Coastal Vulnerability Assessment: Escambia County, Florida

Contract # C1469

Florida Department of Economic Opportunity

June 24, 2016

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EXECUTIVE SUMMARY

Escambia County is one of the three communities involved in the Community Resiliency Initiative Pilot Projects administered through the Florida Department of Economic Opportunity (DEO) and funded by the National Oceanic and Atmospheric Administration (NOAA). The overall effort seeks to assess community vulnerability to projected increases in coastal flooding and develop strategies to improve resilience to the associated impacts.

This report summarizes activities conducted under Task 1 of the pilot project in Escambia County – the community Coastal Vulnerability Assessment. Knowledge, material, and the outputs of Task 1, summarized here, will be leveraged by Task 2 of the pilot study. Task 2 focuses on reviewing existing federal, state, and local programs and policy to provide strategy recommendations that focus on the County's priorities and identified risks. Such strategies are intended to be integrated into existing local planning, policy, and budgeting mechanisms.

Three types of coastal flooding were identified for analysis in the study effort. These included:

- Mean Higher High Water (MHHW), which defines the higher daily high tide elevation, representing the limit of where land is essentially "inundated" or has very little use.
- The 100-yr recurrence interval flood, which defines the Special Flood Hazard area depicted on Federal Emergency Management Agency Flood Insurance Rate Maps. Such an event has a 1% chance of occurring any given year, and a 26% chance of occurring over a 30-year timeframe.
- The 500-yr recurrence interval flood, which represents a catastrophic flood event and is often used to assist in the safe siting of critical infrastructure. Such an event has a 0.2% chance of occurring any given year, and a 6% chance of occurring over a 30-year timeframe.

The study produced flood extents across the County for existing conditions along with projected future scenarios of sea level rise (SLR) in the short term (2045) and the long-term (2085). The study assessed the full range of sea level increases for each of these time frames as projected by the U.S. Army Corps of Engineers (USACE) and National Oceanic and Atmospheric Administration (NOAA). This included a Low scenario, representing a continuation of historical sea level trends, and then three scenarios (Medium, High, and Highest) considering different potential levels of acceleration in the historical rate. Based on the best available science, it is likely that future sea levels increases will be above the Low scenario and below the Highest scenario. The community should monitor changes in the science and update periodically update guidance as needed.

These conditions were used to assess the County's existing and future coastal flooding vulnerability. The study established cartographic layers of each coastal flood type and time-horizon / SLR scenario combination. Changes in land area subject to each flood condition were assessed, and areas subject to future increases in coastal flooding were identified. Future changes in Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) wave hazard zones in response to SLR were modeled using standard Flood Insurance Study (FIS) techniques.

The cartographic layers for the future flooding were overlaid on County, City, and state of Florida GIS data to assess vulnerability of buildings, roads, bridges, educational facilities, and fire and police stations. Additional analyses provided projections of future changes in heavy precipitation that may affect stormwater management, cumulative impacts, and critical issues associated with the County's existing stormwater system.

The key results of these assessments are summarized below:

How much more land may be vulnerable to flooding in Escambia County?

- Escambia County's vulnerability to flooding is relatively low.
- Potential for significant increases is limited to the future High and Highest SLR scenarios.
- Under a Medium SLR scenario, in the short-term (2045), an additional 2, 1, and 2.5 square miles of land are vulnerable to flooding by daily tides, a 1% annual chance event, and a 0.2% annual chance event, respectively (relative to their existing area impacted for each scenario). Increases are projected to be up to 4 times greater with the Highest SLR scenario.
- In the long-term (2085), increases are greater – for a Medium SLR scenario, an additional 7, 4, and 6 square miles of land are to flooding by daily tides, a 1% annual chance event, and a 0.2% annual chance event, respectively. Increases are projected to be up to 4 to 5 times greater with the Highest SLR scenario.

Where are the flooding "hotspots" in Escambia County?

- Downtown Pensacola and areas to the southwest of Bayou Grande have some of the greatest vulnerability to changes in flooding due to increasing sea levels, primarily at the 1% and 0.2% annual chance coastal flood levels.
- Shorelines along Perdido Bay as well as the lower Perdido and Escambia rivers, and the bayside of Santa Rosa Island were also shown to have significant vulnerability to future flooding.

How will wave hazard zones change in the future?

- In the short-term, wave hazard areas will expand along the backside of Santa Rosa Island, especially in the Pensacola Beach area.
- In the longer-term, the FEMA VE Zone will expand across Pensacola Beach, as well as into downtown Pensacola.

How many more land parcels will be exposed?

- In the short-term, a medium SLR scenario increases parcel exposure by 5%, 2% and 3% over today's condition for daily tidal, a 1% annual chance event, and a 0.2% annual chance event, respectively. As many as 1,500 additional parcels could be added to the 1% annual chance floodplain under the highest scenario.
- Over the long term, a medium SLR scenario increases exposure by 17%, 7%, and 7% for daily tidal, a 1% annual chance event, and a 0.2% annual chance event, respectively. An additional 5,700 parcels could be added to the 1% annual chance floodplain under the highest scenario.

How vulnerable is the road network to flooding changes?

- For the evaluated flood types, road vulnerability is a relatively low concern for the next 30 years. Increasing flood frequency and flood depth may become a greater concern in the long-term.

- Generally, road vulnerability is projected to increase the most under the High and Highest SLR scenarios for each time frame.
- As much as 20 and 40 additional miles of roads are vulnerable to flooding during a 1% annual chance event with the Medium SLR scenario in the short and long term, respectively. Increases could be as much as 100-140 additional miles under the High and Highest scenarios.

How will SLR impact bridge functionality?

- Vehicle traffic across several key bridges is projected to be limited under the range of future flood event conditions due to flooded approaches.
- In the near term, projected changes include:
  - The US 90 bridge across the Escambia River could be impassible with daily tidal flooding under a Medium SLR scenario.
  - The US 90 (Perdido River) and US 98 (Pensacola Bay) bridges may be impassable during a 1% annual chance flood given the two highest SLR scenarios.
- In the longer term,
  - Several bridges would be vulnerable to daily tidal flooding, including US 90 (Escambia River), US 98 (Perdido Bay), State Route 399 to Santa Rosa Island.
  - The US 90 (Perdido River) and US 98 (Pensacola Bay) bridges may be impassable during a 1% annual chance flood event.
  - Interstate 10 bridges across Pensacola and Perdido Bays may be impacted under the highest scenario, others include US 90 across the Perdido and Styx rivers and SR112 across the Perdido River.

What essential community facilities will be affected by changes in flooding?

- No hospitals in the County were found to be vulnerable to any flood hazard or SLR combination examined by this study effort.
- Of 112 educational facilities, none are impacted by changes to existing or future daily tidal flooding; however, a small amount of additional facilities are exposed to higher level SLR projections in 2045 and 2085.
- Of 39 fire and police facilities, vulnerability is limited to the 1% and 0.2% annual chance flood events, changes occur mostly at the higher SLR scenarios. For example, an additional 5 facilities would be within the 1% floodplain in the short term under a high SLR scenario.

What changes in heavy precipitation are projected?

- The frequency of heavy rainfall events, characterized here by the 24-hour duration, 25-year and 100-yr recurrence intervals, are expected to remain essentially the same in the next 30 years. Small increases around 5% may occur in the long-term.

What are the key stormwater system vulnerabilities?

- The current 24-hour 100-year design value is about 14 inches, which is based on outdated rainfall recurrence statistics from the US Weather Bureau's TP40 report in 1963. That value is about 15% less than more recent values, such as provided by NOAA Atlas 14. There may be a benefit to updating the standards to incorporate NOAA Atlas 14, which also includes uncertainty estimates unlike many past rainfall recurrence atlases such as the commonly used US Weather Bureau's TP40.

- Projected precipitation increases and land use changes that increase impervious cover may exacerbate capacity issues of the existing under-designed system that has been damaged by several major hurricanes and tropical storms.
- Increase in SLR indicates lesser ability of gravity based drainage systems to effectively drain water out of upland areas through under designed, capacity-exceeded pathways (swale, ditch, canal, pond, etc.).
- Rising sea levels are anticipated to cause damage to the interior drainage system, increasing incidents of sedimentation and excessive benthic and vegetative growth that have already been observed at stormwater outfalls in Escambia County.
- Increase in storm surge downstream of a structure would mean early closure of the structures to avoid inland propagation of the surge, which will further worsen the flooding impacts.

1 OVERVIEW

Florida's low-lying topography, developed coast, and growing population result in the state having one of the greatest needs in the nation to promote and execute sea level rise adaptation planning. In response, the Florida Coastal Management Program Section 309 strategy included a five-year initiative titled "Community Resiliency: Planning for Sea Level Rise" to examine the statewide planning framework and establish best practices for integrating adaptation and coordinating efforts across Florida. Through this initiative, the Florida Department of Economic Opportunity (DEO), in partnership with the National Oceanic Atmospheric Administration (NOAA), Florida Department of Environmental Protection (DEP), the Florida Coastal Management Office (FCMO), and the Florida Division of Emergency Management (DEM), are working together to integrate coastal adaptation measures into existing local planning, policy, and budgeting mechanisms.

As part of the Community Resiliency Initiative, DEO has initiated pilot studies in three communities across the state. The pilot studies will undertake coastal hazard risk and vulnerability analysis to inform adaptation planning measures that may be integrated into existing local planning, policy and budgeting mechanisms. The effort is not seeking to create a "one-size-fits-all" approach, but rather provide unique case studies that reflect the unique exposure, characteristics and goals of the individual communities. The three participating communities including the City of Clearwater, Escambia County, and the City of St. Augustine represent a cross-section of Florida's geography and provide distinctive examples to explore risk informed adaptation planning.

This publication was funded in part, through a grant agreement from the Florida Department of Environmental Protection, Florida Coastal Management Program, by a grant provided by the Office for Coastal Management under the Coastal Zone Management Act of 1972, as amended, National Oceanic and Atmospheric Administration Award No. NA13NOS4190052. The views, statements, findings, conclusions and recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the State of Florida, NOAA or any of their sub-agencies.

2 PROJECT SCOPING

2.1 Initial Questionnaire

To initiate the project, the project team used a questionnaire to learn the County's motivation and goals, existing flood related issues, understanding of SLR, and data assets available for the study. At the project Kickoff Meeting, participants discussed the County's responses and used that information to shape the scope of the discussion during the design meeting.

The questionnaire asked the following eight questions:

1. What do you want the community to get out of the coastal resilience vulnerability and adaptation study?

   Response: Suggested language to be included into the Comprehensive Plan to assist with guiding future development and prioritization of infrastructure projects. Possibly a tool to assist with infrastructure design (i.e. proper sizing and siting for a bridge with a 50+ year lifespan that takes into account anticipated future environmental conditions such as SLR as well as predicting infrastructure failures due to environmental forces.

2. Should the study focus on a particular geography of the community, such as a downtown or area targeted for redevelopment? If so, please describe.

   Response: Generally south of I-10. The goal is to begin to set up the framework for long-term adaptive policy and assist in providing guidance to assure infrastructure funds spent in the near term provide for a product that will survive for its expected lifetime. If funding is sufficient, areas of interest are: (East to West) Pensacola Beach, Downtown Pensacola, Perdido Key, and SW Escambia County. If funding is insufficient, one of these areas may be selected for a more intensive study that could be repeated for the other areas once funding is identified.

3. Should the study focus on particular infrastructure (e.g. due to aging, proximity to hazard, etc.)? If so, please describe.

   Response: A modeling tool would be preferred over a specific study of a roadway or other infrastructure.

4. Has the community discussed planning scenarios in relation to adaptation planning?

   Response: No.

5. Are there particular timelines (e.g. the master planning time frame) that are of interest?

   Response: Focus on the 30-year comprehensive planning timeline, with limited projections at 100 years.

6. What data do you have about the community to help characterize the built environment and natural assets?
   ・ Parcel data | ・ Building footprints | ・ Roads | ・ Above/underground utilities | ・ Others

   Response: Parcel data, roads, floodplains, some topo/lidar, NWI, soils, stormwater outfalls, Cat 1-5 storm surge areas.

7. Studies of this type typically involve leadership from the departments responsible for emergency management, public works, and planning. Who from the community do you anticipate being key points of contact from your community (provide name, phone, and email)?

   Development Services: Horace Jones, Director
   Emergency Management: Brad Hattaway, Program Coordinator
   Public Works: TBD
   Natural Resources Management: Keith Wilkins, Director

8. Stakeholder engagement will be a key to long-term success for any of the initiatives developed during this process. Please list who you perceive as stakeholders to this project.

   a. Internal Stakeholders –
   Various departments including County Extension

   b. External Stakeholders –
   Christian Wagley, Sustainable Town Concepts
   Darryl Boudreau, Nature Conservancy
   Thomas Ruppert, University of Florida

2.2 Design Meeting

The purpose of the design meeting was to frame the problems faced by the County with respect to coastal resilience and to identify analysis products that would support the adaptation planning process. During the meeting, the research team gathered contact information and the names of datasets that could be leveraged to address some of these issues. The breakout sessions during the January 2016 design meeting revealed a number of key issues identified by attendees. A synopsis of the design meeting follows, with a full summary provided in Appendix B

Priority issues included:

- Impacts on public safety and critical infrastructure.
- Floodplain management and stormwater (in-depth look at tailwater conditions).
- Increasing heavy precipitation events.

Representatives of the following institutions participated in the design meeting:

- Sustainable Town Concepts
- Escambia Restore Committee
- City of Pensacola

- Escambia County Stormwater
- IFAS Extension
- Escambia Emergency Management
- The Sea Grant
- The Nature Conservancy
- Escambia County Development Services
- Dewberry Consultants, LLC

Subsequent to the meeting, the research team contacted the designated personnel and collected the data described during the meeting. This data augmented basic geospatial data already supplied by the community. Based on the issues identified, data holdings, and initial data exploration, the team refined the problem statement and developed a proposed approach, which is described in Section 2.3.

2.3 Work Plan

Task 1 of the overall study effort focused on performing a vulnerability and risk assessment to assess Escambia County's potential impacts from SLR. The design meeting, as described in the preceding section, included facilitated breakout sessions to gain an understanding of County goals and concerns, which informed the problem statement. Discussion also focused on establishing the SLR scenarios and flood conditions for the study effort. The flood conditions and SLR scenarios, as decided on from that discussion, are presented in the mapping discussion and thus not repeated here. The study team developed a work plan to address the key items identified during the design meeting breakout sessions and circulated to the County and FLDEO for feedback. The study team finalized the work plan to accommodate feedback and then initiated the vulnerability assessment. The assessments presented in this report reflect this process.

3 MAPPING OF SEA LEVEL RISE CONDITIONS

Geospatial coverages were created for each identified combination of flood event type and SLR scenario. The coverages allowed a visual assessment of where future flooding would increase and what amount of land would be subject to flooding for each scenario. The information was then used to identify major pathways of flooding and key vulnerable areas in Escambia County, FL. A summary of the methodologies for mapping SLR conditions are presented first, followed by the results of the analysis. For further detail on the analytical approach, please refer to Appendix A.

3.1 How Were the SLR Scenarios Established?

The first step for mapping SLR was to establish SLR scenarios in consultation with the community during the design meeting. Federal SLR projections, including those from NOAA (NOAA 2012) and the U.S. Army Corps of Engineers (USACE, USACE 2013) were presented. Relative SLR projections were established for both the NOAA and USACE curves using the USACE Sea-Level Change Curve Calculator (http://www.corpsclimate.us/ccaceslcurves.cfm). The NOAA long-term water level station at Pensacola, FL (station 8729840) was selected as it is located within Escambia County and provides historical sea level observations and trends dating back to 1923, a period of 93 years (Figure 1).

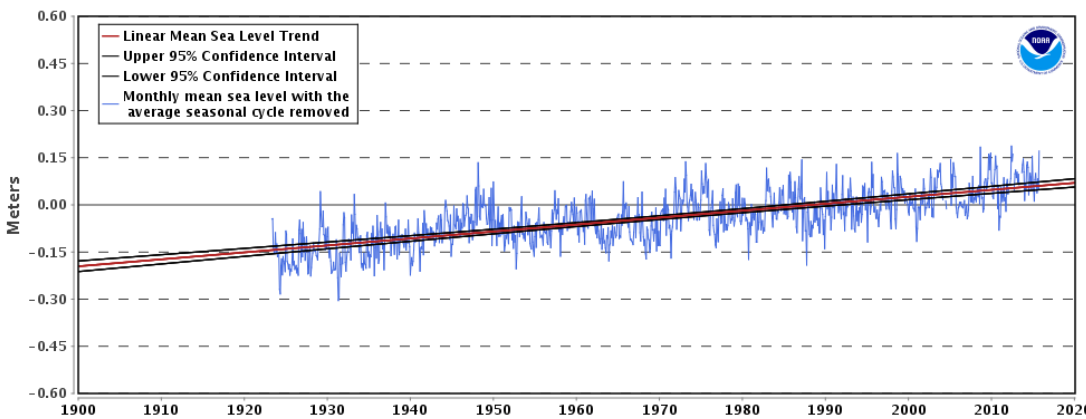

Figure 1. Historical water level records from Pensacola, FL have established a representative long-term historical SLR trend of 0.73 ft/century (source: NOAA Center for Operational Oceanographic Products and Services).

Two future time-frames were considered for the bases of the SLR projections. A relatively short-term horizon approximately 30 years from today (2045), and a relatively long-term horizon 70 years from today (2085). These time horizons relate to municipal planning as shown in Table 1.

Feedback from the community participants was that they preferred to be fully transparent about the range of uncertainty in the future projections. The decision was made to create mapping information and perform the vulnerability assessment using exact values from each for the two future time horizons, in lieu of representative values.

Table 1. Identified time horizons and relevance to municipal planning and infrastructure.

Life Cycle Alignment	Time Horizon/ Time Period	Relevance	Use
Municipal Planning	Circa 30 years 2045	Comprehensive Plan & Outcomes Short end of Commercial and Utility life-cycles	Vulnerability assessment Key planning value Basis for evaluation of all adaptation strategies
Critical Infrastructure/ Long-term awareness	Circa 70 years 2085	Utility Infrastructure life-cycle Transportation infrastructure lifecycles Residential structure lifecycles	Secondary vulnerability assessment to provide insight into long-term risk Basis for long-term infrastructure decisions Evaluate cost-effectiveness of additional protection for adaptable resilience strategies

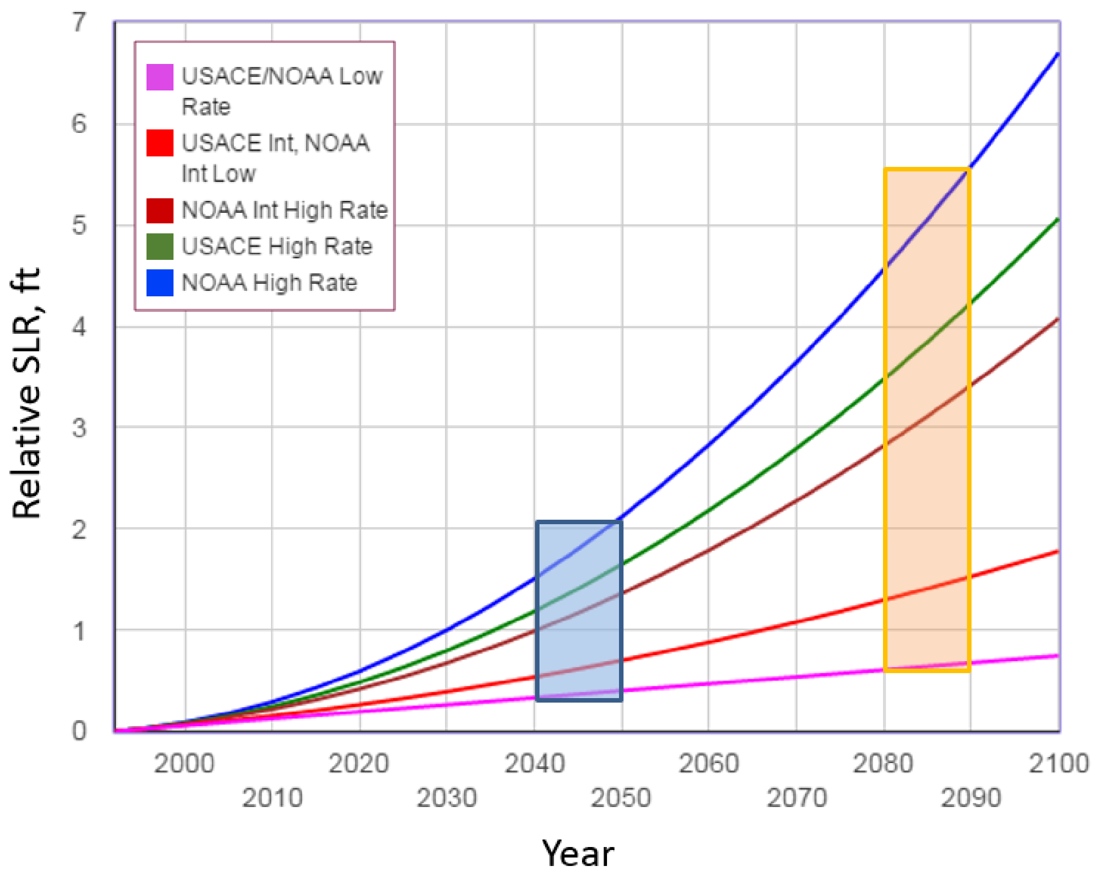

Figure 2. NOAA relative SLR curve for Gauge 8729840, Pensacola, FL (source: USACE Sea-Level Change Curve Calculator).

The USACE and NOAA curves provide a synthesis of the sea level rise projection science that is then represented in discreet levels of future projections. The variation from low to high curves represents several factors, key among them being: a range of future scenarios of temperature increases, different modeling approaches, and assumptions on how atmospheric temperature increases will transfer into the oceans, terrestrial water storage, and varying projections of the amount of future glacial and ice sheet melt.

