Climate Resiliency on Dauphin Island, Alabama

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Abstract: The Southeast Region of the United States and Dauphin Island, Alabama have already began to feel the impacts of a changing climate, and projections suggest that these changes and impacts will continue into the future. Changes in climate could greatly affect Dauphin Island, but the town has the opportunity to proactively plan for these future impacts and make the island more climate resilient. The Mississippi-Alabama Sea Grant Legal Program (MASGLP) is working with Dauphin Island on a two-year climate resiliency study to help with the town's climate adaptation efforts. Because the daunting threats of climate change can result in inert local governments, MASGLP is trying to identify smaller actions the town and other entities could take to address climate impacts, as well as considering larger issues facing the island.

I. Introduction

Across the United States and throughout the world, climate change has become apparent with rising sea levels; increasing temperatures; more frequent, intense rain storms; and decreasing snow and ice levels, which impact the timing and amounts of river flows. These changes and their impacts are projected to continue to grow in the future; depending on the climate model, however, the projected effects of climate change vary due to the uncertainty of future global emission levels of heat-trapping gases and the climate's reaction to those emissions. As a result of this uncertainty, climate models use different emission scenarios to predict the potential impacts of climatic changes.

Although climate change is occurring throughout the world and the United States, regions will experience a changing climate differently. For example, the Eastern United States is experiencing

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increased forest growth, while forest growth is decreasing in the western part of the country. Likewise, the Southeast and Gulf Coast region have and will experience different climate impacts than other regions in the United States. Some current and projected climate changes for the Gulf Coast include:

- Rising sea levels;
- Ocean acidification that threatens coral and shellfish growth;
- More severe weather events;
- Heavy downpours;
- More frequent droughts;
- More intense and frequent heat waves; and
- Increasing demands on water supply.[2]

In particular, the Gulf Coast is particularly vulnerable to sea level rise and coastal storms because of its long, low-lying coastline. Rising sea levels are threatening coastal communities, barrier islands, coastal marshes, and wetlands, and will cause Gulf Coast shorelines to retreat.[3] Because the Gulf Coast is sinking due to land subsidence, the region's relative sea level rise has been significantly higher than the global average rate over the last 50 years, and this trend is expected to continue into the future. The region is also experiencing land loss. For example, the Mississippi-Alabama Barrier-Island Chain has experienced accelerated rates of land loss since the mid-1800s.[4]

In particular, because of its location and geography, Dauphin Island, Alabama has already felt some climate change impacts. Dauphin Island (the island) is a low-lying barrier island with an average elevation of only 7.2 feet, located five miles south of Mobile, Alabama. It is a narrow island, only a mile across at its widest point, and is approximately fifteen miles long. According to the 2010 Census, the Town has 1,238 residents, most of whom live on the more stable eastern seven miles of the island.[5]

Dauphin Island has been in a net erosional phase since the late 1950s, and in 2007, the island was 16% smaller than it was in 1958.[6] Like the rest of the Gulf Coast region, Dauphin Island is particularly vulnerable to sea level rise. Sea level rise will make barrier islands more susceptible to coastal storms and related storm surges, including weaker, seasonal storms. These factors could have a strong impact on barrier islands by increasing erosion, permanently inundating some areas, and leading to higher salinity levels in estuaries and freshwater aquifers. These climate stressors will likely impact the island's natural resources, as well as access to and transportation on Dauphin Island. These stressors could also have a potential economic impact on the island. Storms could destroy homes, which would reduce the

[2] *See Southeast*, GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES: 2009 REPORT, U.S. CLIMATE CHANGE RESEARCH PROGRAM, http://nca2009.globalchange.gov/southeast (last visited Mar. 24, 2014).
[3] U.S. GLOBAL CHANGE RESEARCH PROGRAM, GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES 114 (Thomas R. Karl, Jerry M. Melillo, & Thomas C. Peterson EDS., 2009), *available at* http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf [hereinafter 2009 CLIMATE IMPACT REPORT].
[4] *See* Robert A. Morton, *Historical Changes in the Mississippi-Alabama Barrier-Island Chain and the Roles of Extreme Storms, Sea Level, and Human Activities*, 24 J. OF COASTAL RESEARCH 1587 (2008).
[5] *2010 Census Interactive Population Search*, U.S. CENSUS 2010, http://www.census.gov/2010census/popmap/ipmtext.php?fl=01 (last visited Mar. 24, 2014).
[6] *See* Morton, *supra* note 4.

town's property tax revenue. With fewer rental homes, less tourists could visit the island, which would result in lower sales, gas, and lodging tax revenue and could adversely affect the Town's businesses and restaurants. Increases in population and the amount of development in many coastal areas are amplifying these effects.

The Town of Dauphin Island (Town) was incorporated in 1988.[7] A mayor and a five-member town council govern the Town, establish policy, and provide governmental services for such things as public safety, land use, and solid waste disposal. A planning commission assists the Mayor and Town Council in preparing, maintaining, and implementing plans, regulations, and ordinances for the orderly development of the Town. The Dauphin Island Water and Sewer Authority, which operates independently from the Town, provides water and sewer services. The Dauphin Island Park and Beach Board manages the island's public parks, beaches, campgrounds, and other recreational facilities. Like the Water and Sewer Authority, the Park and Beach Board operates independently from the Town under the leadership of an executive director and board.

In 2007, Dauphin Island completed a Strategic Plan that laid-out a 20-year vision for the Town. The plan was a community-driven process developed with the input of over 1,000 Dauphin Island stakeholders over eight months.[8] The plan identified important focus areas and actions, including community development, environmental protection, economic improvement, coordinated governance, and capitalizing on the island's recreational resources and cultural assets. The stakeholders identified the desire to make the town economically viable and sustainable, while maintaining Dauphin Island's small-town feel, affordability, and valuable natural and cultural assets, as well as balancing the needs of tourists with the island's full-time residents.[9] The stakeholders shaped a shared community vision that states: "On behalf of the people of Dauphin Island, the Town will lead this small island community through the 21st century by preserving the island's history, culture, and environmental assets, while planning for a future that capitalizes on its natural resources to promote economic well-being."[10]

Since 2007, Dauphin Island has continued to feel the effects of storms and other climate events, including storm surge and flooding that damages property and natural resources. The Town also continues to engage in coastal management projects, such as constructing berms along its beaches. Because coastal management is an ongoing process, Dauphin Island has decided to build on the ideas in its Strategic Plan and work towards making the island more storm and climate resilient. In doing so, the town will ensure the island's future economic and environmental viability.

