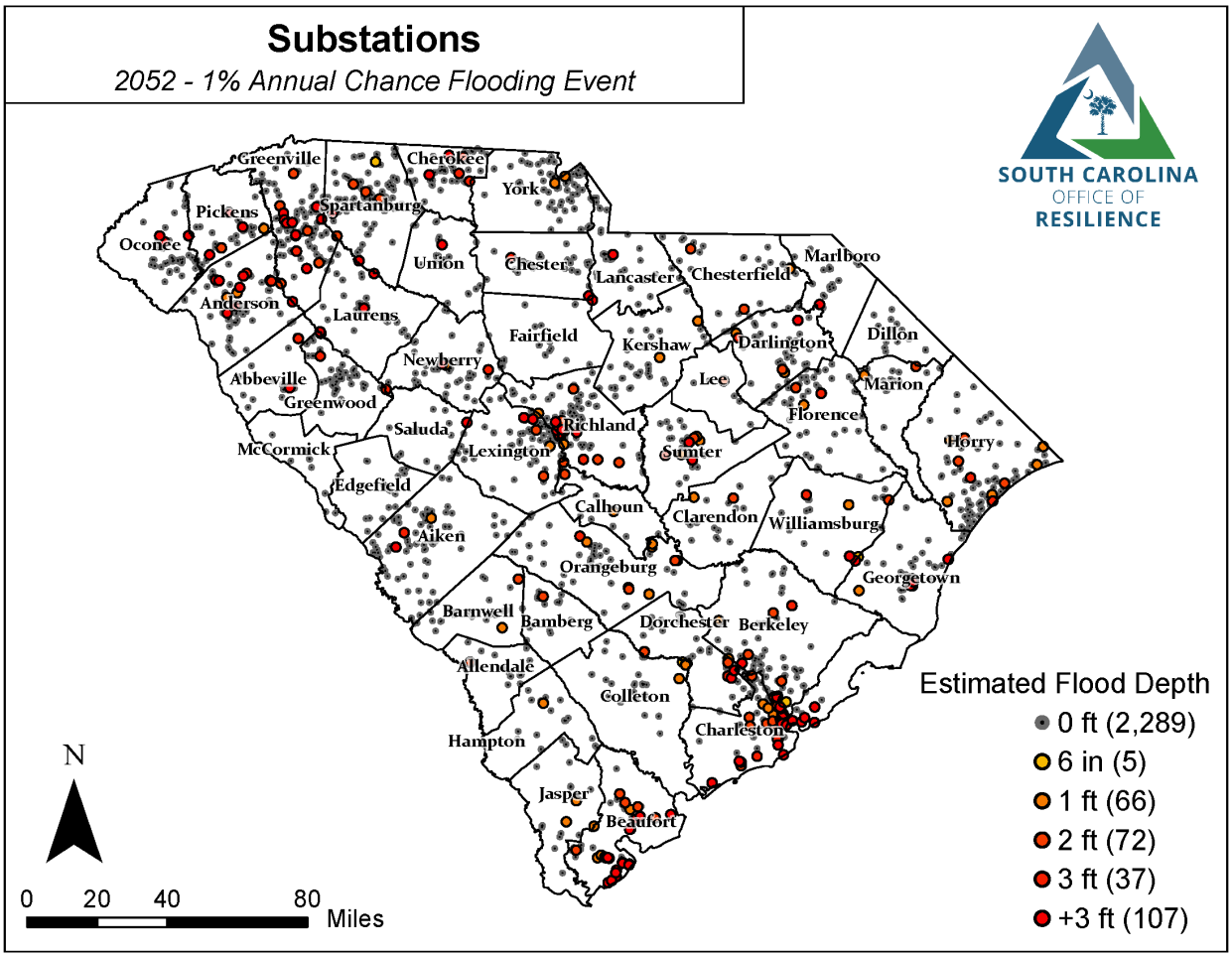


Figure 93: Estimated flooding of power substations in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Economic Systems

Agriculture

According to the SC Department of Agriculture, there are nearly 25,000 farms and 4.7 million acres of farmland in South Carolina. Agribusiness (agriculture + forestry) accounts for 246,957 jobs and $46.2 billion in annual economic impact. The top 10 agricultural commodities are: broilers, turkeys, corn, cattle/calves, soybeans, cotton, chicken eggs, peanuts, floriculture and tobacco (SC Department of Agriculture, 2017) . A study on the 2015 flood estimated losses in the field and from prevented planting totaling over $375 million (SC Department of Agriculture, 2015).

Food Systems

DHEC's GIS Hub includes a SC Food Desert Map to help partner agencies identify underserved areas to develop strategies to increase access to healthy food. Healthy food can be even harder to obtain before, during and after hazardous events.

Public Refrigerated Warehouses

Public refrigerated warehouses support this food system by storing perishable food. These temperature-controlled storage facilities can also serve as other types of products such as medication, plants and flowers. Additionally, there are cultural resources and other fragile items that may need to be kept in a facility with a specific constant temperature. The maps below show the vulnerability of these warehouses to flooding in the 2022 (Figure 94) and 2052 (Figure 95) 1% annual chance flood event.

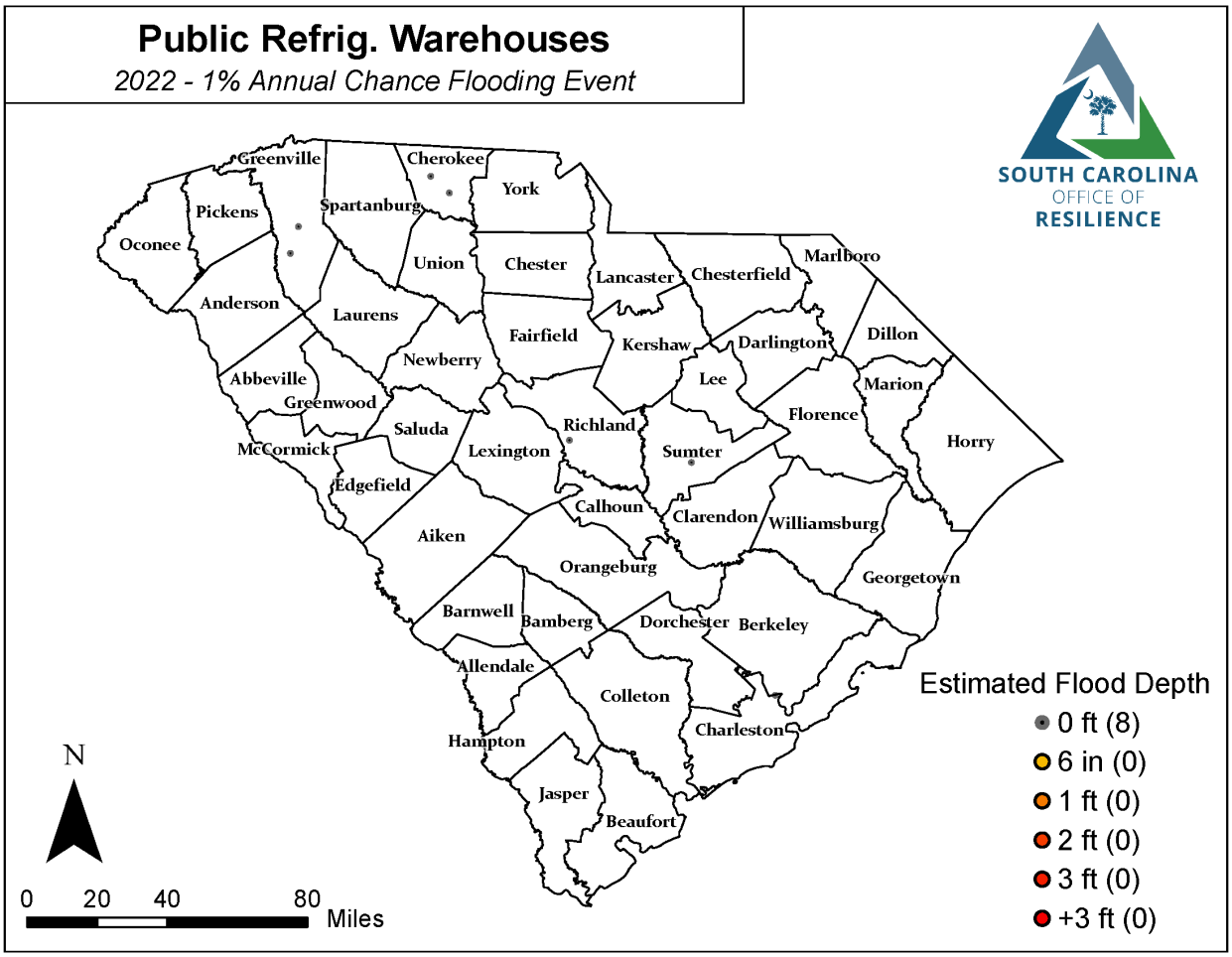


Figure 94 Estimated flooding of public refrigeration warehouses in the 2022 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

