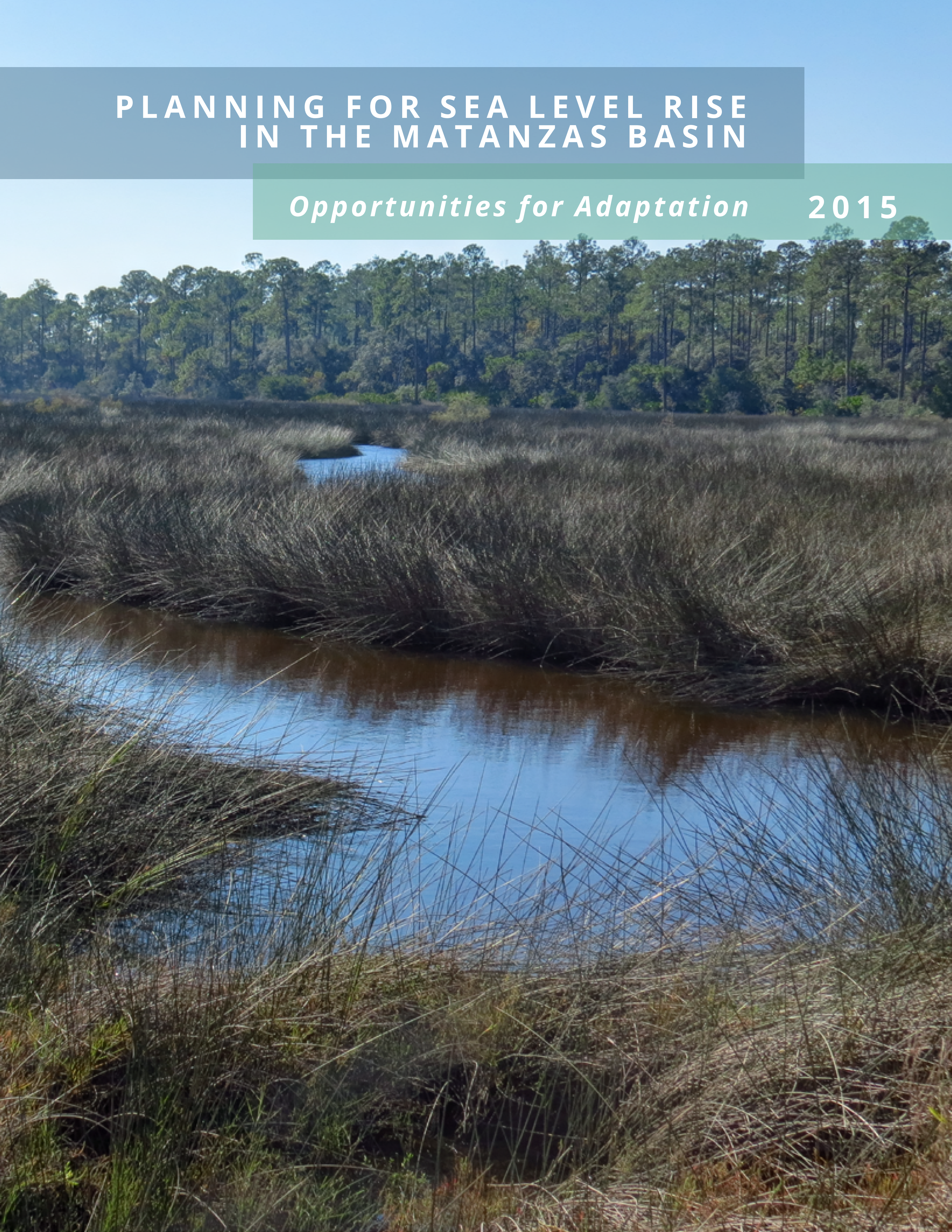
PLANNING FOR SEA LEVEL RISE IN THE MATANZAS BASIN

Opportunities for Adaptation **2015**



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Acknowledgments

Many people and organizations contributed to this project, and without their participation, the project would not have been successful.

The Guana Tolomato Matanzas National Estuarine Research Reserve director, Michael Shirley, initially conceived this project as necessary for responsible, collaborative management of the natural and cultural resources of the reserve. The GTM Research Reserve's local stake in planning for sea level rise, and its missions of research, outreach, and collaboration were vital to forming the steering committee, informing the analyses, conducting the public workshops, and applying the data gathered. The project was conducted as a true partnership between UF and the GTM Research Reserve, sharing responsibilities and activities. We are especially grateful for the involvement of GTM's training and watershed staff: Tina Gordon, Emily Montgomery, Andrea Small, and Lia Sansom.

Photo by Ed Siarkowicz Photographic Images, LLC

The project furthermore received vital local stakeholder guidance and support from the project's volunteer Steering Committee (members are listed on page 3). The diverse members helped ground the project in the values and needs of the Matanzas watershed and neighboring communities. We appreciate each member's leadership and willingness to represent their group's interests and those of the region, and to make public statements in support of the project and planning for sea level rise adaptation.

We appreciate each citizen, stakeholder representative, and official who attended the project's public workshops and participated in their interactive exercises. Participants provided input about the important assets of the Matanzas region and their preferences for planning and policy making. Their input influenced the project's analyses and recommendations, and we summarize the information gathered in this report. We also acknowledge the venues for the workshops and steering committee meetings: Flagler College, the Whitney Lab, St. Johns County Extension, and the GTM Research Reserve.

We thank the teachers and students at three schools for organizing similar workshops, and providing an important youth perspective to the project: Linda Krepp and Wayne King's middle school students participating in the summer program at St. Johns Technical High School in St. Augustine; Chris Feist's six marine science classes at Matanzas High School in Palm Coast; and Chris Farrell's two environmental science classes at St. Johns River State College's campus in St. Augustine.

Experiencing the Matanzas estuary and watershed firsthand was essential to deepening the UF team's connection to the place and people. Chris Kelley and the staff at Ripple Effect Ecotours always accommodated our requests to get out on the water, and they professionally met our varied kayaking abilities and needs. We are indebted to local artist and photographer Ed Siarkowicz. He undertook a special session to capture images of the Matanzas Basin and generously donated them to this project. The photos depict the many beautiful natural and cultural aspects of the area. They grace this report. We are also grateful to David C. Montgomery for the volunteer video and photography assistance for steering committee and workshop activities.

Graduate and undergraduate students at UF played integral and complementary roles in the project as employed research assistants. Mingjian Zhu completed a doctoral dissertation based on the project. Forrest Eddleton, Briana Ozor, and Brad Weitekamp conducted related master's theses. Kristin Buckingham based her capstone study on the project. Two of Kathryn Frank's environmental planning classes at UF supported the project through related assignments of science translation and regional analysis.

The project was intended to serve as a demonstration of scientific and collaborative adaptation planning, with lessons learned shared throughout the National Estuarine Research Reserve System and other coastal areas. We were fortunate to gain national audiences through the reporting of Jonathan Lerner for *Landscape Architecture Magazine*, and a visit by Senator Sheldon Whitehouse of Rhode Island.

To bring our acknowledgments full circle, we recognize the significant financial and technical support of the National Estuarine Research Reserve System Science Collaborative. The organization's expertise in both the scientific and collaborative aspects of effective coastal management enabled this project's strengths in both. Everyone with the Science Collaborative was very helpful and encouraging, and we especially wish to thank Dolores Leonard, Justine Stadler, Kalle Matso, and Cindy Tufts for their attention.

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Executive Summary

Flooding and erosion problems are worsening in Northeast Florida's coastal communities, catching the attention of residents, local governments, and land managers. Contributing to the problems, tide stations in the region show that the average sea level has risen 10 inches over the past century. The impacts of past sea level rise have been less evident in the intra-coastal estuaries due to the resilience of salt marshes, which establish their own substrate. Unfortunately for both coastal communities and ecosystems, scientists anticipate that sea level rise will accelerate over the next century, placing even greater stresses on both communities and ecosystems to adapt. Sea level rise in Northeast Florida is projected to be between 1.5 and 5 feet by 2100, and for all the scenarios, proactive adaptation planning is critical.

Within Northeast Florida, the "Planning for Sea Level Rise in the Matanzas Basin" project was born in 2012 from the leadership of the Guana Tolomato Matanzas National Estuarine Research Reserve. The GTM Research Reserve's mission is to achieve the conservation of natural biodiversity and cultural resources by using the results of research and monitoring to guide science-based stewardship and education strategies. The GTM Research Reserve partnered with the University of Florida to engage stakeholders and residents, and to generate the best available sea level rise science and policy advice tailored to the Matanzas Basin and neighboring communities. The three-year project was funded by the National Estuarine Research Reserve System Science Collaborative, with the additional aim that the project's methods would be transferrable to other reserves in the nation. The project's extensive data and findings are available to the GTM Research Reserve, the Matanzas area stakeholders, and the public via this synthesis report, a set of detailed appendices, and spatial data in GIS format.

The project investigated the Matanzas area's vulnerability to sea level rise and identified potential adaptation strategies. These are common first steps in adaptation planning. The major distinctions of this project were its holistic, integrative, and collaborative approaches, and attention to the local governance context. The project was holistic in its geographic scope, including the Matanzas estuary, watershed, and adjacent communities, and its goals of fostering regional sustainability and resilience. The project integrated

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analyses of the major trends of sea level rise and population growth, and their effects on conservation priorities and development patterns, using the best available data and scientifically defensible computer models. The project was collaboratively guided by a stakeholder-based steering committee and a series of public workshops oriented towards Matanzas area interest sectors, residents, and youth. And, the project suggested spatially explicit adaptation strategies having the greatest relevance in the context of current local plans and governance capacities. The strategies spanned and interrelated the spatial planning fields of land conservation, smart growth and low impact development, and coastal hazard mitigation.

The project's main findings relate to the importance of the Matanzas Basin, its vulnerabilities, potential adaptation strategies, and current governance adaptive capacity.

Importance of Matanzas Basin

An understanding of the values of the Matanzas Basin at local and regional scales is critical input to adaptation planning. The project's 264,000-acre study area within St. Johns and Flagler counties included the Matanzas Basin (the Matanzas River/estuary and watershed) and neighboring coastal communities, the largest of which are the cities of St. Augustine and Palm Coast. The population of the Matanzas study area in 2010 was approximately 150,000. Within the study area is the 29,500-acre southern component of the GTM Research Reserve, which includes the estuary and nine conservation areas in public ownership. In addition to the conservation areas, which are centrally important to the pristine natural character of the region, the Matanzas Basin is remarkably unaffected by urban development. Stakeholders described the Basin as hydrologically and ecologically intact, and the project confirmed this perspective through its landscape analyses. The area is rich in biodiversity, providing vital habitat to iconic Florida species, including black bears, gopher tortoises, wading birds, shorebirds, manatees, and dolphins. The large tracts of forested lands are also important for managing water resources. Inland areas are also attractive to developers, and there are several large-scale "greenfield" developments proposed in the southern half of the watershed. On the whole, the Matanzas Basin has national significance, it delivers many important ecosystem services to area residents and businesses, and there is the potential for future land use conflicts between conservation and development interests.

Vulnerabilities

The large study area afforded landscape-level assessments of multiple types of vulnerabilities through integrated, scenario-based use of the following methods: collection/creation of the best available digital elevation model data (including LiDAR for most of the area); the Sea Level Affecting Marshes Model (SLAMM) to identify long-term landscape transformations under scenarios of less than the historic rate of sea level rise (10 inches) up to 8 feet (2.5 meters) by 2100; the HAZUS model for storm surge scenarios; the Land Use Conflict Identification Strategy (LUCIS) to identify future development patterns; species habitat models and other techniques from the field of conservation ecology; and qualitative research and pubic input. The project did not model future changes due to other climate change effects, such as increasing temperatures and variation of precipitation.

Multiple analyses drew attention to a 2-mile wide strip of coastline as being highly vulnerable to storm surge and sea level rise for all future scenarios. Within the strip, the Matanzas estuary of the GTM Research Reserve is the lowest lying area. In the timeframe of a mid-range scenario of 3 feet rise by 2100 (but possibly occurring as early as 2075), significant vulnerabilities become evident in the areas to the north and south of the Reserve, including in St. Augustine. Coastal hazards and sea level rise changes in inland areas were limited and concentrated along the major streams, such as Pellicer Creek, due to the higher elevations of the Atlantic Coastal Ridge. Just to the west of the study area, future sea level rise impacts were observed in the lower Eastern Valley due to rising of the St. Johns River.

Impacts of Sea Level Rise on the Natural Environment

Impacts of sea level rise on natural features in the study area were determined by comparing current and future conditions, for two sea level rise scenarios (3 and 8 feet (1 and 2.5 meters)), assuming no changes in existing developed land. The features included focal species, natural communities, water resources, biodiversity hotspots, and estuarine habitat. Though some wetland or open water dependent species gained habitat with sea level rise, the majority (particularly terrestrial species) saw a net loss in habitat with sea level rise. Much of the species habitat losses occurred within the Reserve, which suggests the need for additional conservation lands outside the Reserve to mitigate the losses. Some wetland types and all upland types except pine plantations experienced a net loss from sea level rise. Biodiversity hotspots received a moderate to high degree of impact. Within the GTM Research Reserve, 95% of estuarine habitats (salt marshes, tidal flats, mangroves, etc.) converted to open water under the higher sea level rise scenario. The literature indicates that estuarine water quality may improve due to increased flushing with the ocean.

Impacts of Sea Level Rise on Existing Development

Residents and stakeholders described current concerns that may become more severe as sea level rises: erosion, flooding, saltwater intrusion into water supplies, and loss of natural amenities. All the SLAMM scenarios forecasted losses of currently developed land in the Matanzas study area, assuming the land is not protected from inundation. In the Matanzas study area, the 3 feet (1 meter) sea level rise scenario, assuming no protection, affected 2,456 acres of currently developed residential land, which has 16,335 occupied residential units and over 30,000 residents. Impacts to other types of developed land are provided in the report.

Impacts of Sea Level Rise on Future Development

All the SLAMM scenarios forecasted losses of undeveloped dry land in the Matanzas study area, assuming the land is not protected from inundation. For example, the 3 feet (1 meter) sea level rise scenario, assuming no protection, affected 1,637 acres of vacant residential land in the Matanzas study area. Impacts to other types of vacant developable lands are provided in the report.

Population projections from the Florida Bureau of Economic and Business Research (BEBR), which are extrapolations of historic rates, estimate 511,051 additional people in St. Johns and Flagler counties by the year 2060 (an increase of 179%). Using LUCIS methods, if current development patterns continue, but new development avoids areas vulnerable to 3 feet sea level rise (along the Atlantic coast and St. Johns River), and residents of existing development in vulnerable areas (over 50,000 people in both counties) relocate within the counties, then the new and relocated development was found to consume property parcels totaling 133,564 acres. This trend scenario avoided existing conservation lands and wetlands, prioritized development on currently platted parcels (including infill lots) and other lands having high preference for urban development (and with large parcels, typically in agricultural/timber use), redeveloped commercial parcels having buildings at least 50 years old by 2060, and allocated land needed for corresponding infrastructure such as roads. With these modeling criteria, which are based on existing policies, currently platted parcels absorbed much of the next 45 years of growth and relocation. The new “trend” development had gross urban density of 4.3 people per acre, whereas existing development in St. Johns and Flagler counties have densities of 2.2 and 3.7, respectively.

Impacts of Future Development on the Future Natural Environment

Impacts of future development on future natural conditions were also analyzed for the study area. The future development scenario analyzed was the 2060 trend scenario where existing and future development was directed away from vulnerable areas. The future natural conditions were identified using the SLAMM 3 feet sea level rise scenario, combined with existing land cover in upland areas. In the Matanzas study area, nearly all upland natural communities were impacted by future development. Many upland species, such as the gopher tortoise, lost 10-30% of their habitat to future development. Future development affected biodiversity hotspots in several locations.

Adaptation Strategies

The large study area and its diversity of land uses led to a wide range of potential adaptation strategies. Many of the strategies are multi-functional, and oriented towards sustainability and resilience, and therefore the strategies are likely to yield benefits for all future sea level rise scenarios. The project modified a framework from the literature to relate the different adaptation strategies to goals and locations in the Matanzas area.

Future Conservation Priorities

Adaptation of the natural environment involves the related strategies of identifying spatially explicit future conservation priorities and initiating land conservation, such as establishment of conservation easements, in response to the future priorities. The project established future conservation priorities for the negatively impacted natural features of importance to the GTM Research Reserve. For example, the future conservation priorities highlight undeveloped areas directly north and south of the Reserve to compensate for the loss of estuarine habitats within the Reserve. In upland areas, lands having future high conservation priorities include habitats around Pellicer Creek. In areas not showing change from current conditions, the project recognized existing conservation priorities as important for maintaining overall ecosystem resiliency. Additionally, the project created aggregated conservation priorities at Reserve and regional scales, and identified large “coastal to inland” corridors to aid wildlife retreat from sea level rise. The regional scale conservation priorities cover most of the Matanzas Basin, which stresses the importance of continuing initiatives for land conservation and best management practices. The report identifies specific policy tools, programs, and locational opportunities for land conservation in the Matanzas area.

Future Development to Reduce Impacts to Future Conservation Priorities

The project applied LUCIS methods to model future development with the additional constraint of avoiding, to the extent possible, lands having future conservation priorities. Similar to the trend development scenario (above), the future “conservation” development scenario accommodated the two-county population growth projected for 2060 plus the relocation of current development in vulnerable areas. Across the two counties, the conservation scenario resulted in development occupying 13,747 fewer acres , and impacting 63,800 fewer acres of future conservation priorities, as compared to the trend scenario. The gross urban density of the new “ conservation” development was 4.7 people per acre (compared to 4.3 in the trend scenario). In the Matanzas study area, the conservation scenario impacted 20,259 fewer acres of future conservation priorities as compared to the trend scenario. These results indicate that policies guiding density and location of development are important for conservation, and that improvements over current policies are possible.

Local governments have important roles to play in promoting regional sustainability and resilience. They can accommodate population growth and relocation, reduce land consumption, protect conservation priorities, as well as enhance community livability, through land use policies and programs for smart growth, low impact development (LID), and green infrastructure.

Coastal Hazard Mitigation

To attend to the worsening threats to development from coastal hazards, such as flooding and erosion, the project created a toolbox of hazard mitigation strategies modified to explicitly address sea level rise and apply to the Matanzas area. The strategies are organized according to development goals (protection, accommodation, strategic relocation, and avoidance) and local government policy approach (e.g., local planning and zoning, building design, financial, etc.). Of particular interest are strategies that integrate designs for the built and natural environments, and that acknowledge the unique challenges posed by adaptation of historical assets.

Governance Adaptive Capacity and Next Steps

The project reviewed local and regional initiatives and policies for the goals of land conservation, smart growth, coastal hazards mitigation, and sea level rise adaptation to understand the governance context. The findings indicated existing capacities for fostering each of the first three goals, as well as room for strengthening them. Regarding the goal of sea level rise adaptation, the review noted early leadership at the level of the Northeast Florida region, however local government plans in the Matanzas area had not yet begun to explicitly recognize and address the long-term threat. The stakeholder and pubic input gathered throughout the project showed that the Matanzas area is ready to increase attention to sea level rise concerns. The GTM Research Reserve and the project's steering committee members reported that they were already using the information and data from the project, by incorporating it into regular operations and the design of new initiatives. And by the project's conclusion, planning for sea level rise and climate adaptation was prominent across the Northeast Florida region, with governments and organizations at different scales and for various concerns coordinating their activities.

The project's findings represent a better understanding of the Matanzas Basin and its future. The information can be used immediately, yet the project was only the beginning of adaptation planning. The findings should be regularly updated and combined with information about other types of climate change impacts as it becomes available.

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Introduction

This report presents the methods and findings of Planning for Sea Level Rise in the Matanzas Basin, an action research project conducted in Northeast Florida from October 2011 to June 2015. The project was a partnership between the Guana Tolomato Matanzas (GTM) National Estuarine Research Reserve and the University of Florida (UF), with funding provided by the National Estuarine Research Reserve System Science Collaborative. A volunteer steering committee of community and regional leaders guided the project.

The Matanzas project was an integrated adaptation planning process, which identified potential impacts of future sea level rise and land use change on coastal habitats and species, assessed governance capacity to adapt, developed possible adaptation strategies for the natural and built environments, and engaged local stakeholder groups and residents. Beyond the local significance, the Matanzas project served to develop, test, and evaluate the planning process for use by other reserves in the National Estuarine Research Reserve System.

Rising average sea levels have been observed in Northeast Florida for the past century, and scientific models predict that the rate of rise will increase. The impacts of sea level rise on coastal communities and natural areas are numerous and profound, including accelerated erosion, more frequent and severe flooding, saltwater intrusion into aquifers, transformation of ecosystems, and migration of species. Many of these problems are already occurring in the project's study area due to a variety of factors, and sea level rise will exacerbate the problems. The sea level rise impacts combine with other stressors, such as ongoing urbanization and resource degradation, to create challenges for planning.

As stewards of the GTM Research Reserve, the director, Dr. Michael Shirley, and staff initiated this project to better understand the impacts of sea level rise, and to begin a public conversation about adaptation. Data and information from the project will be used to inform the reserve's management, restoration, and future land acquisition priorities.

Matanzas River and Town of Marineland. Source: GTM Research Reserve

The University of Florida project team contributed scientific, collaborative, planning, and policy expertise, as well as project management. The UF team consisted of research faculty, staff, and students in the School of Landscape Architecture and Planning, the Department of Agricultural and Biological Engineering, and Florida Sea Grant. The principal investigator was Dr. Kathryn Frank in the Department of Urban and Regional Planning. The project's Collaboration Lead, Dr. Dawn Jourdan, continued the project from the University of Oklahoma.

The primary audiences for this report are the GTM Research Reserve, stakeholder groups, and residents of the study area, which includes the Matanzas Basin and neighboring coastal communities.

Photo by Ed Siarkowicz Photographic Images, LLC

Erosion at Matanzas Inlet.   Photo by Ed Siarkowicz Photographic Images, LLC

Study Area

The study area was defined as the Matanzas River watershed (i.e., the Matanzas Basin, 128,000 acres) plus a 3-mile buffer, which included the historically significant City of St. Augustine, much of the City of Palm Coast, and all the coastal communities between them (Figure 1). The entire study area is 264,000 acres, and the population in 2010 was approximately 150,000. The urbanized areas of St. Augustine and Palm Coast had populations around 75,000 and 89,000, respectively, some of which extend outside the study area. The study area is located within St. Johns and Flagler counties, with combined population of 286,000. The two counties are in the Northeast Florida region, which includes metropolitan Jacksonville to the north (Figure 2).

The GTM Research Reserve was designated in 1999 with the mission to conserve the natural and cultural resources of the area through science-based stewardship and public education. The GTM Research Reserve consists of two components on the coasts north and south of St. Augustine. The reserve's main office is located at the GTM Environmental Education Center in the northern component. The reserve maintains a smaller office in Marineland in the southern component.

The GTM Research Reserve's 29,500-acre southern component is at the heart of the Matanzas Basin. Included in the southern component are the Pellicer Creek Aquatic Preserve, Faver-Dykes State Park, Washington Oaks Gardens State Park, Moses Creek Conservation Area, Pellicer Creek Conservation Area, Fort Matanzas National Monument, Matanzas State Forest, Princess Place Preserve, and the River to Sea Preserve at Marineland.

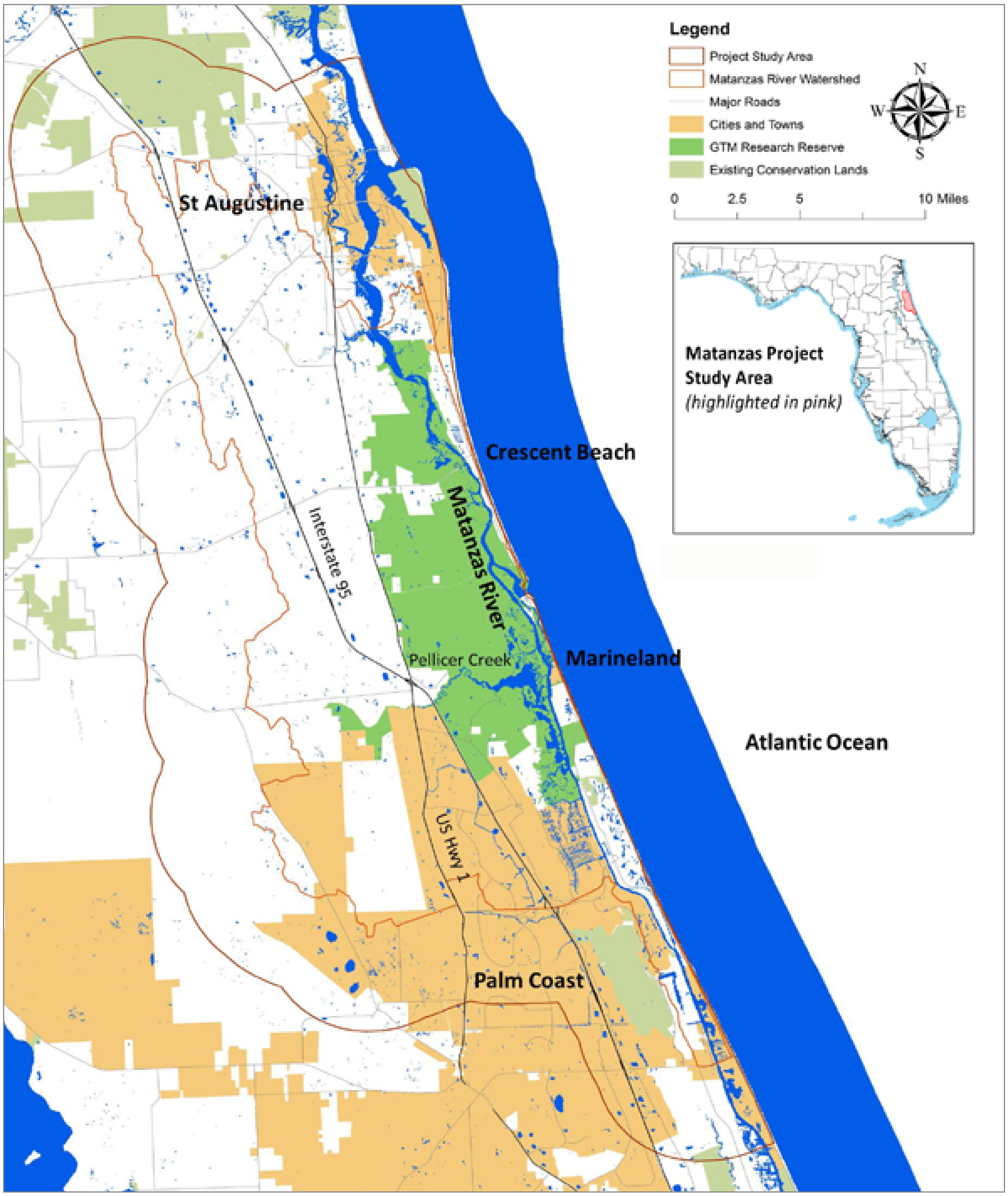
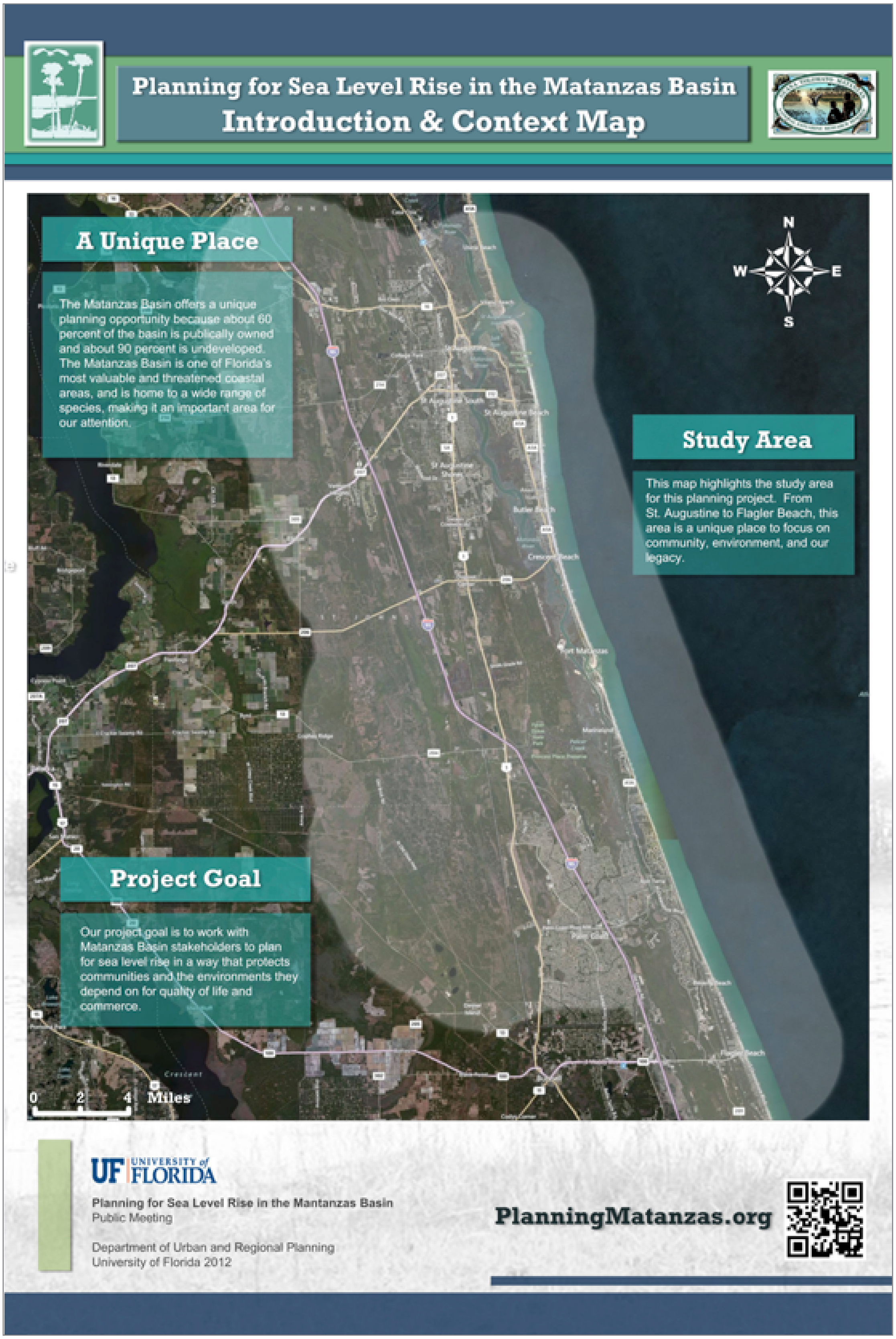


Figure 1. Project study area



Satellite image of the study area

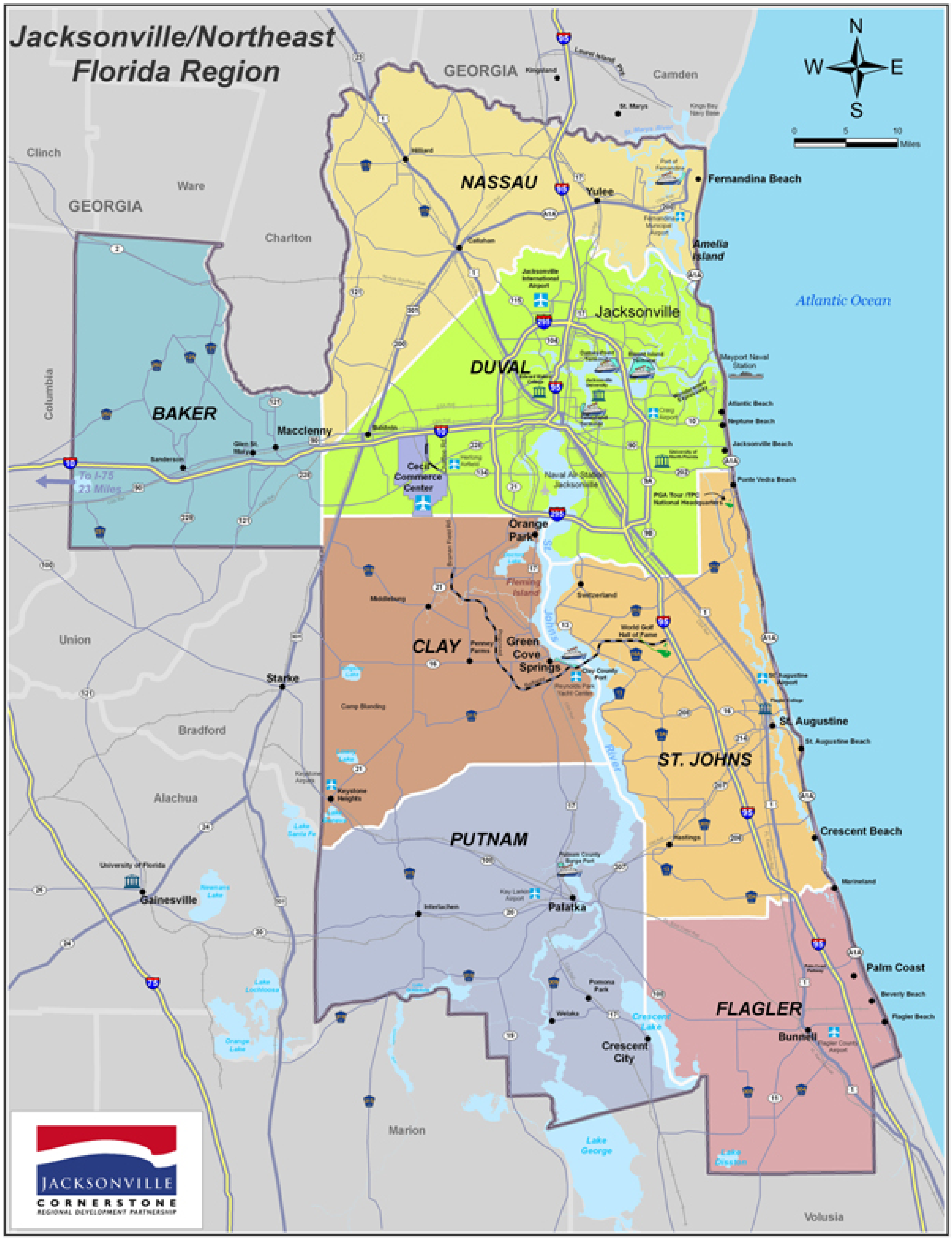


Figure 2. Northeast Florida region. Source: http://www.whatsupjacksonville.com/index.php/northeast-florida-regional-council-recognizes-leaders-who-foster-regional-cooperation/

The project's study area extends beyond the GTM Research Reserve to encompass the watershed, because the Matanzas River is an estuary sensitive to freshwater flows from the land and aquifer. The 3-mile buffer was added to incorporate regional economic, social, and institutional systems, to strengthen stakeholder engagement and enable design for regional resilience. The larger geographic scope is also needed to take into account the landscape shifts with sea level rise and regional conservation priorities. The study area is one of the few locations on the Florida Atlantic coast that is relatively undeveloped. The area has high biodiversity, and it is home to many important species, including black bears, gopher tortoises, wading birds, shorebirds, manatees, and dolphins. The large tracts of forested lands have the potential for management to incorporate habitat and water conservation objectives for coastal resilience.

Land elevations in the study area range from 0 to almost 100 ft above sea level. Habitat types within the GTM Research Reserve include open water, tidal flats, saltmarsh, beaches, coastal scrub, freshwater marshes and swamps, streams, and upland forests. To the west of the reserve, there are vast tracts of rural lands primarily in timber production. The largest tributary in the basin is Pellicer Creek.

Pellicer Creek meets the Matanzas River near Marineland, looking east . Source: GTM Research Reserve

Sea Level Rise Scenarios

Global average sea levels in the past, present, and future are related to the temperature of the Earth's atmosphere (Mitchum 2011). As the atmosphere becomes warmer, which has been occurring since the last Ice Age, the temperature of the ocean water increases, causing the water to expand and hence fill more volume (Figure 3). Additionally, ice on land melts and flows into the ocean, thus contributing to the amount of water in the ocean.

Specific places around the world can experience different rates of sea level change depending on regional factors, such as whether the land is sinking or lifting up (creating the effect of "relative" sea level rise), nearby river flows, and ocean currents. The land in Florida is fairly stable, but the other factors can cause variations in the rates of sea level rise along the state's coastline.

The National Oceanic and Atmospheric Administration (NOAA) maintains tide stations along the US coast. The closest tide station to the Matanzas study area is approximate 40 miles to the north, in Mayport, near Jacksonville. This tide station indicates that the average sea level in the Northeast Florida region has risen about 10 inches in the past 100 years (Figure 4).

Scientific modeling, which is used by universities, federal and state agencies, and corporations, predicts that global average sea level will continue to rise into the future, at an accelerating pace (U.S. Global Change Research Program 2014). The anticipated acceleration is a result of continued atmospheric warming due to increasing levels of heat-trapping "greenhouse" gases.

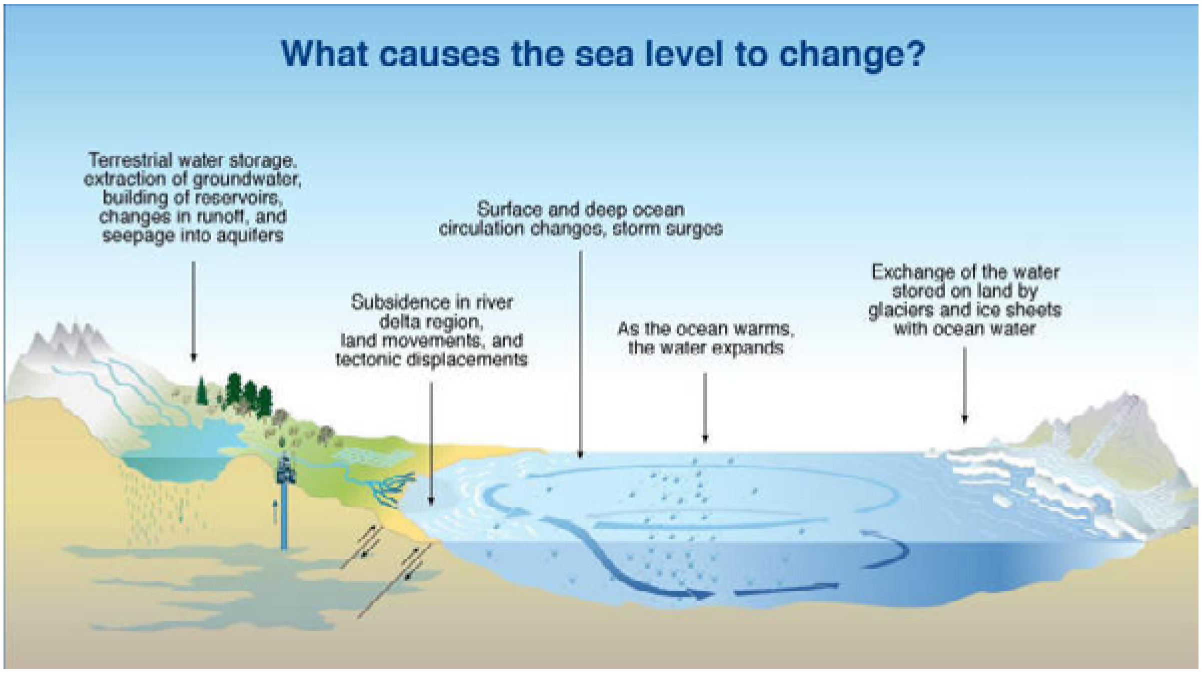


Figure 3. Contributions to sea level change. Source: David Griggs, in Climate Change 2001, Synthesis Report, Contribution of Working Groups I, II and III to the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, 2001

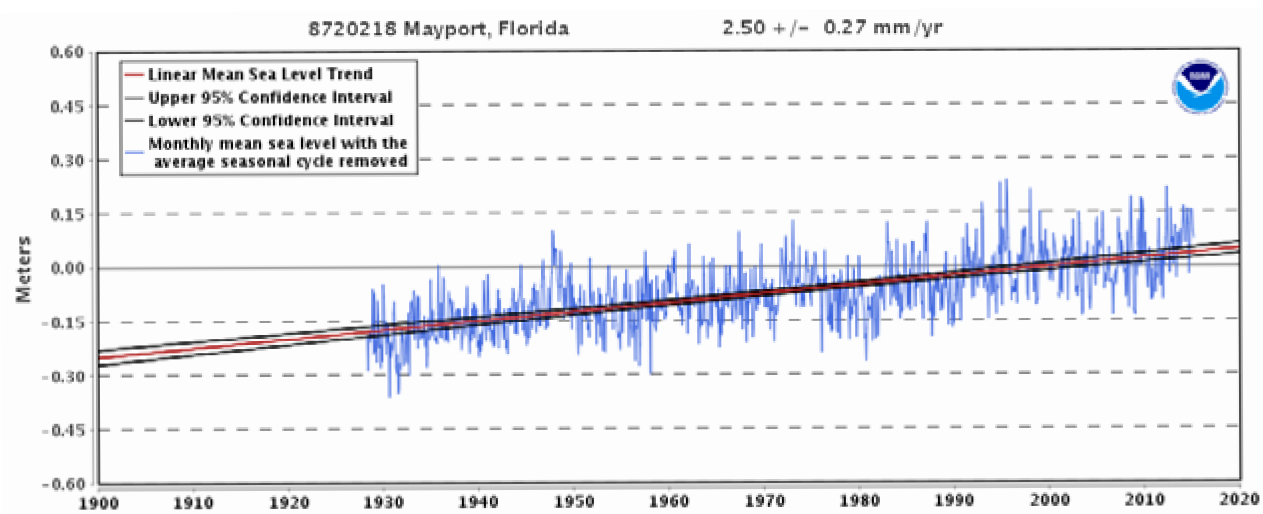


Figure 4. Mayport tide station sea level data, 1928 to 2014, with linear trend line. Source: NOAA, http://co-ops.nos.noaa.gov/sltrends/sltrends_station.shtml?stnid=8720218

A degree of uncertainty is associated with modeling future sea levels, therefore the project team used a set of locally specific and scientifically defensible sea level rise scenarios for the region. The sea level rise scenarios ranged from the historic linear trend of less than a foot to upwards of eight (8) feet by the year 2100. The most likely range of future sea level rise is between one and a half (1.5) and five (5) feet by the end of the century (Figure 5). The mid-range projection of three (3) feet of sea level rise over the next 100 years is faster than the historic rate by three-and-a-half times. Appendix A further discusses the sea level rise projections used by the project. For broader information about sea level rise projections and potential impacts, see "Sea Level Rise in Florida: A Bibliographic Essay of Current Science," by Linhoss et al. (2013), which is included for convenience as Appendix I.

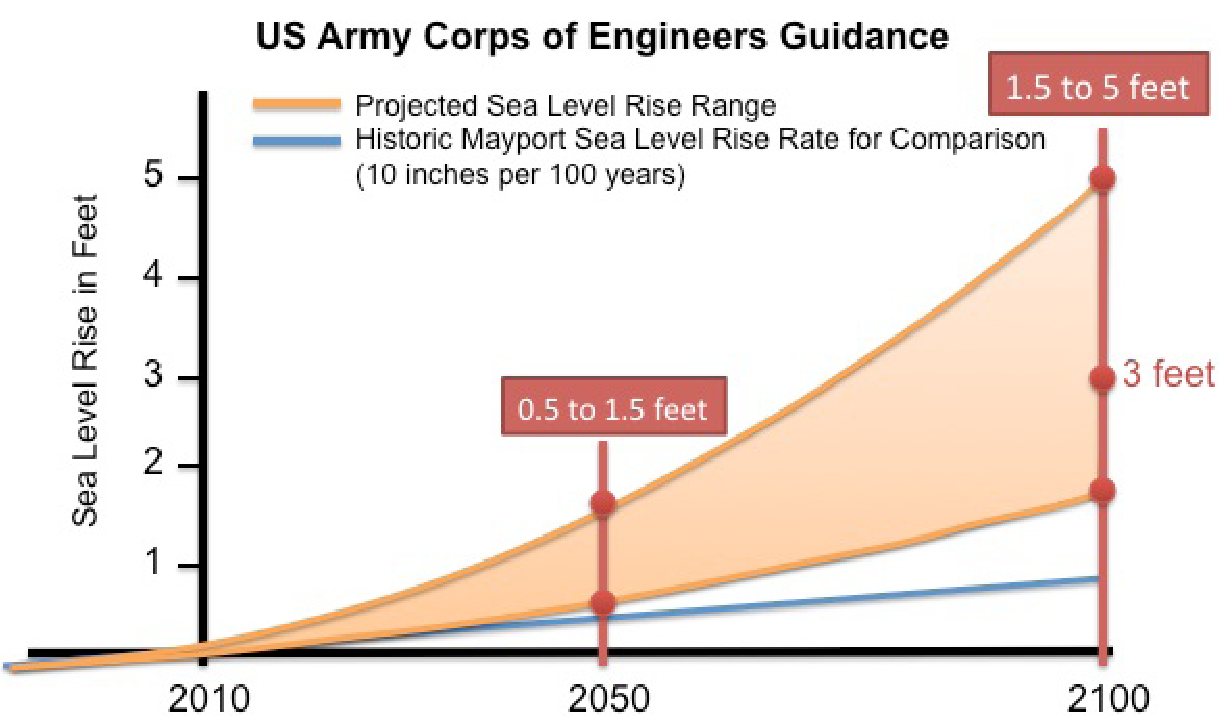


Figure 5. Projected sea level rise range and historic rate, based on US Army Corps of Engineers guidance

Many of the maps and analyses in this report focus on the scenario of three (3) feet of sea level rise by the year 2100. This scenario is particularly useful for planning, because it may reasonably occur within the longest timeframe considered in local land use and project planning. Furthermore, the research found that three feet of sea level rise will result in clearly observable changes in the study area, especially in the GTM Research Reserve and coastal communities.

At a finer scale of analysis, the instantaneous rate of sea level rise becomes more important, such as in determining whether coastal wetlands will keep up with the rising waters (through soil formation, or "accretion") or whether they will be "drowned." The project team took into account the instantaneous rates via the ecological model used to determine the potential impacts of sea level rise on natural habitats (the Sea Level Affecting Marshes Model (SLAMM)).

Mayport tide station. Source: NOAA, http://co-ops.nos.noaa.gov/stationhome.html?id=8720218

Integrated and Collaborative Land Use Planning

The US National Oceanic and Atmospheric Administration (NOAA) advocates for coastal planners to consider the spatial extent of inundation and other changes caused by sea level rise, potential impacts to existing development, future development patterns, and the combined effects on ecological conservation priorities (NOAA 2010). This approach is in keeping with integrated coastal zone management for social and ecological resilience.

The Matanzas project aimed to provide a foundation of high quality land use information about current and potential future development, coastal hazards (storm surge), and natural areas conservation priorities (for species, habitat, ecosystem, and natural resource concerns, such as water), the impacts of sea level rise on each, and adaptation strategies to meet multiple objectives and minimize land use conflicts. These aspects were initially identified by the project team and confirmed through public engagement and research. For instance, the potential for future development is high in the Palm Coast area, since the city has doubled in population each of the past two decades. The dynamic interactions of these land use impacts, responses, and potential conflicts are illustrated in Figure 6.

The project land use modeling and analyses were based in geographic information systems (GIS). They included advanced methods, such as Sea Level Affecting Marshes Model (SLAMM) for sea level rise impacts, Land Use Conflict Identification Strategy (LUCIS) for future development patterns and alternatives, and conservation ecology principles for landscape design. Specialists of each method tailored their analyses to the Matanzas study area, and they coordinated their efforts. For instance, the SLAMM results of spatial vulnerabilities were used as inputs to the future development and conservation scenarios. Each method incorporated uncertainty by conducting analyses for a wide range of sea level rise projections, spanning the historic rate of rise, 10 inches, to up to 8 feet by the year 2100. Additionally, the conservation analyses occurred at multiple spatial scales, ranging from the GTM Research Reserve to the Northeast Florida region. The resulting outputs of the land use analyses were maps and spatial statistics. All GIS data collected and generated by the project were provided digitally to the GTM Research Reserve, and local jurisdictions and regional stakeholders via the project's steering committee (see Appendix J).

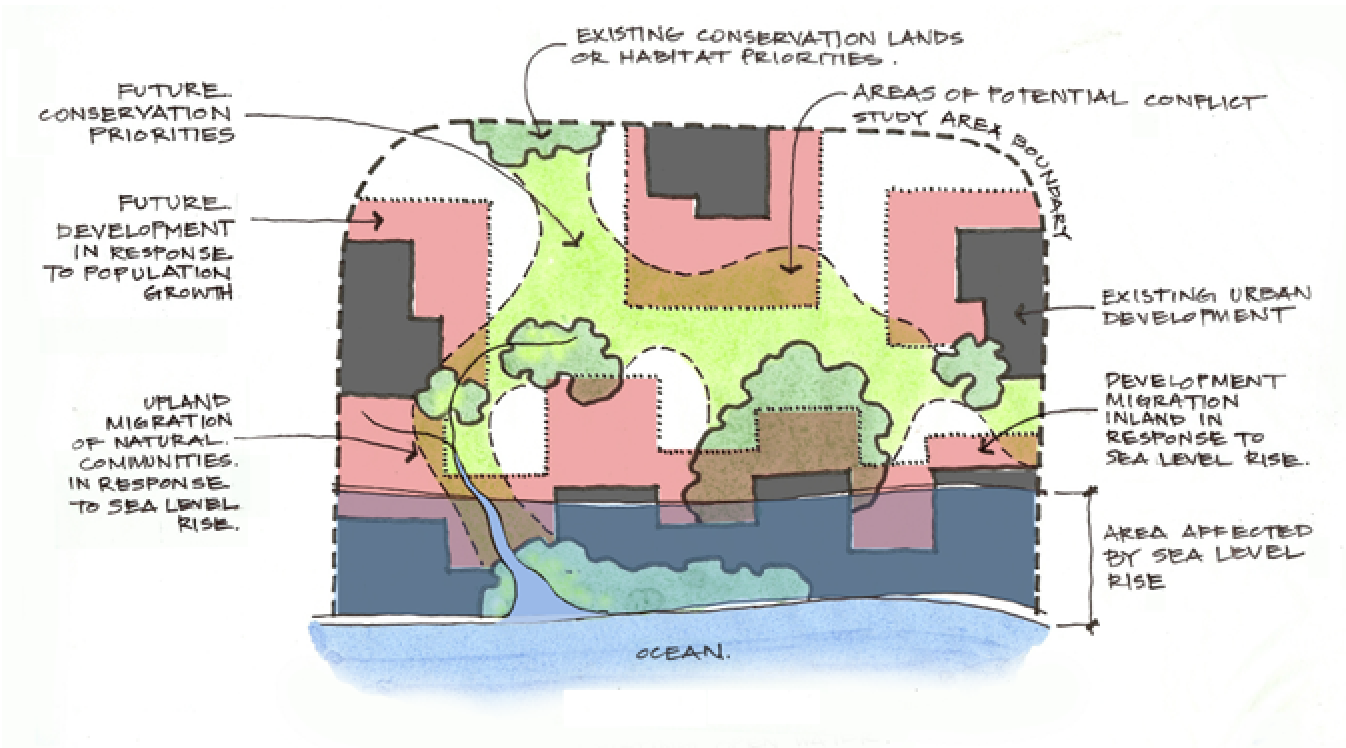
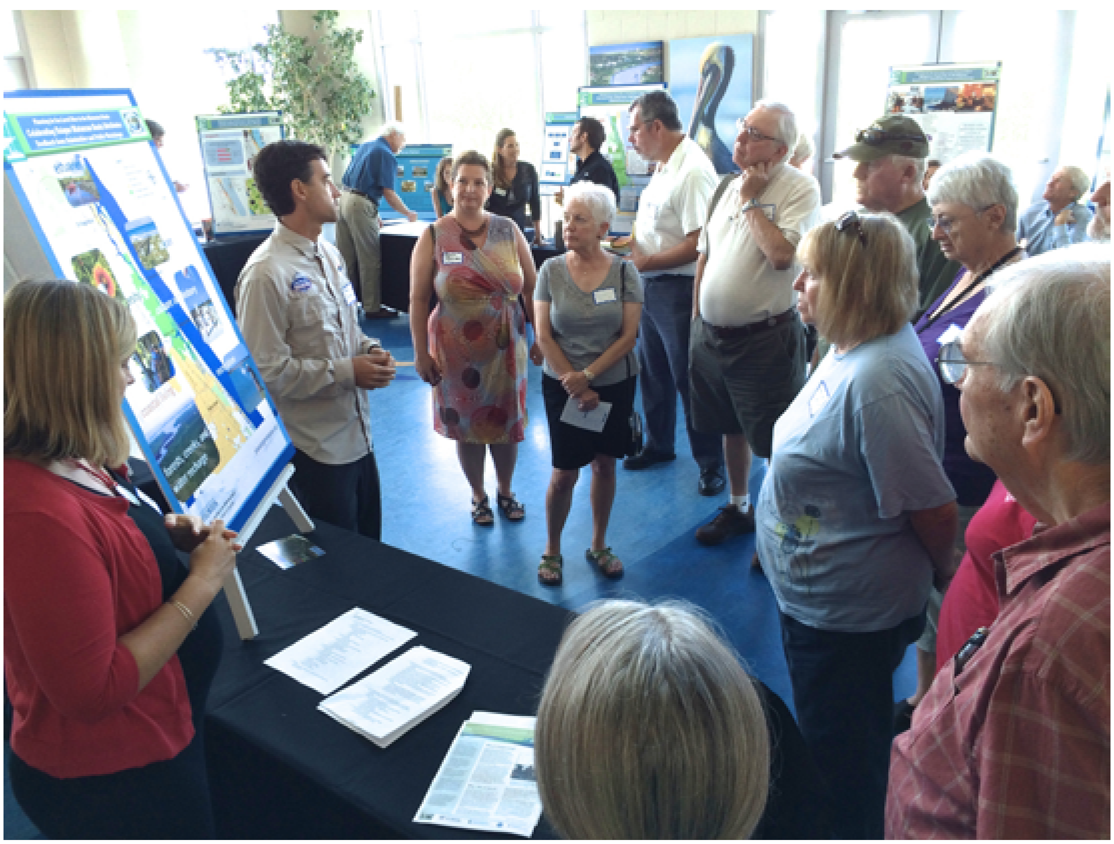


Figure 6. Schematic of land use impacts, adaptation, and potential conflicts

The project team supplemented the GIS analyses with qualitative research of additional major concerns raised through stakeholder and resident engagement: other climate change impacts, such as the conversion of salt marshes to mangrove forests due to a warming climate; saltwater intrusion and its impacts on water supply for cities and agriculture; limitations of current urban storm water management systems; coastal erosion; and cumulative impacts to the estuarine system and local economy. Each of these concerns warrants targeted study and modeling, which was beyond the scope of this project.

The project went beyond analyzing impacts and vulnerabilities to identifying the region's strengths and opportunities for adaptation to maintain social and ecological resilience. The integrated analyses and collaboration enabled the project team to synthesize diverse information to holistically assess the region's adaptive capacity in terms of physical, legal-political, and technical-financial-organizational components. Toward this end, the team reviewed local, regional, and state policies and resources, including the counties' comprehensive plans and state conservation programs. The team researched specific options for adaptation strategies tailored to the built and natural environments of the Matanzas study area. Of special interest were proactive and multifunctional strategies, such as watershed/ecosystem protection, green infrastructure and living shorelines, and habitat restoration.

The collaborative approach throughout the project was important not only for integrating social science and local knowledge, values, and ideas into the analyses. Collaboration – through the UF-GTM partnership, the steering committee, the public workshops, and additional outreach – aimed to foster governance relationships and discourse, encourage leadership, and develop new understanding and attitudes about sea level rise and adaptation. Collaboration enabled the project to progress in a manner and pace desired by the participants, and to produce useful products to enable continued adaptation planning and individual decision making upon conclusion of the project.



Final public workshop

Organization of Report

This report presents a summary of the project methods and the synthesized highlights of the analytic, design, policy, and adaptive capacity findings for the Matanzas study area. Detailed reports of the findings are included as appendices.

The next section, Project Methods, provides an intermediate level of detail regarding the project's organizational approach and activities. Then the Vulnerabilities and Adaptation Strategies sections describe the project's findings of potential local impacts of sea level rise and other coastal changes, adaptive capacities, and promising responses. The Conclusion summarizes the project's accomplishments. And finally, the separate Appendices contain detailed methodologies and results for the project's technical and policy analyses.

Members of the Matanzas project steering committee and project team

Photo by Ed Siarkowicz Photographic Images, LLC


Photo by Ed Siarkowicz Photographic Images, LLC

Project Methods

The goal of the project was to work with Matanzas Basin stakeholders to plan for sea level rise in a way that protects communities and the environments they depend on for quality of life and commerce. The project team used a structured collaborative process to work with planners, property owners, and scientists to assess areas of conflict and agreement related to sea level rise, develop land use scenarios to illustrate the results of different planning decisions, and communicate these scenarios to the general public. Of particular interest to the GTM Research Reserve was to model potential impacts of future sea level rise on coastal habitats and species, and to identify potential ecological migration corridors.

This Methods section describes the project team, the overall project design and evaluation approach, and specific activities of collaboration, technical analyses, future planning and policymaking, information synthesis, and implementation support for the project's findings. Further details of the methods are included in the appendices.

Project Team

The project team was a partnership between the GTM Research Reserve director and staff, and UF faculty, staff, and students in the School of Landscape Architecture and Planning, the Department of Agricultural and Biological Engineering, and Florida Sea Grant.