To assist with this effort, the Mississippi-Alabama Sea Grant Consortium (MASGC) has been working on a two-year climate resiliency study for Dauphin Island. In 2013, the first year of this study, the Mississippi-Alabama Sea Grant Legal Program (MASGLP), which is part of the MASGC's Outreach Program, prepared a report on the anticipated regional changes in climate variables and how these

[7] *See* TOWN OF DAUPHIN ISLAND, http://www.townofdauphinisland.org/home.asp?ID=2 (last visited Mar. 24, 2014).
[8] FIVE E'S UNLIMITED, DAUPHIN ISLAND STRATEGIC PLAN: A 20 YEAR VISION, FINAL REPORT AND FIRST FIVE YEARS OF IMPLEMENTATION RECOMMENDATIONS (2007), *available at* http://www.townofdauphinisland.org/wide.asp?action=search&ID=71&searchin=category&keyword=&keyword2=&keyword3=6&submit=Search.
[9] *Id.* at iii-iv.
[10] *Id.* at iii.

changes can impact Dauphin Island's natural and built resources.[11] MASGLP also organized, with financial assistance from the Mobile Bay National Estuary Program, a Vulnerability-Consequence Adaptation Planning Scenarios (VCAPS) workshop for the Town. Following the VCAPS workshop and release of the scoping document, MASGLP has been working with the Town and Park and Beach Board to address issues associated with sea level rise and flooding, as well as the island's ecologic and economic health.

Part II of this Article reviews the experienced and projected climate impacts the MASGLP identified in its Scoping Document for Dauphin Island. Part III discusses the VCAPS process generally and examines the experience on Dauphin Island. Part IV considers the potential impacts of these changes in climate on Dauphin Island and possible policy responses.

II. MASGLP's Scoping Document: Experienced and Projected Climate Impacts

As mentioned above, as part of its climate resiliency study, MASGLP prepared a scoping document on the anticipated regional changes in climate variables and how these changes can impact Dauphin Island's natural and built resources. A summary of this report is provided below. The Southeast region of the United States has already experienced climatic changes and impacts associated with these changes, including land loss and sea level rise, storms, temperature, and precipitation.

A. Land Loss

A 2008 U.S. Geological Survey Study looked at the historical changes to the Mississippi-Alabama Barrier-Island Chain (MS-AL Barrier Islands) and found that since the mid-1800s, the island chain has sustained accelerated rates of land loss.[12] Specifically, Dauphin Island has been eroding since 1958. From 1958-2007, the island decreased by 16%.[13]

The study found that storm cycles and sand supply were combining with rising sea levels to cause land loss on the MS-AL Barrier Islands. While sea level rise can change landmasses over longer time periods like centuries and millennia, storms have more short-term effects over briefer time periods like years and decades. For example, Hurricane Katrina had a significant effect on the more recent land loss rate of Dauphin Island. From 1958-1996, the island's land loss rate averaged -6.1 hectare/year.[14] However, due in part to how Hurricane Katrina redistributed sand on the island's West End, the land loss rate decreased to -2.2 hectare/year from 1996-2007.[15] Figure 1 below, which is taken from this study, shows how Dauphin Island has changed over time.[16]

Reduced amounts of sand supply also exacerbate land loss. Since the late 1800s, the MS-AL Barrier Islands have experienced a reduction in the volume of sand supply due to the dredging of navigation

[11] The Mississippi- Alabama Sea Grant Legal Program's Scoping Document, *Climate Impacts for the Southeastern U.S. and Dauphin Island, AL*, is available at http://masglp.olemiss.edu/Advisory/dauphin_island_scoping_document.pdf.
[12] Morton, *supra* note 4.
[13] *Id.* at 1599.
[14] *Id.* at 1593.
[15] *Id.* at 1599.
[16] *Id.* at 1589.

channels in the area. Since that time, sand has been trapped in the navigation channels and removed by dredging, making it unavailable for barrier-island nourishment.[17] However, the 2008 U.S. Geological Survey Study concluded that Dauphin Island is probably the least affected of the MS-AL Barrier Islands by sand supply reduction because of sand stored in an ebb-tidal delta.[18]

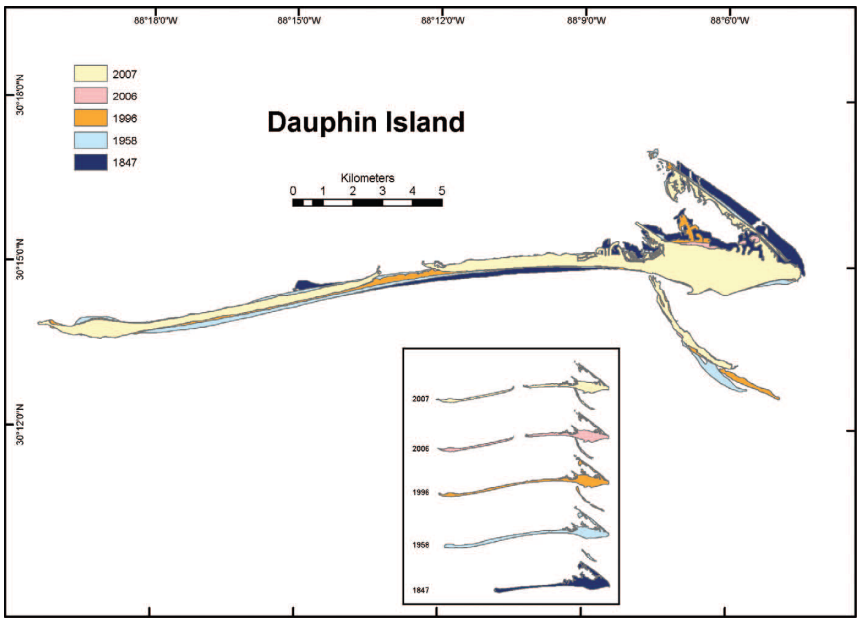

Figure 1. Morphological and spatial changes in Dauphin Island between 1847 and 2007. (Morton 2008).

Specific factors have made the West End of Dauphin Island more susceptible to land loss than the East End, which is relatively stable due in part to riprap and groins around Fort Gaines and bulkheads constructed on the island's sound-side shores. In comparison, the West End is susceptible to storm overwash and erosion on the Gulf beaches. This area of the island is also vulnerable to barrier breaching and island segmentation that exposes more of the island's shores to erosive processes.