The USACE and NOAA curves overlap at the lower levels. A short summary of the curves is provided below; however, readers should refer to the source documents for further information on the details behind the projections. Note: Vertical land movement at the local gauge location is included in the future SLR projections for each curve by the USACE calculator.

- USACE and NOAA Low curves are identical. These are based on a future extrapolation of the historical sea level change trends.
- The USACE Intermediate curve is identical to the NOAA Intermediate-Low curve. Projections based on this curve consider the most recent projections of the Intergovernmental Panel on Climate Change (IPCC) and modified National Research Council (NRC) Projections.
- The NOAA Intermediate-High curve is distinct from the USACE curves, and represents the upper range of a SLR modeling approach based on semi-empirical models.
- The USACE High curve is separate from the NOAA curves, and is based on the modified NRC Curve III, which considers the most recent IPCC and modified NRC projections.
- The NOAA High curve represents SLR with an estimate of maximum possible glacier and ice sheet loss by the end of the century.

The USACE Low, Medium, and High curves were used as the primary basis for the projections, supplemented by the NOAA High curve to represent a "worst-case" condition (Figure 2). Projected SLR values for the short- and long-term horizons across the range of future conditions as established by these curves are provided in Table 2. Throughout the rest of this report, the document will reference these scenarios as shown below:

Table 2. SLR projections extracted from the USACE and NOAA SLR curves and rounded to the nearest tenth of foot. Results in the report will reference the relative scenario for each time horizon.

Time Horizon	USACE Low	USACE Intermediate	USACE High	NOAA High
Short-term (2045)	**0.4**	**0.6**	**1.4**	**1.8**
Long-term (2085)	**0.6**	**1.4**	**3.9**	**5.1**
Report Reference:	**Low**	**Medium**	**High**	**Highest**

In terms of the scenarios considered in this assessment, the Medium and High scenarios are more likely and the Low and Highest scenarios are relatively unlikely. Future SLR projections lack probabilities due to the large uncertainties and varying methodologies in the modeling process. One effort to establish a measure of the relative likelihood within the range of scenarios involved a survey of 90 SLR modeling experts by Horton et al, 2013. The effort provided a "likely" average prediction, a values assessed to have a 66% probability for a low and upper temperature scenario by 2100 of 0.5 and 1.0 m, respectively. The upper temperature scenario assumes a "business as usual" approach to global emissions, whereas the lower temperature scenario assumes successful efforts to mitigate future emissions. The low temperature "likely" value roughly corresponds to USACE Intermediate scenario; whereas the upper temperature "likely" value is between the USACE Intermediate and High scenarios.

3.2 What Was the Process for Mapping Sea Level Rise?

A range of coastal flood event types including tidal, nuisance, and high to low recurrence interval storm surge were discussed with the community at the design meeting. The community selected tidal, the 1% annual chance flood, and the 0.2% annual chance flood. Background information on each is presented in Table 3.

Table 3. Sources of Flood Elevations in Escambia County, FL.

Coastal Flood Event Type	Description	Frequency	Water Elevation, ft NAVD88	Data Source
Daily Tidal Flooding, or Mean Higher High Water	The highest daily tide elevation, defining the limit of what land is essentially "inundated" or has very limited use.	~Once daily	0.94 ft	NOAA Pensacola Water Level Station, NOAA VDatum tool
Changes to 1% annual chance flood event	The 1% annual chance floodplain is defined as the area that will be inundated by the flood event having a 1% chance of flooding of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. This area defines the Special Flood Hazard Area (SFHA) that is delineated on Federal Emergency Management Agency Flood Insurance Rate Maps.	1% chance per year, ~26% chance in 30 years	Between 7 and 11 ft	Preliminary FEMA Flood Insurance Study (FIS) for Escambia County
Changes to 0.2% annual chance flood event	The 0.2% annual chance floodplain is defined as the area that will be inundated by the flood event having a 0.2% chance of flooding of being equaled or exceeded in any given year. The 0.2-percent annual chance flood is also referred to "500-year flood".	0.2% chance per year, ~6% chance in 30 years	Between 9 and 15 ft	Preliminary FEMA FIS for Escambia County

Changes to each coastal flood hazard event were estimated by increasing the present day base surface elevations by simply adding each sea level rise scenario to the base flood conditions. After applying SLR scenario to each coastal flood event type, coastal flooding extents were established for each scenario and flood event type by intersecting the water surface elevation models with the topographic elevation models in a Geographic Information System (GIS). The resulting cartographic coverages were post-processed to remove artifacts. An additional check was performed to remove areas shown as flooded that were not hydraulically connected to a water body.

3.3 How Much More Land Will be Vulnerable to Flooding?

Sea level rise increases water elevations relative to land, resulting in large and deeper floods. Vulnerability to these future conditions varies by each flood type and local land elevations. Changes in the mapping layers produced for each flood type and SLR scenario were reviewed to understand Escambia County's vulnerability to future flooding. This effort included a review of the sequence of increasing flooding, from today's condition (baseline) through the range of SLR scenarios for each event type for both the short-term (2045) and long-term (2085) time horizons.

The mapping layers showed that overall, daily tidal flooding has the most potential to increase, followed by the 0.2%- and 1% annual chance floodplains. Change in flood area by flood type and scenario for both the short- and long-term time horizons are shown in Table 4 and Figure 3. Flood increases very by flood type:

- Daily Tidal Flooding (MHHW):
    - 2045: Projected increases range from 1.1 to 9.8 additional square miles of flooding, depending on scenario.
    - 2085: Increases range from 1.9 to 30 square miles of additional flooding.
    - It should be noted that this flood type will result in daily flooding and severely limit land use. Typically, this land is considered permanently inundated and buildings would be considered unusable unless flood protection measures were constructed to prevent flood exposure.
- 1% Annual Chance Floodplain:
    - 2045: Projected increases range from 0.1 to 6.1 additional square miles of floodplain, depending on scenario. The Medium SLR scenario would result in a 2% change in the regulatory floodplain.
    - 2085: Increases range from 1 to 19.4 additional square miles of floodplain, depending on scenario. The Medium SLR scenario would result in a 9% change in the regulatory floodplain.
- 0.2% Annual Chance Floodplain:
    - 2045: Projected increases range from 1.6 to 7.2 additional square miles of floodplain, depending on scenario. The Medium SLR scenario would result in a 4% change in the regulatory floodplain.
    - 2085: Increases range from 2.4 to 21.9 additional square miles of floodplain, depending on scenario. The Medium SLR scenario would result in a 10% change in the regulatory floodplain.

Table 4. Increases in flood area from present-day conditions to future short (2045) and long-term (2085) time horizons by flood type and SLR scenario. Units in square miles.

Time Horizon	SLR Scenario	MHHW	1% Floodplain	0.2% Floodplain
2045	Low	1.14	0.09	1.57
	Medium	1.89	0.98	2.42
	High	7.14	4.39	5.66
	Highest	9.8	6.1	7.21
2085	Low	1.89	0.98	2.42
	Medium	7.14	4.39	5.66
	High	21.82	14.8	16.37
	Highest	30.27	19.42	21.94

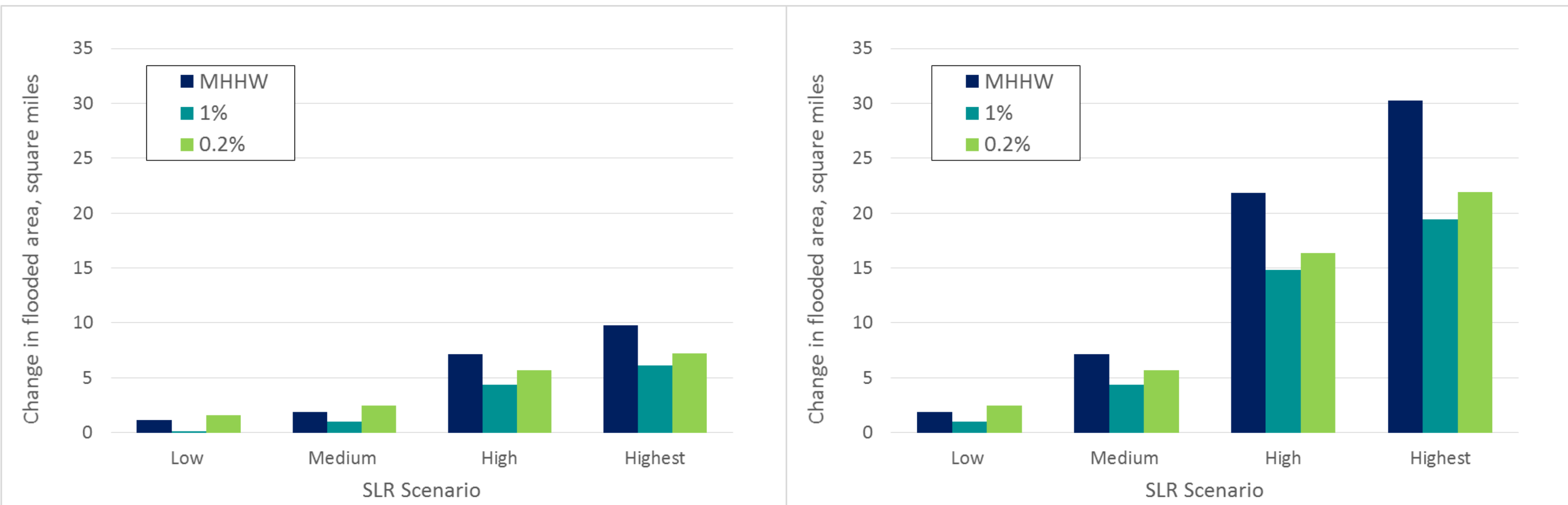

Figure 3. Change in flooded area with SLR by flood type for the short-term (2045, left panel) and the long-term (2085, right panel).

3.4 What Areas Are Vulnerable to Flooding Changes Due to Sea Level Rise?

Map coverages for the County's vulnerability to future flooding were broken out into three geographic areas in this document. Figures visualizing future flood conditions for daily tidal flooding, the 1% annual chance floodplain, and the 0.2% annual chance floodplain are provided for each area. Key place names as mentioned in the identification of vulnerable areas are provided in Figure 4.

- County-wide coverage, showing the full extent of Escambia County that is projected to experience increased flooding due to SLR. Results are provided in Figures 3-8.
- City of Pensacola, results are provided in Figures 9-14.
- Southern Escambia and the barrier islands, results are provided in Figures 15-20.

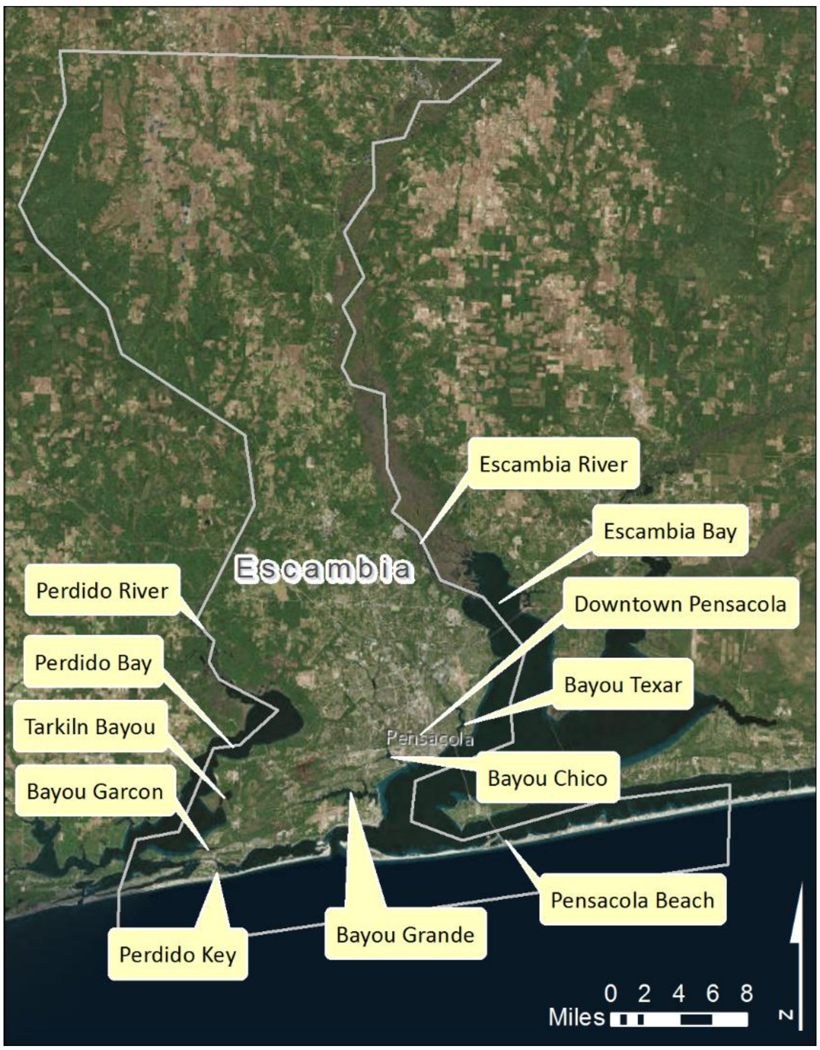

Figure 4. Key place names in Escambia County.

Each map was evaluated to identify areas of future vulnerability, or "hotspots", as well as areas that are projected to be less vulnerable from the impacts of SLR. Key vulnerabilities to each flood type, SLR scenario and time horizon combination are discussed in greater detail in the following text.

- Key Hotspots across Escambia County:
  - Daily Tidal Flooding (MHHW):
    - 2045: overall low vulnerability to increases in tidal flooding at the Low and Medium SLR projections. Limited vulnerability to the High and Highest scenarios, concentrated in upper Perdido Bay and the lower Perdido River, Bayou Tarkiln, Bayou Garcon, Big Lagoon State Park and the lower Escambia River.
    - 2085: Vulnerability to additional flooding from the Low scenario is limited; however, increases from the Medium to Highest scenarios across the county. Areas of increases include: Lower Perdido River, upper Perdido Bay, Lower Perdido Bay, the bayside of Perdido Key, bayside of Pensacola Beach, as well as the lower Escambia River. A large increase in tidal flooding is projected for the lower Escambia in the vicinity of Molino. In Pensacola, East and West Main Streets, as well as the south end of S. Tarragon Street are vulnerable to the two highest scenarios.
  - 1% Annual Chance Floodplain:
    - 2045: Minimal increases in the 1% annual chance floodplain are apparent in 2045. Exceptions are: small increases to the High and Highest scenarios along the floodplain boundary in Perdido Bay, from Halcyon Shores north to Saufley Estates; downtown Pensacola between S. Pace Blvd and S. 9th Ave. On the Escambia River, increases are apparent just south of Melino.
    - 2085: Increases are more widespread, but primarily related to the High and Highest scenarios, and generally in the same locations. The largest increases are seen just south of Tarkiln Bayou on Perdido Bay, along Bayou Grande, in downtown Pensacola, and in the vicinity of Melino on the Escambia River.

  - 0.2% Annual Chance Floodplain:
    - 2045: In similar trend to the 1% floodplain, increases in the 0.2% annual chance floodplain are limited for 2045. Increases are again mostly in response to the High and Highest scenario. Locations are similar to those observed for growth in the 1% floodplain. Vulnerable areas the shoreline along Perdido Bay from Halcyon Shores north to Saufley Estates; Bayou Garcon, downtown Pensacola and on the Escambia River near Melino
    - 2085: Again, most increases are related to the High and Highest SLR scenarios. The largest increases are apparent at the southwestern side of Bayou Grande, Perdido Bay from Halcyon Shores north to Saufley Estates and the Escambia River just north of Melino. Increases are also observed in downtown Pensacola from Bayou Chico to East Chase St.

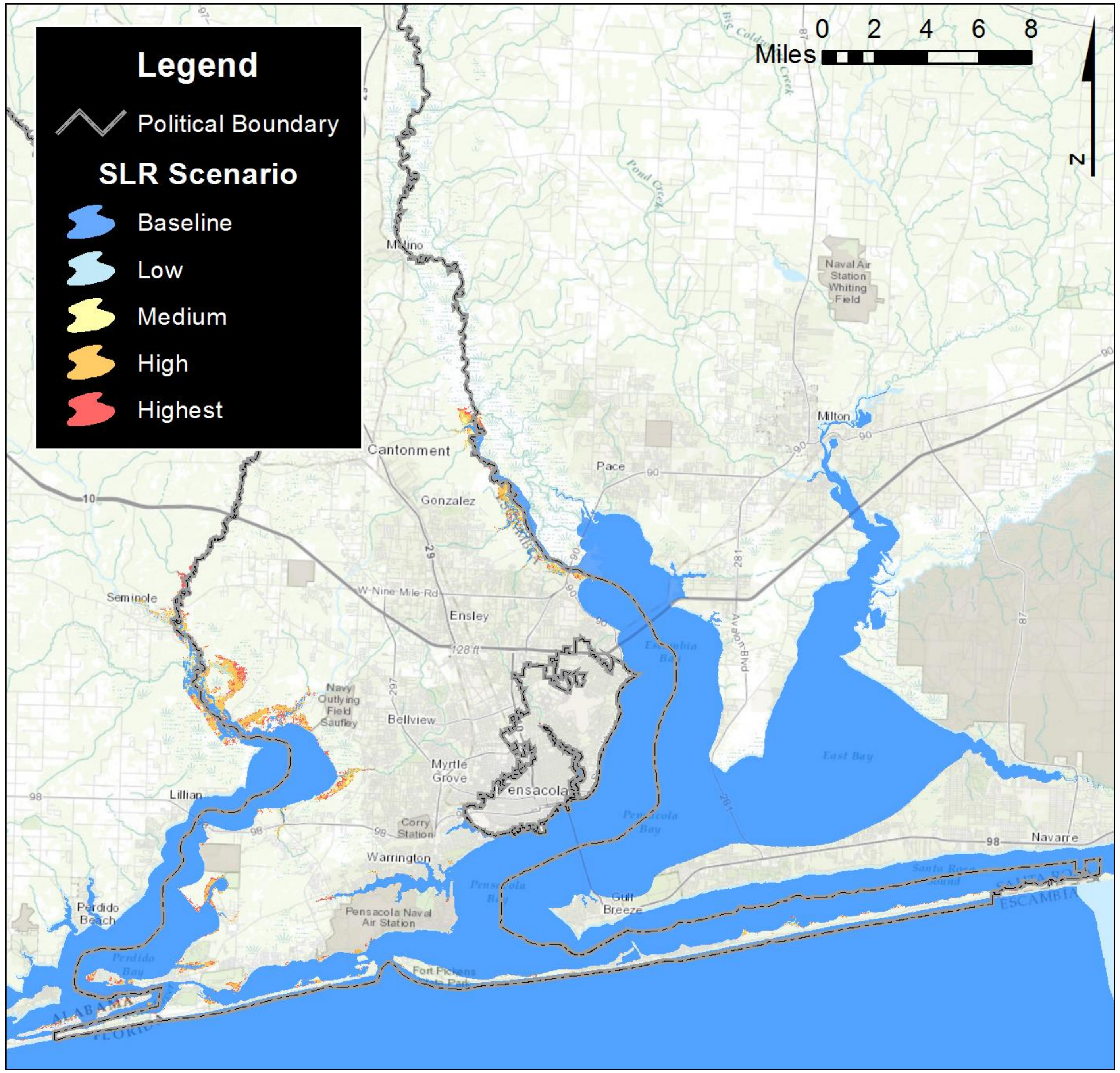

Figure 5. County-wide view of tidal flooding (MHHW) for the range of SLR scenarios in 2045.

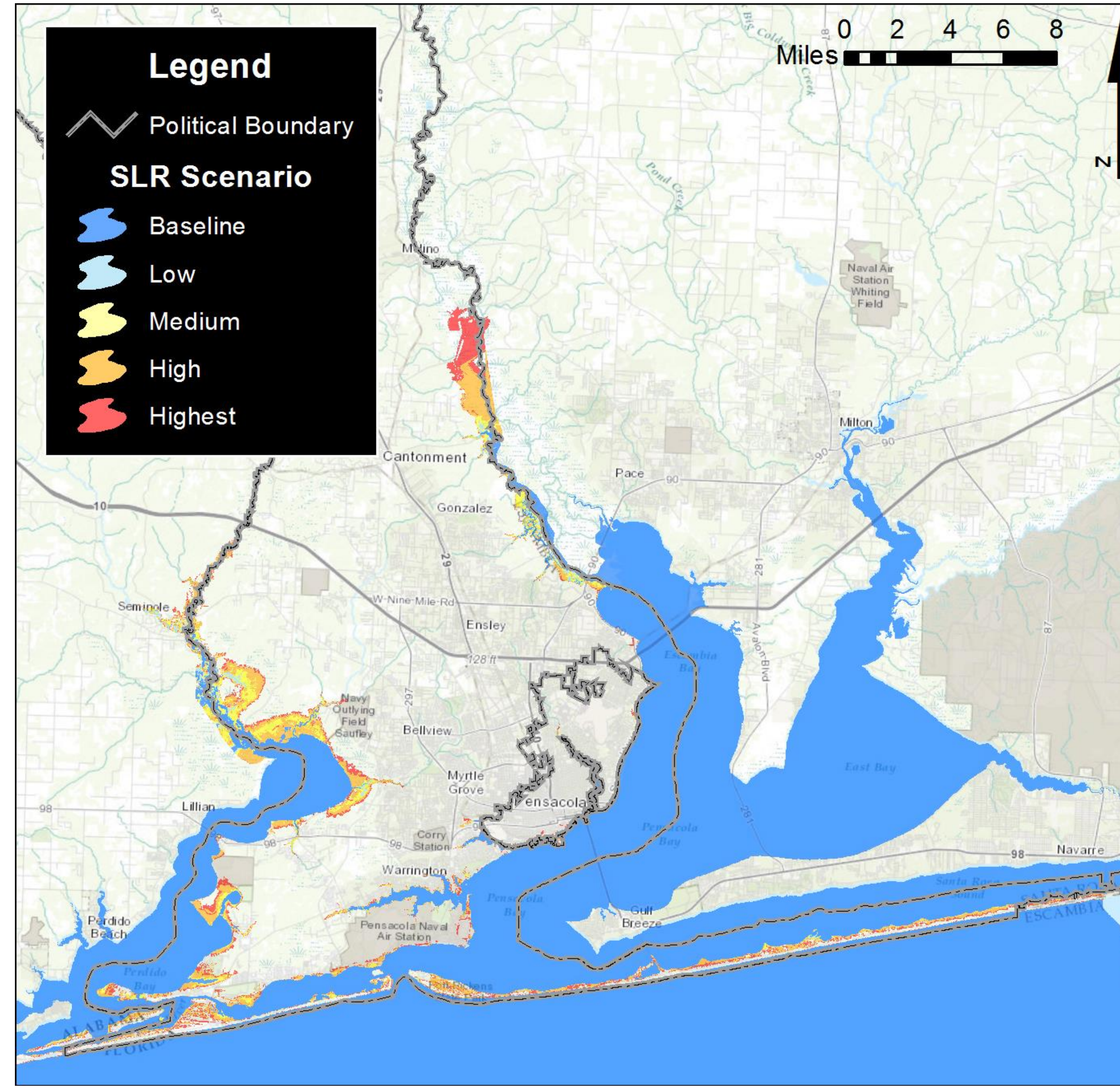

Figure 6. County-wide view of tidal flooding (MHHW) for the range of SLR scenarios in 2085.