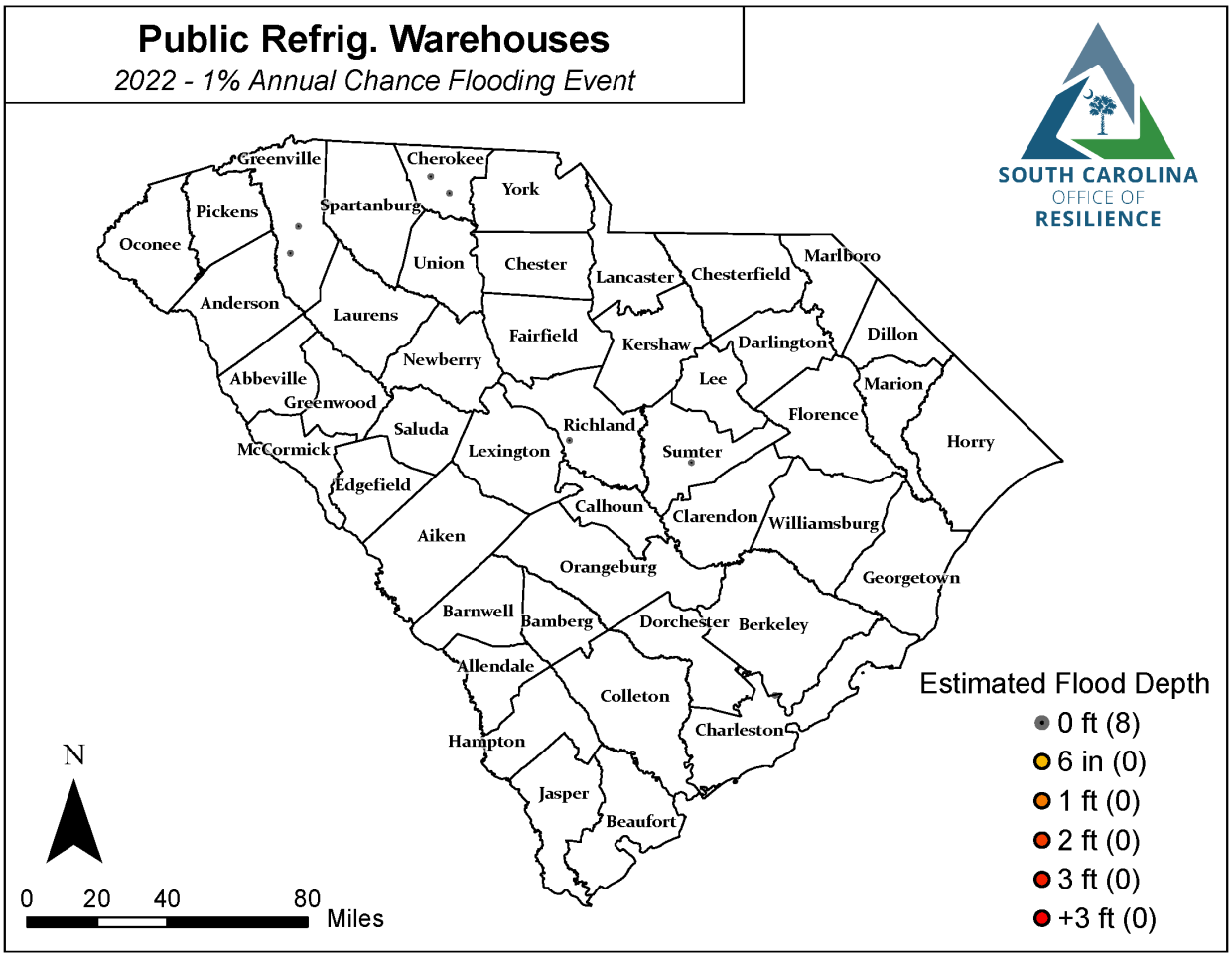


Figure 95: Estimated flooding of public refrigeration warehouses in the 2052 1% annual chance flooding event (DHS). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Manufacturing

Manufacturing accounts for 12% of the employment in the state. There are businesses in South Carolina manufacturing everything from automobiles and appliances to boats and aircraft (SC Department of Commerce, 2020). The maps below show the estimate flooding of these in the 2022 (Figure 96) and 2052 (Figure 97) 1% annual chance flood event.

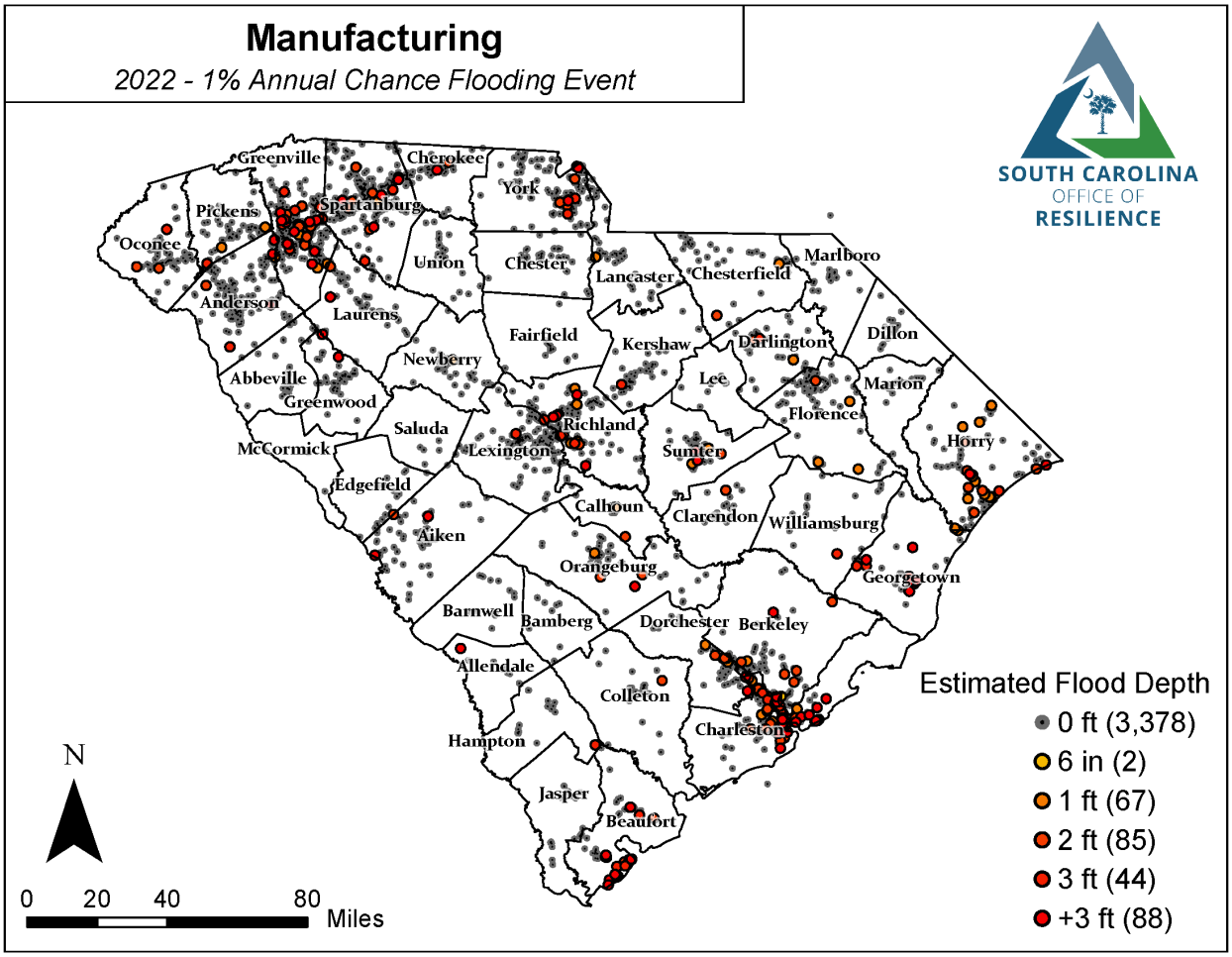


Figure 96: Estimated flooding of manufacturing facilities in the 2022 1% annual chance flooding event (SC Department of Commerce). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

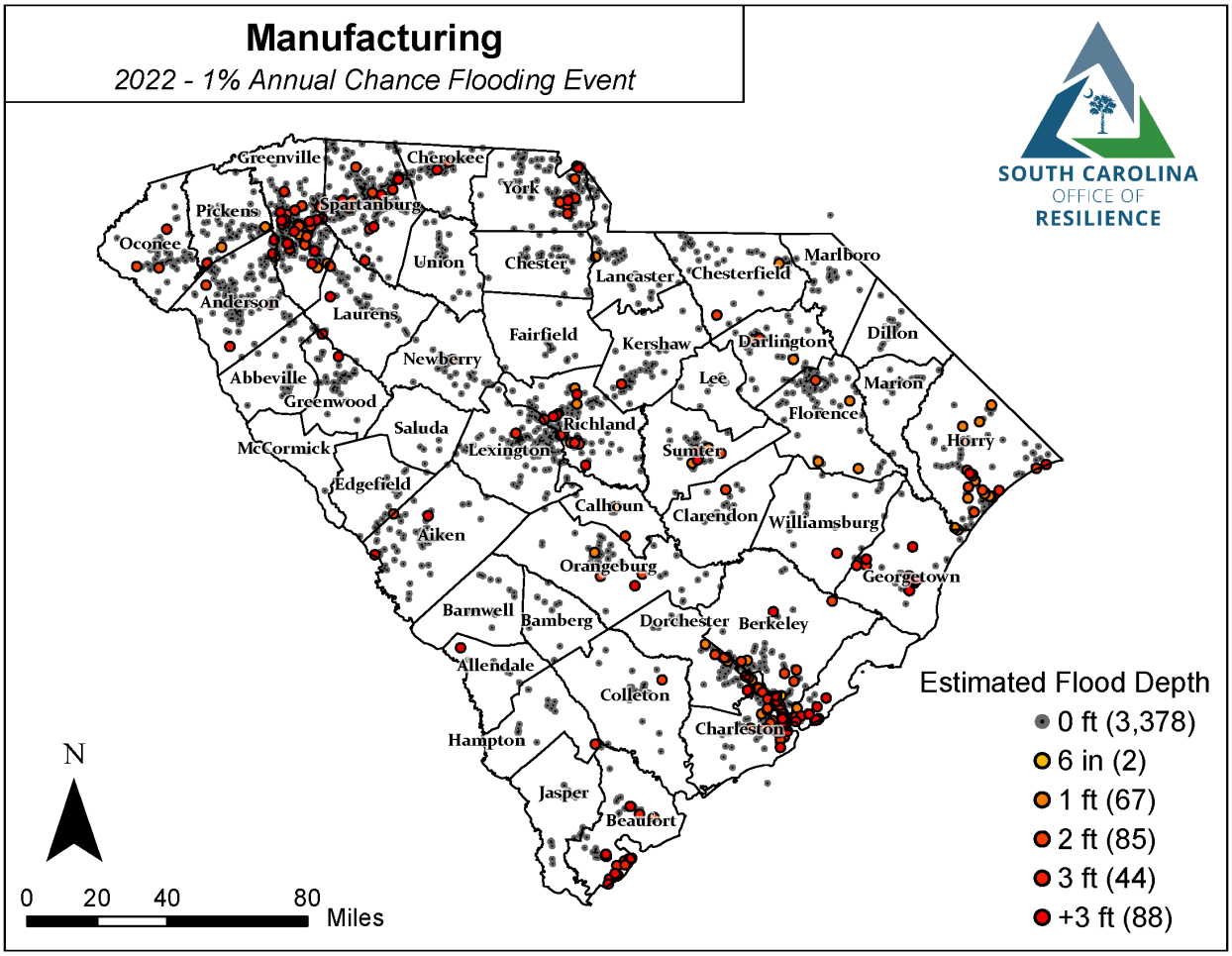


Figure 97: Estimated flooding of manufacturing facilities in the 2052 1% annual chance flooding event (SC Department of Commerce). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Industrial Buildings

According to the South Carolina Department of Commerce, there are over 230 industrial buildings across the state. The maps below show the estimate flooding of these buildings in the 2022 (Figure 98) and 2052 (Figure 99) 1% annual chance flood event.

