REGIONAL FREIGHT TRANSPORTATION PLAN

FREIGHT RESILIENCY

NOVEMBER 17, 2022

CORE
COASTAL REGION MPO

Regional Freight Transportation Plan

Freight Resiliency

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Table of Contents

1 Introduction 1
2 Freight Network Risks and Disruptors 2
2.1 Risks and Disruptor Identification 2
Sea Level Rise/ Coastal Flooding 4
Riverine Flooding 8
Hurricanes 11
Supply Chain Disruptions 15
2.2 Hazard Assessment for Sea Level Rise, Riverine Flooding, Hurricanes, and Supply Chain Disruptions 22
Application of the FEMA NRI to the CORE MPO 22
Quantifying Risk for the CORE MPO Region 24
Vulnerable Freight Assets to Sea Level Rise/Coastal Flooding, Riverine Flooding, and Hurricanes 30
Hazard Assessment for Supply Chain Disruptions 39
3 Risk Adaption Strategies 47
3.1 Sea Level Rise/Coastal Flooding 47
3.2 Hurricanes 48
3.3 Riverine Flooding 48
3.4 Supply Chain Disruptions 49
4 Summary 51

List of Tables

Table 2.1 Natural, Technological and Human-Caused Hazards Reflected in the 2050 SWTP/2020 SSTP Resiliency Analysis ... 3
Table 2.2 Notable Storm Surge Events in Georgia from Tropical Cyclones ... 8
Table 2.3 Notable Flood Events in the CORE MPO Region ... 11
Table 2.4 Saffir-Simpson Hurricane Wind Scale ... 11
Table 2.5 Total Number of Hurricanes That Tracked Over Georgia (1851 - 2022) ... 12
Table 2.6 Notable and Historic Tropical Cyclonic Events Affecting Georgia ... 13
Table 2.7 Notable Drought Events in Georgia ... 16
Table 2.8 Notable Extreme Heat Events in Georgia (1952 – 2017) ... 17
Table 2.9 Notable Tornado Events in Georgia ... 18
Table 2.10 Expected Annual Loss by Hazard Type for Georgia ... 24
Table 2.11 Composite Risk EAL Categories for Georgia ... 28
Table 2.12 Vulnerable Interstate and Arterial Mileage ... 31
Table 2.13 Vulnerable Bridges on Interstates and Arterials ... 33
Table 2.14 Vulnerable Railway Mileage ... 35
Table 2.15 Vulnerable Truck Parking Assets ... 37
Table 2.16 Truck Tonnages & Value on Major Truck Routes ... 42

List of Figures

Figure 2.1. US Army Corps of Engineers (USACE) High Projection Curve (Dark Red) ... 4
Figure 2.2 Sea Level Rise Exposure ... 6
Figure 2.3 Flood Hazard Zones ... 10
Figure 2.4 Peak Wind Gust ... 14
Figure 2.5 Monthly Trips in the CORE MPO Region ... 20
Figure 2.6 Quantifying Risk for the CORE MPO Region’s Freight Network ... 23
Figure 2.7 Sea Level Rise/Coastal Flooding Risk ... 25
Figure 2.8 Riverine Flooding Risk ... 26
Figure 2.9 Hurricane Risk ... 27
Figure 2.10 Composite Risk ... 29
Figure 2.11 Vulnerable Highway Assets ... 32
Figure 2.12 Vulnerable Bridge Assets ... 34

Figure 2.13 Vulnerable Railroad Assets 36
Figure 2.14 Vulnerable Truck Parking Assets 38
Figure 2.15 Truck Freight Tonnage and Composite Risk 40
Figure 2.16 Rail Freight Tonnage and Composite Risk 41
Figure 2.17 State of Origin for Freight Flows on I-16, 2019 43
Figure 2.18 State of Destination for Freight Flow Tonnages on I-16, 2019 44
Figure 2.19 State of Origin for Unique Commodity Types on I-16, 2019 45
Figure 2.20 State of Destination for Unique Commodity Types on I-16, 2019 46

1 INTRODUCTION

The Coastal Region Metropolitan Planning Organization (CORE MPO) region serves a gateway for global trade and for freight movement in the Southeast, due in large part to the Port of Savannah – the nation's 4th largest container port. In addition to the Port of Savannah, the region contains a comprehensive multimodal network of freight railroads and railyards, major highways, cargo-serving airports, as well as a substantial warehousing/distribution/logistics industry to manage freight movements over that network. In addition, the region is an emerging manufacturing hub for businesses looking to create and ship a diverse portfolio of finished products to clients around the globe. Overall, goods movement in the Savannah region has a major impact on the regional and state economy.

In support of the region's multimodal freight network and the people and businesses that rely on it, the CORE MPO is conducting an update of its Regional Freight Transportation Plan. The purpose of this memorandum is to assess the resilience of the CORE MPO region's multimodal freight network. Over the last decade, metropolitan planning organizations (MPOs), state departments of transportation (DOTs), and other transportation agencies have taken steps to assess the vulnerability of transportation infrastructure to extreme weather events and to integrate resilience planning considerations into transportation decision-making. The Federal Highway Administration (FHWA) defines resilience as "the ability to anticipate, prepare for, and adapt to, changing conditions and withstand, respond to, and recover rapidly from disruptions."[1] Freight resiliency entails the ability of the multimodal freight network to withstand disruptions with minimal impacts to safety and the economy. As large-scale disruptions to the freight network and associated supply chains have become more common, resiliency has become a much more important component of freight transportation planning.

This report first identifies the risks, or hazards, which could disrupt the flow of goods across the region's freight network. It then performs a hazard assessment for a select group of those risks, focusing on identifying those parts of the CORE MPO region which are most susceptible. From there, the hazard assessment identifies vulnerable freight transportation assets. Vulnerable freight assets include bridges, roadways, railroads, and other components of the multimodal freight network that are within areas that are at risk for flooding, sea level rise, major storms (e.g., hurricanes) and other risks. By identifying vulnerable freight assets, the region will then know which particular assets may need to be "hardened" in order to withstand disruption and enhance resiliency. Lastly, the report develops preliminary strategies for mitigating those risks. Preliminary strategies include a range of actions that the CORE MPO may take, including planning, operations, and capital investments.

[1] FHWA: https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm

2 FREIGHT NETWORK RISKS AND DISRUPTORS

This section of the report identifies the risks, or hazards, which could disrupt the flow of goods across the region's freight network. It then performs a hazard assessment for a select group of those risks and identifies the parts of the CORE MPO region that are most susceptible to the select group of risks. After that, this section of the report identifies the bridges, roadways, railroads, and other freight assets that are most vulnerable to disruption from the identified risks.

2.1 Risks and Disruptor Identification

Identifying threats and hazards is the first step in developing a hazard assessment. Hazards can be natural events (e.g., severe weather), technological (e.g., bridge failure), or human-caused (e.g., terrorism). For the RFTP Update, relevant hazards for the CORE MPO region were identified using information from the Federal Emergency Management Agency (FEMA) National Risk Index (NRI) and the statewide resiliency analysis performed as part of the 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP).

The National Risk Index (NRI) from the Federal Emergency Management Agency (FEMA) is a dataset and online tool to help illustrate the U.S. communities most at risk for 18 natural hazards. It was designed and built by FEMA in close collaboration with various stakeholders and partners in academia; local, state, and federal government; and private industry. The Risk Index leverages available source data for natural hazard and community risk factors to develop a baseline relative risk measurement for each U.S. county and census tract. The NRI is intended to help users better understand the natural hazard risk of their communities. The hazards covered by the NRI include:

- Avalanche
- Coastal Flooding
- Cold Wave
- Drought
- Earthquake
- Hail
- Heat Wave
- Hurricane
- Ice Storm
- Landslide
- Lightning
- Riverine Flooding
- Strong Wind
- Tornado
- Tsunami
- Volcanic Activity
- Wildfire
- Winter Weather

The resiliency analysis completed as part of the 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP) was the state's first comprehensive resiliency assessment completed as part of the long-range transportation planning process. It assessed GDOT's spending in response to weather related events; the level of risk to the transportation network in Georgia, and resiliency of the system to potential natural, technological, and human-made hazards. Relevant hazards to statewide transportation assets included in the 2050 SWTP/2020 SSTP resiliency analysis are shown in Table 2.1.

TABLE 2.1 NATURAL, TECHNOLOGICAL AND HUMAN-CAUSED HAZARDS REFLECTED IN THE 2050 SWTP/2020 SSTP RESILIENCY ANALYSIS

Natural	Technological	Human Caused
• Hurricane • Storm Surge • Inland Flooding • Tornado • Earthquake • Drought • Extreme Heat • Winter Storm • Sinkhole • Landslide	• Hazardous Materials Release • Pipeline Explosion • Dam Failure	• Cyber Attack Against Infrastructure

Source: Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

A key finding of the 2050 SWTP/2020 SSTP resiliency analysis was that the southeast corner of the state is at the highest risk for multiple hazards, including flooding, hurricane, and storm surge, among others. All modes of transportation in this region could face operation disruptions, structural damage and washout, and erosion of the coastal facilities caused by these hazards, including the Port of Savannah, Port of Brunswick, Savannah-Hilton Head International Airport, Brunswick-Golden Isles Airport, I-95, I-516, and other roadways, railways, and transit systems. Hazards that occur without warning will also pose challenges for evacuation.

Upon consultation with the RFTP steering committee, a subset of national and statewide risks was selected for a detailed investigation as part of the RFTP Update resiliency analysis. These include the following:

- Sea Level Rise/Coastal Flooding.
- Riverine Flooding.

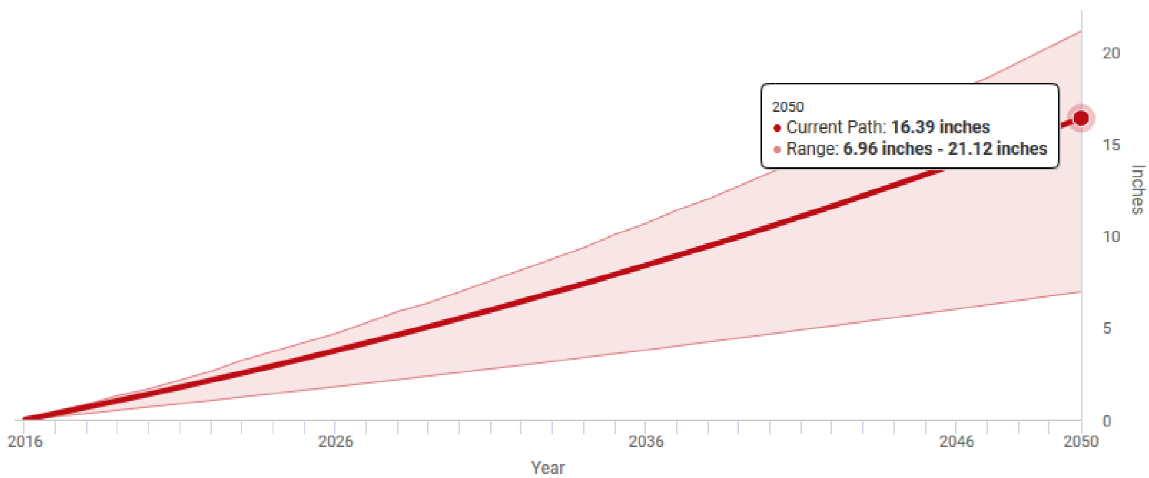
- Hurricanes.
- Supply Chain Disruptors

The following subsections describe the hazards, their ability to disrupt freight flows, and their potential to damage freight assets.

Sea Level Rise/ Coastal Flooding

The sea level around Georgia has increased up to 11 inches higher than it was in the 1950s as a result of both Georgia's sinking land and global warming.[2] In addition, sea level around Georgia is rising at an increasing speed, by as much as 1 inch every 2 years.[2] The sea level around Fort Pulaski has increased around 6 inches in the past 20 years, however, it is forecasted to rise another 6 inches in just the next 14 years.[3] Figure 2.1 below shows the US Army Corps of Engineers (USACE) high forecast curve (darkest red line). It is projected that the sea level around Georgia will increase over 16 inches between 2016 and 2050.

FIGURE 2.1. US ARMY CORPS OF ENGINEERS (USACE) HIGH PROJECTION CURVE (DARK RED)



Source: https://sealevelrise.org/states/georgia/, 2016.

Based on geography alone, the CORE MPO region will be susceptible to sea level rise in the future. This includes the people, property, and infrastructure in the region. Sea level rise will not only affect areas of the CORE MPO region closest to the ocean. When the sea level rises, more ocean water will enter drainage systems that currently empty into the ocean, and water will cause backpressure in these pipes. Water can spill out into the streets far away from the ocean and cause additional flooding.

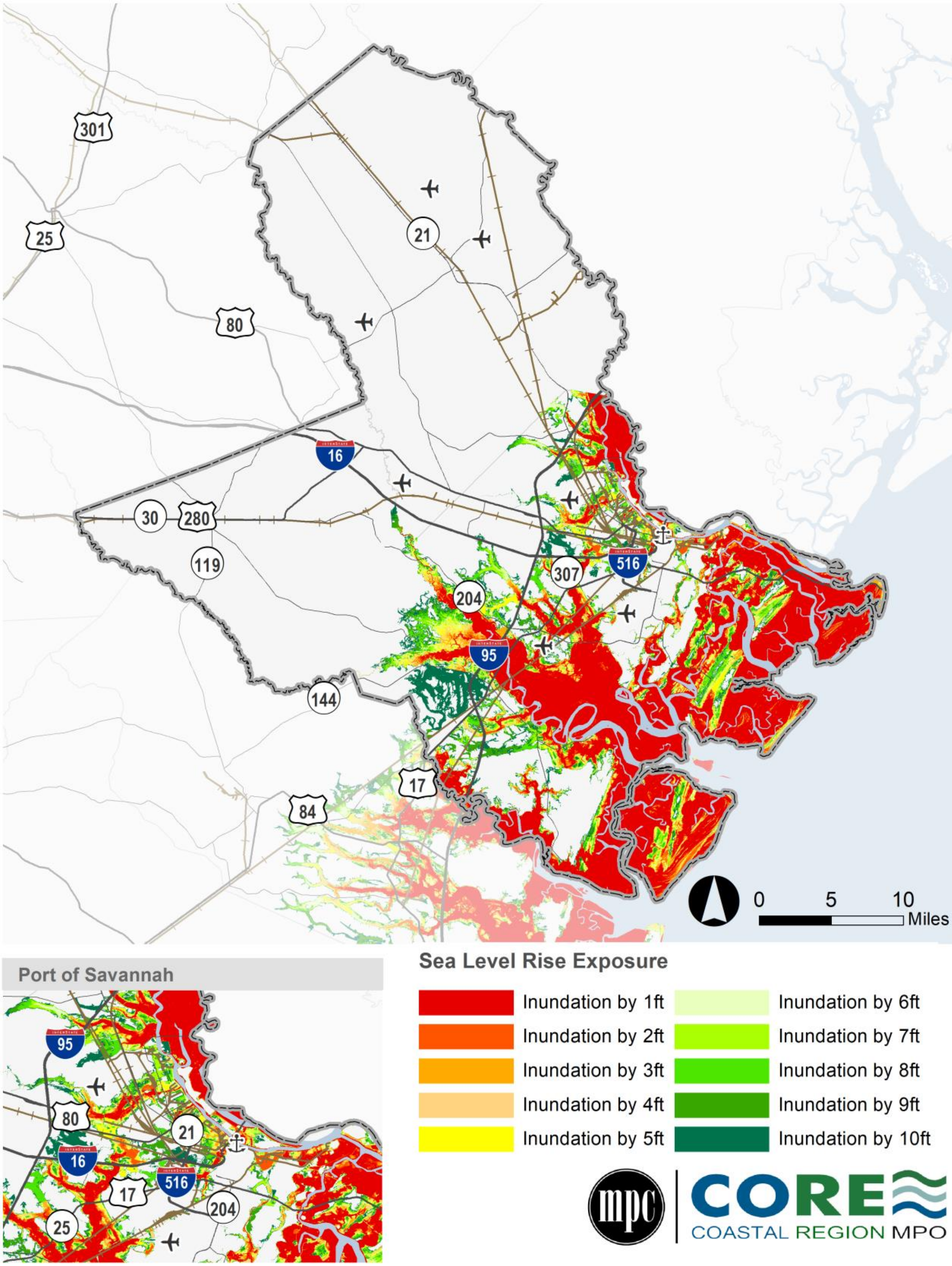
Figure 2.2 shows sea level rise vulnerability in the CORE MPO region, based on areas that are likely to be inundated by different scales of sea level rise. Areas along the major rivers such as the Savannah and Ogeechee Rivers, as well as most of the marshlands in the eastern part of the region are most susceptible to sea level rise, with only one foot of additional sea level enough to inundate most of these locations. It should be noted that though inundation by 5 or more feet of sea level rise is included in Figure 2.2, that magnitude

[2] NOAA Tides and Currents – Fort Pulaski, Georgia (www.tidesandcurrents.noaa.gov).

[3] USACE High Projection (www.corpsclimate.us).

of sea level rise is linked to very long-term projections - beyond the turn of the century. Inundation by 4-feet or less is more consistent with a 30- to 50-year planning horizon.

FIGURE 2.2 SEA LEVEL RISE EXPOSURE



Source: National Oceanic Atmospheric Administration, 2022.

Related to sea level rise is storm surge, which is defined as "an abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed sea surface and the level that would have occurred in the absence of the cyclone"[4]. Storm surge can be produced by tropical cyclones, nor'easters, or strong winter storms, although the latter two are rarely seen in Georgia. Along the Georgia Coast, the difference between low tide and high tide can be up to 10 feet during the spring[5]. Combined with the waves driven by strong winds, the impact of storm surge could cause erosion in coastal areas and damage transportation assets.