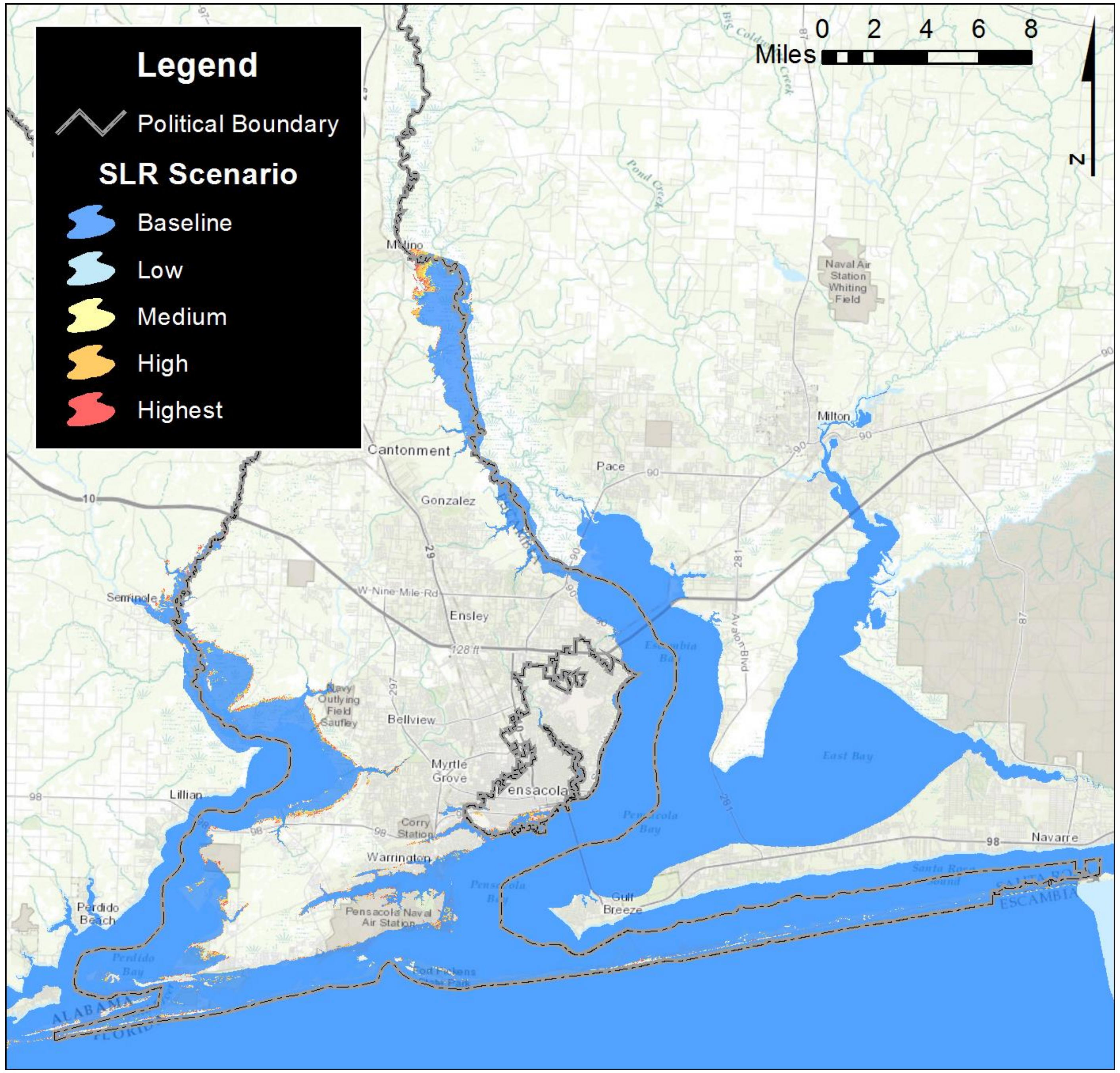

Figure 7. County-wide view of the 1% annual chance floodplain for the range of SLR scenarios in 2045.

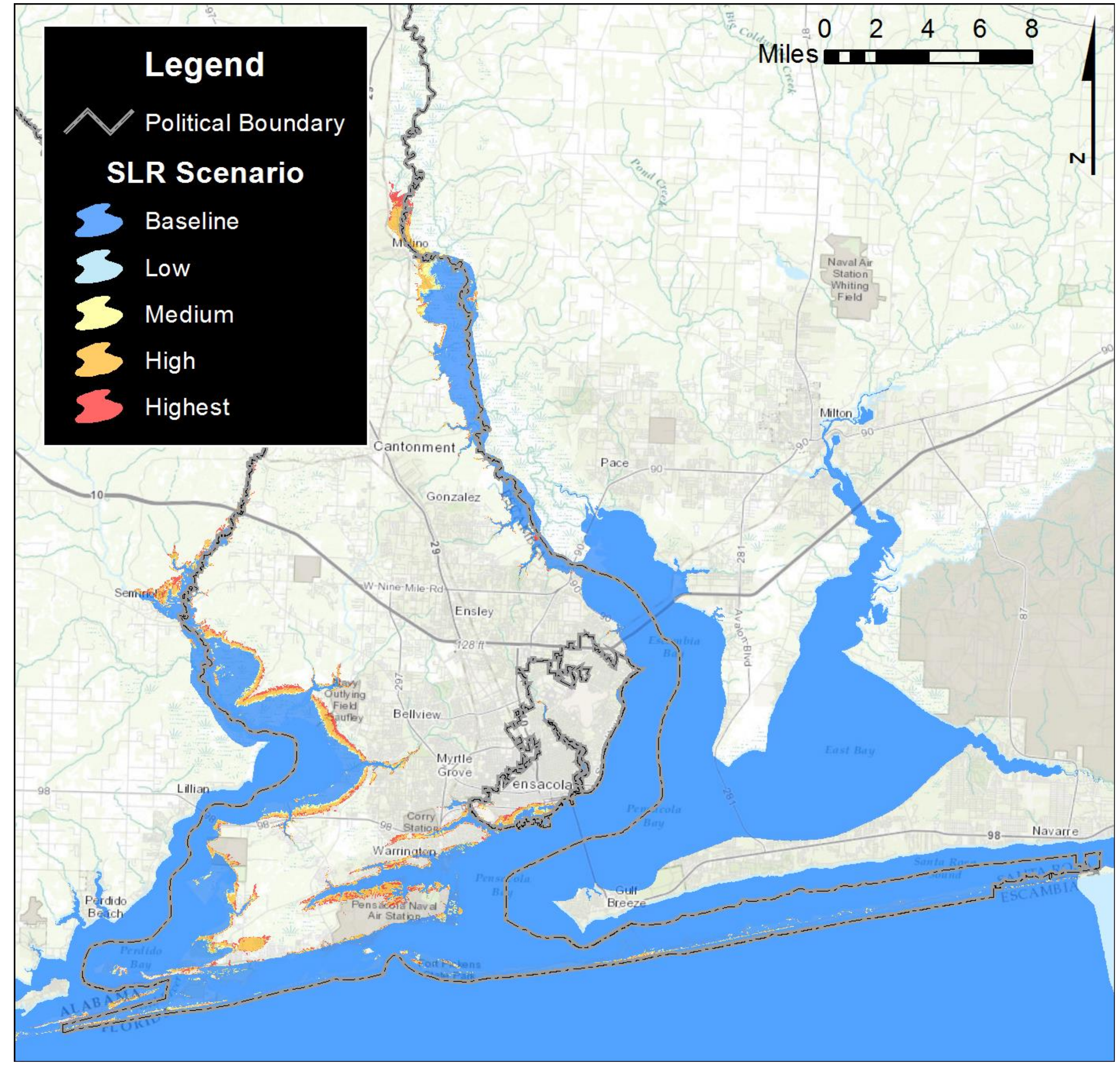

Figure 8. County-wide view of the 1% annual chance floodplain for the range of SLR scenarios in 2085.

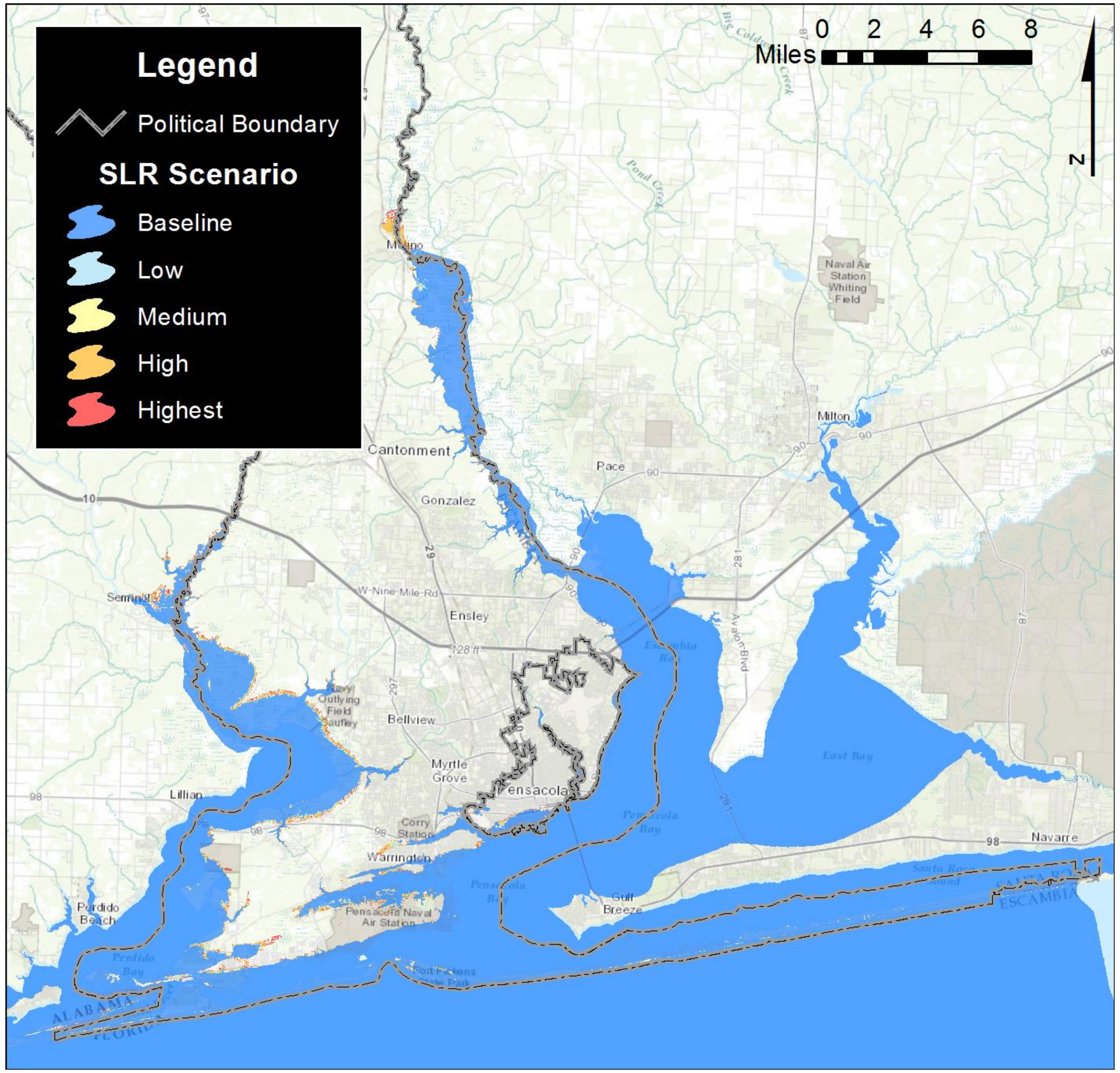

Figure 9. County-wide view of the 0.2% annual chance floodplain for the range of SLR scenarios in 2045.

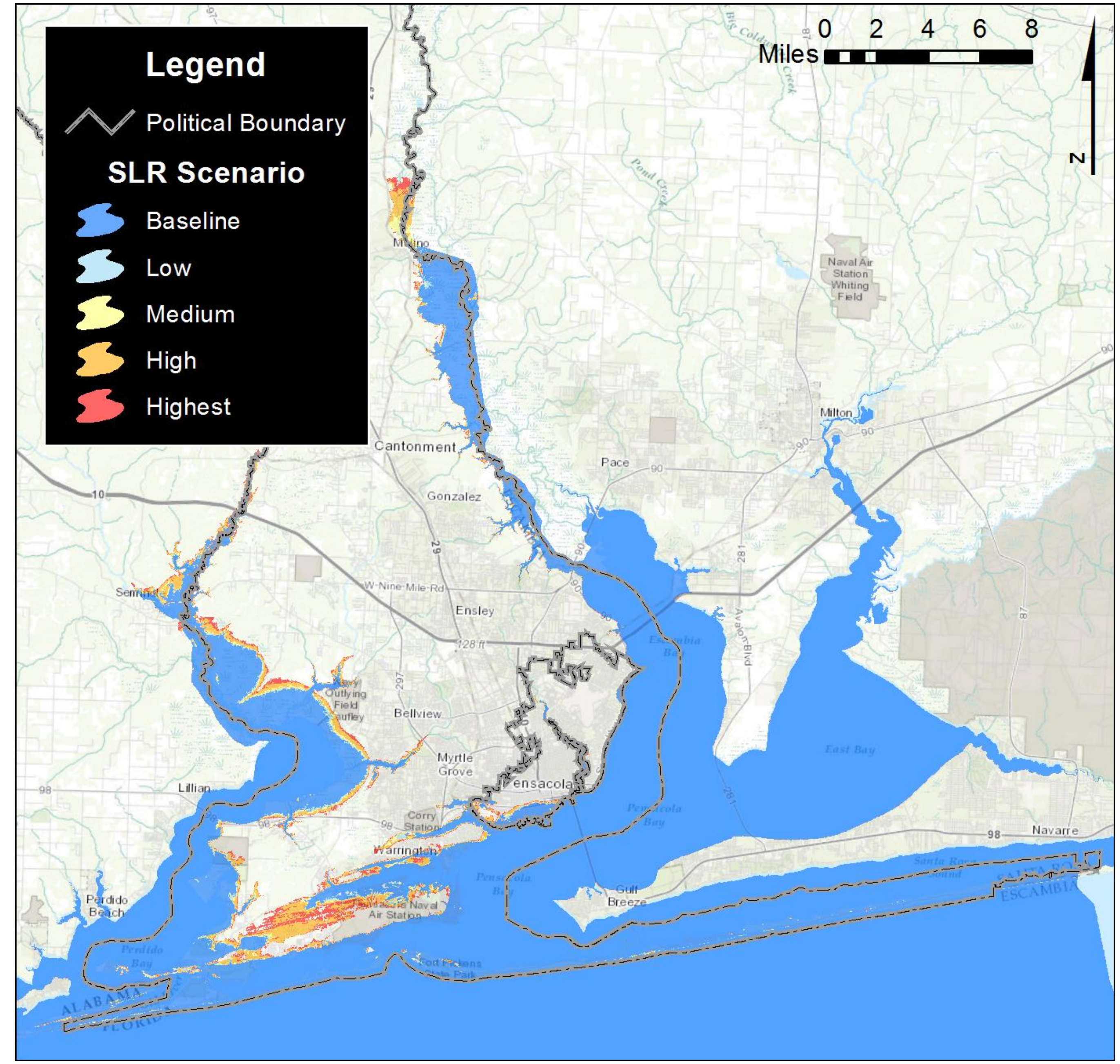

Figure 10. County-wide view of the 0.2% annual chance floodplain for the range of SLR scenarios in 2085.

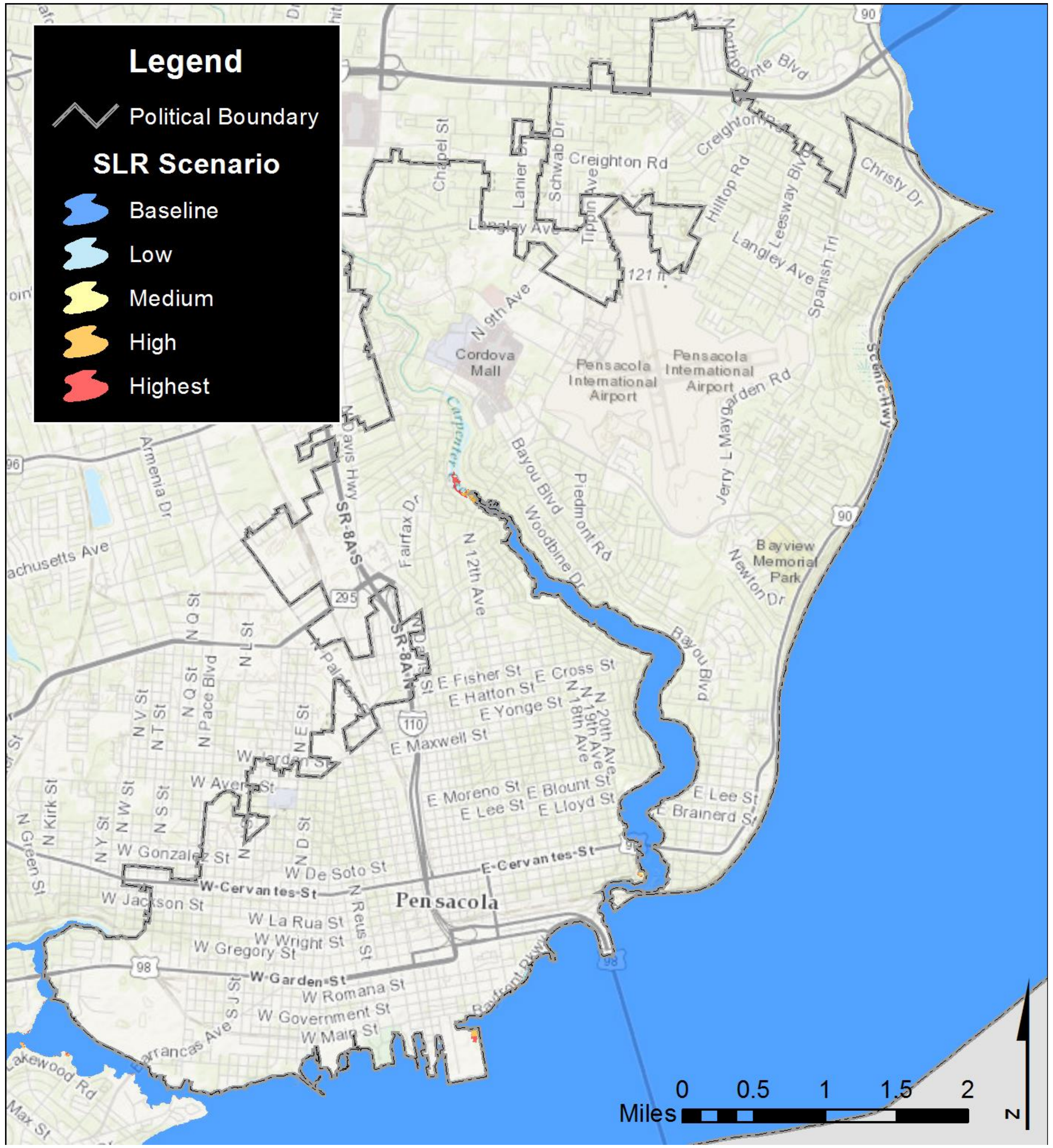

Figure 11. Pensacola, tidal flooding (MHHW) for the range of SLR scenarios in 2045.

Figure 12. Pensacola, tidal flooding (MHHW) for the range of SLR scenarios in 2085.