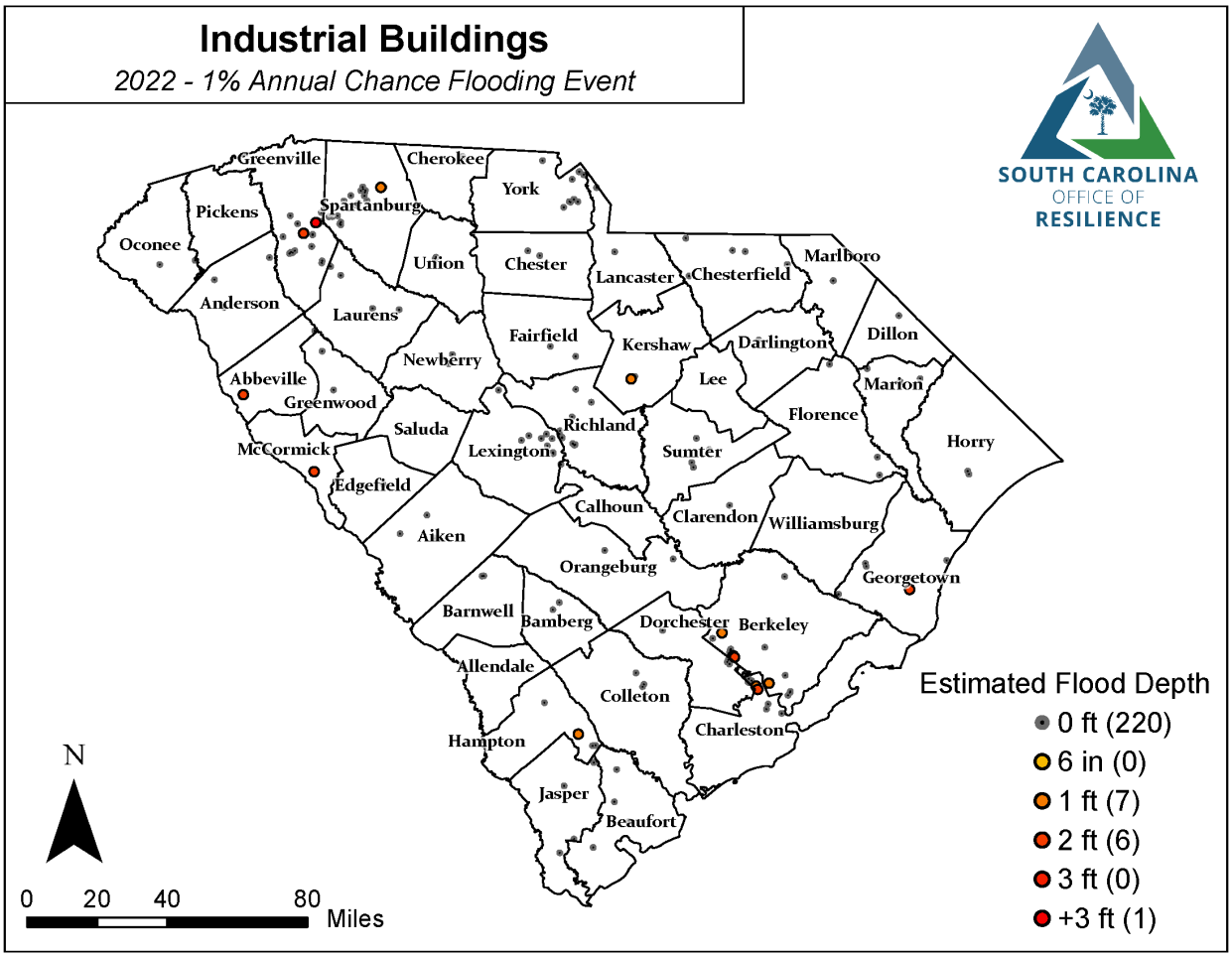


Figure 98: Estimated flooding of commerce industrial buildings in the 2022 1% annual chance flooding event (SC Department of Commerce). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

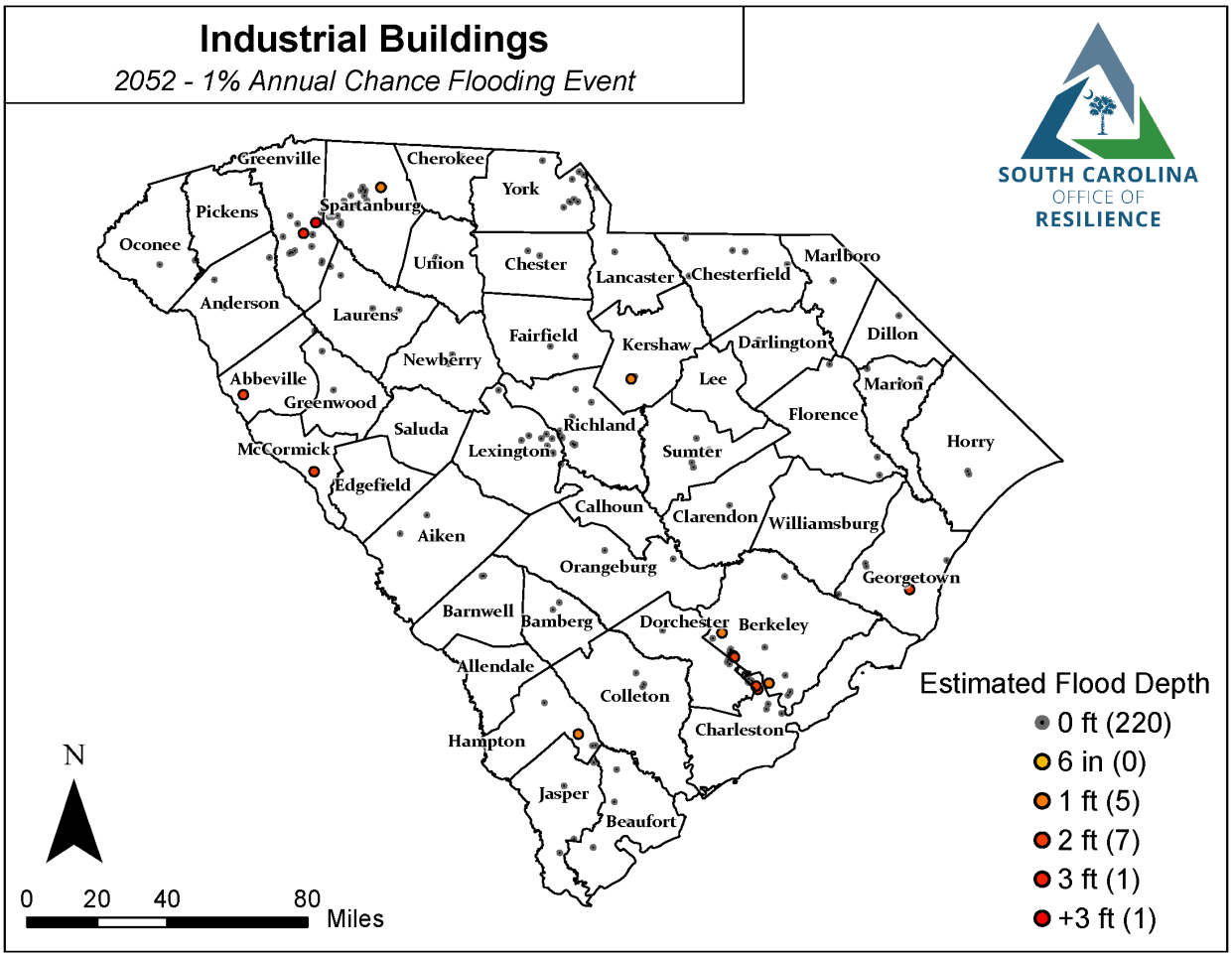


Figure 99: Estimated flooding of commerce industrial buildings in the 2052 1% annual chance flooding event (SC Department of Commerce). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Industrial Sites

Looking at industrial sites can help us predict where we are likely to see industrial buildings constructed in the future. The maps below show the estimated flooding of these in the 2022 (Figure 100) and 2052 (Figure 101) 1% annual chance flood event.

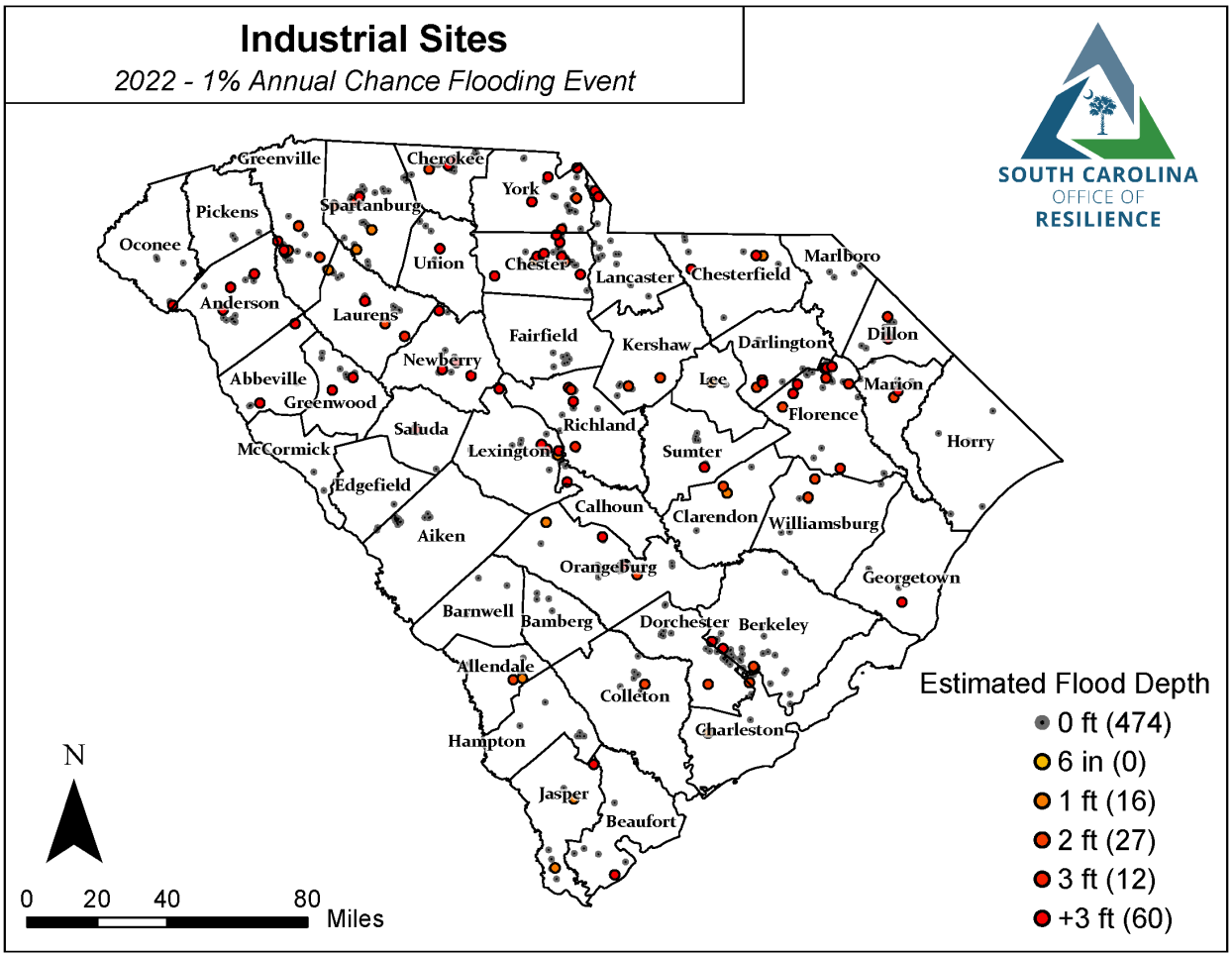


Figure 100: Estimated flooding of industrial sites in the 2022 1% annual chance flooding event (SC Department of Commerce). Flood data provided by the First Street Foundation Hazard Layers, V2.0.