Table 2.2 lists major storm surge events that affected the CORE MPO region and surrounding areas since the early 1800s[6]. The extent of storm surge can reach close to 20 feet above normal. The *2019 Georgia Hazard Mitigation Strategy* estimated that the recurrence interval for a major hurricane making landfall in Georgia is approximately once every 36 years.

[4] National Weather Service, 2022

[5] Georgia Hazard Mitigation Strategy, 2019

[6] This list only includes events with recorded storm tide elevations. Other events during this period may have produced storm surge or coastal flooding, but no storm tide records are available.

TABLE 2.2 NOTABLE STORM SURGE EVENTS IN GEORGIA FROM TROPICAL CYCLONES

Date	Event	Description of Impact on Georgia
September 7–8, 1804	"Great Gale of 1804"	St. Simons Island was flooded with water 7 feet above normal. The tide rose 10 feet above mean sea level on the Savannah waterfront, severely flooding Pablo Creek (currently the intracoastal waterway). More than 500 persons drowned.
September 16–17, 1813	Category 3–4 Hurricane	Storm surge of at least 19 feet above mean low water.
September 8, 1854	Category 3 Hurricane	Fort Pulaski—Storm tide elevation 10.50 feet above normal.
August 27, 1881	Hurricane	Fort Pulaski—Storm tide level 11.57 feet above normal. Isle of Hope—11.82 feet above normal.
August 27, 1893	Category 3 Hurricane	Fort Pulaski—Storm tide elevation between 12 to 13 feet above normal. Heavy storm surge of approximately 16 feet in other areas.
October 2, 1898	Category 4 Hurricane	Hutchinson Island, opposite Savannah, was completely inundated to a depth of 4 to 8 feet. Campbell Island, near Darien, was inundated, while Darien reported a tidal wave of about 13 feet above mean high water mark and Sapelo Island reported about 18 feet above the same. Brunswick experienced a 16-foot storm surge in its downtown. This hurricane caused 179 deaths and damage was estimated at $2.5 million.
October 14, 1947	Hurricane	High tides along the Georgia and South Carolina coasts ranged from 12 feet above mean low tide at Savannah Beach and 9.6 feet at St. Simons Island near Brunswick.
September 4, 1979	Hurricane David	Storm surge of 3 to 5 feet and heavy surf.
October 8–9, 2016	Hurricane Matthew	FEMA Disaster 4284; Storm surge of 2 to 8 feet along the entire Georgia coast, including a surge of 7.5 feet at Fort Pulaski.
September 11–13, 2017	Hurricane Irma	FEMA Disaster 4338; Storm surge of 4 to 8 feet along the entire Georgia coast, including a surge of 5 feet at Fort Pulaski, compounded by a rising tide resulting in the second highest water level on record.

Source: Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

The combined effect of rising sea level and other related phenomenon such as king tide, storm surge, shoreline erosion, and other natural disasters could result in a catastrophic impact on infrastructure and human life.

Riverine Flooding

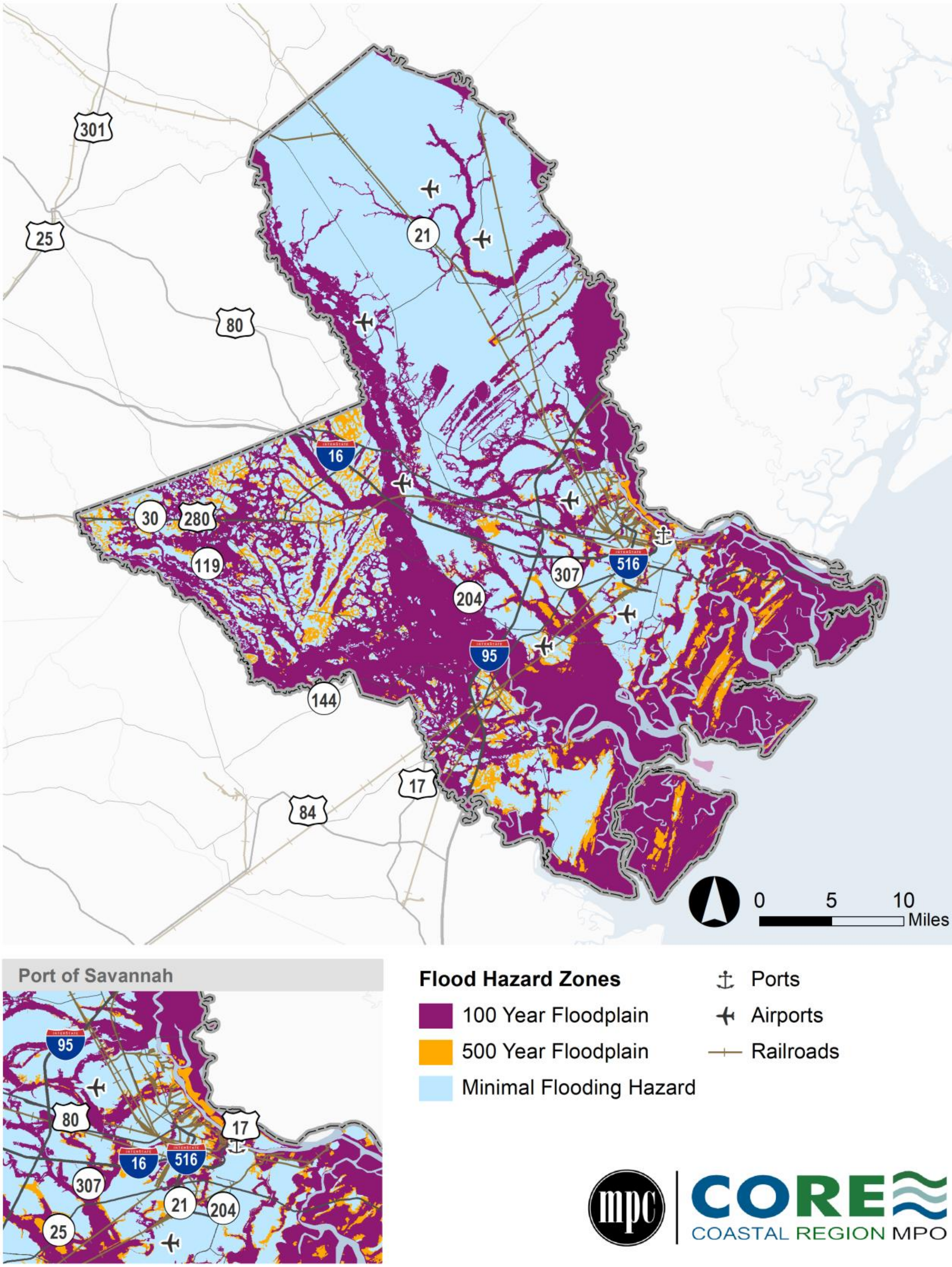
Floods occur when water from different sources overflow their typical boundaries, causing any general or temporary inundation of normally dry land areas. Floods are considered a natural and inevitable occurrence; they happen with seasonal rains or when stormwater drains into river basins and fills them beyond their capacity. However, floods can cause widespread damage to private property and transportation infrastructure and can lead to road closures, bridge damage, and disruptions of travel routes across large areas. Flash floods, which are caused by strong storms and can appear rapidly with little warning, can cause significant damage and dangerous conditions to people and roads.

Floodplain data from the Federal Emergency Management Agency (FEMA) is used to show areas that are vulnerable to riverine flooding. FEMA uses digital flood insurance rate maps (DFIRM), which are flood risk maps that show flood hazard areas like the 100- and 500-year floodplains. This corresponds to a 1 percent chance or a 0.2 percent chance, respectively, of an area being flooded in a given year.

These floodplains are not static and are updated periodically when land erodes, more impervious surfaces are built in the region, and weather patterns change. For example, paving a parking lot will force water to flow into rivers and streams more quickly than if the land was covered with a pervious surface like grass and will cause more flash floods and overwhelm the banks of streams more easily.

These areas of flood vulnerability are mapped in Figure 2.3. Areas in the east, south, and west parts of the region are most susceptible to riverine flooding; most of these areas in 100-year floodplains. Many of these areas overlap with those susceptible to sea level rise, but also include areas further up the Savannah and Ogeechee Rivers, as well as areas to the west of I-95 and south of I-16.

FIGURE 2.3 FLOOD HAZARD ZONES



Source: Federal Emergency Management Agency's Flood Insurance Rate Map, 2022.

Table 2.3 lists some of the most notable flood events in the CORE MPO region.

TABLE 2.3 NOTABLE FLOOD EVENTS IN THE CORE MPO REGION

Year	Area Affected	Recurrence Interval	Remarks
1881	Savannah Area	>100 years	335 deaths; $1.5 million in damages
1893	Savannah Area	>100 years	2,500 deaths; $10 million in damages
1929	Savannah, Ogeechee, and Altamaha Rivers	25 to >100 years	6–10 inches of rain; $3 million in damages
1940	Ogeechee and Savannah Rivers	10 to 75 years	25 deaths; $850,000 in damages; hurricane
1990	Savannah, Ogeechee, and Ohoopee Rivers	>100 years	FEMA Disaster 880; $7.6 million in damages, tropical storm
1991	Altahama, Apalachicola, Ochlockonee, Ogeechee, Satilla, and Savannah Rivers	25 to 50 years	FEMA Disaster 897; $3.4 million in damages
1994	Savannah area	25 to >100 years	FEMA Disaster 1042; 15 inches of rain $10.5 million in damages

Source: Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

Hurricanes

Hurricanes and tropical storms (also known under their formal name as tropical cyclones) are potentially severe storms that have a low-pressure center, colloquially called the “eye” of the storm, surrounded by a distinctive rotating pattern of storms. They bring strong winds and heavy rains that can impact areas stretching hundreds of miles. For the CORE MPO region, tropical cyclones form over the Atlantic Ocean between June 1 and November 30 during the Atlantic hurricane season. They are ranked in order of severity, with tropical depressions having surface wind speeds below 38 mph, tropical storms having a wind speed between 39 and 73 mph, and hurricanes having a windspeed of 74 mph or greater.

Hurricanes are ranked on the Saffir-Simpson Hurricane Wind Scale based on the sustained wind speed. Those categories and associated damage are listed in Table 2.5.

TABLE 2.4 SAFFIR-SIMPSON HURRICANE WIND SCALE

Category	Sustained Wind Speed (mph)	Types of Damage due to Hurricane Winds
1	74-95	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap, and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3	111-129	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted,

Category	Sustained Wind Speed (mph)	Types of Damage due to Hurricane Winds
		blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4	130-156	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted, and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5	> 157	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Source: National Hurricane Center.

Not only can these high winds cause damage, but storm surge that accompanies hurricanes making landfall can be just as deadly. These storm surges are typically caused by the force of the hurricane's winds pushing ocean waters toward the coast, though the low pressure at the center of the hurricane also contributes to a lesser extent.

There have been 23 hurricanes recorded in Georgia since 1851. Most recently, Hurricane Mathew impacted the coastal region in 2016, Irma impacted the entire state in 2017, and Michael impacted southwest and central Georgia in 2018. The *2019 Georgia Hazard Mitigation Strategy* estimated that over a 200-year historical period, 36 tropical cyclones affected the state (not necessarily a direct impact) using the Georgia's tropical cyclone history. This translates to about an 18 percent chance of a tropical cyclone affecting Georgia per year or approximately one hurricane every 5.5 years[7]. Table 2.5 summarizes the number of hurricanes that tracked over Georgia since 1851 by category.

TABLE 2.5 TOTAL NUMBER OF HURRICANES THAT TRACKED OVER GEORGIA (1851 - 2022)

Hurricane Intensity	# of Hurricanes
Category 1	15
Category 2	5
Category 3	2
Category 4	1
Category 5	0
Total	**23**

Source: National Oceanic Atmospheric Administration; Spatial Hazard Events and Losses Database for the United States (SHELDUS); Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

[7] 2019 Georgia Hazard Mitigation Strategy

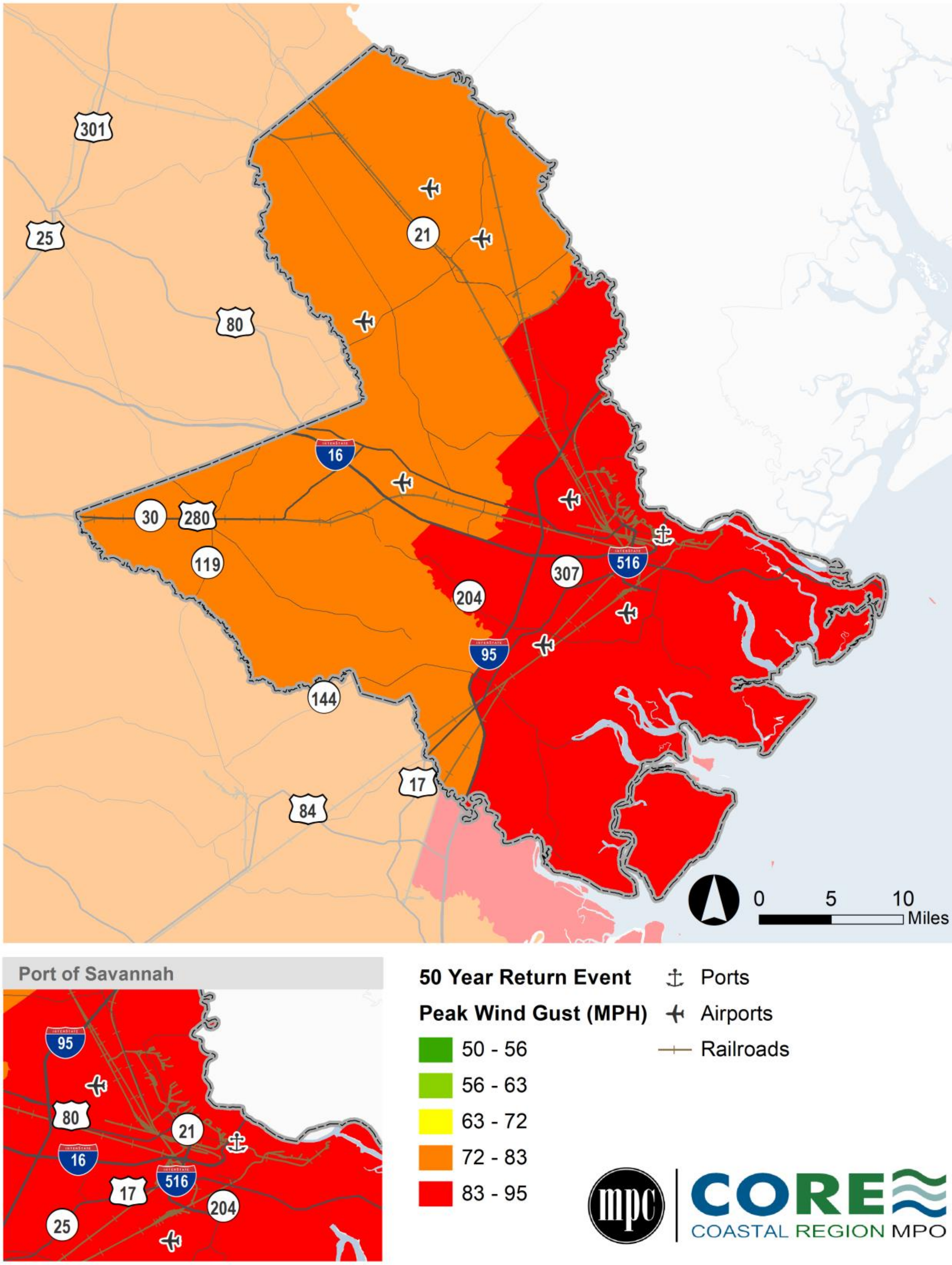
Table 2.6 describes notable and historic tropical cyclonic events that affected the CORE MPO region since 1804.

TABLE 2.6 NOTABLE AND HISTORIC TROPICAL CYCLONIC EVENTS AFFECTING GEORGIA

Year	Name	Area Affected	Details
1804	N/A	Savannah Area	Hutchison Island inundated; 3 deaths
1813	N/A	Coastal Georgia	28 deaths
1881	N/A	Savannah Area	$1.5 million in damages; 335 deaths
1893	N/A	Savannah Area	$10 million in damages; 1,000 deaths
1898	N/A	Coastal Georgia	Category 4; 120 deaths
1911	N/A	Coastal Georgia	18” of rain in 24 hours
1928	N/A	Savannah Area	11” of rain
1940	N/A	Coastal Georgia	>$1 million in damages
1947	N/A	Savannah Area	>$2 million in damages
1959	Gracie	Coastal Georgia	$5 million in damages
1964	Dora	Coastal Georgia	Death Rate 177; $8 million in damages
1979	David	Coastal Georgia	2 deaths
1994	Alberto	Statewide	FEMA Disaster1033; Extreme flooding on Flint and Ocmulgee Rivers; >$400 million in damages
2004	Frances, Ivan, and Jeanne	Statewide	FEMA Disaster 1554 and 1560; Wind/rain damage in 107 counties
2005	Dennis	Statewide	Wind/rain damage; Flooding
2016	Matthew	Coastal Georgia	FEMA Disaster 4284; Wind/rain/coastal flooding in 20 Southeast Georgia counties; $175 million in damages
2017	Irma	Statewide	FEMA Disaster 4338; Wind/rain/coastal flooding affecting all 159 Georgia counties; 1.5 million out of power; 5 fatalities; est. $150 million in uninsured damages

Source: Spatial Hazard Events and Losses Database for the United States (SHELDUS); Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

FIGURE 2.4 PEAK WIND GUST



Source: National Oceanic and Atmospheric Administration, Office for Coastal Management, Hazards U.S. Multihazards (HAZUS-MH) Tool.

Supply Chain Disruptions

As supply chains have become more global and the world economy has become more connected, there is greater potential for disruptions to impact the flow of goods and processes necessary to make supply chains run seamlessly. Disruptions can include a range of events including weather events, labor shortages, pandemics, political unrest, trade wars, infrastructure failures, cyber-attacks, and other natural and man-made events. In recent years, disruptions have become more common, requiring the private sector to adjust their supply chains more frequently. This section explores additional disruptions (beyond those discussed in the previous section) that may impact supply chains, and subsequent freight flows, in the CORE MPO region.