The GTM Research Reserve key persons involved were the director, Michael Shirley, the Coastal Training Program staff – Emily Montgomery, Tina Gordon, and Lia Sansom – and the watershed coordinator Andrea Small. Also participating were the associate director Gary Raulerson, education coordinator Kenneth Rainer, research coordinator Nikki Dix, and stewardship coordinator Joseph Burgess, among others. The GTM Research Reserve director and staff specified the reserve's information needs, provided scientific data about the reserve, networked with local and regional stakeholders, assisted with the project's steering committee meetings and public workshops, conducted the youth workshops, identified adaptation strategies for the reserve, and reviewed draft reports.

The UF team consisted of the lead researchers and roles listed in Table 1. Associate researchers who contributed supplemental analyses and reports in the appendices are listed on page 5. Tracy Shubin created the report's graphic design. Many graduate and undergraduate students participated through assistantships, hourly paid positions, and coursework. These students are listed on page 5. Of note are Mingjian Zhu, Briana Ozor, Brad Weitekamp, Forrest Eddleton, and Kristin Buckingham in the College of Design, Construction and Planning; in addition to their positions as graduate research assistants, they focused their doctoral dissertation (Zhu), master's theses (Ozor, Weitekamp, and Eddleton), and senior capstone (Buckingham) on the project. Also, Briana Ozor and Belinda Nettles led development of the workshop games on adaptation strategies and future development, respectively.

The project team launched their efforts with a tour of the Matanzas Basin, and UF researchers conducted field visits to gather information. During the multi-year project, the GTM Research Reserve and UF members regularly met in person and coordinated by phone, email, and Basecamp, a project management website offered by the NERRS Science Collaborative. The principal investigator maintained meeting notes and reported project progress to the Science Collaborative on a semiannual basis.

Researcher	UF Affiliation	Project Role
Kathryn Frank	Urban and Regional Planning	Principal Investigator
Dawn Jourdan	Regional and City Planning, University of Oklahoma	Collaboration Lead
Michael Volk	Landscape Architecture	Project Manager and Conservation Analyses
Thomas Hoctor	Landscape Architecture	Conservation Analyses
Paul Zwick	Urban and Regional Planning	Development Analyses
Greg Kiker	Agricultural and Biological Engineering	Sea Level Affecting Marshes Model (SLAMM)
Anna Linhoss	Agricultural and Biological Engineering	Sea Level Affecting Marshes Model (SLAMM)
Robert Grist	Landscape Architecture	Visualization
Thomas Ruppert	Florida Sea Grant	Policy Analyses and Adaptation Strategies
Maia McGuire	Florida Sea Grant	Local Outreach

Table 1. Lead university researchers

Project Design and Evaluation

The Matanzas project aimed to initiate regional planning for sea level rise adaptation. As such, it consisted of several components: collaboration, technical analyses, and future planning and policymaking. The project's funder, the NERRS Science Collaborative, and the university researchers, were also interested in sharing the methods and lessons learned from the Matanzas project with other coastal regions throughout the National Estuarine Research Reserve System, and as scientific and planning scholarship. Figure 7 shows the relationships between these overall aims and components, and lead researchers for each component (also see Table 1).

Project team touring the Matanzas Basin

The Matanzas project's collaboration component included a steering committee of stakeholder representatives, public relations, and public workshops (Figure 8).

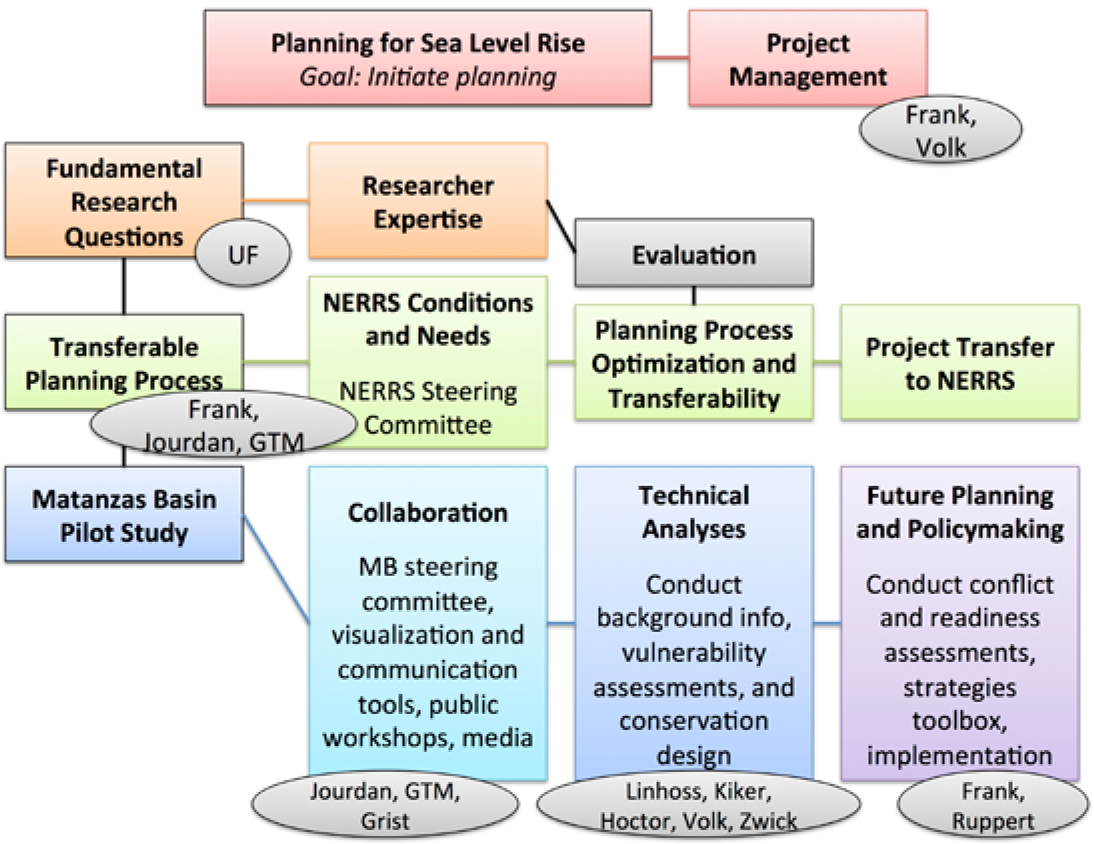


Figure 7. Overall project design

The Matanzas technical analyses progressed through background research, sea level rise vulnerability assessments, and integrated conservation design for natural and built land uses (Figure 9). These components, as well as the component of future planning and policymaking, are discussed below.

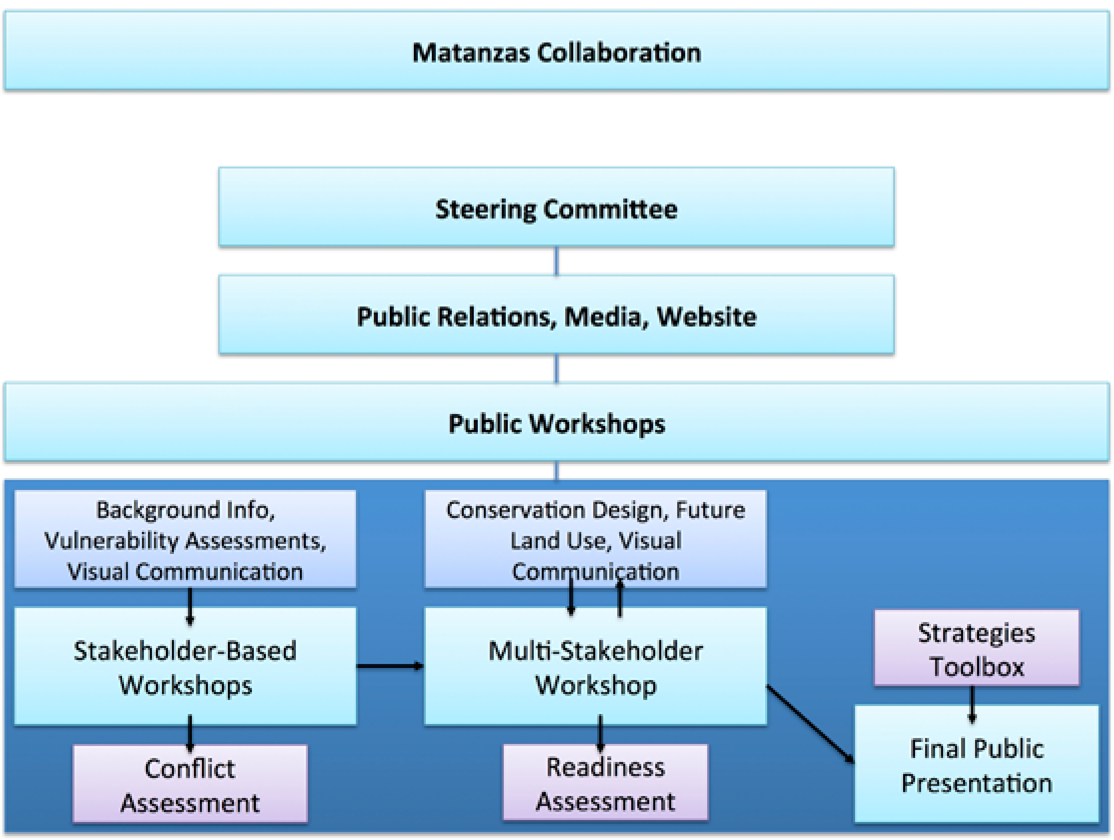


Figure 8. Matanzas project collaboration methods

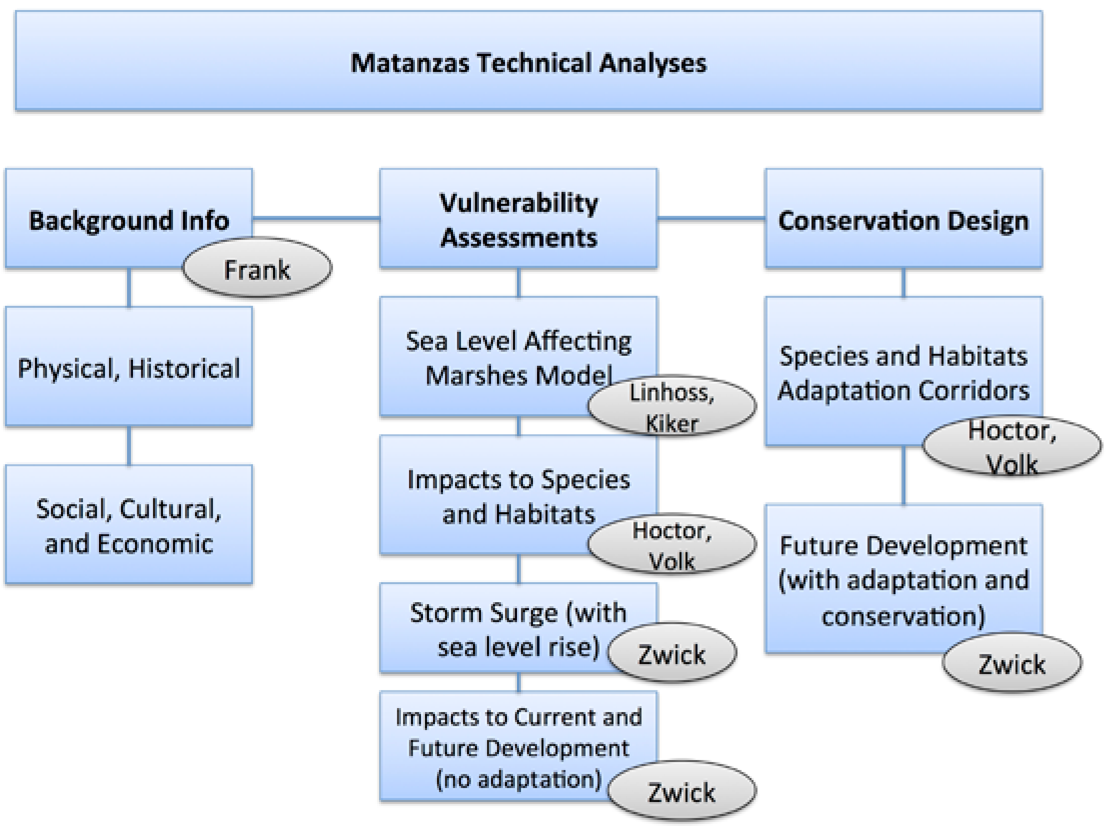


Figure 9. Matanzas project technical methods

The evaluation component is illustrated by a logic model, which relates the project's resources, activities, outputs, and outcomes (Figure 10). The logic model guided the overall project design, scholarship, and methods to collect data for evaluation and social science.

Planning for Sea Level Rise: A Pilot Study to Evaluate and Improve the Development and Delivery of Habitat Vulnerability Assessments and Adaptive Conservation Designs to Coastal Decision Makers (CDMs)

Resources	Activities	Outputs	Short-term Outcomes	Mid-term Outcomes	Long-term Outcomes
• NERRS Science Collaborative Grant • GTM NERR staff time • University of Florida staff and student time • Matanzas Basin • Local Stakeholders and Decision Makers commitment and time (Basin Steering Committee) • Planning tools(i.e. SLAMM, Habitat Priority Planner, LiDAR, etc) • Equipment and materials • NERRS Climate Change Committee	• Create and apply process model handbook • Conduct habitat and development vulnerability and governance readiness assessments • Quarterly meetings with Basin Steering Committee • Conduct informational workshops • Conduct collaborative workshops • Evaluate and assess application of draft process model handbook • Evaluate and assess collaboration methods	• Draft Process Model Handbook • Final Process Model Handbook • Visual aids for sea level rise scenarios • Visual aids for adaptation strategies • Reports • Website • Presentations and articles	• CDMs have an increased understanding of the potential impacts of sea level rise • CDMs have an increased awareness of integrated adaptation strategies • CDMs understand the importance of integrated social-ecological planning for the potential impacts of sea level rise and recognize the barriers	• NERRS system has a model to initiate planning for integrated habitat and development adaptation to sea level rise • CDMs have access to the needed information and tools to plan integrated adaptation to potential sea level rise impacts • Integrated adaptation planning is initiated in the Matanzas Basin • CDMs engage in a collaborative and negotiation process	• Future CDM's will apply the process and communities will be resilient and prepared to adapt to sea level rise • Natural systems, ecological corridors, and ecosystem services are protected and maintained

Figure 10. Project logic model

Collaboration

The project's steering committee, public relations, and public workshop activities were critical to informing the technical and policy analyses, for strengthening regional governance networks, and for raising citizen awareness of sea level rise concerns and strategies.

Steering Committee meeting with the project team

Steering Committee

The GTM Research Reserve director and staff identified local stakeholder representatives to advise the project team, and to communicate the project's importance and findings to interest groups and the public. The interest groups included coastal residents and property owners, coastal businesses, upland developers and land managers (including forestry), local and regional government, and environmental advocates. The committee members are listed in Table 2.

The Steering Committee met with the project team on a quarterly basis over three years. Their primary task was to review the technical analyses and presentations prepared by the project team before they were shared with the public at large. As the project progressed, Steering Committee members transformed their roles from project advisors to regional advocates of planning for sea level rise adaptation. At the project team's request, Steering Committee members spoke on camera about what makes the Matanzas Basin special and the project's importance. The resulting video was placed on the project's website. Members participated in the public workshops, including presenting at the final public meeting, and they recruited attendees. Many members, in their dual roles on the Steering Committee and as community and regional leaders, responded to inquiries from the news media. Most importantly, the Steering Committee became highly knowledgeable about the regional impacts of sea level rise and potential adaptation strategies, and they received the project's spatial (GIS) data (see Appendix J) and printed copies of this report. At the project's conclusion, many of the Steering Committee reported that they had begun complementary adaptation and conservation planning initiatives, or they were using the information in regular activities. Steering Committee members will be a critical force in continuing adaptation planning, design, and implementation in the Matanzas area and the Northeast Florida region.

Member	Affiliation
Neil Armingeon	Riverkeeper, Matanzas Riverkeeper
Denise Bevan	Senior Planner, City of Palm Coast
Mike Brennan	Stormwater Manager, City of Palm Coast
Jan Brewer	Director – Environmental, St. Johns County
Ed Montgomery	Director of Rural Properties, Rayonier
Doug Davis	Senior Vice President, Fletcher Management Company
Patrick Hamilton	Real Estate Broker, coastal property owner
Paul Haydt	Senior Project Manager, St. Johns River Water Management District
Richard Hilsenbeck	Associate Director of Protection, The Nature Conservancy
Sarah Owen Glenhill	Planning Advocate, Florida Wildlife Federation
Jackie Kramer	Board Member, Friends of the GTM Reserve
Maia McGuire	Extension Agent, Northeast Florida Sea Grant
Margo Moehring	Director of Planning and Development, Northeast Florida Regional Council
Eric Ziecheck	Manager/Assistant Dockmaster, Ripple Effect Ecotours, Marineland Marina

Table 2. Steering Committe members

Public Relations

The project used several methods to reach large audiences of the general public, interest groups, and professionals. Within the region, speaking engagements and communications with news media were conducted. At regional, national, and international scales, a website provided a variety of information about the project's purpose, activities, and findings.

US Senator Sheldon Whitehouse (second from right) touring the Matanzas study area

Speaking Engagements

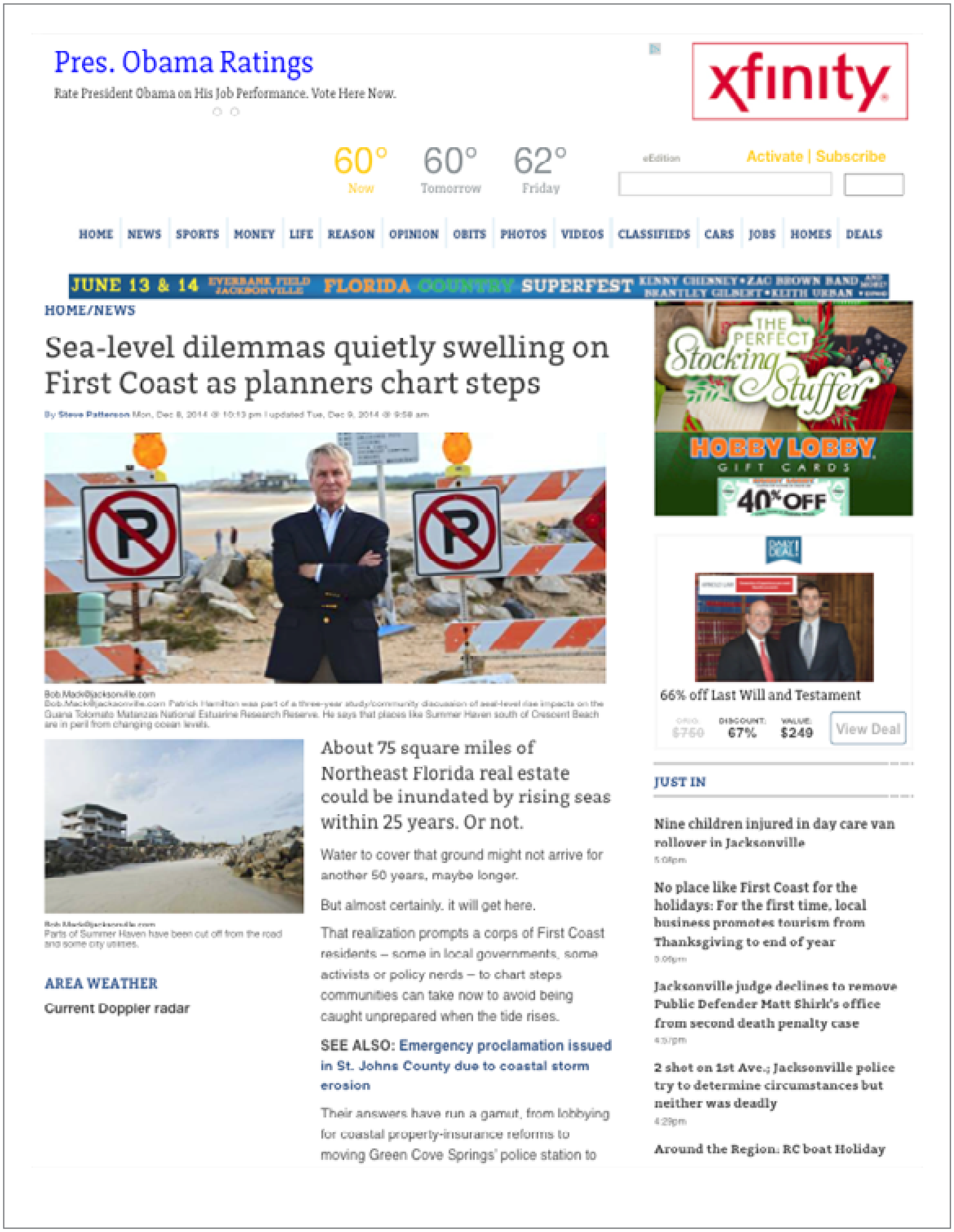
Members of the project team (UF and GTM Research Reserve) and the Steering Committee gave invited presentations to local, regional, and statewide groups throughout the project. Speaking engagements in the study area included staff of St. Johns County, the South Anastasia Civic Association, and the statewide Coastal Hazards Summit in St. Augustine. Presentations within the Northeast and East Central Florida regions were to the following: Amelia Island Chamber of Commerce's Leadership Nassau Class, the First Coast Chapter of the Florida Planning and Zoning Association (FPZA), the Northeast Florida Sierra Club, the Florida Chapter of the American Planning Association annual conference in Jacksonville, and NOAA's Roadmap to Adapting to Coastal Risk in Volusia County.

In April 2014 US Senator Sheldon Whitehouse (Rhode Island) and assistants visited the Matanzas Basin study area as part of his four-day tour of the southeastern United States to view the current impacts of sea level rise and climate change. He met with the GTM Research Reserve director and staff, and project PI Kathryn Frank.

Media

Project team and Steering Committee members issued press releases and spoke with the media (local, regional, and national) throughout the project, and journalists participated in the public workshops. The Daytona Beach *News-Journal* ran the first story about the project a few days after it launched in November 2011: “Study Targets Sea-Level Rise; Flagler Reserve Key to Research.” Next, in December 2012, a series of stories about the project ran in the St. Augustine and Jacksonville news following Hurricane Sandy and around the first set of public workshops. A year later in November 2013, the national *Landscape Architecture Magazine* featured the project in a full-length article, “Think or Swim.” In May 2014 the Union of Concerned Scientists featured St. Augustine in “National Landmarks at Risk: How Rising Seas, Floods, and Wildfires are Threatening the United States’ Most Cherished Historic Sites,” which included a quote by PI Kathryn Frank. At the end of the project following the last public meeting, Jacksonville’s *Florida Times Union* published “Progress is Clear, Challenges Remain in Planning for First Coast Sea-level Change” (September 2014) and “Sea-level Dilemmas Quietly Swelling on First Coast as Planners Chart Steps” (December 2014).

Article in *Landscape Architecture Magazine*, November 2013



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Sea-level dilemmas quietly swelling on First Coast as planners chart steps

By Steve Patterson Mon, Dec 8, 2014 @ 10:13 pm | updated Tue, Dec 9, 2014 @ 9:58 am

Bob.Mack@jacksonville.com
Bob.Mack@jacksonville.com Patrick Hamilton was part of a three-year study/community discussion of sea-level rise impacts on the Guana Tolomato Matanzas National Estuarine Research Reserve. He says that places like Summer Haven south of Crescent Beach are in peril from changing ocean levels.

Bob.Mack@jacksonville.com
Parts of Summer Haven have been cut off from the road and some city utilities.

About 75 square miles of Northeast Florida real estate could be inundated by rising seas within 25 years. Or not.

Water to cover that ground might not arrive for another 50 years, maybe longer.

But almost certainly, it will get here.

That realization prompts a corps of First Coast residents – some in local governments, some activists or policy nerds – to chart steps communities can take now to avoid being caught unprepared when the tide rises.

SEE ALSO: Emergency proclamation issued in St. Johns County due to coastal storm erosion

Their answers have run a gamut, from lobbying for coastal property-insurance reforms to moving Green Cove Springs' police station to

AREA WEATHER

Current Doppler radar

JUST IN

Nine children injured in day care van rollover in Jacksonville
5:08pm

No place like First Coast for the holidays: For the first time, local business promotes tourism from Thanksgiving to end of year
5:06pm

Jacksonville judge declines to remove Public Defender Matt Shirk's office from second death penalty case
4:57pm

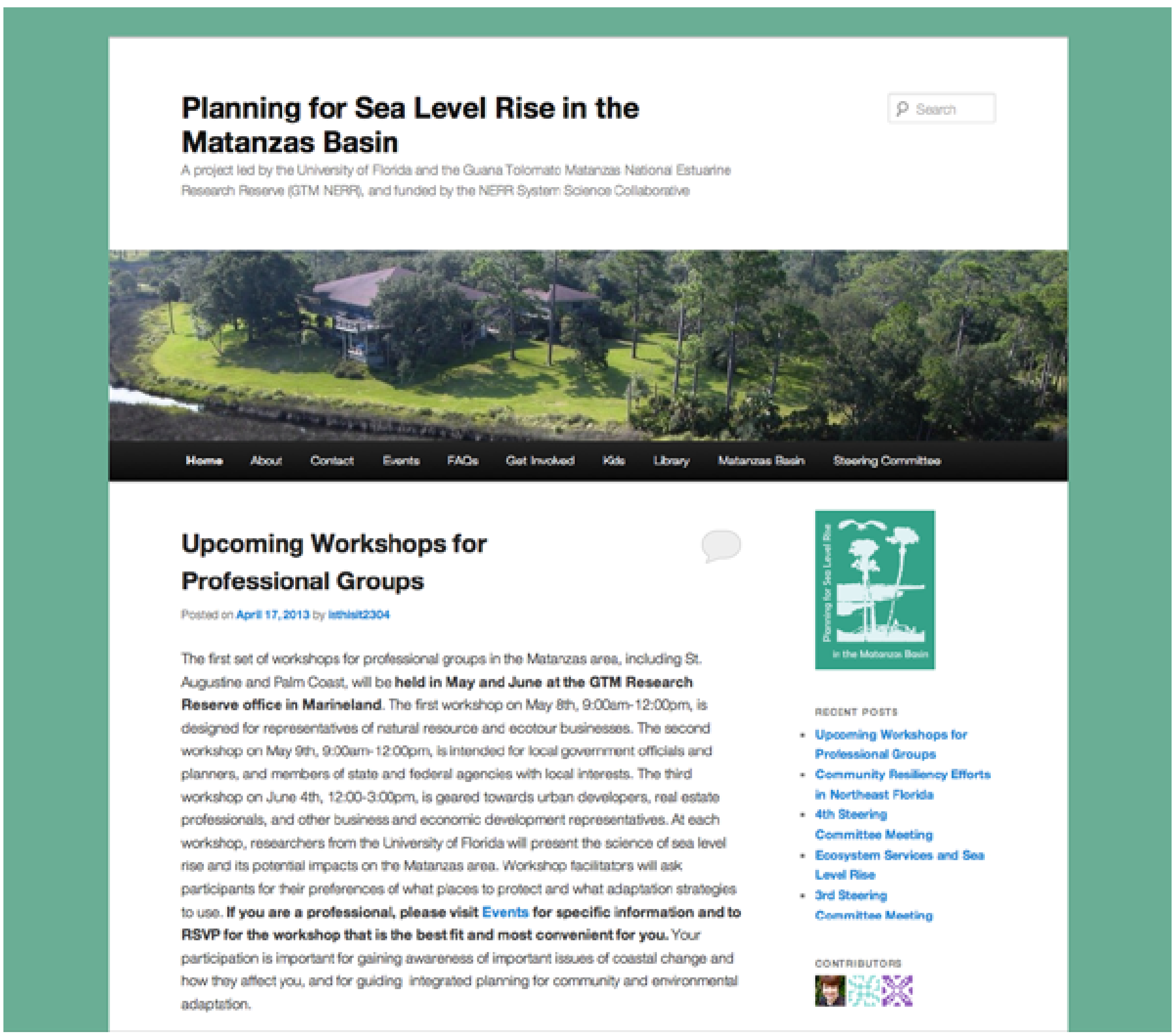
2 shot on 1st Ave.; Jacksonville police try to determine circumstances but neither was deadly
4:29pm

Around the Region: RC boat Holiday

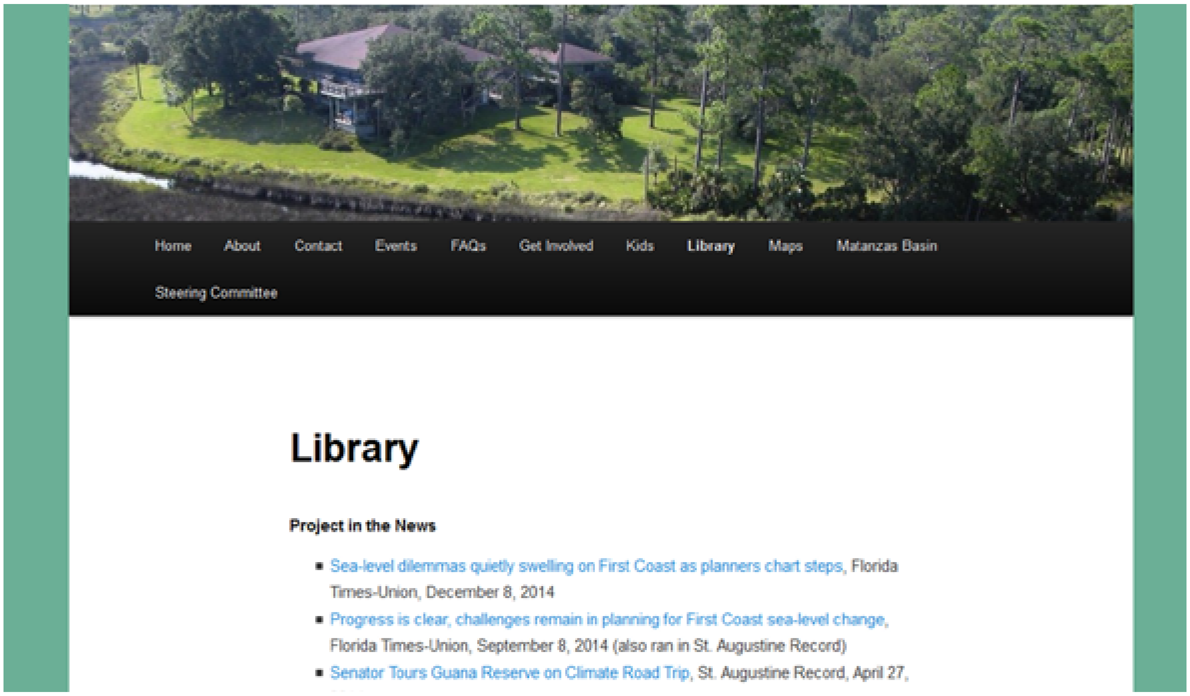
News article featuring Steering Committee members and the project

Website

The project's Wordpress website, PlanningMatanzas.org, went live in June 2012. The website had a homepage with blog, and ten additional pages with project information. The blog contained over 30 posts, which announced the public workshops, posted workshop presentation materials, reported other project activities, and provided general information. The site received comments, but very few were submitted. One reason may be that commenting required a (free) Wordpress account. Over three years the site received over 4,700 visitors and 14,000 views. Ninety percent (90%) of the views were from the United States, and 10% represented 95 other counties.



Project website, PlanningMatanzas.org



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Project in the News
Sea-level dilemmas quietly swelling on First Coast as planners chart steps, Florida Times-Union, December 8, 2014
Progress is clear, challenges remain in planning for First Coast sea-level change, Florida Times-Union, September 8, 2014 (also ran in St. Augustine Record)
Senator Tours Guana Reserve on Climate Road Trip, St. Augustine Record, April 27,

Public Workshops

The project engaged Matanzas stakeholder groups and citizens through a series of three public meetings.

Stakeholder-Based Workshops

The first set of public workshops, conducted from December 2012 to June 2013, engaged specific interest groups, similar to focus groups. The interest groups were area residents, local governments, economic interests, and environmental interests. The residents were invited from three different geographical areas: St. Augustine, Palm Coast, and the coastal communities between them (e.g., Crescent Beach). The GTM Research Reserve's Coastal Training Program staff announced the workshops through the multiple channels they often use to invite participants to their public meetings and training sessions. In addition, at the suggestion of the Steering Committee, the GTM Research Reserve held three youth workshops with middle school, high school, and college students. The stakeholder-based approach enabled the project team to understand each groups' perspective on values of the Matanzas Basin, beliefs and attitudes about sea level rise, and preferences for adaptation. The stakeholder-based workshops, dates, and numbers of participants are shown in Table 3.

The stakeholder-based workshops introduced participants to the project, the science of sea level rise, and project findings of current and future impacts of sea level rise to the Matanzas study area. The workshops also gathered participant input on their values in the Matanzas Basin and preferences for sea level rise adaptation. All the adult stakeholder-based workshops followed a similar agenda: welcome, initial keypad polling, presentation by the UF team, large-group visioning exercise, small-group adaptation strategies role-play game, and final keypad polling. In the workshop rooms, the project team displayed posters with information about the project and the local sea level rise impacts.

Stakeholder Group	Workshop Date	Location	Number of Participants
Residents of Palm Coast and Coastal Communities	Dec 5, 2012, 9:00am-12:00pm	GTM Research Reserve Marineland Office	20
Residents of Palm Coast and Coastal Communities	Dec 5, 2012, 5:30pm-8:30pm	GTM Research Reserve Marineland Office	23
Residents of St. Augustine	Dec 6, 2012, 9:00am-12:00pm	St. Augustine Alligator Farm	33
Residents of St. Augustine	Dec 6, 2012, 5:30-8:30pm	Flagler College	24
		Total Residents	**100**
Environmental Interests	May 8, 2013, 9:00am-12:00pm	GTM Research Reserve Marineland Office	13
Local Governments	May 9, 2013, 9:00am-12:00pm	GTM Research Reserve Marineland Office	13
Economic Interests	Jun 4, 2013, 12:00-3:00pm	GTM Research Reserve Marineland Office	9
		Total Professional Interests	**35**
College Students	Apr 9, 2013	St. Johns River State College, St. Augustine	30
High School Students	Apr 29-May 6, 2013	Matanzas High School, Palm Coast	120
Middle School Students	Jun 26, 2013	Summer Program at St. Johns Technical High School, St. Augustine	40
		Total Youth	**190**

Table 3. Stakeholder-based workshops

The electronic keypad polling was a survey of workshop participants at the beginning and end of the workshop. The survey asked participants about their familiarity with sea level rise, opinions about impacts and adaptation strategies, and satisfaction with the workshop. The aggregated results for the questions about sea level rise were shared with the participants in real time.

The presentation by the UF team was a primer on sea level rise impacts and adaptation strategies. The presentation used local data, maps, examples, and photos whenever possible, including historical images for comparison. The

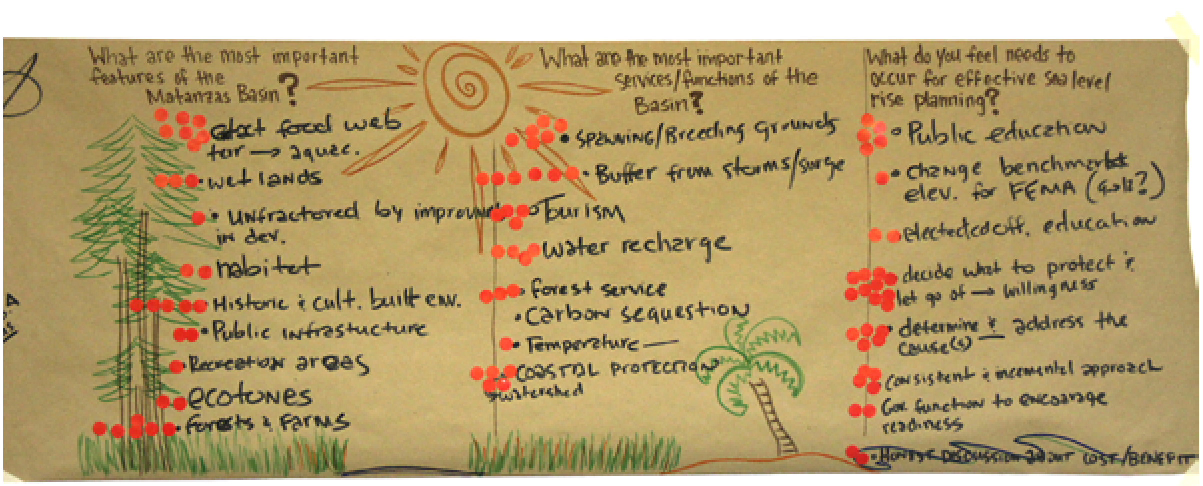
Video simulations of future sea level rise, Marineland sea level rise impacts were identified through the Sea Level Rise Affecting Marshes Model (SLAMM), as well as literature reviews and qualitative analysis. Some of the photos used in the posters were donated to the project from local photographer Ed Siarkowicz. Many of the photos were also posted on the project's website and used in later presentations and materials. The workshop presentation also included video simulations of future sea level rise inundation based on the SLAMM analyses.

Video simulations of future sea level rise, Marineland

The large-group visioning exercise asked three questions of the participants: What are the most important features of the Matanzas Basin? What are the most important services and functions of the Basin? What do you feel needs to occur for effective sea level rise planning? The answers were recorded on a large sheet of paper hung on the wall, and participants marked their top priorities with red dot stickers.

Photo by Ed Siarkowicz Photographic Images, LLC

Visioning exercise



Visioning exercise results from one workshop

For the adaptation strategies role-play game, workshop participants divided into groups of four to six, each with a facilitator from the project team. In each group, each person took on a different coastal stakeholder persona: local resident, government official, environmental scientist, ecotourism business owner, or inland developer. Each player had a certain amount of money, and the object of the game was to work together to “buy” different sea level rise adaptation strategies to help the hypothetical community plan for sea level rise over the next twenty years. Adaptation strategies included seawalls, beach nourishment, raising buildings, coastal ecosystem restoration, steering future development away from the coast, habitat migration corridors, aquifer recharge easements, and planned relocation of existing coastal development.

Adaptation strategies role-play game

The participant input from the visioning exercise and the role-play game were incorporated into the project, and results were presented at the following multi-stakeholder workshop.

Local Resident **$100 million**

- You have been selected to represent your community on this issue.
- Your community is a beach community.
- Members of your community enjoy living where they do because they enjoy seeing wildlife in their backyards, watching dolphins swim into the sunset, and going to the beach.
- Your houses are near the water and your neighborhood floods during heavy storms.

Living Shoreline **$25,000/acre**

- Maintaining natural vegetation along the shoreline.

1. Reintroducing wetlands to areas that have lost them. Wetlands help absorb the impact of coastal dynamics by providing a place for the water to go, acting as a buffer between the sea and development.
2. Using organic and structural materials like wetland plants, sand, aquatic vegetation, oyster reefs and stone to create a protective shoreline and maintain valuable habitat.

Key benefits: Allow migration of habitats and threatened species, protect recreation and tourism, protect fisheries and rookeries; improve water quality via filtration of upland runoff

Adaptation strategies role-play game cards

Multi-Stakeholder Workshop

The second workshop – the multi-stakeholder workshop – was held on February 24, 2014, 2:00-5:00pm, at the Whitney Lab in Marineland. About 70 members of the public and stakeholder representatives attended. The purpose of the multi-stakeholder workshop was to present the synthesized results from the first set of stakeholder-based workshops, and the technical analyses concerning future development and conservation priorities. The aim was to inspire dialog about the relationships between sea level rise, future population growth, development patterns, and environmental conservation. The agenda included the following activities: welcome, initial keypad polling, presentation by the project team, large-group SWOT exercise for conservation priorities, small-group future development game, and final keypad polling.

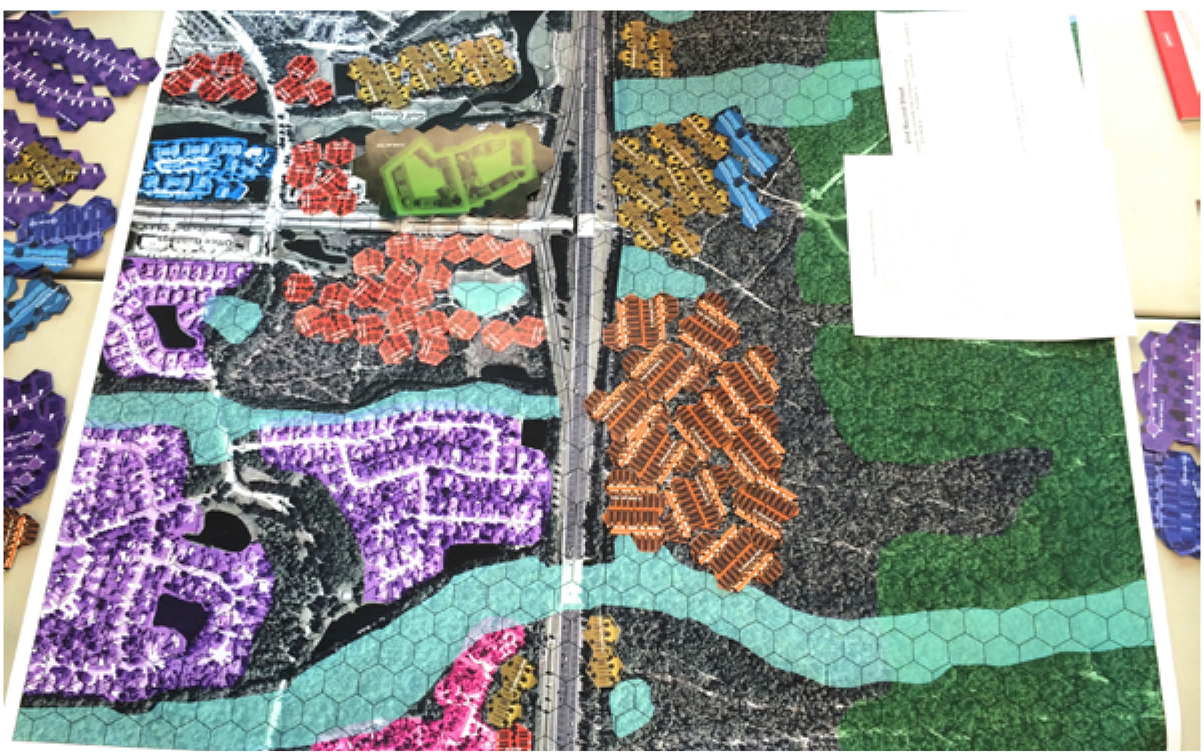
The keypad polling focused on opinions about development patterns and land conservation, as well as satisfaction with the workshop.

The project team's presentation showed the impacts of sea level rise and future development on the habitats of three species in the study area – shorebirds, gopher tortoises, and black bears. The team then described future land development scenarios that would allow the region to adapt to sea level rise and accommodate projected growth while minimizing loss of natural habitat.

The large-group SWOT (strengths, weaknesses, opportunities, and threats) exercise gathered participant feedback regarding the regional conservation priorities map created by the project team.

Multi-stakeholder workshop presentation

In the future development game, each group of ten or less gathered around a hypothetical 700-acre inland tract (not directly coastal) showing areas of development and conservation priorities. The objective of the game was to allocate a certain number of residential units, which represented the projected growth, including sea level rise adaptation away from vulnerable areas, for the region to year 2060. Using game pieces, players were able to choose the densities and locations of the residential units. There was also a game piece showing a mixed-use town center. The game results showed each group's negotiated preferences for "smart growth" principles, including infill, redevelopment, contiguous development, mixed-use town centers, and avoidance of conservation priorities.



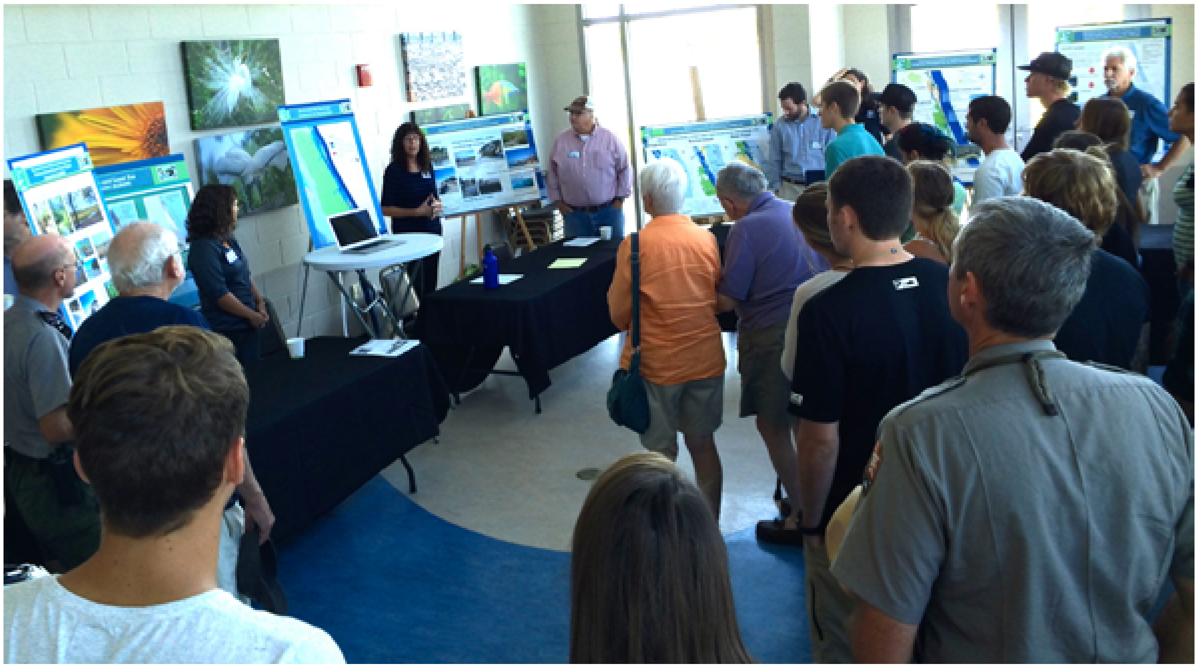
Future development game results from one group

Future development game

Final Public Presentation

The project's final public meeting occurred on September 8, 2014, from 10:00am to 2:00pm, at the Whitney Lab in Marineland. The purpose of the meeting was to present the summarized findings from the all the project's technical and policy analyses, and stakeholder and public input. About 80 community leaders, concerned citizens, local college students, and reporters attended.

The meeting format was similar to an open house. Participants registered for half-hour slots. Each group of 10-20 people began by watching an 8-minute video summarizing the project, followed by a guided tour through stations to learn about the different components of the project, ask questions, and provide feedback. At each station Steering Committee and project team members spoke and showed posters on the following topics: project overview and methods; local values of the Matanzas Basin; sea level rise impacts on the GTM Research Reserve; sea level rise impacts on communities; storm surge modeling results; adaptation strategies for communities; conservation priorities for sea level rise adaptation and eco-protection; historic development patterns; future development scenarios; other sea level rise adaptation strategies for the GTM Research Reserve; and local adaptive capacity. At the end of the tour, attendees were allowed to document their concerns, questions, and willingness to participate in future activities hosted by the GTM Research Reserve.



Steering Committee members speaking at the final public presentation

Technical Analyses

The project team conducted a variety of technical analyses in order to comprehensively understand the major changes occurring within the Matanzas study area, and potential future land use scenarios. The technical analyses contributed background information about the Matanzas study area, sea level rise vulnerability assessments, and land use analyses and conservation priorities. This section is an overview of the methods, and more details are provided in the appendices.

Photo by Ed Siarkowicz Photographic Images, LLC

Background Information

The background information collected related to general topics, as well as characteristics of the Matanzas study area and the Florida planning context.

On general topics, the project team conducted literature reviews about sea level rise and climate change adaptation planning, coastal zone management, rural planning, and aspects of the collaboration methods, such as the use of role-play games in planning, youth engagement, and climate communication. Given the rapid advancements in sea level rise science and adaptation planning, the project team networked with scientists and professionals across the university system, the state, and the nation.

Background information about the Matanzas study area complemented the land use (GIS) analyses. The background information related to the Matanzas area's natural systems, including hydrology (surface flows and groundwater) and climate, and social systems, especially economic and cultural. Literature was also reviewed related to conservation and natural resources. Including species and habitat vulnerability, adaptative capacity, and resilience to sea-level rise within the study area. The background research often occurred in response to stakeholder and public comments regarding observed changes and their implications. Examples are coastal erosion and saltwater intrusion into aquifers. The project also took an historical perspective, gathering information about changes over time and past adaptations. Additional analyses of the Matanzas area's social systems were included in the future planning and policymaking component discussed below. The gathered background information is integrated into the Vulnerabilities and Adaptation Strategies sections.

Vulnerability Assessments

Vulnerability assessments identify places and systems potentially impacted by current and future sea level rise. Vulnerability assessments represent first-order impacts, which can then be analyzed as inputs towards second-order impacts on social, economic, and ecological systems. Detailed analysis of second-order impacts is important for ongoing adaptation planning, but it was beyond the scope of this project. Table 4 relates the potential sea level rise impacts to the research methods applied in the project. The elevation, habitat changes, and storm surge models were based in geographic information systems (GIS). The local knowledge input occurred through the methods of collaboration and background information described above.

Potential Sea Level Rise Impacts	Elevation Model	Storm Surge Model: Hazus	Habitat Changes Model: SLAMM	Local Knowledge
Inundation and increased flooding	✓	✓	✓	✓
Greater coastal erosion				✓
Saltwater intrusion into aquifers				✓
Higher storm surges		✓		✓
Habitat and species changes			✓	✓

Table 4. Project methods for vulnerability assessments

Elevation

Mapping of land elevation was a simple way to identify places vulnerable to long-term inundation and increased flooding from sea level rise. Land elevation was also a key input to advanced models of sea level rise impacts, including the Hazus model for storm surge and the Sea Level Affecting Marshes Model (SLAMM).

"Bathtub models" of land vulnerability are based on elevation data and assume that all land below a specified elevation, and that has a hydrologic connection to the coast, will be inundated when sea level rise equals a specified elevation. Normal tide range may also be included in the analysis of potentially affected lands, called a "tidally adjusted" bathtub model. The tidally adjusted bathtub model thus includes areas that may be subjected to more frequent flooding during daily high tides, which reach higher elevations as a result of sea level rise. The bathtub models do not take into account flood protection measures that may be in place or implemented in the future, and they do not include increased flooding that may result from inadequate stormwater drainage systems or rising groundwater.

When the project began, agencies and researchers were in the process of producing a LiDAR-based digital elevation model (DEM) for the state. The project team pieced together the best available DEM data for the study area, most of it LiDAR-based, from a combination of sources (see Appendix A).

The project team used the DEM in a basic bathtub model (not tidally adjusted) to map low lying areas below 1.5 and 3 feet elevations that would be vulnerable to sea level rise. These results were presented as a poster in the first set of public workshops. The project team also overlaid the bathtub model on the locations of critical public facilities such as schools and fire stations, in order to begin to understand potential social and economic impacts.

Storm Surge

Coastal zone planning and management traditionally includes analysis of high-hazard areas, and adaptation planning should ascertain how sea level rise and other climate changes could affect these hazards. One type of coastal hazard, storm surges from hurricanes and tropical storms, as well as nor'easters, has caused significant erosion, sand deposition, and flooding in the Matanzas area. Sea level rise will increase storm surge depths in already vulnerable areas, and introduce new vulnerable areas.

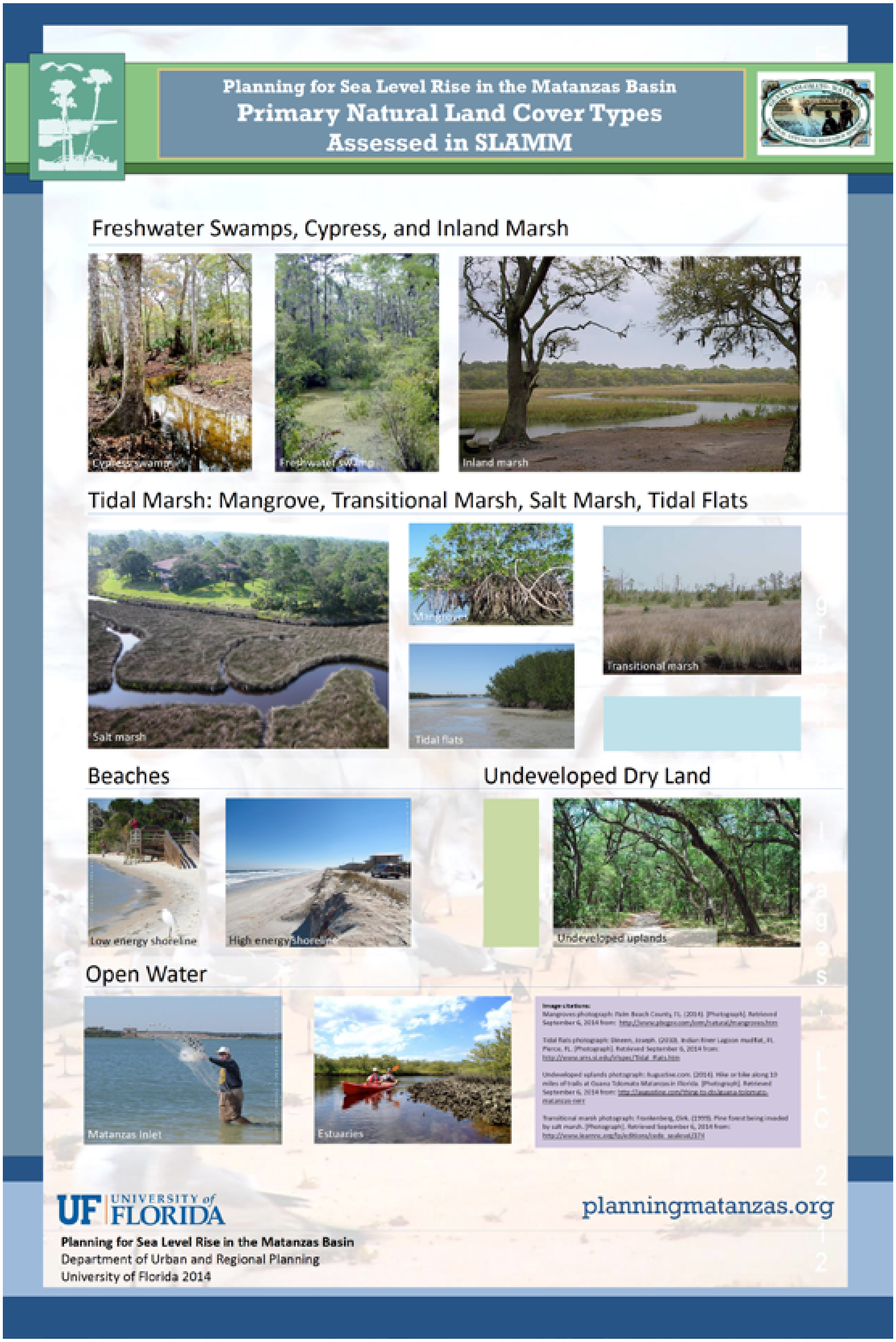
To map areas of increased vulnerability to flooding from storm surges due to sea level rise, the project team applied the Federal Emergency Management Agency's (FEMA) Hazus model. The Hazus modeling identified areas having a 1% chance of flooding due to coastal storm surges, i.e., a "100-year storm," for three scenarios: no sea level rise, 0.5 meters of sea level rise, and 1 meter of sea level rise. The methodology is further described in Appendix B.

Flooding in St. Augustine. Source: http://staugustine.com/news/local-news/2013-09-19/st-augustine-has-plan-help-flooded-streets

Sea Level Affecting Marshes Model (SLAMM)

The Sea Level Affecting Marshes Model (SLAMM) is a GIS-based software tool that simulates incremental changes in shorelines and coastal habitats under various sea level rise scenarios, providing more detailed information than can be obtained with bathtub models. For example, SLAMM can simulate land cover changes showing conversion of upland areas to marsh habitat based on existing land cover, tidal range, and erosion and accretion data; whereas a bathtub model might indicate that the same area converts to open water. SLAMM is primarily a tool for modeling changes in wetland land cover types. It does not dynamically model changes in terrestrial land cover types, except to indicate where they convert to open water or wetlands under sea level rise scenarios. Additionally, the number of land cover types that SLAMM uses is relatively small and generic across different landscape types, making impact assessments for specific natural communities more difficult.

The project team created SLAMM scenarios for 0.2, 0.5, 1.0, 1.5, 2.0, and 2.5 meters (i.e., from 8 inches to 8 feet) sea level rise by the year 2100. The project team used the resulting spatial data to estimate the rate and amount of change in various natural land cover types resulting from sea level rise. SLAMM data were critical inputs to the conservation impact and priority analyses, and the future development scenarios. Details of the SLAMM methodology are contained in Appendix C.



Planning for Sea Level Rise in the Matanzas Basin
Primary Natural Land Cover Types Assessed in SLAMM
Freshwater Swamps, Cypress, and Inland Marsh
Cypress swamp
Freshwater swamp
Inland marsh
Tidal Marsh: Mangrove, Transitional Marsh, Salt Marsh, Tidal Flats
Salt marsh
Mangroves
Tidal flats
Transitional marsh
Beaches
Low energy shoreline
High energy shoreline
Undeveloped Dry Land
Undeveloped uplands
Open Water
Matanzas Inlet
Estuaries
Image citations:
UF UNIVERSITY of FLORIDA
Planning for Sea Level Rise in the Matanzas Basin
Department of Urban and Regional Planning
University of Florida 2014
planningmatanzas.org

Land Use Analyses and Conservation Priorities

Impacts to Current and Future Development

The number of people residing in the Matanzas study area is significant. At about 150,000 people in 2010, the study area for this project contained over half of the total population in the two counties which it overlaps (286,000; 190,000 in St. Johns County and 96,000 in Flagler County, according to the US Census). Population growth pressures in the Matanzas area are also substantial. Based on historic rates, the Florida Bureau of Economic and Business Research (BEBR) projects that by the year 2060 the number of people in St. Johns County will be over two-and-a-half (2.5) times the 2010 level, and in Flagler County over three (3) times. This represents about 310,000 and 200,000 more people in St. Johns and Flagler counties, respectively.