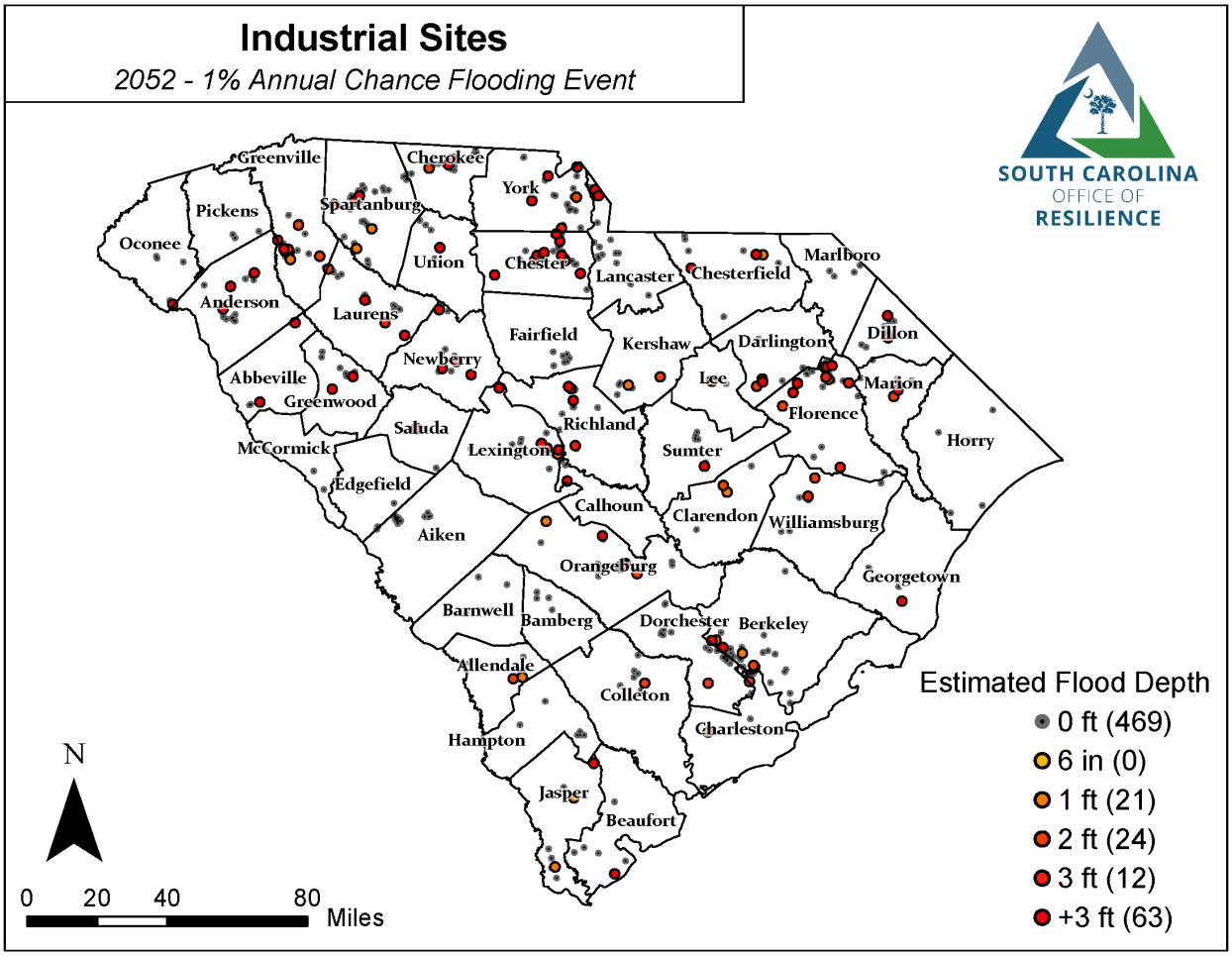


Figure 101: Estimated flooding of industrial sites in the 2052 1% annual chance flooding event (SC Department of Commerce. Flood data provided by the First Street Foundation Hazard Layers, V2.0.

Commercial Losses

First Street Foundation CAAL (Commercial Average Annualized Loss)

First Street Foundation applies their flood model to business locations and estimates the average time in days loss of productivity and the loss in dollars due to loss time (First Street Foundation, 2021). Estimated loss in time and dollars are closely linked to the type of business and the size and characteristics of the building being used. This data is provided by a third party, Lightbox, (First Street Foundation, 2021). Once the building characteristic and commercial type of the business is determined, estimated cost for building restoration, time loss, and revenue loss is calculated based on reported estimates to the Bureau of Economic Analysis in 2020 and then adjusted for region and time (First Street Foundation, 2021). Figure 102 show the commercial properties estimated to be impacted by the 2022 1% annual flood event. Figure 103 shows the estimated count of commercial facilities inundated by 1% annual chance flood event in First Street Foundation Flood Model Scenario mid-2021 in each HUC12 in South Carolina. Figure 104 then shows the estimated total dollars loss, by HUC12, of commercial facilities inundated by 1% annual chance flood event in First Street Foundation Flood Model Scenario mid-2021.

Commercial facilities by county are outlined in Appendix B. Charleston County has the highest estimated impact with a potential of 3,600 properties and over 1 billion dollars being impacted by a 1% annual chance of flooding (Appendix B). Coastal counties, Beaufort, Charleston, Georgetown, and Horry, are modeled to be the most impacted, but urban centers also see a high estimation of impact, including Aiken, Dorchester, Florence, Greenville, Richland, and Spartanburg each having over 200 commercial properties with estimated flooding impact in a 1% annual chance event (Appendix B and Figure 102). All counties in South Carolina can be impacted by 1% annual chance of flood event, with a statewide average of 53 days loss to flooding and construction and an estimated average economic loss of $200,000.

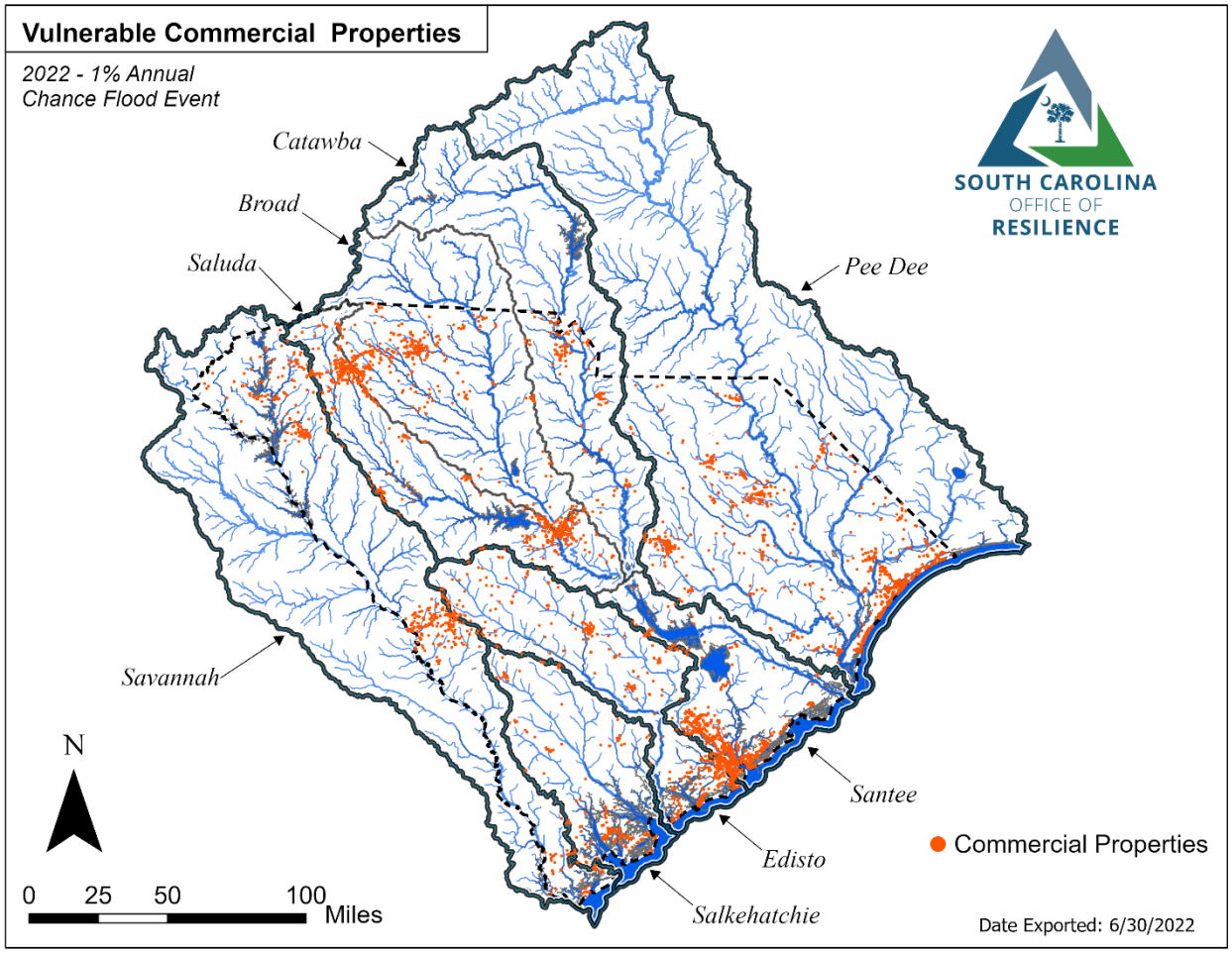


Figure 102 Estimated commercial properties with inundation by the 2022 1% annual chance flood event. Flood data provided by the First Street Foundation Flood Risk Statistics, V2.0.