Extreme Weather Events

While the first portion of this section focused on natural hazards and weather events that are most prevalent in the CORE MPO region, there are multiple extreme weather events that could impact the region and disrupt supply chains.

Droughts are climate events of prolonged shortage of water supply caused by a deficiency of precipitation, dry seasons, or El Nino over an extended period (usually a season or more)[8]. Although the adverse effects of droughts are primarily on environmental, agricultural, and social aspects, there also are transportation system impacts. The shortage of water supply creates challenges for inland waterway transport. Long-term droughts could cause cracks in the asphalt and damage the roadway pavements, leading to wildfires, and creating safety hazards for vehicles and pedestrians. This type of damage to the freight network would limit the ability of supply chains function effectively. Table 2.7 lists some of the most notable drought events in Georgia.

[8] 2019 Georgia Hazard Mitigation Strategy.

TABLE 2.7 NOTABLE DROUGHT EVENTS IN GEORGIA

Year	Area Affected	Remarks
1903–1905	Statewide	Severe
1924–1927	North-Central Georgia	One of the most severe of the century
1930–1935	Mostly statewide	Affected most of the U.S.
1938–1944	Statewide	Regional drought
1950–1957	Statewide	Regional drought
1968–1971	Southern and Central Georgia	Variable severity
1977	Statewide	Disaster 3044
1985–1990	North and Central Georgia	Regional drought
1999–2009	Statewide	Severe
2011–2013	Statewide	Variable severity
2016	Northwest Georgia	Severe drought, associated with North Georgia wildfires

Source: Spatial Hazard Events and Losses Database for the United States (SHELDUS); Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

Earthquakes are sudden motions or shaking of the earth's surface resulting from an abrupt release of energy in the earth's lithosphere creating seismic waves[9]. The size of earthquakes can range from unnoticeable to those violent enough to destroy buildings, roadways, bridges, and infrastructure. While no earthquake events were recorded in Georgia from 1952 to 2017[10], seismic activities outside the state could impact the CORE MPO region. For example, a significant earthquake event on the U.S. West Coast would divert maritime traffic to Savannah and other East Coast ports.

FEMA defines extreme heat as a long period (two to three days) of high heat and humidity with temperatures above 90° F (https://www.ready.gov/heat). Besides health concerns, extreme heat impacts the freight network. It can cause concrete to expand and buckle, crack, or shatter, and asphalt to deform, making the roadways uneven and creating potential safety hazards for driving. Extreme heat can cause steel rails to overheat, causing rails to bend, particularly around curves, increasing the need for slow orders and the risk of train derailments. Extreme heat will also lead to delays or cancelation of flights as airplanes lose lift at higher temperatures which impacts air cargo operations. In addition, extreme heat increases the likelihood of afternoon thunderstorms that can impact air cargo operations (in the form of delayed flights which further cause operational constraints at runways) and result in poor roadway conditions (e.g., low visibility, slick pavements) that would impact trucking. As shown in Table 2.11, there were 31 extreme heat events in Georgia between 1952 and 2017.

9 Disaster Preparedness Plan: Get Prepared Today (https://grizzlytarps.com/blog/disaster-preparedness-plan-get-prepared-today/)

10 Spatial Hazard Events and Losses Database for the United States (SHELDUS); Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

TABLE 2.8 NOTABLE EXTREME HEAT EVENTS IN GEORGIA (1952 – 2017)

Begin Date	End Date	Duration (days)	Impacted Counties
7/1/1980	7/31/1980	31	Statewide
8/1/1980	8/31/1980	31	Statewide
6/1/1985	6/1/1985	1	Muscogee, Montgomery, Henry, Peach
5/20/1987	5/20/1987	1	Thomas
6/2/1987	6/2/1987	1	Muscogee
7/10/1987	7/10/1987	1	Bibb
7/14/1987	7/14/1987	1	Muscogee
7/2/1987	7/2/1987	1	Richmond
7/31/1987	7/31/1987	1	Muscogee
8/1/1987	8/31/1987	31	Carroll, Muscogee, Richmond, Bibb, Burke
6/18/1988	6/18/1988	1	Dodge
6/24/1988	6/24/1988	1	Whitfield
6/27/1988	6/27/1988	1	Bibb
7/1/1988	7/1/1988	1	Dougherty
7/15/1988	7/15/1988	1	Dodge
8/5/1988	8/5/1988	1	Muscogee
7/9/1990	7/9/1990	1	Gwinnett
7/11/1992	7/11/1992	1	Muscogee
6/9/1995	6/9/1995	1	Fulton, Greene
7/20/1999	7/31/1999	12	Coweta
8/1/1999	8/1/1999	1	Elbert, Hart, Coweta
8/8/1999	8/8/1999	1	Sumter
7/31/2006	7/31/2006	1	Rockdale
8/1/2007	8/27/2007	27	Floyd, Fulton
8/11/2007	8/11/2007	1	Burke
7/23/2010	7/24/2010	2	Bleckley
7/26/2010	7/26/2010	1	Twiggs
9/5/2015	9/5/2015	1	Walker
7/26/2016	7/26/2016	1	Muscogee
8/4/2016	8/4/2016	1	Carroll
8/5/2016	8/5/2016	1	Muscogee

Source: Spatial Hazard Events and Losses Database for the United States (SHELDUS); Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

Extreme cold and winter storms can be just as disruptive to supply chains as extreme heat. Winter storms are events in which varieties of precipitation, such as snow, sleet, or freezing rain, are formed due to low temperatures. Winter storms can cause damage to transportation infrastructure, malfunction of traffic control and monitoring devices, and delays or closure of roadways, railways, airports, and seaports. In addition, the excessive snow and ice will often increase the likelihood of traffic accidents. Though counties in northern Georgia are more susceptible to severe winter weather/winter storm events, there is some level of exposure for the CORE MPO region. Furthermore, severe winter weather/winter storm events in other parts of the state could impact freight assets and supply chains that are tied to the CORE MPO region. For example, a winter weather/winter storm event that results in the temporary suspension of operations at the Appalachian Regional Port would impact the Port of Savannah. Or, as another example, Interstate highway closures in Metro Atlanta due to snow or ice would impact truck traffic and truck parking in the CORE MPO region.

A tornado forms from strong low-pressure systems often as part of a cold front when a column of air extends from the cloud and comes in contact with the surface of the ground, resulting in a violently rotating funnel with a very strong updraft. With the strong winds, condensation, dust, and debris they usually contain, tornados are very destructive and often uproot trees, roll vehicles, topple buildings, and launch objects hundreds of yards. Tornadoes can occur anywhere within the state. They can disrupt supply chains by interrupting airport and seaport operations, damaging traffic and rail operating equipment (such as signals, cameras, and other electronic devices), and also by damaging roadway pavement and rail tracks. Table 2.9 lists some of the most notable tornado events that affected the State of Georgia.

TABLE 2.9 NOTABLE TORNADO EVENTS IN GEORGIA

Year	Area Affected	Description
1903	Gainesville Area	200 deaths; 400 injuries; 1,500 homeless
1936	Gainesville Area	203 deaths; >1,000 injuries; 800 homes destroyed
1944	Hall and Franklin Counties	18 deaths
1974	Dawsonville Area	4 deaths
1992*	Lumpkin County	FEMA Disaster 69; F4 tornado; 6 deaths; 170 injuries; >1,000 homes damaged; $2 million in damages
1993*	Hall County	FEMA Disaster 980; 44 homes damaged; $2.5 million in damages
1994*	Northwest Georgia	FEMA Disaster1020; 19 deaths; >200 injuries; $67.5 million in damages
1994*	Camden County	FEMA Disaster 1042; F2 intensity
1995*	Albany Area	FEMA Disaster 1076; 36 injuries; 250 buildings damaged
1998*	Hall County and Metro Atlanta	FEMA Disaster 1209; tornadoes causing extensive damage to homes and critical facilities
1999*	Dooly and Candler Counties	FEMA Disaster 1271; tornadoes causing damage to homes, especially in Vienna
2000*	Southwest Georgia	FEMA Disaster 1315; 18 deaths; >100 injuries; $5 million in damages

Source: Spatial Hazard Events and Losses Database for the United States (SHELDUS); Georgia Department of Transportation, 2050 Statewide Transportation Plan (SWTP)/2020 Statewide Strategic Transportation Plan (SSTP), *Resiliency*, November 2020.

*Note: Presidential declared disaster.

Pandemics

In January 2020, the first case of COVID-19 in the U.S. was confirmed. It had been more than a century since the U.S. had dealt with a virus that was as contagious and deadly. The COVID-19 pandemic had a profound impact on people's day-to-day lives. The impacts to transportation and trip-making behavior were particular notable and include:

- In 2020, passengers traveling by air decreased by 63 percent.[11]
- Monthly trips in the CORE MPO region decreased by about 29 percent between April 2019 and April 2020 (see Figure 2.5).[12]
- In mid-March 2021, 36 percent of people made more purchases online because of COVID-19. This habit peaked during the 2020 holiday shopping season when 56 percent of people made more purchases online because of COVID-19.[13]
- In a 2021 survey, 65 percent of workers reported wanting to work remotely permanently, about one-third of workers want a hybrid work scheduled with some days at home and some in the office, and less than 5 percent of workers wanted to work in the office full-time.[14]

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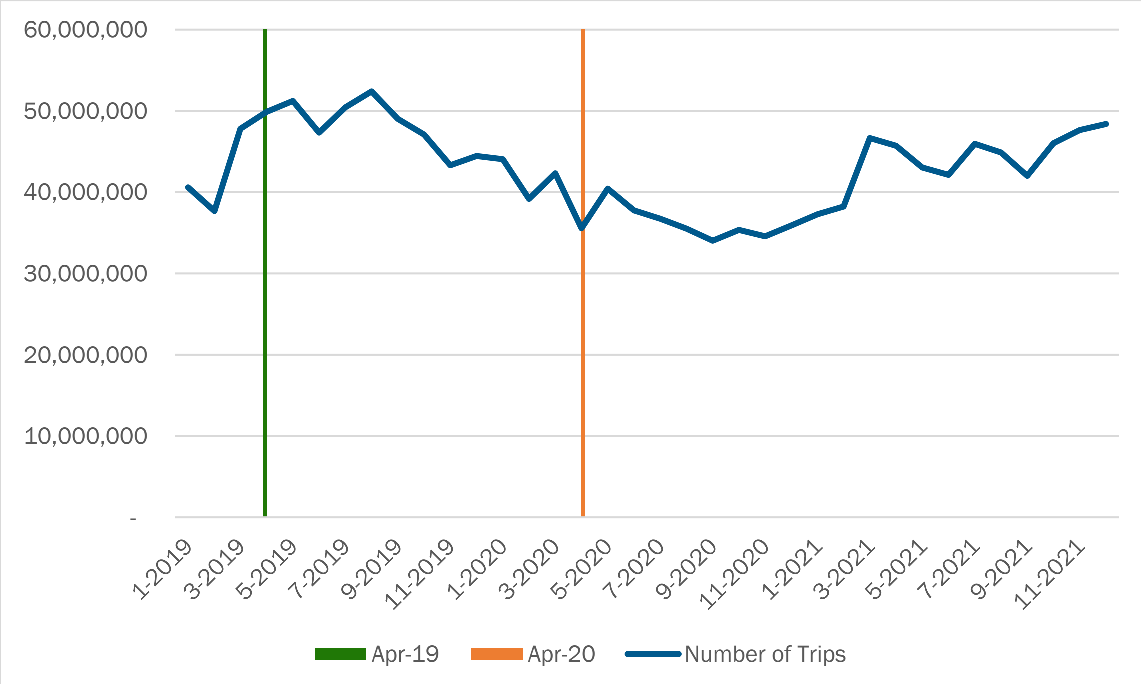
[11] Airports Council International. "The impact of COVID-19 on the airport business and the path to recovery." March 25, 2021. https://aci.aero/2021/03/25/the-impact-of-covid-19-on-the-airport-business-and-the-path-to-recovery/

[12] Bureau of Transportation Statistics, Daily Travel during the COVID-19 Public Health Emergency, https://www.bts.gov/daily-travel.

[13] Bureau of Transportation Statistics. "Effects of COVID-19 on In-Person vs. Online Shopping." https://www.bts.gov/browse-statistical-products-and-data/covid-related/effects-covid-19-person-vs-online-shopping

[14] US DOT Presentation on Transportation Challenges Post COVID-19, Nov. 18, 2020.

FIGURE 2.5 MONTHLY TRIPS IN THE CORE MPO REGION



Source: Bureau of Transportation Statistics, Daily Travel during the COVID-19 Public Health Emergency, https://www.bts.gov/daily-travel; Cambridge Systematics, Inc. analysis.

The pandemic caused a historic demand for goods which had a huge impact on supply chains. Retailers struggled to re-stock store shelves and warehouses as the demand for goods coupled with the substantial increase in e-commerce as the preferred method of shopping led to trucking capacity shortages – an industry with pre-existing labor challenges. In addition, labor shortages in warehouses, distribution centers, and factories due to the pandemic caused capacity constraints on the production side as well. These and the changes listed above are the immediate impacts of the pandemic. At this moment, it is unclear how many, if any, of these impacts may become long-term trends. For instance, some travel patterns and traffic volumes have already exceeded pre-pandemic figures while others have not returned to their pre-pandemic levels. The impacts that do remain as long-term trends will continue to impact supply chains and subsequently alter how supply chains should be considered in the context of freight transportation planning.

Labor Shortages

Labor shortages caused by the COVID-19 pandemic greatly impacted global supply chains as millions succumbed to illness, many more were unable to work due to ailment, and still others could not safely do their jobs while maintaining public health guidelines on social distancing. The pandemic also greatly impacted how, where, and for whom people worked. In 2021, nearly 39 million people quit their jobs.[15] In April 2021, job openings across the country rose to an unprecedented 9.3 million, according to the Bureau of

[15] MarketWatch. "'The Great Resignation' slowed in October, but 4.2 million Americans still quit jobs." December 8, 2021. https://www.marketwatch.com/story/people-quit-jobs-at-slightly-slower-rate-in-october-11638976546

Labor Statistics.[16] That trend continued through March 2022, when job openings rose to 11.9 million.[17] The April record surpassed the January 2019 figure of 7.5 million jobs.[18]

The labor shortage challenges caused by the COVID-19 pandemic exacerbated existing labor shortages within the transportation industry as it was already suffering a labor shortage long before pandemic. The American Trucking Association has reported a truck driver shortage since 2005. This labor shortage acutely impacts the transportation system because trucks move more freight than any other mode and 43 percent of trucking's operational costs is driver compensation.[19] Besides transportation, associated industries such as warehousing and distribution also felt the impacts of pandemic-related labor shortages, worsening the ability of supply chains to keep up with global demand.

Cyberattacks and Infrastructure Failures

Cyberattacks are of concern for public agencies and private companies in the transportation industry, such as airlines, pipeline owners and operators, and trucking companies. On the public sector side, transportation system and infrastructure impacts from cyberattacks include disruptions to highway traffic control and Intelligent Transportation Systems (ITS), port operations and communication, and airport traffic control and communication systems. In addition, as Supervisory Control and Data Acquisition (SCADA) systems are becoming more prevalent in City Management and Public Works departments, public assets that are critical to supply chains are more exposed to ransomware, malware, and other cyberattacks.[20] For example, SCADA systems are used in distribution systems such as electrical power grids and water distribution and wastewater collection systems. [21] They are also used by the private sector to manage oil and natural gas pipelines, railway transportation systems, and other critical infrastructure.

On the private sector side, transportation system and infrastructure impacts from cyberattacks include disruptions to railroad freight operations and communication systems as well as natural gas and refined petroleum pipeline operations and safety control systems. Though privately owned, there is a clear public interest in limiting disruptions to these systems. Between June 2020 and June 2021 there was a 186 percent increase in weekly ransomware attacks on the transportation industry at the national level.[22] Furthermore, cyberattacks are a growing risk as technology becomes increasingly integrated into the transportation industry, especially in the form of connected and autonomous technologies. If outside parties gain unauthorized access to networked transportation systems, these incidents may result in crashes, malfunctions, and damaged infrastructure. Some motor carriers have cited concerns over cybersecurity

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[16] Forbes. "What Does A Worker Want? What The Labor Shortage Really Tells Us." July 8, 2021. https://www.forbes.com/sites/tomspiggle/2021/07/08/what-does-a-worker-want-what-the-labor-shortage-really-tells-us/?sh=5fcaa4f5539d

[17] U.S. Bureau of Labor Statistics. "Job Openings Levels and Rates by Industry and Region, Seasonally Adjusted." June 2022. https://www.bls.gov/news.release/jolts.t01.htm

[18] U.S. Bureau of Labor Statistics. "Monthly Labor Review." June 2020. https://www.bls.gov/opub/mlr/2020/article/job-openings-hires-and-quits-set-record-highs-in-2019.htm

[19] American Trucking Association. "Truck Driver Shortage Analysis 2019." July 2019. https://www.trucking.org/sites/default/files/2020-01/ATAs%20Driver%20Shortage%20Report%202019%20with%20cover.pdf

[20] 2018 Georgia Hazard Identification and Risk Assessment

[21] Cyberthreats, Vulnerabilities and Attacks on SCADA Networks, Rose Tsang, 2010 (https://www.researchgate.net/publication/242464191_Cyberthreats_Vulnerabilities_and_Attacks_on_SCADA_Networks).

[22] Cybertalk.org. "Ransomware attacks on the transportation industry, 2021." July 28, 2021. https://www.cybertalk.org/2021/07/28/ransomware-attacks-on-the-transportation-industry-2021/

attacks as a source of hesitation for implementing Advanced Driver Assistance Systems (ADAS) and other connected vehicle technologies in their fleets.[23]

Cyberattacks have the potential to greatly disrupt supply chains. They can create circumstances where freight transportation providers are unable to operate or cannot operate in a safe fashion. Thus, adaption strategies focused on minimizing risks associated with cyberattacks are important for the region to consider.