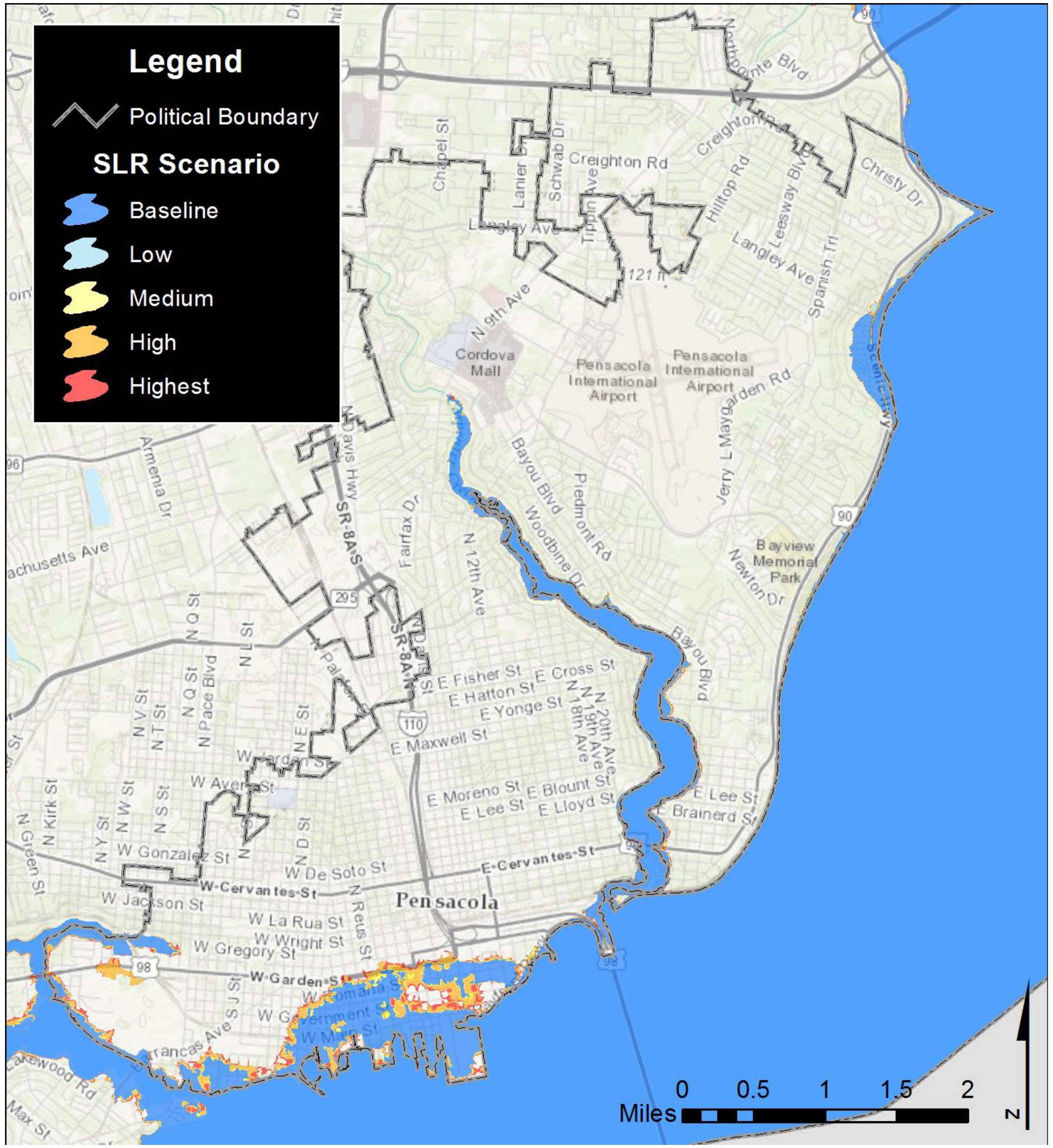

Figure 13. Pensacola, 1% annual chance floodplain for the range of SLR scenarios in 2045.

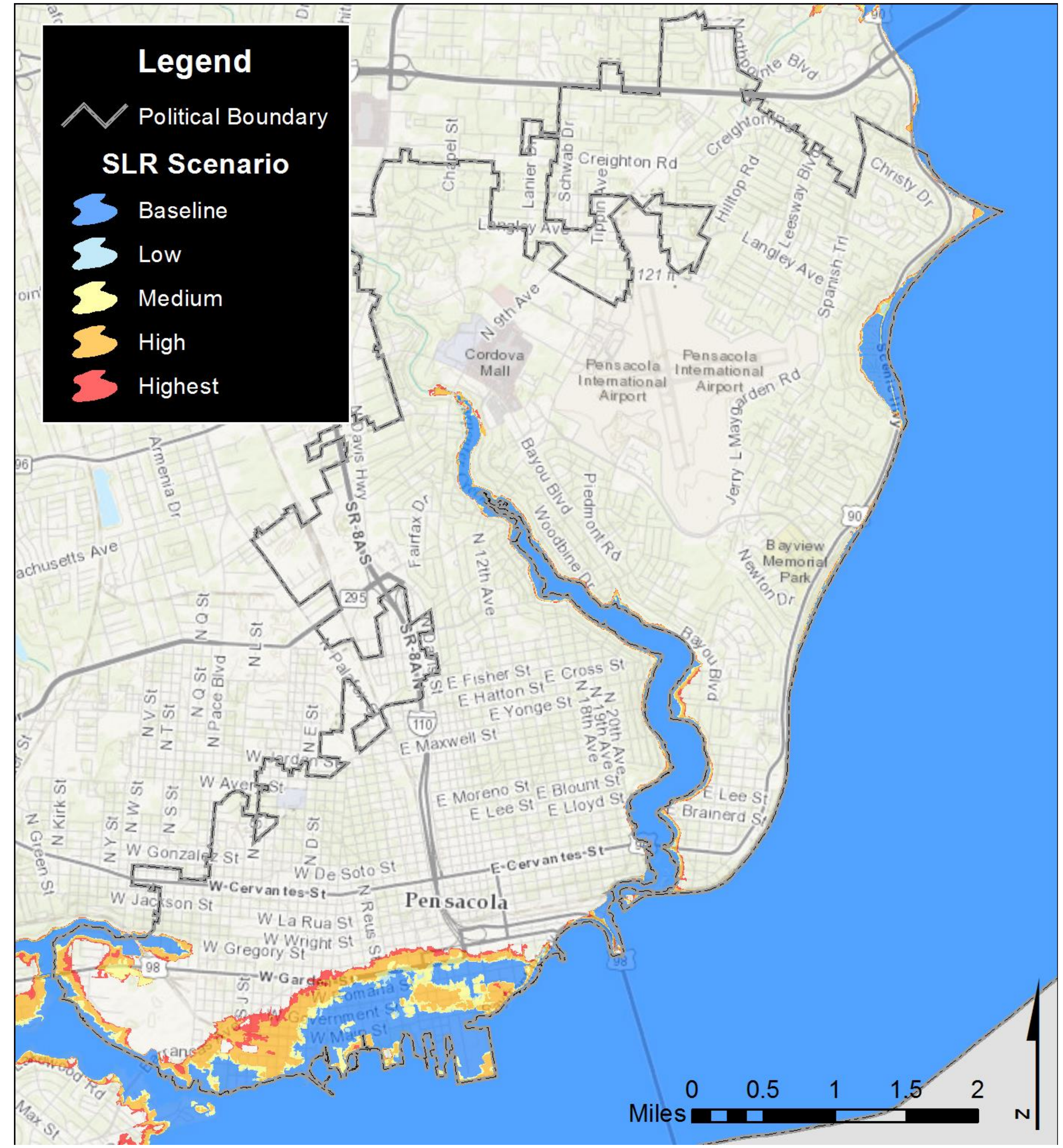

Figure 14. Pensacola, 1% annual chance floodplain for the range of SLR scenarios in 2085.

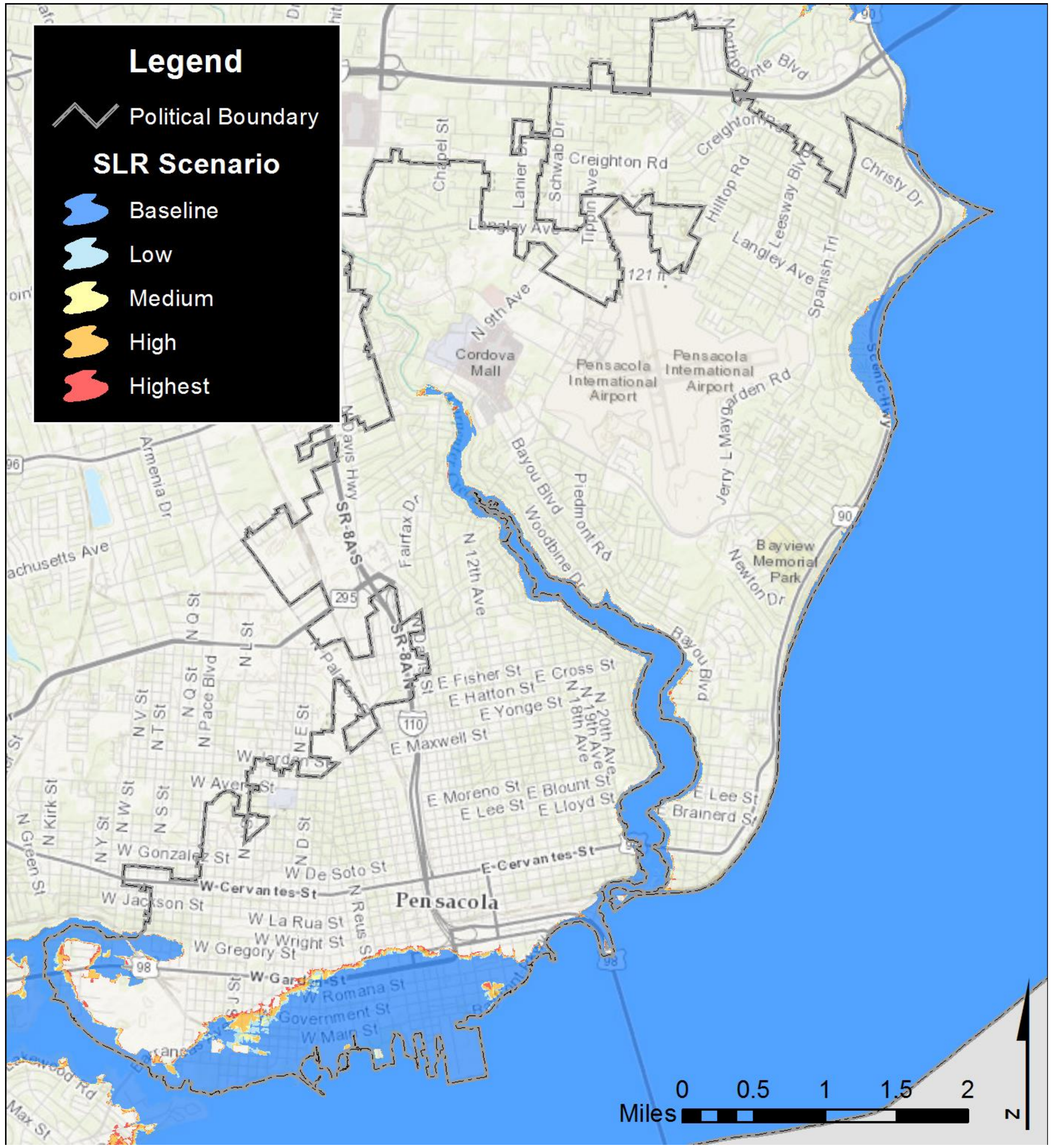

Figure 15. Pensacola, 0.2% annual chance floodplain for the range of SLR scenarios in 2045.

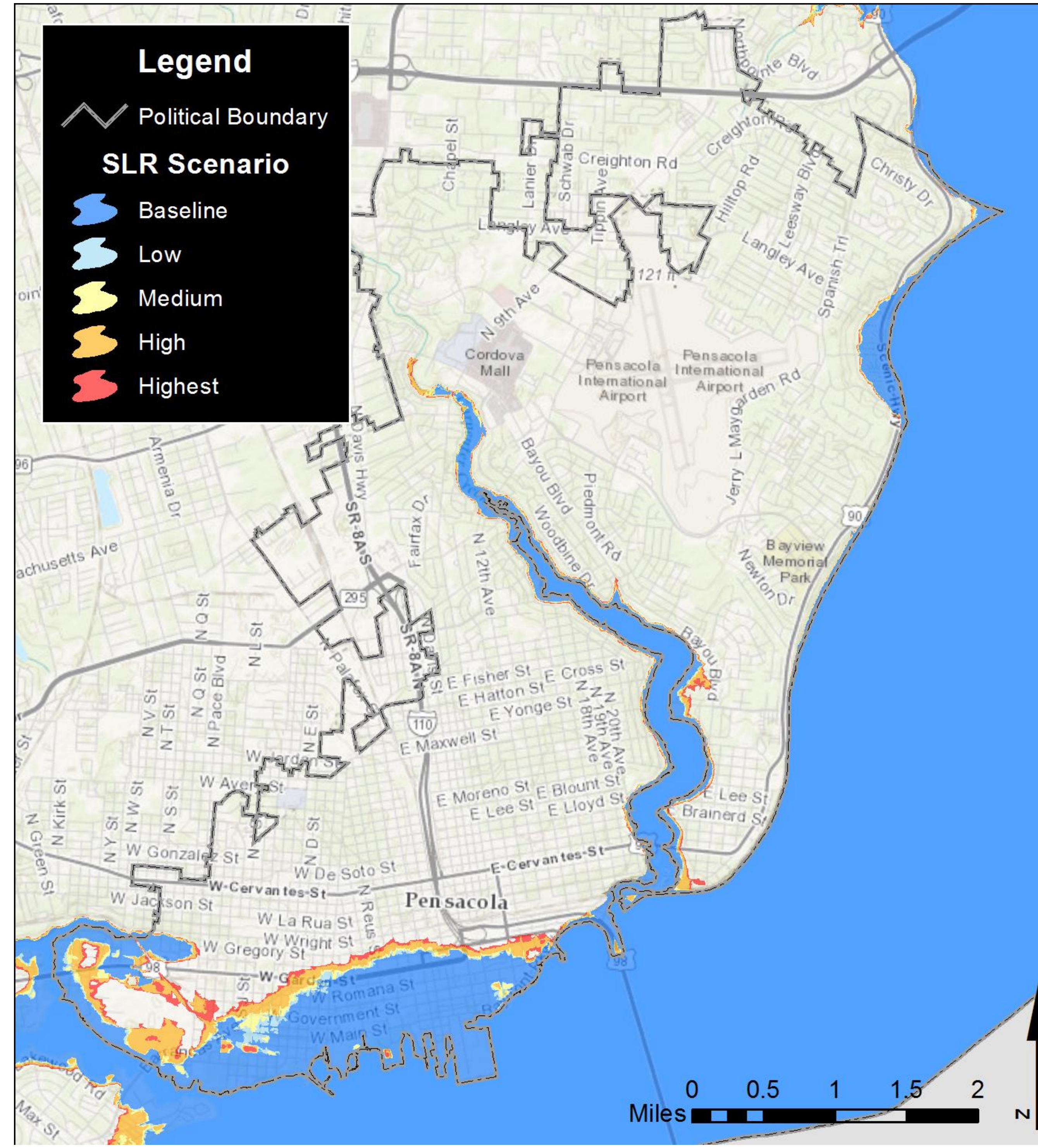

Figure 16. Pensacola, 0.2% annual chance floodplain for the range of SLR scenarios in 2085.

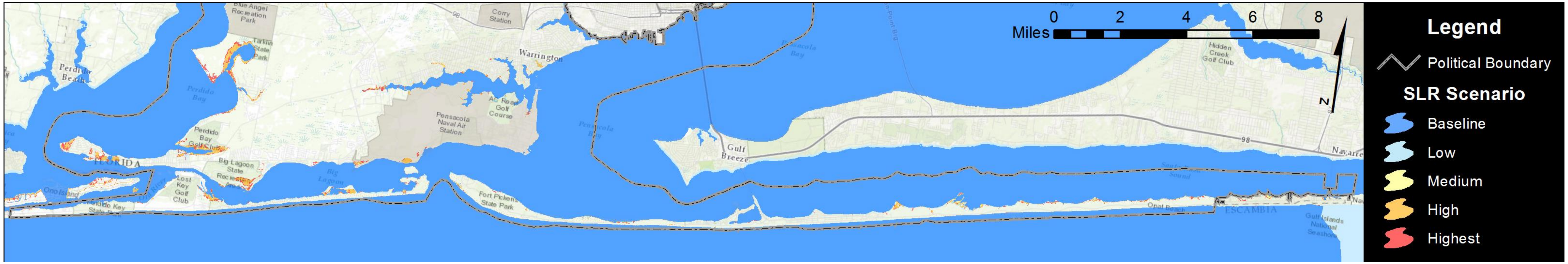

Figure 17. Barrier islands and southern Escambia, tidal flooding (MHHW) for the range of SLR scenarios in 2045.

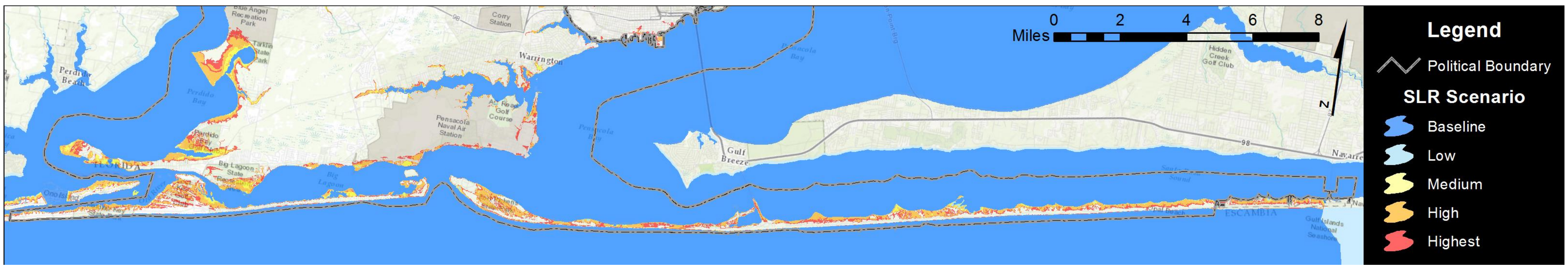

Figure 18. Barrier islands and southern Escambia, tidal flooding (MHHW) for the range of SLR scenarios in 2085.

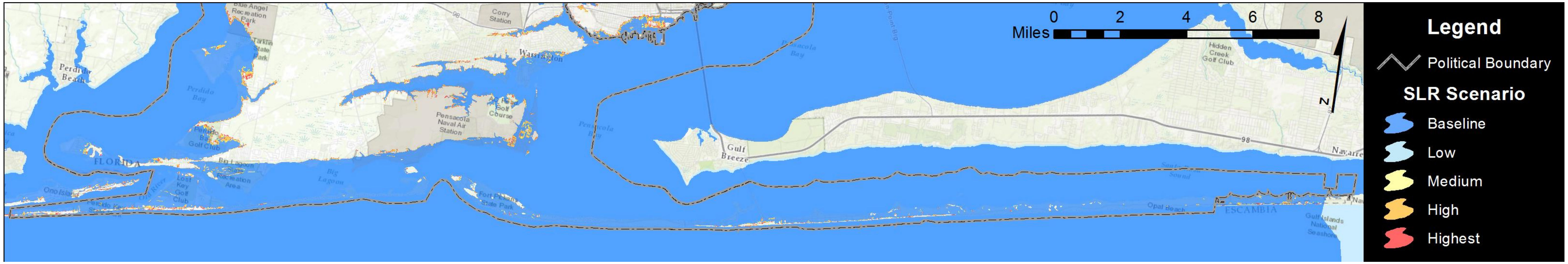

Figure 19. Barrier islands and southern Escambia, 1% annual chance floodplain for range of SLR scenarios in 2045.

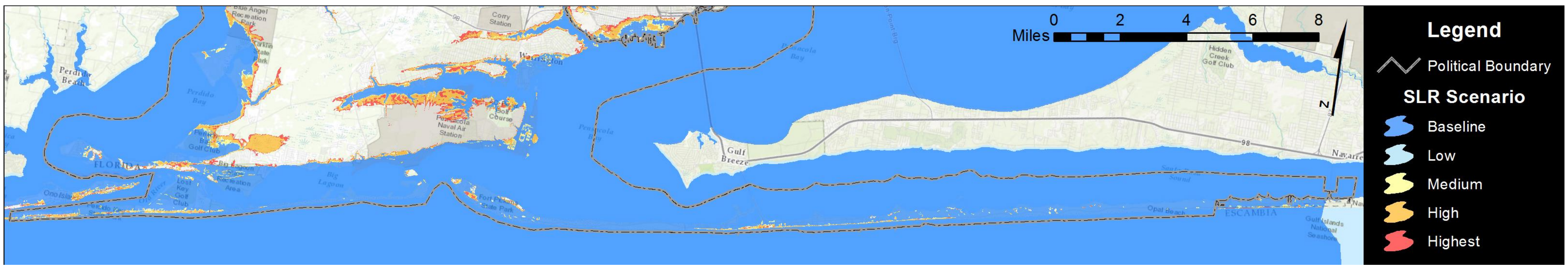

Figure 20. Barrier islands and southern Escambia, 1% annual chance floodplain for range of SLR scenarios in 2085.

Figure 21. Barrier islands and southern Escambia, 0.2% annual chance floodplain for range of SLR scenarios in 2045.

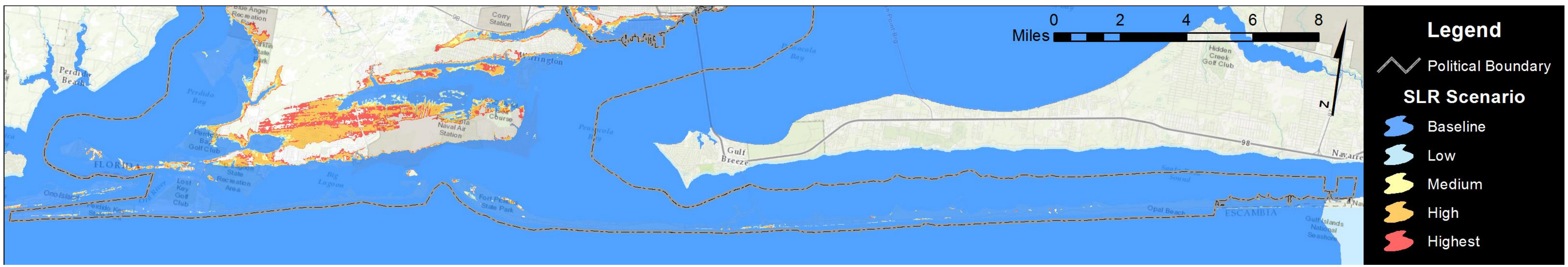

Figure 22. Barrier islands and southern Escambia, 1% annual chance floodplain for range of SLR scenarios in 2085.