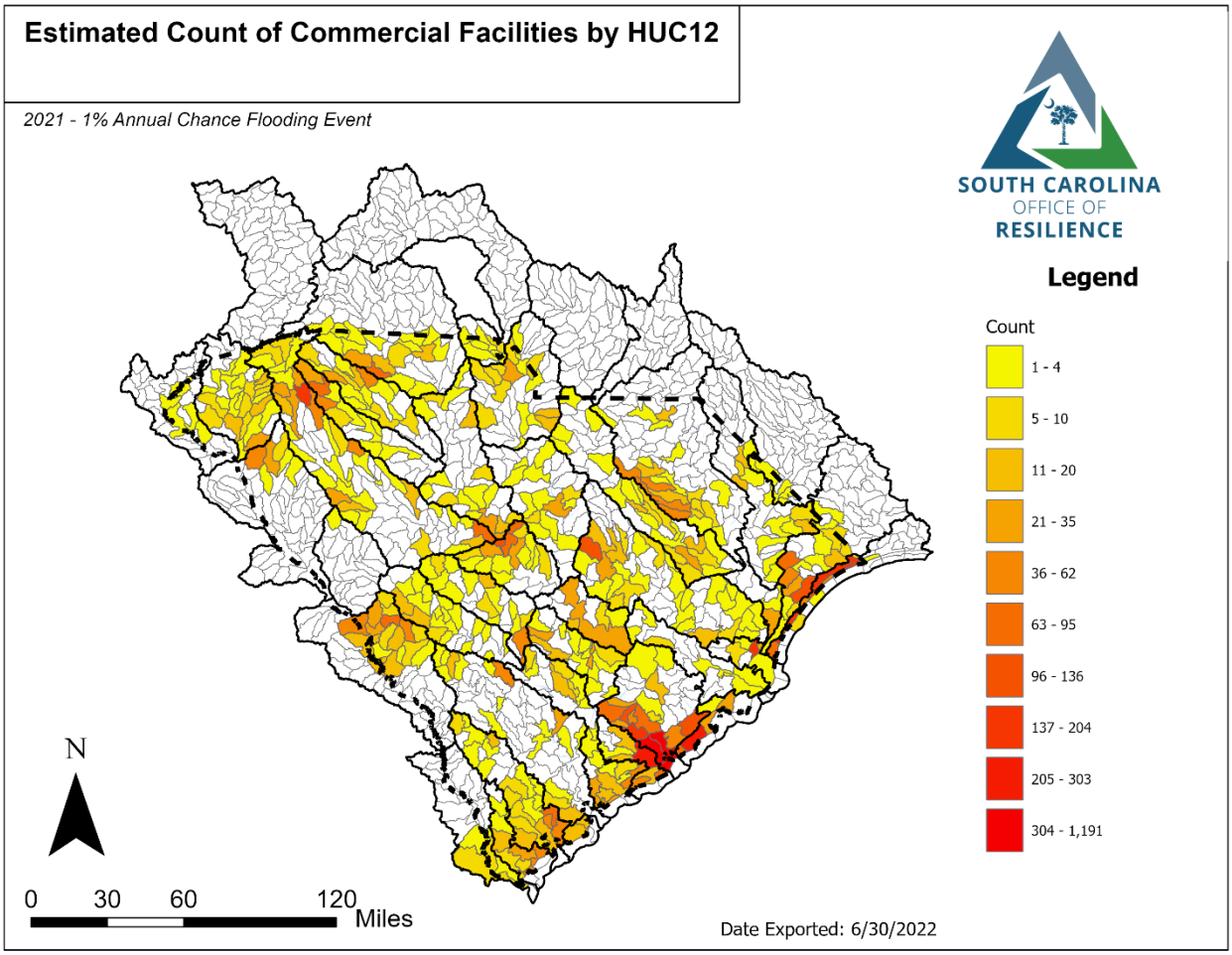


Figure 103: Estimated count of commercial facilities inundated by 1% annual chance flood event in First Street Foundation Flood Model Scenario mid-2021 in each HUC12 in South Carolina. Flood data provided by the First Street Foundation Flood Risk Statistics, V2.0.

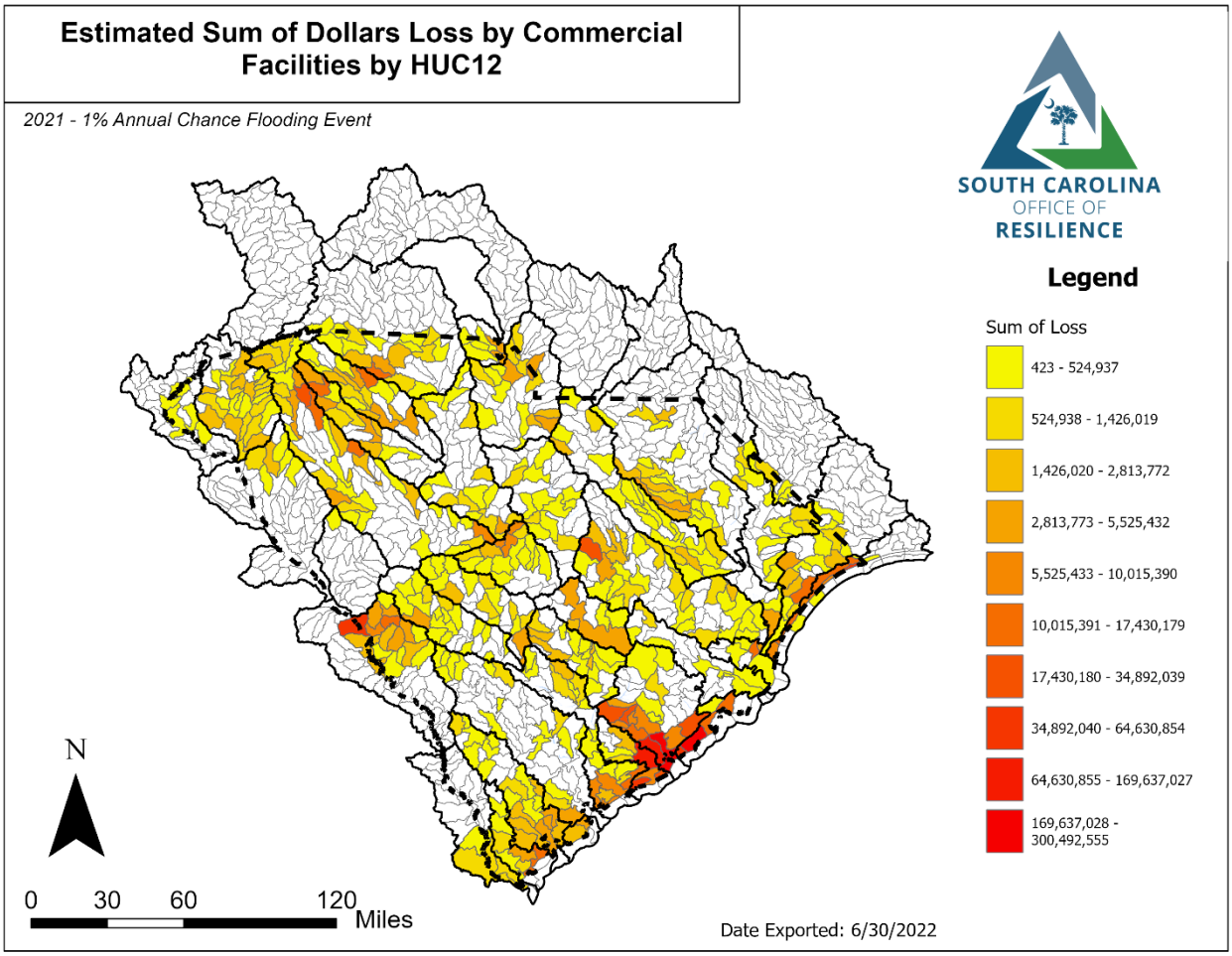


Figure 104: Estimated total dollars loss, by HUC12, of commercial facilities inundated by 1% annual chance flood event in First Street Foundation Flood Model Scenario mid-2021. Flood data provided by the First Street Foundation Flood Risk Statistics, V1.3.