2.2 Hazard Assessment for Sea Level Rise, Riverine Flooding, Hurricanes, and Supply Chain Disruptions

Application of the FEMA NRI to the CORE MPO

Natural hazard risk, in the most general terms, is often defined as the likelihood (or probability) of a natural hazard event happening multiplied by the expected consequence if a natural hazard event occurs, as shown in the equation below.

$$Risk = Likelihood \times Consequence \times Vulnerability$$

As described in section 2.1, the National Risk Index (NRI) dataset and online tool from the Federal Emergency Management Agency (FEMA) illustrates the risk level for 18 natural hazards across the U.S. The primary output of the dataset and tool is the NRI score, a baseline relative risk measurement for each U.S. county and census tract defined at the national level.[24] Essentially, the NRI score is risk weighted by sociodemographic factors to identify populations that are more exposed to hazards and are most vulnerable for experiencing negative outcomes.[25] Communities, at the Census tract or county level, are classified as having “Very Low” to “Very High” risk based on their NRI score.

The risk element of the NRI score is the “Expected Annual Loss” (EAL), which quantifies the anticipated economic damage resulting from natural hazards each year as the average economic loss in dollars. It does this by combining the expected loss of building value, population, and agriculture value each year due to natural hazards.

$$EAL = Annualized\ Frequency \times Historic\ Loss\ Ratio \times Exposure$$

The EAL aligns with the general risk equation where:

- Likelihood = Annualized Frequency (i.e., the number of occurrences of a hazard over time);

[23] Truckinginfo. “ATRI: Class 8 Carriers Hesitant of ADAS Adoption.” April 28, 2021. https://www.truckinginfo.com/10142325/atri-class-8-carriers-hesitant-of-adas-adoption

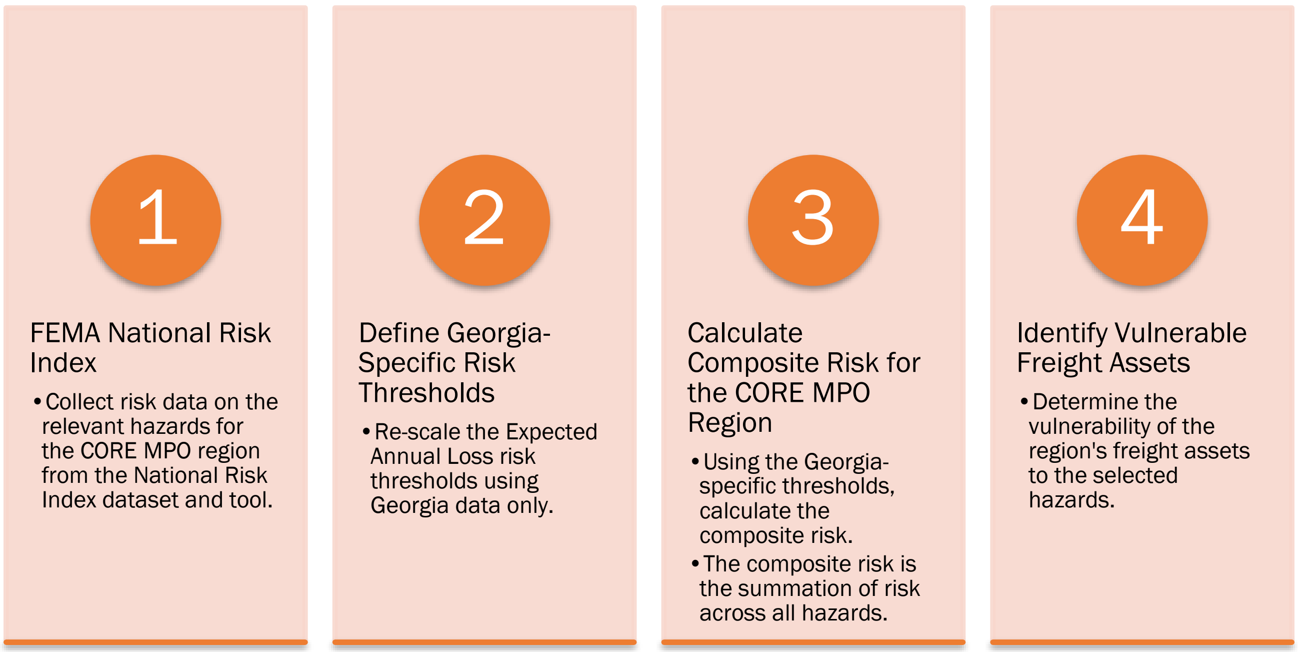
[24] Federal Emergency Management Agency, National Risk Index Technical Documentation, version 1.18.1, November 2021.

[25] The formal definition for the FEMA NRI score is: $Risk = Expected\ Annual\ Loss \times Social\ Vulnerability \times {}^{1}/_{Community\ Resilience}$. “Expected annual loss” is the average economic loss in dollars resulting from a natural hazard. “Social vulnerability” is the susceptibility of social groups to the adverse impacts of natural hazards. It is based on median age, per capita income, unemployment, and other factors. “Community resilience” is the ability of a community to prepare for anticipated natural hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions. It acts as a reduction factor to the consequence of a hazard as communities that are considered more resilient with have lesser negative consequences from a hazard.

- Consequence = Historic Loss Ratio (i.e., the representative percentage of a location's hazard type exposure that experiences loss due to a hazard occurrence or the average rate of loss associated with the hazard occurrence); and
- Vulnerability = Exposure (i.e., the representative value of buildings, population, or agriculture potentially exposed to a natural hazard).

Because of this, Expected Annual Loss can be considered a robust indicator of risk and consequently be used to develop an indicator-based approach to assess the risks of sea level rise, riverine flooding, and hurricanes to the CORE MPO region's multimodal freight network. This process is outlined in Figure 2.6.

FIGURE 2.6 QUANTIFYING RISK FOR THE CORE MPO REGION'S FREIGHT NETWORK



Source: Federal Emergency Management Agency, 2022; Cambridge Systematics.

The process first collected risk data for sea level rise/coastal flooding, riverine flooding, and hurricanes from the FEMA NRI dataset and tool. Specifically, Expected Annual Loss data for each of the hazards was collected for all Census tracts in the 3-county region. The reason the process focuses on Expected Annual Loss, as opposed to the NRI score which accounts for sociodemographic factors, is because the focus on this risk assessment is on the freight network as opposed to a broader societal assessment of risk.

The process then defined Georgia-specific risk thresholds (i.e., "Very Low" to "Very High") using the Expected Annual Loss data for Georgia only. This is in contrast to the FEMA NRI dataset and tool, which defines risk thresholds based on national-level percentiles. This prevented the analysis from overlooking areas of the region that might not be considered at-risk from a national perspective but are important for Georgia.

Next, the process calculated the composite risk by taking the sum of Expected Annual Loss across all hazards. This shows which portions of the region are most susceptible to multiple hazards. Lastly, the process identified which of the region's freight assets (e.g., highways, railroads, etc.) are most vulnerable to the selected hazards.

This was done by examining the location of freight assets in relation to the zones of risk as determined by the composite risk calculation.

Quantifying Risk for the CORE MPO Region

Risk data was collected from the FEMA NRI dataset and tool for the CORE MPO region for three natural hazards: sea level rise/coastal flooding, riverine flooding, and hurricanes. Specifically, Expected Annual Loss data (the anticipated economic damage resulting from natural hazards measured in dollars) for each of the hazards was collected. The process then defined Georgia-specific risk thresholds (i.e., “Very Low” to “Very High”) using the Expected Annual Loss data for Georgia only. These thresholds are shown in Table 2.10.

TABLE 2.10 EXPECTED ANNUAL LOSS BY HAZARD TYPE FOR GEORGIA

Category	Quintile	Coastal Flooding	Riverine Flooding	Hurricanes
Very Low	0% - 20%	$0 - $131	$0 - $2,667	$0 - $516
Low	20% - 40%	$131 - $4,716	$2,667 - $8,370	$516 - $1,060
Moderate	40% - 60%	$4,716 - $26,690	$8,370 - $17,838	$1,060 - $3,716
High	60% - 80%	$26,690 - $76,545	$17,838 - $39,071	$3,716 - $19,606
Very High	80% - 100%	$76,545 - $314,135	$39,071 - $560,878	$19,606 - $1,073,459

Source: FEMA National Risk Index; Cambridge Systematics analysis.

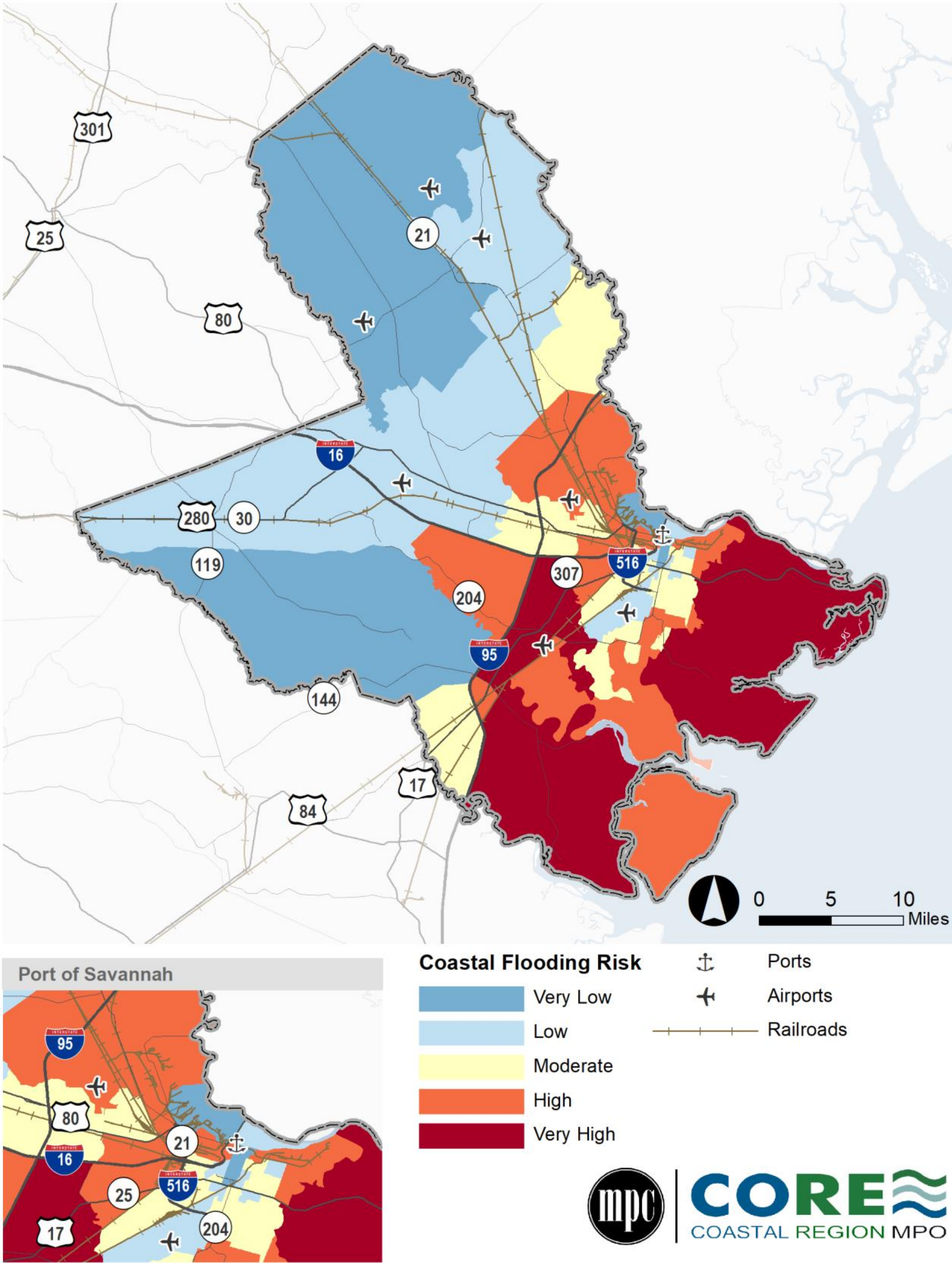
Figure 2.7, Figure 2.8, and Figure 2.9 show these individual EALs as mapped throughout the CORE MPO region. The sea level rise risk map (Figure 2.7) shows that the locations that are most at-risk due to coastal flooding are those closest to the Atlantic Ocean in the eastern part of the region. Much of the region to the east of I-95 is at either very high or high risk to sea level rise. The exception for the city center of Savannah where the higher elevations translate to a moderate or low risk.[26]

The riverine flooding risk map (Figure 2.8) reveals that the areas most susceptible to riverine flooding are in the easternmost part of the study near Tybee Island (where there are many small streams through the marshes), areas south of the Ogeechee River, and areas east of I-95. Other high-risk areas include areas to the west of downtown Savannah such as Pooler, Port Wentworth, Bloomingdale, and Eden. Notably, areas along the banks of the Savannah River generally exhibit low to moderate risk for riverine flooding.

The hurricane risk map (Figure 2.9) indicates that most of the region is at-risk to hurricane damage. The highest risk locations are in north Effingham County, along the I-95 corridor, and the south and eastern parts of the region near the Atlantic Ocean. Much of the remaining part of the study area is at high risk except for a few areas west of I-95 and south of US 280.

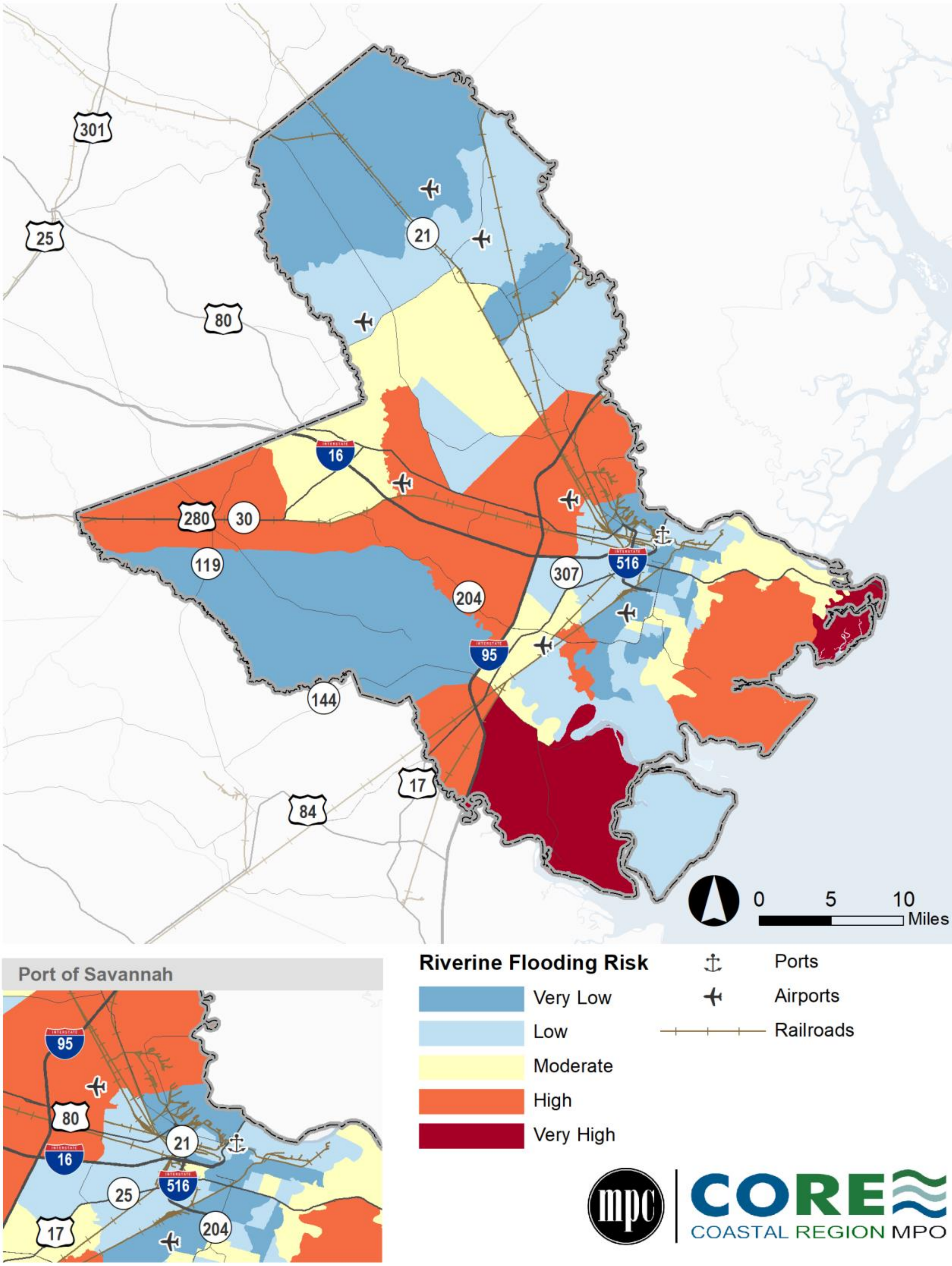
[26] The City of Savannah has an elevation of 49 feet. This is much higher compared to other coastal U.S. southeastern cities such as Charleston (19.69 feet), Jacksonville (16 feet), and Miami (6.6 feet).