Most of the urban development in the study area has occurred along or near the coast, and some of this development is vulnerable to sea level rise. Knowledge of the locations of vulnerable development, and vulnerable dry “developable” areas, is important for land use, infrastructure, and neighborhood planning. Planning and policymaking should consider future development scenarios, including population growth and the potential relocation and redirection of development away from vulnerable areas.

The project team conducted GIS-based analyses of current development, and modeled future development scenarios using methods from the Land Use Conflict Identification Strategy (LUCIS) process (see Appendix E). LUCIS allocates future development based on county population and employment projections, and land suitability for a wide variety of land uses, including urban (e.g., residential and commercial), agricultural (including forestry), and environmental conservation. Land suitability for future urban development includes factors such as current land uses, nearness to existing urban centers and roads, and approved development permits. The LUCIS analyst specifies the land suitability criteria based on established standards and local input, including how to resolve “conflicts” when a given location is equally suitable for two or more different land uses.

For this study, an additional criterion was whether land was vulnerable to sea level rise, with vulnerable areas determined by the SLAMM results for 3 feet (1 meter) sea level rise (by the year 2100). Three feet sea level rise could occur as early as 2075. Vulnerable areas were those showing habitat change due to increased flooding, and patches of land surrounded by vulnerable areas and hence assumed unserviceable for development. Only newly inundated areas connected to existing open water, and new wetlands directly connected to the coast were defined as areas vulnerable to sea level rise. New and existing inland wetlands were generally avoided in the future land use scenarios, though in some cases wetlands were developed when additional land was needed to allocate future population.

Because future population projections and other data are primarily available at the county scale, future development scenarios were developed for the entire area of St Johns and Flagler counties (rather than the smaller Matanzas study area). To identify vulnerable areas at the two-county scale, researchers combined the high resolution SLAMM data for the Matanzas study area with the less resolute (120 meter cell size) SLAMM data produced at the statewide level.

Developments of regional impact (DRIs) were included in the analysis based on data from the Florida Geographic Data Library (www.fgdl.org) and assumed likely to be developed. DRIs that were not approved or pending at the time of the project were not considered. Redevelopment and infill were included as parameters within the model, and parcels with structures defined as near end-of-life and with low market values were considered potential opportunities for redevelopment. Historic rates of redevelopment were referenced, but in some cases higher redevelopment rates were used due to limited availability of new greenfield lands for development (such as in the conservation scenarios described below).

The project team used LUCIS to create four future development scenarios for Flagler and St. Johns counties based on BEBR county population and employment projections for 2060, the furthest point in the future the team deemed reasonable for applying the projections. For the two scenarios relocating and redirecting development away from areas vulnerable to sea level rise, the team assumed that the development would stay within the counties. The two scenarios with sea level rise were modeled by lead researcher Paul Zwick based on detailed current development densities differentiated by types (residential, commercial, etc.). The two scenarios without sea level rise were modeled by research assistant Max Deledda based on average current densities (i.e., gross urban density). Due to the differences in methodologies, the results of the scenarios should not be compared across “with sea level rise” and “without sea level rise.”

The four scenarios were as follows:

- *Trend development with sea level rise.* This scenario showed potential development by the year 2060 based on current patterns (i.e., no change in land use policies or practices), but also relocating and redirecting development away from areas vulnerable to 3 feet of sea level rise. The trend with sea level rise scenario avoided existing conservation lands and wetlands, prioritized development on currently platted parcels (including infill lots) and other lands having high preference for urban development (and with large parcels, typically in agricultural/timber use), redeveloped commercial parcels having buildings at least 50 years old by 2060, and allocated land needed for corresponding infrastructure such as roads. This was the scenario that was used to assess the maximum combined impacts from development and sea level rise on future conservation priorities (including adaptation to sea level rise – see next section).
- *Conservation development with sea level rise.* This scenario shows potential development by the year 2060, using similar modeling criteria as the trend scenario, but avoiding areas identified as future conservation priorities (including adaptation to sea level rise), while also relocating and redirecting development away from areas vulnerable to sea level rise. This scenario takes into account adaptation strategies for the natural environment.
- *Trend development without sea level rise.* This scenario showed potential development by the year 2060 based on continuation of current development patterns and average densities.
- *Conservation development without sea level rise.* This scenario showed potential development by the year 2060 based on avoiding areas identified as future conservation priorities, but not relocating and redirecting development away from areas vulnerable to sea level rise.

Although the analyses were conducted at the scale of the counties, the resulting future development maps were appropriate for the Matanzas study area, because the model differentiated land within each county and allocated the growth based on locational attractiveness (e.g., northern St. Johns county received a larger proportion of the county's future development based on its proximity to Jacksonville). For each future development scenario the project team generated maps and spatial statistics, such as the number of acres developed and development densities. The GIS data were also used as inputs for the conservation impact and priority analyses.

Additionally, in response to questions from participants in the second (multi-stakeholder) workshop, the project team mapped historic patterns of development in the two-county region. Single family houses were grouped by decade using the actual year built field in the 2012 parcel data available from the Florida Geographic Data Library (FGDL). Since the focus was on recent development patterns, parcels with extant houses built prior to 1970 were grouped together.

Photo by Ed Siarkowicz Photographic Images, LLC

Impacts to Ecological Resources and Conservation Priorities

The Matanzas study area has significant ecological resources, with significant lands and waters in public ownership for environmental conservation (e.g., the GTM Research Reserve), and in large privately owned tracts managed for timber production and protection of freshwater wetlands.

With these conservation values and the environmental stewardship mission of the GTM Research Reserve in mind, the project generated GIS-based information for the following:

- Current conservation priorities
- How the current priorities may be affected by the ecological changes caused by sea level rise and future development
- Future conservation priorities based on the ecological changes caused by sea level rise

The types of conservation priorities analyzed included species (37 focal species and species guilds), natural communities (8 upland types, including pine plantation and rangeland, and 12 wetlands and open water habitat types from SLAMM), and landscapes (water resources, biodiversity hotspots, and estuarine habitats). Habitat for focal species was identified based on species occurrence data and habitat models, which are GIS-based scripts that assess the physical characteristics of the landscape and potential habitat suitability for a given species. The ecological changes caused by sea level rise were identified from the SLAMM runs for 1 and 2.5 meters (3 and 8 feet) sea level rise by the year 2100, and assuming currently developed areas did not change, i.e., did not convert to new habitat due to sea level rise. The project team also conducted a literature review of how sea level rise affects the focal species and natural communities. that occur in the study area. Future development impacts were based on the "trend development with sea level rise" scenario discussed above. Future conservation priorities species were identified using SLAMM results to identify potential future priority habitat. The analyses were conducted at various geographic scales (shown in Figure 11). The analyses are summarized in Table 5, and more details about the methods are provided in Appendix D

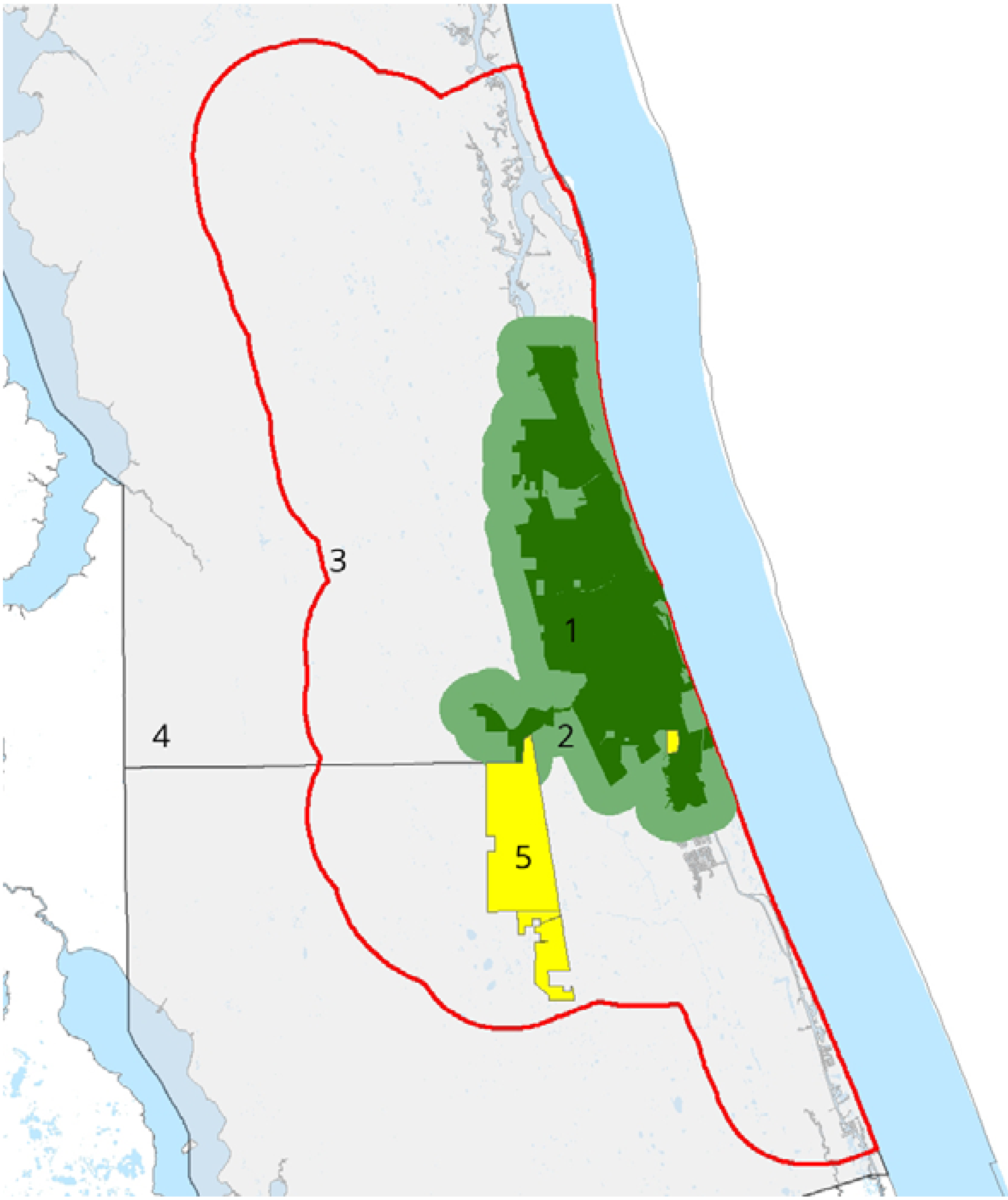


Figure 11. Scales of analysis for conservation impacts and priorities: (1) GTM Research Reserve – Southern Component (dark green), (2) Reserve plus 1-mile buffer (light green), (3) project study area (red), and (4) St. Johns and Flagler counties (grey). Parcels of special interest to the GTM Research Reserve – Pringle Forest and Marsh View – are shown in yellow

Conservation Priority Type	Impacts to Current Priorities	Future Priorities
Focal Species	From 1 and 2.5 meter sea level rise scenarios From trend development with sea level rise scenario In Reserve only, Reserve plus all other existing conservation lands, and the entire project study area	With changes from 1 and 2.5 meter sea level rise In Reserve plus 1 mile buffer
Priority Natural Communities (includes working lands)	From 1 and 2.5 meter sea level rise scenarios From trend development with sea level rise scenario In Project study area	Same as current priorities
Water Resource Priorities	Same as #2	Same as #2
Biodiversity Hotspots	Same as #2	Same as #2
Estuarine Habitat Protection	From 1 and 2.5 meter sea level rise scenarios From trend development with sea level rise scenario In Reserve, Reserve plus 1 mile buffer, and project study area	1 meter sea level rise In project study area
Coastal to Inland Connectivity Priorities	Not applicable	Same as current priorities
Reserve Scale Conservation Priorities	Not applicable	From 1 meter sea level rise In Reserve plus 1 mile buffer
Regional Conservation Priorities	Not applicable	Same as current priorities In St. Johns and Flagler counties

Table 5. Conservation impact and priority analyses: types and scales

Photo by Ed Siarkowicz Photographic Images, LLC

Future Planning and Policymaking

The project included methods to process the social information gathered from the public workshops and background research, and to relate the technical analyses to potential adaptation strategies and supportive local policies. The key methods were conflict assessment, readiness assessment, local policy analysis, and development of adaptation strategies toolboxes.

Conflict Assessment

A conflict assessment is a technique borrowed from the field of negotiation and alternative dispute resolution, and they are increasingly applied in collaborative processes (Schneck 2008). In general, a conflict assessment is a characterization of the points of conflict and agreement among stakeholders on a given matter (Susskind and Thomas-Larner, n.d.). This information can support ongoing planning and policymaking. The basic approach of a conflict assessment is to identify stakeholders, conduct interviews with stakeholders, and present the findings.

For this project, the conflict assessment centered on Matanzas stakeholders' points of conflict and agreement regarding strategies for sea level rise adaptation and related land use planning for regional resilience. Points of conflict and agreement are important to understand due to the fact that sea level rise adaptation planning is a new, sometimes controversial practice. This project modified the basic approach of a conflict assessment. Instead of conducting individual interviews, the project team obtained stakeholder information from the stakeholder-based workshops and observations throughout the project. And, the results are integrated into this report, particularly the Adaptation Strategies section, rather than presented in a standalone document.

Readiness Assessment

A readiness assessment is a social science method with findings that overlap those of a conflict assessment (discussed above). A readiness assessment determines governance capacity to venture into a new arrangement or activity, such as sea level rise adaptation. Governance capacity can be thought of in terms of the strength of civic, professional, political, institutional, and economic resources. A readiness (or capacity) assessment reviews, describes, and evaluates these social systems, including past governance actions and outcomes, and current attitudes and policies (Lincoln Institute of Land Policy 2011, Smith 2011).

In the case of adaptation, the readiness assessment characterizes governance adaptive capacity, which represents the ability to perceive, evaluate, and respond to change, to achieve long-term resilience and sustainability. Adaptive capacity for sea level rise includes, for example, availability and acceptance of sea level rise science, the salience of adaptation planning, and local and regional planning processes in which adaptation issues can be incorporated. Adaptive capacity is the flip side of vulnerability, and hence this project's readiness assessment complements the vulnerability assessments, in order to help communities and regions identify the most promising avenues for implementing strategies. The Adaptation Strategies section presents the results from the readiness assessment.

Adaptation Strategies Toolboxes and Policy Analyses

Vulnerability assessments, conflict and readiness assessments, the creation of adaptation strategies toolboxes, and policy analyses build on one another to move towards tangible responses to sea level rise.

The project conducted an extensive literature review of sea level rise adaptation strategies. The result was a “toolbox” consisting of a comprehensive table of strategies organized by type, and a descriptive report which included a framework for applying the strategies in the Matanzas area (Appendices H1 and H2).

In support of the adaptation strategies toolbox and readiness assessment (above), and the conservation priorities and land use strategies identified in the technical analyses, the team conducted additional research of local, regional, and state policies and programs. The project analyzed local comprehensive plans for St. Johns County, Flagler County, St. Augustine, and Palm Coast, as well as the St. Johns County Local Mitigation Strategy (LMS), to reveal numerous policies related to adaptation (Appendices H3 and H4). The project assembled a primer on smart growth land use, low impact development (LID) , and green infrastructure principles to foster regional resilience, which included a Florida case study and outlined the application of the principles to the Matanzas area (Appendix G). Additionally, the project researched specific land conservation programs and policy mechanisms available at regional and state levels, and their potential application to the Matanzas area (Appendix F). The conservation strategies toolbox includes maps of planned conservation areas, locations of land covers qualifying for conservation programs, and major landowners. The results from toolboxes and policy analyses are summarized in the Adaptation Strategies section.

Information Synthesis

Information synthesis integrated the results from the collaboration, technical analyses, and future planning and policymaking methods. Information synthesis occurred throughout the project for different systems and objectives, and at progressively expanding levels of synthesis. The primary methods of information synthesis were interdisciplinary project team discussions, and "science translation" in order to present the findings in a comprehensible and meaningful way to the Steering Committee and at the public workshops.

A guiding principle for the information synthesis was sustainability science, whereby a place, in this case the Matanzas area, would be known holistically and purposively, to enable the goal of regional resilience to sea level rise. The Matanzas area sustainability science allowed the project team to characterize the types, magnitude, and timing of the sea level rise impacts, and the kinds of strategies that would be most useful and likely to be implemented. In other words, sustainability science represents good judgment.

Sustainability science views communities and regions as linked human-landscape systems. The project analyzed the Matanzas area in terms of system properties, such as the possibility for “tipping points” of rapid change in the natural or built environments, and hence the regional values and economy, as sea level rises.

It is also important to note the limitations of the study towards generating sustainability science. Several critical systems and changes were only lightly examined, including coastal erosion, aquifer saltwater intrusion, adequacy of urban stormwater infrastructure, and impacts from other climate changes. Research and planning for sustainability science in the Matanzas area should continue beyond this project.

Implementation Support

Without conscious support for implementation, research data and planning reports may collect dust, and the same concern applies to this project. The project provided continuous support for implementation through the collaboration methods, especially the engagement of stakeholder representatives and community leaders via the Steering Committee. The actions taken to date by the GTM Research Reserve and the Steering Committee members – to use the project's information and conduct complementary adaptation planning initiatives – are reported in the Adaptation Strategies section.

Toward the end of the project, the project team, with suggestions from the Steering Committee, added mechanisms to facilitate use of the generated data and information. The project team applied the social science gathered by the project to identify possible users of the information, the methods of use, and the best approaches for sharing and communicating the information. As a result, the team designed user-friendly materials at various levels of detail. In addition to the synthesized information in this report, the detailed appendices, and an executive summary, the team is creating one-page briefs of the major findings, with the GTM Research Reserve taking the lead. The project's GIS data were also available to the Steering Committee members and interested organizations and individuals via an FTP site, thus allowing users to tailor analyses and maps to their needs. To facilitate use of the GIS data, a metadata document was included with the files (see Appendix J). The project team remained available to assist users with accessing and understanding the information.

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Photo by Ed Siarkowicz Photographic Images, LLC

Vulnerabilities

Matanzas Values and Concerns

The background research and collaborative activities of the project, including the steering committee and public workshops, provided an understanding of the important values and concerns of the Matanzas area residents and stakeholders.

Values

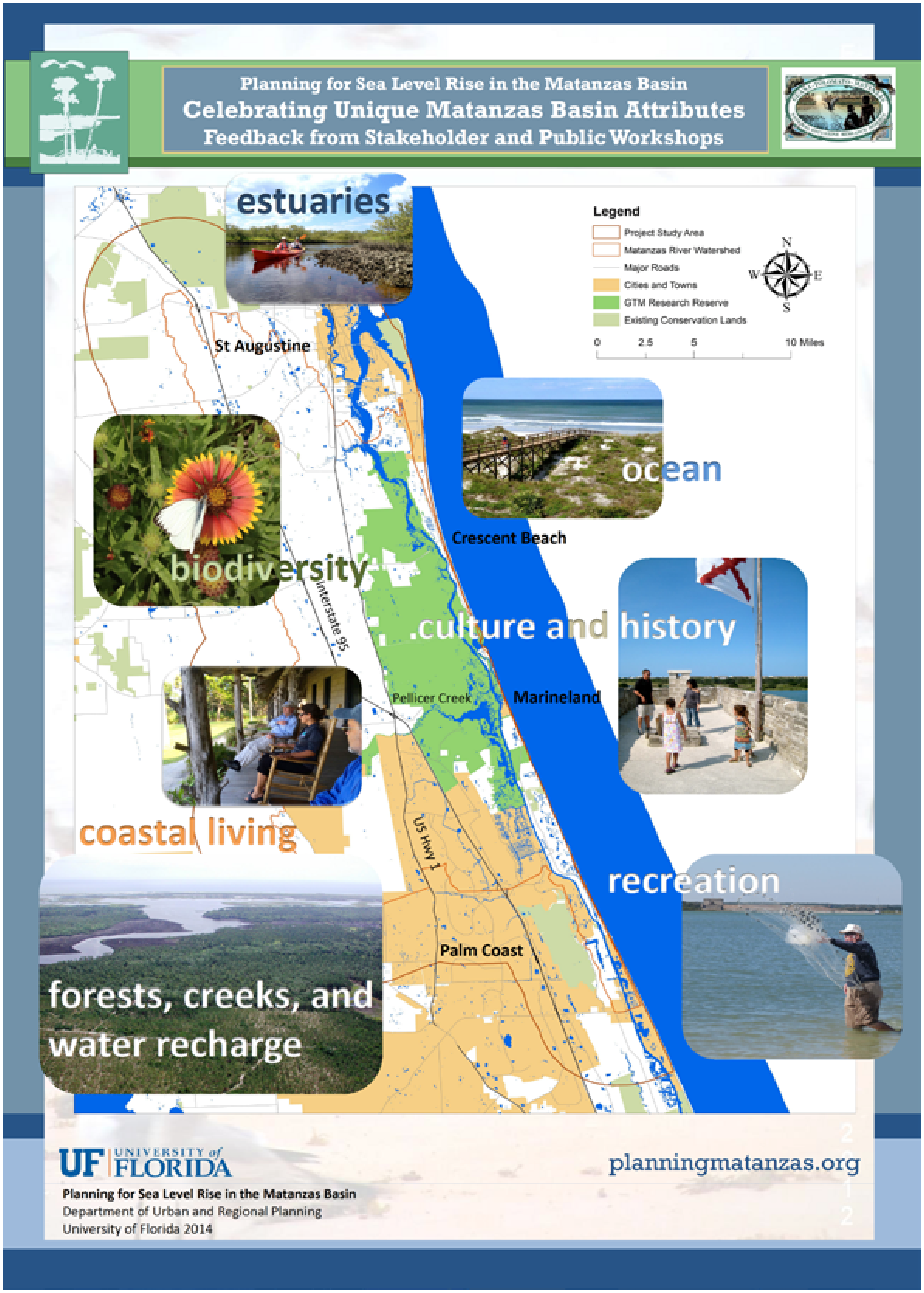
The values of the Matanzas area reflect the varied landscape. Residents and stakeholders appreciate the iconic natural landscapes of the Matanzas River and wetlands, the coastal beaches and dunes, and the freshwater creeks. Residents and stakeholders view the landscapes as a rare intact watershed and food chain, which supports a wide range of species and produces ecosystem services for people. The coastal-to-inland wildlife corridors have regional significance for large species, such as black bear, and boast substantial freshwater wetlands. Ecosystem services recognized in the Matanzas area include storm surge buffering by wetlands, aquifer recharge in the uplands, and carbon sequestration. The natural areas support an ecotourism economy, residents' quality of life, and scientific research and education through the GTM Research Reserve. Other important economic activities in the study area are timber production and residential construction. The area is perhaps best known for its cultural assets, including the City of St. Augustine, and Fort Matanzas National Monument near the Matanzas Inlet. Lesser known historical features include the Old Brick Road (to the west of the Pringle Creek Forest tract), which was a section of the Old Dixie Highway, one of the first cross continental roads constructed in the 1910s. Table 6 and Table 7 contain the most popular values of the Matanzas Basin expressed by different resident and stakeholder groups participating in the workshops.

What are the most important features of the Matanzas Basin? *Adult Workshops*	**What are the most important services/functions of the Basin? *Adult Workshops***
▪ Good water quality ▪ Salt Marshes ▪ High Biodiversity (flora/fauna) ▪ Habitat (tie for 3rd)	▪ Buffer from storms surge/ erosion ▪ Nursery for fisheries/sea life ▪ Water filtration for us and natural systems
Top 3 most important features of the Matanzas Basin from *high school students*	**Top 3 most important services/ functions of the Basin from *high school students***
▪ Our Houses ▪ The Beach ▪ Habitats	▪ Habitat for wildlife ▪ Recreation: Fishing, surfing, swimming, sports ▪ Water filtration
What are the most important features of the Matanzas Basin? Middle School Students	**What are the most important services/functions of the Basin? Middle School Students**
▪ Habitat/Animals ▪ Malls/Shopping Places ▪ Our homes	▪ Fresh water ▪ Food ▪ A place to build Homes

Table 6. Resident values of the Matanzas Basin

Top 3 most important features of the Matanzas Basin from *natural resource and ecotourism*	**Top 3 most important services/ functions of the Basin from *natural resource and ecotourism***
▪ The estuarine system ▪ Salt Marsh ▪ Conservation areas and The Beach tied	▪ Habitat for wildlife ▪ Ground water recharge ▪ Storm surge protection
Top 3 most important features of the Matanzas Basin from *local government and planners*	**Top 3 most important services/ functions of the Basin from *local government and planners***
▪ Habitat – wildlife and human ▪ Infrastructure ▪ Water quality	▪ Water quality ▪ Fisheries ▪ Recreational opportunities
Top 3 most important features of the Matanzas Basin from *business and developers*	**Top 3 most important services/ functions of the Basin from *business and developers***
▪ Intact food web ▪ Forest and farms ▪ Historical/Cultural built environment	▪ Spawning/breeding grounds ▪ Protection from storm surge ▪ Watershed

Table 7. Stakeholder group values of the Matanzas Basin


Planning for Sea Level Rise in the Matanzas Basin
Celebrating Unique Matanzas Basin Attributes
Feedback from Stakeholder and Public Workshops
estuaries
Legend
Project Study Area
Matanzas River Watershed
Major Roads
Cities and Towns
GTM Research Reserve
Existing Conservation Lands
0 2.5 5 10 Miles
N
S
E
W
St Augustine
ocean
Crescent Beach
biodiversity
Interstate 95
culture and history
Pellicer Creek
Marineland
coastal living
US Hwy 1
recreation
Palm Coast
forests, creeks, and
water recharge
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Department of Urban and Regional Planning
University of Florida 2014

Historic St. Augustine. Source: http://goista.com/wp-content/uploads/2014/09/The-Romantic-Ambiance-and-The-Old-World-Charm-of-St.-Augustine.jpg

Pellicer Creek. Source: GTM Research Reserve

Old Brick Road, an historic section of the Old Dixie Highway, near the community of Espanola in Flagler County

Concerns

The Matanzas residents and stakeholders participating in the public workshops expressed similar concerns with several phenomena that may become more severe as sea level rises (Table 8). The top concerns facing participants today in the Matanzas area were erosion, flooding, saltwater intrusion into water supplies, and loss of wildlife habitat. The top concerns participants expected to see in 100 years were similar to today's, but with the loss of personal property chosen more frequently than loss of wildlife habitat.

The project team's background research reinforced the workshop participants' concerns. Comparison of past and current maps, and photos, of the Matanzas area show a dynamic coastline (Figure 12-Figure 18). Sea level rise is one of several factors affecting coastal erosion and sand deposition. News articles have reported frequent flooding in St. Augustine, and occasionally in Palm Coast, with both cities experiencing stormwater drainage problems during heavy rainfall. The flooding in St. Augustine has also been exacerbated by strong winds and high tides. Figure 19 and Figure 20 show storm surge flood zones for St. Johns and Flagler counties, respectively. According to a report by the Northeast Regional Council (2010), storm surges can reach a maximum of 23.9 feet in St. Johns County and 22.8 feet in Flagler County, for "category 5" hurricanes.

What are the top three sea level rise related issues facing your community today? ***Adult residents and stakeholders***	What are the top three sea level rise related issues facing your community in 100 years? ***Adult residents and stakeholders***
• Shoreline erosion/ storm surge • Lack of fresh water resources/ salt water intrusion • Loss of wildlife habitat	• Shoreline erosion/ storm surge • Lack of fresh water resources/ salt water intrusion • Loss of personal property

Table 8. Major sea level rise related concerns facing Matanzas residents and stakeholders today and in 100 years

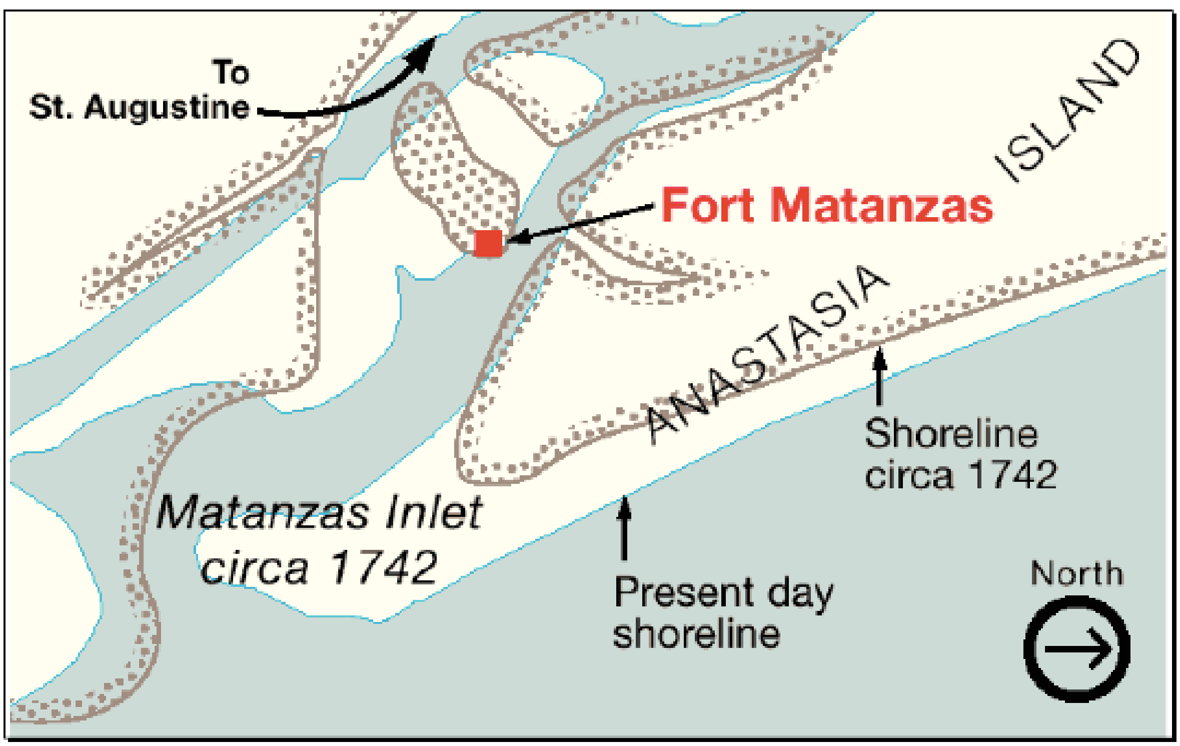


Figure 12. Matanzas Inlet shoreline change 1742 to present. [Source: http://www.staugustinehistoricalsociety.org/matanzas.pdf](http://www.staugustinehistoricalsociety.org/matanzas.pdf)

Figure 13. Matanzas Inlet houses, date unknown. Source: http://www.st-augustine-condo.com/Local%20photos/Local%20Photos.htm

Figure 14. Matanzas Inlet houses, 2012 Photo By Ed Siarkowicz Photographic Images, LLC

Figure 15. Remaining house foundation and septic tank. Source: Florida Sea Grant

Figure 16. Sand deposition in the Summer Haven River near the Matanzas Inlet Photo By Ed Siarkowicz Photographic Images, LLC

Figure 17. Flooding in St. Augustine, 2014. Source: http://staugustine.com/news/local-news/2014-12-08/high-tide-high-winds-cause-flooding-downtown

Figure 18. Flooding in Palm Coast, 2014. Source: http://flaglerlive.com/wp-content/uploads/bird-of-paradise-area.jpg

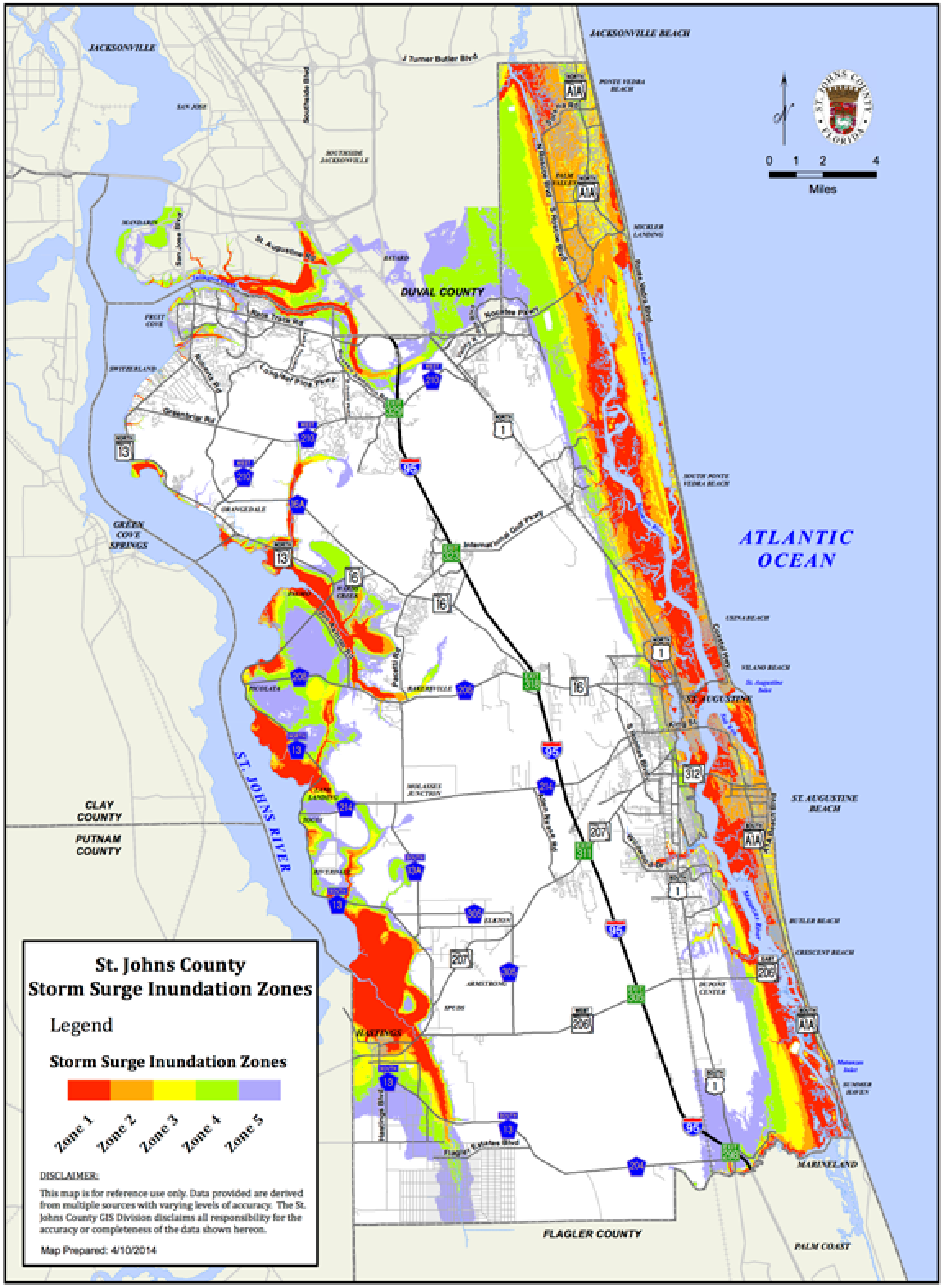


Figure 19. St. Johns County storm surge zones. Source: http://www.staugustinegovernment.com/the-city/maps-libraries/documents/stormsurgemap11.05.14.pdf

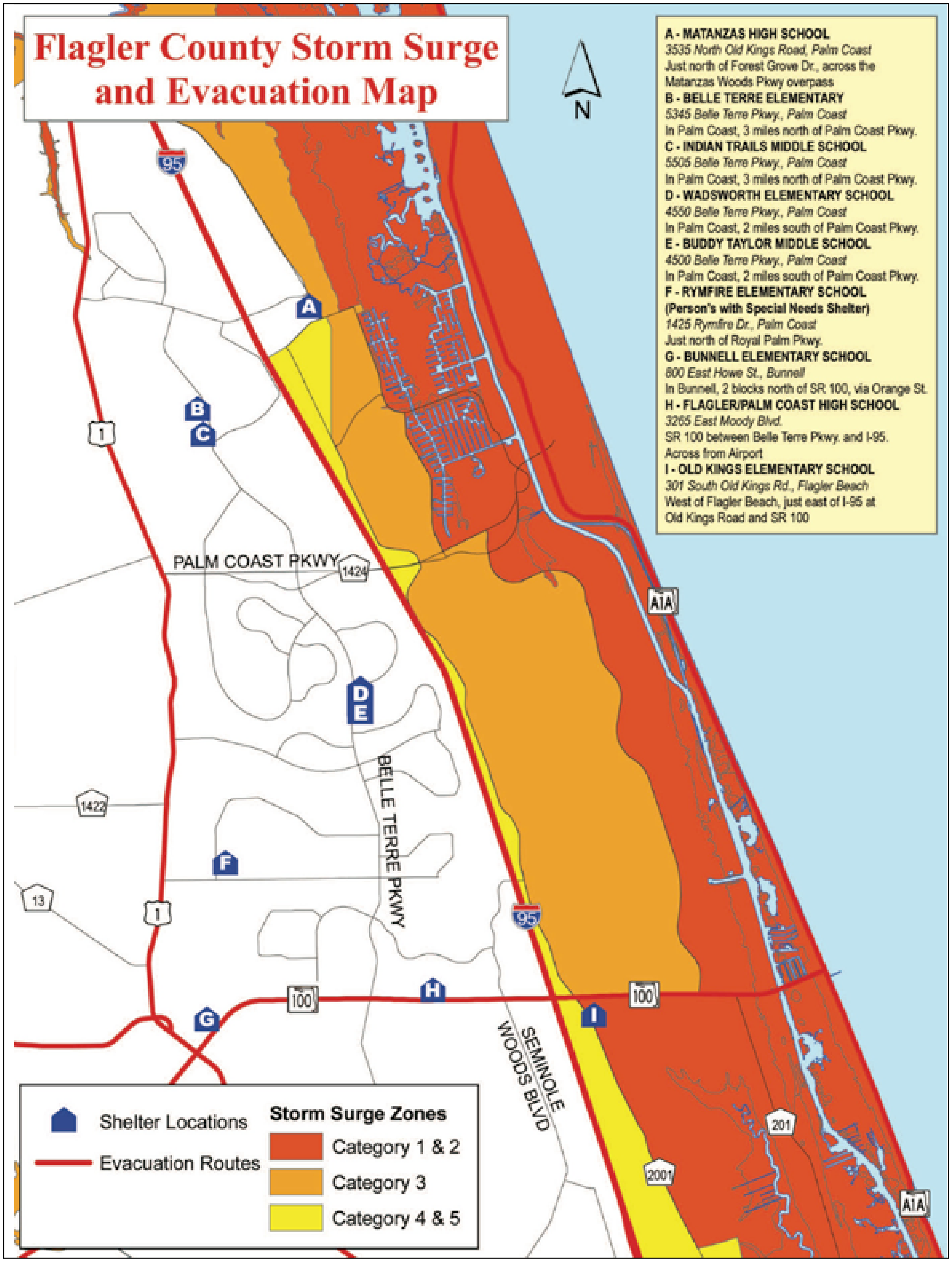


Figure 20. Flagler County storm surge zones. Source: http://www.flagleremergency.com/doc/evac_map.pdf

Water supplies for cities and agriculture are the Surficial and Upper Floridan aquifers, which in the Matanzas area have substantial quality and quantity limitations, including high chloride levels. A literature review found, however, that the spikes in chloride levels are not typically the result of saltwater intrusion from the ocean. Instead, vertical passages allow brackish water from deeper aquifers to be drawn out by wells (Figure 21). It is uncertain how future sea level rise will affect saltwater intrusion and water supplies (Figure 22).

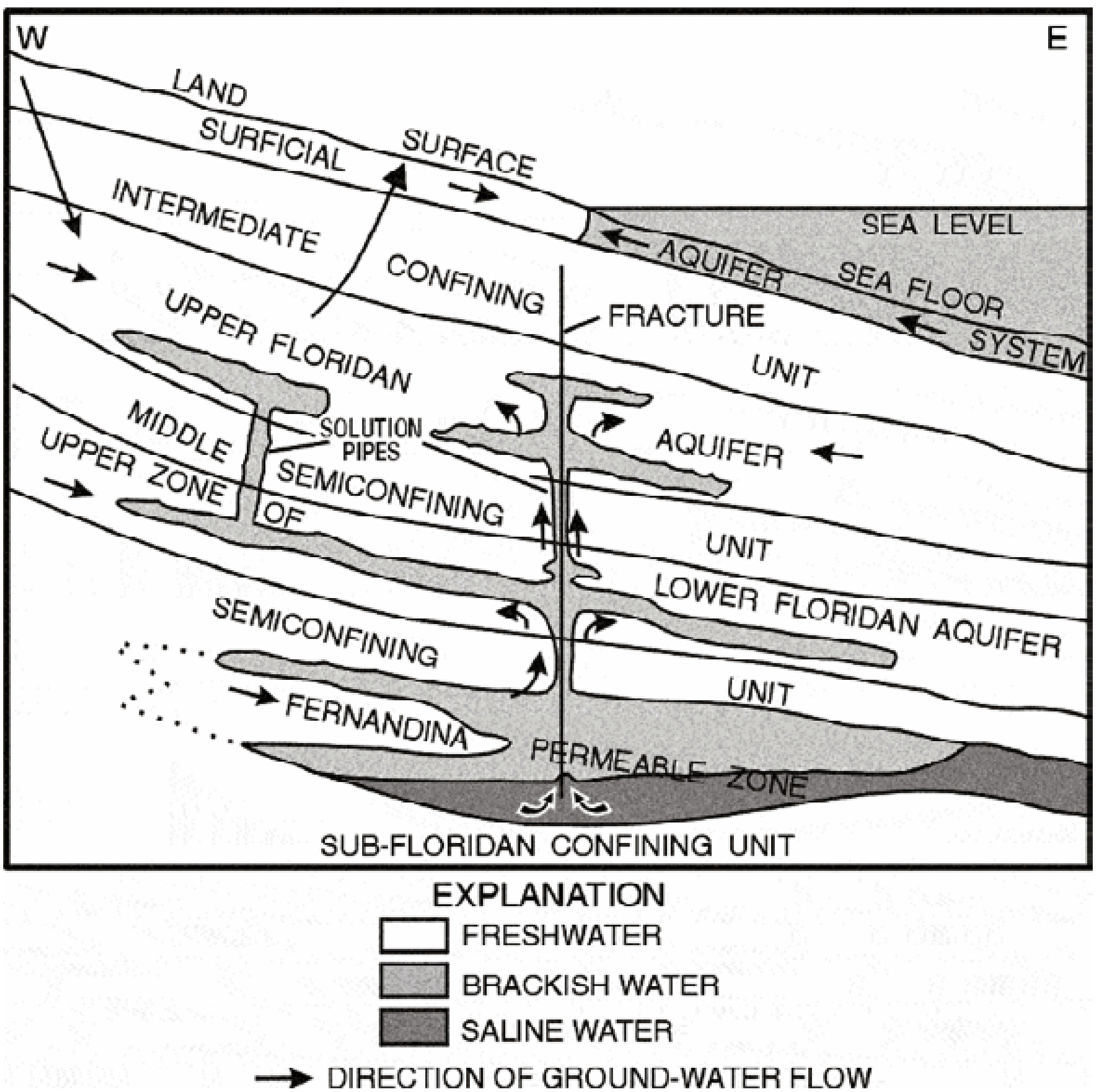


Figure 21. Groundwater high chloride sources in Northeast Florida. Source: http://water.usgs.gov/ogw/karst/kigconference/rms_relationintrusion.htm

Figure 22. One of Palm Coast's 40-plus water supply wells. Source: http://flaglerlive.com/45095/palm-coast-wellfields/

Figure 23. Dune habitat between the ocean and development

Figure 24. Gopher tortoise in the dunes

The concern of sea level rise threatening wildlife is illustrated by Figure 23 and Figure 24, which show how habitats and species between development and the ocean cannot migrate and will be lost as sea level rises.

Public concern for the short- and long-term fate of wildlife in the Matanzas area reinforced the project's focus on environmental conservation. The project team recognized future development patterns as having significant impacts on important conservation areas, and thus modeled the geographic distribution of the growth. Toward this end, the team included local information about planned large-scale developments in the study area. The team found three such developments of regional impact (DRIs) in Flagler County. Palm Coast Park is located to the east of the Pringle Creek Forest tract on US 1 (4,740 acres, 3,600 homes, and 3.2 million square feet of commercial and industrial space) (Figure 25). The other two DRIs are along Old Brick Road to the west of the Pringle Creek Forest tract: the Old Brick Township DRI (5,273 acres, 5,000 homes, and 1.15 million square feet of commercial and industrial space) (Figure 26) and the Neoga Lakes DRI (6,400 acres, 7,000 homes, and 2 million square feet of commercial and industrial space) (Figure 27). Another DRI was identified in St. Johns County along State Road 206 west of Crescent Beach, the Watermark DRI (3,200 acres, 10,000 homes, and 3.5 million square feet of commercial and industrial space), but since the owners sold the land and canceled the plan, the team did not include it in the modeling of future development. St. Johns County planners mapped occurrence of residential building permits in 2013-2014, which is an indication of recent spatial distribution of growth (Figure 28). This map shows high growth in the northern part of the county, near Jacksonville, and moderate growth southwest of St. Augustine.

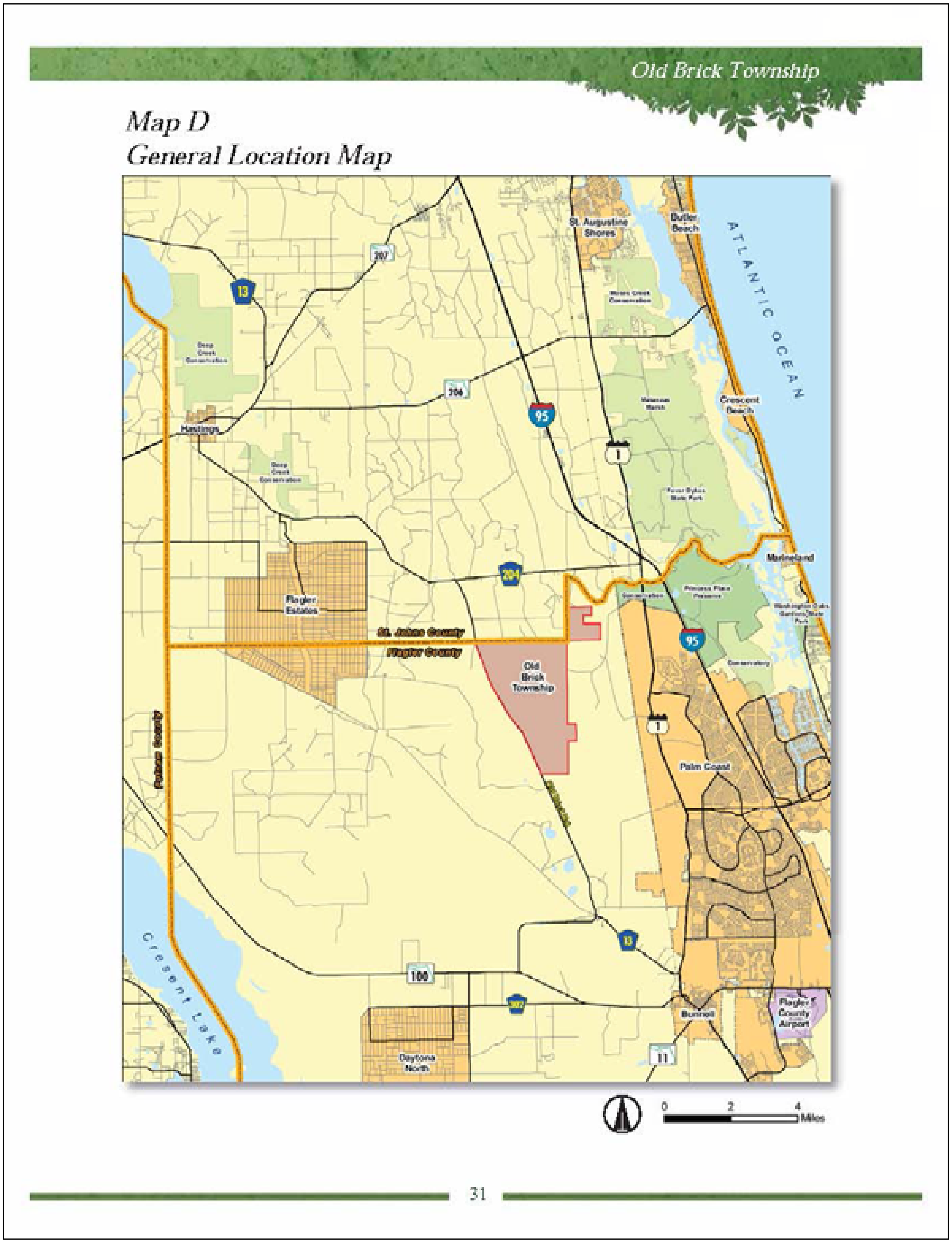


Figure 25. Old Brick Township. Source: http://gotoby.com/userfiles/Old%20Brick%20Township%20Pre-Application%20Document.pdf

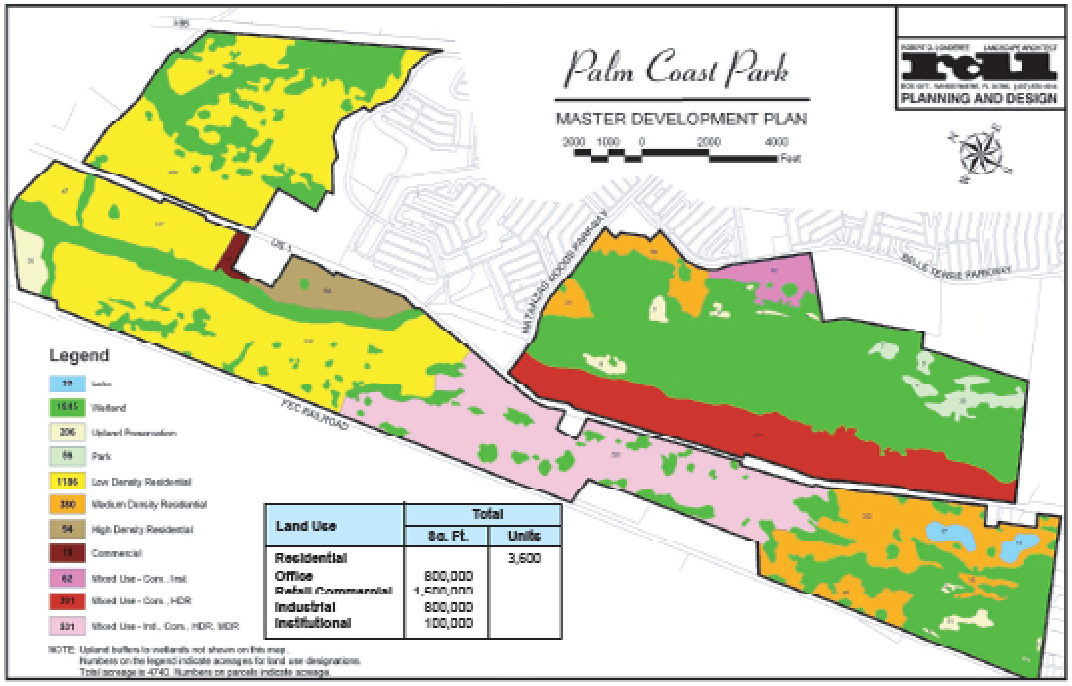


Figure 26. Palm Coast Park. Source: http://www.palmcoast.com/palm-coast-park.html

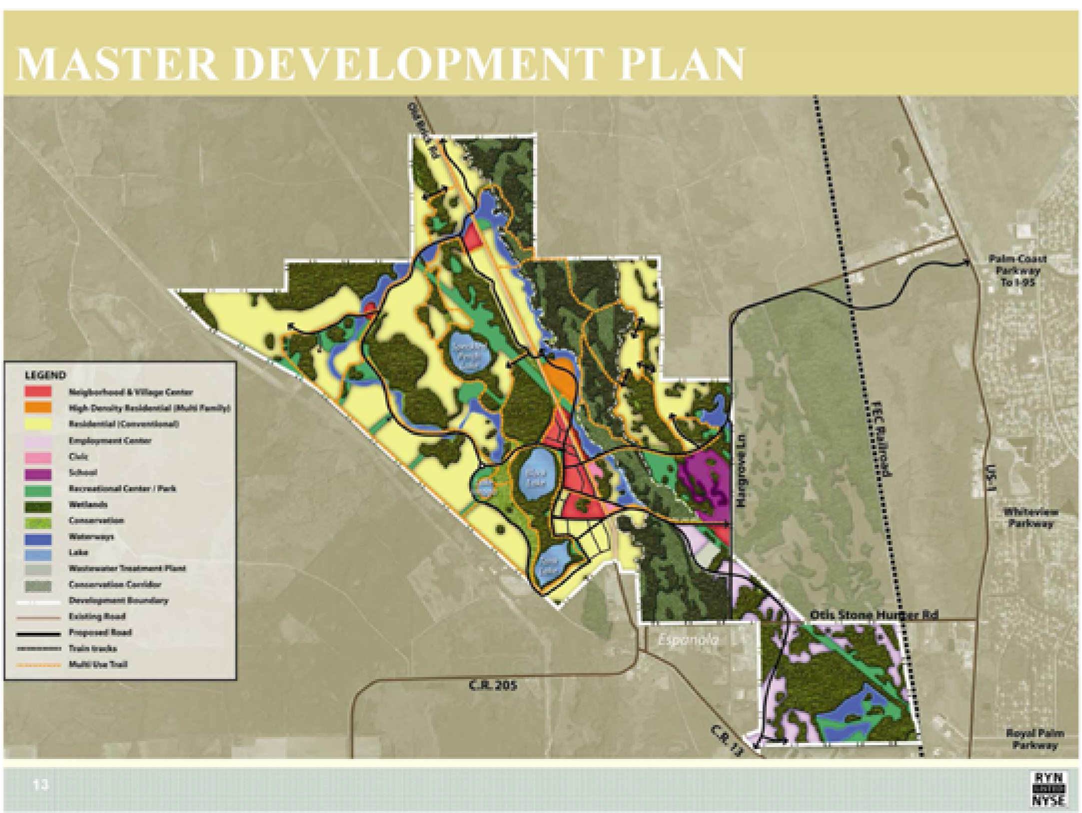


Figure 27. Neoga Lakes. Source: [http://www.nefrc.org/pdfs/Presentations/Board%20 Presentation/2010/04-10/NeogaLakes040110.pdf](http://www.nefrc.org/pdfs/Presentations/Board%20Presentation/2010/04-10/NeogaLakes040110.pdf)

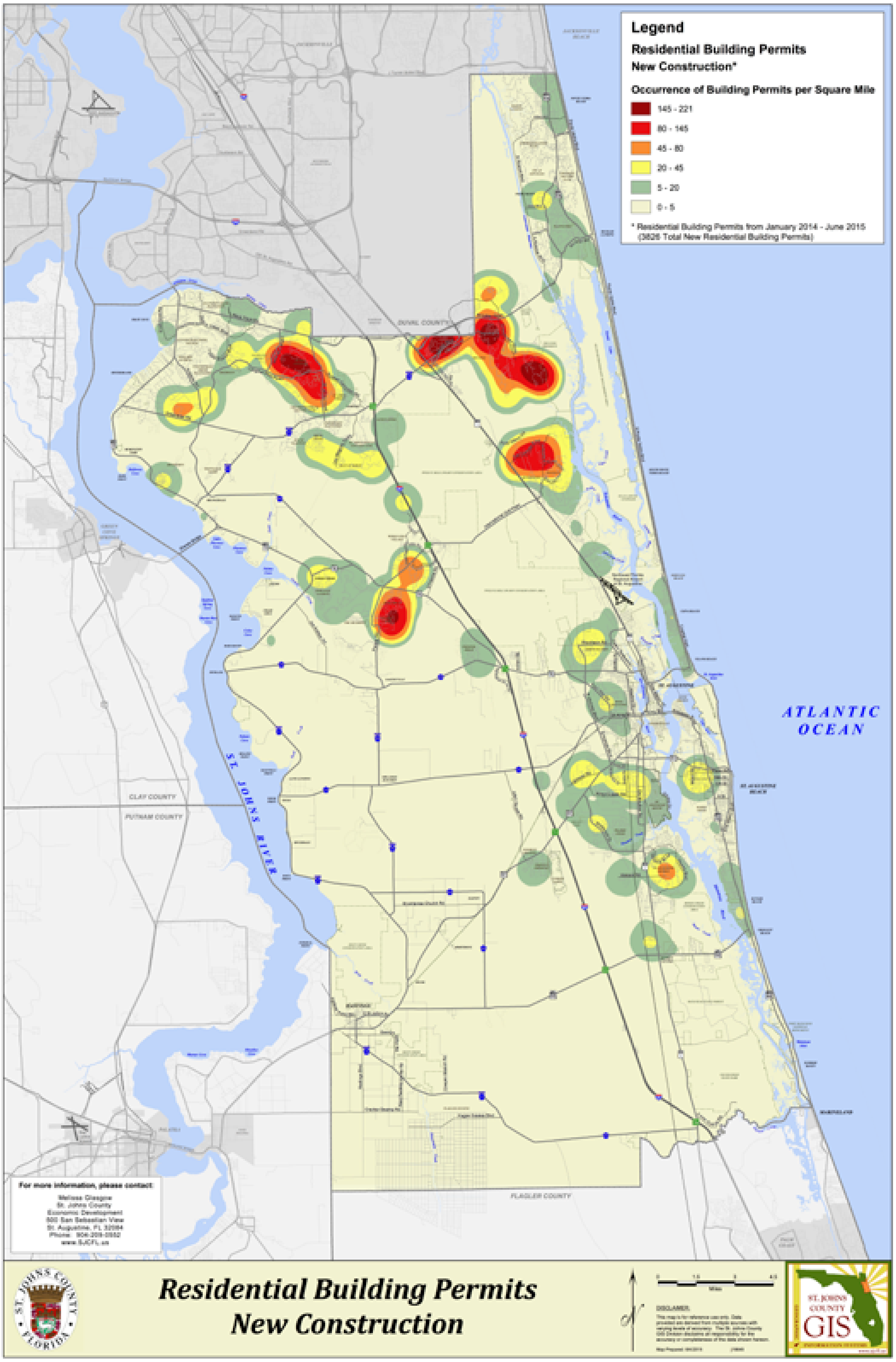


Figure 28. Locations of growth in St. Johns County, 2013-2014. Source: St. Johns County

Sea Level Rise Impacts

The project team employed various spatial analyses to identify locations within the Matanzas area that may be directly affected by increased flooding due to future sea level rise. At the simplest level, the digital elevation model indicated the overall topography, and the bathtub model highlighted low-lying areas having the potential to be inundated first. The analysis of storm surge brought a hazards perspective to vulnerability, by modeling the extent and depth of flooding in the event of an intense storm combined with higher average sea level. The Sea Level Affecting Marshes Model (SLAMM) anticipated possible long-term ecological changes caused by the interaction of rising sea level and the landscape of the Matanzas area. The project team then applied the SLAMM results, which showed types of landscape changes, to understand their implications for current conservation priorities and existing development in the study area.