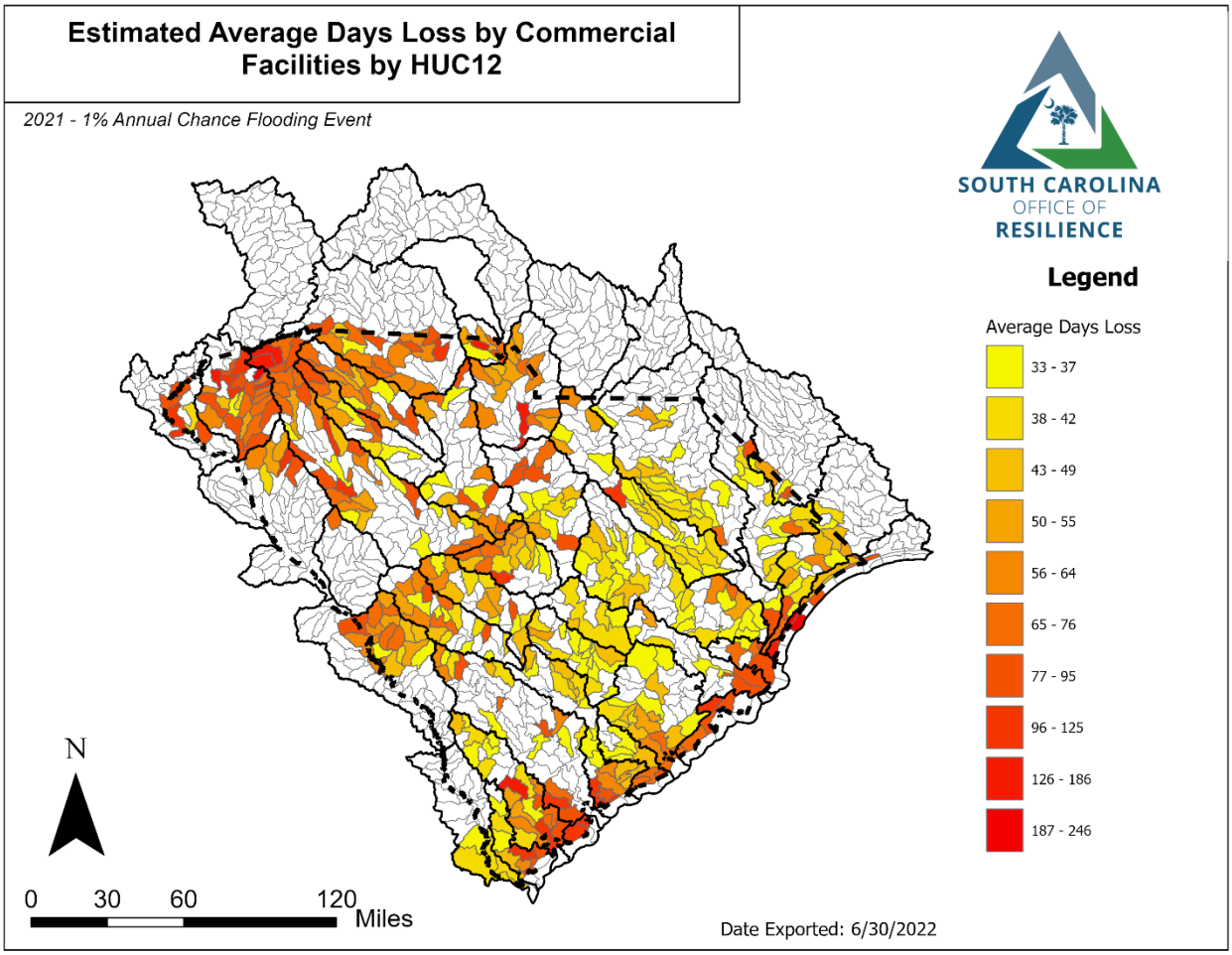


Figure 105: Estimated average days loss, by HUC12, of commercial facilities inundated by 1% annual chance flood event in First Street Foundation Flood Model Scenario mid-2021. Flood data provided by the First Street Foundation Flood Risk Statistics, V2.0.

Next Steps

Based on identified vulnerabilities, the South Carolina Office of Resilience, working with the Resilience Plan Advisory Committee, will develop recommendations, at appropriate scale, to decrease vulnerabilities and enable communities, ecosystems, and economies within South Carolina to anticipate, absorb recover and thrive when presented with environmental change and natural hazards.

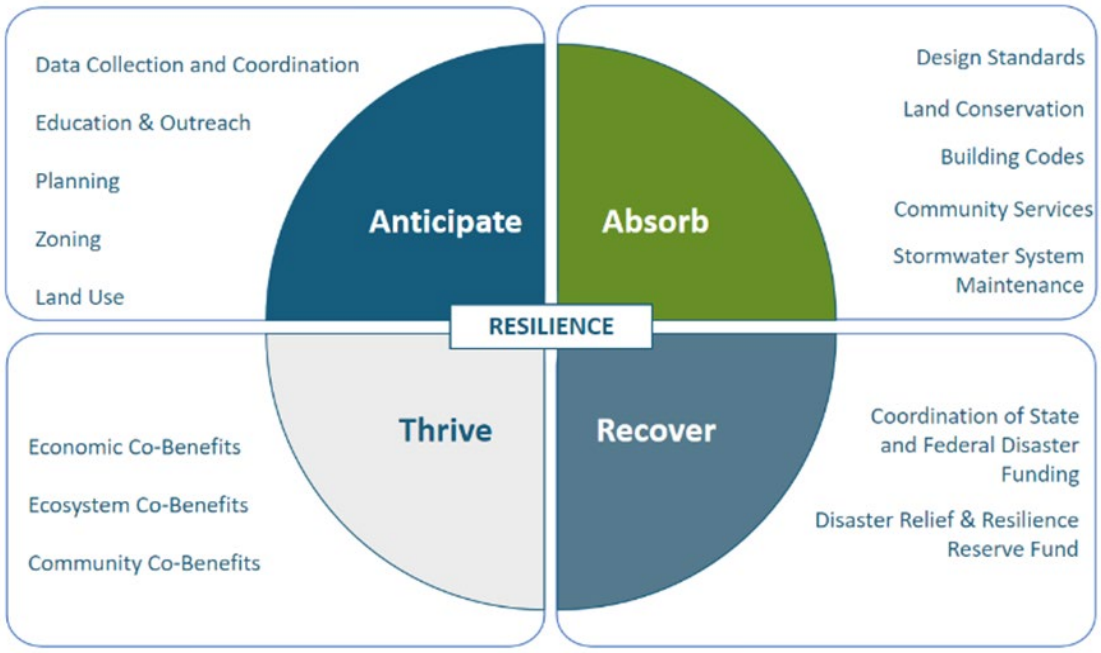


Figure 106 Recommendations

References

Adcox, S. (2016, November 5). Hurricane Matthew brought demise to Nichols, now the S.C. town needs a 'miracle'. *The Post and Courier*.

American Institute for Conservation. (n.d.). *Alliane for Response*. Retrieved from AIC FAIC: https://www.culturalheritage.org/resources/emergencies/alliance-for-response

Anderson, D. G., Bissett, T. G., Yerka, S. J., Wells, J. J., Kansa, E. C., Kansa, S. W., . . . Biehl, P. F. (2012). Anderson, D.G., Bissett, T.G., Yerka, S.J., Wells, J.J., Kansa, E.C., Kansa, S.W., Myers, K.N., DeMuth, R.C., White, D.A. and Biehl, P.F., 2017. Sea-level rise and archaeological site destruction: An example from the southeastern United States using DINAA. *PLos ONE* .

Beck, M. W., Brumbaugh, R. D., Airoldi, L., Carranza, A., Coen, L. D., Crawford, C., . . . Guo, X. (2011). Oyster Reefs at Risk and Recommendations for Conservation, Restoration, and Management. *BioScience*, 107. Retrieved from https://coseenow.net/mare/files/2012/03/Beck-et-al.-2011-Oyster-Reefs.pdf

Bevacqua, E., Vousdoukas, M. I., Zappa, G., Hodges, K., Sheperd, T. G., Maraun, D., . . . Feyen, L. (2020). More meteorological events that drive compound coastal flooding are projected under climate change. *Communications Earth & Environment*. Retrieved from https://www.nature.com/articles/s43247-020-00044-z

Blair, A., Lovelace, S., Sanger, D., Holland, A. F., Vandiver, L., & White, S. (2013). Exploring impacts of development and climate change on stormwater runoff. *Hydrological Processes*. Retrieved from https://onlinelibrary.wiley.com/doi/10.1002/hyp.9840

Bonnin, G. M., Martin, D., Lin, B., Parzybok, T., Yekta, M., & Riley, D. (2006). *Precipitation-Frequency Atlas of the United States; NOAA Atlas 14, Volume 2, Version 3.0.* Silver Spring, Maryland: NOAA.

Bowes, B. D., Sadler, J. M., Morsy, M. M., Behl, M., & Goodall, J. L. (2019). Forecasting Groundwater Table in a Flood Prone Coastal City with Long Short-term Memory and Recurrent Neural Networks. *Water*.

Caserta, S., & Russo, A. P. (2002). More Means Worse: Asymmetric Information, Spatial Displacement and Sustainable Heritage Tourism. *Journal of Cultural Economics*, 245-260.

Clemson. (2022). *Flood Recovery and Pond Help*. Retrieved from https://www.clemson.edu/extension/water/stormwater-ponds/flood-recovery.html

Clemson University. (2022). *Water Modeling*. Retrieved from Public Service and Agriculture: https://www.clemson.edu/public/water-assessment/model.html

Columbia Water. (2022). *Columbia Canal Repair Project; What You Need to Know*. Retrieved from Columbia Water: https://columbiascwater.net/columbiacanalproject/

Cooper, H. H. (1964). *Sea Water in Coastal Aquifers.* Washington, DC: US Government Printing Offce.

Cutter, S. L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the national academy of sciences*, 2301-2306.

Dawson, T., Hambly, J., Kelley, A., Lees, W., & Miller, S. (2020). Coastal heritage, global climate change, public engagement, and citizen science. *Proceedings of the National Academy of Sciences*, 8280-8286.

DHEC. (2003, June 27). *Regulation 89-10 through 89-350 Office of the Governor - Mining Council of South Carolina.* Retrieved from DHEC: https://live-sc-dhec.pantheonsite.io/sites/default/files/Library/Regulations/R.89-10_89-350.pdf

DHEC. (n.d.). *Mining and Relamation*. Retrieved from South Carolina Department of Health and Environmental Control: https://scdhec.gov/environment/land-management/mining-reclamation

DHEC. (n.d.). *Resource Conservation and Recovery Act*. Retrieved from South Carolina Department of Health and Environmental Control: https://scdhec.gov/environment/land-management/hazardous-waste/resource-conservation-recovery-act-rcra

DHS. (n.d.). *Homland Infrastructure Foundation-Level Data Open Data*. Retrieved from DHS: https://hifld-geoplatform.opendata.arcgis.com/

Disaster Relief and Resilience Act, SC Code §48-62. (2020). Retrieved from https://www.scstatehouse.gov/sess123_2019-2020/bills/259.htm

DNR. (2013). *An Overview of the Eitht Major River Basins of South Carolina.* Retrieved from https://www.dnr.sc.gov/water/waterplan/pdf/Major_Basins_of_South_Carolina.pdf

DNR. (n.d.). *Publications Map.* Retrieved from SCDNR Geological Survey: https://www.dnr.sc.gov/geology/publications-map.html

Edwards, M. (2020, October 20). Two years later, S.C. town still recovering from back-to-back hurricane losses. *Carolina News & Reporter*.