FIGURE 2.7 SEA LEVEL RISE/COASTAL FLOODING RISK



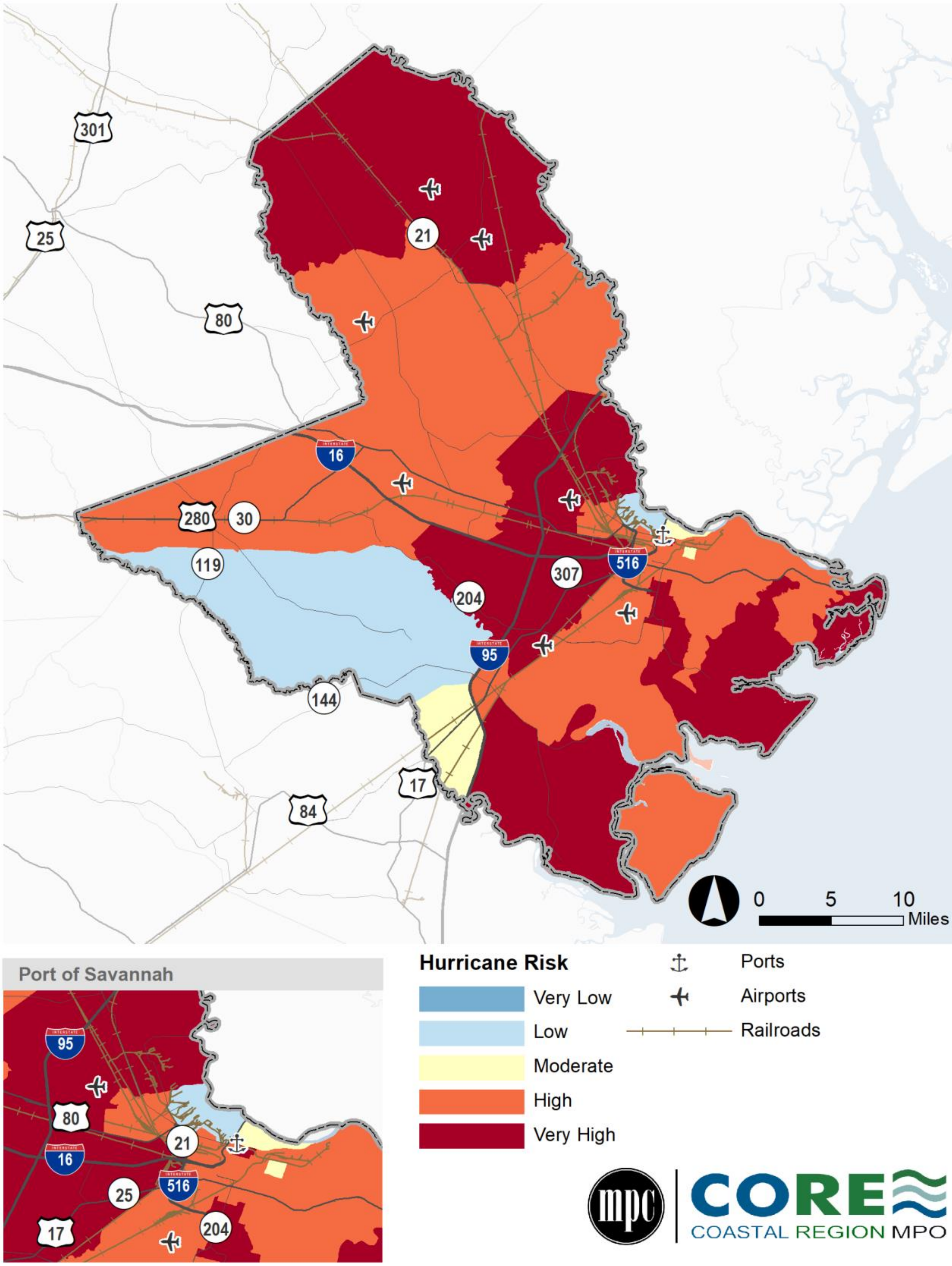
Source: Federal Emergency Management Agency, 2022; Analysis by Cambridge Systematics.

FIGURE 2.8 RIVERINE FLOODING RISK



Source: Federal Emergency Management Agency, 2022; Analysis by Cambridge Systematics.

FIGURE 2.9 HURRICANE RISK



Source: Federal Emergency Management Agency, 2022; Analysis by Cambridge Systematics.

For the CORE MPO region, a composite risk value was calculated by summing the individual EALs of sea level rise, riverine flooding, and hurricanes, as shown in the equation below.

$$Composite\ Risk = EAL_{Sea\ Level\ Rise} + EAL_{Riverine\ Flooding} + EAL_{Hurricanes}$$

Table 2.11 shows the breakdown for the total composite risk quintiles for the state of Georgia. Census tracts in Figure 2.10 are symbolized based on these composite risk EAL values.

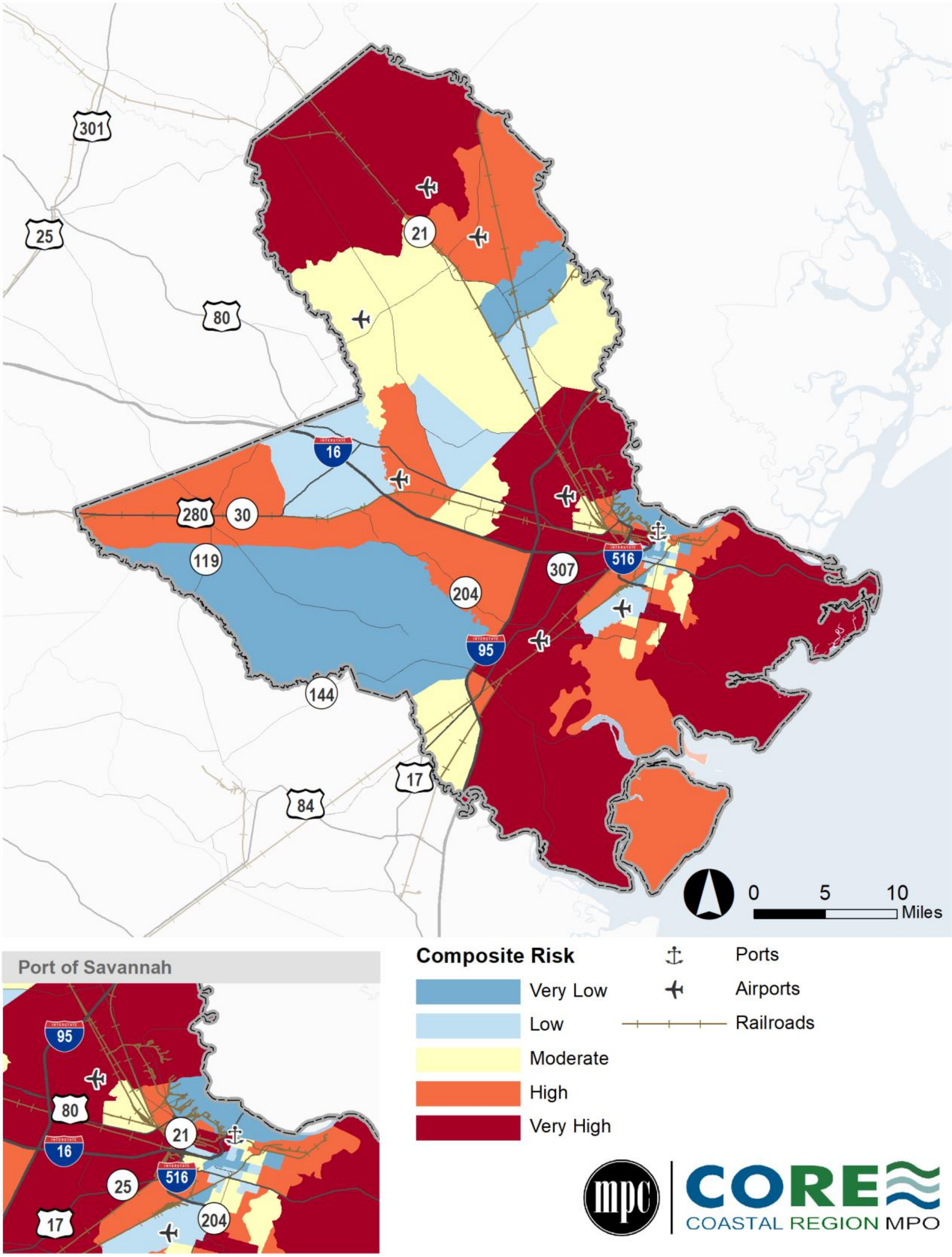
TABLE 2.11 COMPOSITE RISK EAL CATEGORIES FOR GEORGIA

Category	Quintile	Composite Risk
Very Low	0% - 20%	$0 - $7,654
Low	20% - 40%	$7,654 - $17,626
Moderate	40% - 60%	$17,626 - $33,292
High	60% - 80%	$33,292 - $72,807
Very High	80% - 100%	$72,807 - $1,134,797

Source: Federal Emergency Management Agency, 2022; Cambridge Systematics, Inc. analysis.

Figure 2.10 show the census tracts most at risk for all three risk categories (sea level rise, riverine flooding, and hurricanes). Most of the areas to the east of I-95 are either very high risk or high risk, with the most damaging risks being either along I-95 or close to the ocean. The only other area under very high risk is the extreme north part of the region; the “very high” categorization of this area is due mainly to the hurricane EALs.

FIGURE 2.10 COMPOSITE RISK



Source: Federal Emergency Management Agency, 2022; Analysis by Cambridge Systematics.

Vulnerable Freight Assets to Sea Level Rise/Coastal Flooding, Riverine Flooding, and Hurricanes

This section presents freight assets within the CORE MPO region that are under the three risks identified by FEMA in the previous section. The following assets were included in the analysis of vulnerable freight assets:

- Ports.
- Highways and Bridges.
- Railroads.
- Air.
- Truck parking facilities.

In general, much of the area around the Port of Savannah and Savannah/Hilton Head International Airport is under either "very high" or "high risk. Because there is so much freight activity in that area, many of the freight assets such as railroads, highways/bridges, and truck parking facilities are under severe risk levels as well.

Vulnerability of the Port of Savannah

The Port of Savannah is the most significant freight asset in the region and the State. The riverine flooding risk ranges from "high" to "low" with port assets to the north (e.g., Garden City Terminal) generally exhibiting higher risk than those to the south and east (e.g., Ocean Terminal). Similarly, the risk from sea level rise/coastal flooding also ranges from "high" to "low" with port assets to the north generally exhibiting higher risk than those to the south and east. The risk from hurricanes for Port of Savannah facilities is generally "moderate" to "very high" with some centrally located assets (i.e., portions of the Garden City Terminal) showing "low" risk. Given the large amount of area occupied by the Port of Savannah, altogether these three risks combined indicate that the Port ranges from "low" to "very high" composite risk, as seen in Figure 2.10.

While the Port of Savannah's Garden City and Ocean Terminals are generally in lower risk areas, key routes that provide access for trucks to these terminals are in areas of "high" to "very high" combined risk. These include SR 21, SR 307/Dean Forest Parkway, and Jimmy Deloach Parkway. Furthermore, while the Port of Savannah has infrastructure and mitigation measures in place to limit the impacts of disruptions, their effectiveness is limited if the routes providing access to the port's facilities are unable to function.

Vulnerability of Savannah/Hilton Head International Airport

The Savannah/Hilton Head International Airport is the most significant air cargo asset in the region as it is the only facility than handles air freight. Despite being further from the Savannah River, the airport is surrounded by numerous small creeks and streams which have the ability to cause significant riverine flooding, which gives the airport a "high" riverine flooding risk. The risk of coastal flooding is similarly "high," and the risk of hurricanes is considered "very high." Combined, the three risks combined to put the Savannah/Hilton Head International Airport in an area of "very high" combined risk, seen in Figure 2.10.

In addition, key routes that provide access for trucks to the airport are in areas of “very high” combined risk. These include Gulfstream Road and SR 307/Dean Forest Parkway. The effectiveness of any infrastructure and mitigation measures in place at the Savannah/Hilton Head International Airport to minimize the impacts of disruptions is limited if the routes providing access to the airport are unable to function.

Vulnerable Highway and Bridge Assets

Figure 2.11 shows highway assets in the CORE region and depicts their composite risk vulnerability. Only arterial roadways and Interstate highways are included in the map. Many roadways to the west of downtown Savannah are under “very high” composite risk or “high” risk. This includes major freight corridors such as SR 21, SR 307/Dean Forest Parkway, and Jimmy Deloach Parkway as well as several portions of I-95 and I-16.

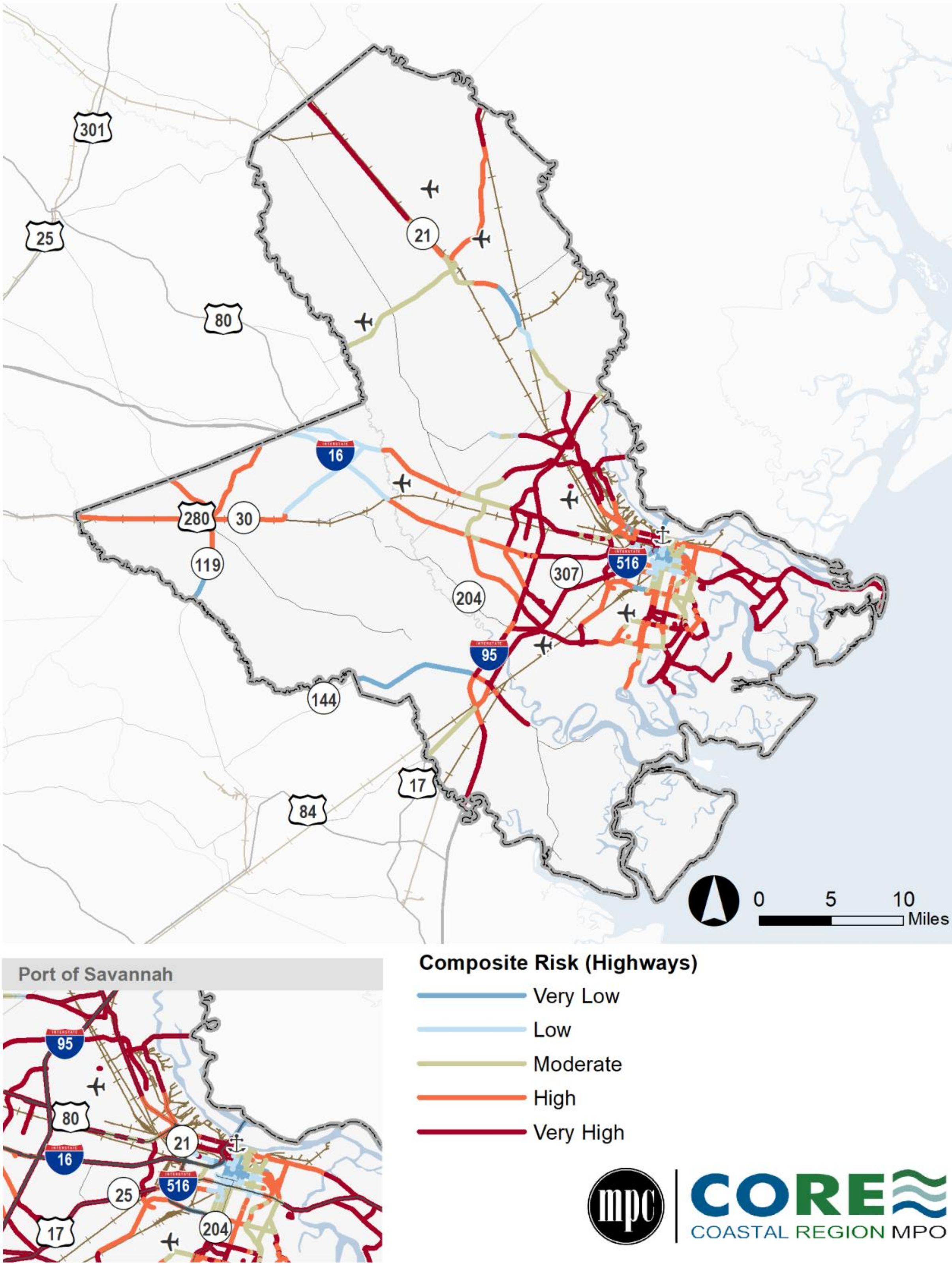
Table 2.12 shows the mileage of arterial roadways and Interstate highways that are within the various composite risk categories. As the risk gets worse, the mileage within each category gets higher. Over 42 percent of the region’s arterials and Interstate highways (almost 600 miles of roadways) are under “very high” risk. Nearly 28 percent of the region’s arterials and Interstate highways (almost 300 miles) under “high” risk.

TABLE 2.12 VULNERABLE INTERSTATE AND ARTERIAL MILEAGE

Risk Category	Mileage	% of Total Mileage
Very Low	83.3	6.0%
Low	126.7	9.1%
Moderate	206.1	14.9%
High	286.6	27.9%
Very High	583.6	42.1%
Total	**1,286.3**	**100.0%**

Source: FEMA, 2022; Highway Performance Management System, 2021; Cambridge Systematics, Inc. analysis.

FIGURE 2.11 VULNERABLE HIGHWAY ASSETS



Source: FEMA, 2022; Highway Performance Management System, 2021; Cambridge Systematics, Inc. analysis.