Photo by Ed Siarkowicz Photographic Images, LLC

Inundation – Digital Elevation and Bathtub Models

Topography

The digital elevation model (DEM), which maps land elevation above current sea level, is shown in Figure 29 (also see Appendix A). This map confirms the presence of marine terraces and scarps, features created thousands of years ago during past changes in sea level (Figure 30). The marine terraces and scarps are steps in the landscape, where the topography alternates between flat and steep areas, respectively, rather than sloping (Figure 31). The higher terraces immediately to the west of the Matanzas River and marshes are together known as the Atlantic Coastal Ridge, with highest point in the study area at close to 100 feet elevation feet. The tributaries of the Matanzas River, including Pellicer Creek, cut into the ridge and have relatively steep banks. The lower elevation surrounding the St. Johns River to the west of the Atlantic Coastal Ridge is known as the Eastern Valley.

The steep sides of the Matanzas River and marshes, and the creeks, have significant implications for inundation of the landscape with future sea level rise. As sea level rises, the inundation will be confined to the lowest marine terrace of the Matanzas River and marshes, i.e., the Silver Bluff, and the margins of the creeks. Figure 31 illustrates the concern of losing marshes near scarps as sea level rises. As sea level reaches the top of the scarp, at about 8 to 10 feet, inundation will begin to spread out across the next terrace, the Pamlico.

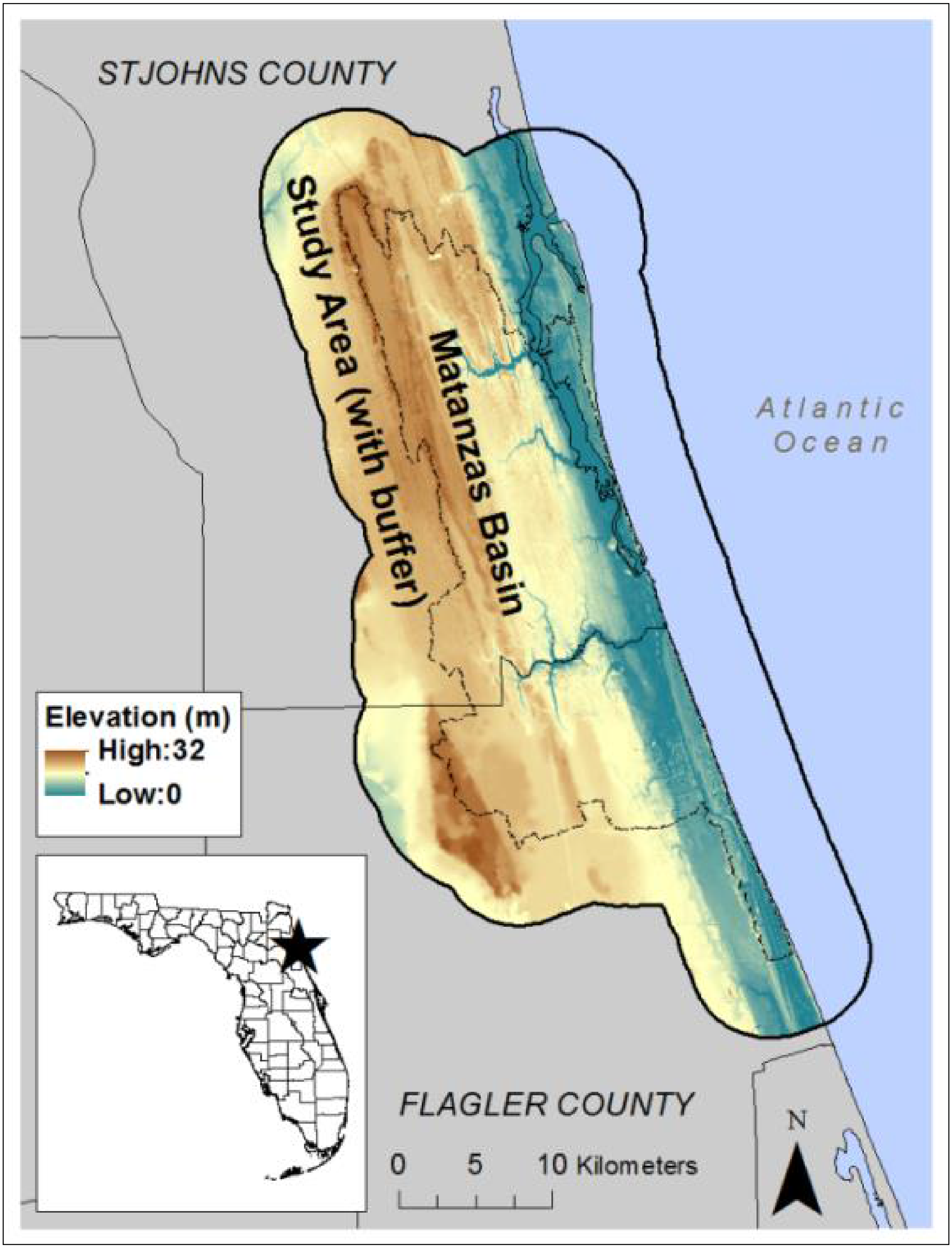
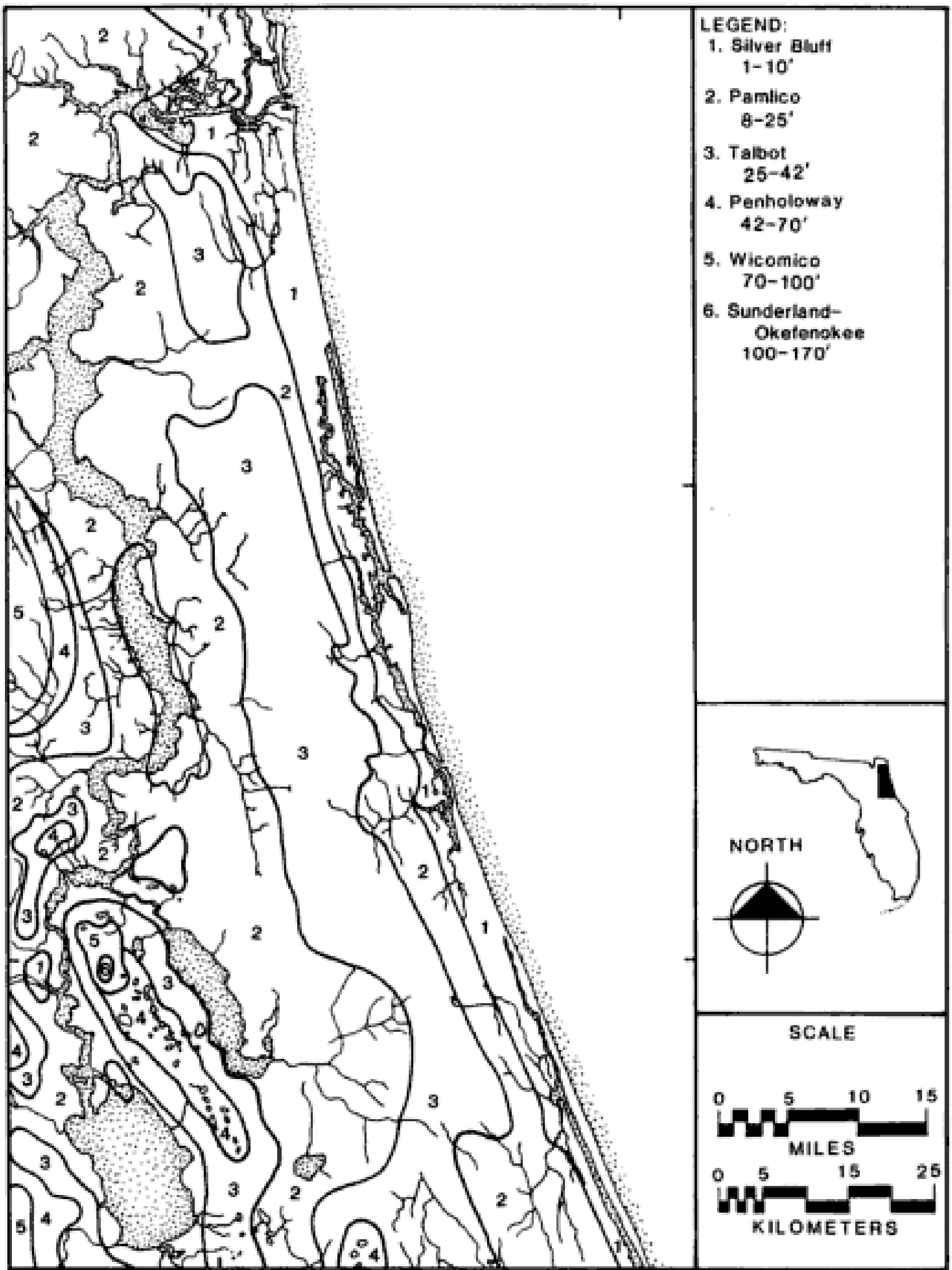


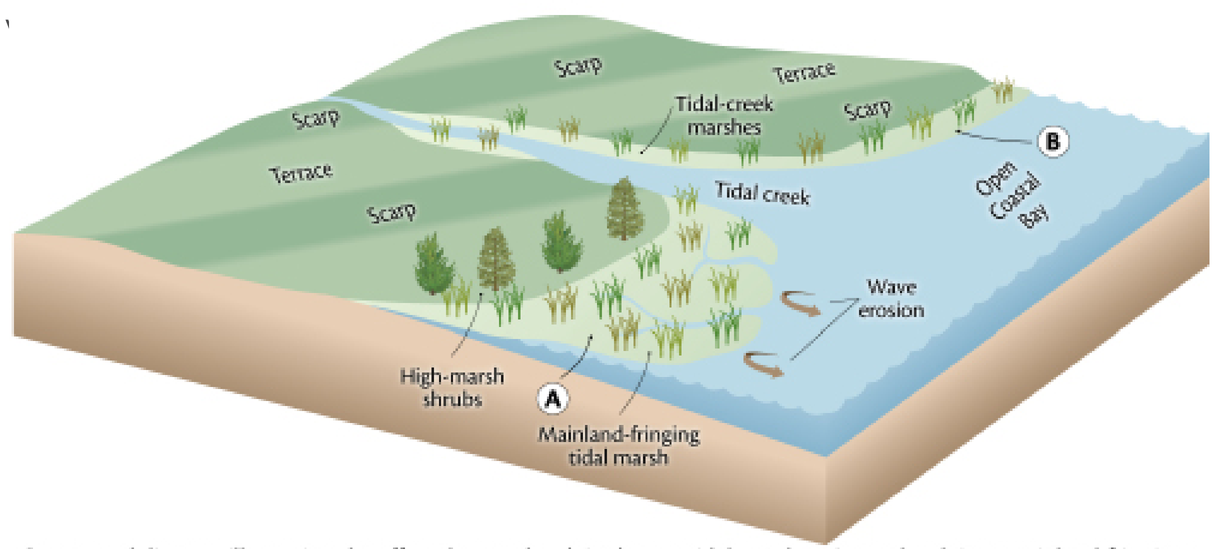
Figure 29. Digital elevation model



Map 1.2. Marine terraces. After Bermes, Leve and Tarver (1963: fig. 3) and Healy (1975)

Figure 30. Northeast Florida marine terraces. Source: *An Environmental History of Northeast Florida* by James J. Miller, 1998 (books.google.com)

Sea level rise & marshes



Conceptual diagram illustrating the effect that sea-level rise has on tidal marshes. As sea-level rises, mainland-fringing marshes are flanked on the landward side by a low-lying land surface (site A) can expand and maintain marsh area. Marshes adjacent to a steep landward slope, such as a scarp (site B), are most likely to be eroded and destroyed. As tidal influence advances upstream in creeks, new marsh area will be created along the margins of the creek.

Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Enviromental Science. Source: *Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, and D.E. Wilson. 2009. Shifting Sands: Environmental and cultural change in Maryland's Coastal Bays. IAN Press, University of Maryland Center for Enviromental Science*

Figure 31. Conceptual diagram of topography, habitats, and sea level rise impacts similar to those of the Matanzas area

Low-Lying Areas

The bathtub model is a simple highlighting of all land at or below a certain elevation, which can be roughly interpreted as those areas that would be inundated by a rise in sea level by the same height (assuming no protection measures such as sea walls) (also see Appendix A). Low-lying areas in the Matanzas study area, at elevations of 1.5 and 3 feet, are shown in Figure 32-Figure 34. Most of these areas are located within two miles of the coast. Many of the areas at 1.5 feet elevation or less are currently saltmarsh and tidal flats, since they receive regular flooding due to a tidal range of over six feet. Significant low-lying areas are seen in the GTM Research Reserve, St Augustine, parts of Palm Coast, including to the northeast near the Matanzas River and southwest in the Eastern Valley, and some coastal communities to the east of the Matanzas River. The small amount of land between 1.5 and 3 feet elevation is indicative of the scarp between the Silver Bluff and Pamlico marine terraces discussed above, and sand dunes created by the current sea level.

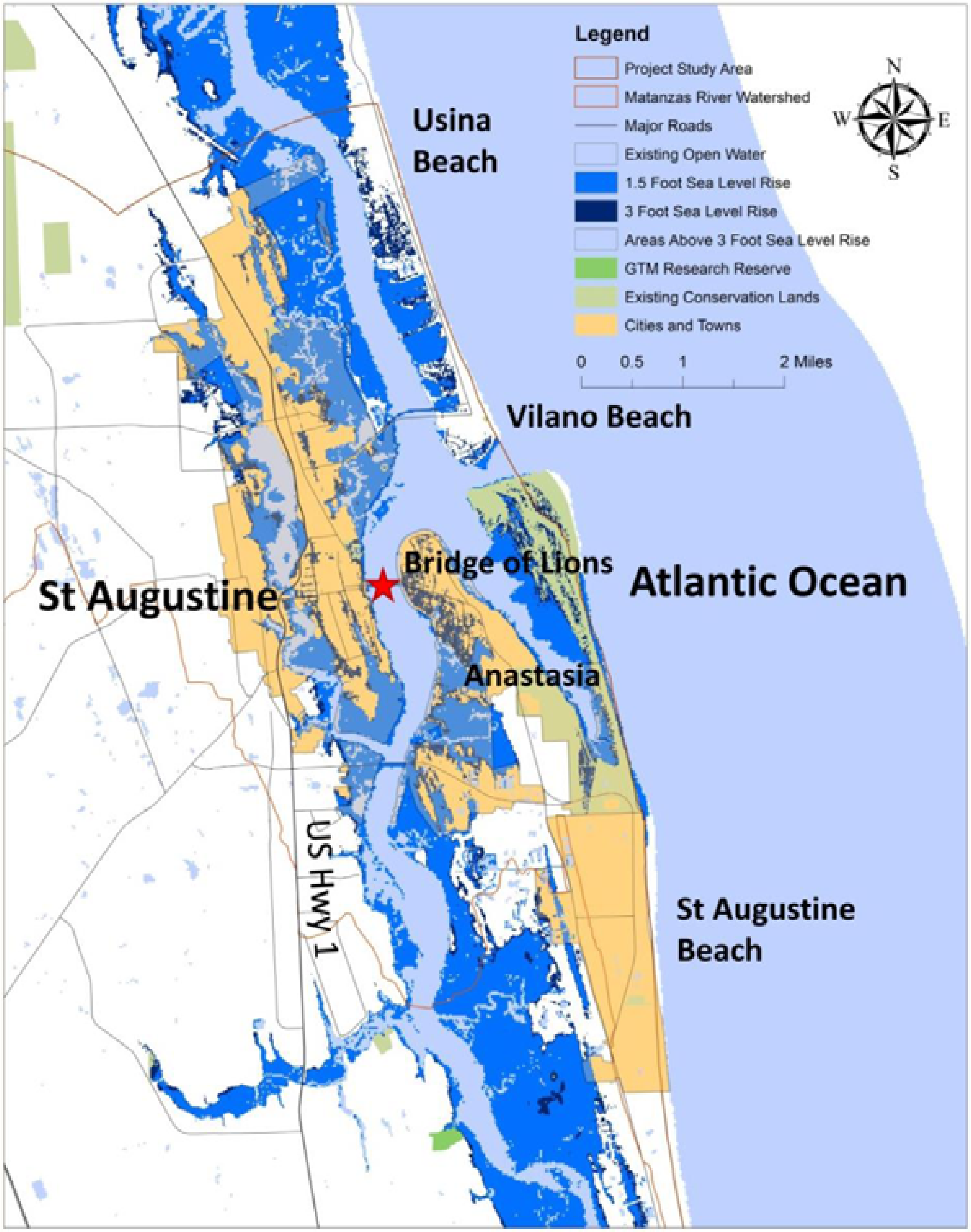


Figure 32. Inundation from 1.5 and 3 feet of sea level rise around St. Augustine

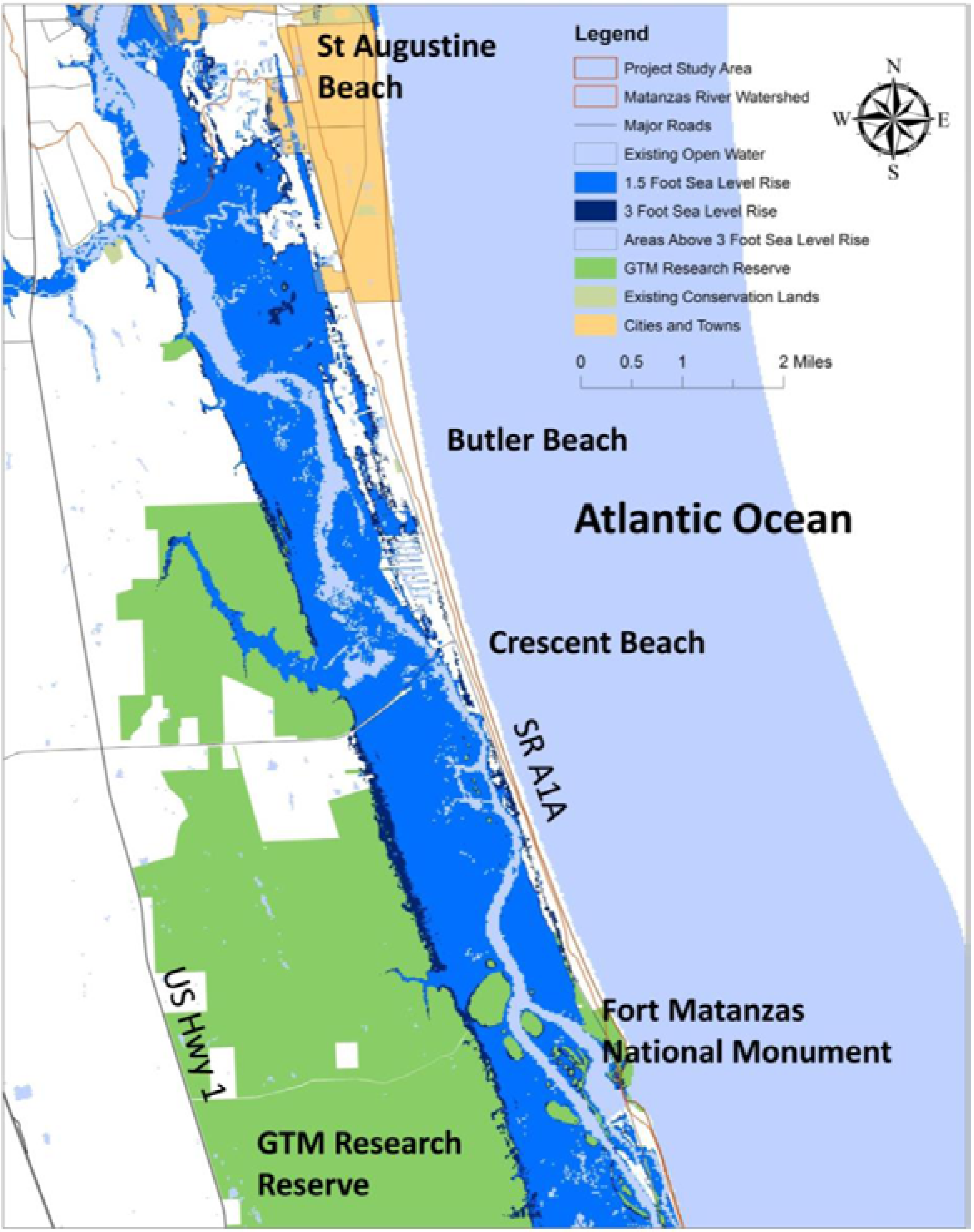


Figure 33. Inundation from 1.5 and 3 feet of sea level rise around the GTM Research Reserve

Figure 34. Inundation from 1.5 and 3 feet of sea level rise around Palm Coast

Storm Surge- Hazus Model

Impacts from base storm surge, as well as storm surge after 1.5 and 3 feet (0.5 and 1 meter) sea level rise, are summarized in Table 9 and Figure 35-Figure 36 for St. Johns and Flagler counties (also see Appendix B). A base 100 year storm surge (1% probability) will have significant impacts within both St. Johns and Flagler counties in terms of the total terrestrial acreage inundated. Sea level rise causes an increase in impacted acreage, particularly in inland areas adjacent to the St. Johns River, impacting extensive areas of agricultural and conservation land. In coastal areas, a base storm surge will impact the population centers of Palm Coast and St. Augustine, including the historically and culturally significant core of St. Augustine. In coastal areas, the total acreage of areas impacted by storm surge does not increase significantly as sea level rises, most likely due to the coastal geomorphology and inland dune structure. However water depth will increase, potentially causing more severe impacts in the areas that are inundated.

Within the GTM Research Reserve and contiguous conservation lands, results are similar in that the number of acres impacted by storm surge does not increase significantly with sea level rise. However a significant percentage of the GTM Reserve is impacted by storm surge relative to current acreage (see Table 9 and Figure 36).

	Existing Acres	Base Storm Surge	0.5m SLR Storm Surge	1m SLR Storm Surge	Percent Existing Acres Inundated by 1m SLR Storm Surge
Flagler County	310,694 (land only)	35,665	48,015	60,087	19%
St Johns County	384,422 (land only)	67,461	80,123	90,732	24%
Existing Developed Lands*	69,007	13,376	16,741	19,366	28%
GTM NERR	29,457	11,953	12,537	13,052	44%

**Based on 2010 parcel data including residential, commercial, industrial, institutional, and related land uses*

Table 9. Cumulative storm surge impacts (acres) for base 100yr storm surge, and storm surge with 0.5m and 1m sea level rise

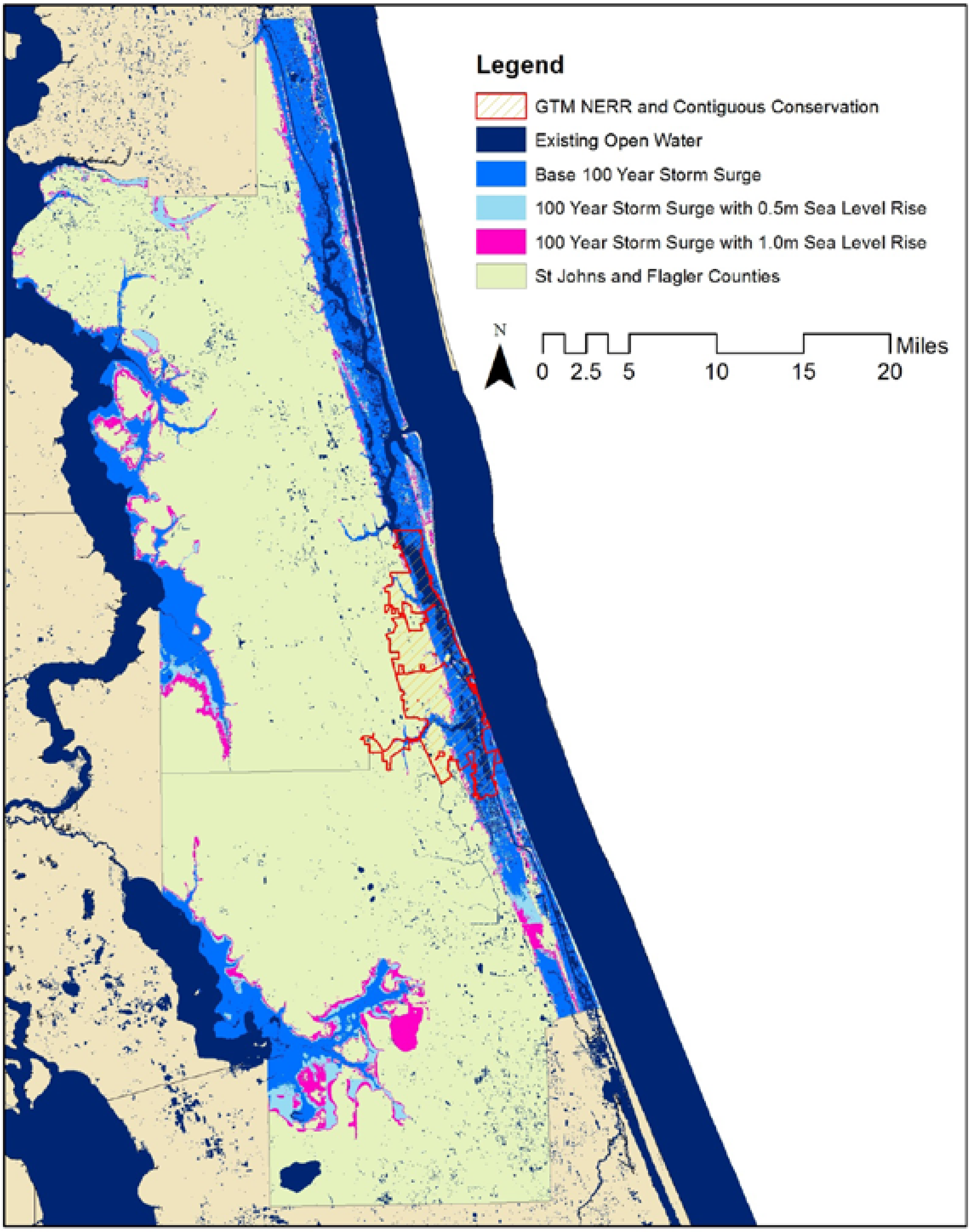


Figure 35. Storm surge impacts at current sea levels, 0.5m, and 1.0m sea level rise in St Johns and Flagler Counties

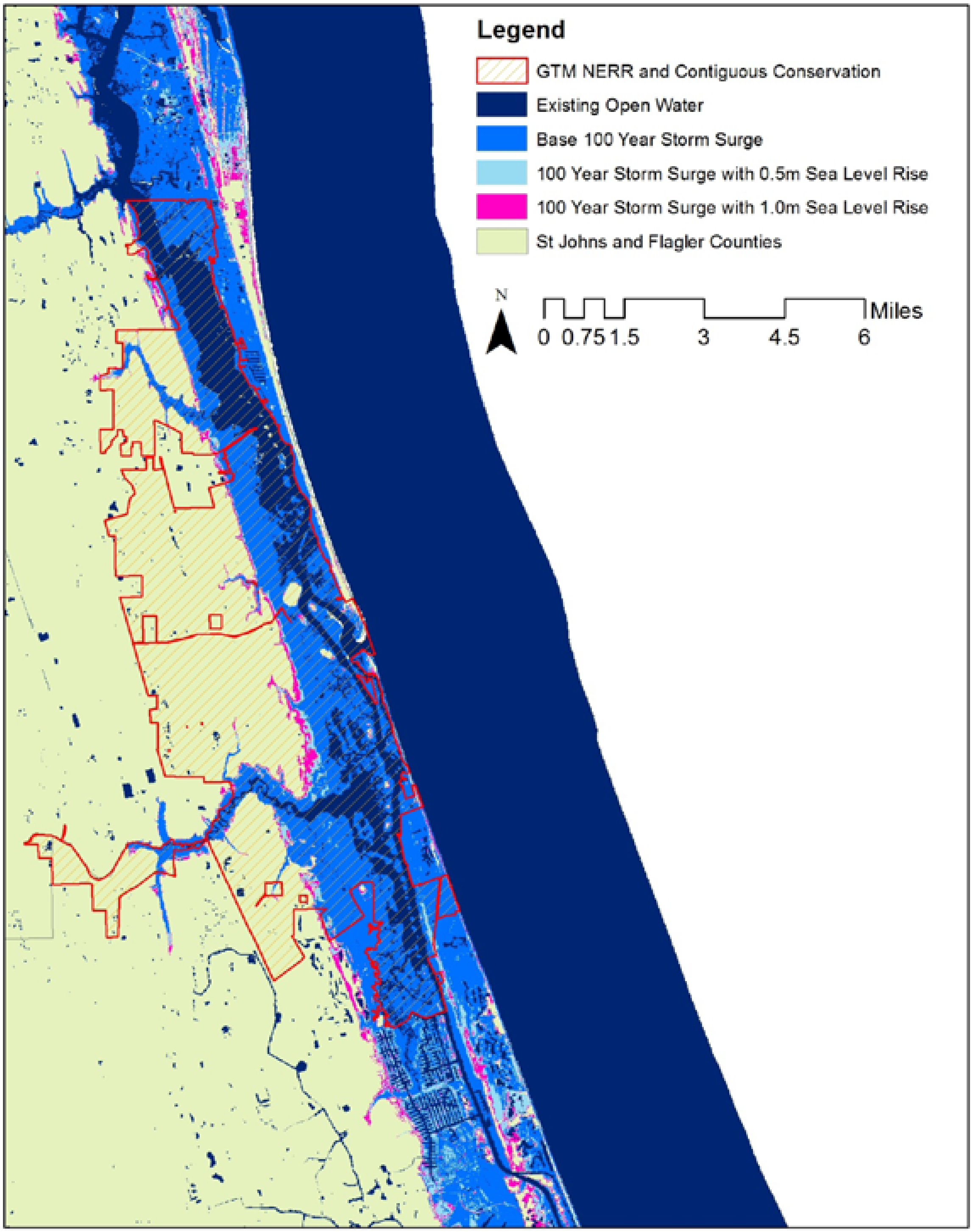


Figure 36. Storm surge impacts at current sea levels, 0.5m, and 1.0m sea level rise within the GTM Research Reserve and contiguous conservation lands

Ecological Changes- Sea Level Affecting Marshes Model (SLAMM)

The SLAMM modeling for the Matanzas study area projected varying types of land cover changes depending on the sea level rise scenario that was used (see Appendix C). Table 10 shows the forecasted rates of land cover loss/gain for each sea level rise scenario (up to 2 meters (6.5 feet)) and the land cover categories used in SLAMM. Negative numbers indicate a loss of land cover relative to current conditions, while positive numbers indicate a gain in a specific land cover type.

Land Cover Type	0.2m	0.5m	1m	1.5m	2m
Developed Dry Land	-0.7%	-2.5%	-7.7%	-14.7%	-20.8%
Undeveloped Dry Land	-1.2%	-2.2%	-3.5%	-5.5%	-7.1%
Swamp	0.6%	-0.1%	-2.5%	-4.3%	-6.4%
Cypress Swamp	-0.1%	-0.3%	-2.3%	-4.0%	-8.2%
Inland-Fresh Marsh	-0.1%	-0.1%	-2.2%	-4.5%	-5.7%
Transitional Saltmarsh	-19.9%	36.0%	81.4%	78.5%	56.1%
Regularly-Flooded Marsh	20.6%	-16.0%	-31.0%	-2.6%	12.1%
Tidal Flat	0.6%	82.5%	49.0%	62.6%	86.2%
Vegetated Tidal Flat	0.0%	-0.1%	-14.7%	-46.7%	-98.6%
Beach	-1.2%	9.0%	35.4%	101.3%	143.7%
Open Water	2.4%	8.3%	56.9%	89.3%	132.3%

Table 10. Forecasted rates of loss/gain for SLAMM land cover categories with various sea level rise scenarios

In the 0.2 meter (8 inches) sea level rise scenario only slight changes are seen in land cover. However, even under the 0.5 meter (1.5 feet) scenario noteworthy changes are seen in saltmarshes and tidal flats. And under the 2 meters (6.5 feet) scenario large changes are seen in developed dry land, transitional saltmarsh, tidal flats, vegetated tidal flats, and beaches. In all cases, dry land shows a net loss of acreage as sea levels rise and dry land converts to open water or wetlands. However certain wetland land cover types such as transitional saltmarsh, regularly flooded marsh, tidal flats, and beaches actually show increases in acreage as sea levels rise. Additionally, These changes are simulated assuming that developed and undeveloped land can transition to wetland and open water. In reality human intervention will likely prohibit much of the wetland migration on to developed and undeveloped lands. Additionally, with a 1 meter (3 feet) sea level rise, over 6,300 acres of existing conservation land will be impacted within the study area, out of more than 36,000 acres that exists within the Matanzas study area. Figure 37-Figure 40 shows these changes within the study area and adjacent to the GTM Research Reserve.

Based on these analyses, the conserved lands in the GTM Research Reserve appear to be wide enough to include the western most effects of sea level rise. As such, future acquisition of conservation lands by GTM Research Reserve in an attempt to mitigate for sea level rise could focus in either the northeastern or southeastern direction (while maintaining resilience of the watershed and region remains critical). Based solely on the SLAMM analyses, large tracts of undeveloped land where areas of saltmarsh migration are simulated may be best suited for conservation. These results can be compared to those described in the conservation impacts and priorities analyses, which identify and prioritize conservation areas of future marsh habitat, or where existing marsh habitat will continue to exist as sea levels rise.

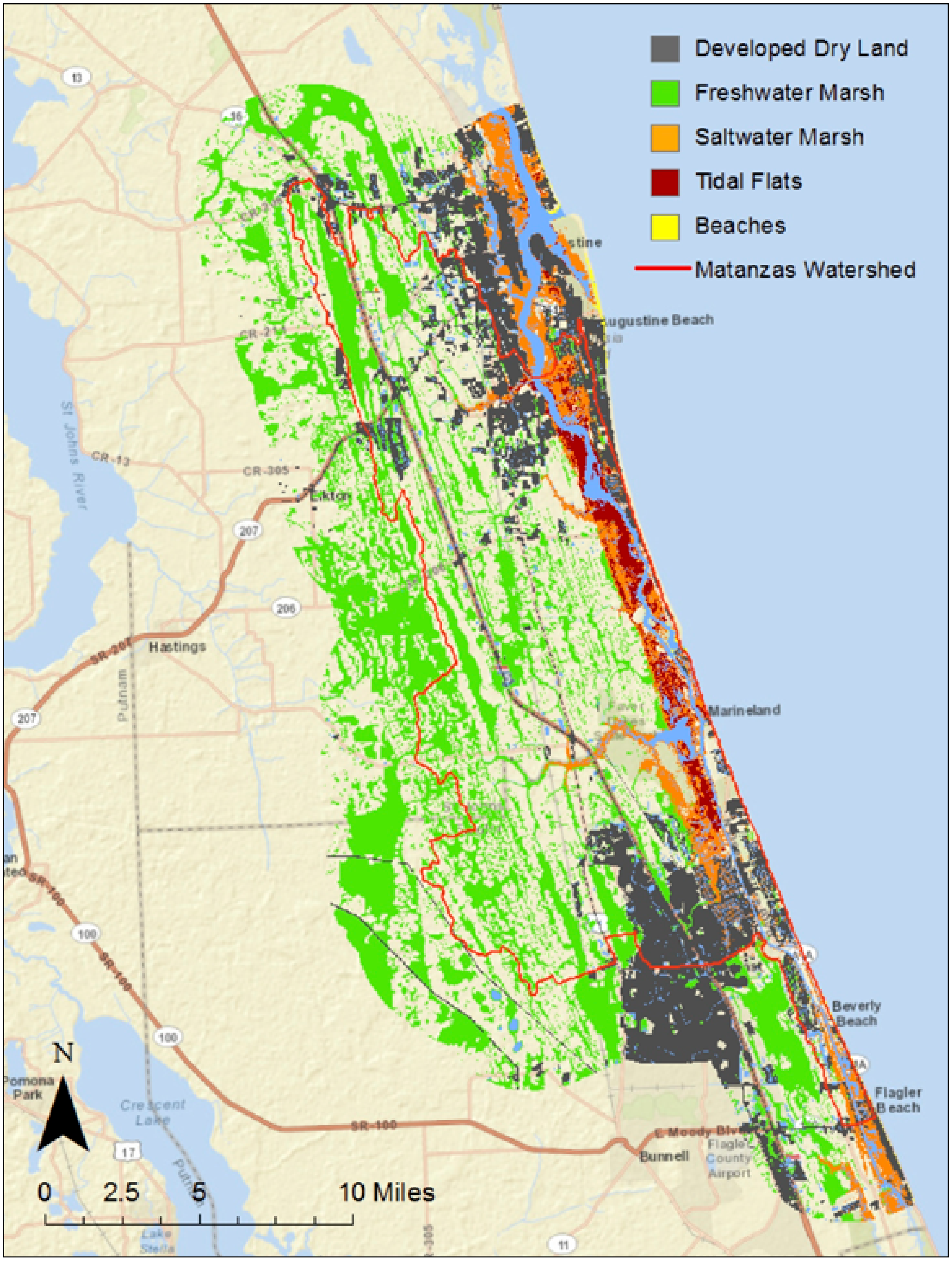


Figure 37. SLAMM results for the Matanzas Study Area: 2008, initial conditions

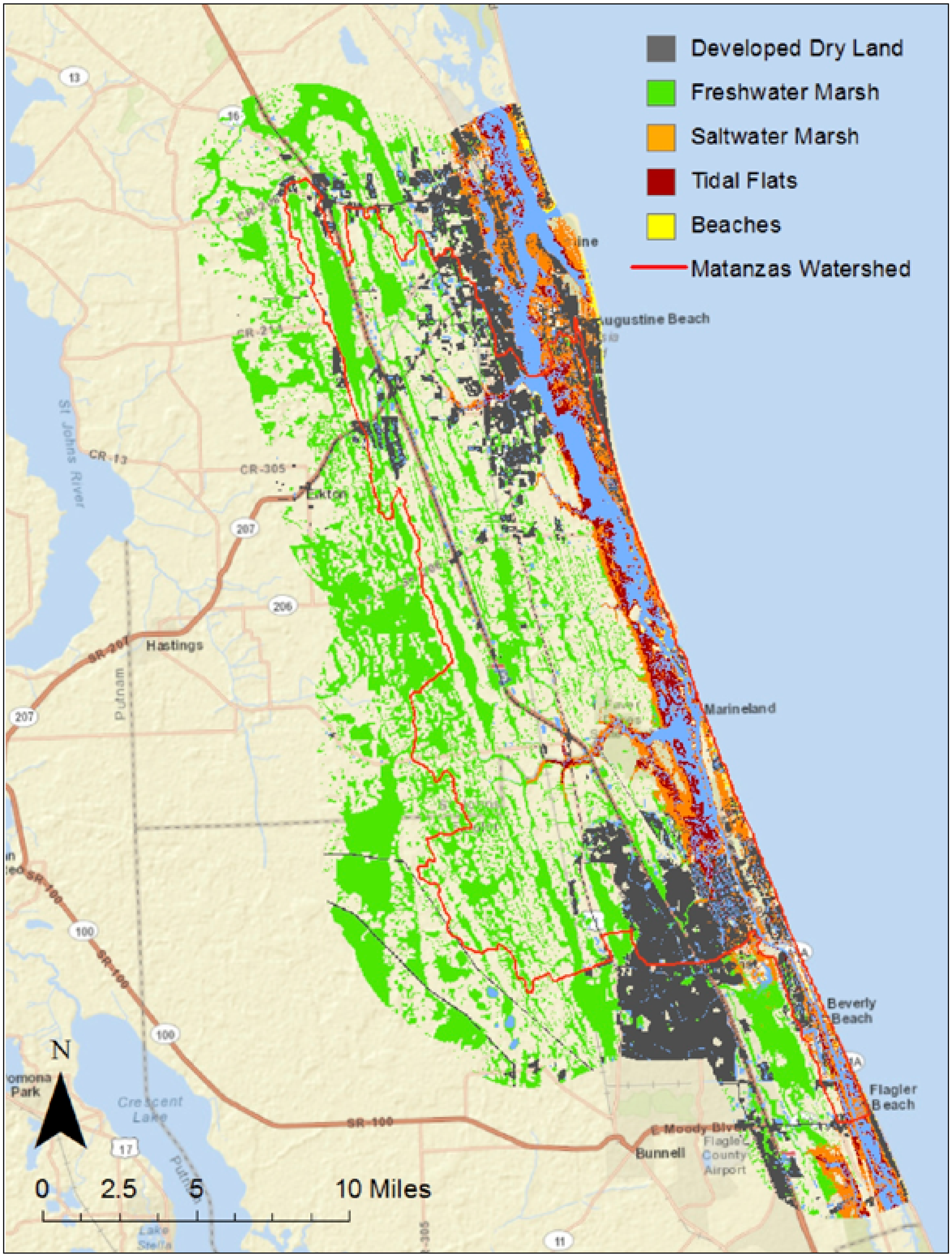


Figure 38. SLAMM results for the Matanzas Study Area: 1m sea level rise in 2100 where developed lands are allowed to convert to wetlands or open water

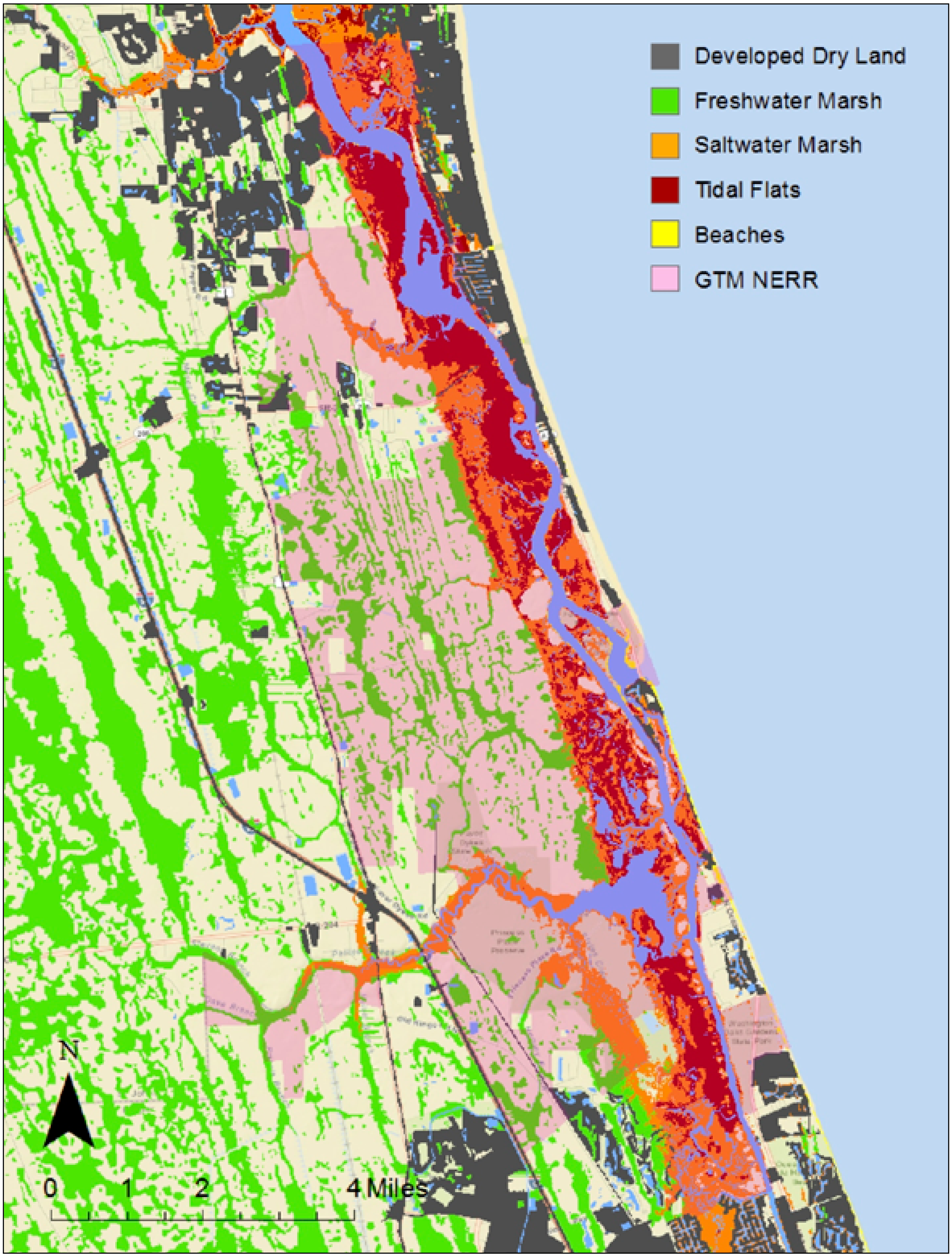


Figure 39. SLAMM results for the GTM Research Reserve: 2008, initial conditions

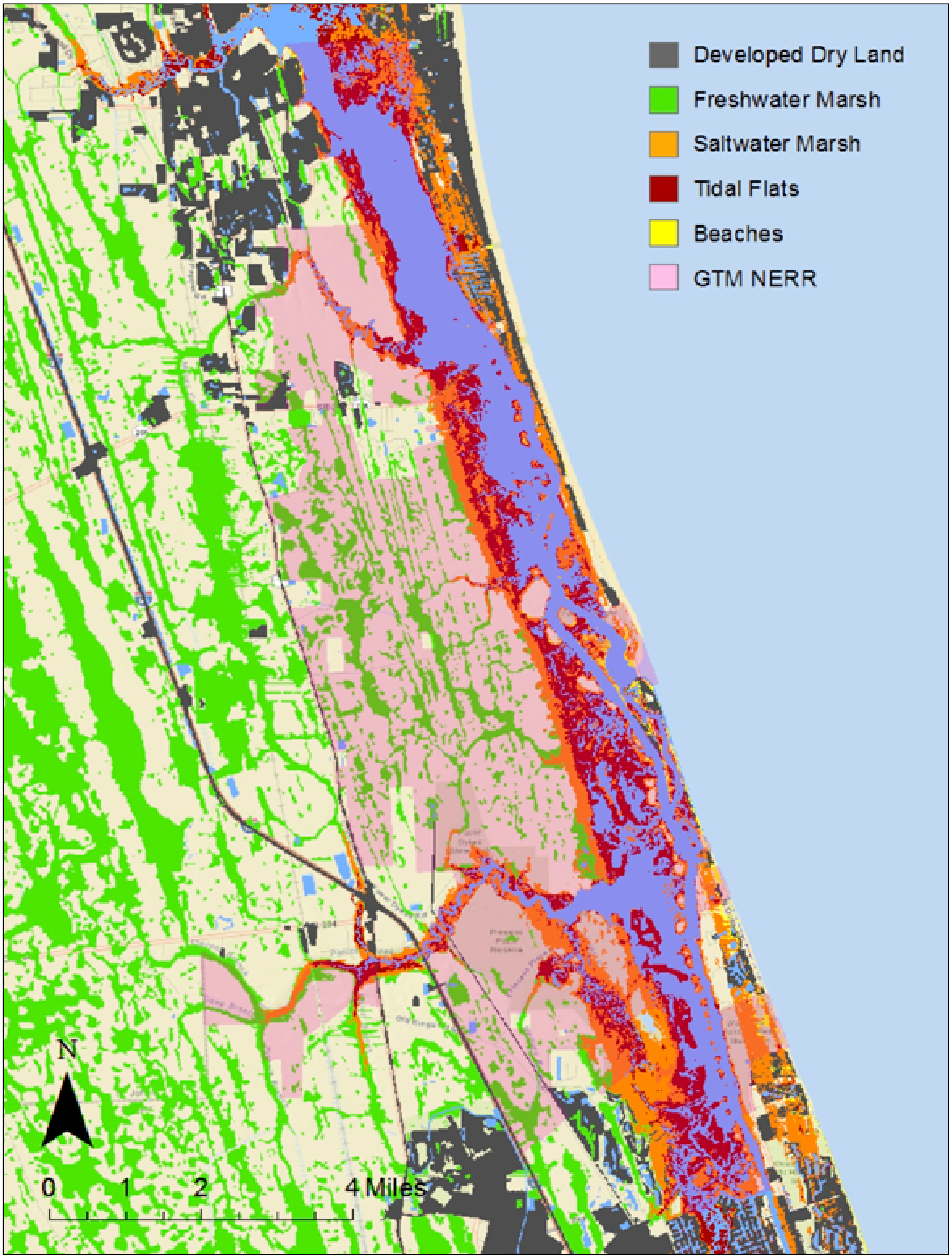


Figure 40. SLAMM results for the GTM Research Reserve: 1 meter sea level rise in 2100

When comparing the bathtub model analysis of low lying areas and the SLAMM analysis of land cover change, the total area impacted by some sort of land cover change (conversion to wetlands, open water, etc) should be similar. One difference, is the total amount of land projected to convert to open water. The bathtub models predict that everything below 1 meter (3 feet) converts to open water, indicating extensive loss of saltwater wetlands. In contrast, SLAMM indicates that some of the area below 1 meter in elevation converts to saltwater wetlands, resulting in a lower net loss of wetlands, less open water, and in some cases actually indicating gains in wetland habitat. Figure 41 below compares the extent of open water projected to occur by SLAMM with that projected by a bathtub model.

Palm Coast canal

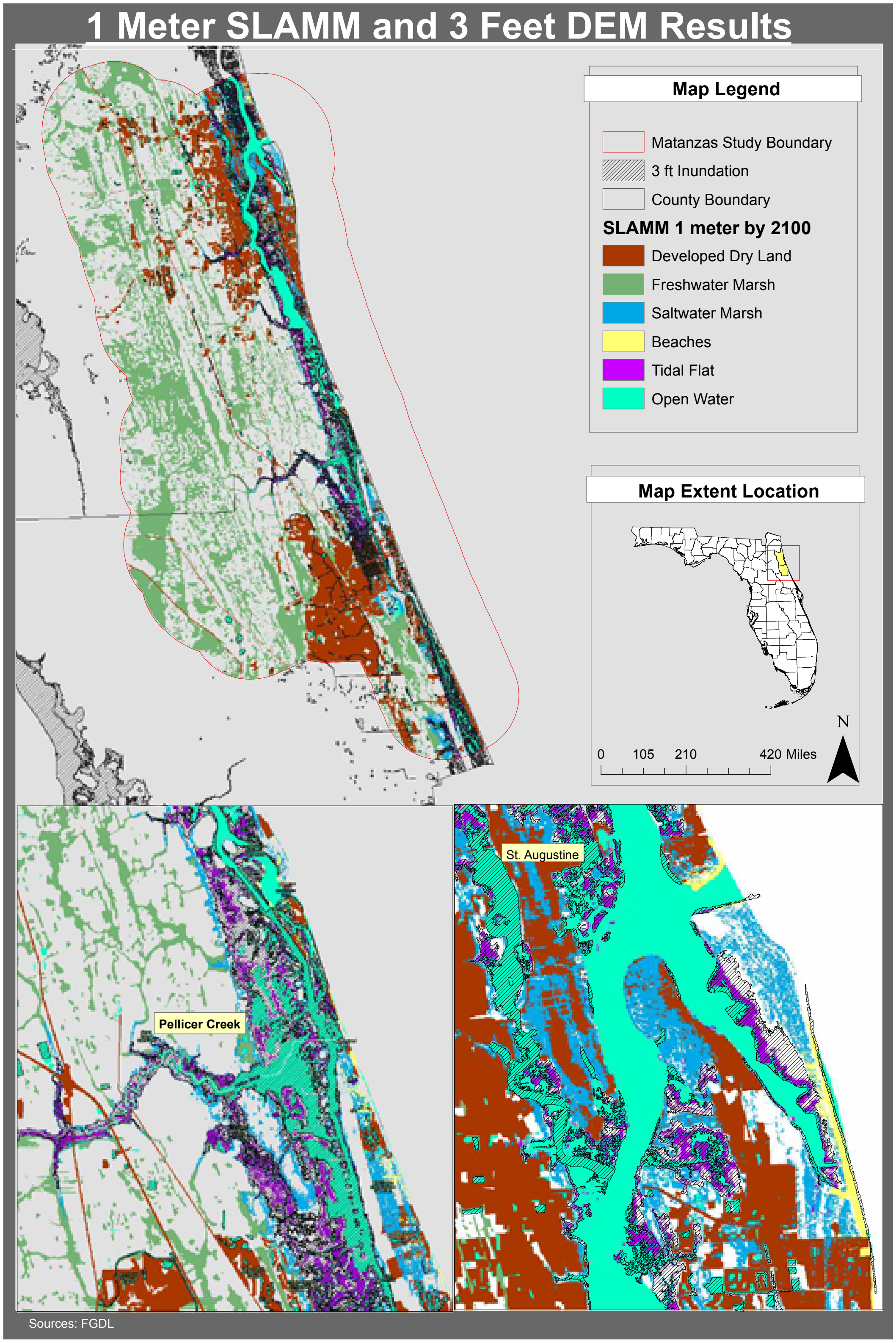


Figure 41. Comparison between SLAMM and bathtub model inundation results

Current Conservation Priorities

Analyses of conservation impacts from sea level rise indicate various scales and types of vulnerability from sea level rise. The following summarizes some of the main findings related to vulnerability of focal species, natural communities, water resources, biodiversity hotspots, and estuarine habitat. More information is included in Appendix D.

Florida Mink Source: http://cdn2.bigcommerce.com/server100/6ca92/product_images/uploaded_images/mink-with-fish-ng-01.jpg

Black Rail Source: http://www.whatbird.com/forum/uploads/profile/photo-77158.jpg?_r=1390784761

American Oystercatcher Source: http://deniseippolito.com/wp-content/gallery/avian/nickerson-beach-667-edit.jpg

Focal Species

Impact assessments for 1 and 2.5 meters (3 and 8 feet) sea level rise were conducted for 37 focal species determined to be important for management and conservation within the Matanzas study area. The full list of focal species and a detailed description of the species selection process, as well as a description of the GIS-based process of species impact analysis are in Appendix D. The species assessed included focal species currently described in management plans for conservation areas within the study area, as well as others deemed significant by the project team, and included specific species such as bald eagle, and guilds such as shorebird and sea turtle guilds.

Of the 37 species that were assessed, the species losing the greatest amount of habitat to 1 meter sea level rise was the black rail, projected to lose up to 58% of its current habitat. However some wetland or open water dependent species actually are projected to gain habitat. In the most extreme example, American oystercatcher is projected to see a 167% gain in habitat. The majority of species for which assessments were completed lost or gained between 0-10% of current habitat. If American oystercatcher is excluded, the change in habitat for all other species with 1 meter sea level rise was a loss of approximately 6%.

Similar patterns of habitat change were seen with 2.5 meters sea level rise, with some wetland or open water dependent species gaining habitat, while upland species generally lost habitat. However in this case the average loss across all species was over 12%, which is almost twice the average loss seen with 1 meter sea level rise. Again, American oystercatcher was excluded from this figure because the amount of habitat this species is projected to gain would skew the statistic.

Statistics were also created to identify the amount of focal species habitat lost or gained within existing conservation areas. These statistics are valuable as an indicator of which species might be inadequately protected by current conservation lands as sea levels rise. In this case, some species gain or lose habitat. Species losing the most habitat within the GTM Research Reserve under 1 meter sea level rise include the black rail (-57%), Florida mink (-43%), and seaside sparrow (-43%), though several other species lose significant acreage of habitat as well. With 2.5 meters sea level rise, Florida pine snake loses 79% of existing habitat, neotropical migrant forest birds lose 55%, black rail loses 96%, and limpkins lose 57% of their current habitat. Other species lose similar amounts: Seaside sparrows (-83%), Marian's marsh wren (-76%), mangrove forest birds (-99%), Gulf saltmarsh snake (-66%), merlin (-69%), painted bunting (-41%), sand foraging shorebirds (-67%), and Florida mink (-83%).

A comparison of average loss/gain statistics for focal species within the GTM Research Reserve and contiguous conservation lands, and separately within all conservation areas in the study area is below in Table 11. It indicates that there is a significant increase in habitat lost with 2.5 meters sea level rise, but that consideration of focal species habitat across all conservation lands in the study area (rather than just the GTM reserve) mitigates those impacts.