Hurricane Katrina and subsequent tropical storms severely impacted the low-lying beaches on the West End, and the flooding conditions and wave action exacerbated by these storms accelerated and worsened the effects of erosion throughout the island. The relatively undeveloped western end of the island has been particularly susceptible to the effects of erosion, with over 350 feet of beach destroyed to date. Hurricanes Ivan and Katrina also caused the island to lose over 300 homes.[19]

In August 2011, Dauphin Island completed a three-phase study that looked at ways to address chronic beach erosion on the island and preserve the barrier island and beaches for future generations. The study found that while the shoreline on the East End of the island was receding at a rate of 9.0

[17] *Id.* at p. 1597.
[18] *Id.*
[19] Justin Gillis & Felicity Barringer, *As Coasts Rebuild and U.S. Pays, Repeatedly, the Critics Ask Why*, N.Y. TIMES, Nov. 18, 2012, http://www.nytimes.com/2012/11/19/science/earth/as-coasts-rebuild-and-us-pays-again-critics-stop-to-ask-why.html?pagewanted=all&_r=0.

feet/year, the shoreline on the West End of Dauphin Island was receding at a faster rate of 12.7 feet/year.[20]

B. Sea Level Rise

Although there were large swings in sea level throughout the last 20,000 years, sea levels reached a state of equilibrium with coastlines around 6,000 years ago, which allowed coastal landforms, including barrier islands, estuaries, and coastal wetlands, to develop. For the last 2,000 years, sea levels have remained mostly constant, and the sea level history of the northern Gulf Coast and Florida has closely followed this trend.[21] However, this trend began to change over the past 100 years, as global sea level rose around 8 inches during the 20th century. This rate is projected to increase throughout the 21st century.[22]

Warmer global temperatures cause sea level to rise in two ways. First, water molecules expand when they are warmer, causing the warmer water to take up more space.[23] Since temperatures are expected to continue to rise, water molecules are likely to continue to expand. Second, warmer temperatures cause ice sheets and glaciers to melt, which adds more water to the oceans and makes sea levels rise.[24] Currently, Arctic ice is melting at unprecedented rates, creating a vicious cycle. Ice reflects sunlight, while the darker ocean water absorbs heat. As more ice melts, more of the dark ocean is uncovered and the exposed water absorbs heat. This leads to increased heat in the air, which results in more ice loss.

The National Weather Service reported in August 2012 that the ice sheet covering the North Pole had melted to the smallest size ever recorded, shattering the previous record from 2007.[25] During the summer of 2007, the Arctic experienced almost ideal weather to melt ice with heat-trapping water vapor in the air, unusually sunny skies, and warm winds.[26] In comparison, the summer of 2012 had unremarkable weather for melting ice, providing strong evidence of the earth's long-term warming.[27]

Factors other than average global sea level rise will affect the rate of sea level rise in a particular location, including the location's proximity to melting ice sheets. An area's relative sea level rise will also depend on whether the area is rising or sinking. While some areas along the U.S. coastline are rising, a process referred to as uplift, most areas are sinking, a process referred to as subsidence. In the U.S., this subsidence has ranged from as little as a few inches to more than 2 feet per century. Because

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[20] TOWN OF DAUPHIN ISLAND, BEACH AND BARRIER ISLAND RESTORATION EFFORTS UPDATE (2011).

[21] *See generally* Joseph F. Donoghue, *Sea Level History of the Northern Gulf of Mexico Coast and Sea Level Rise Scenarios for the Near Future*, 107 CLIMATIC CHANGE 17 (2011).

[22] 2009 CLIMATE IMPACTS REPORT, *supra* note 3, at 114.

[23] NATIONAL CLIMATE ASSESSMENT AND DEVELOPMENT ADVISORY COMMITTEE, 2013 DRAFT FOR PUBLIC COMMENT 4 (2013), *available at* http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-fulldraft.pdf [hereinafter 2013 DRAFT CLIMATE ASSESSMENT].

[24] 2009 CLIMATE IMPACT REPORT, *supra* note 3, at 18.

[25] Terrell Johnson, *Arctic Sea Ice Shrinks to Record Low*, THE WEATHER CHANNEL, Sept. 12, 2012, http://www.weather.com/news/arctic-sea-ice-record-low-20120911?fb_ref=local-fb-activity&cm_ven=Email&cm_cat=article_share.

[26] Andrew C. Revkin, *Artic Melts Unnerves the Experts*, THE N.Y. TIMES, Oct. 2, 2007, http://www.nytimes.com/2007/10/02/science/earth/02arct.html.

[27] *Johnson*, supra note 25.

the Gulf Coast is sinking, the region's relative sea level rise has been significantly higher than the global average rate over the last 50 years, and this trend is expected to continue into the future.[28]

Globally, sea levels have risen an average of about 1.7 mm/year over the past 100 years, but this rate has increased in the past 15 years to around 3.1 mm/year.[29] Table 1 shows how sea levels have risen in different parts of the Gulf Coast. From 1966-1997, Dauphin Island experienced a rise in sea level of 2.98 mm/year, which is comparable to Pensacola's sea-level rise (2.1 mm/year) and greater than the rise in global sea level.

Table 1. Long-term tide-gauge data for all Northern Gulf of Mexico stations with more than 40 years of record.[30]

Station Location	Mean Sea-Level Rise (Mm/Yr)	+/-	Earliest Record
Key West, FL	2.24	0.16	1913
Naples, FL	2.02	0.60	1965
Fort Meyers, FL	2.40	0.65	1965
St. Petersburg, FL	2.36	0.29	1947
Cedar Key, FL	1.80	0.19	1914
Pensacola, FL	2.10	0.26	1923
Dauphin Island, AL	**2.98**	**0.87**	**1966**
Grand Isle, LA	9.24	0.59	1947
Sabine Pass, TX	5.66	1.07	1958
Galveston Pier, TX	6.39	0.28	1908
Freeport, TX	4.35	1.12	1954
Rockport, TX	5.16	0.67	1948
Port Mansfield, TX	1.93	0.97	1963
Port Isabel, TX	3.64	0.44	1944
Padre Island, TX	3.84	0.75	1958

Although sea levels are expected to continue to rise, models differ as to the extent of the rise.[31] While climate models often vary due to different emission scenarios, the uncertainty in how ice sheets affect sea level rise also influences sea level projections. Ice sheets, also known as continental glaciers, are glacier ice that cover terrain and are larger than 20,000 square miles. While scientists understand how melting glaciers and the thermal expansion of water will affect sea level, they do not fully understand how ice sheets will contribute to sea level rise.[32] Because of this uncertainty, the Intergovernmental Panel on Climate Change's (IPCC) earlier reports did not account for changes in sea level due to ice sheet dynamics and projected that by the end of the century the world's oceans would rise anywhere from 8 inches to 2 feet.