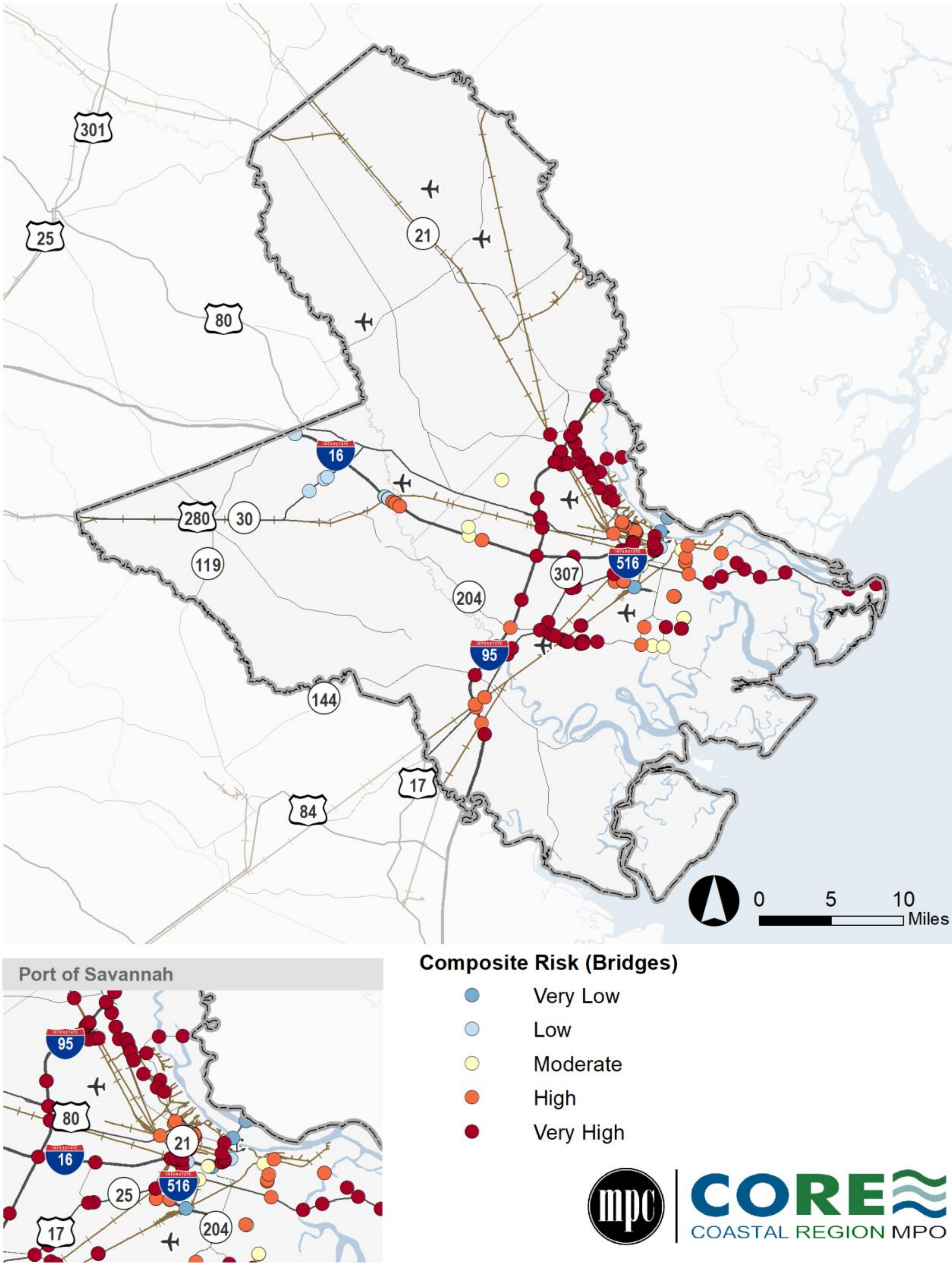
Figure 2.12 depicts the region's bridges and their composite risk vulnerability. Only bridges that carry arterial roadways and Interstate highways are shown. In total, out of 181 bridges, over half are located in areas under "very high" risk (94 in total) and another 46 bridges (over 25 percent) are in "high" risk areas as shown in Table 2.13.

TABLE 2.13 VULNERABLE BRIDGES ON INTERSTATES AND ARTERIALS

Risk Category	# of Bridges	% of Total Bridges
Very Low	14	7.7%
Low	14	7.7%
Moderate	13	7.2%
High	46	25.4%
Very High	94	51.9%
Total	**181**	**100.0%**

Source: FEMA, 2022; National Bridge Inventory, 2021; Cambridge Systematics, Inc. analysis.

FIGURE 2.12 VULNERABLE BRIDGE ASSETS



Source: FEMA, 2022; National Bridge Inventory, 2021; Cambridge Systematics, Inc. analysis.

Vulnerable Railroad Assets

Figure 2.13 depicts the region's railroads and their composite risk vulnerability. It also shows the location of three of the region's major rail yards:

- CSX Southover Yard (the southernmost rail yard)
- CSX Savannah Yard
- Norfolk Southern Dillard Yard (the northernmost rail yard)

Similar to the other assets, the railroads to the west of downtown Savannah, especially the railroads serving the Port of Savannah, are under "very high" composite risk from riverine flooding, coastal flooding, and hurricanes.

Table 2.14 shows the mileage of railways in the region under the various risk levels. Over 60 percent of the region's railway mileage (over 200 miles) is under either "very high" or "high risk", with over 120 miles of that being under "very high" risk.

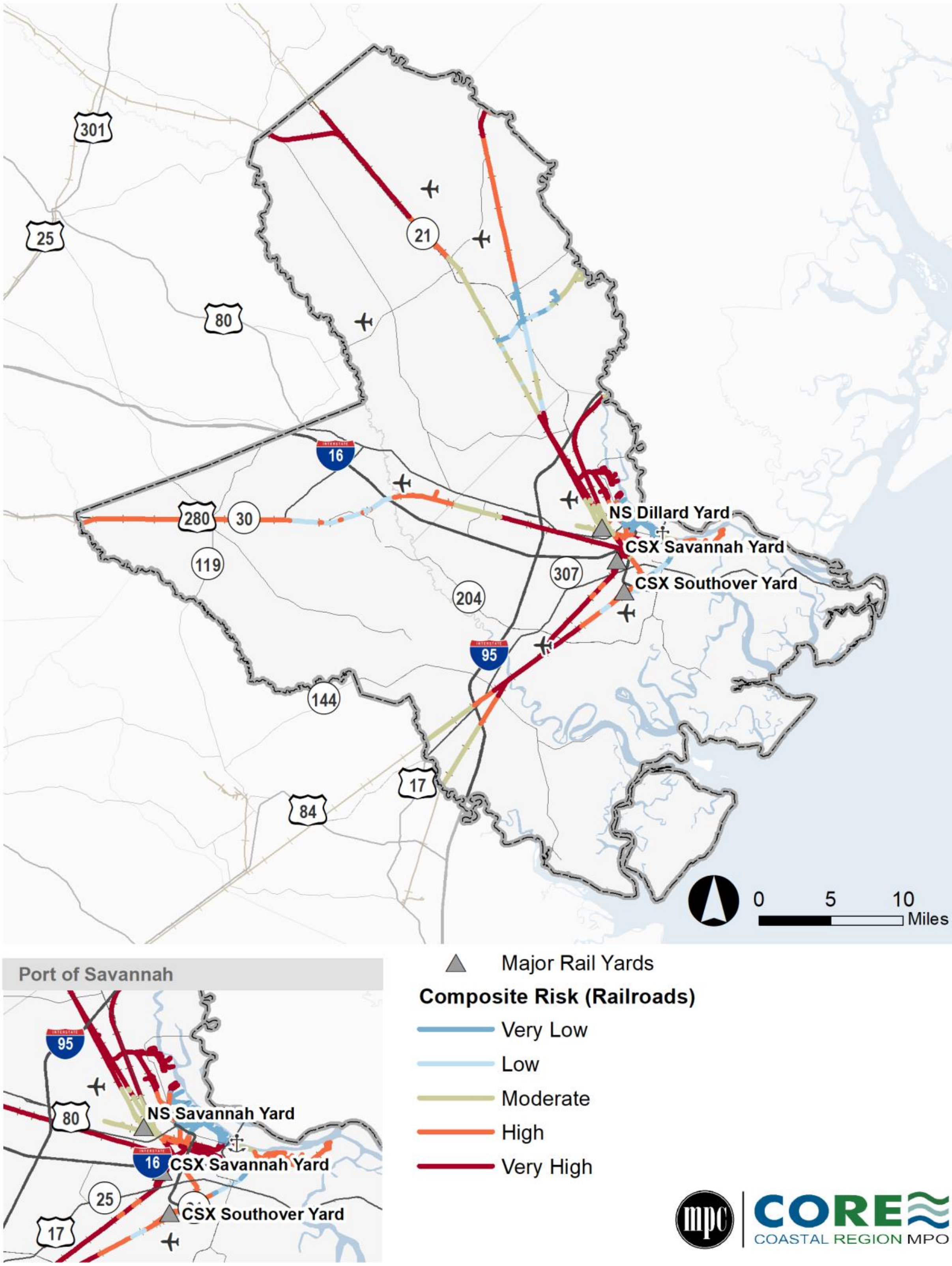
TABLE 2.14 VULNERABLE RAILWAY MILEAGE

Risk Category	Mileage	% of Total Mileage
Very Low	40.5	12.3%
Low	24.7	7.5%
Moderate	57.3	17.4%
High	86.1	26.1%
Very High	121.2	36.7%
Total	**329.8**	**100.0%**

Source: FEMA, 2022; Federal Railway Administration, 2021 Cambridge Systematics, Inc. analysis.

The three major rail yards in the region are all in risk areas of at least "moderate" combined risk. The CSX Southover Yard and Savannah Yard are within "high" risk areas, while the Norfolk Southern Dillard Yard is in a "moderate" risk area.

FIGURE 2.13 VULNERABLE RAILROAD ASSETS



Source: FEMA, 2022; Federal Railway Administration, 2021; Cambridge Systematics, Inc. analysis.

Vulnerable Truck Parking Assets

Figure 2.14 depicts the region's truck parking facilities and their composite risk scores. The pattern is the same as the other freight assets: the facilities to the west of downtown Savannah and between the port and the airport are under the most risk from flooding and hurricanes. Table 2.15 also shows this information and includes breakdowns of the actual truck parking spaces in each risk category.

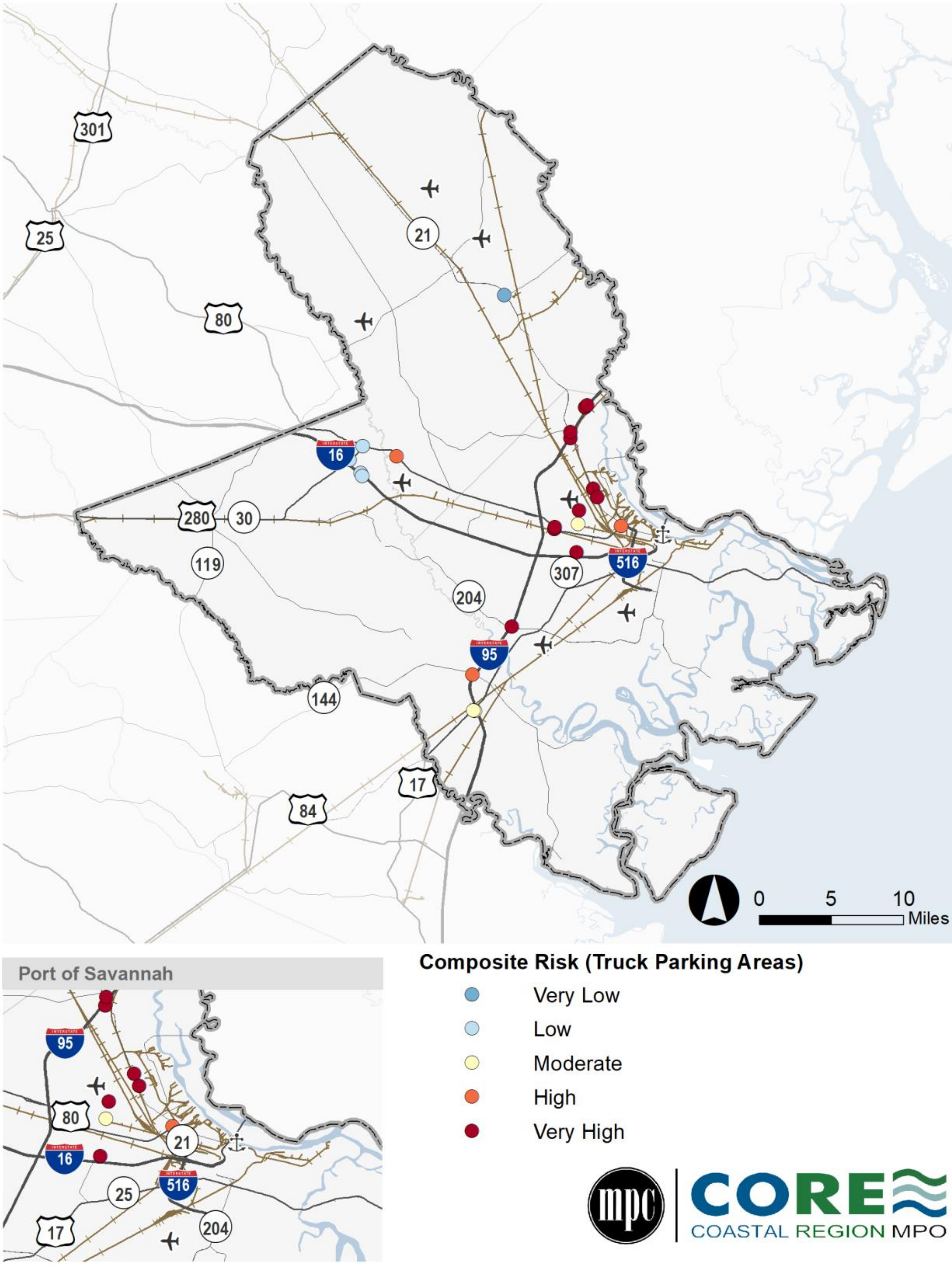
Out of the 22 truck parking facilities in the region, half are under "very high" risk, with another six being either under "high" or "very high" risk. Regarding truck parking spaces, almost half of the more than 1,000 truck parking spaces in the region are under "very high" or "high" risk. If including spaces under "moderate" risk, almost 75 percent of all spaces in the region are under a significant threat.

TABLE 2.15 VULNERABLE TRUCK PARKING ASSETS

Risk Category	# of Truck Parking Facilities	% of Total Facilities	# of Truck Parking Spaces	% of Total Spaces
Very Low	1	4.5%	74	6.4%
Low	4	18.2%	226	19.4%
Moderate	3	13.6%	321	27.6%
High	3	13.6%	167	14.4%
Very High	11	50.0%	375	32.2%
Total	**22**	**100.0%**	**1,163**	**100.0%**

Source: FEMA, 2022; Federal Railway Administration, 2021; Analysis by Cambridge Systematics.

FIGURE 2.14 VULNERABLE TRUCK PARKING ASSETS



Source: FEMA, 2022; FHWA Jason's Law Truck Parking Survey, 2019; Various third party and travel plaza company websites; Cambridge Systematics, Inc. analysis.

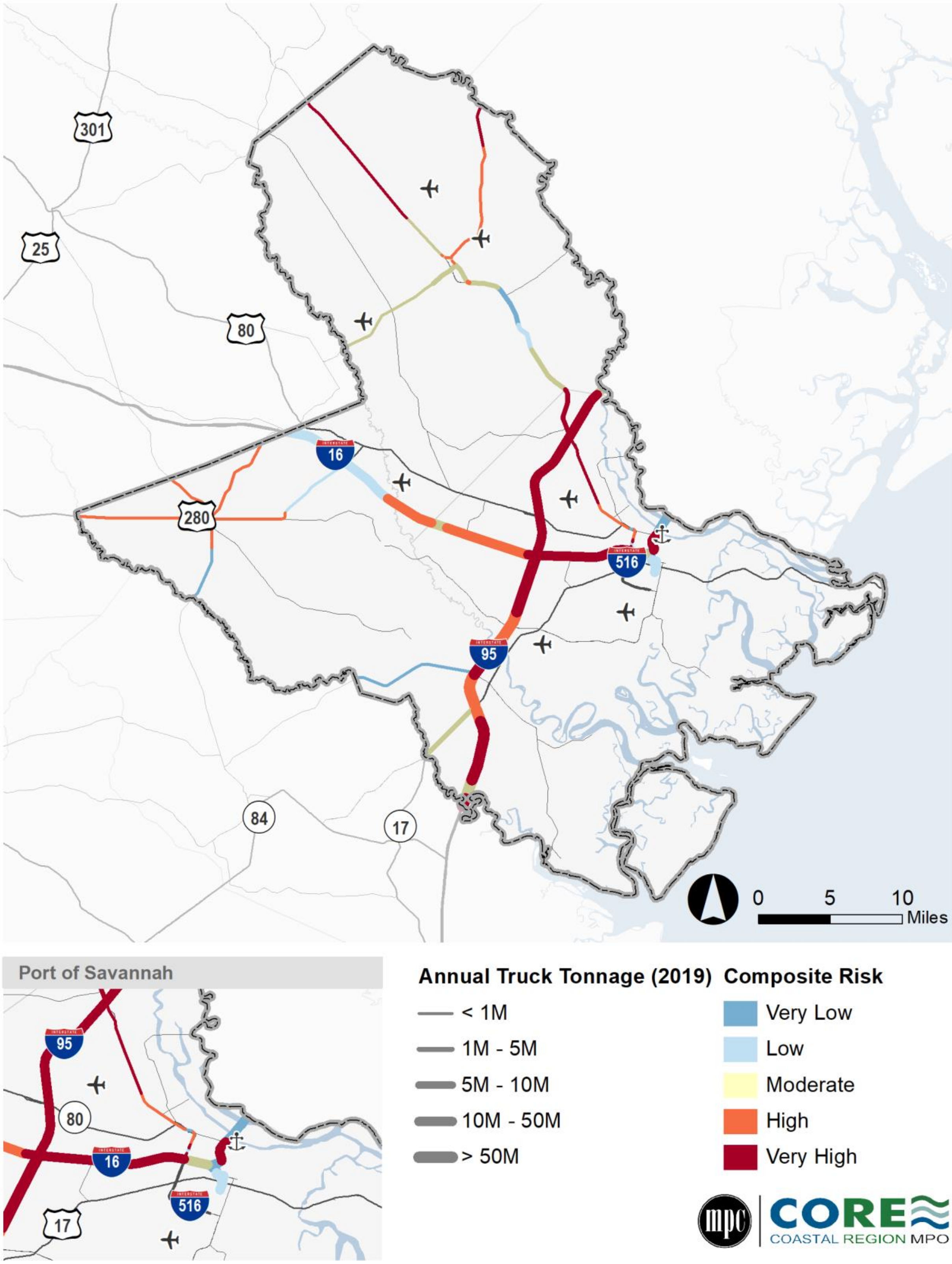
Hazard Assessment for Supply Chain Disruptions

As freight assets are put at risk, so too are the supply chains of which those assets are a part. As vital roads, railroads, airport assets, and port assets are disrupted due to flooding, hurricanes, or other events, those crucial supply chain links are hindered or even broken. As a result, freight movements are forced to find alternative and often unsuitable routes. In order to understand how supply chains are impacted by resiliency challenges in the CORE MPO region, routed tonnages of goods traveling by truck and rail from TRANSEARCH were overlayed with the composite risk assessment results for the region. The results are shown in Figure 2.15 and Figure 2.16.