	1m sea level rise impacts within the GTM and contiguous conservation lands	2.5m sea level rise impacts within the GTM and contiguous conservation lands	1m sea level rise impacts within all conservation lands in the study area	2.5m sea level rise impacts within all conservation lands in the study area
Average loss/ gain of habitat for all focal species (% of current habitat)	-3.12%	-27.88%	-2.39%	-19.25%

Table 11. Average loss/gain of focal species habitat in conservation areas

Natural Communities

Impacts to priority upland natural communities in the Matanzas study area were assessed from 1 and 2.5 meters sea level rise. In addition to solely natural communities, pine plantations and rangeland were also included in this assessment because of the number of acres of these uses that occur within the region and their value for conservation goals. These include providing valuable natural and semi-natural habitat for a variety of upland species that occur within the area, such as black bear. For wetland natural communities we used the analyses included as part of the project's SLAMM analysis. Upland natural communities and land cover types included in this assessment are listed below:

1. Rangeland
2. Scrub
3. Pine flatwoods
4. Sandhill
5. Upland hardwood forest
6. Cabbage palm hammock
7. Mixed conifer-hardwood upland forest
8. Pine plantation

Results from the natural community and land cover impact analysis are shown in Table 12, based on a combination of upland land cover data from the FLUCCS and Cooperative Land Cover (CLC) datasets and wetland natural community data from the SLAMM model results. A more detailed version of Table 12 is included in Appendix D. Impacts from sea level rise to upland land cover types show that virtually all upland land cover included in this assessment will experience a decline in acreage from sea level rise. The natural community type with the most loss is cabbage palm hammock. Pine plantation is minimally impacted by sea level rise, with most acreage occurring farther to the west of the estuary. Some, though not all wetland land cover types experience a net loss from sea level rise. Impact assessments of wetland communities is more nuanced, since SLAMM analyses show that some wetland land cover types actually see a net gain in acreage as sea levels rise.

Cabbage palm hammock

Natural Community Type	Percent loss/gain to 1m SLR	Percent loss/gain to 2.5m SLR
Upland land cover impacts		
Rangeland	-5.5%	-20.1%
Scrub	-4.8%	-32.0%
Pine flatwoods	-2.6%	-9.0%
Sandhill	-1.1%	-4.5%
Upland hardwood forest	-16.6%	-79.6%
Cabbage palm hammock	-16.6%	-98.8%
Mixed conifer-hardwood upland forest	-8.1%	-34.7%
Pine plantation	-0.3%	-1.2%
Wetland land cover impacts based on SLAMM results		
Swamp	-2.5%	-7.9%
Cypress swamp	-2.3%	-11.2%
Inland Freshwater Marsh	-2.2%	-6.9%
Transitional Saltmarsh	81.4%	15.6%
Regularly Flooded Marsh	-31.0%	13.6%
Mangrove	38.0%	-99.7%
Estuarine Beach	100.0%	100.0%
Tidal flat	49.0%	139.1%
Ocean Beach	32.0%	136.6%
Irregularly Flooded Marsh	34.0%	-99.4%
Vegetated tidal flat	-14.7%	-100.0%
Open water	56.9%	166.2%

Table 12. Natural community and land cover impacts from sea level rise

Water Resources

Impacts from sea level rise were assessed for water resource priorities, including CLIP Surface Water Protection priorities, CLIP Groundwater Recharge priorities, draft CLIP Surface Water Restoration priorities, and the riparian network supporting water quality and quantity for the Matanzas River watershed. These are included in Table 13 below, with more detailed statistics and explanation in Appendix D. These analyses are intended to be coarse indicators of water resource protection priorities (both surface water and groundwater) as well as potential restoration priorities for improving water quality and quantity. Except for the Riparian Network analysis, these analyses use existing CLIP 3.0 or new CLIP data under development. The impact assessment was an overlay of the priority resources identified in the subsections below and both sea level rise inundation scenarios 1 and 2.5 meters (3 and 8 feet) and the future development scenario. Results from the sea level rise impact analyses on water resources show greater impacts on water resource priority areas in a the 2.5 meters sea level rise scenario compared to a 1 meter scenario. In both cases impacts on areas identified as high priority for surface water protection are greatest.

Analyses included the following:

1. *CLIP Significant Surface Waters Protection*
   This data layer identifies areas that contribute water runoff to a surface water feature that has statewide significance, including: aquatic preserves, shellfish harvesting areas, seagrass beds, springs, public water supply sources, watersheds important for rare fish species, Outstanding Florida Waters, National Wild & Scenic Rivers, and National Estuaries. Highest priorities are immediately adjacent to significant surface waters, while lower priorities include all watersheds that contribute to significant surface waters.
2. *CLIP Aquifer Recharge Priorities*
   This data layer identifies priorities for potential recharge to an underlying aquifer system (typically the Floridan aquifer, but could be intermediate or surficial aquifers in some portions of the state). The highest priorities indicate high potential for recharge to springs or public water supplies.

3. *CLIP Surface Water Restoration Priorities*

This data layer is a draft analysis of areas important for restoring impaired water bodies. Areas identified as high priorities are higher to moderate intensity land uses on soils with higher runoff potential and nearer to surface water features in or flowing to impaired water bodies. Areas identified as high priorities could either be restored to more natural land cover, institute best management practices including enhanced water quality buffers, remove or manage drainage features such as ditches and canals where feasible to allow for more natural water storage and treatment (dispersed water storage), or retrofit storm water drainage in urban and suburban areas to store more water (such as bioswales, etc.).

4. *Riparian Network*

This layer was created specifically for the Matanzas study area. It identifies functionally connected buffers around the Matanzas River and major creeks including all the wetlands and water bodies connected to them. Buffers are up to 1,000 meters (3,300 feet) wide and include all connected natural and semi-natural land cover adjacent to the connected surface water network. Areas identified within the Riparian Network are more likely contributing to protecting water quality in the Matanzas watershed.

	Total areas(acres)	Innundated by 1m SLR (acres)	Percentage innundated by 1m SLR	Innundated by 2.5m SLR(acres)	Percentage impacted by development
CLIP Groundwater recharge priorities					
CLIP Priorities 1 (highest) - 5	184,461.10	2,831.60	2%	13,610.20	7%
Riparian network priorities					
Including functional upland buffers, wetlands, and open water in the riparian network	63,222.50	5,474.00	9%	16,505.60	26%
CLIP Surface water protection priorities					
CLIP Priorities 1 (highest) - 5	160,975.17	7,642.40	5%	25,035.22	16%
Draft CLIP Surface water restoration priorities					
Priorities 5-9 (highest priority)	95,985.62	2,312.89	2%	3,313.67	3%

Table 13. Impacts sea level rise on water resource priorities

Biodiversity Hotpots

In addition to impact assessments for specific species, assessments of sea level rise impacts on biodiversity hotspots in the Matanzas study area were completed using the Critical Lands and Waters Identification Project (CLIP) Biodiversity Resource Category dataset. The Biodiversity Resource Category is intended to represent statewide biodiversity priorities based on a combination of several core data layers from the CLIP database. These include datasets representing Strategic Habitat Conservation Areas (SHCAs) and areas of potential habitat richness for vertebrates identified by the Florida Fish and Wildlife Conservation Commission, and rare species habitat conservation priorities and priority natural communities identified by the Florida Natural Areas Inventory.

The core data layers are combined to create an aggregated dataset ranked from Priority 1 to 5, with Priority 1 being representing lands that are most important for preserving biodiversity. Within the Matanzas project study area, lands representing all five levels of biodiversity priority are currently present. Existing lands within the GTM Research Reserve are a high priority for biodiversity, as well as patches of land along the coast and on the western edges of our study area. Figure 42 shows current biodiversity priorities identified by the CLIP 3.0 dataset.

Analysis of the impacts from sea level rise on biodiversity priorities indicates a moderate to high degree of impact. Under 1 meter (3 feet) sea level rise, coastal Priority 1 and 3 lands are most impacted, whereas under a the 2.5 meters (8 feet) sea level rise scenario, coastal Priorities 1, 3, and 5 are most highly impacted. The term “impacts” in this analysis refers to any biodiversity priority that changes to open water or wetlands under a sea level rise scenario. SLAMM analyses show that there actually may be significant conversions of upland areas to coastal wetlands in the areas shown to be “impacted” in this analysis, meaning that they may still support some level of biodiversity. Table 14 shows impacts to biodiversity priorities from 1 and 2.5 meters sea level rise.

CLIP Biodiversity Value	Existing Acres	Acres Impacted by Sea Level Rise	Percent Impacted
Impacts to Biodiversity Priorities from 1m Sea Level Rise			
Priority 5	2,604	87	3%
Priority 4	16,895	417	2%
Priority 3	35,992	2,102	6%
Priority 2	34,324	470	1%
Priority 1- Highest	3,966	300	8%
Total Impacts	**93,781**	**3,375**	**4%**
Impacts to Biodiversity Priorities from 2.5m Sea Level Rise			
Priority 5	2,604	264	10%
Priority 4	16,895	1,477	9%
Priority 3	35,992	5,364	15%
Priority 2	34,324	2,259	7%
Priority 1- Highest	3,966	1,324	33%
Total Impacts	**93,781**	**10,687**	**11%**

Table 14. Impacts to biodiversity priorities from sea level rise

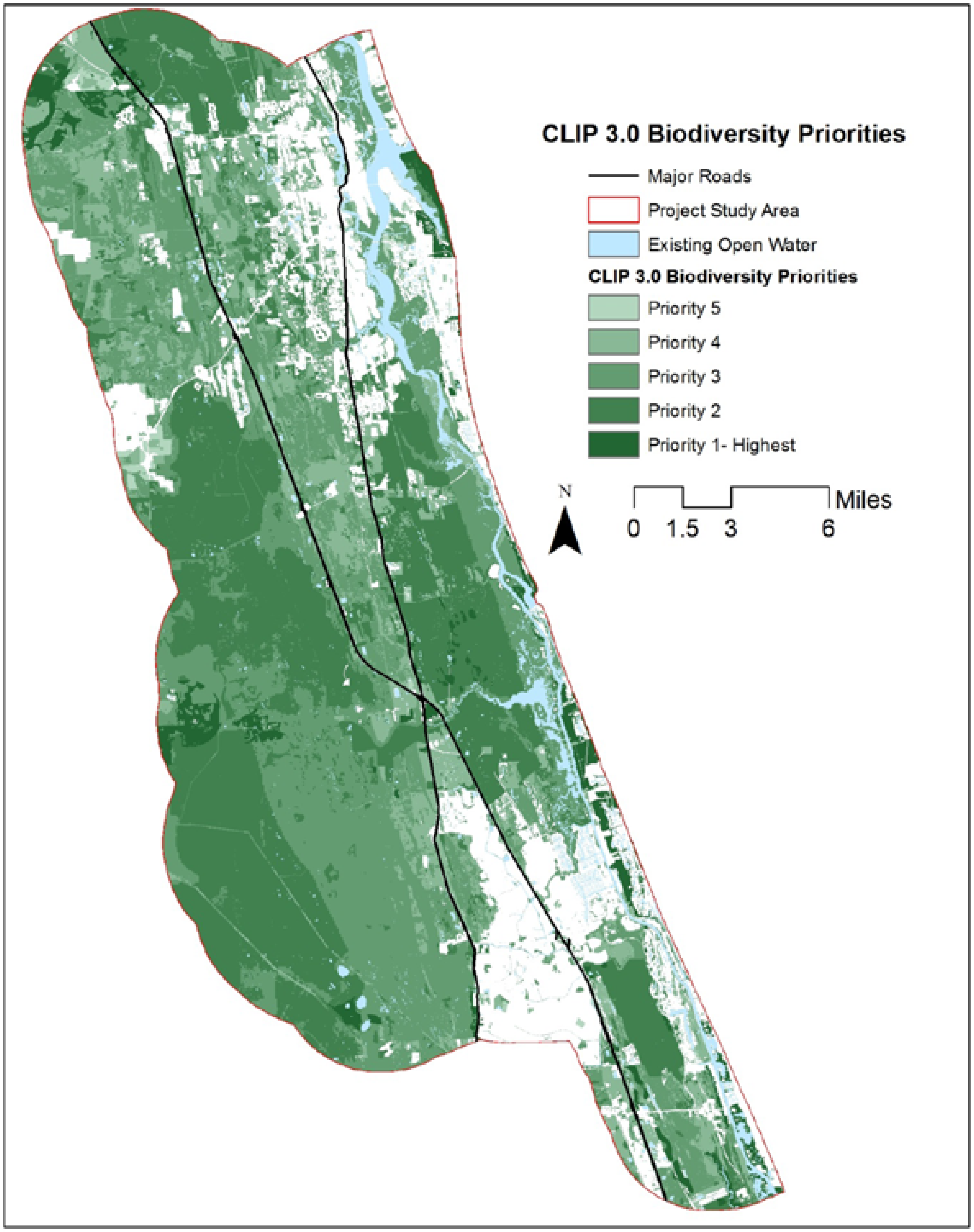


Figure 42. Current CLIP biodiversity priorities

Photo by Ed Siarkowicz Photographic Images, LLC

Estuarine Habitat

In addition to the impact assessments for specific natural community types from sea level rise that were conducted, more detailed assessments of potential changes and impacts on estuarine habitat in general were completed upon request from GTM Research Reserve staff. Figure 43-Figure 44 show various classifications of estuarine habitat resulting from 1 and 2.5 meters sea level rise including 1) existing estuarine habitat lost to sea level rise, 2) existing estuarine habitat that remains after sea level rise, 3) existing uplands that convert to estuarine habitat as sea levels rise (i.e. future estuarine habitat), and 4) future estuarine habitat contiguous with areas of existing estuarine habitat projected to remain after sea level rise. Table 15 shows the acreage of these categories, both within current conservation lands and the Matanzas study area as a whole. Estuarine habitat “lost” to sea level rise included any of the land cover types listed in Table 12. that converted to open water in future scenarios.

Photo by Ed Siarkowicz Photographic Images, LLC

Habitat Type	Total Acres Within Project Study Area	Acres Within Existing Managed Lands
Estuarine Habitat after 1m Sea Level Rise		
Existing Estuarine Habitat Lost to SLR	3,751	1,661
Existing Estuarine Habitat that Remains	10,460	6,338
Future Estuarine Habitat Not Contiguous with Existing	898	190
Future Estuarine Habitat Contiguous with Existing	2,319	1,084
Estuarine Habitat after 2.5m Sea Level Rise		
Existing Estuarine Habitat Lost to SLR	13,726	7,818
Existing Estuarine Habitat that Remains	935	370
Future Estuarine Habitat Not Contiguous with Existing	4,227	812
Future Estuarine Habitat Contiguous with Existing	9,495	5,210

Table 15. Estuarine habitat resulting from sea level rise

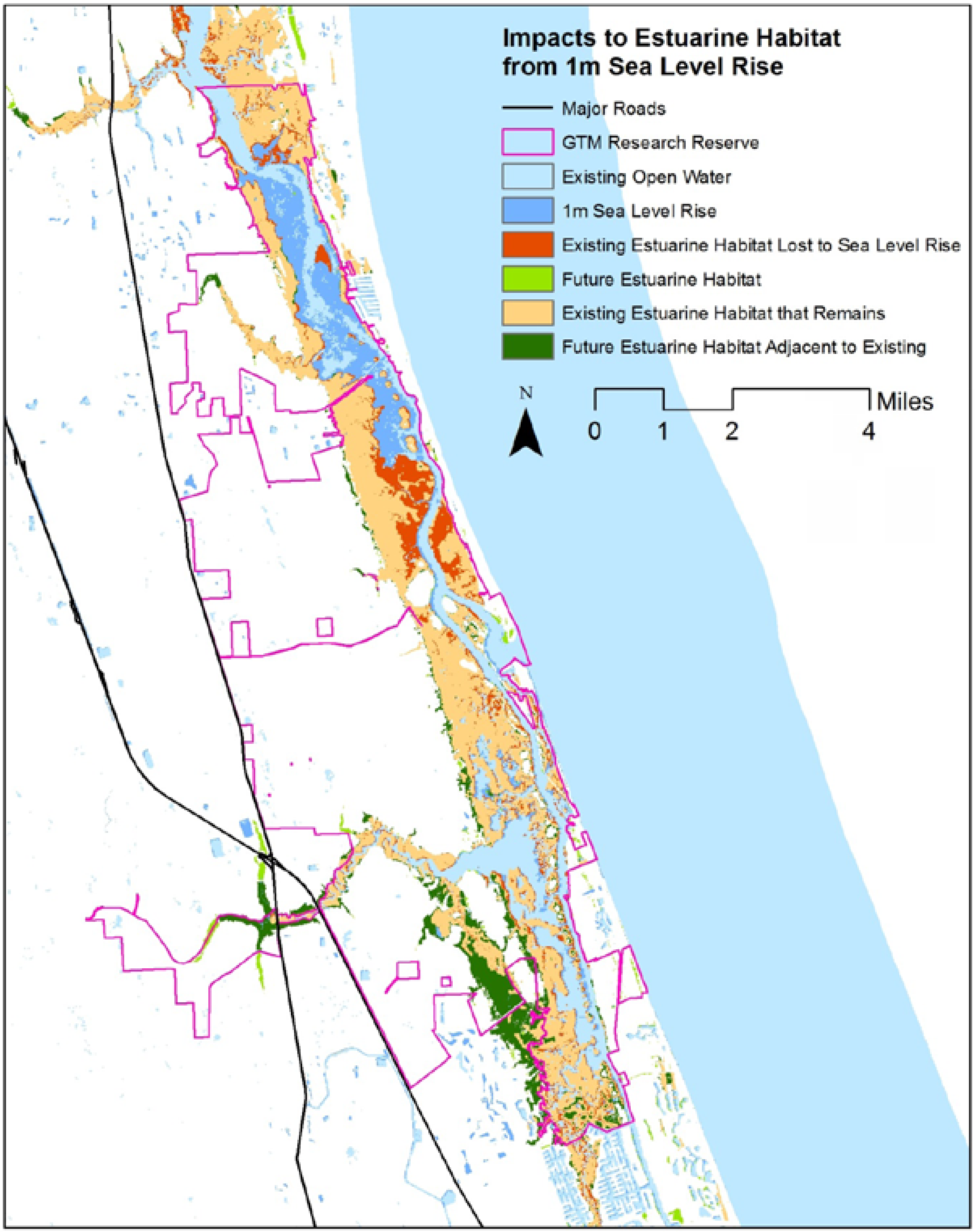


Figure 43. Estuarine habitat resulting from 1 meter sea level rise

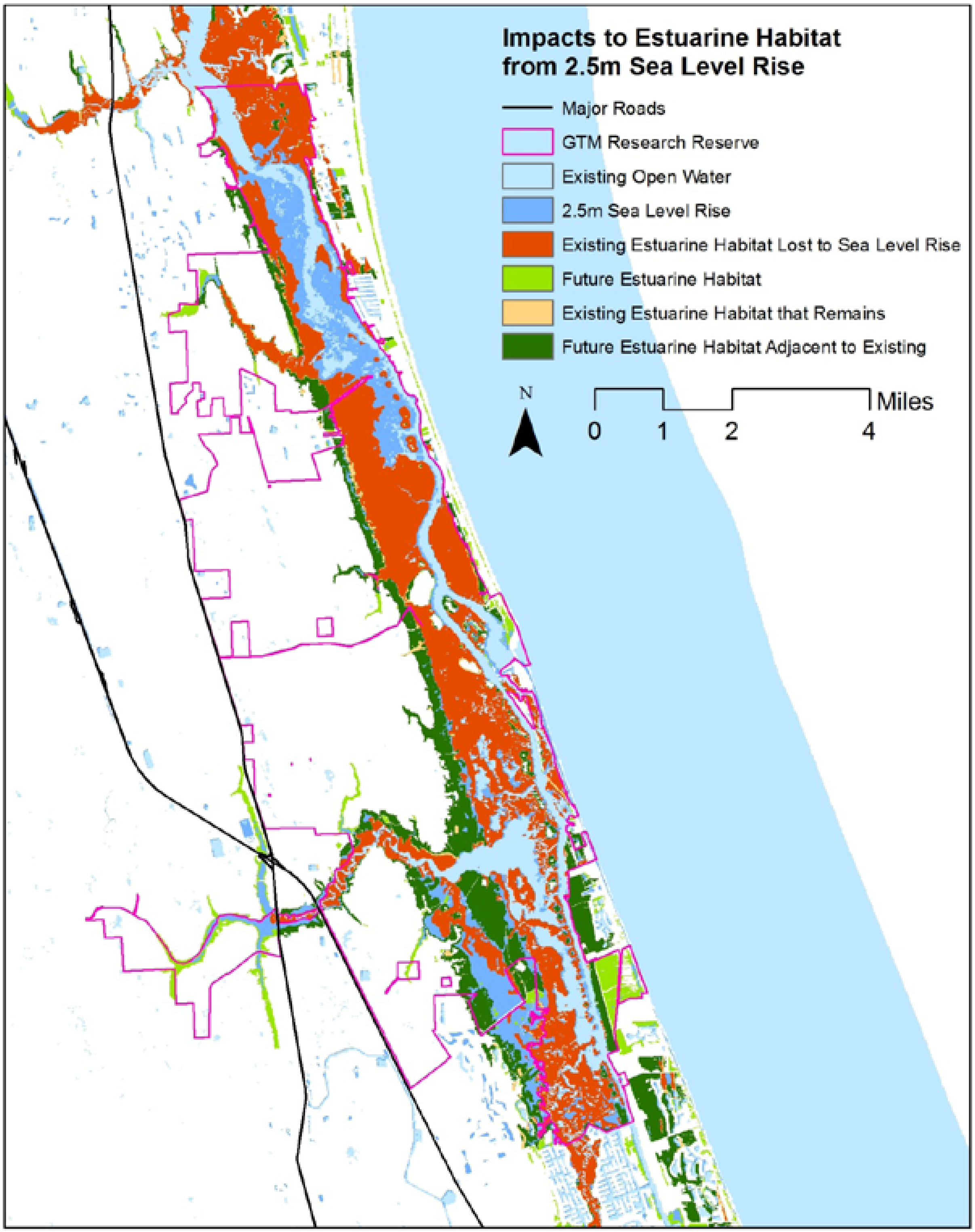


Figure 44. Estuarine habitat resulting from 2.5 m sea level rise. It should be clear from this map that at a 2.5m SLR there will be almost complete "turnover" in estuarine wetland habitat, which means that virtually all current habitat will be lost and potentially replaced by newly created habitat in areas that are currently uplands

Existing Development

Analyses show that current coastal development is vulnerable to sea level rise. It is important to note that impact analyses in this project focused primarily on sea level rise impacts on landscapes, but other coastal changes may also impact development including saltwater intrusion and coastal erosion. Impacts from storm surge are summarized in an earlier section, finding that sea level rise will increase storm surge impacts on developed areas. Impacts to current developed areas from sea level rise are summarized in Table 16 for the Matanzas study area, based on the 1 meter sea level rise SLAMM scenario. The land use types most impacted by 1 meter sea level rise are residential and recreational uses (in terms of total acreage impacted), but lands classified as government use are most impacted relative to existing acreage (only military and municipal lands included in totals below). This sea level rise scenario affected 2,456 acres of currently developed residential land, which has 16,335 occupied residential units and over 30,000 residents. At the two-county scale, the number of impacted occupied residential units was 24,631, with a population over 50,000. More information is available in Appendix E.

Impacts to critical facilities within the study area were also assessed by overlaying critical facility locations on SLAMM model results (Figure 45). This analysis indicates that, while the majority of critical facilities are beyond the reach of a 3 feet sea level rise, there are some at risk of inundation or periodic flooding.

Land use description	Current acres	Acres inundated by 1m sea level rise	Percent inundated
Acreage not zoned for agriculture	8,613	1,690	20%
Industry	1,634	94	6%
Institutional	2,855	238	8%
Commercial, retail, or service	4,891	609	12%
Residential	22,343	2,456	11%
Recreational	12,919	2,371	18%
Government (including municipal and military lands only)	2,271	1,140	50%
Agriculture	119,748	257	0%
Vacant commercial	3,907	268	7%
Vacant institutional	416	12	3%
Vacant industrial	1,088	69	6%
Vacant residential	11,994	1,637	14%
Total	**192,677**	**10,841**	**6%**

Table 16. Impacts from 1 meter sea level rise on land uses within the study area

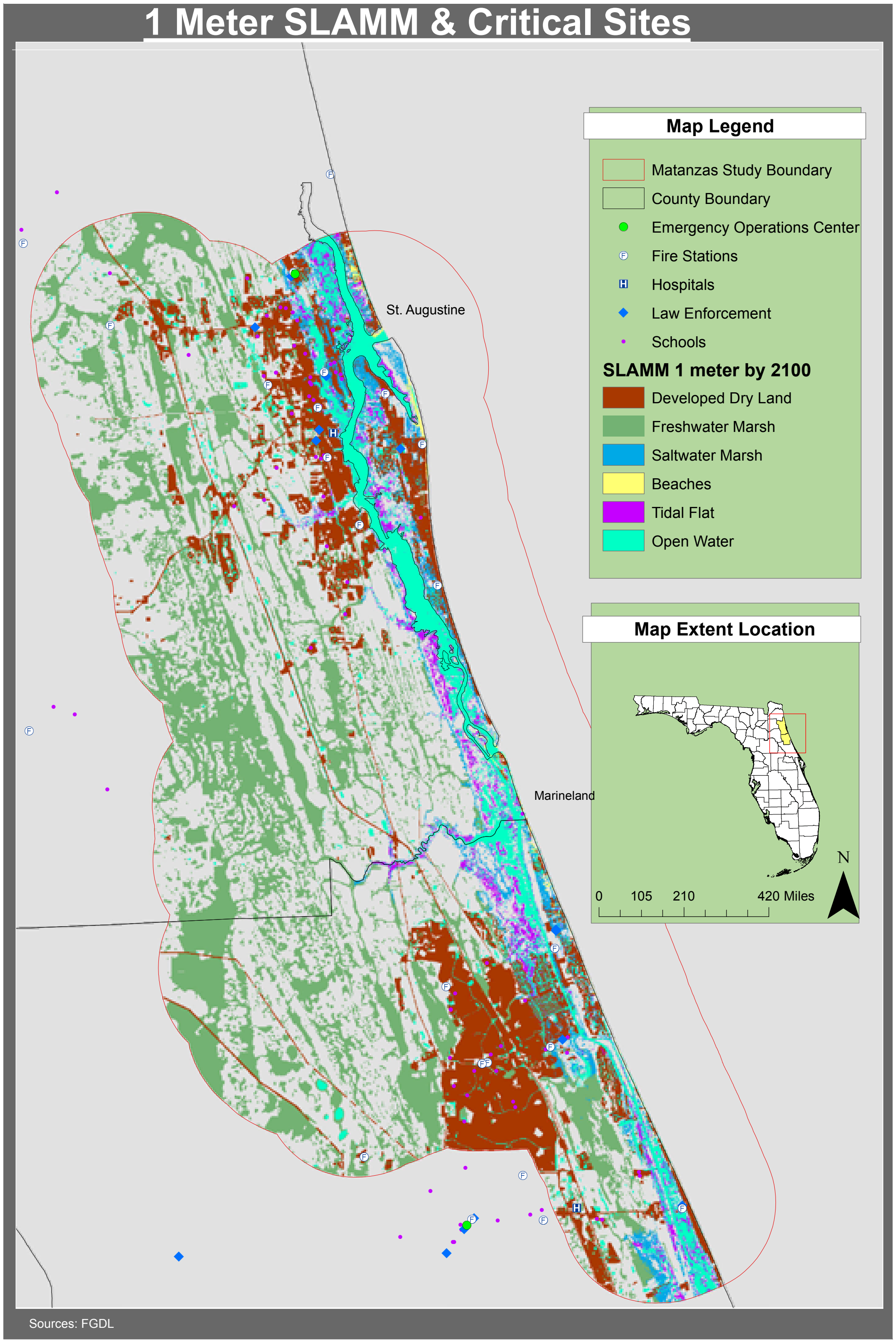


Figure 45. Impacts to critical facilities as indicated by SLAMM model results

Current development in low-lying areas is potentially quite vulnerable to sea level rise. In addition, while developed areas may be armored, elevated, or otherwise protected, SLAMM indicates that there will be a tendency for some developed areas to generally become more wet and flooded on a periodic basis, separate from the permanent inundation that may occur in other areas. Coastal developed areas are a small portion of the total acreage of upland areas within the study area. However these are also the most densely populated areas, and include a number of important cultural and historic resources, such as the historic core of St. Augustine and Fort Matanzas.

View from Ft. Matanzas

Future Development Scenarios

Population projections provided by the Bureau of Economic and Business Research (BEBR) anticipate significant population growth within St. Johns and Flagler counties by the year 2060. New homes, businesses, and infrastructure will be developed, and the pattern will affect its vulnerability to coastal hazards and sea level rise, as well as impact the character of the Matanzas Basin and the viability of its existing conservation lands and agricultural industries.

The following section summarizes findings related to historic and current development patterns in the study area, as well as future development if it holds to current trends and patterns and adapts to sea level rise. Additional information is in Appendix E.

Photo by Ed Siarkowicz Photographic Images, LLC

Historic Population and Development Trends

As a starting point for assessing development patterns within the study area and possible future changes, some basic analyses of historic population growth and development were conducted. These analyses were conducted at the county level. Table 17 shows population growth trends for St. Johns and Flagler counties, starting in 1950 and ending with the 2010 Census.

	1950 population	2010 population	Total Change	Percent Change
St Johns County	24,998	190,039	165,041	660%
Flagler County	3,367	95,696	92,329	2,742%
Total	**28,365**	**285,735**	**257,370**	**907%**

Table 17. Population growth in Flagler and St Johns counties from 1950 through 2010

St. Johns County, containing the historic City of St. Augustine, has approximately 6,250 extant (still existing) single family houses built prior to 1970. This early development was primarily in, and around, St. Augustine, Ponte Vedra Beach, and Fruit Cove. During the 1970s, development spread south from St. Augustine to the current areas of St. Augustine South and St. Augustine Shores. Earlier development in Ponte Vedra Beach was located along the coast and eastern shore of the Tolomato River, and later development began filling the area between the coast and river. Near Fruit Cove, development spread southeast from the St. Johns River. During more recent decades, development continued in similar directions. Housing also expanded west of St. Augustine and more developments have grown in the area between St. Augustine and Fruit Cove. Figure 46 and Table 18 show the number of existing single family houses by decade built in St. Johns county.

St Johns County	
Decade Built	**Number of Extant Single Family Houses**
Pre-1970s	6,247
1970s	4,691
1980s	9,258
1990s	12,949
2000s	25,496
2010s	1,190

Table 18. Existing single family houses by decade built in St. Johns County

Flagler County	
Decade Built	**Number of Extant Single Family Houses**
Pre-1970s	647
1970s	2,478
1980s	6,752
1990s	8,676
2000s	18,963
2010s	180

Table 19. Existing single family houses by decade built in Flagler County

Flagler County has approximately 650 extant single family houses built prior to 1970. Many of these earlier houses are clustered in, or near, Flagler Beach and Bunnell, and later growth continued in these areas. In the 1970s the Palm Coast developed on the eastern side of I-95, and in subsequent decades spread to the western side of I-95. Since the 1990s, development in Palm Coast also continued eastward across Highway AIA. Figure 47 and Table 19 show the number of existing single family houses by decade built in Flagler County.

Photo by Ed Siarkowicz Photographic Images, LLC

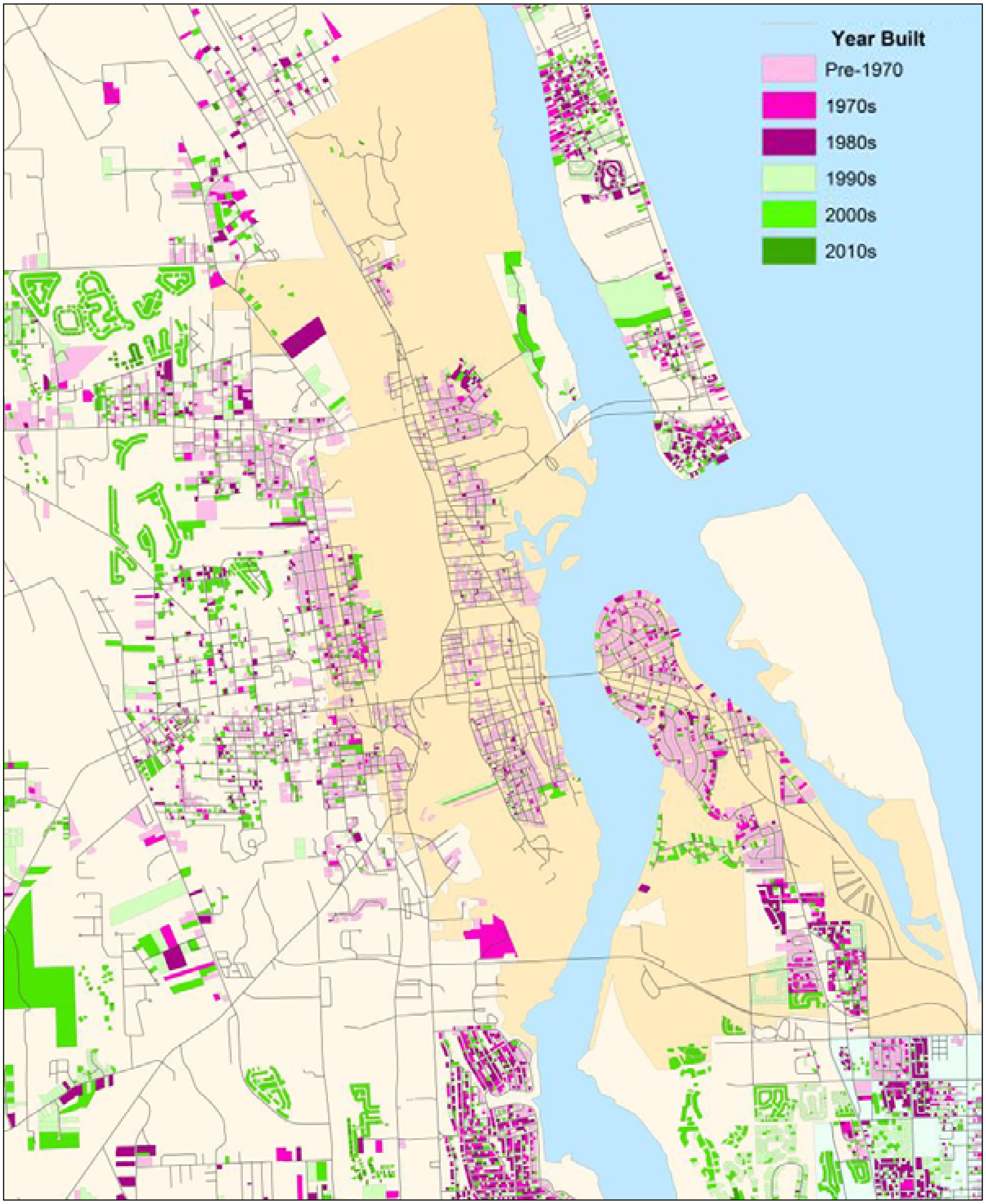


Figure 46. Historic development patterns near St Augustine. Pink and purple colors show a fairly even distribution of pre-1990's construction throughout the St Augustine area, and particularly in central historic St Augustine

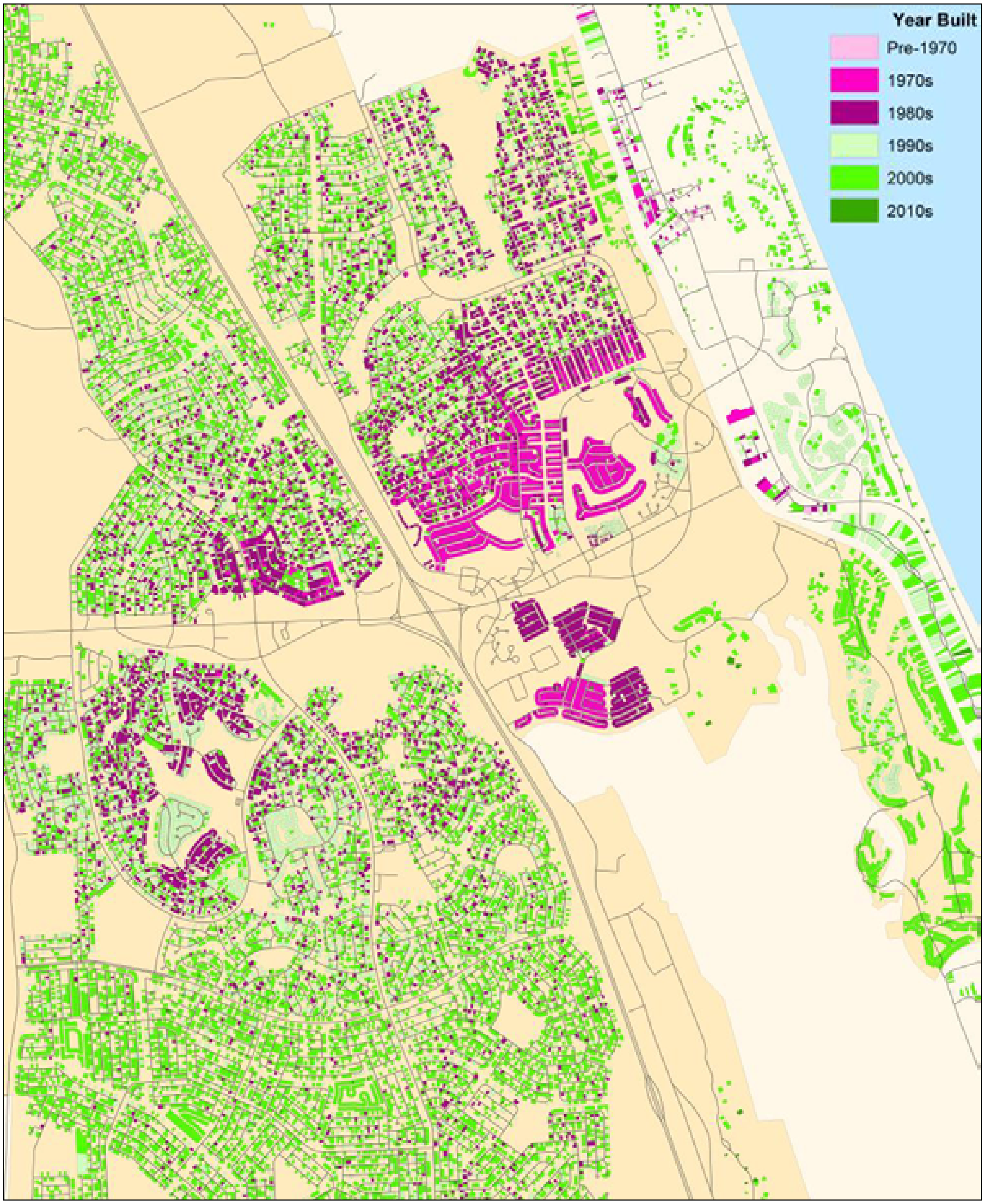


Figure 47. Historic development patterns near Palm Coast. Purple and pink colors are fairly concentrated, showing significant construction in the 1970's, with outward expansion in the 2000's

Future Population and Development Trends

Future population projections supplied by BEBR project 311,523 additional people moving to St. Johns County and 199,528 people moving to Flagler County by the year 2060. Table 20 shows current population based on the 2010 Census compared to population projections for 2060 developed by BEBR. Some of the population growth projected in St. Johns County likely stems from expansion south from the Jacksonville metropolitan area.

These population projections were used to create future development scenarios for St. Johns and Flagler counties based on methods from the LUCIS suitability analysis and allocation process. The trend scenarios are summarized below, which include the additional 2060 population allocated based on current patterns of development. Conservation oriented future development scenarios were created and are described in a later section.

Figure 48 shows that much of current development in the study area is in the lower density range, between 1 unit per 10 acres and 4 to 5 units per acre The low density is in part due to the high number of undeveloped (vacant) residential parcels. There are small areas where densities increase significantly to as many as 19 or 20 units per acre. Condominium density, especially along the coastline, can exceed 20 units per acre. Overall, the “gross urban density” of St. Johns County is 3.7 people per acre, and Flagler County is 2.3.

	2010 population	2060 population projection	Total Change	Percent Change
St Johns County	190,039	501,562	311,523	163%
Flagler County	95,696	295,224	199,528	208%
Total	285,735	796,786	511,051	178%

Table 20. Projected population growth in Flagler and St Johns counties from 2010 to 2060

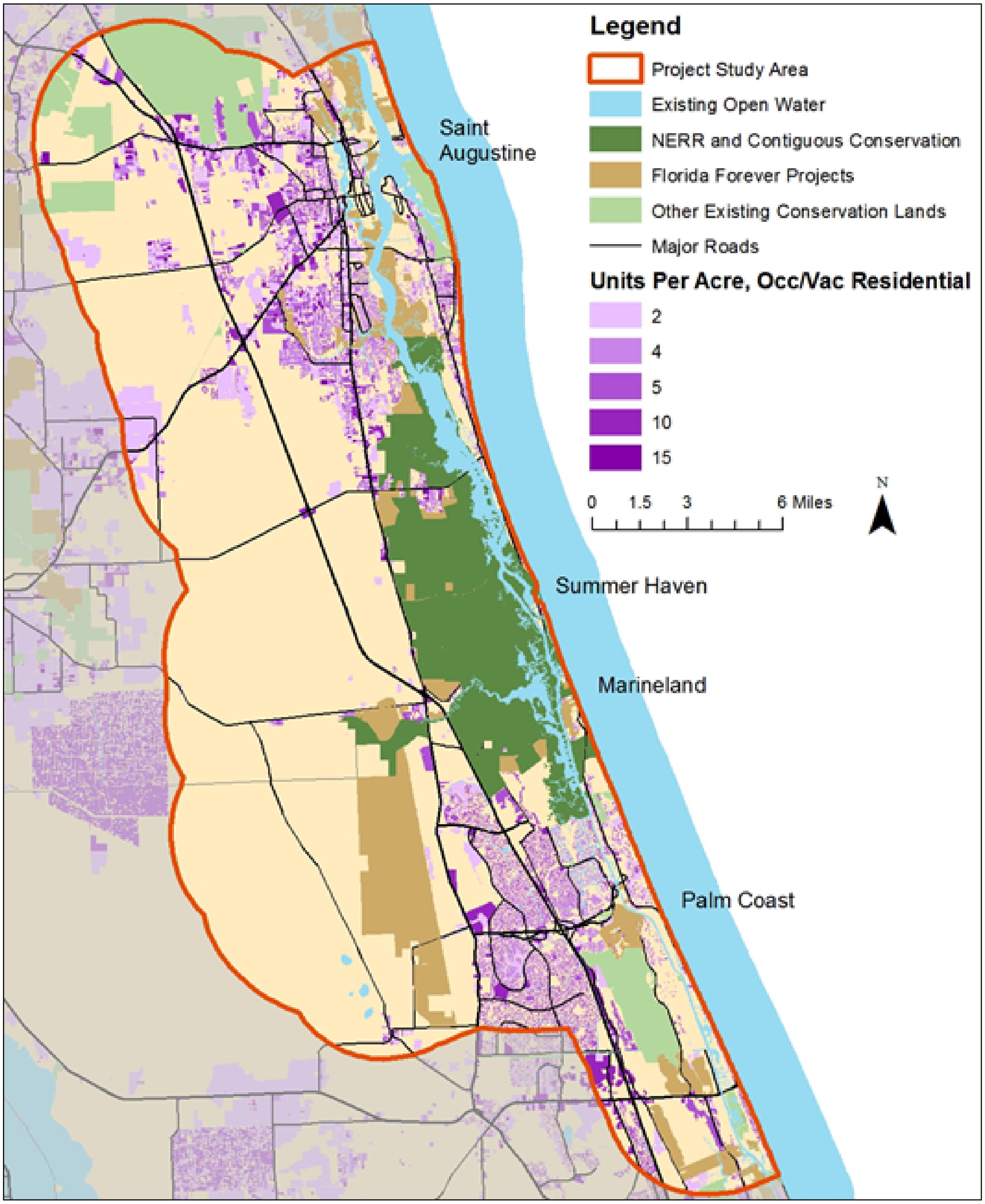


Figure 48. Residential parcel density for existing development

Figure 49 shows the future trend development scenario with no sea level rise. Figure 50 shows the future trend scenario with 1 meter (3 feet) sea level rise included. Based on current development trends with no sea level rise, by 2060 an additional 172,092 acres of currently undeveloped land will need to be developed to accommodate projected population within the two counties. If 1 meter sea level rise is factored in causing displacement of coastal residents, a total of 133,564 acres of currently undeveloped land will need to be developed by 2060 within the counties. These parcels include currently platted vacant residential, commercial, institutional, and industrial parcels, as well as timberlands and other undeveloped uplands. The result of less land developed when adding relocation of existing development in vulnerable areas seems counterintuitive, and this is partly explained by differences in methodologies.. The method of the “without sea level rise” scenarios, for both trend and conservation development patterns, was coarser based on current average urban densities. Therefore we caution against drawing any policy conclusions until the reasons for the different scenario results can be explored. Thus, the safer comparisons are between the two sea level rise scenarios, and between the two without sea level rise scenarios, but not necessarily across the sea level rise and without sea level rise scenarios. For the sake of communicating the results, we provide some analysis of the differences, but these should be viewed tentatively.

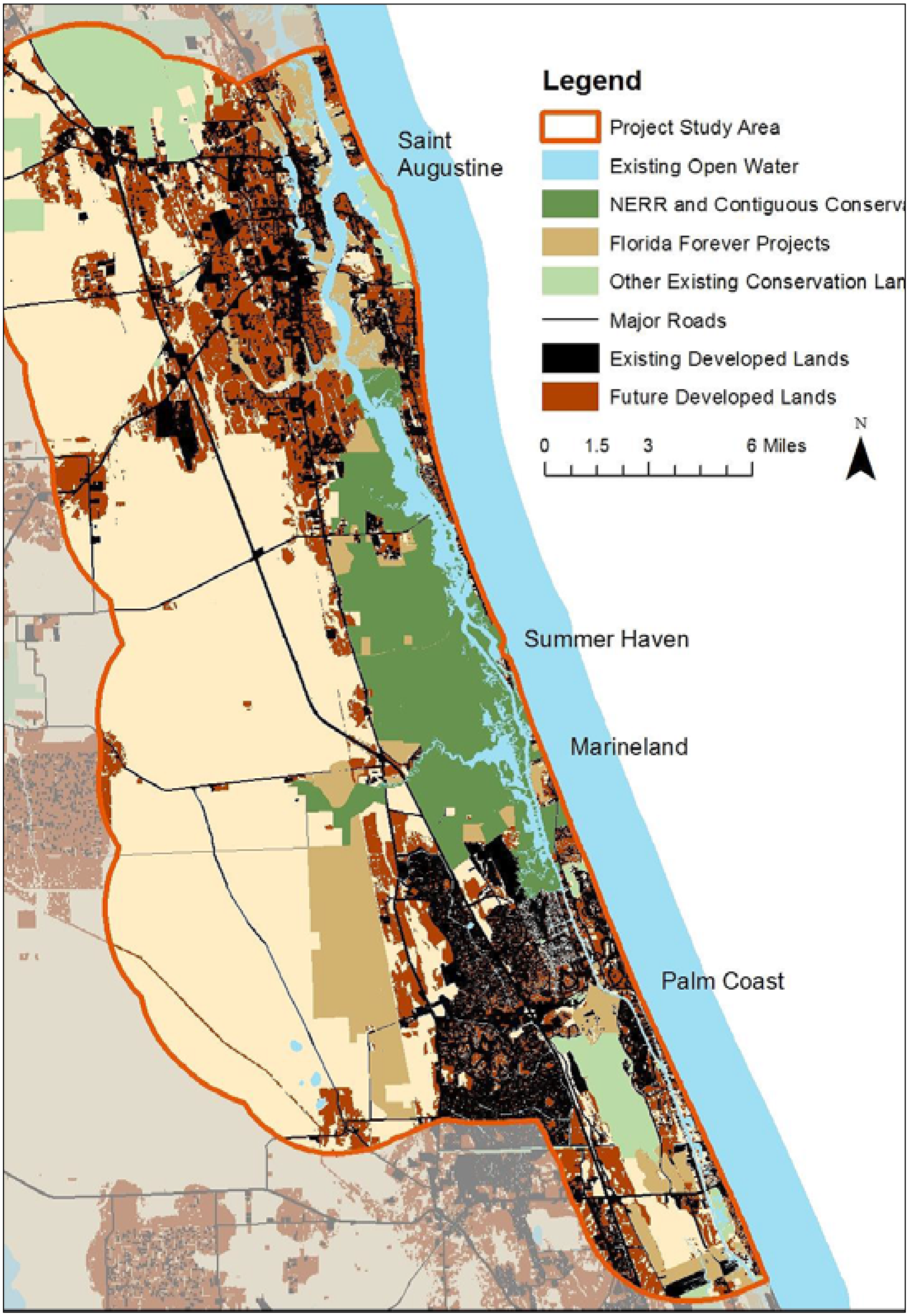


Figure 49. Future trend development scenario with no sea level rise

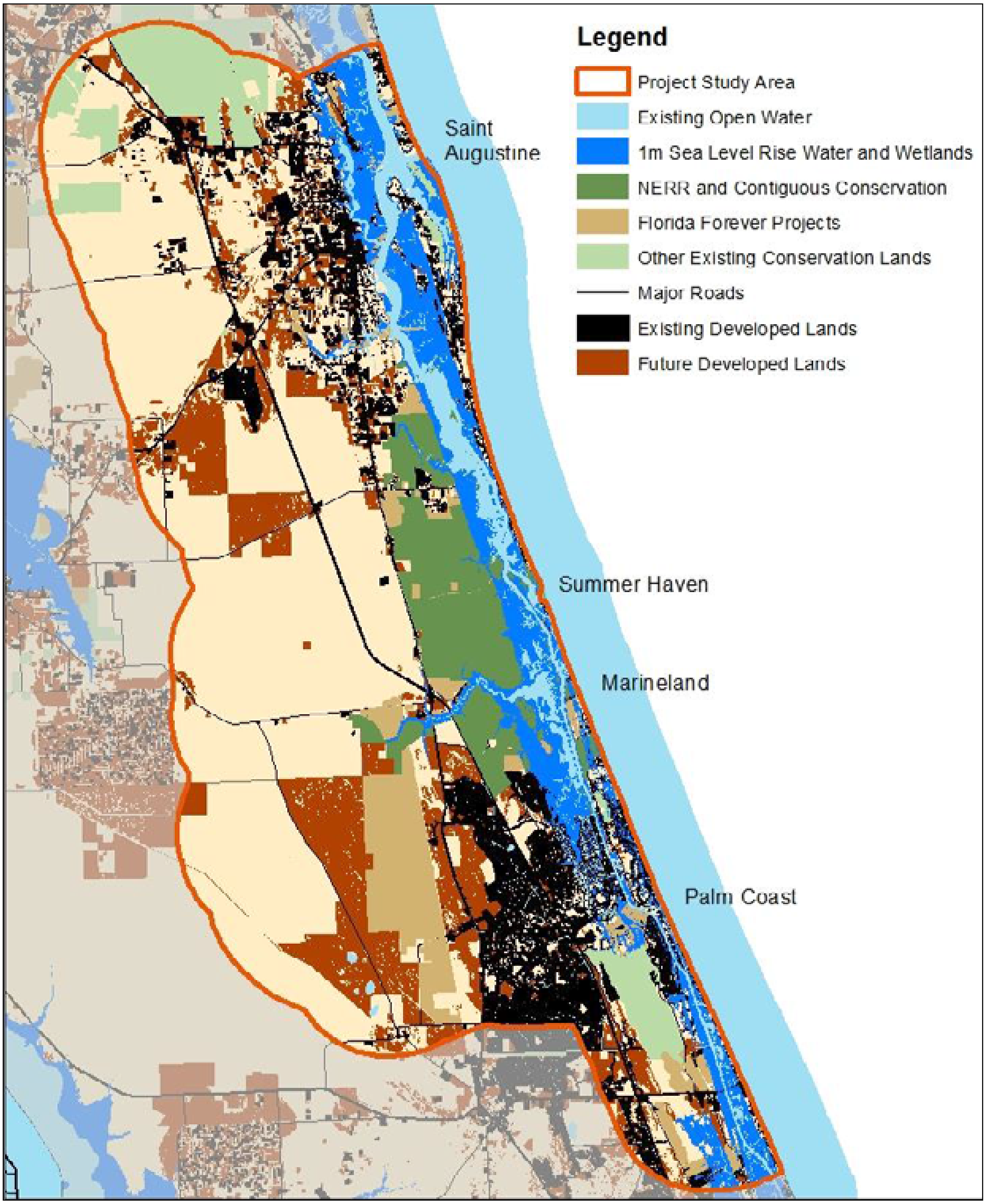


Figure 50. Future trend development scenario with 1 meter sea level rise

Figure 51 shows the development densities used for the trend scenario with sea level rise. These are consistent with current maximum densities within the region, but show a slight increase in average density due to the need to allocate more people within an area made smaller by sea level rise inundation. Detailed density statistics were not produced for the non-sea level rise trend scenario since current average densities were used across the study area as a basis for future allocation.

Comparing the two trend scenarios, there are large areas of additional land in the western portion of the study area that were allocated for future development in the 1 meter sea level rise scenario. Additionally, much of the development projected to occur around St Augustine moves inland under the sea level rise scenario.

Future development will significantly impact ecological resources, including areas important for adaptation of species to sea level rise, biodiversity, water resources, and other ecosystem services. The specific nature of these impacts is described in later sections, and future land use and development choices can be made to reduce these impacts.

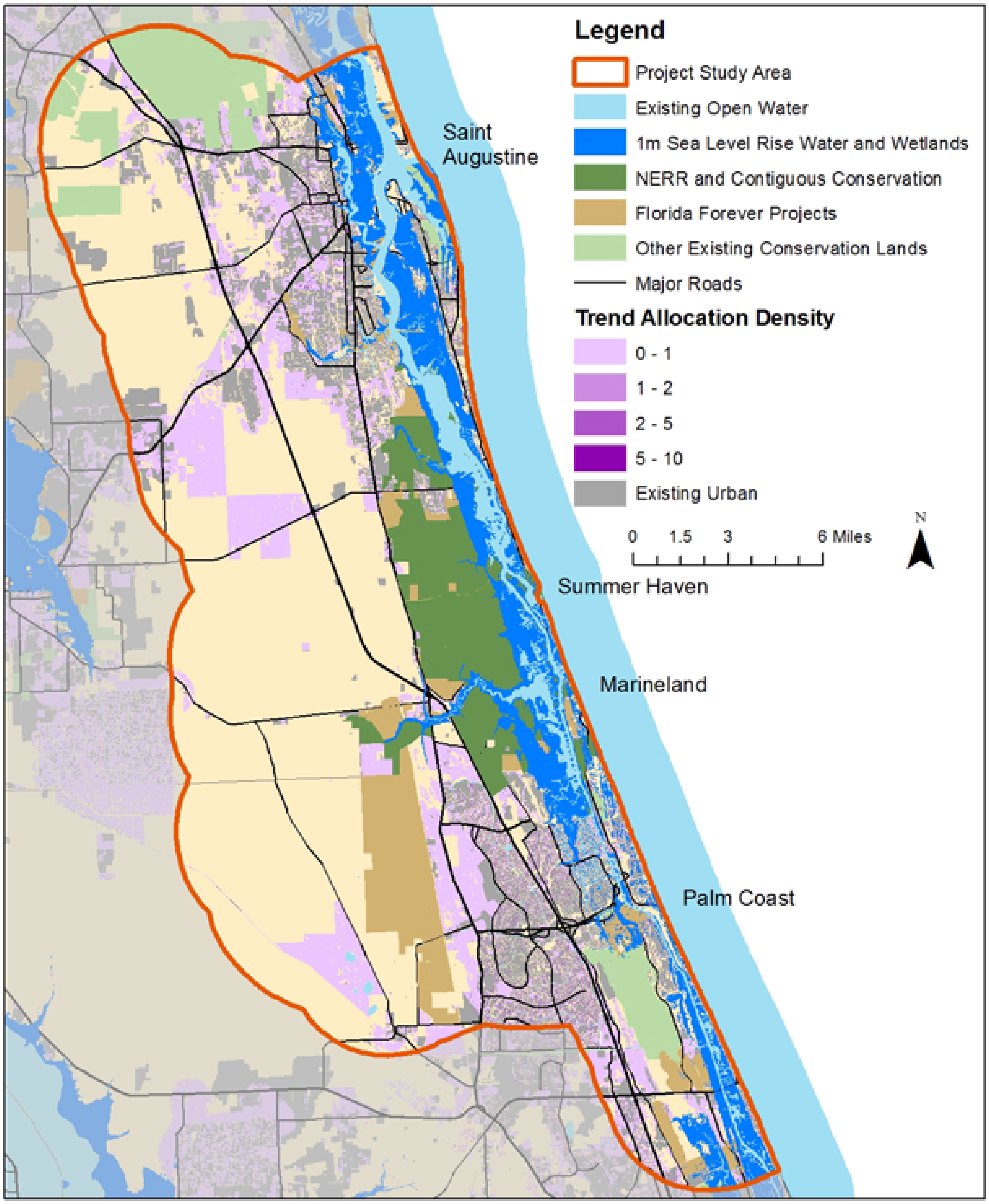


Figure 51. Parcels per acre, for the trend with sea level rise scenario

Impacts of Trend Development Scenarios on Current Conservation Priorities

Analyses of conservation impacts from future development indicate varying impacts depending on species or natural community type. In short, upland focal species and natural communities are likely to be negatively impacted by development where it occurs. Wetland species and communities are less likely to see negative impacts due to the unlikelihood of development occurring in these areas. The following summarizes some of the main findings related to vulnerability of focal species, natural communities, and water resources based on the 1 meter (3 feet) sea level rise “trend” development scenario. Later in this report, a “conservation” development scenario, which avoids future conservation priorities, is presented for comparison. More information is included in Appendix D.

Statistics in this section include impacts from sea level rise described earlier. The cumulative impacts from development and sea level rise are important, as development exacerbates the impacts caused by sea level rise for a number of species and natural communities.