[28] 2009 CLIMATE IMPACT REPORT, *supra* note 3, at 37.
[29] Donoghue, *supra* note 21, at 18.
[30] *Id.*
[31] 2009 CLIMATE IMPACTS REPORT, *supra* note 3, at 25.
[32] *Id.*

More recent studies, however, have tried to quantify how melting ice sheets will contribute to rising sea levels, and these recent studies have suggested that the IPCC's earlier projections for sea level rise were too conservative.[33] These more recent studies exceed the IPCC's predictions, with average estimates of a 3- to 4-foot sea level rise this century under higher emissions scenarios.[34] Most recently, the 2013 Draft Report on Global Climate Change Impacts in the United States found that sea levels would rise an additional 1 to 4 feet during this current century, depending on the emissions scenario.[35] Although few studies have looked at what the maximum amount of sea level rise could be, there is evidence suggesting that a sea level rise greater than 6.5 feet by the end of this century would be almost impossible.[36]

With an average elevation of only 7.2 feet, Dauphin Island is highly susceptible to rising sea levels, which are expected to result in coastal inundation and retreating shorelines. Wetlands are also expected to erode, with some ecosystems and areas becoming permanently lost. As discussed above, there are various projections as to the extent of sea level rise that the island may face. However, because of the small size and relatively low elevation of the island, a slight vertical increase in sea level can force the shoreline to move significantly inland, particularly in the low-lying areas of the island already threatened by erosion and shoreline retreat. Sea level rise will therefore serve as a threat to property in these parts of the island.

Sea level rise may also affect the mainland highway that provides access to Dauphin Island, as well as other infrastructure on the island. For example, Dauphin Island's wastewater treatment plant is currently only about 2 feet from the water, making it very vulnerable to sea level rise. As shorelines erode and the island loses both dunes and vegetation on the dunes, the island will become more susceptible to storms. Higher sea levels will also increase the possibility of saltwater intrusion in the region's porous aquifers, threatening the Town's drinking water supply.

C. Storms

In the last 100 or so years, the number of hurricanes based in the Atlantic Ocean has increased. Since 1970 the Southeast has experienced an increased number of Category 4 and 5 hurricanes, and this increase is thought to have been caused by both changes in climate and natural variability.[37] Although projections differ as to how storms will be affected by climate change, many believe the region will face stronger hurricanes since hurricanes gain strength over warmer water. Some projections also suggest that while the number of tropical storms will decrease globally, there will be an increase in stronger Category 4 and 5 storms. Stronger hurricanes could further stress infrastructure, ecosystems, and threaten human safety.

Storms can erode large quantities of sand from the area's beaches. From the spring through fall, wave energy is low, allowing some sand from offshore sandbars to be added to the shoreline. During storms, wave energy increases, and these waves can remove sand from the beach and deposit the sand

[33] *Id.*
[34] *Id.* at 150.
[35] 2013 DRAFT CLIMATE ASSESSMENT, *supra* note 23, at 26.
[36] 2009 CLIMATE IMPACTS REPORT, *supra* note 3, at 25.
[37] 2013 DRAFT CLIMATE ASSESSMENT, *supra* note 23, at 586.

offshore. When wave and wind action return to normal, this sand may redeposit on the area's beaches.[38] However, strong storms have the potential to remove a significant amount of sand from the beach very quickly. Therefore, if the area is expected to face stronger storms in the future, these storms could have a large effect on the amount of sand eroded from Dauphin Island's and the region's beaches.

Less intense seasonal storms could also adversely affect Dauphin Island. Coastal storms and associated surge flooding, combined with sea level rise, may increase erosion and inundate some areas, causing low areas on the island to be permanently lost.[39] The loss of land and marshes will reduce Dauphin Island's storm resiliency. The island will also face the cumulative impact of heavier storms in the fall, when sea levels are already at their highest. Dauphin Island has already become less resilient due to repetitive storms, allowing weaker storms to have a larger impact on the island. With these weaker, seasonal storms, areas of the island are expected to become flooded, and rising sea levels, land subsidence, and erosion could magnify this flooding.

Coastal storms can also lead to increased salinity in estuaries and freshwater aquifers.[40] This shift in salinity can kill native species and allow invasive species to take over an area. In addition, the salt spray from storms can weaken or kill trees on the island, which can lead to erosion. Further, the loss of trees will mean that the island will lose the protection of the trees against storm winds. Previous storms have also caused the loss of vegetated dunes on the island, which makes the island more susceptible to future storms.

Other potential storm impacts include the loss of shoreline, the rollover of sand into the Mississippi Sound, and a loss of elevation. Storms can also inundate docks, and the overtopping of bulkheads during storms could lead to additional erosion. Further, the island could be susceptible to further breaches as water rolls over or actually cuts through the island. While storms can erode sand from the area's beaches, storms surge and winds can also push sand onto property and the island's roads. For example, Hurricane Isaac caused the roads on the West End of Dauphin Island to be blocked by sand, which limited access to that part of the island.

Because Town employees will evacuate the island along with the Town's other residents before a dangerous storm, there are also limited resources on the island during and after a storm. Storms could also lead to a loss of infrastructure on the island, including the loss of sewers and roads, which would make these services unavailable to residents for periods of time.

D. Temperature

Globally, temperatures have increased during the last fifty years. In the Southeast, the average annual temperature has increased around 2° F since 1970, with the region experiencing the largest increase in the summer. In addition, most of the Southeast has experienced a decline of four to seven freezing days a year since the mid-1970s. There have also been more days above 95° F and nights above 75° F.[41]

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[38] *See Causes of Erosion,* TEXAS GENERAL LAND OFFICE, http://www.glo.texas.gov/what-we-do/caring-for-the-coast/coastal-erosion/causes-of-erosion.html (last visited Mar. 24, 2014).
[39] 2009 CLIMATE IMPACTS REPORT, *supra* note 3, at 114.
[40] *Id.*
[41] 2013 DRAFT CLIMATE ASSESSMENT, *supra* note 23, at 586.