Elko, N., Roberts Briggs, T., Benedet, L., Robertson, Q., Thomson, G., Webb, B. M., & Garvey, K. (2021). A century of U.S. beach nourishment. *Ocean & Coastal Management*. doi:https://doi.org/10.1016/j.ocecoaman.2020.105406

EPA. (2022). *Storm Water Management Model* . Retrieved from EPA : https://www.epa.gov/water-research/storm-water-management-model-swmm

eRegulations. (2022). *General Rules and Regulations*. Retrieved from South Carolina Hunting: https://www.eregulations.com/southcarolina/hunting/general-rules-regulations

Espenak, F., & Meeus, J. (2006). *FIVE MILLENNIUM CANON OF SOLAR ECLIPSES: -1999 TO +3000.* NASA. Retrieved from https://eclipse.gsfc.nasa.gov/SEpubs/5MCSE.html

FEMA. (2020, July 8). *Manufactured (Mobile) Home.* Retrieved from FEMA Glossary: https://www.fema.gov/glossary/manufactured-mobile-home

FEMA. (2021, March). *2021 Building code adoption tracking: FEMA region 4.* Retrieved from FEMA: https://www.fema.gov/sites/default/files/documents/fema_bcat-region-4-report_03-31-21.pdf

FEMA. (2021, December 31). *Flood Insurnace Data and Analytics*. Retrieved from National Flood Insurance Program: https://nfipservices.floodsmart.gov/reports-flood-insurance-data

First Street Foundation. (2021, December 13). *Commercial Flood Economic Implications*. Retrieved from https://firststreet.org/research-lab/published-research/methodology-2021-first-street-foundation-commercial-aal/

Florida Fish and Wildlife Conservation Commission. (2022). *Post Hurricane Fish Kills*. Retrieved from https://myfwc.com/research/freshwater/fisheries-resources/techniques/fish-kills/

Forest Service. (2020). *Urban Forest Systems and Green Stormawater Infrastructure.* U.S. Departement of Agriculture. Retrieved from https://www.fs.usda.gov/sites/default/files/fs_media/fs_document/Urban-Forest-Systems-GSI-FS-1146.pdf

Green, G., Carloss, M., Rader, J., & Brasher, M. (n.d.). *Conservation on the Coasts*. Retrieved March 22, 2022, from Ducks Unlimited: https://www.ducks.org/conservation/national/conservation-on-the-coasts

HDR. (2014). *USER'S GUIDE for the Catawba-Wateree River Basin CHEOPS™ Model.* HDR Engineering, Inc. Retrieved from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww.ncwater.org%2FData_and_Modeling%2FCatawba%2Ffiles%2F20141205%2520CHEOPS%2520II%2520User%27s%2520Manual%2520and%2520Appendices.pdf&clen=4191072&chunk=true

Hensel, M. J., Silliman, B. R., van de Koppel, J., Hensel, E., Sharp, S. J., Crotty, S. M., & Byrnes, J. E. (2021). A large invasive consumer reduces coastal ecosystem resilience by disabling positive species interactions. *Nature Communications*. doi:https://doi.org/10.1038/s41467-021-26504-4

Hoover, D. J., Odigie, K. O., Swarzenski, P. W., & Barnard, P. (2017). Sea-level rise and coastal groundwater inundation and shoaling at select sites in California, USA. *Journal of Hydrology: Regional Studies*.

IAFWA. (2002). *Economic Importance of Hunting in America.* Washington, DC: International Association of Fish and Wildlife Agencies. Retrieved from https://buffalo.extension.wisc.edu/files/2011/01/Economic-Importance-of-Hunting-in-America.pdf

Institute of Museum and Library Services. (2019, February). *Protecting America's Collections.* Retrieved from IMLS: https://www.imls.gov/sites/default/files/publications/documents/imls-hhis-report.pdf

Insurance Services Office. (n.d.). *Facts and Figures about BCEGS Grades around the Country*. Retrieved from Verisk: https://www.isomitigation.com/bcegs/facts-and-figures/

International Institute for Conservation of Historic and Artistic Work. (2008, September). *Climate Change and Museum Collections.* Retrieved from International Institute for Conservation of Historic and Artistic Works: https://www.iiconservation.org/sites/default/files/dialogues/climate-change-en.pdf

Kana, T. W., Traynum, S. B., Gaudiano, D., Kaczowski, H. L., & Hair, T. (2013). The Physical Condition of South Carolina Beaches 1980–2010. *Journal of Coastal Research*.

Kana, T., & Barrineau, P. (2021, September 24). *GLOBAL CLIMATE CHANGE AND SEA LEVEL RISE-WHAT DOES IT MEAN FOR COASTAL COMMUNITIES?* Retrieved from http://coastalscience.com/news/global-climate-change-and-sea-level-rise-what-does-it-mean-for-coastal-communities/

Kennish, M. J. (2001). Coastal Salt Marsh Systems in the U.S.: A Review of Anthropogenic Impacts. *Journal of Coastal Research*. Retrieved from https://www.jstor.org/stable/4300224

Kern, J., & Miranda, L. P. (2021, May 1). *Assessing Operational Flooding Risks for Substations and the Wider North Carolina Power Grid.* Retrieved from NC State University: https://collaboratory.unc.edu/wp-content/uploads/sites/476/2021/05/assessing-operational-flooding-risks-for-substations-and-the-wider-north-carolina-power-grid.pdf

Konrad, C. P. (2003). *Effects of Urban Development on Floods.* USGS.

Lempert, K. D., & Kopp, J. B. (2013). Hurricane Sandy as a kidney failure disaster. *American Journal of Kidney Diseases*, 865-868.

Marsh, A. (2015, October 9). *Water, water everywhere: The history behind Columbia, South Carolina's troubled canal*. Retrieved from Natonal Museum of American History: https://americanhistory.si.edu/blog/columbia-south-carolinas-troubled-canal

Moftakhari, H. R., AghaKouchak, A., Sanders, B. F., Allaire, M., & Matthew, R. A. (2018). What Is Nuisance Flooding? Defining and Monitoring an Emerging Challenge. *Water Resources Research*. doi:https://doi.org/10.1029/2018WR022828

NAHAR. (2020). *About NAHAR*. Retrieved from North American Heritage at Risk: https://nahar.hcommons.org/about/

National Hurricane Center. (n.d.). *Introduction to Storm Surge.* Retrieved from https://www.nhc.noaa.gov/surge/surge_intro.pdf

Natural Resources Conservation Service. (2009). Ch. 7; Hydrologic Soil Groups. In N. R. Service, *Part 630 Hydrology National Engineering Handbook* (p. Ch. 7). Washington, DC: U.S. Department of Agriculture. Retrieved from https://directives.sc.egov.usda.gov/22526.wba

NCEI. (2021). *National Center for Environmental Inforamation*. Retrieved from https://www.ngdc.noaa.gov/hazel/view/hazards/tsunami/event-more-info/2360

NMFS. (2014). *Fisheries Economics of the United States, 2012.* U.S. Dept. Commerce, NOAA. Retrieved from https://www.st.nmfs.noaa.gov/st5/publication/index.html

NOAA. (1989, November 10). *Medical Examiner/Coroner Reports of Deaths Associated with Hurricane Hugo -- South Carolina*. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/00001495.htm

NOAA. (2016, May 9). *NOAA Shorline.* Retrieved from https://coast.noaa.gov/data/docs/states/shorelines.pdf

NOAA. (2016). *The Historic South Carolina Floods of October 1–5, 2015.* Silver Spring, Maryland: National Weather Service. Retrieved from https://www.dnr.sc.gov/climate/sco/Publications/NOAA_2015_FLOOD_ASSESSMENT.pdf

NOAA. (2021). *Storm Events Database*. Retrieved from https://www.ncdc.noaa.gov/stormevents/

NOAA. (2021, March 26). *What is a perigean spring tide?* Retrieved from National Oceanic and Atmospheric Administration: https://oceanservice.noaa.gov/facts/perigean-spring-tide.html

NOAA. (2021, 02 26). *What is high tide flooding?* Retrieved from National Oceanic and Atmospheric Administration: https://oceanservice.noaa.gov/facts/high-tide-flooding.html

NOAA. (2022). *Storm Data FAQ Page*. Retrieved from https://www.ncdc.noaa.gov/stormevents/faq.jsp

NOAA. (2022). *The State of High Tide Flooding and 2022 Outlook*. Retrieved from Tides and Currents: https://tidesandcurrents.noaa.gov/HighTideFlooding_AnnualOutlook.html

NWC. (2018, September 24). *Post Storm Hurricane Report*. Retrieved from National Weather Service Regional Headquarters : https://web.archive.org/web/20181001070142/https://forecast.weather.gov/product.php?site=CRH&product=PSH&issuedby=ILM

NWS. (2022). *Coastal Flood Event Database*. Retrieved from National Weather Service: https://www.weather.gov/chs/coastalflood

NWS. (n.d.). *Flood and flash flood definitions*. Retrieved from https://www.weather.gov/mrx/flood_and_flash

Payne, D. F. (2010). *Effects of Sea-Level Rise and Pumpage Elimination on Saltwater Intrusion in the Hilton Head Island Area, South Carolina, 2004–2104.* Reston, VA: U.S. Geological Survey.

Plane, E., Hill, K., & May, C. (2019). A Rapis Assessment Method to Identify Potential Groundwater Flooding Hotspots as Sea Level Rise in Coastal Cities. *Water*.

Rosaen, A. L., Grover, E. A., & Spencer, C. W. (2016). *The Costs of Aquatic Invasice Species to Great Lakes States.* Anderson Economic Group LLC. Retrieved from https://www.andersoneconomicgroup.com/Portals/0/upload/AEG - AIS Impact_ 9-20-2016 Public new.pdf

Rosenzweig, B. R., McPhillips, L., Chang, H., Cheng, C., Wetly, C., Matsler, M., . . . Davidson, C. I. (2018). Pluvial flood risk and opportunities for resilience. *WIREs Water*. doi:https://doi.org/10.1002/wat2.1302

Rotzoll, K., & Fletcher, C. H. (2013). Assessment of groundwater inundation as a consequence of sea-level rise. *Nature Climate Change*.

Rumbach, A., Sullivan, E., & Makarewicz, C. (2020). Mobile home parks and disasters: understanding risk to America's third housing type. *Natural hazards review*.

S.C. Sea Grant Consortium. (2020). *Assessing South Carolina's Ocean Economy.* Sea Grant. Retrieved from https://dc.statelibrary.sc.gov/bitstream/handle/10827/35727/SG_Assessing_South_Carolinas_Ocean_Economy_2020.pdf?sequence=1&isAllowed=y

SC Commission on Higher Education. (2021). *2021 statistical Abstract.* Retrieved from SC Commission on Higher Education: https://www.che.sc.gov/CHE_Docs/finance/abstract/2021_Statistical_Abstract-Final-Web.pdf

SC Department of Agriculture. (2015, December 7). *2015 flood impact on south carolina infrastructure.* Retrieved from SCDA: https://www.scstatehouse.gov/CommitteeInfo/SenateSpecialCommitteeRegardingFloodReliefEffortsInSC/December72015Meeting/SCDA-flood-presentation.pdf

SC Department of Agriculture. (2017). *About*. Retrieved from SCDA: https://agriculture.sc.gov/about/

SC Department of Commerce. (2020). *Research and Data*. Retrieved from SC Depatment of Commerce: https://www.sccommerce.com/research-data

SC Department of Health and Human Services. (n.d.). *Community Long Term Care*. Retrieved from SC DHHS: https://www.scdhhs.gov/historic/insideDHHS/Bureaus/BureauofLongTermCareServices/CLTCOverview.html

SC Department of Parks, Recreation & Tourism. (2021, January). *The eonomic contribution of tourism in south carolina*. Retrieved from SC PRT: https://embed.widencdn.net/pdf/plus/scprt/zrp7nkb0gb/Final%202019%20SC%20TSA.pdf?u=kceaj9

SC Department of Veterans' Affairs. (n.d.). *SC Military Base Task Force*. Retrieved from SC Department of Veterans' Affairs: https://scdva.sc.gov/sc-military-base-task-force

SC DHEC. (n.d.). *Dry Cleaners - A Source of Pollution*. Retrieved from DHEC: https://scdhec.gov/environment/your-land/dry-cleaners-source-pollution#:~:text=South%20Carolina's%20environmental%20regulatory%20standards,or%20water%20above%20these%20levels.