The map of routed highway tonnages in Figure 2.15 shows that the region's two major interstates, I-95 and I-16, pass through areas of "very high" risk. Other major routes in terms of total tonnage, such as SR 21 and U.S. 17, also traverse high risk areas. As these routes are the primary truck routes for freight flows in the region, a blockage on any of them, would severely impact the supply chains that depend on these routes.

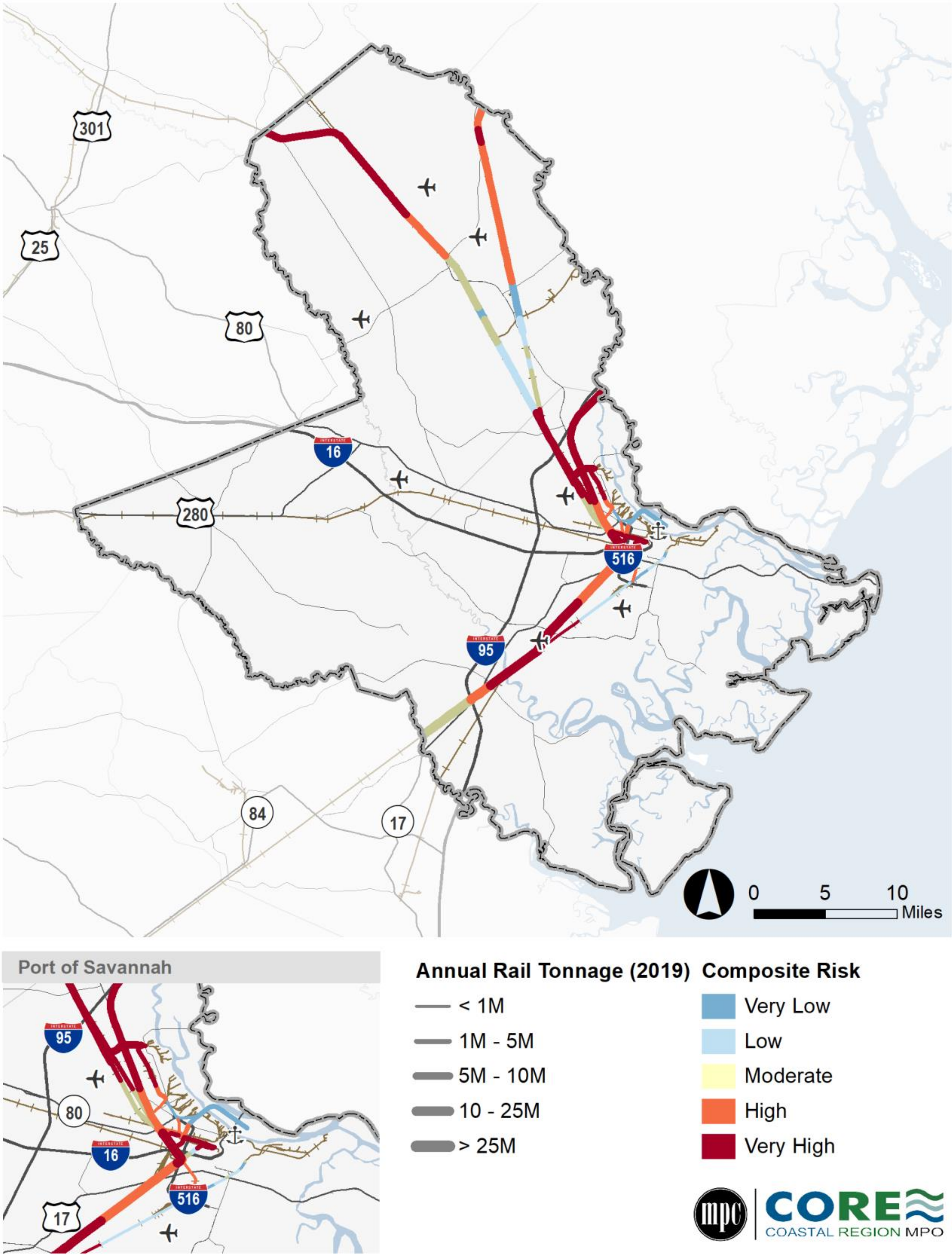
Figure 2.16 shows the routed rail tonnage overlaid on the composite risk categories. It shows that there are no viable freight rail routes serving the Port of Savannah that do not pass through a zone of "very high" composite risk. If a disruption occurs on one or both of these routes, then it would be very difficult or even impossible for rail traffic to enter or leave the Port of Savannah. In 2019 and 2050, this would mean at least 25 percent of the region's total freight tonnage and at least 30 percent of the region's total freight value would not be able to move along the supply chain.

FIGURE 2.15 TRUCK FREIGHT TONNAGE AND COMPOSITE RISK



Source: FEMA, 2022; TRANSEARCH; Cambridge Systematics, Inc. analysis.

FIGURE 2.16 RAIL FREIGHT TONNAGE AND COMPOSITE RISK



Source: FEMA, 2022; TRANSEARCH; Cambridge Systematics, Inc. analysis.

To provide an indication of the magnitude of the importance of these highway routes in supporting various supply chains, Table 2.16 shows their percentages of the region's total tonnage and value. In 2019, I-95 carried about 58 percent of the region's total truck tonnage and 53 percent of its value. I-16 carried approximately 22 percent of truck tonnage and 21 percent of value in 2019. About 16 percent of the region's truck tonnage and 20 percent of its value was carried on US 17. These results demonstrate how valuable these routes are to the supply chains that depend on them. If any of these major truck routes were to be blocked, then trucks would have to either find an alternative path or delay their trips. Either option would cause delays that would ripple through the entire supply chain.

TABLE 2.16 TRUCK TONNAGES & VALUE ON MAJOR TRUCK ROUTES

Major Truck Route	% of Total 2019 Truck Tonnage	# of Total 2019 Truck Value
Interstate 95	58%	53%
Interstate 16	22%	21%
US 17	16%	20%
State Route 21	1%	1%

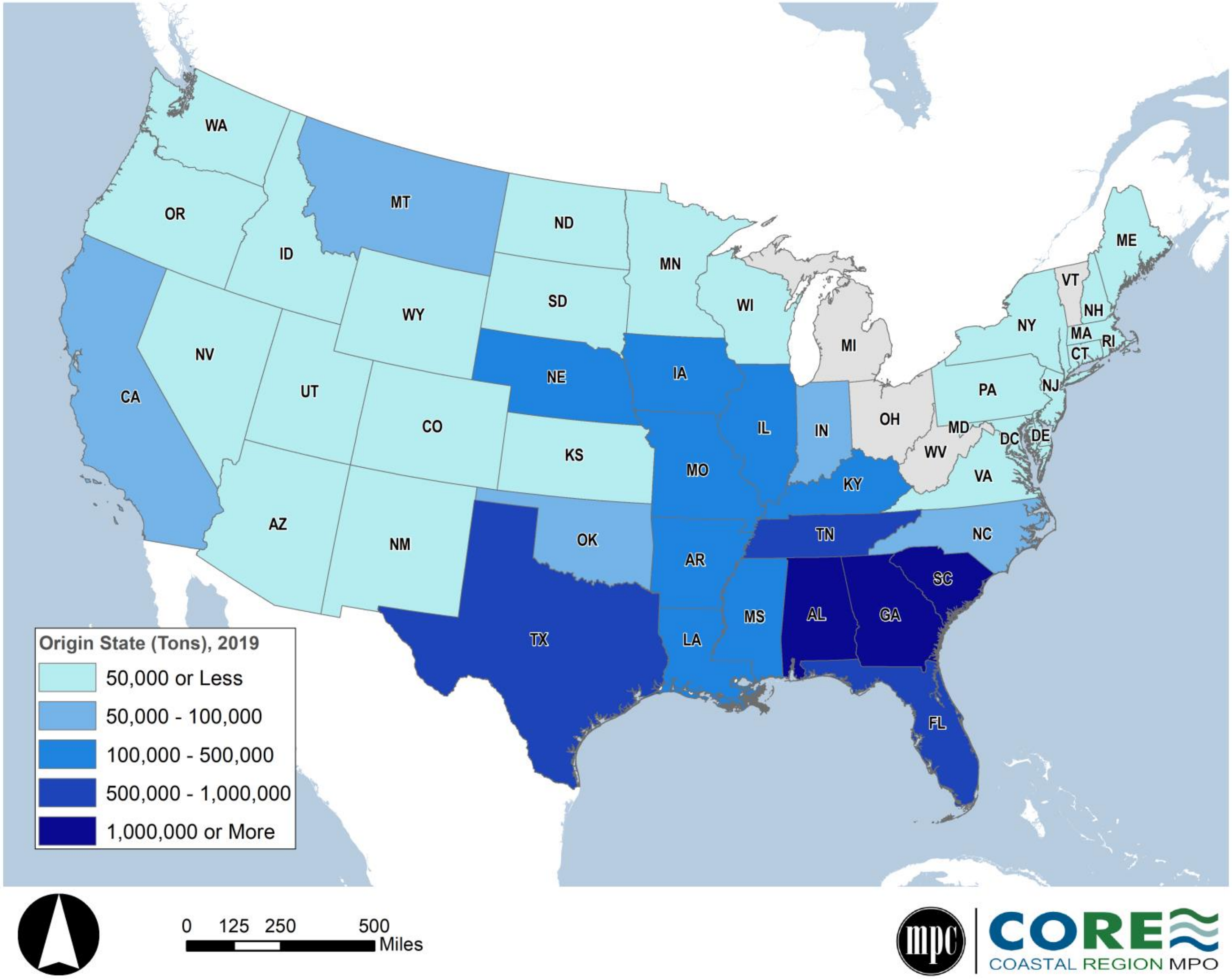
Source: TRANSEARCH; Cambridge Systematics, Inc. analysis.

The magnitude of the importance of these highway routes to various supply chains is also illustrated by examining the freight trips served by a single segment – I-16 between Old River Road and Jimmy Deloach Parkway. As shown in Figure 2.17, in 2019 45 states including the District of Columbia were estimated to originate truck trips that traverse that segment. Those trips were destined for 46 different states including the District of Columbia as shown in Figure 2.18.

In addition to facilitating substantial volumes of highway freight between states, I-16 between Old River Road and Jimmy Deloach Parkway also carried a broad range of commodities. For example, in 2019 six different states (such as Texas, Missouri, and California) originated truck trips on I-16 between Old River Road and Jimmy Deloach Parkway that carried over 300 different types of commodities as indicated by 4-digit Standard Transportation Commodity Codes (STCC) as shown in Figure 2.19.[27] As shown in Figure 2.20, nine different states were the destinations of truck trips on I-16 between Old River Road and Jimmy Deloach Parkway that carried over 300 different types of commodities. The magnitude of the unique commodity types using this single link in the CORE MPO region's freight network indicates how disruptions on the network can impact national and global supply chains.

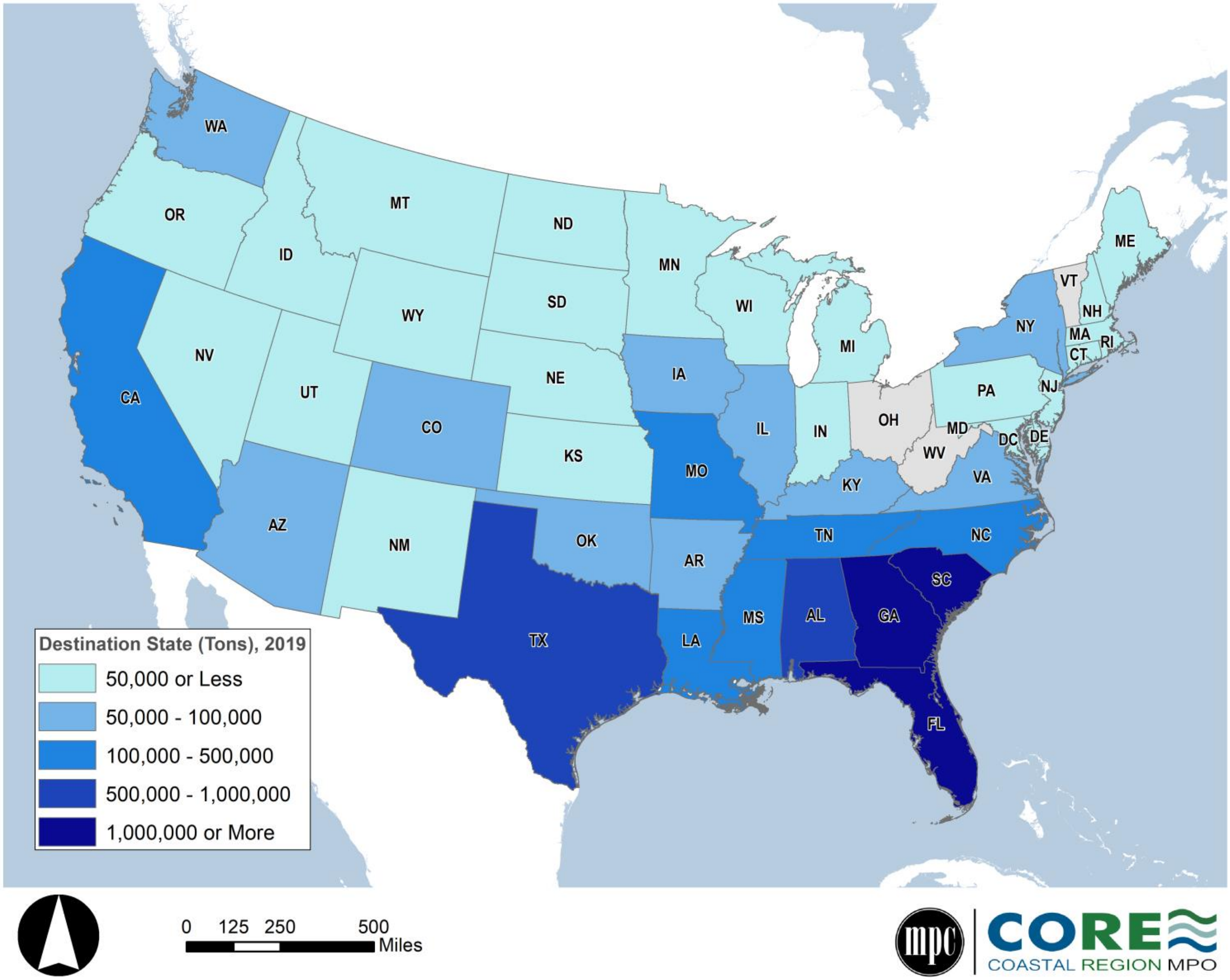
[27] https://public.railinc.com/resources/standard-transportation-commodity-code

FIGURE 2.17 STATE OF ORIGIN FOR FREIGHT FLOWS ON I-16, 2019



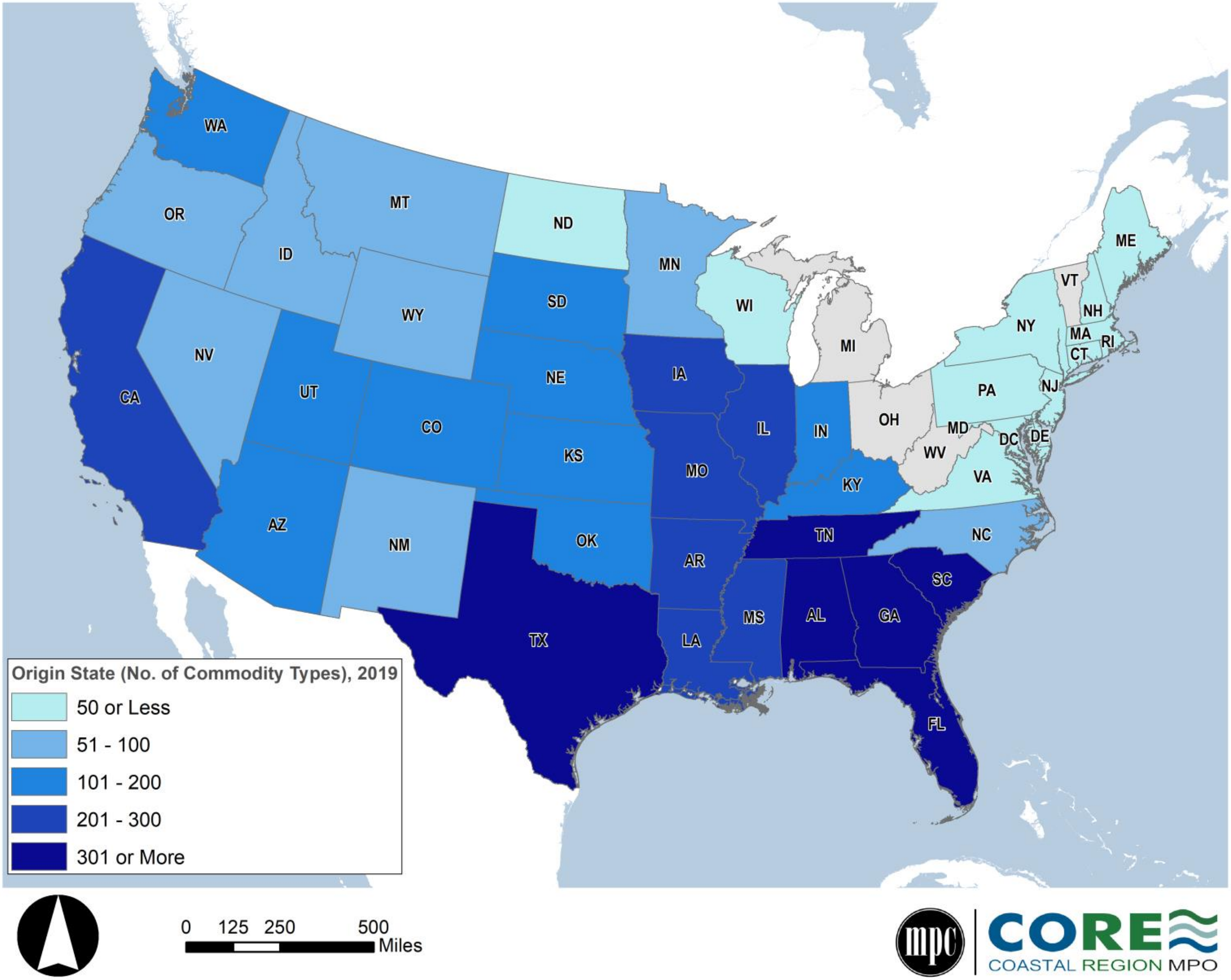
Source: TRANSEARCH; Cambridge Systematics, Inc. analysis.