	Number of species losing habitat	**Number of species gaining habitat**
Focal species impacts from 1m sea level rise	27	10
Focal species impacts from future development	37	0
Focal species impacts from 1m sea level rise and development combined	33	4
Focal species impacts from 2.5m sea level rise	30	7

Table 21. Habitat loss/gain for focal species from a combination of sea level rise and development

Focal Species

No focal species gained habitat as a result of future development, though some species were minimally affected, such as wetland dependent species where future development is less likely to occur. Upland species were the most significantly impacted by future development, with many species losing greater than 10% of current habitat, and several losing between 20-30% of current habitat. Gopher tortoise is an example, which is projected to lose a little over 20% of its habitat to future development. Complete statistics and maps for all focal species impacts are included in Appendix D. A sample map is included below (Figure 52) showing impacts from 1 meter sea level rise and development for wood stork.

When changes from 1 meter sea level rise and future development were combined, impacts were compounded or reversed for some species. Striped newt for example, was projected to gain habitat with sea level rise, but the net change in habitat reversed to a loss of over 22% of current habitat when future development and sea level rise statistics were combined. Table 21 summarizes the number of species that are projected to gain or lose habitat with sea level rise and future development.

Striped Newt Source: http://www.apalachee.org/aas/wp-content/uploads/2015/01/StripedNewtadult.jpg

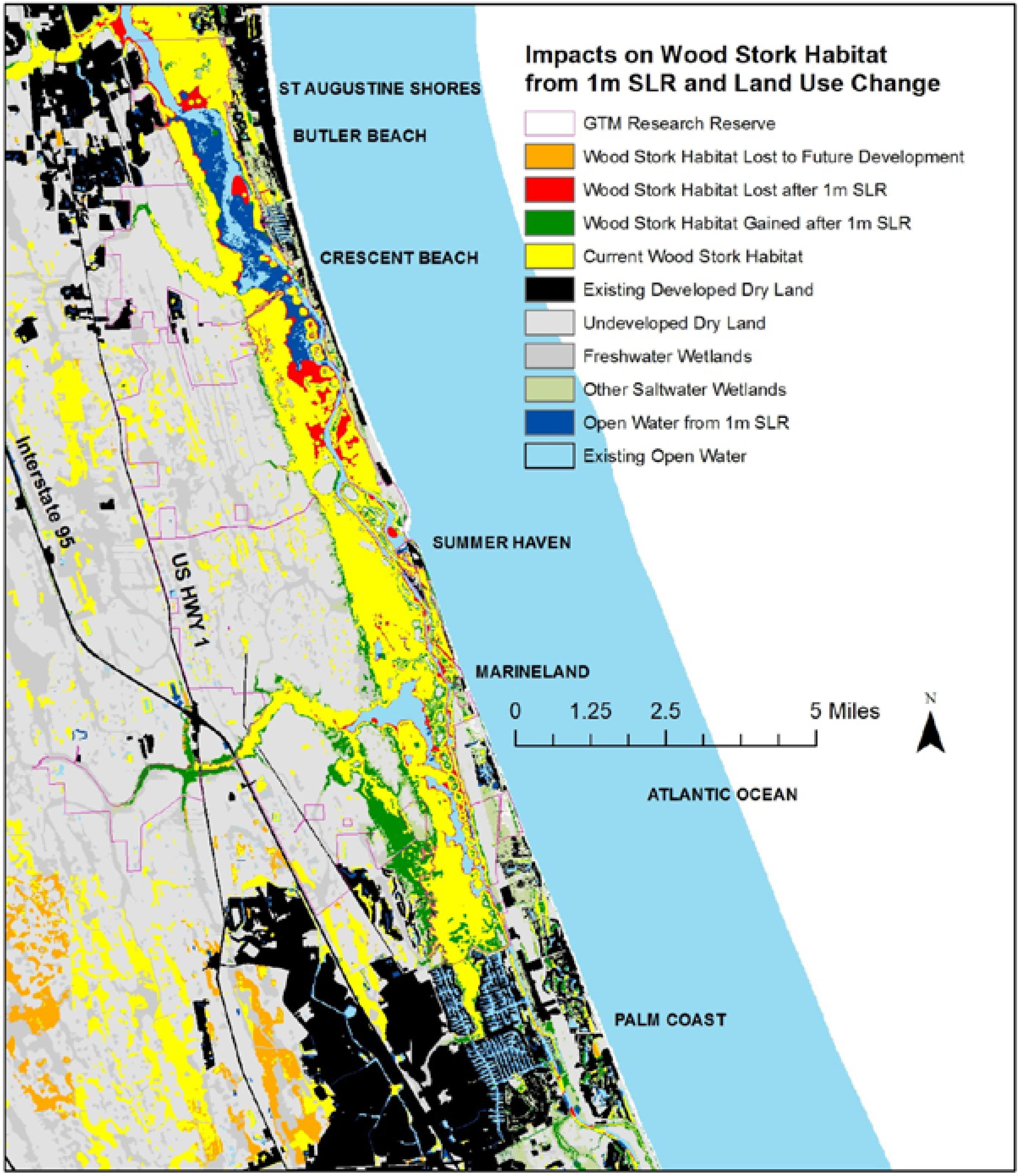


Figure 52. Wood stork impacts from 1 meter sea level rise and future development

Natural Communities

Analyses of the impacts impacts from development on upland natural community and natural/semi-natural land cover types indicate that nearly all upland land cover types will be impacted by future development. Table 22-Table 23 provides a summary of these analyses. A more detailed version of these tables is included in Appendix D along with maps illustrating projected impacts on each upland land cover type.

Impacts on wetlands from future development are summarized in the analysis of estuarine priorities described later.

Wood Stork Photo by S. Hunter Spenceley. Source: http://huntersphotography.zenfolio.com/img/s4/v64/p1354866730-5.jpg

Natural Community Type	Percent loss/ gain to 1m SLR	Percent loss/ gain to 2.5m SLR	Percent Loss to future development
Upland land cover impacts			
Rangeland	-5.5%	-20.1%	31%
Scrub	-4.8%	-32.0%	28%
Pine flatwoods	-2.6%	-9.0%	20%
Sandhill	-1.1%	-4.5%	36%
Upland hardwood forest	-16.6%	-79.6%	6%
Cabbage palm hammock	-16.6%	-98.8%	0%
Mixed conifer-hardwood upland forest	-8.1%	-34.7%	21%
Pine plantation	-0.3%	-1.2%	20%

Table 22. Natural community and land cover impacts from sea level rise and land use change combined: uplands

Natural Community Type	Percent loss/gain to 1m SLR	Percent loss/gain to 2.5m SLR
Wetland land cover impacts based on SLAMM results		
Swamp	-2.5%	-7.9%
Cypress swamp	-2.3%	-11.2%
Inland Freshwater Marsh	-2.2%	-6.9%
Transitional Saltmarsh	81.4%	15.6%
Regularly Flooded Marsh	-31.0%	13.6%
Mangrove	38.0%	-99.7%
Estuarine Beach	100.0%	100.0%
Tidal flat	49.0%	139.1%
Ocean Beach	32.0%	136.6%
Irregularly Flooded Marsh	34.0%	-99.4%
Vegetated tidal flat	-14.7%	-100.0%
Open water	56.9%	166.2%

Table 23. Natural community and land cover impacts from sea level rise and land use change combined: wetlands

Water Resources

Impacts from future development were assessed for water resource priorities including CLIP Surface Water Protection priorities, CLIP Groundwater Recharge priorities, draft CLIP Surface Water Restoration priorities, and the riparian network supporting water quality and quantity for the Matanzas River watershed. Maps of the water resource priorities are presented in the Adaptation Strategies section. These are included in Table 24, with more detailed statistics and explanation in Appendix D. Future development, if continued at current trends, will greatly impact upland areas important for water resources, in most cases even more significantly than sea level rise. These analyses do not take into account saltwater intrusion, stormwater runoff, and other secondary impacts from sea level rise and land use change that will impact water resources.

Photo by Ed Siarkowicz Photographic Images, LLC

	Acres impacted by trend 1m SLR development scenario	Percentage impacted by development
CLIP Groundwater recharge priorities		
CLIP Priorities 1 (highest) - 5	36,397.44	20%
Riparian network priorities		
Including functional upland buffers, wetlands, and open water in the riparian network	13,597.00	22%
CLIP Surface water protection priorities		
CLIP Priorities 1 (highest) - 5	22,422.31	14%
Draft CLIP Surface water restoration priorities		
Priorities 5-9 (highest priority)	19,481.76	20%

Table 24. Impacts from sea level rise and future development on water resource priorities

Biodiversity Hotspots

Impacts to biodiversity priorities from future development were assessed using the CLIP 3.0 Biodiversity Resource Category priorities data. The total acreages of biodiversity priorities impacted by future development under 1 and 2.5 meters (3 and 8 feet) sea level rise are fairly similar, probably reflecting the fact that inland development is responsible for the majority of the impacts. In both scenarios, Priority 3 and 4 lands are most impacted by development. Impacts occur primarily in the upland areas west of Interstate 75, and in the upland areas around Palm Coast and St Augustine. Table 25 and Figure 53-Figure 54 illustrate these results.

Photo by Ed Siarkowicz Photographic Images, LLC

CLIP Biodiversity Value	Existing Acres	Acres Impacted by Sea Level Rise	Percent Impacted	Acres Impacted by Future Develop-ment	Percent Impacted	Total Acres Impacted	Total Percent Impacted
Impacts to Biodiversity Priorities from 1m Sea Level Rise							
Priority 5	2,604	87	3%	343	13%	430	17%
Priority 4	16,895	417	2%	3,466	21%	3,883	23%
Priority 3	35,992	2,102	6%	7,393	21%	9,495	26%
Priority 2	34,324	470	1%	4,228	12%	4,698	14%
Priority 1-Highest	3,966	300	8%	420	11%	720	18%
Total impacts	**93,781**	**3,375**	**4%**	**15,850**	**17%**	**19,225**	**21%**
Impacts to Biodiversity Priorities from 2.5m Sea Level Rise							
Priority 5	2,604	264	10%	318	12%	582	22%
Priority 4	16,895	1,477	9%	3,365	20%	4,842	29%
Priority 3	35,992	5,364	15%	7,352	20%	12,716	35%
Priority 2	34,324	2,259	7%	4,194	12%	6,453	19%
Priority 1-Highest	3,966	1,324	33%	385	10%	1,709	43%
Total impacts	**93,781**	**10,687**	**11%**	**15,614**	**17%**	**26,301**	**28%**

Table 25. Impacts to CLIP biodiversity priorities from sea level rise and future development

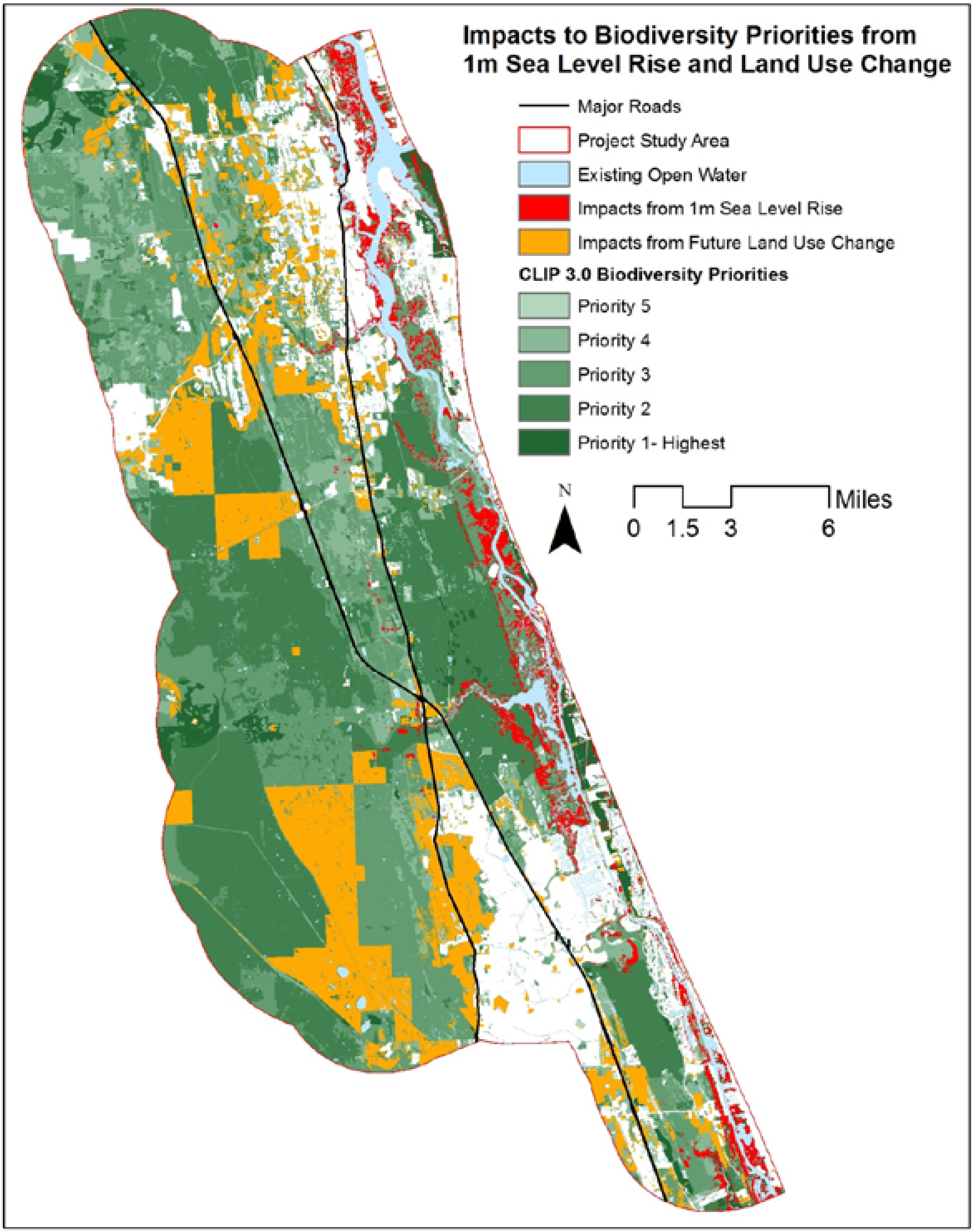


Figure 53. Impacts from 1 meter sea level rise and future development on biodiversity priorities

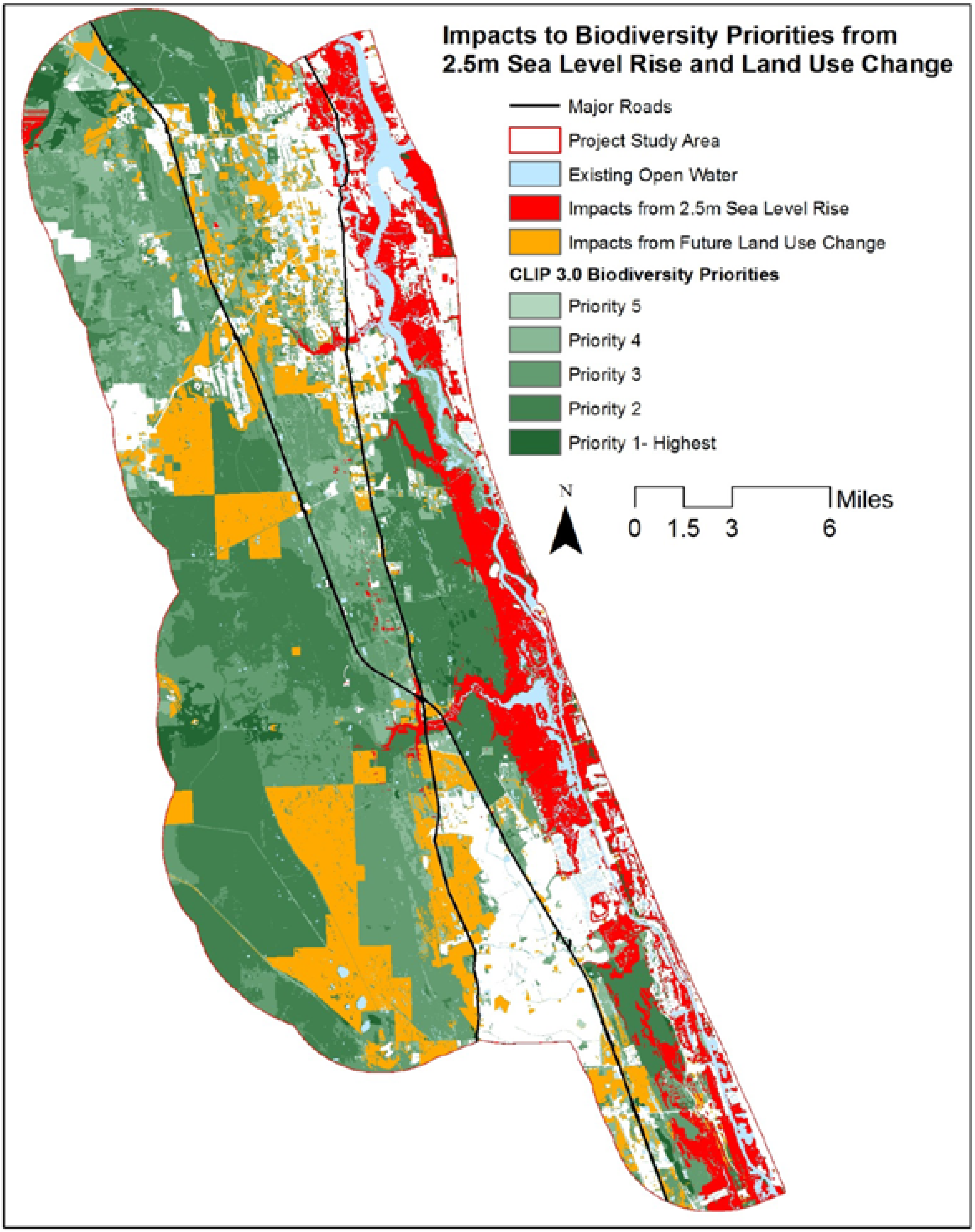


Figure 54. Impacts from 2.5 meter sea level rise and future development on biodiversity priorities

Estuarine Habitat

An assessments of impacts from development was completed for the estuarine habitat categories described earlier within the study area. Table 26 includes the acreages for the four categories of estuarine habitat projected to exist within the study area as sea levels rise, with the addition of impacts from future development. Note that "N/A" is listed in the row identifying development impacts on existing habitat impacted by sea level rise, since it is assumed that areas impacted by sea level rise are not also impacted by development.

Kayaking the Matanzas estuary with Ripple Effect Ecotours

Habitat Type	Total Acres Within Project Study Area	Acres Impacted by Future Development	Acres Within Existing Managed Lands
Estuarine Habitat after 1m Sea Level Rise			
Existing Estuarine Habitat Lost to SLR	3,751	N/A	1,661
Existing Estuarine Habitat that Remains	10,460	11	6,338
Future Estuarine Habitat Not Contiguous with Existing	898	27	190
Future Estuarine Habitat Contiguous with Existing	2,319	11	1,084
Estuarine Habitat after 2.5m Sea Level Rise			
Existing Estuarine Habitat Lost to SLR	13,726	N/A	7,818
Existing Estuarine Habitat that Remains	935	19	370
Future Estuarine Habitat Not Contiguous with Existing	4,227	461	812
Future Estuarine Habitat Contiguous with Existing	9,495	311	5,210

Table 26. Estuarine habitat resulting from sea level rise and development

Photo by Ed Siarkowicz Photographic Images, LLC

Adaptation Strategies

Future Conservation Priorities in Response to Sea Level Rise

Conservation analyses identified future conservation priorities, in some cases taking sea level rise into account, at the focal species, natural community, and landscape scales, as well as for water resources. Several analyses of landscape scale priorities were completed. These included conservation priorities proximal and contiguous to the GTM Research Reserve, regional landscape priorities at the St. Johns and Flagler counties scale, and an analysis of coastal to inland corridor priorities from the Reserve to points inland. More detailed and complete results from these analyses are included in Appendix D. A summary is provided below, including a broad discussion of findings resulting from the overall set of analyses.

Focal Species

Based on the results of the species impact analysis, we identified a subset of focal species that had more projected habitat loss from sea level rise (a loss of 10% or more of the current protected habitat base) as well as species included in GTM Research Reserve management plans. We then identified priority habitat for each of those species within 1 mile of the Reserve, where all higher priority classes of habitat from each species model was identified as potential priority. This was done for both the 1 and 2.5 meter (3 and 8 feet) sea level rise habitat models for each species. For most of the focal species the habitat models were rerun for each scenario so that habitat lost to fragmentation or habitat gained from natural community change due to sea level rise are reflected in the priority habitats identified for each of the two scenarios. The species selected for identifying priority habitat within 1 mile of the Reserve included:

1. Gopher frog
2. Striped newt
3. Gopher tortoise
4. Sea turtles
5. Pine snake
6. Diamondback rattlesnake
7. Shorebird sand-foraging guild
8. Swallow-tailed kite
9. Wading bird guild
10. Black rail
11. Limpkin
12. Painted bunting
13. Anastasia beach mouse
14. Florida Mink
15. Black bear

The species specific habitat priorities are intended to identify unprotected habitat near the Reserve that could be conserved to mitigate for habitat lost to sea level rise within (or near) the Reserve. We present one example of these maps (Figure 55) for wading birds, which indicates that though habitat will be lost as sea level rise progresses beyond 1 meter sea level rise, there is potential priority habitat in all directions surrounding the Reserve that could be added to the protected habitat base. The rest of the maps and discussion of species-specific habitat conservation priorities are in Appendix D. There are several major trends across these results for all fifteen species or guilds. Estuarine wetland dependent species will lose extensive existing habitat but will also see potential gain of new habitat as sea level rise continues from up to 2.5 meters. For those species with cumulative habitat loss within the Reserve, other blocks of future marsh that may be available to mitigate losses include areas southeast of the Reserve. Upland species will see progressive habitat loss within the Reserve as sea level rise continues, but there are available areas of potential priority habitat west of the Reserve including around Pellicer Creek. In addition, some upland species have potential priority habitat available outside the Reserve on the barrier islands at 1 meter sea level rise, but virtually all of that habitat is unlikely to be available at the 2.5 meters scenario. Highways US1 and I-95 limit the potential for functional connectivity between some of the potential habitat additions and the Reserve. Beach-related species have similar

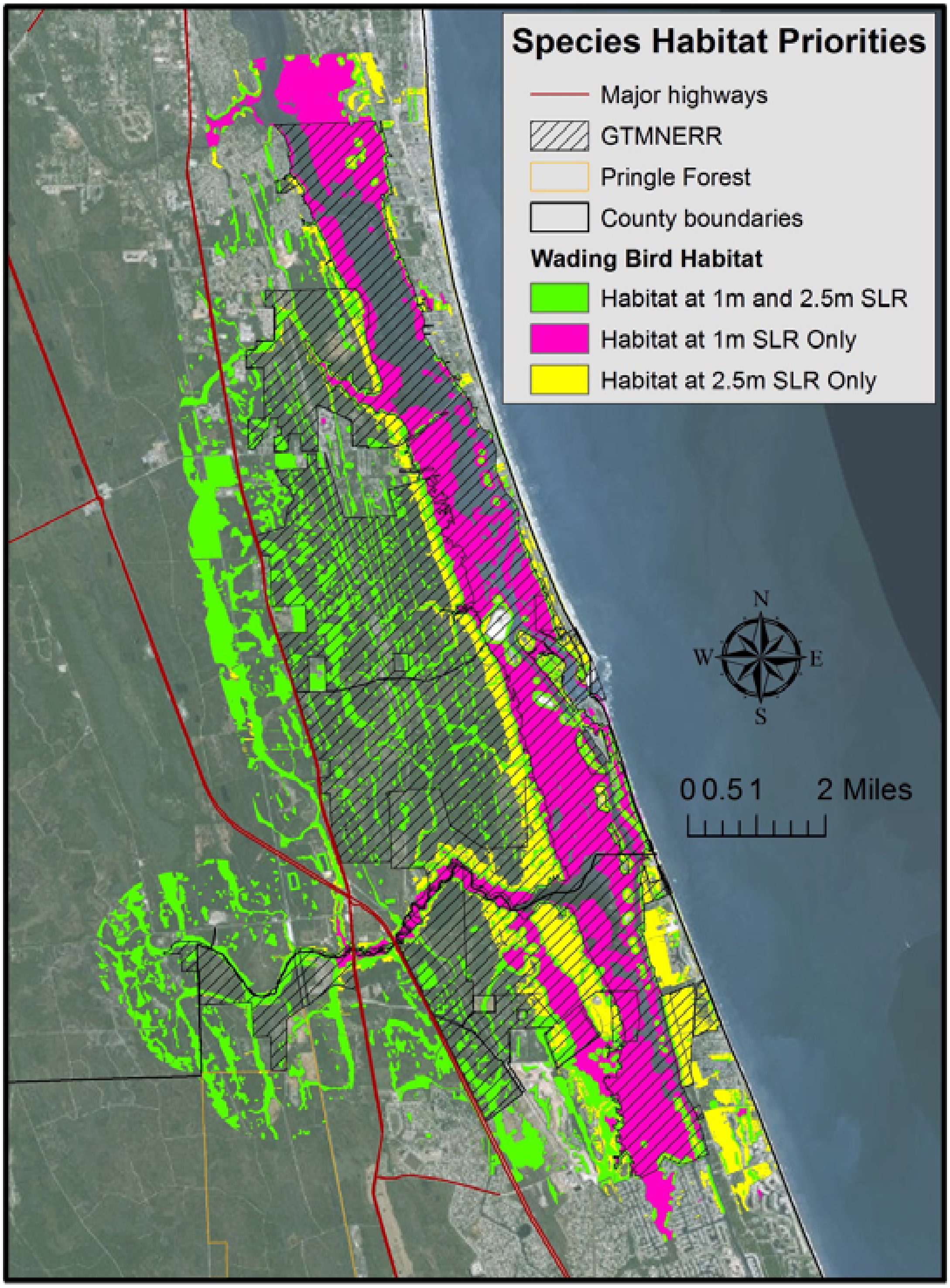


Figure 55. Wading bird guild potential habitat priorities at 1 and 2.5 meters sea level rise within 1 mile of the GTM Research Reserve

issues where available additional habitat priorities become much scarcer if sea level rise reaches 2.5 meters. Beach dynamics are complicated to model, and our SLAMM-based habitat models may under-represent future beach and beach dune habitats.

Natural Communities

Current priority natural communities and areas of natural or semi-natural land cover were identified based on existing land cover data (CLC and FLUCCS). Impacts to these communities and land cover types are described in other sections.

Water Resources

Figure 56-Figure 59 represent water resource priorities for the Matanzas study area based on CLIP Surface Water Protection priorities, CLIP Groundwater Recharge priorities, draft CLIP Surface Water Restoration priorities, and the riparian network supporting water quality and quantity for the Matanzas River watershed. Collectively these four maps identify water resource conservation and restoration priorities near the GTM Research Reserve that could be targets for land acquisition, wetland mitigation, dispersed water storage, minimization of future development impacts, best management practices, and stormwater management improvements in current developed areas.

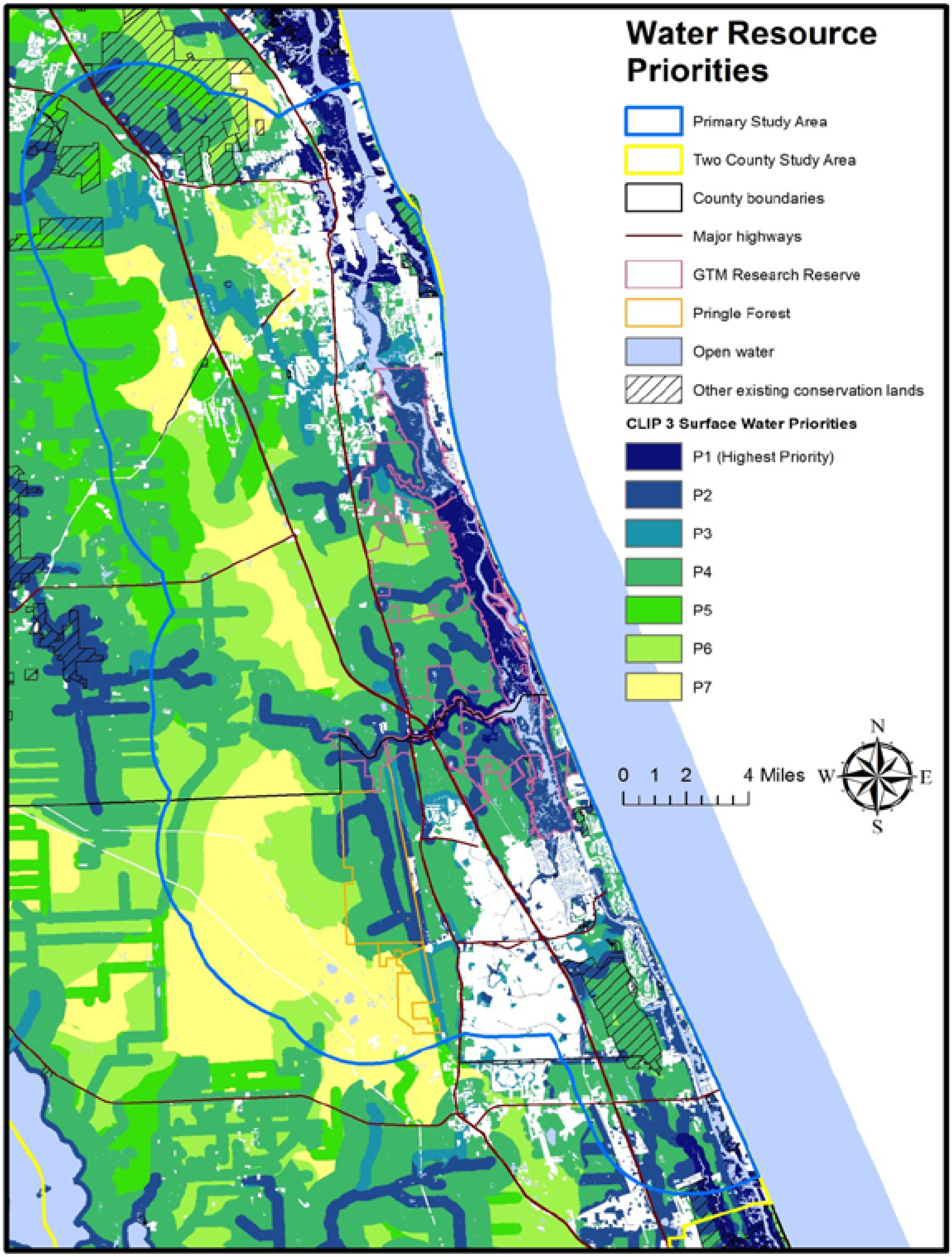


Figure 56. CLIP Surface water protection priorities, where the darkest blues represent the highest priorities

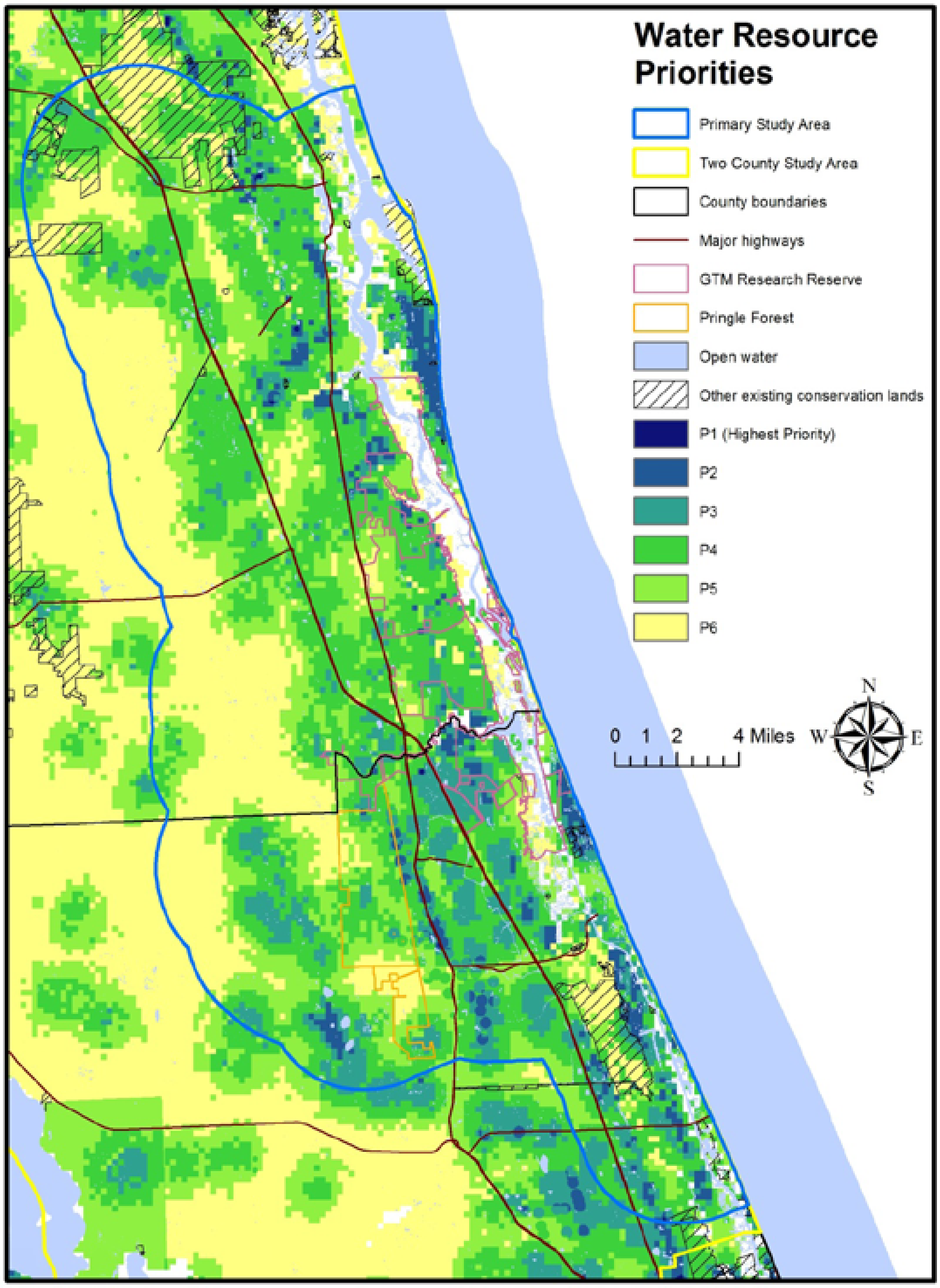


Figure 57. CLIP Groundwater recharge priorities, where the dark blues and blues represent the highest priorities and the greens represent moderate priorities

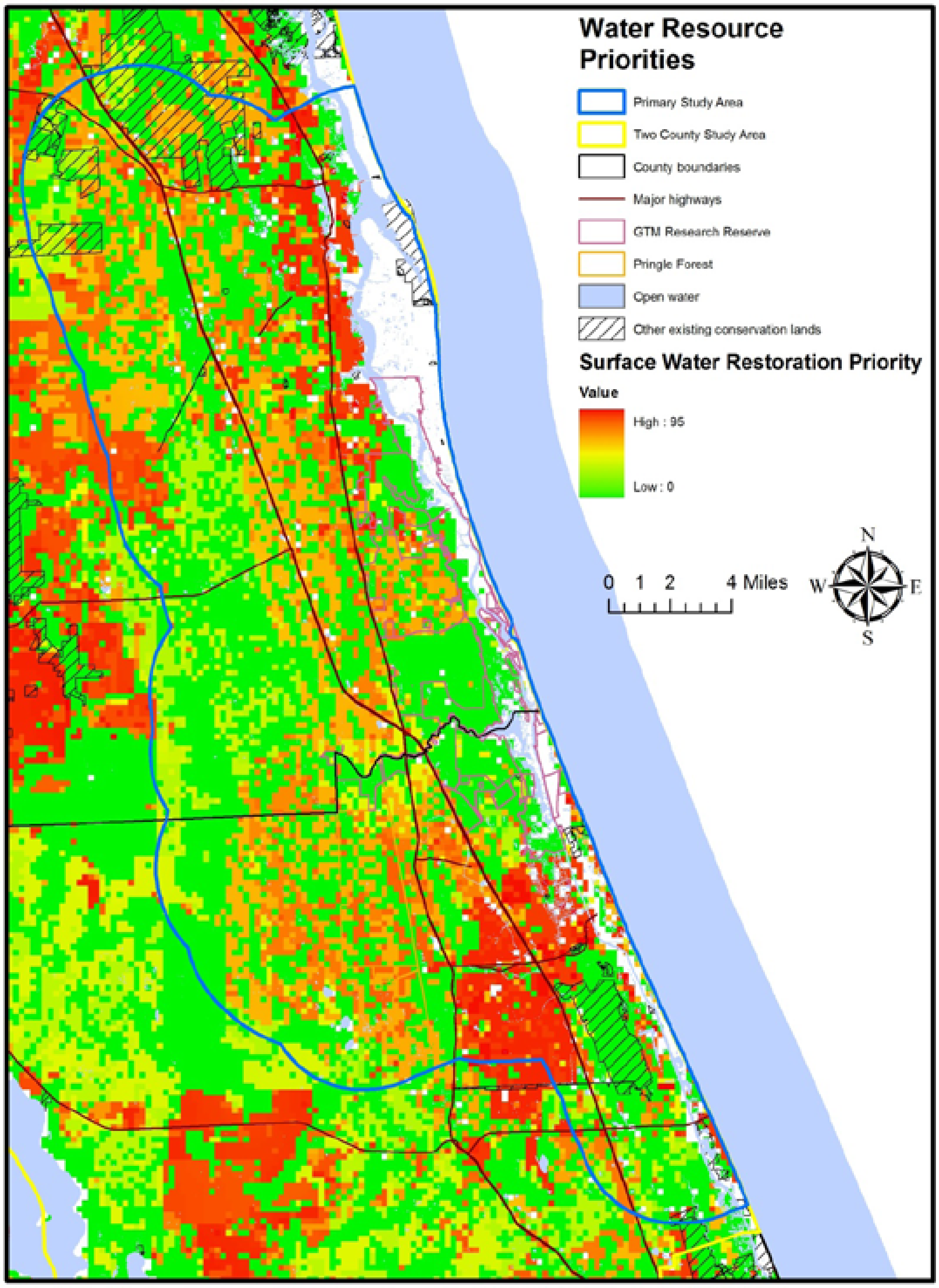


Figure 58. Surface water restoration priorities, where the reds and oranges represent areas where various types of restoration, retrofitting, best management, or other water management activities could significantly improve impaired water bodies

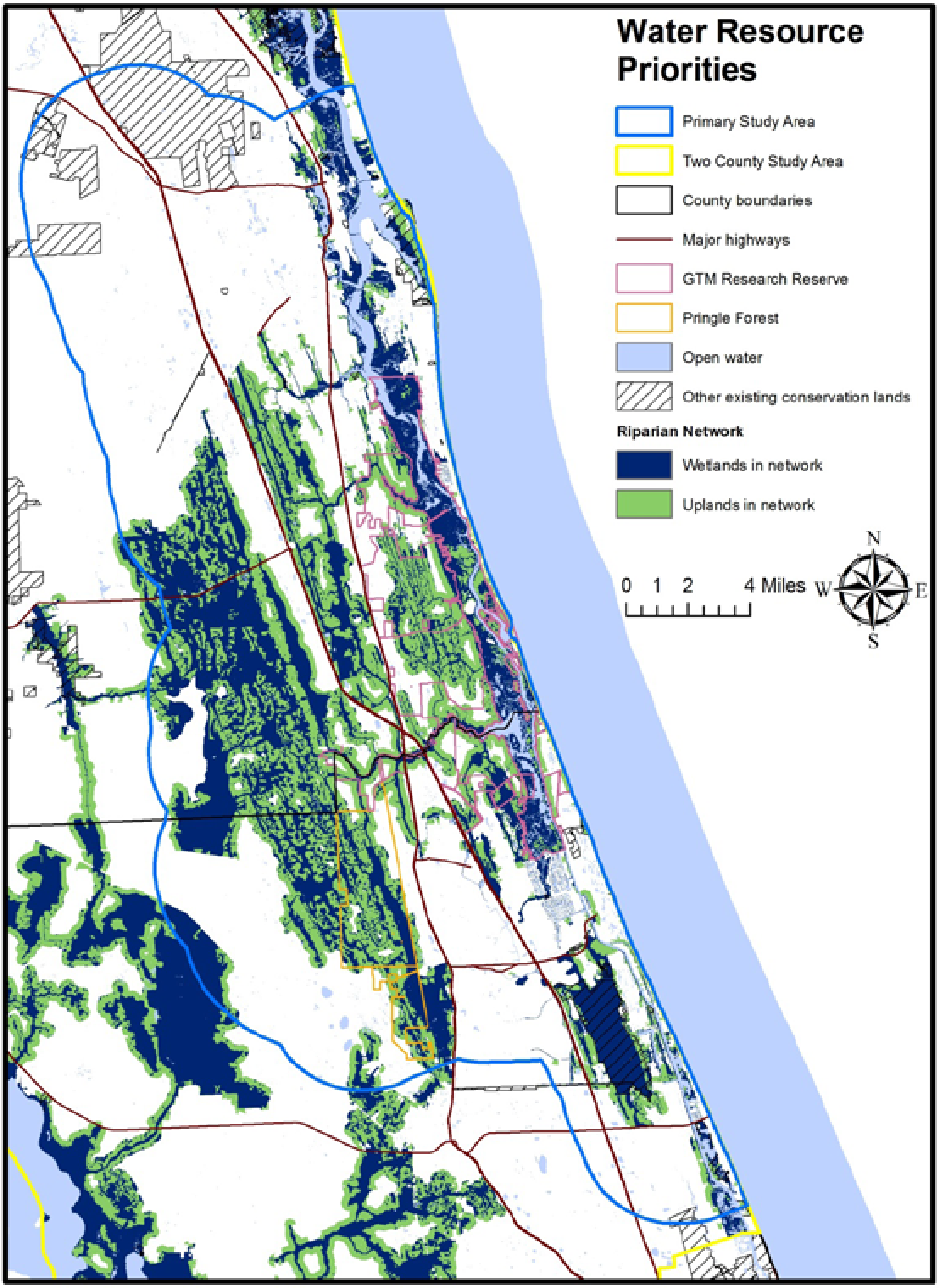


Figure 59. Riparian networks: all areas in dark blue or green are most important for protecting the integrity of the freshwater inflows to primarily the Matanzas River estuary (except for the portions of the network furthest to the west that flow into the St. Johns River). Maintaining or improving water flows with natural levels of nutrient (nitrogen and phosophorous) is critical for maintaining or improving the resistance and resilience of salt marshes to sea level rise

Tributary of Pellicer Creek

Biodiversity Hotspots

As noted earlier, biodiversity priorities for the study area were identified using CLIP Biodiversity Resource Category data. Figure 60 shows current biodiversity priorities identified by the CLIP 3.0 dataset. This data was used to conduct assessments of potential impacts from sea level rise and future development.

Based on these analyses, future priorities for protecting biodiversity could be focused in several ways. One important recommendation is to manage existing lands important for biodiversity to maintain resiliency in the face of climate change. In terms of future conservation priorities, priority could also be place on upland areas adjacent to the GTM Research Reserve, which have less risk of being impacted by sea level rise, but are potentially at risk from future development. Other strategies include minimizing the impacts of any future development on the highest priority areas for biodiversity. There exist good data for identifying these areas, but they are often ignored in the land use planning process at the local and regional scales.

Biodiversity hotspot

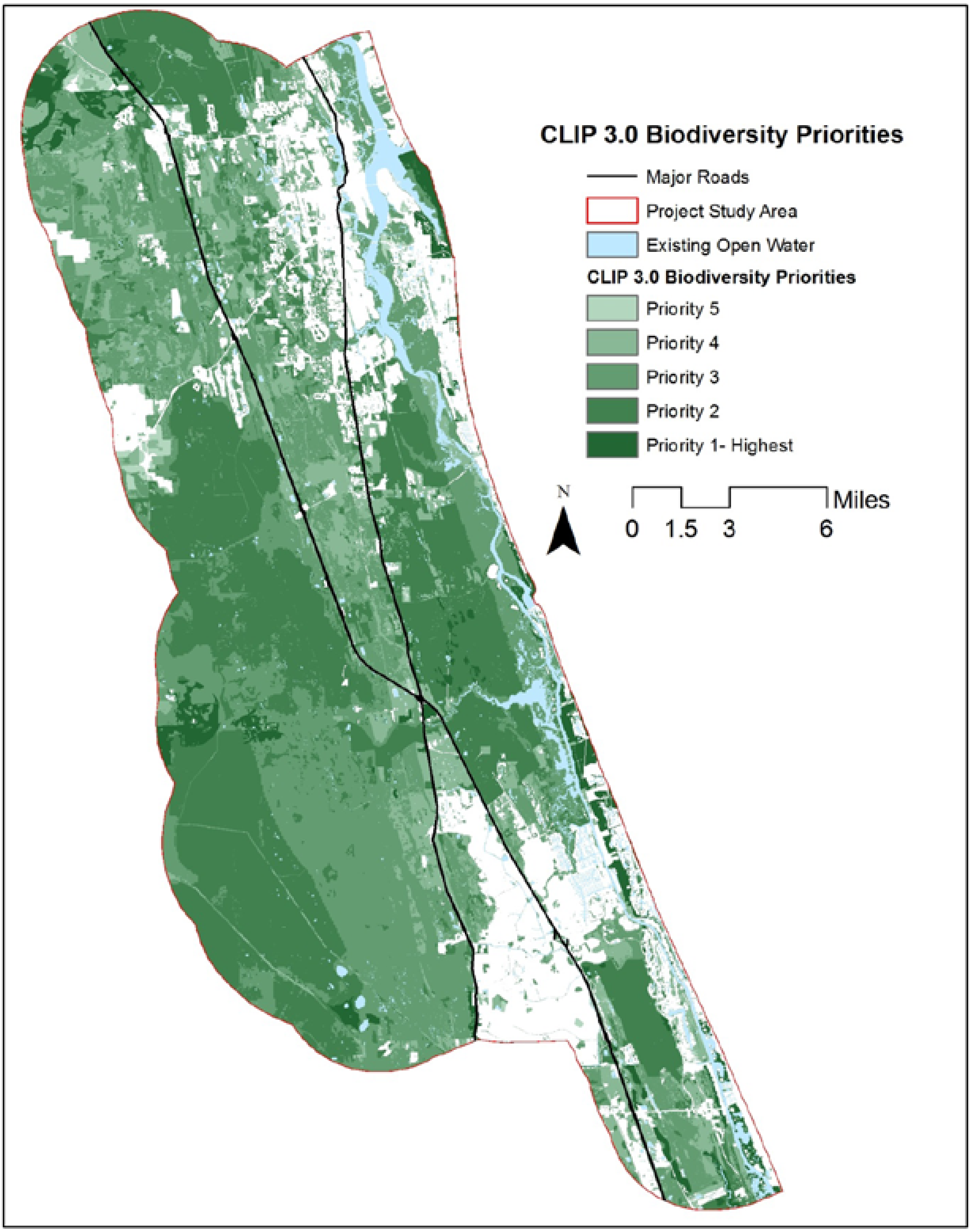


Figure 60. Current CLIP biodiversity priorities

Estuarine Habitat

As described earlier, additional analyses were completed to specifically identify estuarine habitat priorities and impacts. To this end, current and future land use scenarios were overlaid to locate 1) existing estuarine habitat lost to sea level rise, 2) existing estuarine habitat that remains after sea level rise, 3) existing uplands that convert to estuarine habitat as sea levels rise (i.e. future estuarine habitat), and 4) future estuarine habitat contiguous with areas of existing estuarine habitat projected to remain after sea level rise. Additional prioritization was then completed by identifying areas of future or existing estuarine habitat that remains after sea level rise that were 1) within the GTM Research Reserve, 2) outside of current Reserve boundaries, but contiguous with the Reserve, 3) within 1 mile from the Reserve, 4) within the Matanzas study area but not contiguous with the Reserve and further than 1 mile from existing Reserve lands.

Figure 61 shows the results of this analysis in lands proximal to the Reserve. Reserve lands protect a large amount of the important future or existing estuarine habitat in the region. However, there are several relatively large patches of estuarine habitat after 1 meter (3 feet) sea level rise, which are contiguous with existing Reserve lands and unprotected by current conservation areas. These include a large patch of existing habitat that borders the north edge of the Reserve, a smaller patch to the south of the Reserve surrounded by developed lands, and a large patch that is projected to be future estuarine habitat on the southwest edge of the Reserve. There is also at least one large area of future or existing estuarine habitat, just to the west of St. Augustine Shores, which will no longer be contiguous with the Reserve after sea levels rise and is beyond the 1 mile radius from the Reserve, but could be important for protecting riparian habitat. These areas are circled in red on Figure 61.

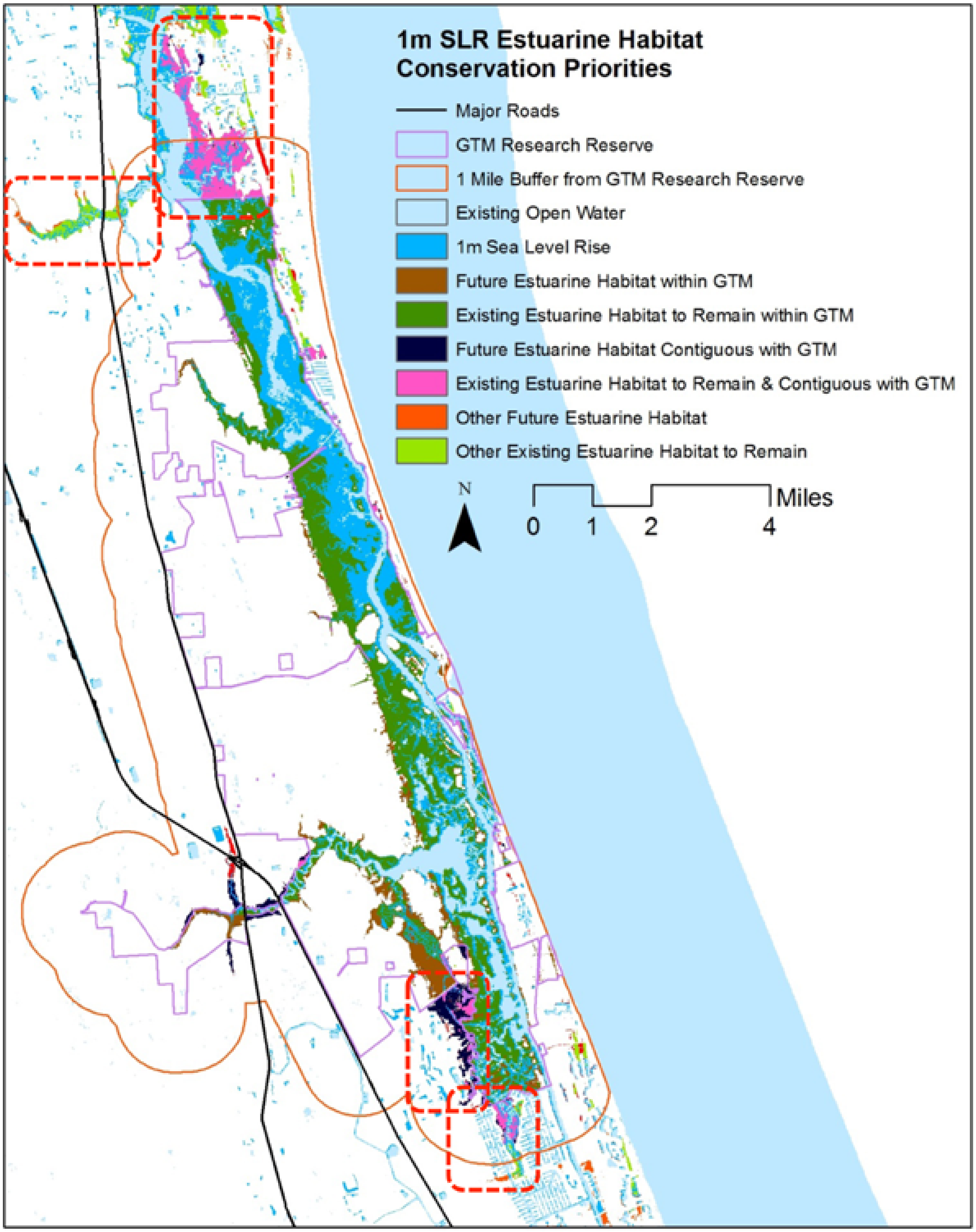


Figure 61. Estuarine habitat priorities proximal to the GTM Research Reserve. Areas circled in red are potential priorities

The results from this analysis can be used to make decisions about estuarine habitat conservation priorities in several ways. For example, management of existing habitat that will be lost to sea level rise is important for maintaining resilient populations of focal species within estuarine habitat, as well as maintaining estuarine based ecosystem services to the greatest extent possible. Conservation of existing estuarine habitat that is projected to remain in place as sea levels rise is potentially the safest bet for maintaining these natural communities, since land cover changes in response to inundation, saltwater intrusion, and other coastal changes are difficult to predict and SLAMM model results are by any account still an estimate of what may occur. Conservation of future estuarine habitat and especially future estuarine habitat adjacent to existing habitat may provide coastal to inland retreat options for estuarine species and natural communities. However it should be noted that our identification of future estuarine habitat that is contiguous with existing habitat does not take into account the length of the border where these two habitat categories meet. For example it may be possible to have a very large area of future estuarine habitat that is only tangentially connected to existing habitat in one small location. Therefore it may be important to assess the length of the border shared between existing habitat and areas projected to be future habitat, and potentially to give higher priority to future habitat that has the longest edge in common with existing.

Reserve Scale Conservation Priorities

Figure 62-Figure 63 show "reserve scale" landscape conservation priorities. These were developed based on the aggregation of all primary habitat for focal species directly connected to the GTM Research Reserve and within a 1 mile buffer. These may be useful for identifying near or long-term conservation priorities and opportunities for expanding the Reserve. The identification of areas directly connected to the Reserve disregarded potential fragmentation by roads. However road fragmentation is an important consideration, and lands separated from the Reserve by roads could potentially be considered a lower priority than those that are completely contiguous- particularly major roads such as Interstate 95 or US Highway 1. These results indicate that there are still ample opportunities to conserve focal species habitat around the Reserve to expand the current amount of protected habitat (and potentially increase focal species population size) or to mitigate the impact of sea level rise as current habitat is either lost to various focal species within the current Reserve boundary.