4 FUTURE WAVE HAZARD ZONES

The study included an assessment of how the location of coastal wave hazard zones would change in response to SLR. Proactive management of building requirements in such areas could help mitigate future storm damages.

FEMA identifies three areas of wave action – Zone V – the coastal high hazard zone, the Area of Moderate Wave Action (MoWA), sometimes referred to as the "Coastal A Zone," and the Area of Minimum Wave Action (MiWA). Zone V is defined as the area where wave heights are greater than 3 ft. Typically Zone V is adjacent to open water, and during a 1% annual chance event, structures within Zone V would be expected to suffer extensive damages. The MoWA is defined as "the portion of the coastal SFHA referenced by building codes and standards, where base flood wave heights are between 1.5 and 3 ft, and where wave characteristics are deemed sufficient to damage many [National Flood Insurance Program]-compliant structures on shallow or solid wall foundations." The Coastal A Zone includes areas landward of a V Zone or landward of an open coast without mapped V Zones (Figure 23). The LiMWA depicts the landward extent of the MoWA on FIRMs produced in 2009 and after. The MiWA includes all areas not subject to wave effects over 1.5 feet which appear landward of the LiMWA on a FIRM.

A summary of the methodologies for modeling future wave hazard zones are presented first, followed by the results of the analysis.

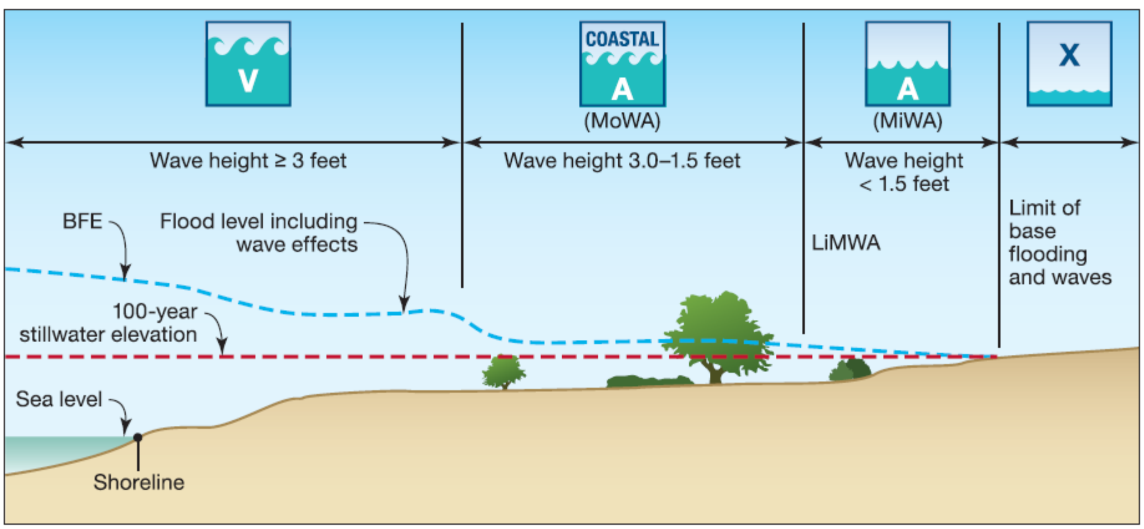

Figure 23. Diagram of FEMA coastal flood hazard zones. Damage potential becomes less as wave heights decrease (FEMA 2011).

4.1 How Were Changes in the VE and Coastal A Zone Modeled?

The future location of Zone VE and the Coastal A Zone were estimated using the Wave Height Analysis for Flood Insurance Studies (WHAFIS) model – the standard model for determining the elevation and location of FIRM zones. The existing FEMA Flood Insurance Study (FIS) modeling framework was directly leveraged, including all input parameters such as topography, starting wave conditions and obstruction carding. The baseline 10% and 1% annual chance condition stillwater surfaces were increased by the Medium SLR scenario for the short (2045) and long-term (2085) time frames. Potential erosion of dune features was reassessed for each scenario via standard FIS approaches, including a failure and/or retreat analysis against the updated 1% annual chance flood elevation. Re-simulation of overland wave heights was then performed for all FIS modeling transects in the county with the SLR scenario implemented into the modeling framework. For further detail on the analytical approach, refer Appendix A.

4.2 How Will Wave Hazard Zones Change in the Future?

Outputs of the wave hazard modeling included GIS coverages delineating changes to the VE Zone and LiMWA. Notable changes in the VE Zone and LiMWA were limited to the southern portion of Escambia County. Three areas were broken out to illustrate the modeled changes:

- Western Santa Rosa Island and Pensacola Beach (Figure 24)
    - 2045: Relatively small growth of the LiMWA occurs along the backside of the island through the Pensacola Beach area. The future LiMWA would reach Via De Luna Dr. through much of the developed area.
    - 2085: Projected water depth increases due to SLR would result in the growth of the VE Zone across essentially the entire developed area of the island.

- Downtown Pensacola (Figure 25)
    - 2045: Negligible growth in the LiMWA is projected.
    - 2085: Significant growth of the VE Zone is projected in downtown Pensacola, especially within a reach between E and 9th streets, extending back to E. Garden St. Some growth of the LiMWA is projected in the vicinities of Harbour Pointe, Sonia St, and Oak Point.

- Southern Escambia (Figure 26)
    - 2045: Relatively small growth of the LiMWA occurs along the shoreline of Bayou Tarkiln and along the north shoreline of Big Lagoon.
    - 2085: Growth of the VE Zone is negligible but continued growth of the LiMWA is projected. In addition, further growth of the areas identified in 2045, Innerarity Point, they bay shoreline of Fort McRee, and areas in the vicinity of Ft. Pickens and Gulf Islands National Seashore all show increased areas within the LiMWA.

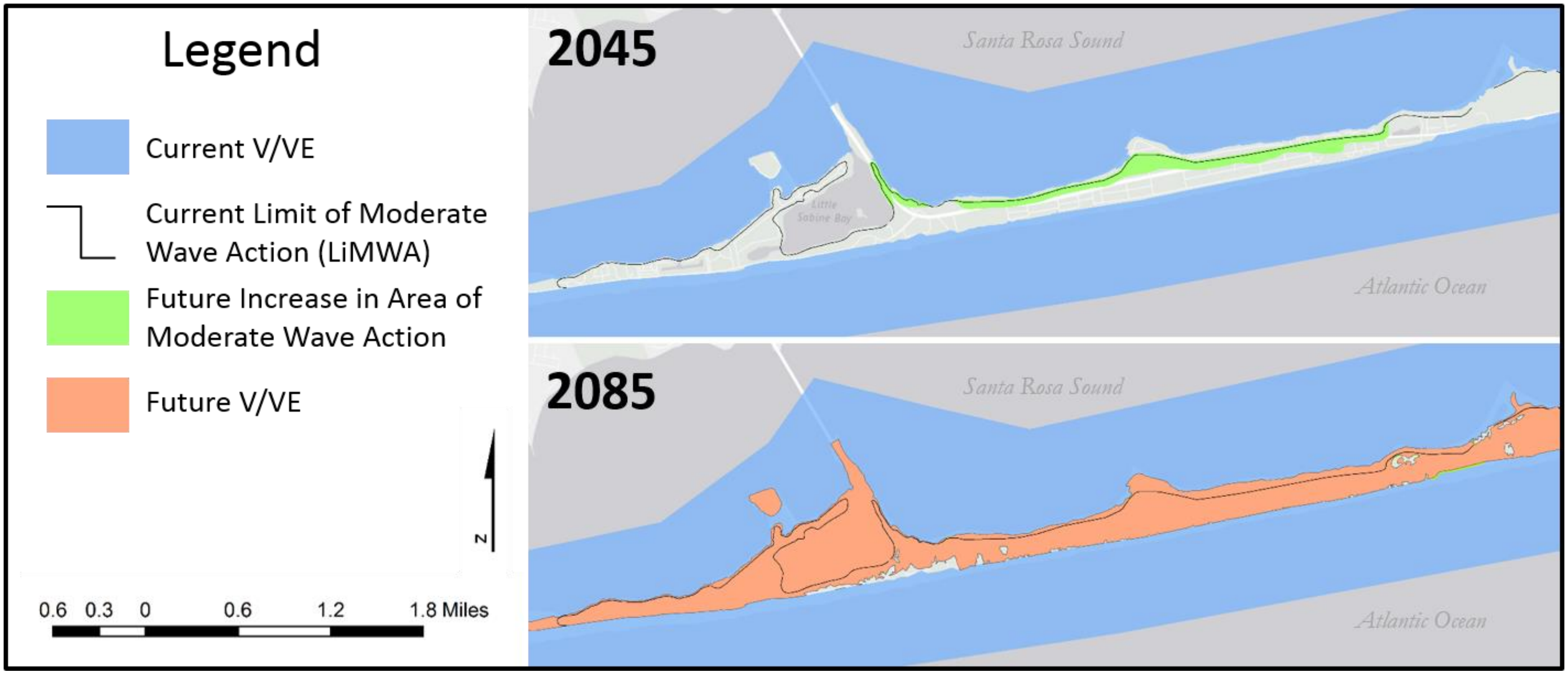

Figure 24. Changes in the VE and LiMWA along western Santa Rosa Island and Pensacola Beach area for the short- the long-term time horizons. Changes depict response to wave hazards to the Medium SLR scenario. Note that the floodplain is not shown to more clearly illustrate changes to the wave hazard zones.

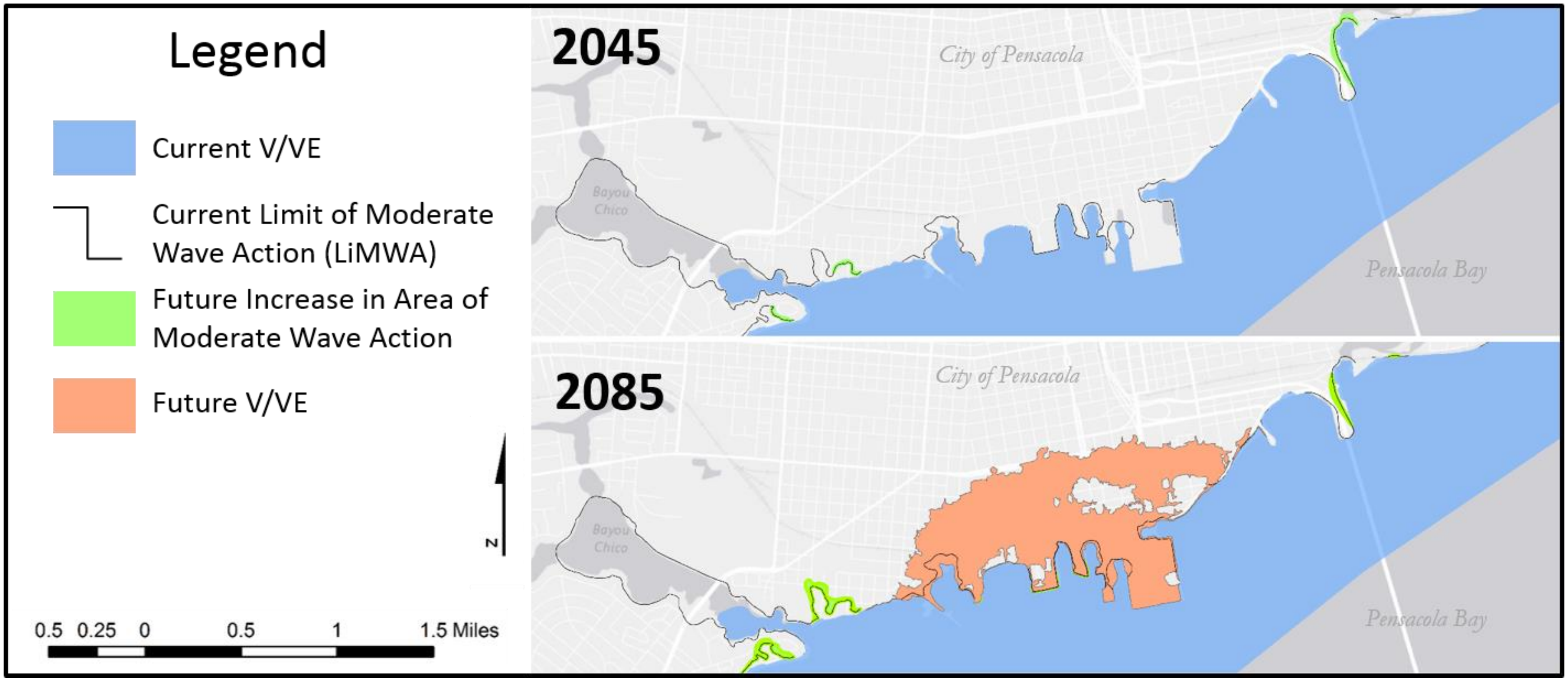

Figure 25. Changes in the VE and LiMWA for downtown Pensacola for the short- the long-term time horizons. Changes depict response to wave hazards to the Medium SLR scenario. Note that the floodplain is not shown to more clearly illustrate changes to the wave hazard zones.

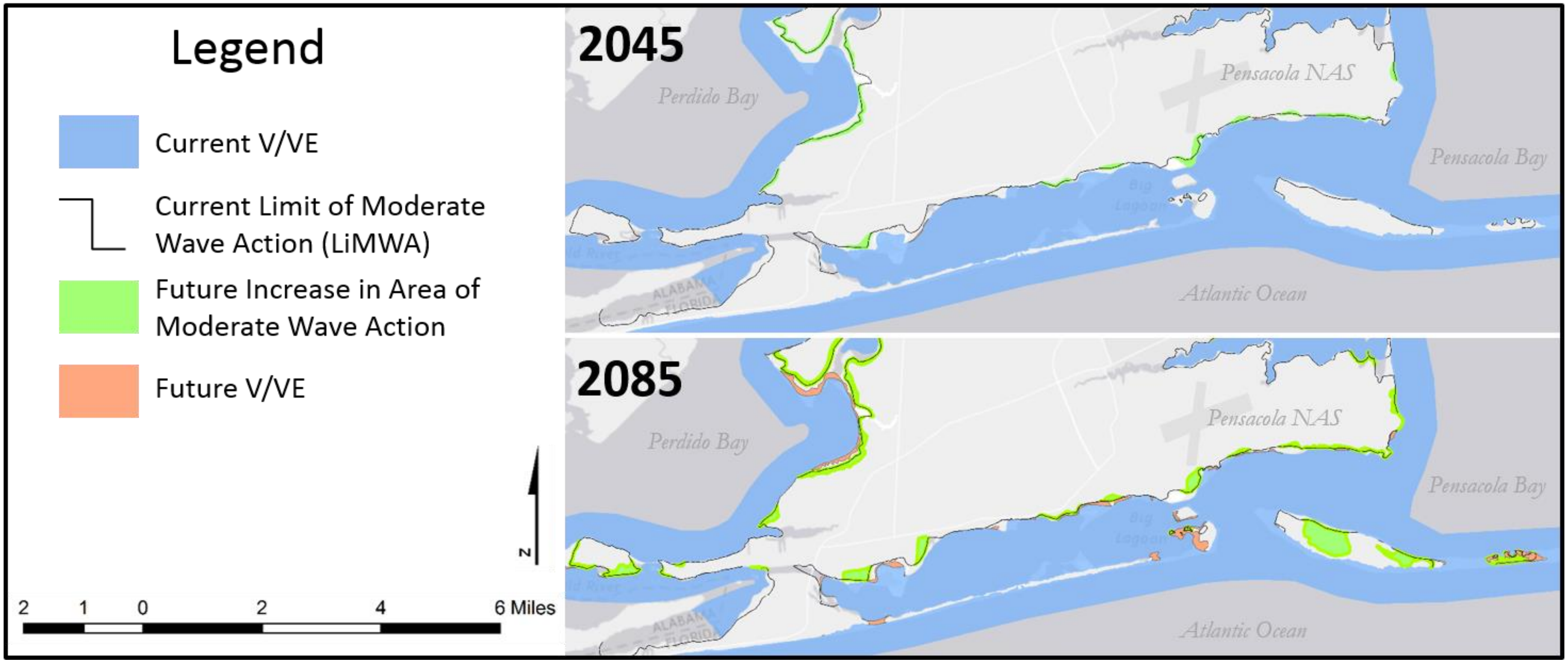

Figure 26. Changes in the VE and LiMWA for Perdido Key, the western end of Pensacola Beach, and south Escambia County for the short- the long-term time horizons. Changes depict response to wave hazards to the Medium SLR scenario. Note that the floodplain is not shown to more clearly illustrate changes to the wave hazard zones.

5 ASSET EXPOSURE ASSESSMENT

The objective of the asset exposure assessment was to identify assets impacted by different flood hazard types with SLR and to summarize key impacts. In order to evaluate asset exposure in Escambia, the analysis focused on three main assets categories, presented in the following table.

Asset	Information Analyzed for Each Asset
Parcel Vulnerability	• Number of vulnerable parcels
Road Vulnerability	• Miles of network affected
Bridge Vulnerability	• Bridges impacted
Community Facilities	• Identified vulnerable structures

Exposure to the above assets was evaluated against each flood type and scenario by using a GIS overlay approach, where the mapped flooding extents were overlaid on top of assets, which is described in more detail in Appendix A.

Data layers were selected for attribution based on community preferences as defined during the design meeting in conjunction with the availability and quality of geospatial data. Escambia County provided limited data outside of land parcel and stormwater system information. Road data for this task were sourced from U.S. Census TIGER files. Other facility and asset data were sourced from the State of Florida HAZUS database. Escambia parcel data were leveraged from internal data holdings.

5.1 What is the Vulnerability of County Land Parcels to Increased Flooding?

The study effort identified the number of land parcels subject to each flooding type and SLR scenario. Building footprints would allow a better assessment of vulnerability, as some parcels are undeveloped and periodic flooding of such areas would not pose any loss to the County. Additionally, some parcels are large and buildings may be sited in less vulnerable sites within the parcel. For reference, a total of 155,790 parcels existing in the parcel file provided by the County.

Overall, the greatest potential for a change in exposure of parcels in unincorporated areas is to the 0.2% annual chance flood event. In contrast, the greatest changes in parcel exposure within the City of Pensacola were to the 1% annual chance event.

Summary of changes:

- Daily Tidal Flooding (MHHW):
  - 2045: Parcel exposure increases range from about 200 to 1,700 additional parcels across the range of future SLR scenarios. The Medium SLR scenario increases exposure by 5% over today's condition.
  - 2085: Increases range from approximately 300 to 8,600 across the range of future SLR scenarios. The Medium SLR scenario increases exposure by 17% over today's condition.

- 1% Annual Chance Floodplain:
  - 2045: Parcel exposure increases range from about 100 to 1,500 additional parcels across the range of future SLR scenarios. The Medium SLR scenario increases exposure by 2% over today's condition.

- 2085: Increases range from approximately 400 to 5,700 across the range of future SLR scenarios. The Medium SLR scenario increases exposure by 7% over today's condition.

- 0.2% Annual Chance Floodplain:
  - 2045: Parcel exposure increases range from about 400 to 2,200 additional parcels across the range of future SLR scenarios. The Medium SLR scenario increases exposure by 3% over today's condition.
  - 2085: Increases range from approximately 700 to 6,100 across the range of future SLR scenarios. The Medium SLR scenario increases exposure by 7% over today's condition.

Total counts of exposed parcels are provided for unincorporated areas of Escambia County in Table 5, the City of Pensacola in Table 6, and total exposed parcels are reported in

Table 7.

Table 5. Total exposed parcels in unincorporated areas of Escambia County for all flood types and SLR scenarios combinations.

Time Horizon	SLR Scenario	MHHW	1% Floodplain	0.2% Floodplain
Today	Baseline	5,071	20,109	22,697
2045	Low	5,248	20,212	23,070
	Medium	5,303	20,425	23,286
	High	5,908	21,112	24,164
	Highest	6,543	21,427	24,594
2085	Low	5,303	20,425	23,286
	Medium	5,908	21,112	24,164
	High	10,095	23,429	26,809
	Highest	13,017	24,509	28,025

Table 6. Total exposed parcels in the City of Pensacola for all flood types and SLR scenarios combinations.

Time Horizon	SLR Scenario	MHHW	1% Floodplain	0.2% Floodplain
Today	Baseline	593	2,081	3,124
2045	Low	618	2,089	3,194
	Medium	633	2,141	3,225
	High	745	2,548	3,379
	Highest	771	2,657	3,436
2085	Low	633	2,141	3,225
	Medium	745	2,548	3,379
	High	889	3,213	3,730
	Highest	1,229	3,374	3,896

Table 7. Total exposed parcels in Escambia County for all flood types and SLR scenarios combinations.

Time Horizon	SLR Scenario	MHHW	1% Floodplain	0.2% Floodplain
Today	Baseline	5,664	22,190	25,821
2045	Low	5,866	22,301	26,264
	Medium	5,936	22,566	26,511
	High	6,653	23,660	27,543
	Highest	7,314	24,084	28,030
2085	Low	5,936	22,566	26,511
	Medium	6,653	23,660	27,543
	High	10,984	26,642	30,539
	Highest	14,246	27,883	31,921

5.2 What Roads Are Vulnerable to Increased Flooding?

A total of 3,100 miles of road network were evaluated against the coastal flooding data to evaluate changes in exposure with SLR. The total length of roads exposed to each flood condition is reported in

.

Summary of changes, presented graphically in Figure 27 (short-term) and Figure 28 (long-term):

- Daily Tidal Flooding (MHHW)
    - 2045: Escambia has negligible exposure to changes in road flooding from daily tides in the short-term.
    - 2085: Road exposure increases significantly in the context of the High and Highest SLR scenarios. A 1.5-fold increase in vulnerability is estimated for the Medium SLR scenario.