Globally, temperatures are expected to rise, though the extent of the increase varies among the various climate scenarios. In the Southeast, rates for projected temperature increases are more than twice the rate that has already occurred in the Southeast since 1975.[42] Overall, on average, temperatures in the region are expected to increase between 2° F and 6° F. The Southeast is expected to experience the greatest temperature increases during the summer.[43] The region will continue to experience an increase in the number of days over 95° F and a decrease in the number of freezing events. Further, the Southeast is projected to experience the country's highest increase in heat index, which is a measure of comfort that combines relative humidity and temperature.[44]

Higher temperatures are expected to adversely affect the natural environment in various ways. Specifically, higher temperatures will lead to increased rates of evaporation and plant water loss that will in turn alter the amount of water available for groundwater recharge into aquifers.[45] In coastal areas, this may also lead to saltwater intrusion in shallow aquifers because there will be less freshwater available to flow into and recharge the aquifers. Temperature increases will also stress agricultural crops and may lead to degraded water quality in coastal waterbodies. Warmer waters are susceptible to algal blooms and the growth of bacteria that affect shellfish, both of which could be harmful to human health. Warming is also expected to influence the range of species, including allowing invasive species to enter an area. Further, higher temperatures will heighten the risk of forest fires.

Warming can also have numerous impacts on the built and human environment. Increased temperatures can have negative effects on infrastructure, such as causing pavement and railways to buckle.[46] Humans will also feel the effects of increased temperatures. As stated above, changes to groundwater recharge and saltwater intrusion could stress water resources. Warmer summers could also lead to greater energy demands and higher power bills. Heat-related deaths are also expected to increase, due to more frequent heat waves. Hotter temperatures can also lead to poor air quality, which may cause more respiratory problems. Because the Southeast is expected to experience the United States' greatest increase in heat index, the quality of life in the region could also decrease.[47]

E. Precipitation

The Southeast has also seen changes to the amount of rainfall. Since 1901, the amount of precipitation in the region has increased by 30% during the fall months.[48] During this same time period though, the extent of drought in the region increased by 9%.[49] In the spring and summer, the region has experienced more moderate to severe droughts, with an increase of 12-14% since the mid-1970s.[50] The fact that overall precipitation has increased while the number of droughts has also increased is because

[42] *Southeast*, *supra* note 2.
[43] *Id.*
[44] 2013 DRAFT CLIMATE ASSESSMENT, *supra* note 23, at 595.
[45] *Southeast*, *supra* note 2.
[46] *Id.*
[47] 2013 DRAFT CLIMATE ASSESSMENT, *supra* note 23, at 595.
[48] *Id.*
[49] *Southeast*, *supra* note 2.
[50] *Id.*

rain events have occurred in more intense storms, with longer periods of dryness between precipitation events.

The projections for precipitation patterns in the region are less certain than the region's temperature projections. During the winter and spring, Gulf Coast states are projected to have less rainfall.[51] The U.S. Environmental Protection Agency states that although precipitation is projected to decrease in Florida, climate models are unclear as to whether precipitation will increase or decrease in the rest of the Southeast region. However, models do suggest that rain will be in heavier downpours, with longer periods of dryness between storms and an increased number of droughts that are longer and more intense.[52]

The region will have to adapt to longer, more intense, and more frequent droughts. Decreased precipitation could also make areas more susceptible to fires that could damage both property and ecosystems. However, because precipitation is expected to come in heavier downpours, the region is also expected to experience increased flooding. Flooding can have many negative impacts, including interfering with roads and other transportation infrastructure and damaging property and natural resources. Strong storms that suddenly increase water flow, and the related run-off can also impede an ecosystem's ability to process pollutants by reducing the time the ecosystem has to filter pollutants and washing away pollutant-removing plants and microbes.

These stressors will likely also impact stormwater systems. Where communities use combined stormwater overflows, greater rainfall and sudden storm events can lead to sewer overflows that jeopardize water quality and human safety. These events can present risks to human health and could trigger boil water notices and beach closures in coastal areas. For example, on September 5, 2012, there was a sanitary sewer overflow into Salt Creek on Dauphin Island of around 2,360 gallons.[53] The overflow was due to heavy rainfall and a partially blocked sewer main. As a result, the Mobile County Health Department advised residents to thoroughly wash their hands and clothing if they came into contact with untreated sewage. The health department also advised residents to fully wash and cook seafood harvested in the affected areas. A similar sanitary sewer overflow of an estimated 1,800 gallons into Salt Creek occurred on May 2, 2013, once again due to heavy rainfall.[54]

III. The VCAPS Process

As part of its climate resiliency study, MASGLP in collaboration with the Mobile Bay National Estuary Program organized a Vulnerability-Consequence Adaptation Planning Scenarios (VCAPS) workshop for the Town. VCAPS is a facilitated, scenario-building process that uses an interactive, computer-based program to create a diagram with causal pathways that link climate stressors,

[51] *Id.*
[52] *Id.*
[53] Cassandra Andrews, *More than 2,000 Gallons of Sewer Spilled into Dauphin Island's Salt Creek*, PRESS-REGISTER, Sept. 7, 2012, http://blog.al.com/live/2012/09/more_than_2000_gallons_of_sewe.html.
[54] News Release, Mobile County Health Department, Sanitary Sewer Overflows Reported on Dauphin Island and in Bayou La Batre (May 3, 2013) (on file with author).

vulnerabilities, and consequences with appropriate local adaptation options.[55] North and South Carolina Sea Grant, the Social and Environmental Research Institute (SERI), and the University of South Carolina developed VCAPS as a way for local decision makers to "clarify their understandings and assumptions about [the] climate change adaptation challenges their communities will face in the future."[56]

SERI has facilitated VCAPS meetings throughout the Northeast and Southeast regions of the United States, including in:

- South Thomaston, Maine;
- Boston, Plymouth, New Bedford, and Fair Haven, Massachusetts;
- Plymouth, North Carolina;
- Sullivan's Island and McClellanville, South Carolina; and
- Orange Beach, Alabama.[57]

SERI also provides training information on its website if individuals would like to facilitate their own meeting.

At a VCAPS session, participants from the community are provided with a locally relevant climate scenario, such as increased rainfall, and then the participants go through a diagramming process to define the potential climate implications for the area. The VCAPS facilitator leads the participants through choosing a management context, selecting applicable climate stressors, and asking participants for the outcomes and consequences of these stressors and how the stressors might affect management decisions. The facilitator will also ask the group for actions that private individuals and public institutions could take to manage these consequences, as well as any factors that make the town unique, which VCAPS refers to as contextual factors.[58]

VCAPS was designed as way for communities to gather and use the specialized knowledge and experience of its community members in identifying future climate stressors, what makes the town unique in regards to these stressors, and how the town might adapt. Through this process, local leaders can potentially identify and integrate adaptation measures into their existing planning activities and resource allocations. VCAPS provides an opportunity for participants to work together on how to best manage the consequences of these climate events by collecting information and creating diagrams that can be used as sources of information in future decision-making.