Photo by Ed Siarkowicz Photographic Images, LLC

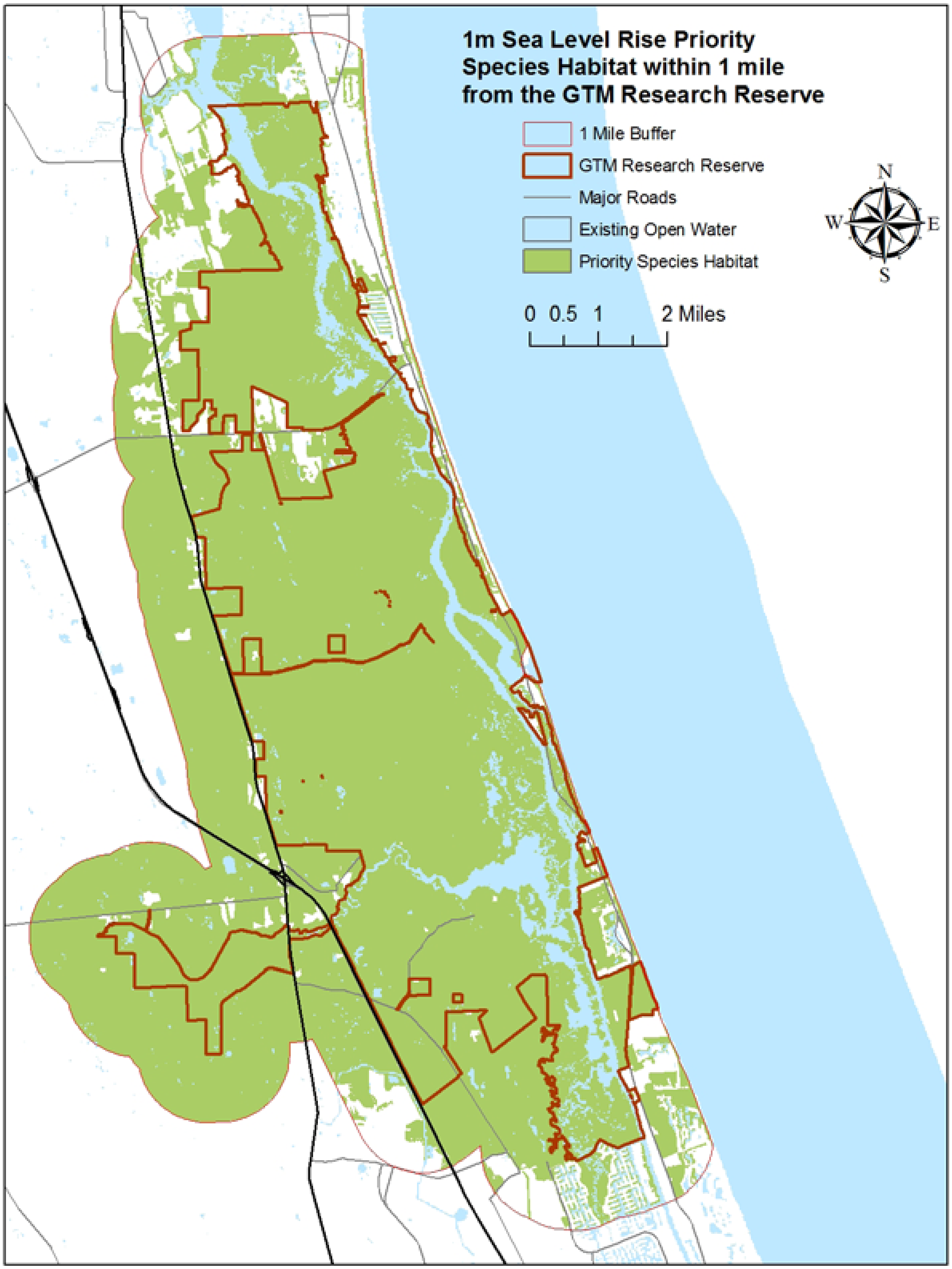


Figure 62. 1 meter sea level rise priority species habitat within 1 mile of the GTM Research Reserve

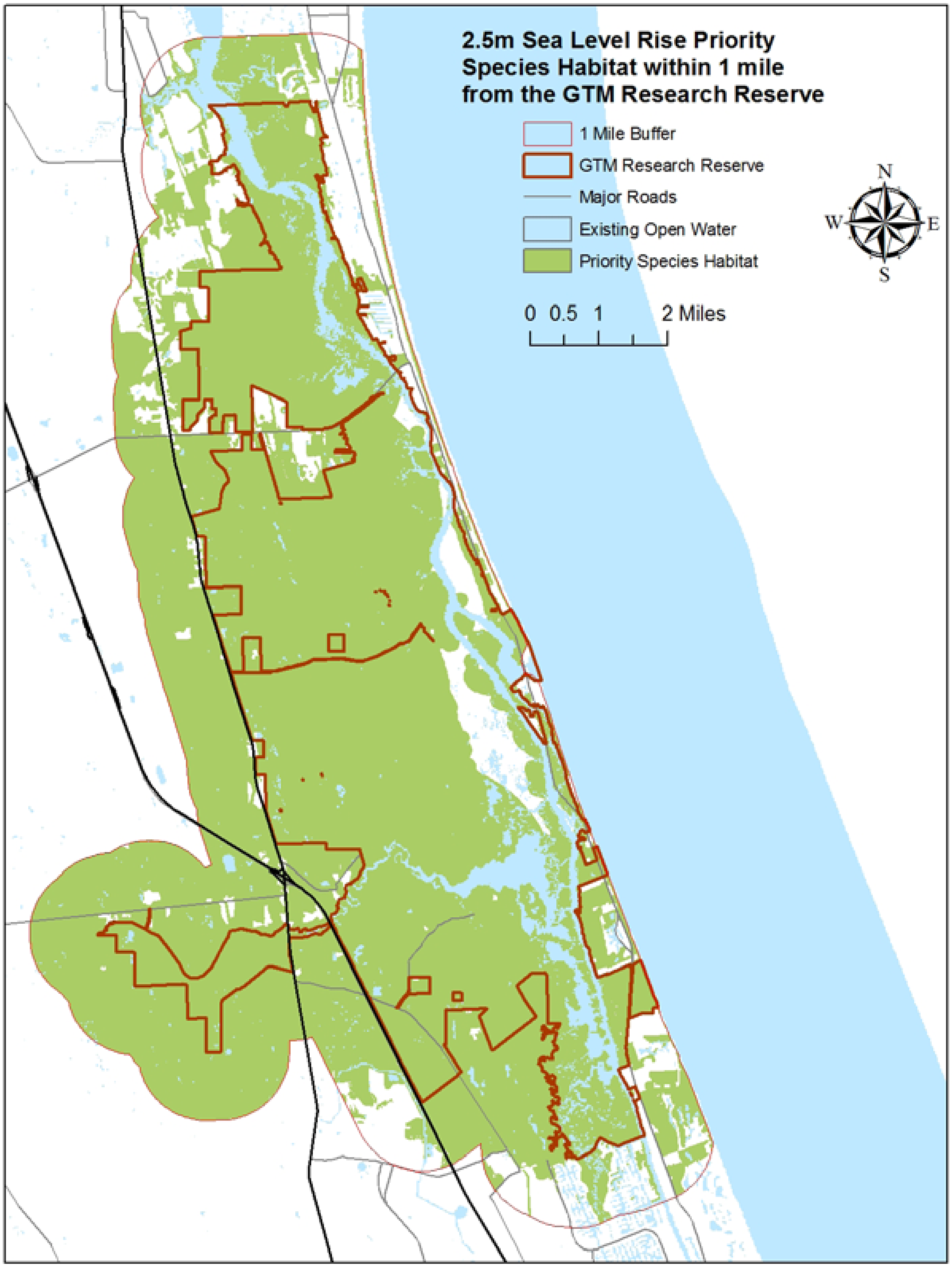


Figure 63. 2.5 meter sea level rise priority species habitat within 1 mile of the GTM Research Reserve

Regional Landscape Conservation Priorities

Regional scale conservation priorities were developed for the study area to identify a regional conservation priority context for the GTM Research Reserve as well as to serve as a data resource for helping to guide conservation planning within the study area. We have provided maps of each of the individual data layers used to create these priorities in Appendix D with the combination of all layers into the Regional Conservation Priority Aggregation provided in this section (Figure 65-Figure 66). The data aggregation is intended to provide regional context for the corridor, species habitat, and natural community priorities for the Reserve, and it incorporated data created through statewide analyses (such as CLIP and the FEGN) into broad priorities for the two county region. The Florida Ecological Greenways Network is shown in Figure 64. The aggregation makes clear that there are areas of broad, landscape-scale conservation priorities in the study area despite significant development pressure in the region. There is an opportunity to protect a functionally connected ecological network incorporating the GTM Research Reserve and other existing conservation lands from southeastern Duval County south to central Flagler County and west to the eastern edges of the St. Johns River, as well as across the river to the Ocala National Forest. Though these data should only serve as a general guide to conservation and land use planning in the two county region, it indicates significant potential for development impacts in rapidly growing areas including north St. Johns County. These priorities could be used as a general guide to emphasize green infrastructure based planning to maximize protection of biodiversity and ecosystem services while accommodating future development in the areas with the least impact on these critical natural resources. The following layers and priority levels were used to create the Regional Conservation Priorities:

- FEGN (all priority levels)
- Florida black bear priority habitat from FEGN analysis
- FEGN Coastal to Inland Connectivity areas
- FEGN Major River Buffers
- CLIP Landscape Integrity (Index levels 7-10)
- CLIP Aggregated Priorities (P1-P3)

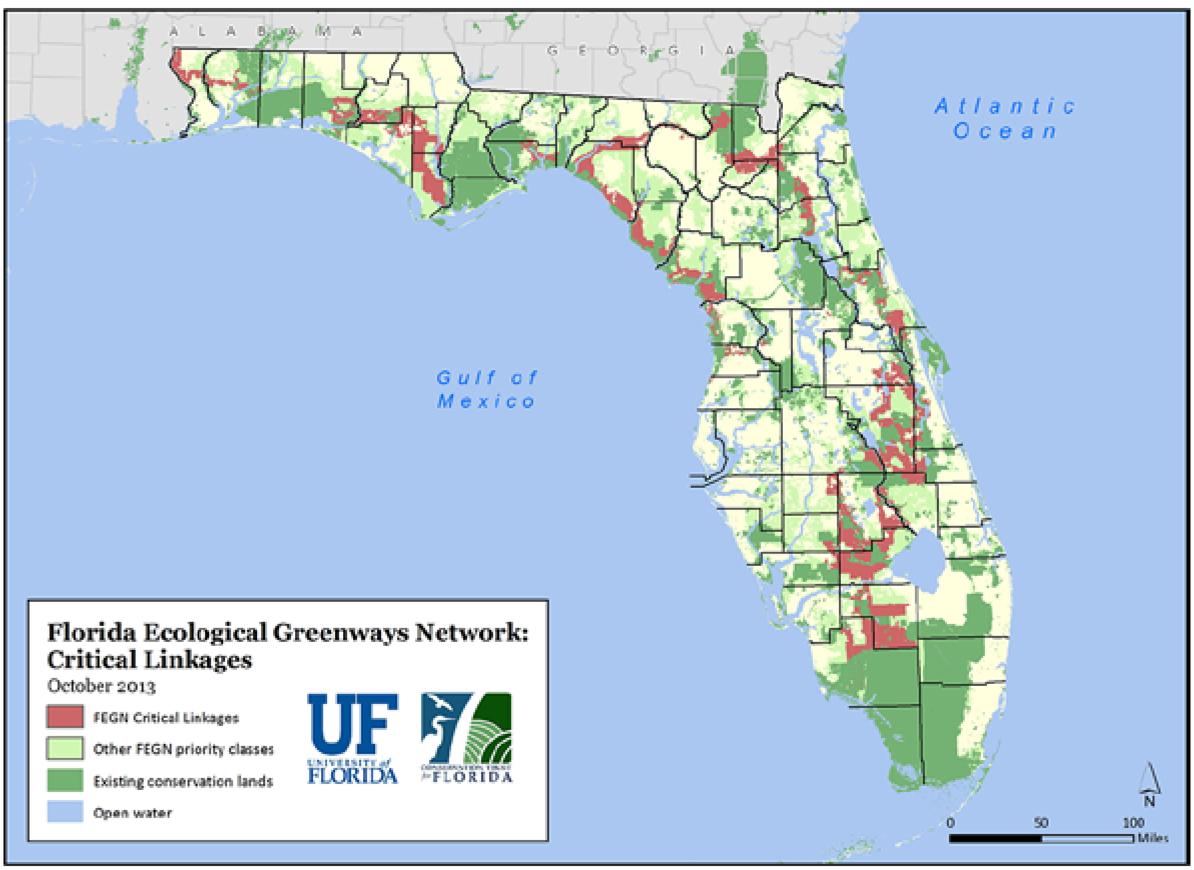


Figure 64. Florida Ecological Greenways Network. Source: http://conserveflorida.org/wp-content/uploads/2014/12/CTF_CriticalLinkages_Landscape-web.jpg

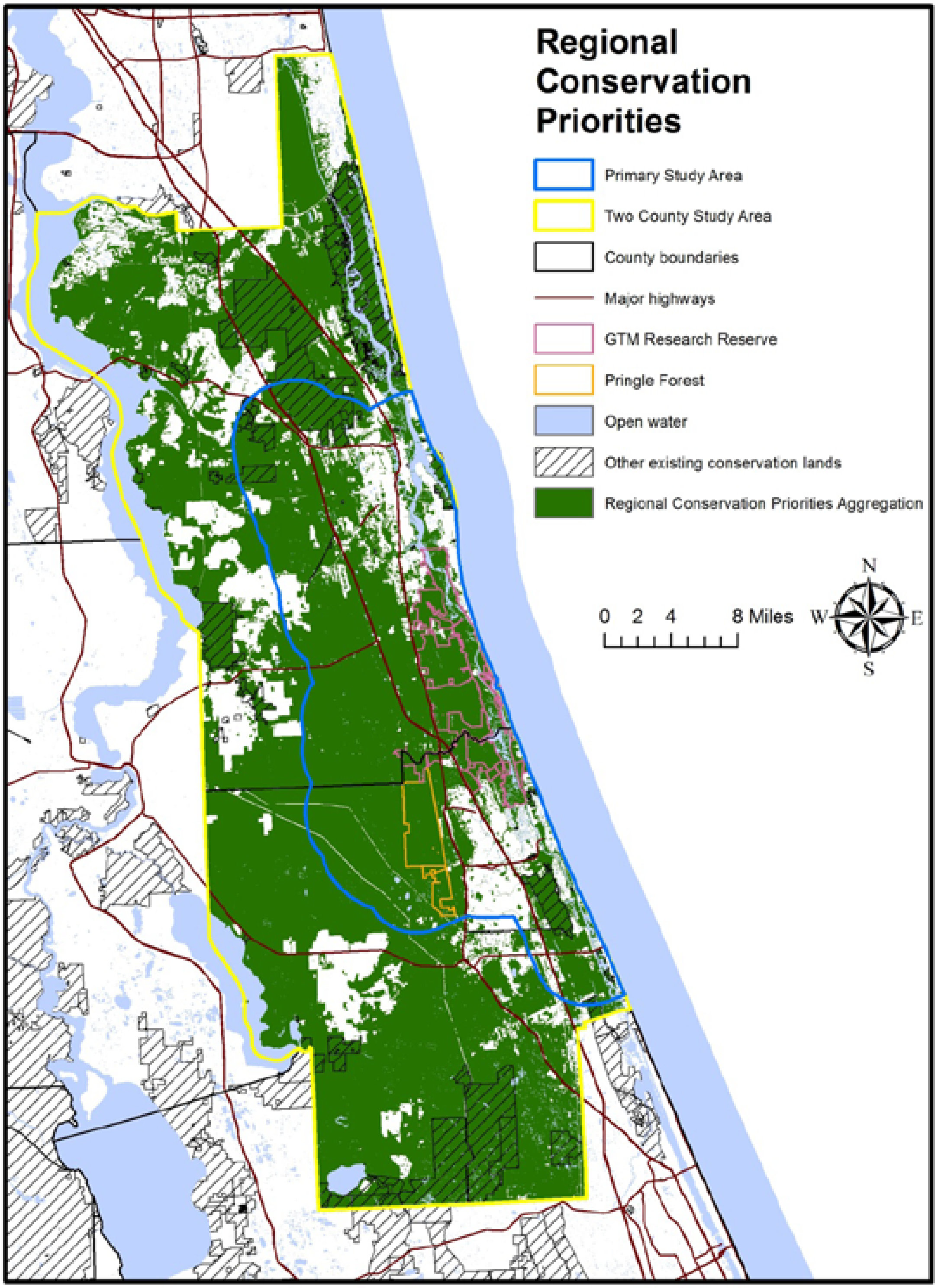


Figure 65. Regional conservation priorities within St. Johns and Flagler counties. The two county regional conservation priorities were based on various statewide data layers identifying biodiversity, wildlife corridor, and ecosystem service priorities. These results indicate that there is still an ample and very significant green infrastructure in the region. These data should be used as a general guide for avoiding and minimizing the impact of future development on this important natural resources within the region

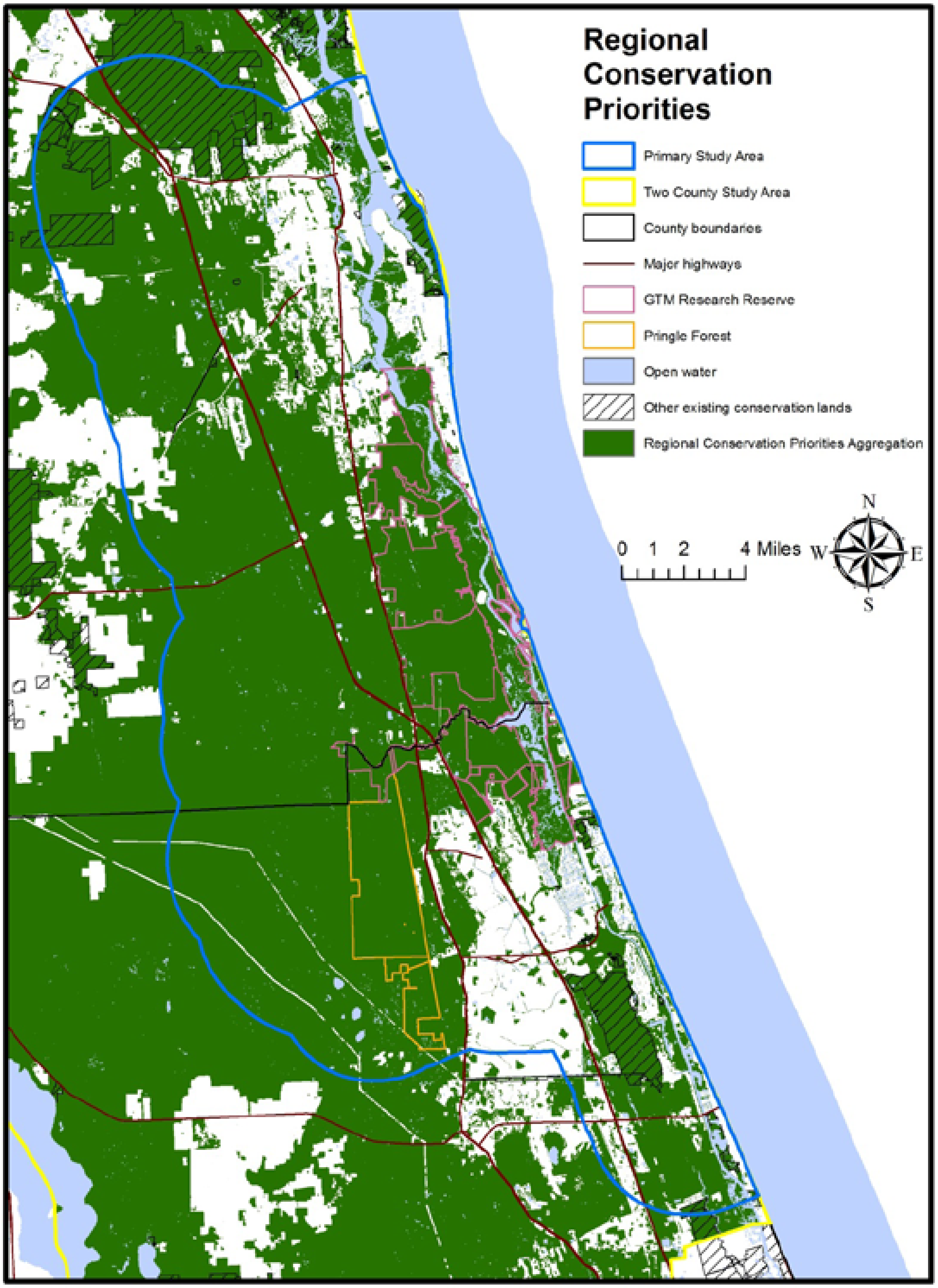


Figure 66. Regional conservation priorities, zoomed in within the Matanzas study area

Coastal to Inland Connectivity Analysis

The coastal to inland connectivity analysis augments state identified wildlife corridors (the Florida Ecological Greenways Network (FEGN)) to ensure that opportunities for inland retreat from the GTM Research Reserve are maintained, and regional ecological connectivity is achieved, to help facilitate the conservation of wildlife in an era of climate change and ongoing development. The Princess Place tract within the Reserve was used as a central location to serve as the source for all connectivity analyses. Three existing conservation land destinations were selected to produce north, west, and southern connectivity options and to represent a diverse and spatially expansive regional ecological network. These destinations were Twelve Mile Swamp to the north, the Ocala National Forest to the west, and the Relay Tract in Flagler County to the south. The results of these corridor analyses are similar to the corridors within the Florida Ecological Greenways Network; however, they more specifically address ecological connectivity between the GTM Research Reserve and other existing conservation lands in the region (Figure 66-Figure 67). These opportunities are all currently still feasible; however the fast pace of growth and the minimal consideration of the importance of corridor in the northern portion of St. Johns County and southeastern Duval County threaten to fragment the remaining corridor opportunities, which would isolate what is currently the northernmost portion of the Ocala-St. Johns Florida black bear population still found in the Twelve Mile Swamp Conservation Area and remaining undeveloped lands connected to it. The corridor to the Relay Tract in Flagler County is threatened by DRIs and other potential future development west of I-95. The corridor to the Ocala National Forest is most threatened by low density development in the southeast corner of Putnam County on the east side of the St. Johns River.

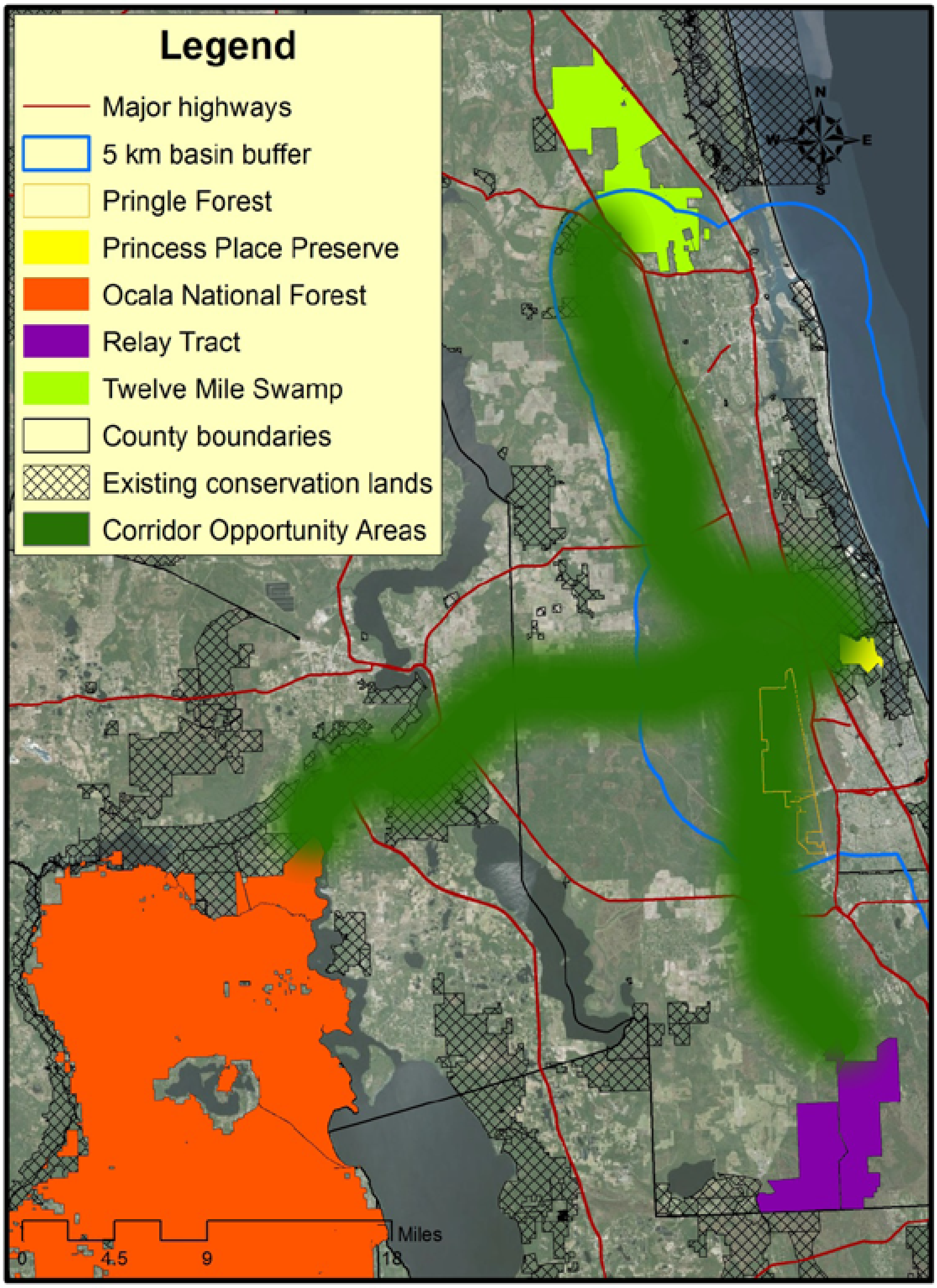
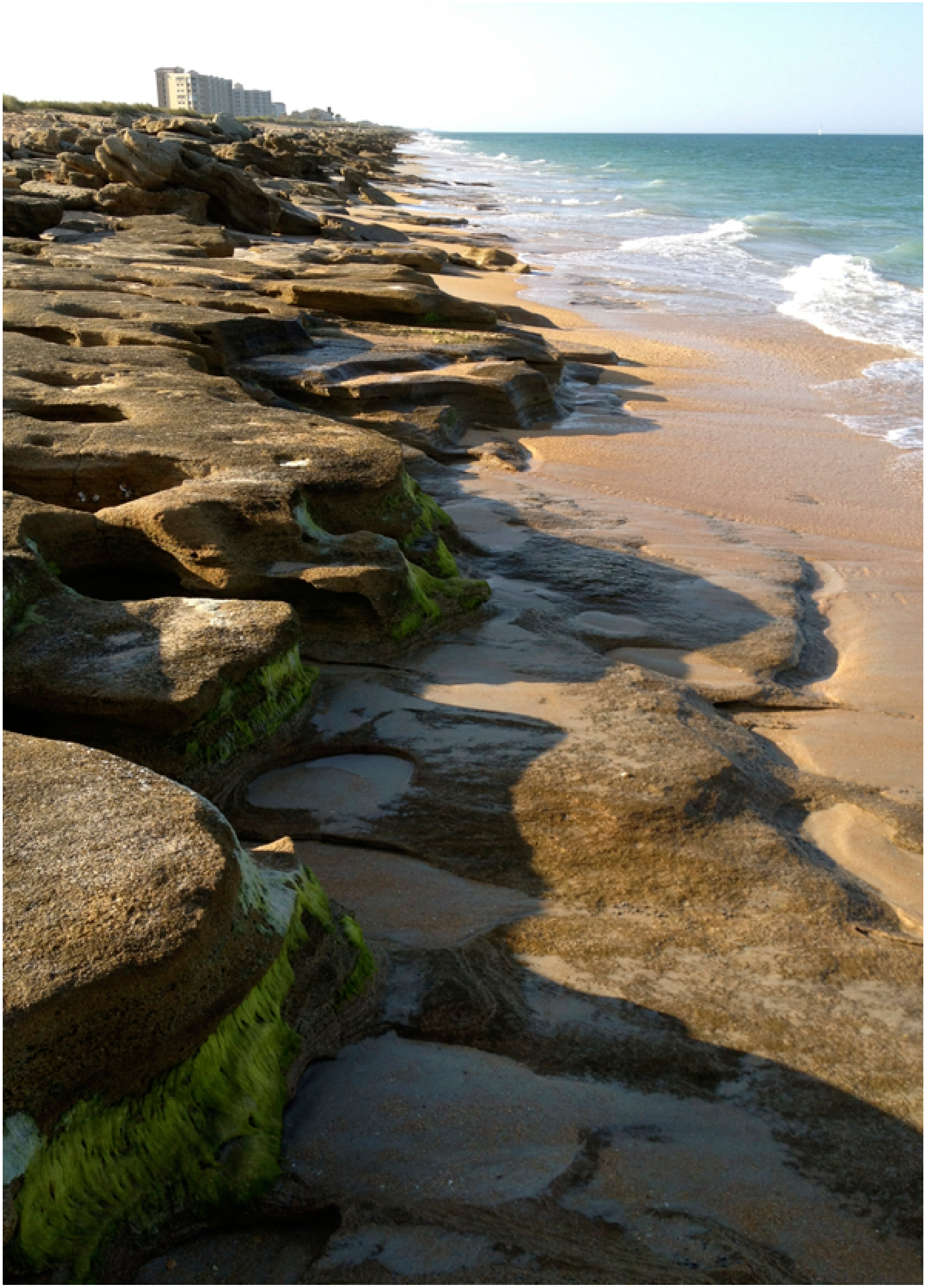


Figure 67. GTM Research Reserve coastal to inland connectivity analysis



Land Conservation Policies and Programs

Non-regulatory land conservation policies and programs at the state, federal, and local levels can be used to protect properties in the Matanzas area that have high conservation priorities for adaptation and resilience to sea level rise. As discussed in the previous section, the conservation priorities for adaptation and resilience address a variety of environmental values, including biodiversity, ecosystems, natural resources such as water, and landscape connectivity. Land conservation policies and programs are similarly varied with the environmental values they support. Conservation planners should thus seek a match between the characteristics of the properties they wish to protect, based on the conservation priorities above, with the goals of specific land conservation policies and programs. As covered in detail in Appendix F, the Matanzas area lands are particularly strong matches for policies and programs supporting climate change mitigation and adaptation, biodiversity, working lands, wetlands, and watersheds. Lands may also match programs based on the lands' role in protecting existing conservation lands, such as the GTM Research Reserve. Regulatory policies, primarily use of the local comprehensive plan, for sea level rise adaptation and conservation are discussed in later sections and Appendices H1-H4

Florida Forever is the state's program, administered by the Florida Department of Environmental Protection (DEP), to prioritize and fund land conservation for a wide range of priorities. Florida Forever will be an important funding resource going forward due to the passage in 2014 of Amendment 1 (the Water and Land Conservation Amendment). Florida Forever uses an application process whereby governmental and non-governmental organizations request that properties be placed on a prioritized list to receive funding for conservation. The program currently favors land matching the program's project categories, such as climate change, and efficient use of funds through conservation easements and cost-sharing partnerships with other agencies and organizations.

Current Florida Forever listed projects in the study area include the Northeast Florida Blueway in St. Johns County and the Flagler County Blueway, both of which follow the intracoastal waterway (shown in Figure 69). The latter may be ranked higher if moved into the Climate Change Lands Category (as is the former). The Pringle Creek Forest is a sizable tract of land listed as a Florida Forever project (Figure 69). This project is also eligible for a conservation grant from the federal agency NOAA, due to its location in the watershed of the GTM Research Reserve. There are currently efforts by local leaders and the Conservation Trust for Florida to apply for Florida Forever funding for a large wildlife corridor between the Ocala National Forest and the Matanzas area. Figure 68 shows the properties considered for this corridor.

In addition to Florida Forever, other agencies have land conservation programs of relevance. The substantial rural section of the Matanzas Basin has extensive wetlands and waterways, and “working lands” primarily in timber production, and both land uses are popular with conservation programs (Figure 69). The St. Johns River Water Management District (SJRWMD) is common partner in funding Florida Forever projects. The federal Natural Resources Conservation Service (NRCS) offers a Wetland Reserve Easement, which could be used for restoring wetlands on timber land for “dispersed water storage,” to enhance ecosystem services and watershed resilience. A wetlands mitigation bank is another option, through a permit by the SJRWMD, DEP, or the US Army Corps of Engineers. Incentives for land conservation and management in aquifer recharge areas have also been explored to support the water supply for the City of Palm Coast. Programs for conservation on forestry lands include the US Forest Service’s Forest Legacy Program, the Florida Forest Service’s Rural and Family Lands Protection Program, and the NCRS Agricultural Conservation Land Easement - Agricultural Land Easements.

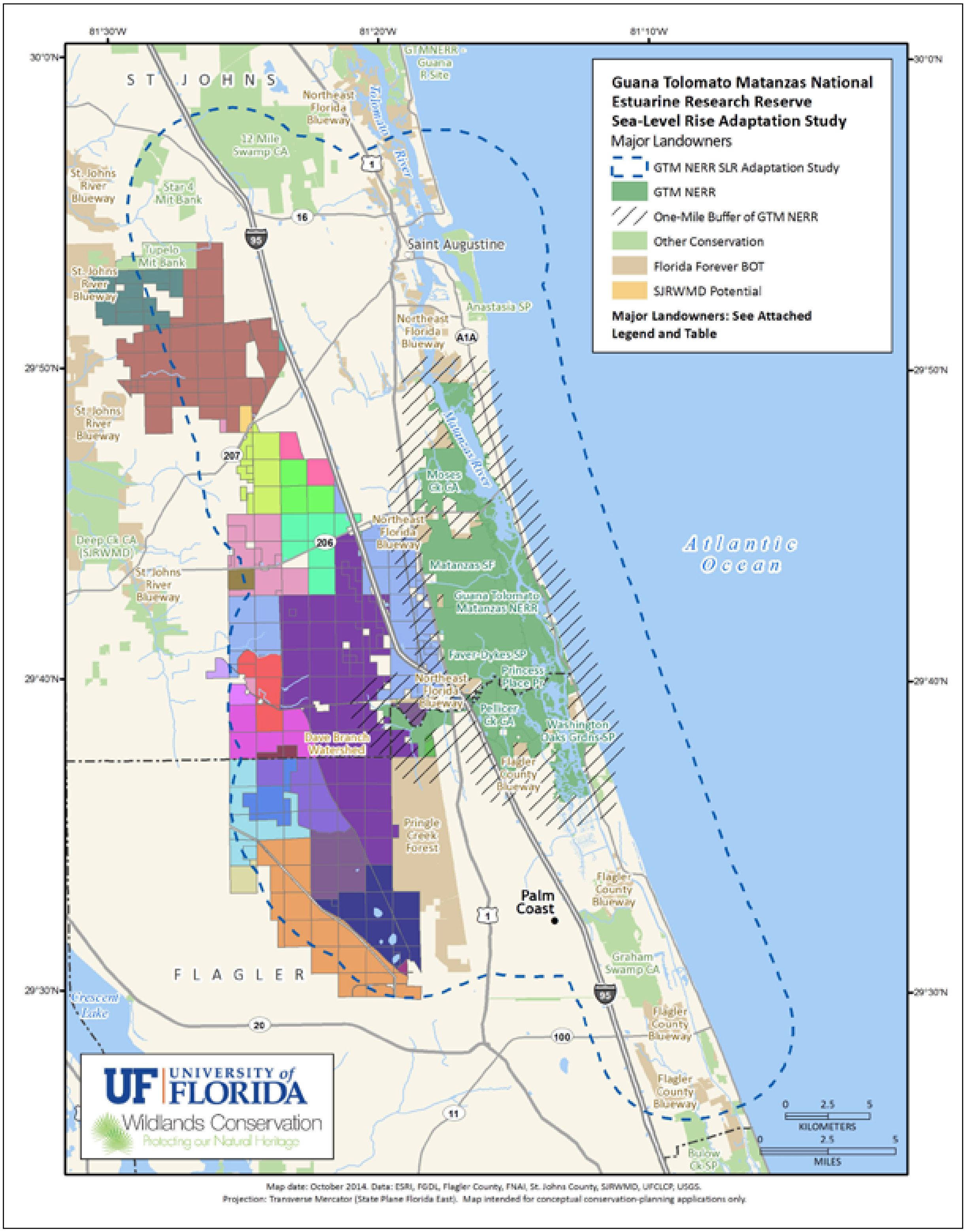


Figure 68. Conservation lands and properties considered for a conservation corridor between Ocala National Forest and the GTM Research Reserve

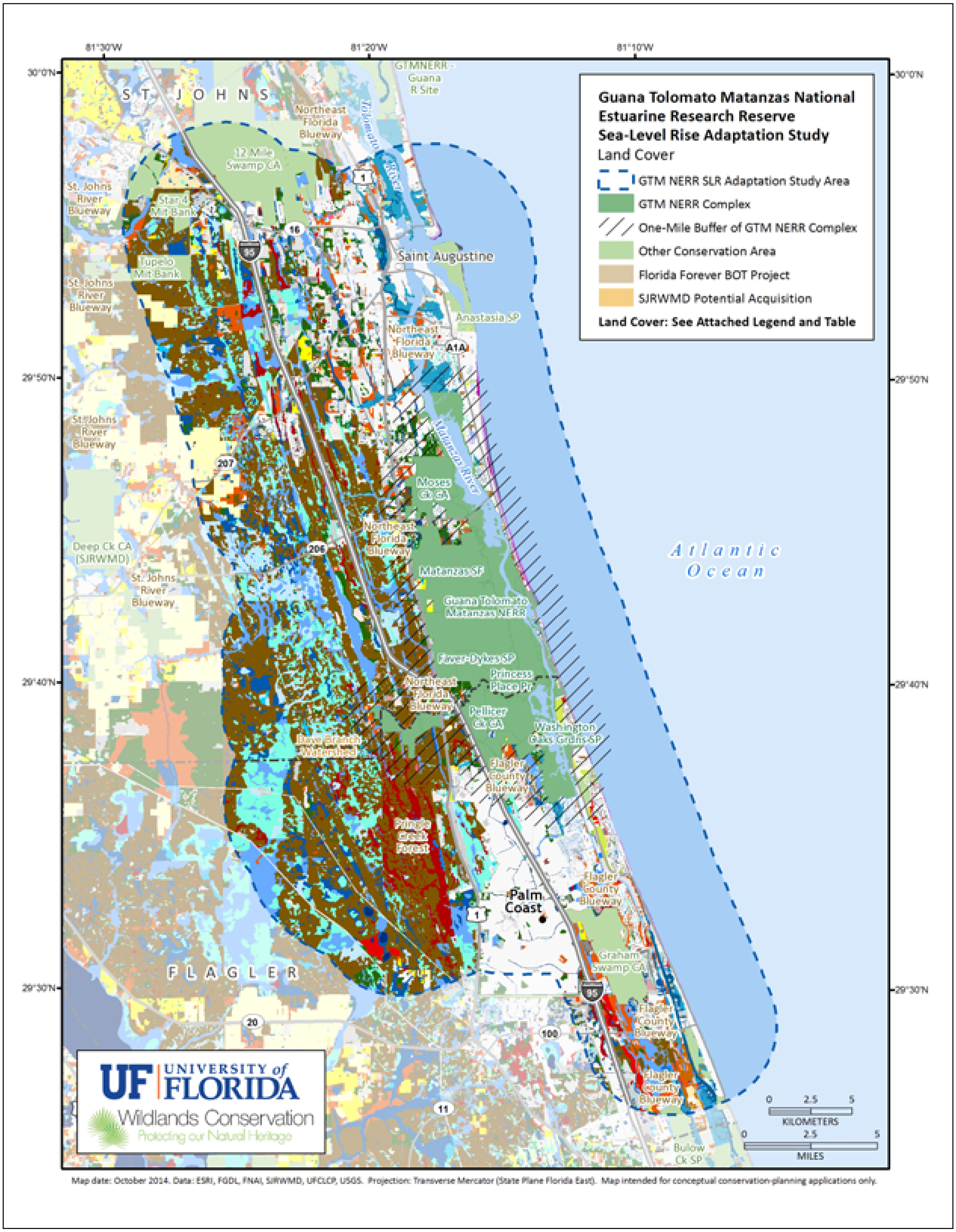


Figure 69. Land cover in the Matanzas study area, as it relates to conservation policies and programs

Guana Tolomato Matanzas National Estuarine Research Reserve Sea-Level Rise Adaptation Study

Land Cover Legend and Acreage Table

Land Cover	Acres
11 - Hardwood Forested Uplands	1,618.8
121 - Scrub	1,230.1
124 - Sandhill	369.2
1311 - Mesic Flatwoods	14,788.3
1312 - Scrubby Flatwoods	374.8
14 - Mixed Hardwood-Coniferous	8,916.3
15 - Shrub and Brushland	3,971.0
161 - Beach Dune/Coastal Grassland	659.8
162 - Coastal Berm	0.6
164 - Coastal Strand	184.3
165 - Maritime Hammock	1,553.0
167 - Sand Beach (Dry)	1,102.5
1821 - Low Intensity Urban	8,204.7
1822 - High Intensity Urban	33,764.3
183 - Rural Lands	5,859.8
1832 - Agriculture	3,888.4
183213 - Improved Pasture	941.7
183214 - Unimproved/Woodland Pasture	737.0
18323 - Tree Plantations	69,559.9
184 - Transportation	2,665.8
185 - Communication	24.6
186 - Utilities	1,448.1
187 - Extractive	852.3
21 - Freshwater Non-Forested Wetlands	115.6
211 - Prairies and Bogs	19,297.8
2111 - Wet Prairie	1,005.8
212 - Freshwater Marshes	1,148.4
2122 - Coastal Interdunal Swale	171.4
221 - Cypress/Tupelo	12,656.8
2221 - Wet Flatwoods	10,213.0
223 - Mixed Wetland Hardwoods	20,420.6
2232 - Hydric Hammock	246.9
224 - Other Wetland Forested Mixed	10,941.2
23 - Non-vegetated Wetland	727.6
245 - Wet Coniferous Plantations	32.4
31 - Natural Lakes and Ponds	183.0
32 - Artificial Lakes and Ponds	3,548.1
41 - Natural Rivers and Streams	1,367.8
42 - Canal/Ditch	16.7
5 - Estuarine	9,139.3
524 - Saltwater Marsh	10,824.9
525 - Mangrove Swamp	259.2
6 - Marine	69,000.3
7 - Exotic Plants	4.9

Future Development Scenarios in Response to Future Conservation Priorities

One approach to adaptation of the built environment is to use land use planning to proactively steer current and future development away from vulnerable areas, as well as away from the conservation lands identified as high priority for adaptation and resilience of the natural environment (see above). Toward this end, the project team modeled four future, year 2060, development scenarios using methods from the Land Use Conflict Identification Strategy (LUCIS) (see Appendix E for details). Through LUCIS the team allocated land to accommodate the anticipated population and employment growth, using the 2060 BEBR projections for St. Johns and Flagler counties. The two "trend" scenarios, which were based on extrapolating current development densities and policies, are covered in the Vulnerabilities section.

Below we present the two "conservation" scenarios, in which future development occurs in strategic locations and at higher densities than with current development patterns, in order to reduce land consumption and avoid impacting important conservation lands. The conservation scenarios illustrate the kinds of land use patterns, and hence land use policies, that could accommodate future growth while also conserving the environment, which is critical for resilience.

Ideally, land use planning in the Matanzas area would take into account sea level rise and conservation. For comparison purposes, the first conservation scenario discussed below does not include adaptation of current and future development to sea level rise, only the minimization of impacts to conservation priorities. The second conservation scenario adapts current development to sea level rise by specifying not only that future development will avoid conflict with vulnerable areas and conservation priorities, it will also allocate land to the relocation of the development currently in the vulnerable areas (as identified by the SLAMM runs of 3 feet (1 meter) of sea level rise by the year 2100 for all areas in the counties, including St. Johns River).

Without Sea Level Rise

The future development conservation without sea level rise scenario was created using LUCIS, however it assumed gross current urban density figures (average number of people per acre) from BEBR for the two counties, and therefore did not specify types of urban land use or variations in development density. Figure 70 shows the locations of future development allocated to avoid high priority conservation areas, while continuing development in areas vulnerable to sea level rise. For comparison, Figure 49 (in Vulnerabilities section) maps the location of development for the trend scenario without sea level rise.

New development

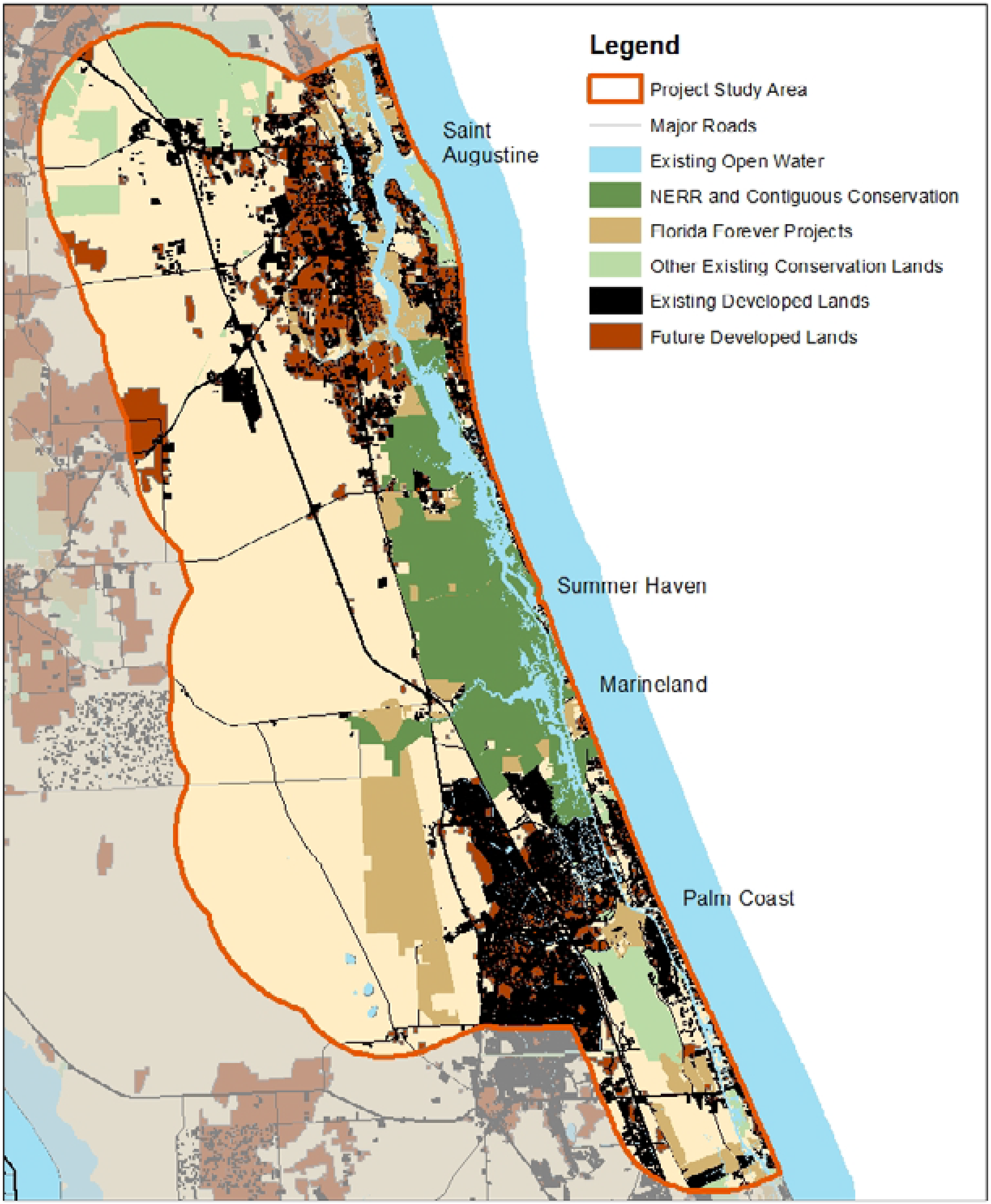


Figure 70. Conservation scenario without sea level rise

With Sea Level Rise

The "with sea level rise" conservation scenario allocated land to the same numbers of population and employment growth in the two counties as the "without sea level rise" conservation scenario (see above), plus the current population and employment displaced in vulnerable areas as determined by the SLAMM run of 3 feet sea level rise by the year 2100. For the two-county region, vulnerable areas existed along the coast as well as inland adjacent to the St. Johns River.

Figure 71 shows the location and density of development for the conservation scenario with sea level rise. For comparison, Figure 50 (in Vulnerabilities section) maps the location and density of development for the trend scenario with sea level rise.

Photo by Ed Siarkowicz Photographic Images, LLC

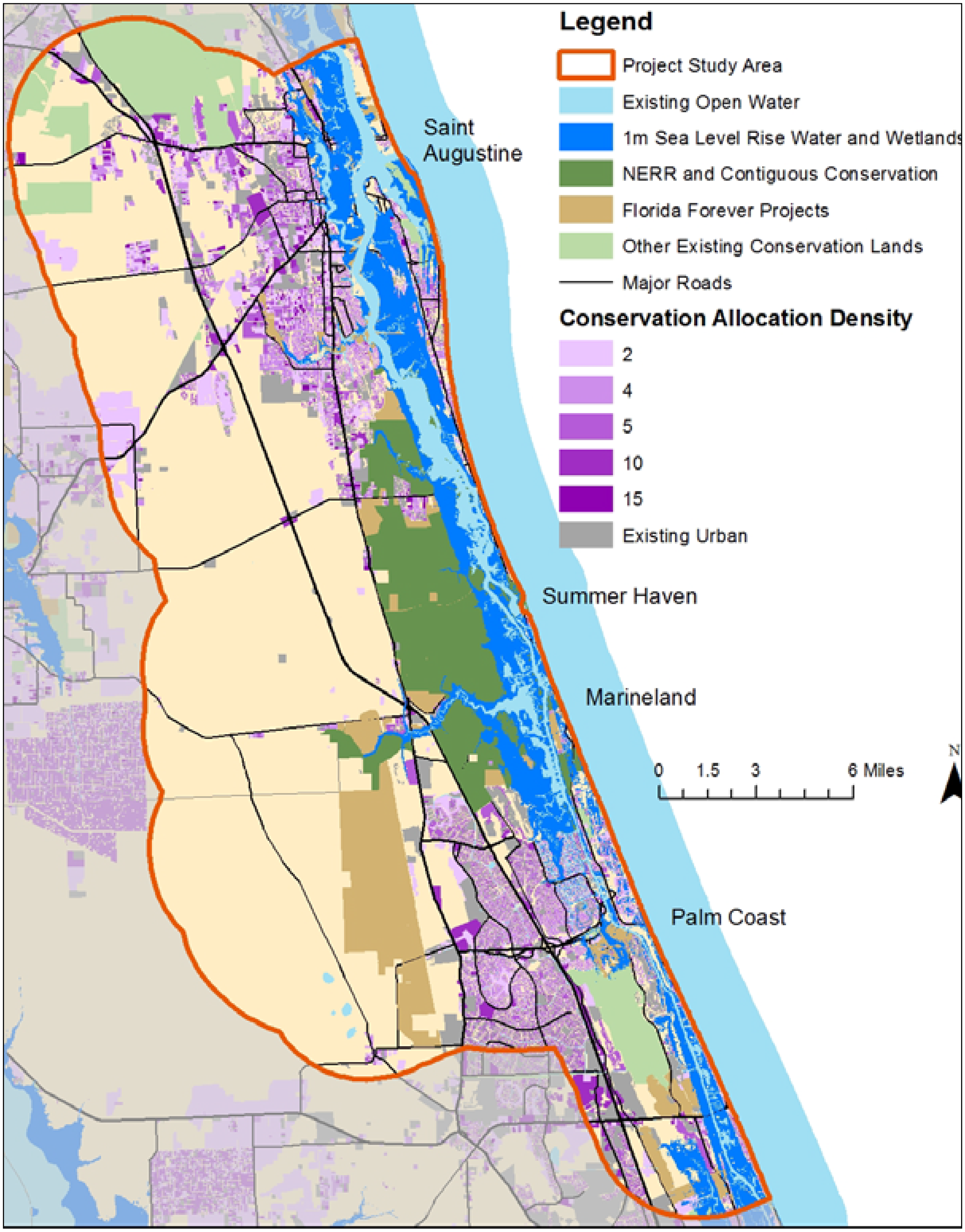


Figure 71. Parcels per acre, for the conservation with sea level rise scenario

Table 27 summarizes all four future development scenarios, with the amount of new land developed for the two counties, including any land designated for residential, commercial, or similar developed land uses, but generally excluding wetlands. Across the two counties, the conservation scenario resulted in development occupying 13,747 fewer acres, and impacting 63,800 fewer acres of future conservation priorities, as compared to the trend scenario. The gross urban density of the new “conservation” development was 4.7 people per acre (compared to 4.3 in the trend scenario). In the Matanzas study area, the conservation scenario impacted 20,259 fewer acres of future conservation priorities as compared to the trend scenario. In some cases vacant parcels that were already platted for development were developed, even though they were located within an area identified as a conservation priority. A substantial portion of future development can be accommodated within the existing suburban/urban fabric due to the relatively low density of current development, though factors such as the number of vacant parcels and end-of-life buildings within the area will affect the feasibility of redevelopment/infill.

The conservation scenarios also reduce habitat and watershed fragmentation by locating future development adjacent to currently developed areas and highway intersections, rather than in non-contiguous areas (known as leap-frog development or sprawl). Local governments can guide development to achieve these and further reductions in land consumption, as well as improvements in community livability, through “smart growth” land use policies and programs. Next, we discuss smart growth principles more generally, along with the principles of “low impact development” to reduce development’s impacts to the watershed.

Scenario	New Development in St Johns and Flagler Counties (Acres)
Trend Scenario (1m SLR)	133,564
Conservation Scenario (1m SLR)	119,817
Trend Scenario (no SLR)	172,092
Conservation Scenario (no SLR)	104,481

Table 27. Comparison of future development scenarios

New development

Smart Growth and Low Impact Development

The conservation scenarios for future development showed flip sides of planning: avoiding high priority conservation areas while still accommodating the anticipated growth and adaptation through changes in development patterns. Two approaches to guiding development patterns are particularly relevant to reducing environmental impacts while also promoting community livability and maintaining quality of life for current and future residents: smart growth and low impact development (LID). Smart growth is primarily concerned with the location, density, and mix of development. Low impact development approaches (also known as green infrastructure) complement smart growth, by adding design features, especially those that foster more natural stormwater management and water conservation practices in the built environment.

Appendix G is a primer of smart growth and LID, with a case study of a Florida coastal town (Rosemary Beach) to illustrate how the strategies can work together. Figure 72 shows the types of places within the Matanzas area where the various smart growth, LID, and land conservation strategies may be applied. Three of the most important smart growth strategies – contiguous development, infill/redevelopment, and higher density residential developments – present significant challenges to implementation. The urban planning literature is meeting these challenges with more guidance and examples. For example, there is growing awareness and use of well-designed "middle housing," such as duplexes, townhomes, and bungalow courts (see Figure 73), which have densities that fall between those of single family detached homes and large apartment complexes.

Figure 72. Potential application of smart growth, LID, and land conservation principles in the Matanzas study area

Figure 73. A bungalow court, an example of “middle housing.” Source: http://buildabetterburb.org/2013/wp-content/uploads/2013/07/001_HC_article_slideshow_01.jpg

Integrated Adaptation Framework and Toolbox

Adaptation strategies discussed thus far have focused on the promotion of long-term regional resilience through land conservation, smart growth, and low impact development (LID). This section complements these discussions in two main ways: First, an integrated adaptation framework is presented to comprehensively address the geography, values, and goals of the Matanzas area. The adaptation framework defines types of places and goals, and matches them with broad categories of adaptation strategies, resulting in the identification of specific areas for protection, accommodation, relocation, avoidance, and land conservation/smart growth/LID. The adaptation framework thus adds an important focus on strategies for current development in vulnerable areas. Second, a toolbox of supportive local government policies and programs is provided to enable implementation of land use and infrastructure adaptation strategies. Local governments – towns, cities, and counties – can play an important role in planning and implementing sea level rise adaptation strategies based on their authority to protect public health, safety, and welfare.

The integrated adaptation framework and toolbox are described below, including their application to the Matanzas area. Appendices H1 and H2 contain further details of the framework and toolbox, addressing the myriad legal, economic, political, administrative, and environmental considerations, potential secondary effects (such as spurring development or degrading natural amenities), and ways in which strategies can be phased, coordinated, and combined. A sophisticated, contextual understanding of the adaptation strategies will enable local governments and stakeholders to compare the strategies to make choices among them. For example, upon further analysis of strategies, local governments may determine that protecting all developed areas from increased flooding over the long term may not be financially or technically realistic, or environmentally sound.

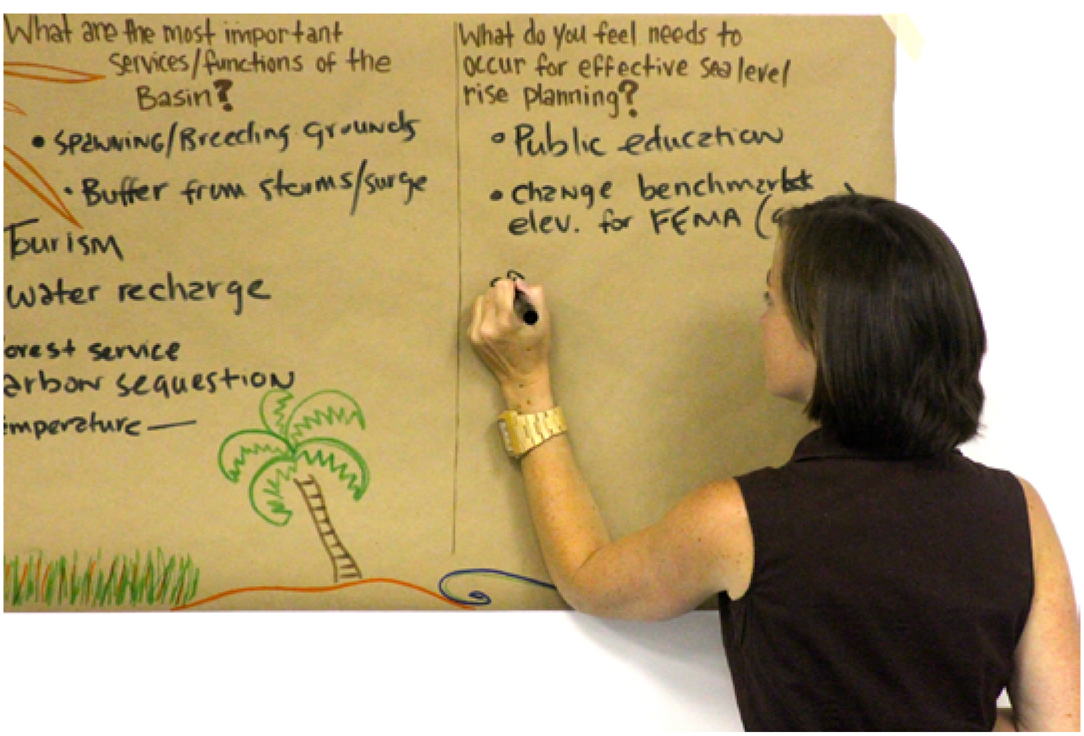
Matanzas Needs for Adaptation Planning

Before covering the adaptation framework and toolbox, it is useful to report the related input received during the project's public workshops and from the steering committee. Participants were asked the question, "What do you feel needs to occur for effective sea level rise planning?" The prioritized responses combined across the workshops are summarized below:

Physical and social sciences

- Increase understanding of the Matanzas area, including communities and ecosystems
- Identify economic effects of sea level rise and adaptation on businesses and resource use
- Ask what citizens and stakeholders are actually thinking and want
- Make information about the Matanzas area accessible to local governments, stakeholders, and the public

Engagement



- Engage and educate the public, key stakeholders, officials, and leadership
- Relate adaptation to the needs of the communities, and impacts to personal lives and interests
- Build capacity to implement adaptation plans; people have to care

Planning and policy-making

- Acknowledge the problem
- Recognize that adaptation responses take time, and start prevention now
- Incorporate adaptation into routine planning
- Put good regulations into place
- Explore alternatives
- Develop short term and long term approaches
- Equitably share costs
- Incentivize economically, and have flexibility in regulation

Adaptation strategies

- Determine and address causes of change
- Decide what to protect and what to let go
- Value and conserve the ecosystem and the services it provides
- Explore new places for resources
- Guide future development patterns and coordinate with environment conservation

Local governments and stakeholders can use the above list to guide the selection of adaptation strategies in the toolbox that would be most needed and promising for the Matanzas area.