SC Revenue and Fiscal Affairs Office. (2019). *Populaion projections 2000-2035*. Retrieved from SC Revenue and Fiscal Affairs Office: https://rfa.sc.gov/data-research/population-demographics/census-state-data-center/population-projections-2000-2035-rev2019

SC Sea Grant Consortium. (2019). *Susceptibility of Public Health Impacts from Flooded Water, Wastewater and Public Health Infrastructure.* Retrieved from SC Sea Grant: https://www.scseagrant.org/wp-content/uploads/Water-Infrastructure-Assessment-Guidebook-Digital.pdf

SCDHEC. (2022). *S.C. Beach Renourishment*. Retrieved from https://gis.dhec.sc.gov/renourishment/

SCDHEC. (n.d.). *SC Flood Information*. Retrieved from SCDHEC: https://scdhec.gov/disaster-preparedness/hurricanes-floods/sc-flood-information

SCDNR. (2015). *Historic Rainfall Event Mesoscale Synoptic Review.* Retrieved from http://www.dnr.sc.gov/climate/sco/flood2015/HRE2015.pdf

SCDNR. (2015). *South Carolina's State Wildlife Action Plan (SWAP).* Columbia, SC: South Carolina Department of Natural Resources.

SCDNR. (2020). *Coastal Birds in South Carolina - Shorebirds*. Retrieved from https://www.dnr.sc.gov/wildlife/species/coastalbirds/shorebirds/index.html

SCDNR. (2020). *Scenic Rivers - Map*. Retrieved from https://www.dnr.sc.gov/water/river/riversmarked.html

SCDNR. (2022). *Simplified Water Allocation Models (SWAM)*. Retrieved from SCDNR Hydrology: https://hydrology.dnr.sc.gov/swam-models.html#background

SCDNR. (2022). *Wildlife - WMA Waterfowl Hunt Results for 2020-2021*. Retrieved March 22, 2022, from South Carolina Department of Natural Resources: https://www.dnr.sc.gov/wildlife/waterfowl/wfresults2122.html

SCDOT. (2022, January 7). *SCDOT Annual Report.* Retrieved from SCDOT: https://www.scdot.org/performance/pdf/reports/SCDOT_Annual_Report_2021.pdf?v=2

SCFC. (2015, October 14). SCFS estimates $65M economic impact from flooding. *Release from the South Caro.ina Forestry Commission*.

SCFC. (2021, October). *South Carolina Forests.* Retrieved from https://www.scfc.gov/wp-content/uploads/2021/10/SCForests.pdf

Sharpe, J. D., & Clennon, J. A. (2020). Pharmacy functionality during the Hurricane Florence disaster. *Disaster medicine and public health preparedness*, 93-102.

Smithsonian Institute . (n.d.). *Heritage Emergency Task Force*. Retrieved from Smithsonian Cultural Rescue Initiative: The South Carolina Institute for Archeology and Anthropology (SCIAA) and the South Carolina Department of Archives and History's online cultural resources information system, SC ArchSite

South Carolina Aeronautics Commission. (2018). *South Carolina Statewide Aviation System Plan & Economic Impact Report Executive Summary.* Retrieved from SC Aeronautics: https://scaeronautics.sc.gov/download/2018%20South%20Carolina%20Executive%20Summary-Final.pdf

South Carolina Commission for Minority Affairs. (2022). *South Carolina's Recognized Native American Indian Entities*. Retrieved from South Carolina Commission for Minority Affairs: https://cma.sc.gov/minority-population-initiatives/native-american-affairs/south-carolinas-recognized-native-american-indian-entities

South Carolina Department of Education. (2022, April). *Active Student Headcounts*. Retrieved from SC Department of Education: https://ed.sc.gov/data/other/student-counts/active-student-headcounts/

South Carolina Department of Social Services. (n.d.). *Child Care Licensing*. Retrieved from SC Child Care: https://www.scchildcare.org/programs/child-care-licensing/

South Carolina Department of Transportation. (2020). *South Carolina Statewide Rail Plan Update.* Retrieved from SC DOT: https://www.scdot.org/multimodal/pdf/SC_MTP_Rail_Plan_FINAL.pdf

South Carolina Institute of Medicine & Public Health. (2021). *South Carolina Behavioral Health 2021 Progress Report.*

South Carolina Office of Regulatory Staff. (n.d.). Retrieved from South Carolina Office of Regulatory Staff: https://ors.sc.gov/

South Carolina Ports Authority. (n.d.). *About the Port*. Retrieved from South Carolina Ports: http://scspa.com/about/

South Carolina State Library. (2020). *Annual Library Statistics*. Retrieved from South Carolina State Library : https://guides.statelibrary.sc.gov/sc-public-library-statistics/annual

South Carolina Telehealth Alliance. (n.d.). *South Carolina Telehealth Alliance*. Retrieved from South Carolina Telehealth Alliance: https://sctelehealth.org/

South Carolina's Sea Level is Rising. (2022). Retrieved from Sea Level Rise: https://sealevelrise.org/states/south-carolina/#:~:text=The%20sea%20level%20around%20Charleston,1%20inch%20every%202%20years.

Stewart, S. R., & Berg, R. (2019). *Tropical Cyclone Report: Hurricane Florence.* NATIONAL HURRICANE CENTER.

Sweet, W. V., Hamlington, B. D., Kopp, R. E., Weaver, C., Barnard, P., Bekaert, D., . . . Zuzak, C. (2022). *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines.* Silver Spring, MD: National Oceanic and Atmospheric Administration, National Ocean Service. Retrieved from https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf

The Pew Charitable Trusts. (2017). *Flooding Threatens Public Schools Across the Country: Infrastructure Analysis evaluates county-level flood risk.* Retrieved from The Pew Charitable Trusts: https://www.pewtrusts.org/-/media/assets/2017/08/fpc_flooding_threatens_public_schools_across_the_country.pdf

Tweel, A., Sanger, D., Blair, A., Montie, E., Turner, A., & Leffler, J. (2015). *Collaborative Research to Prioritize and Model the Runoff Volume Sensitivities of Tidal Headwaters.* National Estuarine Reserch Reserve System Science Collaborative.

U.S. Census Bureau. (2021). *Redistricting data, 2020 decennial census*. Retrieved from U.S. Census Bureau: https://data.census.gov/cedsci/

U.S. Department of Homeland Security. (2022, February 15). *Electric Power Transmission Lines*. Retrieved from Homeland Infrastructure Foundation-Level Data (HIFLD): https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::electric-power-transmission-lines/about

Underwood, T. (2021, October 4). *Six Years After Historic Flood, Columbia Canal Prepares for Repairs*. Retrieved from South Carolina Public Radio: https://www.southcarolinapublicradio.org/sc-news/2021-10-04/six-years-after-historic-flood-columbia-canal-prepares-for-repairs

University of South Carolina. (2021, December 14). *South Carolina tourism is growing. Here's why.* Retrieved from University of South Carolina College of Information and Communications: https://www.sc.edu/study/colleges_schools/cic/initiatives/social_media_insights_lab/reports/2021/sc_tourism_is_growing.php#.YpoOrKjMKUl

University of South Carolina. (n.d.). *SoVI Social Vulnerability Index for the United States - 2010-14.* Retrieved from University of South Carolina College of Arts and Sciences: https://www.sc.edu/study/colleges_schools/artsandsciences/centers_and_institutes/hvri/data_and_resources/sovi/index.php

Urevig, A. (2017, December 21). *Seeking answers on climate change, scientists venture into the vaults of the past.* Retrieved from Ensia: https://ensia.com/features/natural-history-museums-climate-change/

US Census Bureau. (2021). *QuickFacts South Caroline*. Retrieved from US Census Bureau: https://www.census.gov/quickfacts/SC

USACE. (2022). *HEC-RAS*. Retrieved from US Army Crops of Engineers: Hydrologic Engineering Center: https://www.hec.usace.army.mil/software/hec-ras/

USFWS. (2014). *2011 National Survey of Fishing, Hunting, and Wildlife-Associated.* Washington, DC: U.S. Department of INterior, U.S. Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau.

USGS. (2019). *National Land Cover Database*. Retrieved from https://www.usgs.gov/centers/eros/science/national-land-cover-database

Wahl, T. (2017). Compound flooding: examples, methods, and challenges. *American Geophysical Union, Fall Meeting 2017.*

Weaver, E. (2016, October 19). 1928 hurricane left its mark in Horry County, but then came Matthew. *The Sun News*.

Weidensaul, S. (2021). *Vast flocks of Whimbrels were thought to be a thing of the past, until a wildlife biologist discovered nearly 20,000 of these declining shorebirds on a tiny South Carolina island.* Retrieved from All About Birds: https://www.allaboutbirds.org/news/a-miracle-of-abundance-as-20000-whimbrel-take-refuge-on-a-tiny-island/?utm_source=Cornell+Lab+eNews&utm_campaign=b15fc86069-Cornell-Lab-eNews-November-2021&utm_medium=email&utm_term=0_47588b5758-b15fc86069-306645181

West, B. C., Cooper, A. L., & Armstrong, J. B. (2009). *Managing Wild Pigs: A technical guide. Human-Wildlife Interactions Monograph.* Starkville, MS and Logan, UT: The Berryman Institute. Retrieved from https://www.aphis.usda.gov/wildlife_damage/feral_swine/pdfs/managing-feral-pigs.pdf

Westphal, K., & Boyer, J. (2014). Overview of the Simplified Water Allocation Model (SWAM). Retrieved from https://hydrology.dnr.sc.gov/pdfs/swm/Presentations/SWAMoverviewDEC2014.pdf

Willis, D. B., & Straka, T. J. (2017). The Economic Contribution of Natural Resources to a State Economy: A South Carolina Case Study. *Natural Resources*. Retrieved from https://www.scirp.org/html/1-2000714_74891.htm

Zurich. (2020, July 22). *Three common types of flood explained*. Retrieved from https://www.zurich.com/knowledge/topics/flood-and-water-damage/three-common-types-of-flood