In preparation for the VCAPS workshop on Dauphin Island, MASGLP attended and observed the June 2012 VCAPS meeting in Orange Beach, AL. The participants in Orange Beach chose to examine the effects of heavy rainfall and severe coastal storms on the community. After finishing the discussion of these climate stressors, the SERI facilitators asked the group to look at management actions that the town of Orange Beach and its residents could take to address some of the impacts discussed during the

[55] For more information on the VCAPS process, *see Overview and Purposes,* VULNERABILITY, CONSEQUENCES, AND ADAPTATION PLANNING SCENARIOS, https://sites.google.com/site/vcapsprojects/home (last visited Mar. 24, 2014).
[56] SOCIAL AND ENVIRONMENTAL RESEARCH INSTITUTE, DIAGRAMMING CLIMATE CHANGE-RELATED VULNERABILITY-CONSEQUENCE ADAPTATION PLANNING SCENARIOS (VCAPS)- A FACILITATION GUIDE AND TUTORIAL (2011), *available at* http://www.seri-us.org/sites/default/files/VCAPS%20UserGuide.15July11.pdf.
[57] *Cases,* VULNERABILITY, CONSEQUENCES, AND ADAPTATION PLANNING SCENARIOS, https://sites.google.com/site/vcapsprojects/cases (last visited Feb. 14, 2014).
[58] *Tutorials and Resources,* VULNERABILITY, CONSEQUENCES, AND ADAPTATION PLANNING SCENARIOS, https://sites.google.com/site/vcapsprojects/tutorials-and-resources (last visited Mar. 24, 2014).

meeting. Although time was limited, the meeting's participants were able to identify some potential management actions. For example, the participants discussed developing an information system to keep evacuated residents updated on the status of the town and their property after coastal storms, since one of the major reasons people try to re-enter neighborhoods after storms is to see the condition of their properties.[59]

For the December 2012 VCAPS meeting on Dauphin Island, MASGLP and the Town invited a wide-variety of stakeholders to attend the meeting.[60] To encourage participation, MASGLP created a short brochure to help explain the VCAPS process to the invitees. By inviting a wide array of participants, MASGLP and the Town aimed to take advantage of the individual knowledge and expertise of the island's community members. In addition, MASGLP and the Town wanted to ensure that all of the interests and resources of the island were represented in the VCAPS process so that the Town would be able to identify areas where it has knowledge gaps. The process also aimed to identify how the Town's different governing entities are currently working together and how this coordination could be improved in the future.

In addition to representatives from SERI, the Mobile Bay NEP, and Mississippi-Alabama Sea Grant, representatives from the Town, Park and Beach Board, Water and Sewer Authority, Dauphin Island Planning Commission, Dauphin Island Sea Lab, and the Dauphin Island Property Owners Association were among the attendees of the Dauphin Island VCAPS workshop. To start the meeting, MASGLP gave a short presentation on the changes in climate facing the Southeast region of the U.S. After this presentation, the workshop's participants decided to focus on severe coastal storms and the effect of storms in connection to sea level rise.

The discussion of these two climate stressors highlighted two issues currently facing the island. First, the meeting reinforced the differences between the island's more stable East End and more vulnerable West End and further elucidated the difficulty in deciding how to manage the West End in the future. In addition, the meeting emphasized the problem of identifying small actions that could help ameliorate some of the larger, long-term climate impacts facing the island.

The discussion regarding rebuilding and repairing the island's West End after storms was particularly tense. Since many of the island's permanent residents live on the East End, some of these residents feel like they are repeatedly financing the rebuilding of the West End for the benefit of rental homeowners and tourists with little benefit to themselves. As a result, some participants advocated a gradual retreat from the West End by allowing that area of the island to slowly become undeveloped property by not rebuilding homes and roads damaged by storms. It was then suggested that this part of the island could be used in the future solely as recreational property. However, the participants who

[59] *See* SOCIAL AND ENVIRONMENTAL RESEARCH INSTITUTE, RESULTS FROM A VCAPS PLANNING WORKSHOP FOR EXTREME WEATHER IN ORANGE BEACH, ALABAMA: FINAL REPORT (2012), *available at* https://docs.google.com/file/d/0By5enT3tgjj4azVJQ1F3eVIxWlk/edit.

[60] MASGLP worked with the Town to create an invite list with representatives from the: Dauphin Island Park and Beach Board; Dauphin Island Water and Sewer Authority; Dauphin Island Foundation; Dauphin Island Chamber of Commerce; Dauphin Island Property Owners Association; Dauphin Island Sea Lab; Dauphin Island Elementary School; Federal Food and Drug Administration; Dauphin Island Department of Conservation; Town of Dauphin Island Planning Commission; Town of Dauphin Island Police Department; Town of Dauphin Island Volunteer Fire and Rescue; and Audubon Bird Sanctuary.

support sustaining the West End indefinitely resisted these suggestions and emphasized the economic activity generated by the West End and how this activity boosts the economy of the entire island.

Further, while most of the participants agreed that the island was vulnerable to climate stressors and impacts, the SERI facilitators struggled to get the VCAPS participants to generate management solutions for these stressors and impacts. Most of the meeting's discussion focused on problems, while the discussion of solutions often stalled. During the VCAPS session, participants from Dauphin Island struggled to identify small actions that the town could take to help mitigate some of the consequences of climate stressors affecting the island. Instead, participants often focused on barriers to potential solutions, such as lack of funding or support for an action.

However, Dauphin Island is not unique in this regard. It is much easier for a community to identify its vulnerabilities to changes in climate than to make decisions on the best way to move forward. In addition, as discussed above, VCAPS did help identify some of the climate impacts facing the island, some of which are discussed in Part IV below.

IV. Potential Impacts and Solutions

The climate change impacts facing Dauphin Island could affect the island in multiple ways. These potential effects include negative impacts on the island's natural resources, ecosystems, and economy, as well as transportation and access to, from, and around the island. Each of these potential effects is discussed in turn below, as well as some potential policy responses.

A. Natural Resources and Ecosystems

Climate change impacts will negatively affect the natural resources of Dauphin Island. As discussed above, higher temperatures can lead to the introduction of nonnative invasive species, as well as increase the risk of wildfires. Increases in temperature will also alter groundwater recharge, which can lead to saltwater intrusion in shallow aquifers. Rising sea levels and saltwater storm surge can also lead to increased salinity levels in estuaries and freshwater aquifers.