- 1% Annual Chance Floodplain:
    - 2045: A notable increase in road exposure is apparent between the Medium and High SLR scenarios.
    - 2085: Road vulnerability sees step-wise gains in exposed miles with each increasing SLR scenario.

- 0.2% Annual Chance Floodplain:
    - 2045: Road exposure gradually increases with increasing SLR scenario, with an additional 17 miles of roads vulnerable to flooding with a Medium SLR scenario.
    - 2085: Similar to changes in exposure for the 1% annual chance floodplain, road vulnerability under this condition sees step-wise gains in exposed miles.

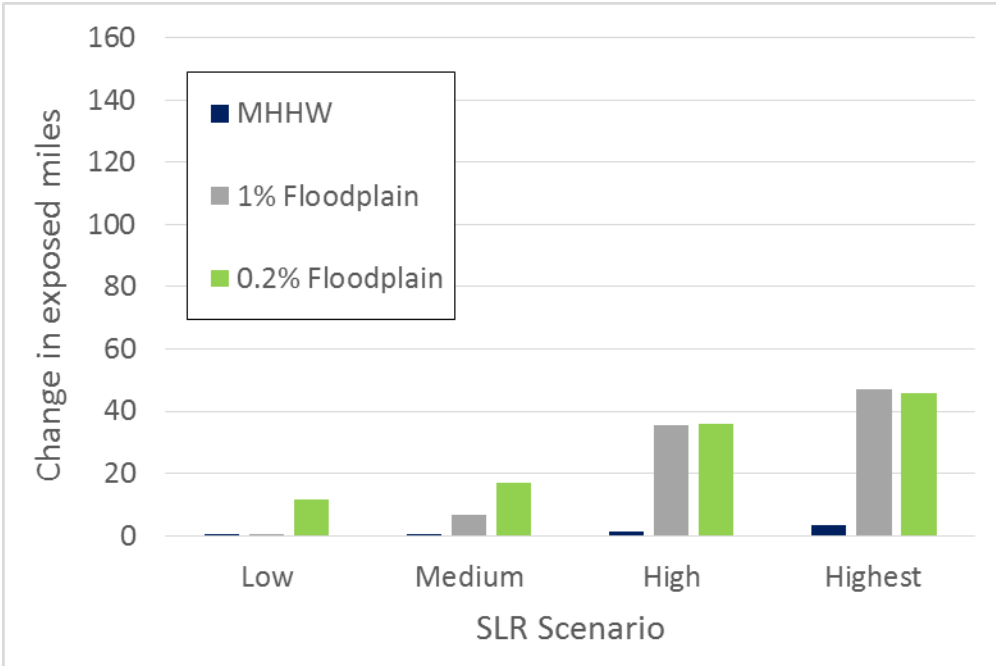

Figure 27. Projected short-term (2045) changes in road exposure to each flood type and projected SLR.

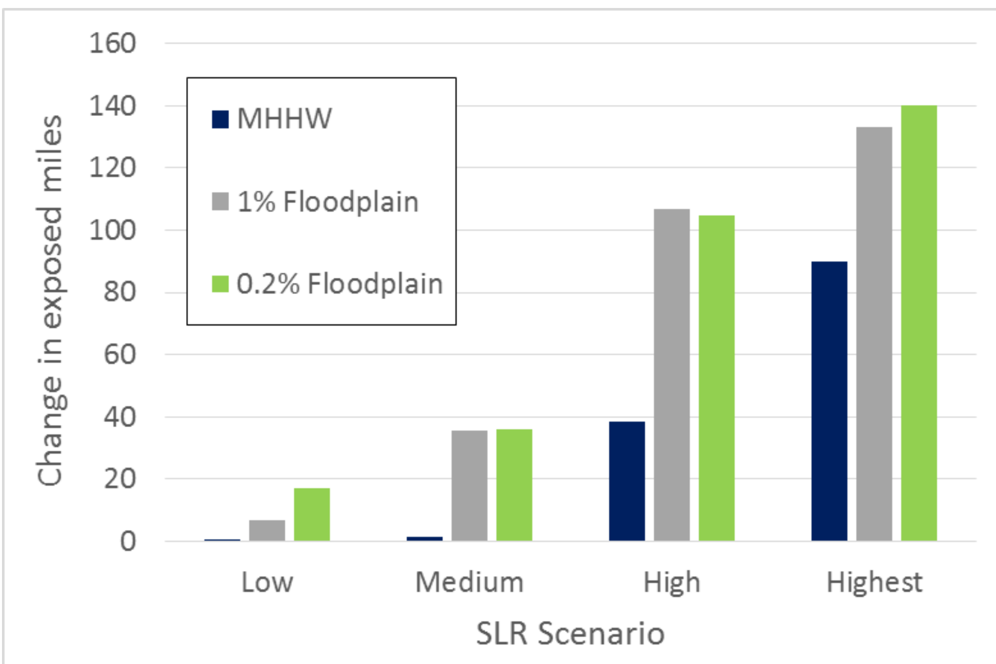

Figure 28. Projected long-term (2085) changes in road exposure to each flood type and projected SLR scenario.

Table 8. Total road exposure to each flood condition and SLR scenario. Units of linear miles.

Time Horizon	SLR Scenario	MHHW	1% Floodplain	0.2% Floodplain
Today	Baseline	0.9	230.3	319.5
2045	Low	1.0	230.7	331.0
	Medium	1.1	237.0	336.6
	High	2.4	265.9	355.6
	Highest	4.2	277.3	365.3
2085	Low	1.1	237.0	336.6
	Medium	2.4	265.9	355.6
	High	39.3	337.0	424.4
	Highest	90.8	363.4	459.8

5.3 How Vulnerable Are Bridges to Future Increases in Coastal Flooding?

Bridge vulnerability to the different flood hazard types with SLR was evaluated in order to identify potential issues with bridge passability under future conditions. It should be noted that bridge deck elevation data was not provided as part of this study. Bridges could appear "vulnerable" if a simple overlay of the floodplain and bridge location were performed without consideration to deck height. To limit potential misclassification, the vulnerability of bridges was determined by inspecting the floodplain extents and bridge approaches. When bridge approaches were inundated by a particular flood type and SLR scenario, the bridge was deemed to have limited passability.

Overall, bridge vulnerability does not significantly increase except for the 1% and 0.2% annual chance flooding conditions combined with the High and Highest scenarios. Counts of bridges with impaired passability for each scenario are provided in Table 9.

Summary of main vulnerabilities, presented graphically in Figure 29 (short-term) and Figure 30 (long-term):

- Daily Tidal Flooding (MHHW)
  - 2045:
    - U.S. 90 at the Escambia River (Medium scenario)
  - 2085:
    - U.S. 90 at the Escambia River (Low scenario)
    - U.S. 98 across Perdido Bay (Highest scenario)
    - State Route (SR) 399 between Gulf Breeze and Santa Rosa Island (Highest scenario)
    - Quinette Rd across Escambia River (Highest scenario)

- 1% Annual Chance Floodplain:
  - 2045:
    - U.S. 98 across Pensacola Bay (High scenario)
    - U.S. 90 across Perdido River (Highest scenario)
  - 2085:
    - U.S. 98 across Pensacola Bay (Medium scenario)
    - U.S. 90 across Perdido River (High scenario)

- 0.2% Annual Chance Floodplain:
  - 2045:
    - U.S. 90 across Perdido River (Highest scenario)
  - 2085:
    - U.S. 90 across Perdido River (High scenario)
    - U.S. 90 across Styx River (Highest scenario)
    - Interstate 10 across Pensacola Bay (Highest scenario)
    - Interstate 10 across Perdido River (Highest scenario)
    - SR112 across the Perdido River (Highest scenario)

Table 9. Number a bridges with impeded passability for each flood event and SLR scenario combination.

Time Horizon	SLR Scenario	MHHW	1% Floodplain	0.2% Floodplain
Today	Baseline	0	9	13
2045	Low	0	9	14
	Medium	1	9	15
	High	1	10	15
	Highest	1	14	16
2085	Low	1	9	15
	Medium	1	10	15
	High	1	16	17
	Highest	4	16	22

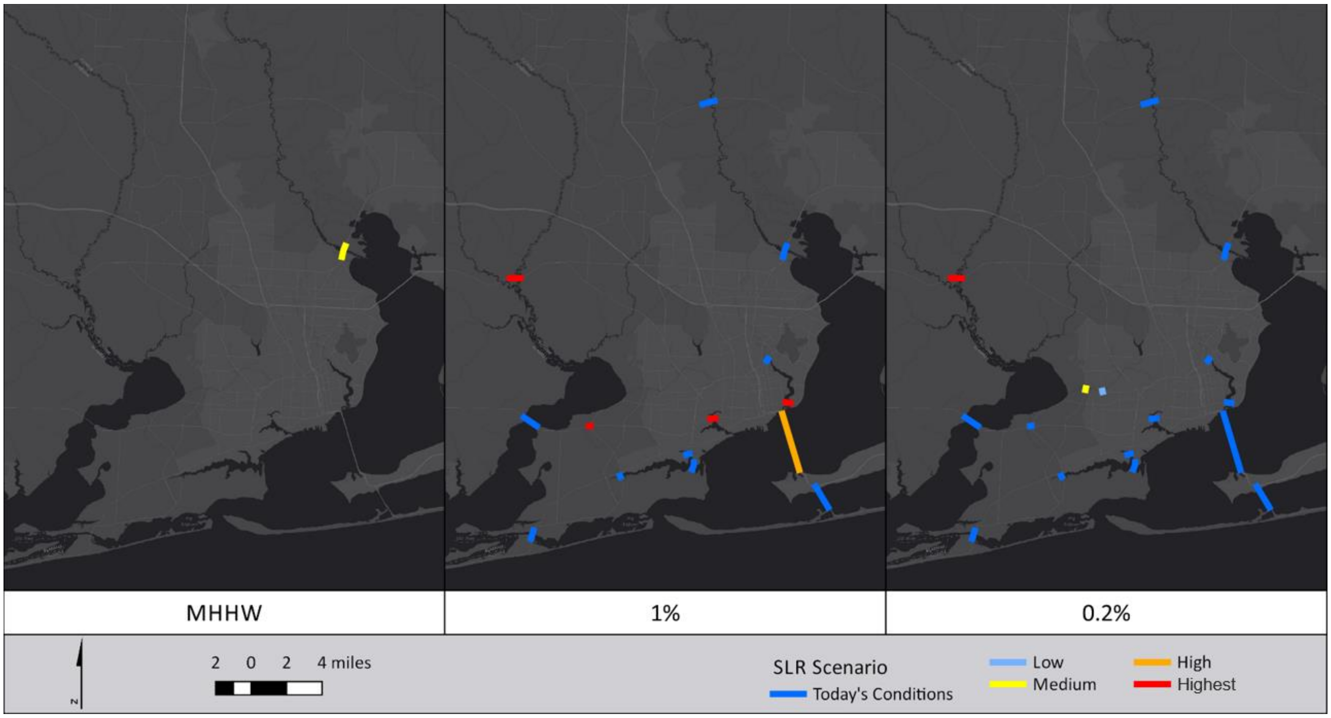

Figure 29. Short-term (2045) projections of the earliest scenario that would affect bridge passability for each flood type and SLR scenario combination.

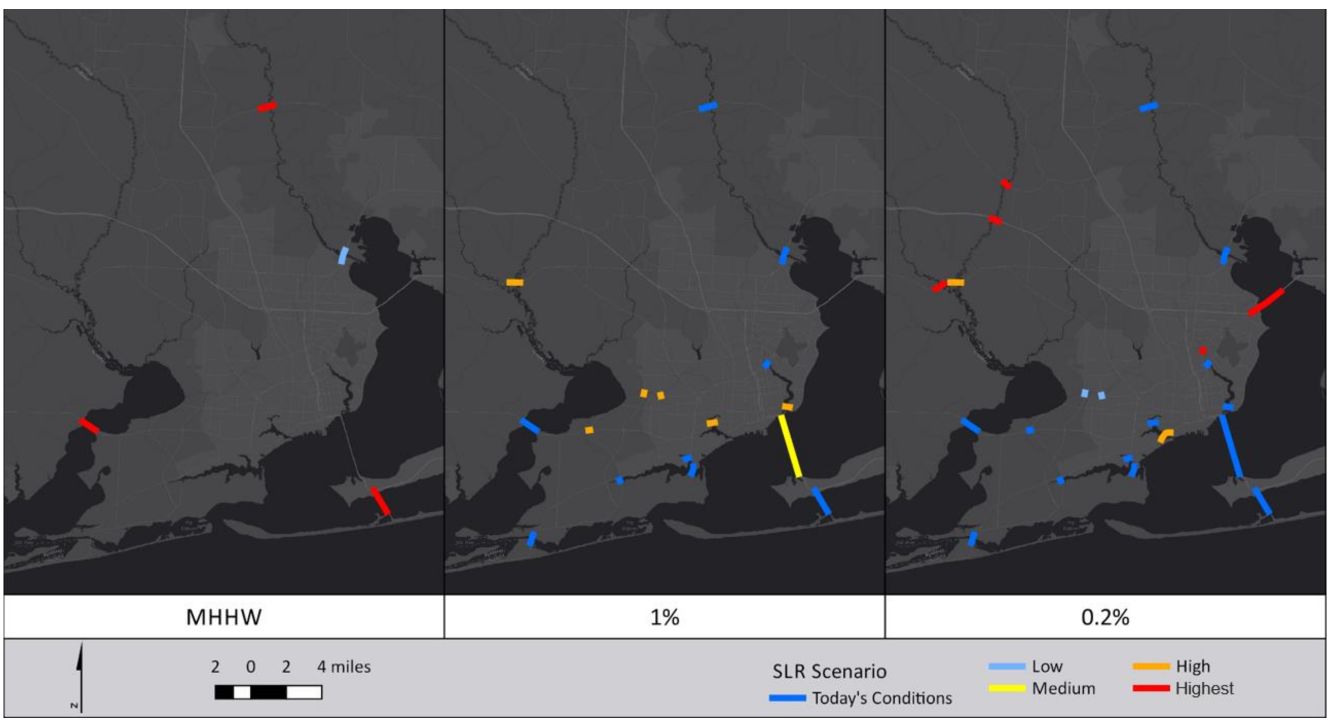

Figure 30. Long-term (2085) projections of the earliest scenario that would affect bridge passability for each flood type and SLR scenario combination.

5.4 How Will SLR Impact Community Infrastructure?

Community infrastructure exposure to flooding was evaluated in order to identify impacts to critical community assets. The GIS analysis revealed the following findings:

- Educational Facilities (Table 10)
  - Daily Tidal Flooding (MHHW):
    - Of 112 educational facilities, none are impacted by changes to existing or future daily tidal flooding.
  - 1% Annual Chance Floodplain:
    - Four facilities are exposed to flooding under existing conditions, three additional facilities have exposure to higher level SLR projections in 2045 and 2085.
  - 0.2% Annual Chance Floodplain:
    - A total of 6 facilities are presently exposed to this flood type, this is expected to increase to 8 facilities with higher level scenarios in 2045 and 2085.

Table 10. Summary of educational facility exposure to each flood type and SLR scenario.

Educational Facilities	MHHW		1%		0.2%	
	2045	2085	2045	2085	2045	2085
Virginia College			High	Medium	Today	Today
Pleasant Grove Elementary School				Highest	High	Medium
St. John the Evangelist School			Today	Today	Today	Today
Pensacola Beach Charter School			Today	Today	Today	Today
George S. Hallmark Elementary						High
Seville Montessori School			Highest	High	Today	Today
Redeemer Lutheran School			Today	Today	Today	Today
Escambia County Superintendent's Office			Today	Today	Today	Today

- Hospitals
  - There are no hospitals in the floodplain under any scenario.

Of the 39 fire and police facilities in Escambia County, up to 25% are projected to be vulnerable to flooding under higher SLR scenarios. Seven facilities are vulnerable to existing flood conditions:

- Police, Fire and Emergency Facilities (Table 11)
  - Daily Tidal Flooding (MHHW):
    - Vulnerability is low, with only a single facility exposed under the highest SLR scenario in 2085.
  - 1% Annual Chance Floodplain:
    - Two facilities are exposed to existing conditions.
    - An additional five facilities will be exposed in 2045 under a High SLR scenario.
    - In 2085, the total number of exposed facilities could be as high as nine, including five Fire and EMS stations on the Naval Air Station.

- 0.2% Annual Chance Floodplain:
  - Seven facilities are exposed to flooding under current conditions;
  - Two additional facilities are exposed with SLR in 2045;
  - Four additional facilities, for a total of 11 are exposed by 2085.

Table 11. Summary of emergency facility exposure to each flood type and SLR scenario.

Emergency Facilities	MHHW		1%		0.2%	
	2045	2085	2045	2085	2045	2085
Escambia County EMS Station 13		Highest	Today	Today	Today	Today
Escambia County EMS Station 14				Highest	High	Medium
Innerarity Point Fire Station 8				High	Low	Medium
NAS Fire & EMS Station 1			High	Medium	Today	Today
NAS Fire & EMS Station 2			High	Medium	Today	Today
NAS Fire & EMS Station 3			High	Medium	Today	Today
NAS Fire & EMS Station 4			High	Medium	Today	Today
NAS Fire & EMS Station 5			High	Medium	Today	Today
Pensacola State College Police Dept.						High
Perdido Key Fire Department			Today	Today	Today	Today
Warrington Fire District						Highest

6 FUTURE CHANGES TO PRECIPITATION

Historical and projected changes in future precipitation were reviewed at the local and national levels in order to evaluate potential changes in frequency of heavy rainfall events.

A summary of the methodologies for evaluating changes to precipitation is presented first, followed by the results of the analysis.

6.1 How Were Precipitation Projections Developed?

This study evaluated changes to the 24-, 48- and 72-hour events in addition to percentage and absolute change in precipitation intensity. The research team evaluated historical and projected precipitation changes through the following tasks:

1. Literature review.
2. Establish benchmark statistics for historical period.
3. Obtain downscaled climate projection for Escambia County.
4. From daily data, determine recurrence statistics.
5. Focus on 24-hour 25-year and 100-year rainfall events.
6. Evaluate potential changes in frequency of heavy precipitation.

6.2 What are the Changes in Frequency of Heavy Precipitation Events in the Recent Past?

Pensacola (Escambia County) is located on the west coast of Florida with a Koppen climate classification of "humid subtropical". Data from the Southeast Regional Climate Center was accessed to investigate rainfall statistics. Analysis showed that the area experiences frequent rainfall, quite often in the form of thunderstorms. There is a subtle, but statistically significant wet season from June through September, with average monthly precipitation during that period being about 40% higher than the remaining months.

NOAA Atlas 14 Volume 9 (Perica et al. 2013) was used to analyze heavy rainfall recurrence statistics for the area. Figure 31 shows the Depth-Duration-Frequency curve which shows rainfall intensity as a function of duration, ranging from 5-minutes to 60-days. Colored lines show how rainfall increases with rarer recurrence intervals, ranging from 1 year to 1000 years. The particular focus herein is the 24-hour event, in particular the 25-year and 100-year return periods, partially based on information found in the Escambia County Storm Water Advisory Team's Execute Summary Report (2015). In addition, the 24-hour timeframe is also a good proxy of tropical storm and hurricane induced rainfall, which are an important contribution to the heavy rainfall statistics for Pensacola. In fact, more than 50% of the heavy rainfall events are caused by tropical cyclones in the area (Figure 32).

From Figure 31, it is seen that the Atlas 14 value for the 25-year 24-hour event is 9.2 inches, while incorporating the uncertainty at the 90% confidence level yields a range of 7.6 to 12.2 (not shown). The 100-year 24-hour event is 13.3 inches, with a range from 10.2 to 18.2.

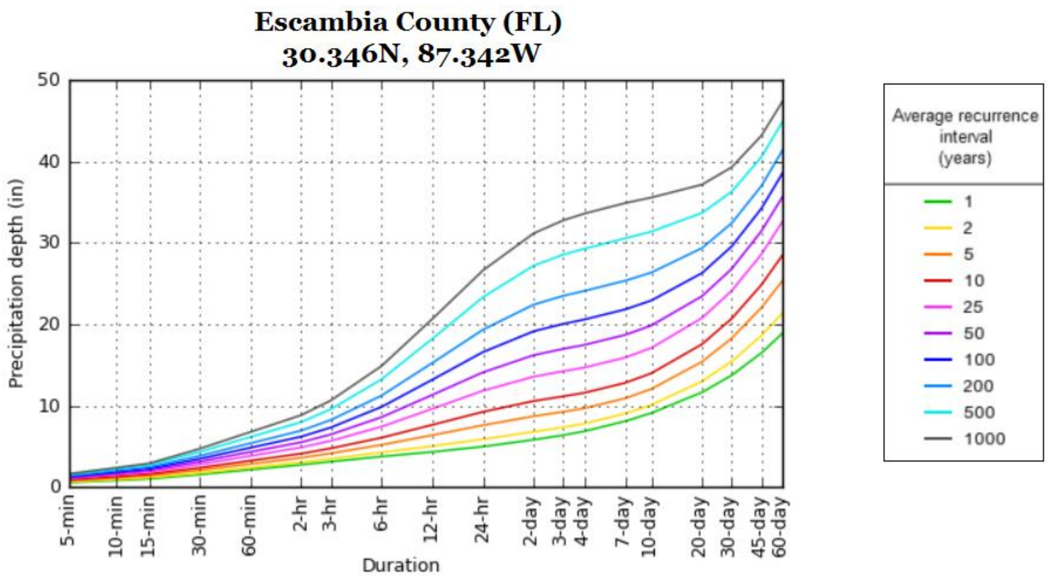

Figure 31. Depth-Duration-Frequency curve for Escambia County. Source: NOAA Atlas 14, Volume 9, Version 2.