FIGURE 2.18 STATE OF DESTINATION FOR FREIGHT FLOW TONNAGES ON I-16, 2019



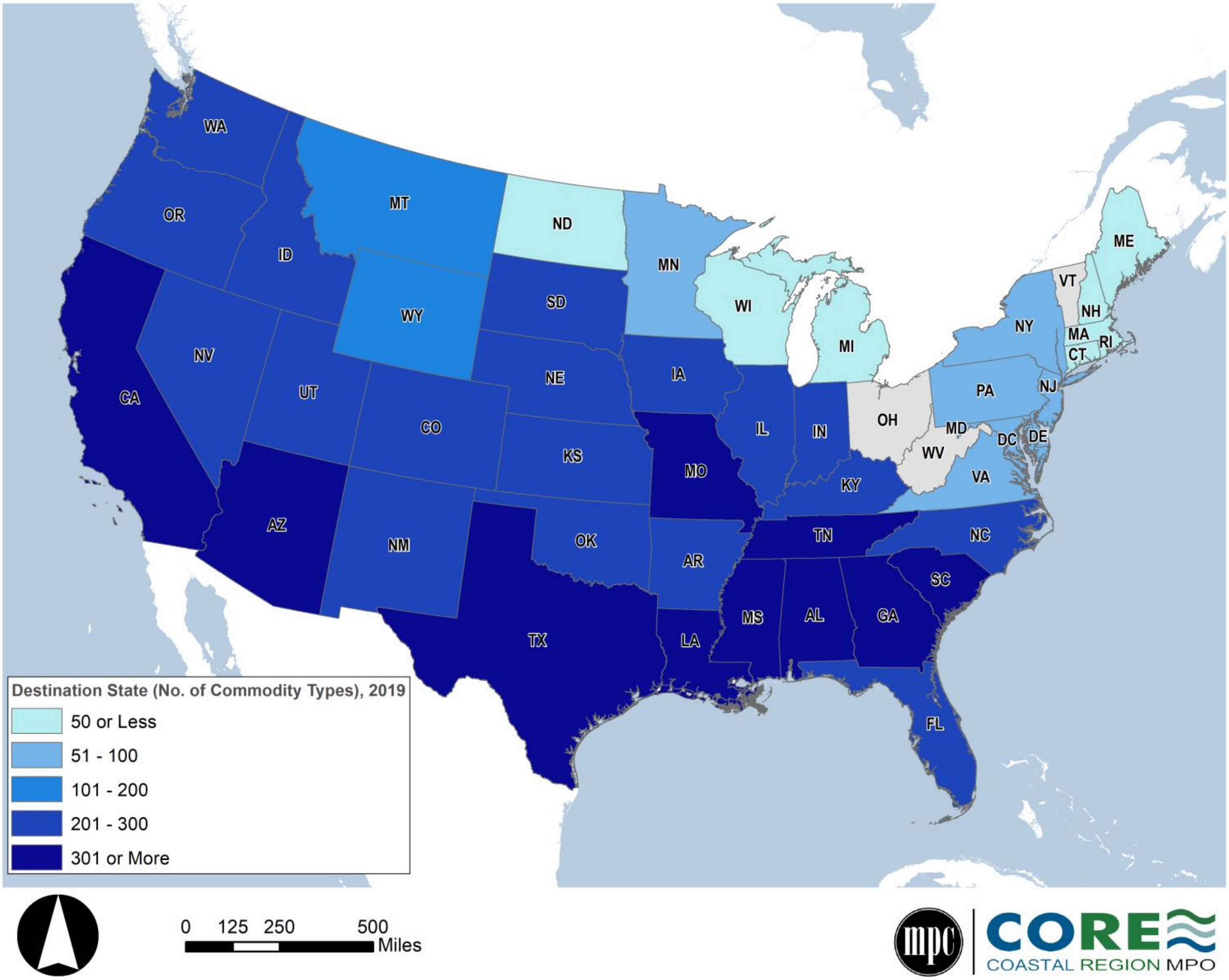
Source: TRANSEARCH; Cambridge Systematics, Inc. analysis.

FIGURE 2.19 STATE OF ORIGIN FOR UNIQUE COMMODITY TYPES ON I-16, 2019



Source: TRANSEARCH; Cambridge Systematics, Inc. analysis.

FIGURE 2.20 STATE OF DESTINATION FOR UNIQUE COMMODITY TYPES ON I-16, 2019



Source: TRANSEARCH; Analysis by Cambridge Systematics.

3 RISK ADAPTION STRATEGIES

This section of the report presents potential strategies for addressing the region's freight resiliency needs. The strategies consist of actions the region may take to "harden" freight assets so that the potential for disruption is limited, and to quickly recover in the event that disruptions do occur. These strategies are not final recommendations, but instead represent starting points for addressing freight resiliency challenges. Recommended strategies will be identified as part of Task 7.

3.1 Sea Level Rise/Coastal Flooding

Potential strategies for improving freight resiliency against sea level rise/coastal flooding include the following:

- **Relocate and Reroute Freight Assets to Avoid Flooding Risks.** The avoiding risk strategy moves critical freight assets out of harm's way where possible. In some cases, roadways may be relocated and alignments can be changed to avoid flooding risks.
- **Harden Freight Assets to Inundation, Flooding, and Scour.** Hardening freight assets entails modifying aspects of their design so that they are less susceptible to disruption. This potential strategy is further divided into slow onset and rapid onset actions. Slow onset actions are those that take a greater amount of time to implement and focus on the long-term impacts of sea level rise/coastal flooding. Rapid onset actions are those that focus on mitigating more near-term disruptions.
    - **Slow Onset of Sea Level Rise/Coastal Flooding Actions.** This includes actions such as redesigning roadway embankments and scour protection for bridges and elevating roadways, bridges, rail lines, runways, and other critical transportation facilities so they are less prone to flooding.
    - **Rapid Onset Disruptions from Sea Level Rise/Coastal Flooding Actions.** This includes actions such as strengthening roadway slopes and shoulders; implementing bridge scour monitoring techniques; and maintaining culverts to remove debris.
- **Increase Network Redundancy around Areas at Risk to Sea Level Rise/Coastal Flooding.** This strategy focuses on studying and identifying opportunities for redundant roadway and rail access to major freight terminals. It also includes opportunities for parallel routes along major freight corridors.
- **Develop Protective Barriers.** A number of safeguards can be implemented to limit the exposure of freight assets to sea level rise/coastal flooding. These include constructing flood mitigation infrastructure (e.g., levees, sea walls, flood gates, pumping facilities, etc.); implementing vegetation management, living shoreline protection (e.g., natural barriers, etc.), and green infrastructure; constructing sand dunes; and implementing backflow prevention techniques.
- **Information Sharing to Manage Coastal Flooding Events.** This strategy focuses on information sharing as means of limiting the impacts of disruptive events such as heavy precipitation or hurricanes. These include using intelligent transportation systems (ITS) for detour management, creating an information sharing back-up system in the event of storm/power outages, and upgrading/maintaining event response systems for maintenance crews to be ready to respond to debris clearance. The Smart Sea Level Sensors Project (https://www.sealevelsensors.org/) being led by the Chatham County Emergency Management Agency (CEMA), the City of Savannah, and the Georgia Institute of Technology provides an example of how real-time data on coastal flooding can be incorporated into this strategy. The project includes a network of water-level sensors across flood vulnerable areas of Chatham County. The real-time data on coastal flooding can be used for emergency planning and response during a flooding event.

3.2 Hurricanes

Potential strategies for improving freight resiliency against hurricanes include the following:

- **Wind Resistant Roadside Assets.** Take steps to ensure that signage, controller cabinets, signals and other roadside assets are wind resistant. This will limit hurricane damage to those assets as well as their potential to cause danger to people or damage other infrastructure.
- **Prune Vegetation.** Prune branches and other vegetation near major freight corridors that are susceptible to wind. This strategy would also include removing dead or dying trees that could topple over in a hurricane. Pruning vegetation would limit the potential for freight corridors to be blocked by debris resulting from hurricane winds.
- **Debris Management.** This strategy focuses on upgrading and/or maintaining event response systems to be ready to respond to debris clearance. It may also include maintenance activities such as removing debris from roadways and culverts and other drainage assets.
- **Coordinate with the Georgia Ports Authority.** Coordinate with the Georgia Ports Authority to implement adaptation measures such as strengthening mooring and berthing fixtures at port facilities; and installing fender or dolphin systems to protect vulnerable piers from vessel impacts and debris.
- **Strengthen and Expand Natural Barriers to Protect Against Hurricanes.** This strategy takes a watershed instead of a project-by-project approach for improving freight resiliency against hurricanes. In the event of heavy rainfall or storm surge, green infrastructure such as wetlands and parks can be flooded to delay or offset impacts to people and freight assets. Vegetation management and living shoreline solutions also fall under this strategy. Living shorelines use plants or other natural elements (sometimes in combination with harder shoreline structures) to stabilize estuarine coasts, bays, and tributaries.[28]
- **Information Sharing to Manage Hurricane Events.** This strategy is consistent with the information sharing strategy outlined for sea level rise/coastal flooding events. It focuses on information sharing as means of limiting the impacts of hurricanes and includes detour management, information sharing back-up systems in the event of storm/power outages, upgrading/maintaining event response systems for maintenance crews to be ready to respond to debris clearance, and coordination with state and local emergency management agencies. It also includes information sharing to more effectively stage materials and equipment needed for recovery such as signal heads, backhoes, and generators among others.

In addition to these, all of the potential strategies identified for sea level rise/coastal flooding are applicable to hurricane events. This is because hurricanes are often accompanied by storm surge that results in coastal flooding events.

3.3 Riverine Flooding

Potential strategies for improving freight resiliency against riverine flooding include the following:

- **Upgrade and Maintain Drainage Systems.** This strategy focuses on upgrading and maintaining drainage systems to handle riverine flooding events. It includes actions such as re-designing drainage systems; increasing culverts' carrying capacity by replacing with larger culverts or with bridges; adding new culverts where none exist; adding inlets/intakes; and installing pumps.

[28] https://www.fisheries.noaa.gov/insight/understanding-living-shorelines#what-is-a-living-shoreline?

- **Strengthen and Expand Natural Barriers to Protect Against Riverine Flooding.** This strategy is consistent with the natural barriers strategy outlined for hurricanes. It takes a watershed approach for improving freight resiliency against riverine flooding through green infrastructures such as wetlands and parks. Those areas can be flooded to delay or offset impacts to people and freight assets.
- **Stormwater Runoff.** Reduce storm water run-off by reducing the amount of impervious surfaces near freight corridors and by incorporating green infrastructure into roadway designs. Green infrastructure such as bioswales, planter boxes, and street trees can serve as another layer of flooding control for freight corridors. It can also help to preserve existing, aging gray infrastructure (e.g., curbs, gutters, pipes) as green infrastructure would divert some stormwater before it enters those systems.

In addition to these, the adaption strategies identified for sea level/coastal flooding events are applicable to riverine flooding events. Particularly, slow onset and rapid onset actions related to hardening freight assets to inundation, flooding, and scour are applicable.

3.4 Supply Chain Disruptions

All of the natural hazards investigated as part of this report have the potential to disrupt supply chains by reducing or eliminating the ability of freight assets to move goods. Thus, all of the potential strategies discussed in sections 3.1 to 3.3 can be considered as components of a broader strategy to limit supply chain disruptions. Additional potential components of a broader supply chain resiliency strategy include the following:

- **Harden Freight Assets Against Other Extreme Weather Events.** Though sea level rise/coastal flooding, riverine flooding, and hurricanes occur more frequently in the region than other hazards, other extreme weather events still pose a risk to freight assets and supply chains. The CORE MPO, along with its state and local partners, may need to consider adjusting pavement standards to minimize disruptions to the roadway network from an increase in the number of droughts, extreme heat events, and extreme cold events. Tornadoes can occur anywhere within Georgia and disrupt key nodes in supply chains including airports, seaports, roadways, and rail lines. Similar to strategies to mitigate risks from hurricanes, the region should take steps to ensure that signage, controller cabinets, signals and other roadside assets are wind resistant and can withstand power disruptions.

- **Develop an Action Plan for Handling Disruptions to Freight Assets Outside the Region.** Disruptions to freight assets outside the region that are critical to goods movement at the national level can impact supply chains within the region. For example, a significant earthquake event on the U.S. West Coast would divert maritime traffic to Savannah and other East Coast ports. This strategy focuses on developing a plan of action for how the region would handle these types of supply chain disruptions. The pop-up container yards established by the Georgia Ports Authority to alleviate supply chain strains throughout 2021 is an example of the types of actions that could be proactively identified as part of a strategic plan for handling disruptions.[29]

- **Develop an Action Plan for Handling Cyberattacks.** Cyberattacks and infrastructure incidents require the ability to quickly repair a wide variety of infrastructure and sometimes reroute traffic safely around incidents. The types of infrastructure that may need repair include both physical infrastructure and electronic and network systems. CORE MPO and partners should have staff and materials on hand to respond to these incidents. In addition, CORE MPO and partner agencies should take preventive

[29] Van Cleave, K. “Georgia port uses pop-up concept to alleviate supply chain strain,” CBS Evening News, https://www.cbsnews.com/news/supply-chain-issues-georgia-port-pop-up-concept/, Accessed November 5, 2022.

measures to increase security to minimize the number of cyberattacks and the impact from cyberattacks. This includes enhancing security to critical computer systems, developing routine backup plans of computer systems and data, and coordinating with GDOT, the Georgia Emergency Management Agency local emergency management agencies, and others to develop/initiate an immediate regional response plan.

4 SUMMARY

This technical memorandum assessed the resilience of the CORE MPO region's multimodal freight network. It identified the risks, or hazards, which could disrupt the flow of goods across the region's freight network. For a select group of risks, it then performed a hazard assessment that focused on identifying those parts of the CORE MPO region which are most susceptible to the selected hazards. From there, the hazard assessment identified vulnerable freight transportation assets. Vulnerable freight assets include bridges, roadways, railroads, and other components of the multimodal freight network that are within areas that are at risk for disruption. Lastly, the report identified potential risk adaption strategies for mitigating those risks.

There are a few key insights that can be taken away from the technical memorandum:

- **Sea Level Rise/ Coastal Flooding Risk.** The areas of the region that are most at-risk due to sea level rise/coastal flooding are those closest to the Atlantic Ocean in the eastern part of the region. Much of the region to the east of I-95 is at either very high or high risk to sea level rise. The exception for the city center of Savannah where the higher elevations translate to a moderate or low risk.

- **Riverine Flooding Risk.** The areas in the easternmost part of the region near Tybee Island (where there are many small streams through the marshes), areas south of the Ogeechee River, and areas east of I-95 are most at-risk to riverine flooding. Other high-risk areas include Pooler, Port Wentworth, Bloomingdale, and Eden.

- **Hurricane Risk.** Most of the region is at-risk to hurricane damage. The highest risk locations are in north Effingham County, along the I-95 corridor, and the south and eastern parts of the region near the Atlantic Ocean. Much of the remaining part of the study area is at high risk except for a few areas west of I-95 and south of US 280.

- **Major Freight Terminals.** Several of the region's major freight terminals are at-risk from multiple hazards. The Port of Savannah is the most significant freight asset in the region and the State. Its composite risk ranges from "low" to "very high" given the significant amount of land occupied by the port. The Savannah-Hilton Head International Airport is surrounded by numerous small creeks and streams, causing the airport a "high" riverine flooding risk. Generally, the Savannah/Hilton Head International Airport in an area of "very high" combined risk. The three major rail yards in the region are all in risk areas of at least "moderate" combined risk. The CSX Southover Yard and Savannah Yard are within "high" risk areas, while the Norfolk Southern Savannah Yard is in a "moderate" risk area. Out of the 22 truck parking facilities in the region, half are under "very high" risk.

- **Supply Chains.** The region's freight assets support a broad range of national and global supply chains. As a result, disruptions to major freight terminals and corridors would have impacts that ripple far outside the Savannah region. In 2019, I-95 carried about 58 percent of the region's total truck tonnage and 53 percent of its value. I-16 carried approximately 22 percent of truck tonnage and 21 percent of value in 2019. Segments along these corridors carry over 300 different types of commodities that originate or terminate in over 45 states. Major disruptions on either of these routes would have a severe impact on supply chains.