Although it is a global issue, ocean acidification could impact the region and Dauphin Island. Ocean acidification is the change to the carbon chemistry of the ocean due to increased amounts of carbon dioxide in the atmosphere. Ocean waters absorb the carbon dioxide, which acidifies the water by reducing the water's pH. Globally, the pH of the world's oceans has been reduced by 0.1, which is an increase of acidity of around 30%.[61] Projections expect pH to be reduced by another 0.3 over the next 100 years if global carbon emissions are not significantly reduced. Scientists believe that this change would be at a minimum 10 times faster than any other change over the last 50 million years. Certain factors will affect the amount of ocean acidification that a region experiences, including the amount of nutrients and hypoxia in the area.[62]

[61] National Oceanic and Atmospheric Administration, State of the Science Fact Sheet: Ocean Acidification (2013), *available at* http://www.noaa.gov/factsheets/new%20version/SoS%20Fact%20Sheet_Ocean%20Acidification%20201303 06%20Final.pdf.

[62] *Id.*

Ocean acidification causes there to be less carbonate in the water, and carbonate is important to coral reef and shell formation. As a result, ocean acidification is a significant threat to both coral reefs and shellfish populations. Since coral reefs provide habitat for a multitude of species, as well as coastal protection, food, and income for people, the loss of coral reefs due to ocean acidification could have adverse impacts on an area.[63] Likewise, shellfish represents a large portion of the nation's seafood revenue, including a large amount of revenue in the Gulf. Due to ocean acidification, the region could also lose the ecosystem services of shellfish reefs.

Increased salinity levels could also threaten the marine resources of Dauphin Island, such as by threatening oyster beds that cannot tolerate large changes in salinity. A shift in salinity could also kill native species and allow invasive species to take over an area. For example, according to participants of the 2012 VCAPS workshop on Dauphin Island, the island experienced a shift in tree species after Hurricane Frederick in 1979 with the introduction of popcorn trees.

In addition, climate impacts such as salt spray from storms can also weaken or kill trees on the island, which can lead to erosion and a loss of protection from strong winds. Climate stressors like storms and fires also occur over short time frames, making it hard for local plants to adapt. Trees that are weakened will become more susceptible to disease and pests, and the loss of trees can cause erosion that can weaken the soil and destroy the island's canopy, which serves as wildlife habitat. This loss of habitat could serve as an additional threat to the island's bird watching and other tourist activities.

Climate impacts can also lead to a loss of habitat for other species on the island. The island's wildlife habitat could face a constant state of disruption as the shape of the island changes and dunes shift inland. Sea level rise will also threaten important coastal wetland ecosystems, which serve as both wildlife habitat and protection for inland areas from the effects of storms.

Potential Solution: Outreach to the Birding Community and Town Maintenance Workers

During the second year of the project, MASGLP met with the Park and Beach Board to discuss the issues facing the island's ecosystems and its bird sanctuary in particular. In terms of public outreach on these issues, there is the potential to reach out to both the island's birding community and the Town's maintenance workers. The birding community likely has a strong interest in enhancing Dauphin Island's wildlife habitat; therefore, they may be interested in workshops on invasive species, rain barrels, or other related topics. Similarly, the Town's maintenance workers could benefit from a workshop on the invasive species that pose a threat to the island's ecosystems, like popcorn trees. Further, a workshop could provide information on native species that would flourish on the island.

In addition, at the VCAPS meeting, there was some discussion on how rainwater could be captured and re-used on the island, since predictions show that the island may face more intense rainstorms with longer periods of drought between storms. In this way, the use of rain barrels on the island could be helpful to the sustainability of the island's ecosystems.

[63] *Id.*

B. Transportation and Access

Sea level rise and flooding will affect transportation systems and access to and around Dauphin Island. For example, storms make the causeway to the island impassable, and rocks that are used to protect the highway often end up in the road, blocking passage until the rocks can be removed. The Town also faces issues with evacuation and re-entry of the island before and after a storm, including having limited access to the causeway. As a result of these access issues, more and more people have been choosing to stay on the island during storms. This could have disastrous consequences for those who stay if a storm intensifies after it is no longer feasible to leave the island. Because re-entry to the island can be delayed after storms, utility and emergency workers have difficulty getting back onto the island, which makes it difficult for the Town to get up and running after a storm.

With sea level rise and increased flooding, Dauphin Island may also face access problems with its docks, as well as the ramps and roads to those docks. When the causeway and bridge to the island are inaccessible due to flooding, the ferry to Dauphin Island has been used as backup access to the island. However, if sea level rise and increased flooding inundate the ferry docks, this mode of transportation may be impaired in the future as well.

Finally, increased temperatures could stress the roads to and on Dauphin Island. Extreme heat for long periods of time can soften asphalt, leading to damage on roadways.[64] Further, storms can cause roadways to be covered by sand, impeding the use of these roads around the island.

Potential Solutions: Rain Barrels and Ordinance Review

At the VCAPS meeting there was some concern with the vulnerability of the access ramps to the island's docks to flooding. As a result, there is the opportunity to make the island's marinas, docks, and roads more climate resilient, and the opportunity exists for public outreach on steps private property owners could take to reduce flooding. For example, as discussed above, the use of rain barrels could help alleviate some of the flooding on the island after storms.

In addition, MASGLP is considering a review of the Town's current flood ordinance, as well as research on other regulatory steps the Town could take in regards to flooding. Recognizing the ability of zoning to address climate hazards, the Georgetown Climate Center developed a model sea level rise ordinance to help local communities manage increased flooding events.[65] The model ordinance addresses sea level rise in two ways. In order to protect development, the ordinance expands the areas protected by floodplain regulations. The model law also creates two new sea level rise zones that will be subject to more rigorous regulations: a Conservation Zone, which aims to facilitate retreat, and an Accommodation Zone, which allows continued development in an area, but requires more resilient structures.[66] The model ordinance also provides language for standards to be applied in both of these

[64] 2013 DRAFT CLIMATE ASSESSMENT, *supra* note 23, at 598.

[65] *See Zoning for Sea Level Rise*, GEORGETOWN CLIMATE CENTER, http://www.georgetownclimate.org/zoning-for-sea-level-rise (last visited Mar. 24, 2014).