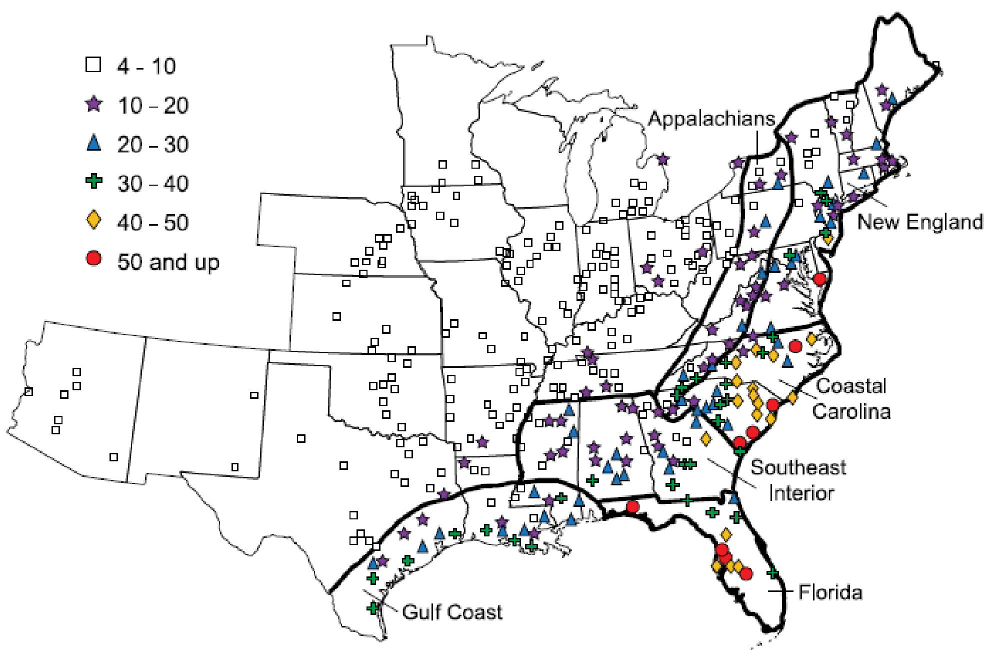

Figure 32. Percent of heavy events associated with tropical cyclones (TC) at individual stations (delineated by color and symbol type) and regional groupings (delineated by thick black lines). Only stations with at least 1 TC-associated event are plotted. Source: Figure 3 from Kunkel et al. 2010.

Figure 33 shows the Atlas 14 seasonal decomposition for the 24-hour event. There is a distinct peak across all recurrence intervals from August to November, coincident with climatological peak of the Atlantic tropical cyclone season. Interestingly, there is an additional peak in March and April that is indicative of stationary frontal rainfall that occurs in the area. This appears to be unique to the Florida panhandle and does not occur elsewhere in the state. Nonetheless, Figure 33 indicates that the chances of receiving very heavy rainfall (100-year event) are especially high in September compared to the other months.

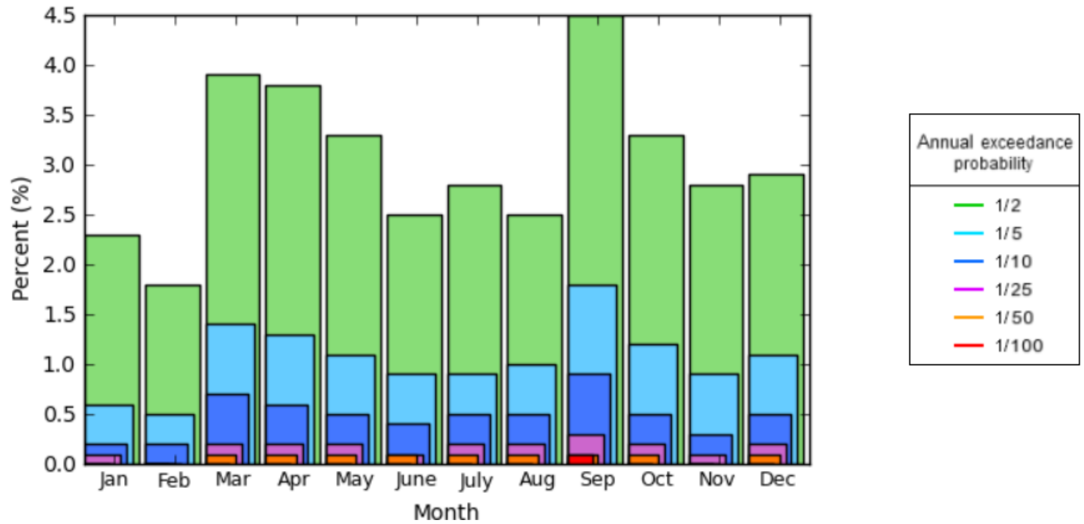

Figure 33. Seasonal decomposition of heavy rainfall recurrence probability using the 24-hour duration. Source: NOAA Atlas 14, Volume 9, Version 2.

In terms of historical precipitation change at the national level, the analysis of observed heavy rainfall statistics since 1958 show a 27% increase in frequency in the Southeastern U.S. (Figure 34). This statistic is particularly relevant to coastal flood hazard vulnerability because when coastal flooding, storm surge, and heavy precipitation co-occur, the potential for flooding in low-lying areas is often much greater than from either in isolation.

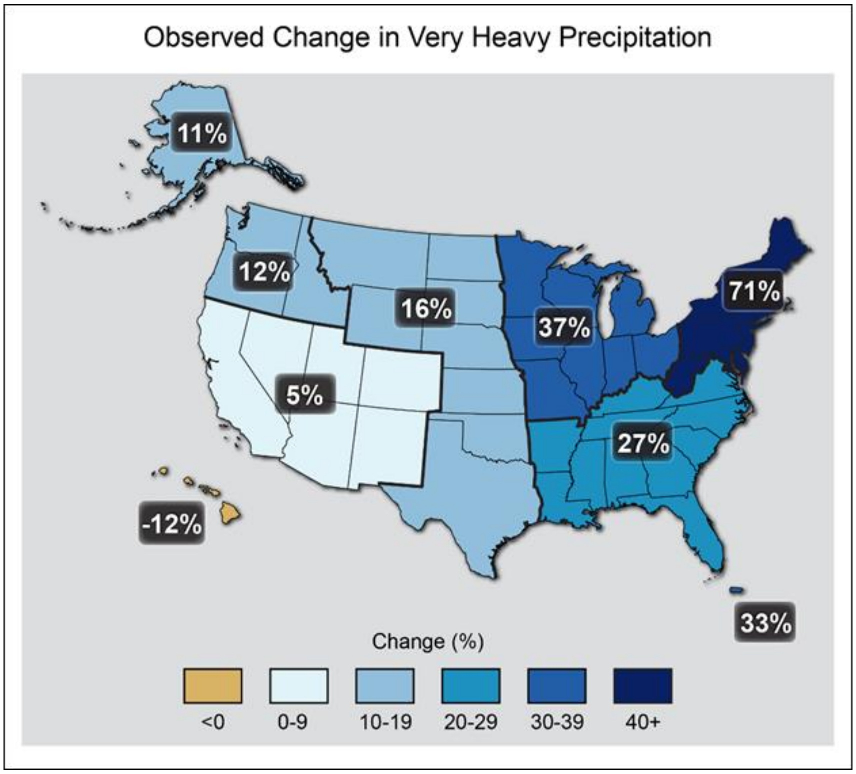

Figure 34. Observed change in heavy precipitation events (i.e. downpours, the heaviest 1% of annual rainfall events). The estimate over Florida shows a 27% increase in occurrence. However, a local analysis could reveal slightly different results depending on which exact rainfall gage is considered. Graphic obtained from the 2014 National Climate Assessment.

6.3 How Will the Frequency of Heavy Precipitation Events Change in the Future?

As of this writing, national and international data sources for climate data include the following:

- **The U.S. Global Change Research Program (USGCRP).** This is the organization responsible for producing the National Climate Assessment. The website contains links to both historical and projected climate data sets.
- **www.data.gov/climate.** The US government's open data catalog, which includes useful products such as storm data, hurricane tracks, 15 minute and hourly precipitation, and river forecasting center outputs. Downscaled (relatively fine resolution) future projections made available through the United States Geological Survey are also linked at this site.
- **The Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report.** The IPCC is an international entity that produces climate assessment reports at regular intervals. Their Data Distribution Center includes historical estimates from 1960-1990, global climate models (GCMs), socio-economic scenarios, scenarios for other environmental changes, and a number of other resources. The latest set of model simulations is the Coupled Model Intercomparison Project Phase 5 (CMIP5).

These catalogs are notable for having historical, projected, and other supporting data sets in a single location. Although this list is not exhaustive, the three sources indicated below are an excellent starting point for organizations seeking to obtain up-to-date data from a reputable source.

Figure 33Figure 35 shows future projections for precipitation, specifically, heavy precipitation events. Model results estimating future annual precipitation totals are somewhat mixed for much of the continental United States. However, both the historical record (Figure 34) and future projections are in agreement that heavy precipitation events (i.e. downpours as well as prolonged heavy rain events) are on the rise.

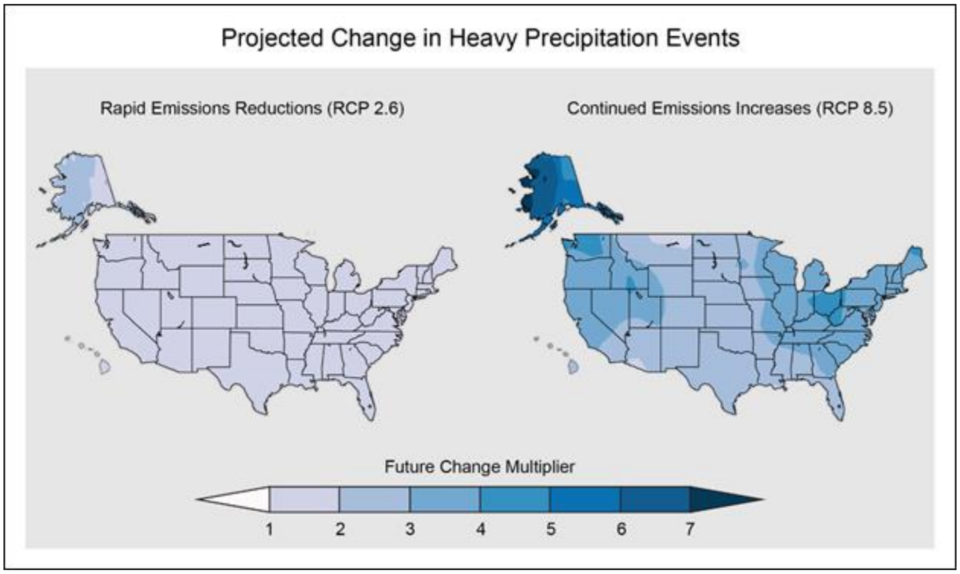

Figure 35. The most recent climate data uses four future emissions scenarios (representative concentration pathways, or RCPs). The figure above shows projected changes under the highest (RCP 8.5, "business as usual") and lowest (RCP 2.6, rapid and sustained decrease of emissions) scenarios. Projections are for the 20-year event, which has a 5% chance of being equaled or exceeded in a given year. Future change multiplier indicates frequency, meaning under the low scenario, heavy precipitation events in Clearwater may occur up to twice as often by the late 21st century, whereas in the high emissions scenario, these events would occur between two and three times as often.

Local, county specific estimates of future precipitation were made for three time periods, each having a duration of 30 years: (1) a historical period (1980 – 2009), (2) a mid-term outlook (2030 – 2059), and (3) a long-term outlook (2060 – 2089).

Estimates of the peak 24-hour rainfall event for recurrence intervals up to 200 years were made using combined data from eight different General Circulation Models (Table 12) and the HydroMetriks – Frequency/Intensity Tool (Hydro-FIT).

Table 12. Downscaled daily precipitation data was accessed for the following GCM simulations.

CESM1-BGC	CESM1-CAM5	MPI-ESM-MR	GFDL-ESM2M
GFDL-ESM2G	HadGEM2-ES	HadGEM2-AO	ACCESS1-0

Figure 36 shows a projected increase of rainfall intensities across all recurrence intervals during for the long-term projection, while the mid-term projection shows mixed results with a slight decrease at rarer recurrence intervals. Table 13 lists the specific values for changes in the 24-hour 25-year and 100-year event (compared to the historical period).

Overall, the projected changes are relatively small and within the bounds of the error of the historical data. These results indicate that is it not likely that a significant change in rainfall intensity will occur. It is important to note that these estimates may be conservative given that the statistically downscaled precipitation data used in this analysis does not fully capture the impact of changes in tropical cyclone activity. For example, if one compares the above results to the NOAA Atlas 14 estimated 100-yr exceedance event mentioned above (16.5 inches with 90 percent confidence limits of 12.9 inches to 20.9 inches), the NOAA value is about twice as high as the values that were estimated based on the GCM data for each time period.

It should also be noted that this does not undermine the analysis this portion of the study is focused on projecting changes using a consistent framework, which this dataset allowed the research team to do. In other words, the focus of this analysis was on the *relative changes* between the historical period and the future projection. In relation to the tropical storm and hurricane impact, peer-reviewed scientific literature confirms that rainfall increases of about 10% can be expected across the entire area of a tropical storm/hurricane, however localized changes of up to 30% can be expected especially near the inner core of a stronger hurricane.

Table 13. Projected percent increases in 24-hour 25-year and 100-year rainfall for the mid-term and long-term periods.

24-hour duration event	Mid-term (2045)	Long-term (2085)
25-year recurrence interval	0%	+7%
100-year recurrence interval	-3%	+3%

Although the projected increases in rainfall may not appear all that large, they may still impact design criteria. This is also confirmed by the Storm Water Advisory Team's Executive Summary Report (2015). For example, the current 24-hour 100-year design value is about 14 inches, which is based on outdated rainfall recurrence statistics from the US Weather Bureau's TP40 report in 1963. That value is about 15% less than the Atlas 14 value (and 33% less if we use the upper bound of the Atlas 14 estimate of 20.9 inches). This suggests there may be a benefit to update standards to incorporate NOAA Atlas 14, which also includes the added benefit of uncertainty estimates unlike many past rainfall recurrence atlases such as the commonly used US Weather Bureau's TP40.

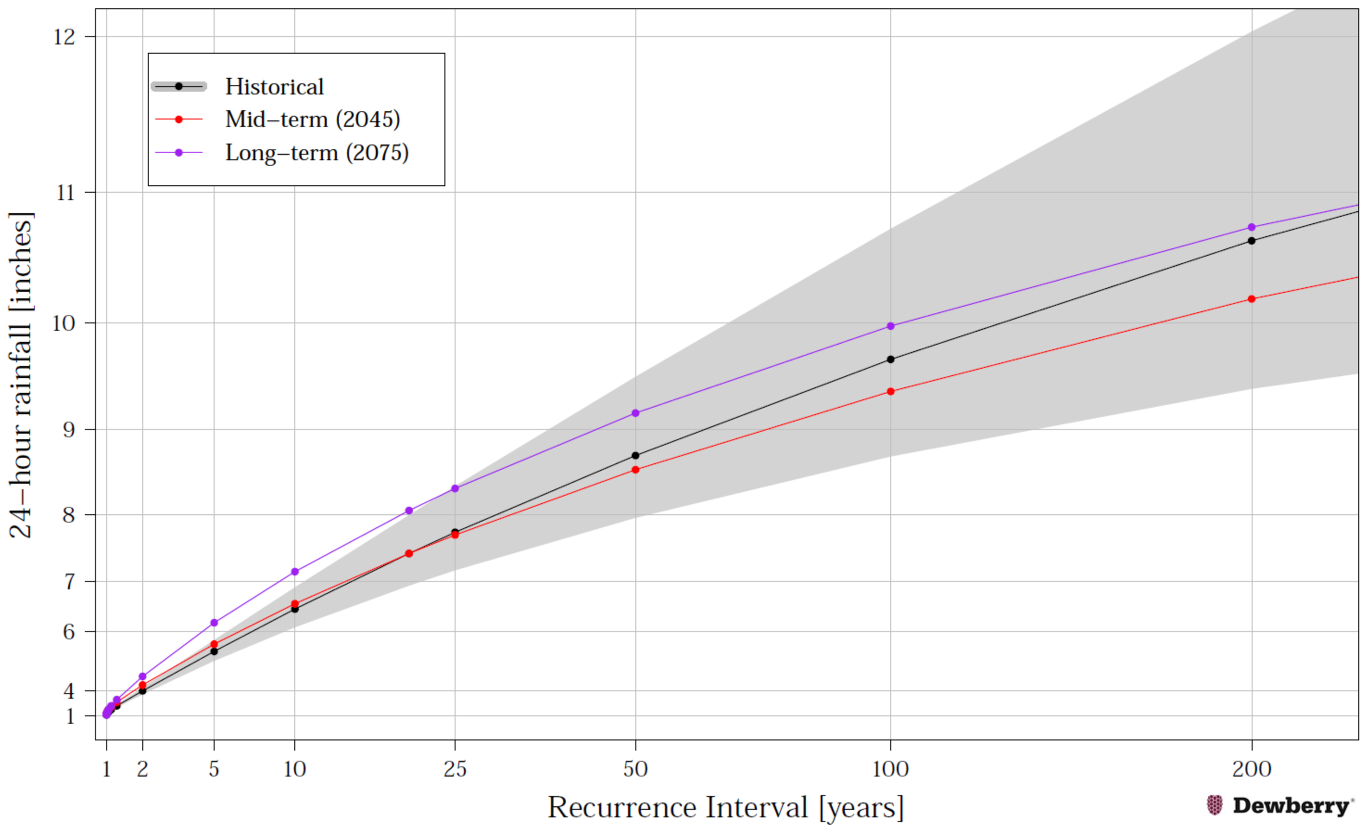

Figure 36. Estimated annual 24-hour peak precipitation amounts using data from the years 1980 – 2009 (historical; black line with gray shading showing the error range), 2030 – 2059 (mid-term outlook; red line), and 2060 – 2089 (long-term outlook; purple line), based on composite analysis from eight different GCMs.

The black line represents fits to the historical GCM data by fitting the Generalized Extreme Value (GEV; orange) and Pearson Type III (PE3; blue) distributions and then averaging; The red line represents the most likely fit to the mid-term outlook, while the purple line represents the most likely fit to the long-term outlook. The GEV and PE3 distributions were found to be the two distributions out of 13 tested that produced the best fits to the GCM data. The grey bounds represent the range of historically observed precipitation data (i.e. historical error range). This means that where the projected increases in rainfall intensity fall outside of the historical error range, it is likely that there will be a significant change in rainfall intensity.

7 STORMWATER SYSTEM VULNERABILITY

A qualitative review of the vulnerability of Escambia's Stormwater system was performed through the study effort. The overall objective of the stormwater system vulnerability portion of this study was to evaluate cumulative impacts and critical issues associated with Escambia County's existing stormwater system. Specifically, the research team focused on the following tasks to achieve this objective:

- Identify historical and existing stormwater standards.
- Discuss changes in tailwater over the historical record.
- Project changes in tailwater due to sea level rise and precipitation.

7.1 What are the Historical and Existing Stormwater Standards?

Escambia County comprises of two primary watersheds / drainage basins draining into the Escambia and Perdido Rivers. A total of forty sub-drainage basins drain into the individual rivers, tributaries directly and/or through a networks of pipes, manholes, swales and structures making this a complex interior drainage system. The two basins are subdivided into forty smaller drainage basins draining into the rivers shown in Figure 37, which also depicts the major basins and streams within the County.

A review of the 1994 Escambia County Stormwater Master Plan indicates that the interior stormwater infrastructure has been designed as per Florida Department of Transportation (FDOT) standards in the 1950's. Research by the SWAT indicates that a 100-year storm in the 1994 plan is currently being experienced four times a year (25% annual chance) in the last eighty years. The increase in frequency is expected for the lower intensity storms as well, which will overburden the existing systems. Table 14 shows a comparison of the design rainfall event that the systems are assumed to be designed for in comparison to the currently valid and more accurate NOAA Atlas 14 based point precipitation data for the region.

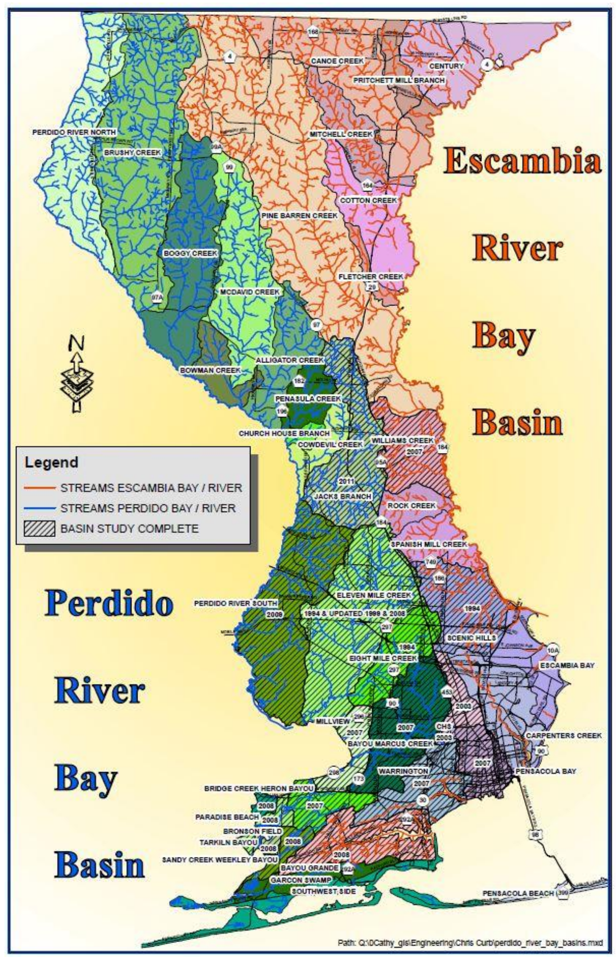

Figure 37. Major Basins and River Systems within Escambia County

Table 14. Overview of assumed historical and current stormwater design standards.

Duration	Rainfall depth in inches by recurrence interval					
	2-year	5-year	10-year	25-year	50-year	100-year
8-hr (assumed design event)	N/A	N/A	N/A	7.98	N/A	N/A
24-hr (current standards)	5.9	7.47	9.01	11.5	13.7	16.2

In addition to being under-designed, the existing system has experienced damages to interior infrastructure due to rising sea levels and major hurricanes and tropical storms. There has been a steady increase of 2 mm to 2.5 mm per year in mean sea level from 1923 to present (Figure 1), which indicates a 6" rise in sea level since 1950. With the changes in land use (increased urbanization) and increase in frequency and intensity of rainfall events, it is very likely that the stormwater infrastructure was challenged multiple times in the past sixty-six years. Several major hurricanes and tropical storms including Baker (Category 1, 1950), Hurricane Flossy (1956), Hurricane Eloise (1975), Hurricane Elena (1985), Hurricane Opal (1995), Hurricane Ivan (2004), Hurricane Dennis (2005) have impacted the area causing damage to an under-designed interior stormwater infrastructure.

7.2 What are the Key Stormwater System Issues and Vulnerabilities?

As noted in the previous section, the existing system may be under-designed (potentially at two-thirds capacity). Critical issues that increase vulnerability to the under-designed system are discussed in greater detail in the following text.

- Projected land use changes (increase in impervious cover) will likely aggravate the system's capacity issues
- Anticipated increased precipitation for the region may exacerbate system's capacity issues.
- Impacts to flood protection measures, interior drainage systems, and natural ecosystems.

Sedimentation, excessive benthic and vegetative growth that have been observed at the stormwater outfalls (

  - Table 15). Based on survey data from 2009 – 2015, Figure 38 shows the location of outfalls ad spillways that provide connection with Escambia, Perdido and Pensacola bays. Sizes of the outfalls located within Escambia County are between 24" to 160".
- Increase in SLR indicates lesser ability of gravity based drainage systems to effectively drain water out of upland areas through under designed, capacity-exceeded pathways (swale, ditch, canal, pond, etc.).
- Increase in storm surge downstream of a structure would mean early closure of the structures to avoid inland propagation of the surge, which will further worsen the flooding impacts.
  - Coastal structures which serve to maintain groundwater levels (prevent salt water intrusion) might already maintain canal elevations very close to the upper end of the normal tidal elevation range.
  - It is likely that spring tides already exceed the normal canal elevation, requiring gate closures during those periods.
  - It is likely that spring tides already exceed the normal canal elevation, requiring gate closures during those periods.

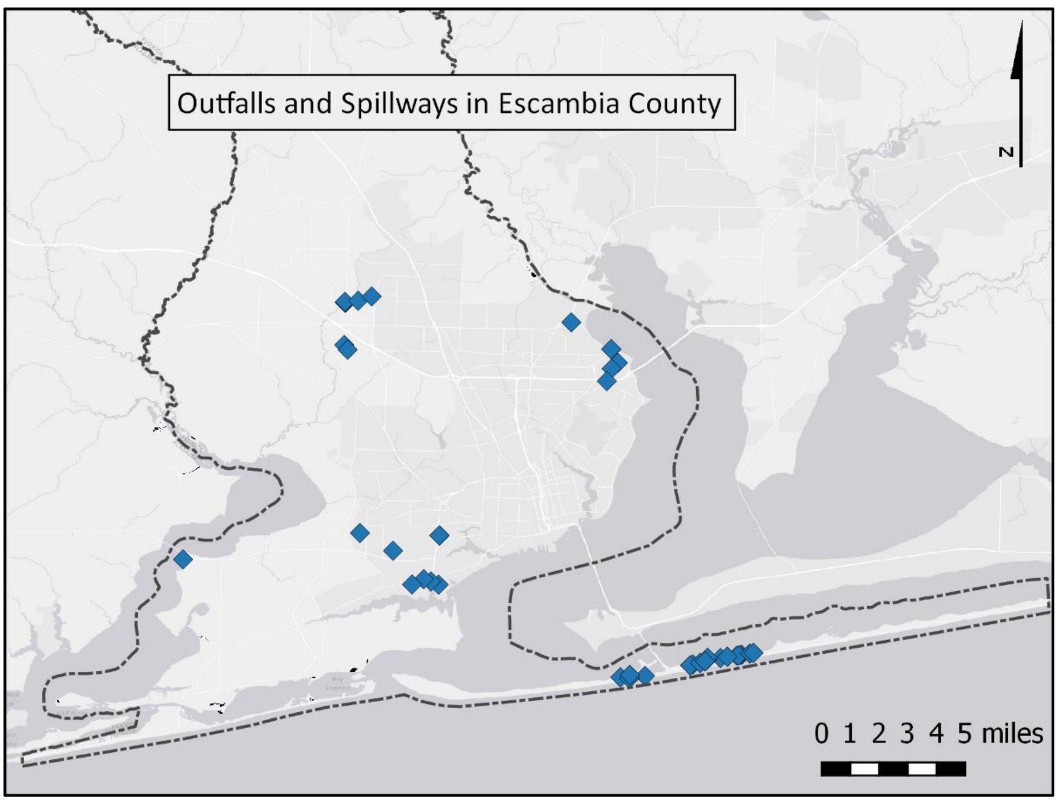

Figure 38. Outfalls and spillways in Escambia County as located in provided GIS data.

Table 15. Apparent conditions of major outfalls within Escambia County.

Outfall Designation	Outfall Size, inches	Assessed Condition
CMO2024	24	Benthic growth, bad pool quality. Needs flushed out
CMO1014	48	Benthic growth, spalling, cracking, chipping; corrosion
CMO1006	60	Eutrophication of water.
CMO1009	36	Excessive benthic growth
CMO1004	48	Excessive overgrowth
CMO1002	72	Sedimentation in outfall
CMO1007	36	Sedimentation
CMO1010	160	Benthic growth, sedimentation - needs dredge.
AVENIDA 11	45	Spalling, cracking, chipping, some damage
AVENIDA 14	36	Spalling, cracking, chipping, cracking only on face of outfall, sand built up blocking flow causing backup
AVENIDA 15 1/2	36	Petroleum stains along outfall odors; colors; excessive algae and deposits causing ponding
AVENIDA 20	48	Car parts, construction debris in outfall, spalling, cracking, chipping; corrosion, moderate wear, sediment basin needs cleaning
AVENIDA 22	36	Spalling, cracking, chipping, some damage, sediment basin needs to be cleaned, sediment buildup in pipe
AVENIDA 23	20	Trash blocking flow, spalling, cracking, chipping; excessive corrosion
STARBOARD	42	Excessive algae, benthic growth on rip rap
AVENIDA 18 1/2	30	Excessive algae, sediment basin needs cleaning
ENSENADA DOS	N/A	Spalling, cracking, chipping, sediment needs to be removed
217 PANFERIO	N/A	Spalling, cracking, chipping, corrosion
AVENIDA 16	N/A	Not an outfall - no discharge point directly to waterway vegetation provides buffer
CORTO	CONCRETE SWALE	Spalling, cracking, chipping, vegetation growing through cracks in swale provides buffer excessive algae, ponding at end of swale before discharging into water
ENTRANDA 1	SWALE	Excessive algae buildup at discharge point on rip rap
ENSANADO UNO	N/A	Spalling, cracking, chipping, lower portion cracked on rip rap
ENSANADO UNO	N/A	Sediment buildup in swale
ENSANADO DOS	N/A	Trash, sediment buildup in swale, swale needs to be cleaned out

8 DISCUSSION

The results of Escambia County's Vulnerability Assessment provide quantitative and qualitative building blocks for the next phase of the project, Adaptation Planning. The County's participants were instrumental in providing feedback throughout the project from the questionnaire, to the design meeting, to the review of draft results. In order to focus the assessment, the County chose to quantify land exposure to future tidal, 1%-, and 0.2%- annual chance flooding, identify flood hotspots, evaluate how wave hazard zones will respond to SLR, assess possible vulnerabilities to the built environment, forecast changes to precipitation, and evaluate stormwater system issues.

The uncertainties associated with sea level rise require the city to take a pragmatic approach as to how it proceeds with addressing the vulnerabilities identified in this report. This report is not meant to identify all possible future impacts from sea level rise but helps to prioritize those issues most concerning to the city staff at the present time and may serve as a starting point for additional vulnerabilities as the science changes and more planning resources become available. The results of this report and the documentation of the planning process throughout will be captured as part of the State's Community Resiliency Initiative and thus help other communities facing stressors from sea level rise.

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APPENDIX A: TECHNICAL APPROACH

A-1 Flood Hazard Elevations:

The mean higher high water datum (MHHW) tidal datum is defined by NOAA as the "The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch." In practice, elevations below this datum are typically "wetted" or "near-wetted" by tides on a daily basis by the higher high tide. A base, "present day" MHHW surface was established using the NOAA VDatum software, which provided for a continuous, spatially variable value across the community geography. The surface was created by first establishing a regular point grid over the study area. The point grid was then input into the VDatum software to return the MHHW elevation relative to NAVD88, the datum of the topographic base. The base coverage output from VDatum was limited to "water" areas, and did not intersect the topographic at the MHHW elevation. This was corrected by extrapolating the coverage until intersection was consistently achieved throughout the county.

The 1% annual chance floodplain is defined as the area that will be inundated by the flood event having a 1% chance of flooding of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. This area defines the Special Flood Hazard Area (SFHA) that is delineated on Federal Emergency Management Agency Flood Insurance Rate Maps. The 0.2% annual chance floodplain is also known as the 500-year recurrence interval. The base coastal flood elevations for these recurrence intervals data were sourced from the ongoing Flood Insurance Study update for Escambia County, FL. These data are considered provisional at the time of this effort. Permission to use the data in this study was granted by FEMA Region IV. Data were provided by FEMA as a raster surface that provided sufficient extent to geospatially model floodplains for all scenarios against the base topography.

A-2 Implementation of SLR conditions for each water level type

Changes to each coastal flood type were estimated by increasing the present day base surface elevations by the projected changes to sea level for each scenario. Implementation was accomplished by the method of linear superposition, which entails simple addition of the scenario to the base surface. For example, to achieve a scenario of 0.5 ft. above present day condition, 0.5 ft. was added to the baseline water surface elevation models.

Each selected scenario value (Table A-1) was assigned a model scenario designation (S1 – S6). Some SLR scenario values were identical, for example, the high scenario for 2045 and the intermediate value for 2085 both produce a relative SLR value of 1.4. In these cases, both scenarios were assigned the same scenario designation, as the flood elevations and vulnerability for the two different times would be identical for the purposes of this study. These model scenario designations presented in Table A-2 are used for data within the product deliverable.

Table A-1. Values extracted from the USACE and NOAA SLR curves and rounded to the nearest tenth of foot.

Time Horizon	USACE Low	USACE Intermediate	USACE High	NOAA High
Short-term (2045)	**0.4**	**0.6**	**1.4**	**1.8**
Long-term (2085)	**0.6**	**1.4**	**3.9**	**5.1**

Table A-2. Model scenario designations (S1 – S6). Scenario designations repeat because there are more than one time horizon/scenario combination that produce the same extracted value.

Time Horizon	Low	Intermediate-Low	Intermediate-High	High
Short-term (2045)	**S1**	**S2**	**S3**	**S4**
Long-term (2085)	**S2**	**S3**	**S5**	**S6**

A-3 Flood Layer Production:

Inundation and coastal flooding extents were established for each scenario and flood frequency by intersecting the WSEL raster surfaces with the topographic elevation models. The process resulted in raw polygon coverage representing the flood extent for each frequency. Flood extent coverages were post-processed to remove small artifacts, hydraulically disconnected areas, and to smooth boundary edges.

Automated post-processing for artifacts involved the removal of voids (relatively small areas surrounded by flooding) and islands (relatively small disconnected areas of flooding). Tolerances for voids and islands were evaluated and set at 22,500 and 40,000 square ft. The void tolerance was based on the desire to exclude un-inundated areas (such as an individual building footprint) less than 150 x 150 ft. Likewise, the island tolerance was based on the desire to remove insignificant disconnected areas less than 200 x 200 ft. After removal of the voids and islands, flood extent boundaries were smoothed with a tolerance of 20 ft.

The next processing step involved removing disconnected areas of flooding. The steps are described below:

- Disconnected polygons were evaluated for proximity to the main floodplain through an automated process. Polygons within 150 ft. of the main polygon were identified for inclusion in the draft floodplain (ancillary flood extent). This was followed by a second pass to identify polygons within 150 ft. of the ancillary floodplain for inclusion. The 150-ft distance was based on a representative four-lane highway, under which flooding could propagate through a culvert.
- A visual review of the automated process results was performed to confirm or change the exclusion/inclusion of disconnected polygons. This effort focused on larger areas of flooding that were disconnected by culverts.
- Floodplain extents were passed through a topologic enforcement process to ensure a lower-level floodplain did not exceed a higher level floodplain due to geo-processing or editing variances. This was accomplished by clipping lower-elevation floodplains to the next highest scenario floodplain for each flood type.

A-4 GIS Overlay on buildings and infrastructure:

Asset exposure was evaluated to each flood type and scenario. Data layers were selected for attribution based on community preferences as defined during the design meeting in conjunction with the availability and quality of geospatial data.

Escambia County provided limited data outside of stormwater system information. Road data for this task were sourced from U.S. Census TIGER files. Other facility and asset data were sourced from the State of Florida HAZUS database. Escambia parcel data were leveraged from internal data holdings.

For the selected data, three attribute fields, one corresponding to each flood type, were added to each data layer. A select by location query was performed for the set of floodplain layers for each flood type and SLR combination. At the completion of each query, feature selection was attributed to the scenario. Attribute values recorded for each asset represent the minimum SLR scenario that the feature was exposed to. For summary purposes, it is assumed that the feature is then exposed to all higher SLR conditions for that flood type. Null values (no exposure) were set to “-1”. Initial map, tabular or chart summaries of asset exposure are provided in the draft PowerPoints.

APPENDIX B: DESIGN MEETING

Attendees:

Name	Organization	Contact
Christian Wagley	Sustainable Town Concepts Escambia Restore Committee	christianwagley@earthlink.net
Brad Hinote	City of Pensacola	bradhinote@cityofpensacola.com
Chris Curb	Escambia County Stormwater	cacurb@myescambia.com
Carrie Stevenson	IFAS Extension	ctsteven@ufl.edu
Brad Hattaway	Escambia EM	Brad_Hattaway@co.escambia.fl.us
Rick O'Connor	Sea Grant	Roc1@ufl.edu
Darryl Boudreau	The Nature Conservancy	dboudreau@tnc.org
Tim Day	Escambia Co. Development Services	trday@co.escambia.fl.us
Brian, Krista, Chris	Dewberry	bbatten@dewberry.com krand@dewberry.com czambito@dewberry.com

Priorities:

- Impacts on public safety and critical infrastructure
- Floodplain management and stormwater (in-depth look at tailwater conditions)
- Increased precipitation

Breakout Session Action Items:

Floodplain Management Action Items
Code: build to VE standards in coastal Zone As. • Needs: maps of changes to Zone As
Investigate economic value of floodplain management • Development Services pursues
Re-define floodplain extents • Needs: maps (need metrics for impacts, such as acreage and homes affected) • Development Services guides scenario selection and timeframe
Establish credits for floodplain development • Development Services pursues
Discussion
• Coastal Zone A regulations may be appealing • Floodplains can serve as wildlife corridors and habitat • It would be useful to understand the degree of state vs. local control in coastal high hazard zones • Wetland management within conservation easements may be beneficial • Consider offering floodplain development credits in alignment with CRS • How big will the SLR effect be? • May be able to use protected floodplain to provide wetland mitigation credits • Could include language in easements to allow for management: beach dunes, storm damage • Option to develop a zoning category for floodplains, leading to less development with higher standards

- Return repetitive loss properties back to floodplain (apartment complex example may be helpful)
- What are the long-term costs of improper vs. proper development?
- Tell a story/build a case for economic value of floodplain management, such as impacts to Carpenter Creek. Sherry Harper at ISO may be able to help with CRS (currently a Class 6 community)
- Need to establish political buy-in for any proposed changes

Stormwater Action Items

Perform cost benefit analysis of implementing development impact or stormwater utility fees

- Development Services pursues (maybe with UWF's Haas Center)

Create sea level rise outfall map

- Needs: maps
- Chris from Escambia CO provides outfall maps and elevations (from basin studies)

Make downscaled precipitation data available to support LID pilot

- Needs: precipitation data
- Development Services provides:
    - Geographic areas
    - Wetlands
    - Intended use

Discussion

- Tailwater at outfalls impacts the drainage system upstream with SLR
- Stormwater infrastructure is aging; nuisance flooding is common
- Pipes are currently undersized. Where and how do we retrofit old, and what should the new standards be? Retrofits would need to accommodate business needs
- City cooperation would be needed to take a watershed approach to stormwater
- Water quality impacts haven't been addressed; some stormwater is untreated.
- Basin studies need to be updated to consider SLR
- Stormwater Capital Improvement Plan needs to be updated to consider SLR
- Development standards acknowledging SLR need to be incorporated into our floodplain regulations, but political buy-in is needed to address SLR
- Zoning options may exist for areas impacted by SLR, perhaps existing coastal areas
- Without action, Carpenter's Creek-type issues may appear in the development accommodating population influx from Navy Federal Credit Union. About 1/3 of NFCU development completed.
- State mentioned that any redevelopment activity needs to consider SLR impacts
- Some communities utilize adaptation action areas within coastal management element of comprehensive plan or within their Capital Improvements Program (CIP).

Habitat Loss

Sea level rise impact on listed species

- Needs: SLR maps
- Development Services performs overlays

Identify opportunities for setbacks allowing for migration

- Needs: SLR maps
- Development Services provides:
    - SLAMM
    - Parcels
    - Land use

Discussion
• Steepness of topography will influence the extent to which SLR impacts an area • Floodplain management will create habitat and migration corridors • SLR may pose threats to listed species: nesting sea turtles, shorebirds, and beach mouse on Perdido Key • Southwest Escambia could become a salt marsh • Unclear to what extent SLR would create or expand habitat areas • A changing mix of species, leaning toward more tropical species, has already been observed (birds, fish, mangroves) • Is it possible to do anything for 100% developed areas? • It may be desirable to build more marshes in Escambia • Interest in codifying migrating setbacks • Erosion concerns and loss of property (consider living shorelines for property protection) • Potential for loss of economically important habitat/species (i.e. blue crabs)

Hurricanes and Coastal Storms
Sea level rise projections for beach nourishment (at what point is renourishment not cost-effective/feasible) • Needs: calculations for erosion rate
Critical infrastructure analysis • Performed by Development Services
Discussion
• The intensity of storms (Category 3 and 4) is expected in to increase, but not necessarily the frequency • Problematic storms for the area: Ivan, Dennis, Katrina and Gustav • 45% of tree canopy was lost in Ivan, but public responded well to information about storm-resistant trees • Rebuild NW Florida hardened 12,000 homes in Santa Rosa and Escambia • Beach nourishment can be pursued, but there is a point at which we run out of sand • Extreme flooding may become more common; limited resources to respond • Coastal erosion due to storms is expected to increase • Ft. Pickens, downtown, and Johnson's Beach are areas of concerns (New ferry system connecting these areas may be impacted) • Evacuation routes and bridges may be at risk and more people will need to evacuate • Design of I-10 bridges and marinas may be inadequate • Impacts will occur further inland • Buffers are needed to stabilize shorelines with vegetation • Rolling (migrating) easements and greenshores may be useful tools (Texas example) • What are the implications to tax base if increased storminess and larger storms impact the community

APPENDIX C: LESSONS LEARNED

In performing the vulnerability assessment with representatives from Escambia County and the City of Pensacola, there were valuable insights worth noting as other communities go through similar processes:

- Scoping the Vulnerability Assessment
    - Going through an iterative process (questionnaire, kickoff discussion, facilitated design meeting) was helpful to gather feedback from multiple stakeholders and focus the community's priorities.
    - Engagement between the study team and the participating community was irregular after the design meeting. Community feedback on the report and analyses would have helped refine the products. Additional time for community coordination and product delivery would have improved the products.
    - Community engagement on the draft products omitted some initial stakeholders from resulting in some confusion on the study status by those stakeholders. We would encourage better continuity with the initial group through the study process.
    - It was somewhat difficult to find the appropriate middle-ground between coastal impacts of SLR and inland impacts from potentially more severe rainfall (exacerbated by outfalls further constrained by SLR). Preliminary assessments provided by the Study Team (to help discussion) showed potentially limited changes to coastal extent of SLR impacts while the community had recently been severely impacted by heavy rainfall inland.
    - Of the three pilot communities, Escambia County had the smallest percent of area vulnerable to SLR (relative to its community) and somewhat accordingly, less concern shown by stakeholders during initial discussions.

- Data Quality/Availability
    - Escambia County should work to improve data resources. The state database was leveraged to assess facility exposure. A building footprint coverage should be a priority for the County and City of Pensacola.
    - A large amount of Stormwater data was provided by the community. Although pieces of this data assisted in the analysis, the data were generally not well organized. This situation limited analysis given the time that would have been needed for the study team to undertake necessary coordination to understand the data.

- Communicating the Results
    - It is very challenging to communicate the technical and scientific aspects of the project in a way that easily understood by the diverse community stakeholders.

- Opportunities to Build on the Vulnerability Assessment
    - Availability of building footprints would greatly improve flood risk assessments.
    - Collection and/or conflation of building attributes, such as foundation type, construction attributes, value, and finished floor elevations would allow the community be assess exposed building value and perform depth damage analysis on existing building stock.

- Development of the above data could be limited to existing and future flood areas to provide the best value for flood mitigation purposes.
- An improved analysis of stormwater system issues and vulnerability could be accomplished with additional time and better understanding of the data resources.
- Nuisance flooding provided valuable insights for other communities in the study. Given the relatively low-vulnerability to future daily tidal flooding in Escambia, the community may want to assess this condition, especially in downtown Pensacola and Santa Rosa Island.