[66] JESSICA GRANNIS, GEORGETOWN CLIMATE CENTER & HARRISON INSTITUTE FOR PUBLIC LAW, ZONING FOR SEA LEVEL RISE: A MODEL SEA-LEVEL RISE ORDINANCE AND CASE STUDY OF IMPLEMENTATION BARRIERS IN MARYLAND, EXECUTIVE SUMMARY 2-3 (pre-publication draft 2012), *available at*

zones. The Georgetown Climate Center then compared the model language to existing Maryland and federal laws to see if there would be any barriers to implementing the model ordinance in the state.[67] MASGLP is planning on doing a similar exercise to see what type of sea level rise zoning ordinances would be allowed in Alabama and what potential language the Town could use in such an ordinance.

C. Economic Effects

Many climate change impacts could have an adverse economic effect on the island. The degradation of ecosystems that help protect the island from storms may lead to more property loss on the island when storm events occur. Storms have also led to a loss of residential and rental property on the island. For instance, due to Hurricanes Ivan and Katrina, the Town lost over 300 homes. Because storms have the potential to destroy houses, the Town will likely lose property tax revenue in the future, as the homes cannot be rebuilt if the property remains under water. In addition, due to a loss of rental properties, fewer people may visit the island, which results in lower sales tax, gas tax, and lodging tax revenue. Fewer tourists will also adversely affect the Town's businesses and restaurants.

Hurricanes and more common winter storms have led to homes becoming uninhabitable when water and sewer lines are broken or turned off. Since the electric company will turn off power if a house is under water, properties that become permanently flooded will also permanently lose power. Storms can lead to a loss of infrastructure on the island, including the loss of sewers and roads, and the Town faces the cost of repairing this infrastructure after storms. For example, this past fall, Hurricane Isaac pushed sand onto the island, blocking roads on the West End. The Town had to expend both time and resources to clear the roads and make this part of the island accessible to the Town's residents.

The Town and property owners on the island could also face increased insurance costs or the prospect of self-insuring their property due to storms. With the release of new Alabama Flood Insurance Rate Maps (FIRMs), the town may face increased requirements for building codes and elevation standards.[68] These insurance issues and building requirements may cause people to move from Dauphin Island, further reducing the island's economic activity.

Climate impacts could also affect people's decisions to live on or visit the island. By 2100 the Southeast is expected to face a large increase to its heat index,[69] and this could lead to a decreased quality of life on the island. Stressed water resources could also contribute to this decreased quality of life.

Climate impacts could also impose a constant state of disruption on the island's wildlife habitat. This disruption will affect vegetation on the island, imposing a cost on the Town, Park and Beach Board, or property owners to replant damaged vegetation. Tree loss could also reduce property values, and property owners will have to pay to remove dead trees. Dead or weakened trees can also pose a public

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http://www.georgetownclimate.org/sites/default/files/Zoning%20for%20Sea-Level%20Rise%20Executive%20Summary%20Final.pdf.

[67] *Id.* at 4.

[68] The Federal Emergency Management Agency has begun the process of updating the flood maps for coastal Alabama. According to the Alabama Department of Economic and Community Affairs, the revised FIRMs will be effective sometime in 2016. *See County Status,* AL. DEP'T OF ECONOMIC AND COMMUNITY AFFAIRS, http://www.adeca.alabama.gov/Divisions/owr/floodplain/Pages/County-Status.aspx (last visited Mar. 24, 2014).

[69] 2013 DRAFT CLIMATE ASSESSMENT, *supra* note 23, at 595.

safety problem, as they can fall on property or people. Invasive species entering the area can have a negative economic impact as well. The Town will have to expend resources to eradicate the introduction of invasive species on the island. Changes to wildlife habitat because of invasive species can also affect tourist revenue, as the island relies on revenue created from its bird-watching habitat.

Finally, climate impacts could threaten the economic health of the entire region. With erosion causing the beaches to recede along the western portion of Dauphin Island, a significant amount of Alabama's coastal marshes have been destroyed, which in turn could present a substantial threat to the state's seafood industry. Ocean acidification could also threaten the region's shellfish industry. Because most of the Gulf Coast is low-lying, its transportation infrastructure is susceptible to sea level rise. This area sees a great deal of commercial transportation with large ports, freight gateways, and United States operations of the oil and gas industry. Further, about two-thirds of the nation's oil imports travel through the region. Sea level rise could affect this transportation network that is valued in the hundreds of billions of dollars.[70] Finally, the energy facilities located on the Gulf Coast are considered to be very vulnerable to rising sea levels, and the area could face having to repair or raise damaged equipment or build new inland facilities.[71]

Potential Solutions: Beach Nourishment and Working Waterfronts

Since the island relies on its tourist economy, the Town is interested in preserving the island's beaches and rental properties. One way to do this would be through beach nourishment projects. In meetings with MASGLP, the Town expressed concern with the status of the current boundary between private and public property on the island's Gulf side. MASGLP has been working on legal research on how property lines along the island's Gulf coast can change due to gradual or sudden and natural or man-made changes to the beach.

Further, in its 2013 Comprehensive Plan, Dauphin Island established a working waterfront district on the island as a way to promote water-related industries, such as charter fishing boats. In developing this district, the Town will have to consider what uses it wishes to protect or promote. In its regulations, Alabama has defined a water dependent use as a use "that must, under normal operating conditions, be located on or in or immediately adjacent to coastal waters in order to be physically and economically practicable."[72] The state has also defined a water dependent activity as "an activity which can only be conducted on, in, over, or adjacent to water areas because the activity requires direct access to the water body or state owned submerged lands for transportation, recreation, energy production or transmission, or source of waters, and where the use of the water or state owned submerged lands is an integral part of the activity."[73]

In developing the uses in this new district, Dauphin Island will have to work through what uses and activities it wants to allow in the area. For example, a restaurant or hotel may not fit in to the state's definition of water dependent use, but the Town may want to allow for these uses in its working waterfront. Similarly, non-water dependent uses may exist in the area that the Town will allow to

[70] 2009 CLIMATE IMPACTS REPORT, *supra* note 3, at 595.
[71] *Id.*
[72] AL. ADMIN. CODE r. 335-8-1-.02.
[73] AL. ADMIN. CODE r. 220-4-.09.

continue as non-conforming uses. Moreover, the Town should work to make the working waterfront district climate resilient.

V. Conclusion

The southeast region of the United States and Dauphin Island have already experienced impacts from changes to climate, and these changes and impacts are expected to continue into the future. As discussed above, these impacts could have potentially large effects on the island. Because of this, the Town currently has the opportunity to proactively plan for these future impacts and make the island more climate resilient. As a next step, the Town can continue working to help focus its climate change adaptation efforts. As part of this process, MASGLP is trying to identify smaller actions the Town and other entities can take to address climate impacts, as well as considering larger issues facing the island.