Integrated Adaptation Framework

In taking a regional resilience, or whole system, perspective, the project team found that not only were adaptation strategies crucial for vulnerable areas, they were needed for inland areas. The team's findings resonated with the Deyle and Butler's (2013) framework of associating adaptation strategies with land characteristics along two axes: coastal vulnerability (high and low) and importance for natural conservation or urban development. This framework leads to four types of areas, and two additional noteworthy intermediates between the types (see Table 28). The intermediates are represented in the table as medium conservation and medium urban values, however, other values combinations can lead to the intermediates: high conservation and high urban values (i.e., high conflict between these land uses), and low conservation and low urban values (e.g., this kind of land may be primarily agricultural).

The types of areas are generally associated with six approaches to adaptation (shown in Table 28 and discussed below), which furthermore account for differences in addressing current versus future development. The six approaches to adaptation are protection, accommodation, strategic relocation, avoidance, land conservation, and smart growth/LID. All six adaptation approaches have appropriate places of application in the Matanzas area, as shown by the examples in Figure 74. The adaptation framework is a guide, whereas the specific conditions of a site and scales of planning may lead decision makers to choose different strategies than those suggested by the framework.

Coastal vulnerability	Importance for natural conservation or urban development		
	Type 1: • High vulnerability • High natural value **Response:** Avoidance, land conservation, and relocation	**Intermediate Type 1-2:** • High vulnerability • Medium natural value • Medium urban value **Response:** Accommodation	**Type 2:** • High vulnerability • High urban value **Response:** Protection
	Type 3: • Low vulnerability • High natural value **Response:** Land conservation	**Intermediate Type 3-4** • Low vulnerability • Medium natural value • Medium urban value **Response:** Smart growth/ LID for low-density development	**Type 4:** • Low vulnerability • High urban value **Response:** Smart growth/LID for high-density development

Table 28. Types of geographic areas with different adaptation strategies. Modified from Deyle and Butler (2013)

As discussed in the Vulnerabilities section, the entire coast of the Matanzas area, in a strip several miles wide, is low-lying and highly vulnerable to sea level rise. Land adjacent to the tidally connected canals and streams, such as Pellicer Creek, are also directly vulnerable. To successfully shift future development and redevelopment away from the vulnerable areas would require a new vision of coastal-inland development, including alternate means of providing access to the coast to meet market demand. Jurisdictions for which all or most of the land is vulnerable, such as St. Augustine, do not have many options for shifting development to more suitable areas, nor may they desire to relocate their substantial historical and cultural assets. It is important to recognize the goals and constraints unique to each jurisdiction, and to consider mechanisms of intergovernmental coordination and support.

The six adaptation approaches are not mutually exclusive but complementary, and they should be coordinated geographically and over time as vulnerabilities and values change. Vulnerable areas are projected to continuously expand due to the rising sea, therefore the choice of planning horizon, at 20-, 50-, or 100-years, is a key input for applying the framework and toolbox. Longer planning horizons allow jurisdictions to become proactive, and to evaluate the long-term implications of short-term, reactive strategies. It is recommended that local governments pay attention to the longer planning horizons due to the expectation that sea level rise will accelerate, and the potential for tipping points, which could lead to rapid expansions of vulnerable areas and systems in short periods of time. The Matanzas area's terraced landscape makes such geographic tipping points likely.

The adaptation framework is oriented towards land use planning and geographic vulnerabilities. While largely beyond the scope of this project, it is important to keep in mind that sea level rise vulnerabilities can exist in other systems, such as groundwater, which is the main water source for development and agriculture in the Matanzas area. Also, vulnerabilities created by phenomena other than sea level rise may occur, such the potential for stronger precipitation (rainfall) events from climate change, which would increase flood risk in all low-lying areas, coastal and inland.

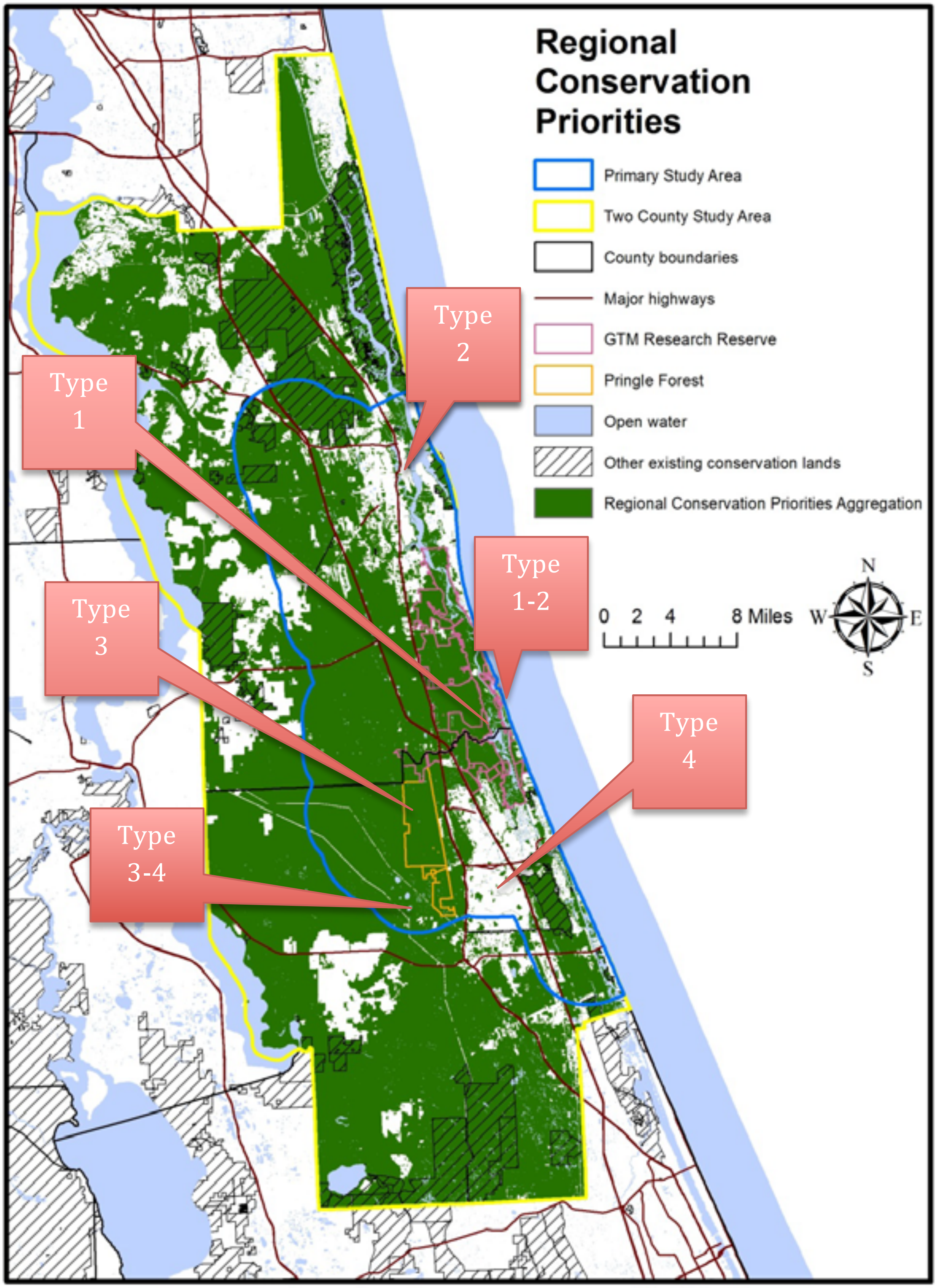


Figure 74. Types of adaptation areas with examples in the Matanzas study area

Protection

Protection, as defined in the context of vulnerability to sea level rise, is the goal of reducing risk to development by "holding back the sea" through armoring and other measures to prevent flooding and erosion (Figure 75-Figure 77), as well as applying robust construction practices. Included in protection would be strategies that accomplish the protection goal while also restoring and ecologically engineering beaches, dunes, reefs, and wetlands (Figure 78). Protection strategies are likely to be used in vulnerable areas with high urban value areas, and for current development.

New Inlet erosion on A1A looking south at washover with Hurricane Irene rain band. Photo by Ed Siarkowicz Photographic Images, LLC

Figure 75. New seawall and preservation of historic seawall, St. Augustine. Source: http://staugustine.com/news/local-news/2014-07-09/visitors-locals-enjoying-new-seawall

Figure 76. Riprap along houses in the Matanzas area. Source: http://staugustine.com/news/local-news/2012-12-22/scientists-rising-seas-will-transform-matanzas-basin

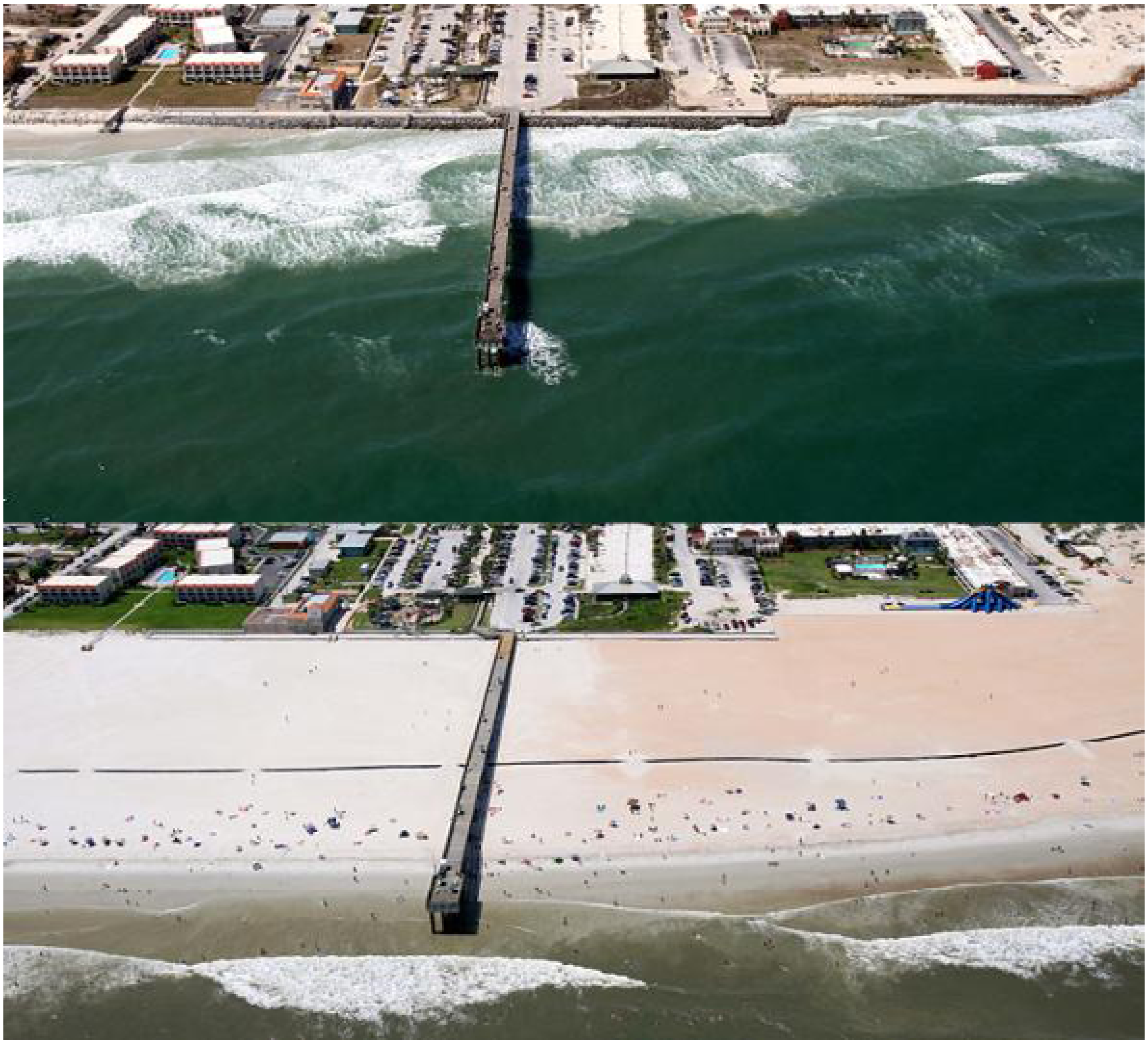


Figure 77. St. Augustine Beach, before (top photo) and after beach renourishment in 2012. Source: http://staugustine.com/news/local-news/2012-09-12/renourishment-gives-st-augustine-beach-new-look

Figure 78. Living shoreline installed to protect the historic seawall at Castillo de San Marcos, St. Augustine

Accommodation

Accommodation is the goal of continuing active use of vulnerable areas but in ways that allow the environmental dynamics to occur, including flooding and erosion. Accommodation strategies are likely to be used in vulnerable areas with intermediate conservation and intermediate urban values, and for both current and future development. The most common and well-known accommodation strategies are building setbacks from the ocean and rivers, including the maintenance of natural dunes, scrub, and riparian areas (Figure 79), and raising buildings above specified flood levels. There is growing interest in the accommodation goal due to the limitations of protection, especially its high expense, environmental and cultural impacts, and long-term futility in the face of an ever-rising sea. With this interest in accommodation, professionals are designing new accommodation strategies to satisfy more community objectives, such as maintaining community character, resident accessibility, and affordability, and for retrofitting existing development.

Figure 79. Building setbacks, Crescent Beach

Photo by Ed Siarkowicz Photographic Images, LLC

Strategic Relocation

Strategic relocation is the goal of reducing the level of development in vulnerable areas, usually through attrition, i.e., not rebuilding or maintaining structures and infrastructure in place, and by supporting siting replacements in less vulnerable locations. Strategic relocation strategies are likely to be used in “sending areas” – developed vulnerable areas with intermediate conservation and intermediate urban value areas – and the non-vulnerable “receiving areas.” Decisions to relocate public buildings and services, and to neglect or dismantle infrastructure, are challenging, as illustrated by the controversy over whether the county will maintain an eroding section of Old A1A serving houses north of Marineland (Figure 80). Loss over a longer timeframe is evoked by the scene of remnants of a Flagler sightseeing trolley line emerging from the beach (Figure 81). Local governments can incorporate strategic relocation strategies into policy through several means, including post-disaster redevelopment plans.

Figure 80. Erosion along Old A1A

Figure 81. Abandoned Flagler sightseeing trolley track. Photo by Ed Siarkowicz Photographic Images, LLC

Avoidance

Avoidance is the goal of proactively guiding future development away from vulnerable areas. Like the strategic relocation goal for current development, avoidance identifies sending and receiving areas for future development rights and services. Avoidance strategies are likely to be used in areas of high conservation value, for either wildlife concerns or ecosystem services to existing development. Avoidance strategies restrict the rate of new development in coastal areas, which may stifle growth and maintenance of the tax base for some communities and counties. The belief, however, is that over the long term, they will pay off in avoided costs to maintain the development in increasingly hazardous places. Moreover, the foregone tax roll to local governments may not be as high as expected, since property insurance rates are increased, thereby reducing property values and taxes. Avoidance strategies should therefore be analyzed on the basis of economic/fiscal matters, and taking into account development lifespans and secondary effects, such as public infrastructure and services spurring additional development. Local governments can implement avoidance strategies through local comprehensive plans and development codes, such as by “down-zoning” to a lower allowable density and restricting certain land uses. Capital improvement plans can also be useful tools to responsibly site public facilities and infrastructure.

Land Conservation

Land conservation as a goal, along with specific strategies of relevance to the Matanzas area, were discussed in earlier sections and Appendix F. Land conservation strategies are likely to be used in both high and low vulnerability areas, to enable habitat migration and overall regional resilience, wherever high conservation priorities exist. Land conservation doubles as an avoidance strategy to limit redevelopment and future development in vulnerable areas. A related strategy is restoration of habitats and ecosystems to meet single or multiple objectives for resilience.

Smart Growth/LID

Smart growth and low impact development, as covered elsewhere in this report and Appendix G, are likely to be most effective in low vulnerability areas having medium to high urban values. Professionals have tailored smart growth and LID strategies to the development densities, from low (rural/exurban), to medium (suburban), and high (urban), all of which exist in the Matanzas area.

Adaptation Toolbox

The adaptation toolbox, which is elaborated in Appendices H1 and H2, is a large set of specific local government policy, program, and design strategies selected for their potential utility for addressing sea level rise challenges in the Matanzas area. As explained in Appendix H1, each goal in the adaptation framework – protection, accommodation, strategic relocation, avoidance, land conservation, and smart growth/LID – can be addressed through the application of a particular sub-set of the tools.

Many of the adaptation tools were originally developed for reducing coastal hazards risks associated with storms. These tools are suitable for managing the flooding and erosion problems associated with sea level rise, and the goal of storm preparedness may resonate with the public. The coastal hazards management tools, however, are insufficient alone, because of the associated long-term trends towards increasing intensities of the coastal hazards, and the ultimate loss of land. For example, if changes in the level risk due to sea level rise are not taken into account, communities may continue to rebuild after disasters in increasingly vulnerable areas. The adaptation toolbox therefore modifies coastal hazards management tools for sea level rise and climate change challenges, and adds other kinds of tools as needed.

The adaptation tools are organized by types of policies/programs and design objectives: planning and zoning, building design, coastal habitat and ecosystem protection, armoring and protection, financial, and education. This organization relates to their implementation by local governments and stakeholders. It also reduces duplication of presentation, since organization by adaptation goals (see Appendix H1) shows that many tools can be used for more than one goal.

Sunset at Fort Matanzas as Hurricane Irene passes, 2011. Photo by Ed Siarkowicz Photographic Images, LLC

Planning and Zoning

Once a local government has a sense of its sea level rise adaptation goals, it can lay the policy foundation by adding specific language about the concern to its comprehensive plan. In Florida, coastal communities and counties are required to include a coastal management element in their plans, and this is one place to start.

Beginning with the Community Planning Act of 2011, state legislation has sought to reinforce local governments' ability to address sea level rise. This legislation defines adaptation action areas as possible overlay planning zones in areas "vulnerable to the related impacts of rising sea levels." In May 2015, Senate Bill 1094 created a new Florida Statute section 163.3178(2)(f), which now includes sea level rise as one of the causes of flood risk that must be addressed by redevelopment in the coastal zone. The Florida Department of Economic Opportunity provides technical assistance to local governments on issues of coastal hazards and sea level rise through four programs (www.floridajobs.org/adaptationplanning): Community Resiliency, Statewide Regional Evacuation Study Program, Post-Disaster Redevelopment Planning, and Waterfronts Florida Partnership Program.

Comprehensive plan statements require further ordinances or zoning actions to implement. Possible tools include the following:

- *Overlay zones* to define geographic areas where special zoning or other adaptation tools apply.
- *Development limitations* on location and type.
- *Conditional use permitting*. A conditional use is one permitted in a zoning area provided that the applicant can demonstrate that certain conditions or facts exist.
- *Downzoning and non-conforming uses* decrease allowable density or development types. Non-conforming uses can be phased out over time by limitations on their expansion and rebuilding.
- *Transfer of development rights* programs define an area where the right to develop is restricted or eliminated, but property owners are granted the right to transfer the development rights from the restricted property to other property owners in a receiving zone, to increase development density. TDR programs can be challenging to implement effectively.
- *Setback requirements.* The state's Coastal Construction Control Line policy requires a setback in the form of the 30-year erosion projection line, however this accomplishes little due to deficiencies in how it is determined and exceptions to its application. Florida

statutes also create a setback line 50 feet from the mean high water line, which is weakened further by exceptions. Local governments could implement additional setbacks combining sea level rise, erosion, and structure lifespans.

- *Increased floodplain management requirements* include higher elevations for buildings, oversizing drainage systems, flood-proofing commercial buildings, and reducing development density in floodplains. Such measures can decrease flood insurance premiums if a local government participates in the National Flood Insurance Program's Community Rating System Program.
- *Rebuilding requirements*. A local government may create a post-disaster redevelopment plan that applies many of the tools. For example, St. Johns County has one in its Local Mitigation Strategy (LMS).
- *Establishment of minimum standards for protective structures.* Private property owners own and maintain many sea walls. Local governments can maintain standards for these structures through a mix of incentives, permitting regulations, and assistance programs.
- *Building moratoria* prohibit permitting or building for a limited time, as a stopgap measure while information is gathered and policy developed and implemented. A building moratorium could avoid a rush to secure building permits and create vested rights when a local government makes known its intention to develop sea level rise adaptation zoning.

As illustrated in Figure 82 local governments can coordinate their various plans having specific roles in managing coastal hazards and land use across the disaster preparedness phases of pre-disaster planning, disaster response, short-term recovery, and long-term recovery. The plans are the local comprehensive plan, comprehensive emergency management plan, local mitigation strategy, and post-disaster redevelopment plan. The overlay of the disaster phases indicates the highest relevance of the plans' roles to the phases. The overlap between the plans suggests opportunities for integration and transition points (Florida Department of Community Affairs and the Florida Division of Emergency Management 2010).

Photo by Ed Siarkowicz Photographic Images, LLC

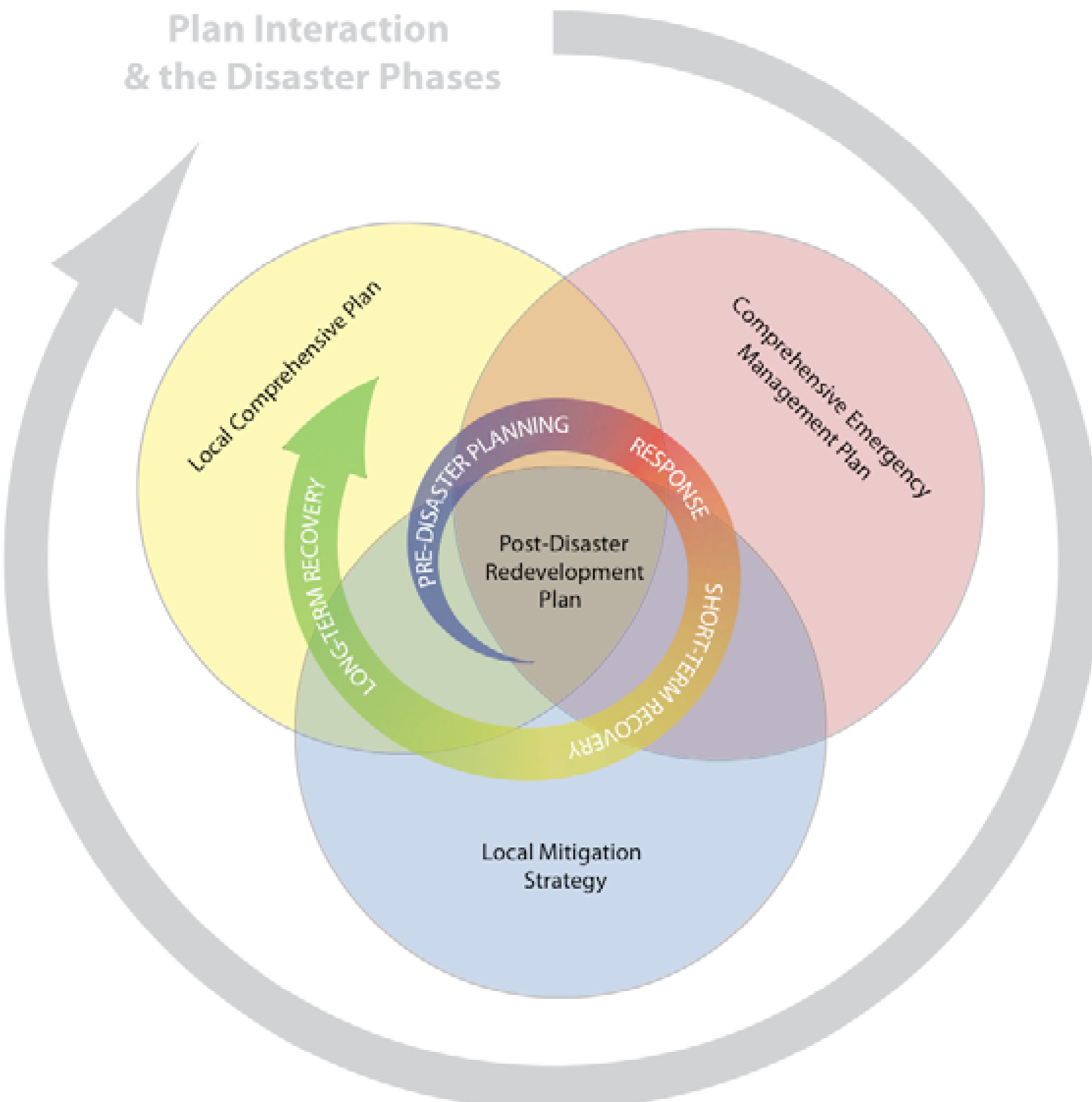


Figure 82. Interaction of local plans and disaster phases. Source: Florida Department of Community Affairs (2010)

Building Design

State and local governments establish building design standards to reduce risk from natural hazards, such as storm surge. The most stringent building requirements in the Florida Building Code (FBC) are typically applied according to the requirements of Florida's Coastal Construction Control Line (CCCL) program, and a community's floodplain ordinance and flood maps that are part of a community's participation in the National Flood Insurance Program. This approach has limited utility for sea level rise adaptation, however, and local governments may decide to increase the geographic applicability of current FBC building requirements and/or increase the building standards contained in the FBC. Local governments can also promote building in ways that allow relocation or removal of structures in accommodation and strategic relocation/avoidance areas.

Coastal Habitat and Ecosystem Protection

Coastal habitat and ecosystem protection not only support wildlife, water resources, and overall environmental quality, they can be applied to support the protection, accommodation, strategic relocation, and avoidance goals of vulnerable development. In other words, natural systems can be harnessed and enhanced to provide ecosystem services that protect the safety, health, and welfare of people. Tools for land conservation were covered in an earlier section, whereas here we include a two illustrations showing how coastal habitat and ecosystem protection tools can be combined with design tools for hazards management and low impact development (Figure 83-Figure 84).

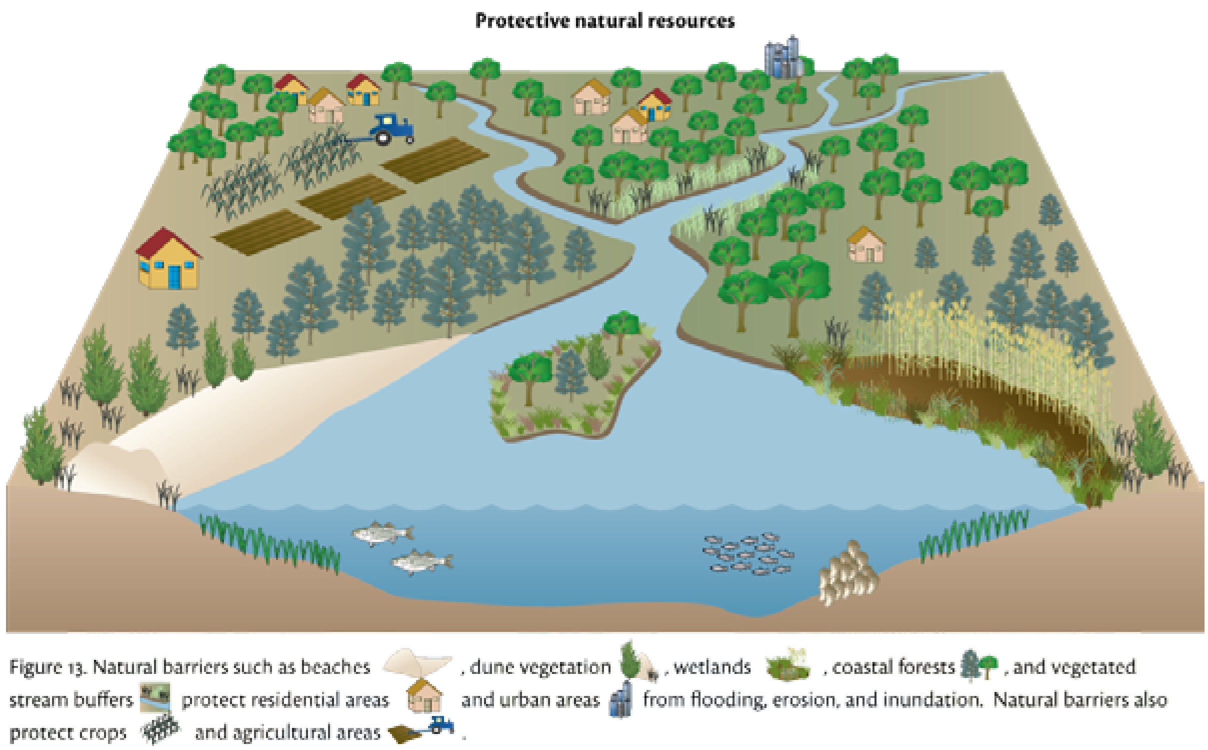
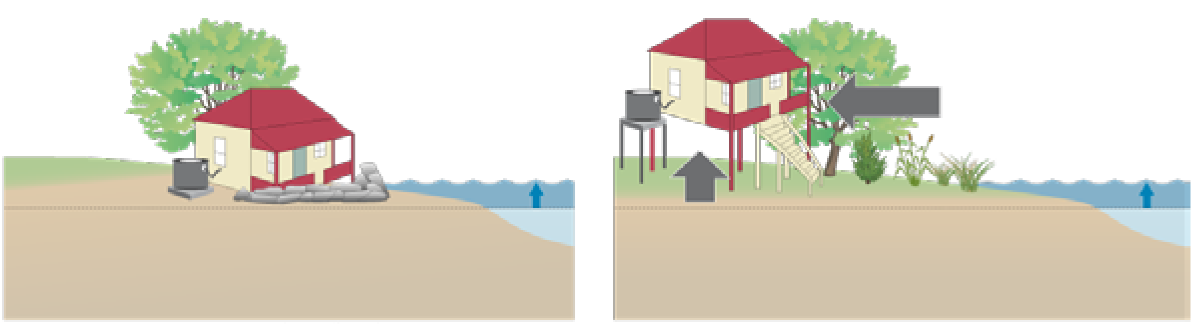


Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Enviromental Science. Source: Boesch, D.F. (editor). 2008. Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change Phase I: Sea-level rise and coastal storms. Report of the Scientific and Technical Working Group of the Maryland Commission on Climate Change. University of Maryland Center for Environmental Science, Cambridge, Maryland. This report is a component of the Plan of Action of the Maryland Commission on Climate Change, submitted to the Governor and General Assembly pursuant to Executive Order 01.10.2007.07.

Figure 83. Types and locations of protective natural resources



Conceptual diagram illustrating preparations for the effects of climate change:
Elevating and moving houses and utilities away from flood plain boundaries make them less vulnerable to storms and may lower flood insurance rates. Rather than building a concrete levy to protect property, consider a natural shoreline that offers the same benefit.
Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Rising to the Challenge. 2012. Assateague Island National Seashore, National Park Service. http://ian.umces.edu/press/newsletters/publication/380/rising_to_the_challenge_2012-10-24/

Figure 84. Combined used of adaptation designs for accommodation and environmental quality

Armoring and Protection

Local governments can control “hard” coastal armoring, including seawalls, bulkheads, riprap, and revetments, and “soft” beach nourishment and living shorelines, by establishing a local permitting requirement. Standards should be oriented towards the particular goal of the area, which could be protection, accommodation, or strategic retreat/avoidance.

Financial

Local governments can apply powerful financial tools to complement the regulatory approach:

- *Voluntary sale and acquisition.* Florida Statutes allow the use of Florida Forever funds for acquisition of land for adaptation to sea level rise via the Florida Communities Trust Fund. Voluntary buyout faces economic and administrative hurdles, therefore conservation easements may be a compromise solution. Purchase may become more affordable due to decreases in property values caused by increases in insurance rates under changes to the National Flood Insurance Program (Biggert-Waters Act of 2012 and subsequent changes in 2014 with the Grimm-Waters Act, aka Homeowners' Flood Insurance Affordability Act).
- *Requirements and assistance to improve private armoring and defenses.* A local government can establish a permitting program and regulatory program in which coastal protection structures that do not meet minimum standards are declared "nonconforming," or a program can encourage voluntary actions through financial assistance.
- *Acquisition through eminent domain*. A local government can "take" private lands for public purposes as long as it pays "just compensation" for the land. Eminent domain has limited use due to host of constraints and concerns, especially for issues that are not well understood by the public, such as sea level rise.
- *Capital improvement plans*. Infrastructure planning should take account existing and projected vulnerabilities, including for any new development spurred by the project, and the resulting expectations for continued/additional flood control and other services. Capital improvement plans can include decisions on whether to maintain but not upgrade infrastructure, and the costs of relocating facilities.

- *Insurance considerations.* Government-sponsored insurance systems, namely Florida's Citizens Property Insurance and the National Flood Insurance Program, are financially unstable. To address this concern, the Homeowners' Flood Insurance Affordability Act of 2015 allows for up to 18% yearly increase in premiums for primary residences and up to 25% yearly increases for other properties, particularly for structures built below the "base flood elevation." The Federal Emergency Management Agency (FEMA) is developing a community resilience index that considers environmental, economic, and social resilience.
- *Impact fees and exactions.* Florida law requires impact fees to be used for costs related to providing the services necessitated by the development paying the fees. Since impact fees typically fund infrastructure development, they are not usually good tools for adaptation unless they are used to pay for new armoring and other protection strategies. Other types of exactions include permit conditions and conditional permitting. Permit stipulations must have an "essential nexus" with the reason for which a permit could be denied. One stipulation that meets this requirement is a deed restriction against future shoreline armoring, because there is nexus with the public goal of maintaining the coastal ecosystem. Exaction of a "rolling easement" may have less clarity of a "nexus." Another exaction is for property owners to sign a waiver/release form as a requirement to receive a permit, but this presents some legal issues.

- *Performance bond for structural removal.* Local regulations regarding new development and redevelopment can be modified to require a long-term financial bond that provides the funds to remove structures if they are destroyed or condemned due to the impact of coastal hazards.
- *Tax and assessment strategies.* Taxes can either be reduced in exchange for desired actions by property owners, or increased to offset the higher-than-normal government costs to help protect the property and provide services. Many tax incentive strategies are the exclusive domain of federal and state governments, which means that property tax incentives to promote rolling or other conservation easements are of limited value. The most promising tax strategies for adaptation shift the costs from the general public to the vulnerable development, thus sending market signals reflecting the true costs. New property taxes can be geographically targeted and spent on adaptation strategies through tools known as Municipal Services Benefit Units and Municipal Services Taxing Units, with the latter having greater flexibility of how to use the collected monies.

Education

Education of the public about coastal hazards, vulnerability of properties, and regulatory limitations may affect property purchasing and public actions, and these actions may impact property values. Local governments can raise awareness of vulnerable areas with locational markers. Local governments may also require notice of coastal hazards and sea level rise to prospective property purchasers or permit applicants.

Governance Adaptive Capacity

Knowledge of the current capacities of local governments, stakeholders, and citizens to implement adaptation strategies can suggest areas of strength from which to build, as well as significant opportunities to fill gaps. Assessment of governance adaptive capacity can also indicates how “ready” communities are to proactively address sea level rise, the potential for stakeholder conflict, issues that can be locally influenced, and the kinds of regional, state, and federal assistance desired.

Governance adaptive capacity for planning and implementing sea level rise strategies can be assessed in terms of individual and collective ability to recognize current and future threats, identify possible responses, evaluate tradeoffs between them, implement the responses, and evaluate them. This report has categorized the types of adaptation responses in terms of goals – protection, accommodation, strategic relocation, avoidance, smart growth/LID, and land conservation – and specific strategy tools. Because sea level rise concerns and adaptation strategies have far-reaching effects and long time horizons, high governance adaptive capacity involves the ability to take community/regional and future perspectives, and to balance and coordinate with individual and present interests (Myers 2007). As shown in Figure 85, community-future concerns are the purview of planning, which includes not only government plans and policies, but also collaborative initiatives between governments, the private sector, non-profits, and civic leaders.

The project team took initial steps to understand governance adaptive capacity in the Matanzas area through analyses of past and current adaptations, current planning and policies, and input from the project’s public workshops. The results are presented below.

As shown by the analyses, the Matanzas area has high governance adaptive capacities in many regards, as well as opportunities for strengthening other needed capacities. Matanzas area governance has plans, policies, and initiatives that are supportive of all the major adaptation goals. These efforts have occurred at the neighborhood, municipal, county, and regional levels, and they have been formulated through collaboration across all governance sectors. The efforts have achieved many remarkable successes, such as the creation of

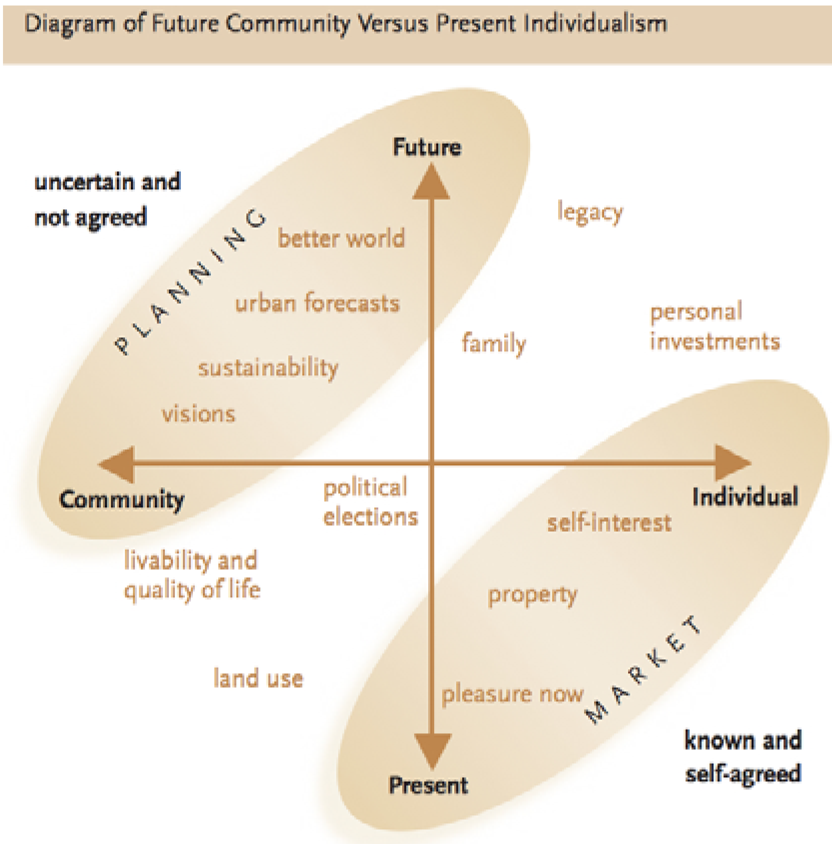


Figure 85. Types of decision-making in relation to community-individual and future-present concerns. Source: Myers (2007)

the GTM Research Reserve and planning centered on the Matanzas Basin (e.g., this project), as well as the fact that all of the counties and major municipalities in the Matanzas area have plans, policy language, and tools in support of hazards management (protection, accommodation, and avoidance) and growth management. Governance in the Matanzas area also has experience with the difficult choices involved in strategic relocation of development in vulnerable areas. The Matanzas area and larger Northeast Florida region, however, are still in the early stages of incorporating the long-term projections of sea level rise into planning. Additionally, the Matanzas area's experiences of managing existing hazards and growth have met with mixed results and encountered conflicts. Overall, there is optimism for the continued strengthening of governance adaptive capacity due the remarkable institutional and civic foundations, the expanding awareness of sea level rise concerns, and the growing momentum of adaptation planning.

Figure 86. Summer Haven dune breach. Source: Florida Sea Grant

Past and Current Adaptations

Experiences of past and current adaptations to coastal vulnerabilities indicate governance capacities, including priorities and challenges. The easiest adaptations to observe are those involving the protection and strategic relocation goals. Determination of governance impacts towards the other goals – accommodation, avoidance, smart growth/LID, and land conservation – would require research beyond the scope of this project. As a proxy, however, existing adaptation planning and policies are discussed in the next sub-section.

As is typical of coastal communities and regions, adaptations in the Matanzas area have been primarily reactive rather than proactive, sometimes lacking good coordination between government levels, and in many cases dependent on the choices of individual property owners.

The City of St. Augustine is now responding to flooding problems, which have worsened over the past 20 years, through improvements to its drainage system and increasing the height of its seawall. Citizens are beginning to acknowledge sea level rise as a contributing factor, and the city's engineer anticipates the eventual need for a pumping system (Dearen and Kay 2015).

In unincorporated St. Johns County, the small coastal community of Summer Haven has suffered from severe erosion and shifting sands (Figure 86). The intensification of these problems in 2004 and 2008, respectively, led to two major conflicts between residents and the county and state regarding road maintenance, emergency responses, river dredging, and species protection (Guinta 2013a and 2013b). The residents wanted to maintain their previous amenities of road access and estuarine river, whereas the governments denied the residents' requests on the grounds of short-term and long-term costs to taxpayers (due to high vulnerability), species concerns, and administrative procedures. The county also instituted in Summer Haven a building moratorium and a special tax to partly cover maintenance costs. The residents reacted with lawsuits based on local government obligations to ensure safety and health to residents. In 2013, both conflicts were settled. The county promised to repair and maintain the road in "as is" condition, and the state agreed to issue a permit to dredge the river, with the dredging project to be paid for by the residents and to include species habitat mitigation.

As seen in the Summer Haven case, adaptation decisions at the local level may involve, and in some cases be led by, state and federal agencies. A few examples in the Matanzas area are the adaptation of state and federal highways (e.g., Figure 87-Figure 88), and protection of historic resources, such as the restoration of Fort Matanzas National Monument (Figure 89-Figure 90). The agencies are increasingly considering sea level rise in their planning. Most recently, the National Park Service released a study that found that the Castillo de San Marcos in St. Augustine is vulnerable to sea level rise, and that it should be protected because it would cost a staggering $26 billion to rebuild (Dial 2015).

Figure 87. Matanzas Inlet bridge, 1954. Source: FDOT Archive

Figure 88. Matanzas Inlet bridge, current. Source: http://www.st-augustine-condo.com/Local%20photos/Local%20Photos.htm


Ruins of a Spanish Fort at Matanzas Inlet.

Figure 89. Fort Matanzas in decay, 1872. Source: *Scenes in Florida in Picturesque America*, Illustrations by Harry Fenn (1872)

Figure 90. Fort Matanzas restored Photo by Ed Siarkowicz Photographic Images, LLC

View from Ft. Matanzas

Planning and Policy Analysis

Across the Matanzas area, the project team researched regional planning initiatives, and analyzed county and municipal land use and hazards policies, in relation to sea level rise adaptation. The findings are summarized below, with details of the local plan analyses in Appendices H3 and H4.

Regional Governance

The Northeast Florida Regional Council (NEFRC) and its not-for-profit partner, the Regional Community Institute of Northeast Florida (RCINEF), have been strong leaders in building regional capacities for growth management, hazards management, and recently sea level rise and climate change adaptation (Figure 2).

The first sea level rise study in Northeast Florida was led by the U.S. Environmental Protection Agency and involved the NEFRC and local governments. The results were published in 2009, although the study had begun as early as 2003 (Patterson 2009). The study identified coastal areas vulnerable to sea level rise (less than 10 feet elevation), current and future development in those areas, impacts to wetlands, and the locations likely to receive either protection or strategic relocation based on development densities. As reported in the news at the time, “The Jacksonville area is just starting to take on sea-level questions” (Patterson 2009).

The RCINEF has led several highly participatory regional visioning processes focused on growth management, and acknowledging climate change concerns. The First Coast Reality Check report mentioned climate change mitigation (reducing greenhouse gas emissions) but not adaptation (RCINEF 2009). In terms of growth management, the Reality Check report stressed engaging the business sector, using incentives, and building political consensus and public support by making connections between economic, societal, and environmental values. The following First Coast Vision report supported smart growth principles, resource conservation, and resiliency, including adaptation for climate change and sea level rise (RCINEF 2011).

Based on the First Coast Vision, the NEFRC solicited regional input on climate change impacts, and the responses emphasized sea level rise. As a result, the RCINEF's Emergency Preparedness Committee took on sea level rise as a policy issue. After a year of study, the committee reached consensus that the region was vulnerable, agreed upon a range of future sea level rise scenarios and a planning timeframe (up to six feet rise by year 2100), and conducted community resiliency assessments for several local governments. The committee's recommendations for a regional action plan were largely adopted by the NEFRC. The recommendations focused on building individual, local, and regional adaptation capacities: create a clearinghouse on understanding risk, engage the community, relate implementation of adaptation strategies to cost savings, collaborate and leverage success, and engage the business sector in long term resiliency (RCINER 2013).

The last recommendation of the RCINEF committee's report, "engage the business sector," led the NEFRC to establish the Public/Private Regional Resilience (P2R2) Committee. The P2R2 Committee had the goal to "develop a regional strategy that will incentivize population and private development to locate outside of vulnerable areas" (RCINEF 2013). At the end of the P2R2 Committee's first phase of analysis, which included assessment of economic vulnerabilities, they drafted a comprehensive set of recommendations: incentivize growth at higher elevations while avoiding high priority conservation lands, strengthen storm surge risk management, promote alternative energy and energy conservation, address water supply and green infrastructure, learn best practices from the region's coastal military facilities, and improve emergency preparedness (RCINEF 2015). The P2R2 Committee kicked off their next phase in summer 2015.

In support of coastal hazards and floodplain management, the state published the Northeast Florida Regional Evacuation Study in 2013. Additionally, the Federal Emergency Management Agency (FEMA) is currently updating its digital Flood Insurance Rate Maps (FIRMs) for the Northeast Florida counties (www.southeastcoastalmaps.com). The updated FIRMs will use current sea levels, but they will not reflect future sea level rise. Once prepared, the FIRMs report for Northeast Florida will be available at FEMA's Flood Map Service Center (msc.fema.gov).

Other notable regional efforts include the North Florida Land Trust's analysis of potential impacts of sea level rise to environmental assets, and the St. Johns River Water Management District's inclusion of sea level rise as a strategic priority in the agency's 2015-19 Strategic Plan. Within the region, the small city of Fernandina Beach has proved to be a leader, writing into its comprehensive plan that it "recognizes sea-level rise as a potential coastal hazard, and shall work with Nassau County and state and regional entities…to develop strategies for responding" (Patterson 2014). The City of Jacksonville and its utility JEA are still in the early stages of assessing the potential impacts of sea level rise (Patterson 2014).

County and City Plans and Policies

The study team assessed Matanzas area local government plans for their policies regarding sea level rise and coastal hazards. The plans reviewed were the comprehensive plans for St. Johns County, Flagler County, St. Augustine, and Palm Coast, and the St. Johns County Local Mitigation Strategy. The Flagler County Local Mitigation Strategy was not reviewed, nor were the plans for other municipalities in the area (St. Augustine Beach, Marineland, Beverly Beach, and Flagler Beach). Details of the assessment are presented in Appendices H3 and H4.

The assessment noted strengths among the plans regarding hazards management, smart growth, and land conservation. A major weakness was that none of the plans referenced sea level rise.

The plans generally used the Coastal High Hazard Area (CHHA) to designate areas subject to local coastal hazard risk management policies, and sometimes ecosystem and habitat protections. The CHHA is defined by the state based on SLOSH-modeled flooding from a category 1 storm. The CHHA is fairly limited in geographic scope, especially on barrier islands. One option is for local governments to define their own type of area. For example, Pinellas County's "coastal storms area" includes the CHHA, islands, SLOSH category 2 flood areas, and FEMA's Velocity Zone. St. Augustine has a "coastal planning area" designation, but further research would be needed to understand how this works.

All plans had excellent focus on floodplain management and protection, based on floodplain maps, however they did not include future changes, including due to sea level rise. Palm Coast, like Flagler County, included the objective to "direct population concentrations away from known or *predicted* high-hazard areas" (emphasis added). "Predicted high-hazard areas" could be more precisely defined in the plan to include areas vulnerable to future sea level rise. Likewise, local policies establishing protections for habitats and ecosystems could reference future conservation priorities for sea level rise adaptation. And, while Flagler County requires new construction to be elevated at least one foot above the 100-year flood elevation, many local governments have adopted 2- or 3-feet requirement.

Many of the plans limited development density in vulnerable areas, such as downzoning, overlay zones, and conservation easements (for a discussion of these tools, see Appendices H1 and H2). However, the plans lacked explicit direction to use the tools to address future sea level rise impacts. The plans for St. Augustine and Palm Coast contained provisions for master stormwater plans, which could incorporate adaptation strategies.

Voluntary participation in FEMA's Community Rating System (CRS) can provide a financial incentive, via reduction of national flood insurance rates, for local governments to manage floodplains beyond the minimum federal requirements. The Matanzas area local governments participating in the CRS are St. Johns County, St. Augustine, St. Augustine Beach, Flagler County, Palm Coast, and Flagler Beach. None of the local governments in the Matanzas area had standalone post-disaster redevelopment plans.

St. Augustine's numerous historic structures pose special challenges to hazard mitigation and sea level rise adaptation. The city requires new or rebuilt development to be elevated above the base-flood elevation as determined by FEMA, however the historic structures are exempted. Furthermore, government, religious, and educational institutions own more than half of St. Augustine's properties, which exempts them from property taxes, an important source of local government revenues. The city could instead generate greater income for hazard mitigation and adaptation by applying fees and assessments for infrastructure, for which these institutions would not be exempt.

Historic St. Augustine. Source: http://magazine.ufl.edu/2012/04/st-augustine-sitting-pretty/

Public and Stakeholder Input

The public and stakeholder input gathered through this project provided a complementary perspective of governance adaptive capacity, because participants represented diverse interests and organizational perspectives, and they were directly asked about sea level rise adaptation planning.

At the start of the project in 2012, the project's Steering Committee described the status of sea level rise planning and public awareness in the Matanzas area. The discussion confirmed that local governments were addressing coastal hazards and floodplain issues but not sea level rise. The committee expressed that citizens were generally supportive of natural resource protection, but that local governments had difficulty enforcing the comprehensive plans in the face of development pressures. The committee reported an overall lack of awareness of sea level rise, due to the fact that coastal changes in the Matanzas area have either been attributed to storms or not apparent. The committee was uncertain over how the public and interest groups would react to information

about sea level rise and other climate change issues. Some steering committee members had observed colleagues dismiss climate change science. The committee noted that attention to sea level rise appeared strongest among state and federal agencies (although state support varied with elections), in corporate headquarters, and within the insurance industry.

The Steering Committee also reflected on their vision for adaptive governance in the Matanzas area. The vision involved an informed citizenry and productive dialog. The Matanzas area would be proactively adapting to change based on science, and in economically feasible and socially responsible ways. Adaptation would be a component of truly sustainable communities and natural systems. Some members advocated linking sea level rise adaptation to broader concerns of climate change impacts and mitigation (greenhouse gas emission reduction), while others recommended keeping the immediate focus on sea level rise. Vigorous planning and engagement would support the vision, using effective tools, piloting new strategies, sharing information, and generating consensus. The resulting plans and policies would be implemented. Toward the end of the project in late 2014, the Steering Committee advocated for principles of regional resilience to guide adaptation planning.

The project's first set of public workshops, organized around Matanzas area residents and stakeholder groups, solicited participant input about sea level rise awareness and adaptation preferences through keypad polling, a visioning exercise, and a role-play game. At the second public workshop, focused on land use planning, participants engaged in a SWOT analysis of conservation corridors and a game about future growth patterns.

Figure 91 distills the adaptive capacity findings from the workshops. Diverse groups and individuals participated in the workshops, and across all the meetings several themes emerged. Participants were on average highly supportive of sea level rise science and adaptation planning, believed they personally were well informed, and desired greater communication of the issues to the general public and elected officials. Similar to the adaptive capacity findings for the Northeast Florida region, Matanzas area participants described tensions between development and environmental interests, both of which were well-organized regional networks, but they also demonstrated that divergent groups were collaborative and open-minded. The expressed values of the Matanzas Basin were remarkably similar across all the resident and interest groups, and there was a strong sense of place, appreciation of the area's high quality of life, and affirmation of sustainability principles.

Workshop participants were open to the full spectrum of adaptation goals (protection, accommodation, strategic relocation, avoidance, growth management/LID, and land conservation). Participants were accepting of change, and demonstrated flexible thinking and a willingness to adapt socially, economically, and technologically in concert with the changing landscape. Participants remarked that the choice of goal for a vulnerable location would depend on whose needs are considered (e.g., individual property owner or the entire community/ecosystem), the timeframe of concern (short- versus long-term), and the rate of sea level rise. For example, participants supported choosing a suite of adaptation strategies to creatively balance needs across interests – human and natural, land and water, present and future. Recommendations emerged for phasing adaptation planning and strategies, and applying other principles of managing uncertainty and risk. Local government and state/federal agency representatives considered different ways in which they could begin addressing sea level rise within their organizations and management sites.

In terms of regional land use planning, participants supported smart growth in non-vulnerable and non-environmentally sensitive areas, including through infill and redevelopment to increase development densities, and if necessary greenfield development adjacent to existing development. Participants questioned, however, whether the growth projections would materialize, and they doubted that new protections for large regional conservation corridors would receive support from county commissioners. Development interests saw opportunities in well-designed inland developments with maintained public access to coastal amenities. They furthermore welcomed sea level rise adaptation planning and outreach to provide their sector with valuable information and regulatory consistency. Figure 92 summarizes the land use planning input in relation to adaptive capacity.

The last meeting of the project's Steering Committee in late 2014 was devoted to each member describing his or her organization's current activities and intentions towards using the information generated from this project. The GTM Research Reserve was in the process of incorporating sea level rise considerations into several initiatives (Figure 93): an update of Reserve's management and stewardship plan, prioritization of land acquisition and restoration projects, the design of interactive coastal change exhibits in the Reserve's Education Center (Figure 94), and research into habitat changes. Grant proposals to implement many of these initiatives were in progress. Other Steering Committee members said they were currently using project information for decision making, such as for siting of development, infrastructure, and conservation corridor projects, and sharing the information within their organizations, and with professional and public contacts. Several government representatives said they have plans to revise local policies and create new planning initiatives influenced by the project. The GTM Reserve staff and Steering Committee members offered to present the Matanzas project's findings to elected officials and the public.

Figure 91. Adaptive capacity of the Matanzas area based on stakeholder workshops

Figure 92. Public workshop feedback regarding the capacity for regional land conservation

Figure 93. Adaptation strategies being considered by the GTM Research Reserve

Figure 94. GTM Research Reserve Education Center, Ponta Vedra Beach. Source: http://augustine.com/thing-to-do/guana-tolomato-matanzas-nerr

Photo by Ed Siarkowicz Photographic Images, LLC

Conclusion

The Matanzas estuary and watershed comprise an ecosystem, the Matanzas Basin, of great conservation value at local, regional, state, and national levels. The ecosystem is relatively intact, which is rare along Florida's Atlantic Coast, and it presents a vital link to statewide ecological greenways. The ecosystem supports diverse wildlife, is an asset in the local economy, and provides "ecosystem services" to people living and working in the area. These values were reflected in the establishment of the Guana Tolomato Matanzas (GTM) National Estuarine Research Reserve, which includes the Matanzas estuary and surrounding public conservation lands. Current conservation of the Matanzas Basin, while a significant achievement, still faces concerns of the impacts of high rates of urban development on private lands, and the more recently recognized threats of sea level rise and climate change.

The "Planning for Sea Level Rise in the Matanzas Basin" project responded to the concerns of the area by providing tailored, scientifically defensible future scenarios, integrating projections of urban development and sea level rise with analyses of conservation priorities and adaptation strategies, to aid planning and management decisions of the GTM Research Reserve, local governments, and other stakeholders. The three-year project was led by a partnership between the GTM Research Reserve and the University of Florida, with funding from the National Estuarine Research Reserve System Science Collaborative. The Matanzas project will also serve as a demonstration of adaptation planning methods for potential transfer to other NERR sites across the country.

The project built upon the strong governance capacities in the Matanzas area and Northeast Florida region, which enabled the formation of a Steering Committee of diverse local stakeholders to guide the project and well-attended public workshops for gathering local input.

The project assessed Matanzas area vulnerability to sea level rise, identified future conservation priorities and potential adaptation strategies, and helped build governance capacity for adaptation. The information generated by the project is available in three formats: this report, the detailed appendices, and geographic information system (GIS) data. The report and appendices are useful for understanding the project methods and findings. The GIS data will be used by the GTM Research Reserve, local governments, and other organizations in their own initiatives, including further analyses and public outreach. The project's website, PlanningMatanzas.org, will be maintained to provide the report and appendices, and current contact information for GIS data requests.

The project found that several locations in the Matanzas Basin, especially the estuary and nearby coastal communities, will be likely significantly impacted by both sea level rise and development pressures. Past sea level rise in the Matanzas Basin has not been easily observable in the estuary's marshes due to their ability to make soil to keep up with gradually rising waters. Future sea level rise, however, is anticipated to begin accelerating presently. Given the uncertainties of future sea level rise projections, the project team modeled sea level rise scenarios from about the recent historic rate of 10 inches per century up to 8 feet (2.5 meters) by the year 2100. The mid-range projections of 3 feet (1 meter) sea level rise by 2100 was the scenario that began showing substantial estuary and community vulnerabilities. As sea level rise accelerates over longer timeframes, the project's ecological modeling showed that the marshes would no longer keep up and will be "drowned." The natural replacement of marshes and other "migrating" habitats in new areas will be limited by the lack of suitable areas due to elevations, existing development, and future development. Figure 95 illustrates the relatively narrow geographic extent of the landscape changes observed up to the 2.5 meter SLAMM scenario (see Appendix C for details). This finding suggests that conservation interests in the Matanzas area will need to examine the details of the project's conservation analyses for policy/project guidance.

The developed areas of greatest vulnerability to sea level rise are within this band of change (Figure 95), which is indicative of the increasing frequency and severity of inundation responsible for the ecological transitions. The vulnerable developed areas include St. Augustine, which has tremendous historical assets, all the seaside cities and unincorporated communities, and a small portion of Palm Coast. In addition to modeled inundation concerns, these areas will also experience higher storm surges and erosion. Many communities in the Matanzas area are already dealing with these kinds of problems.

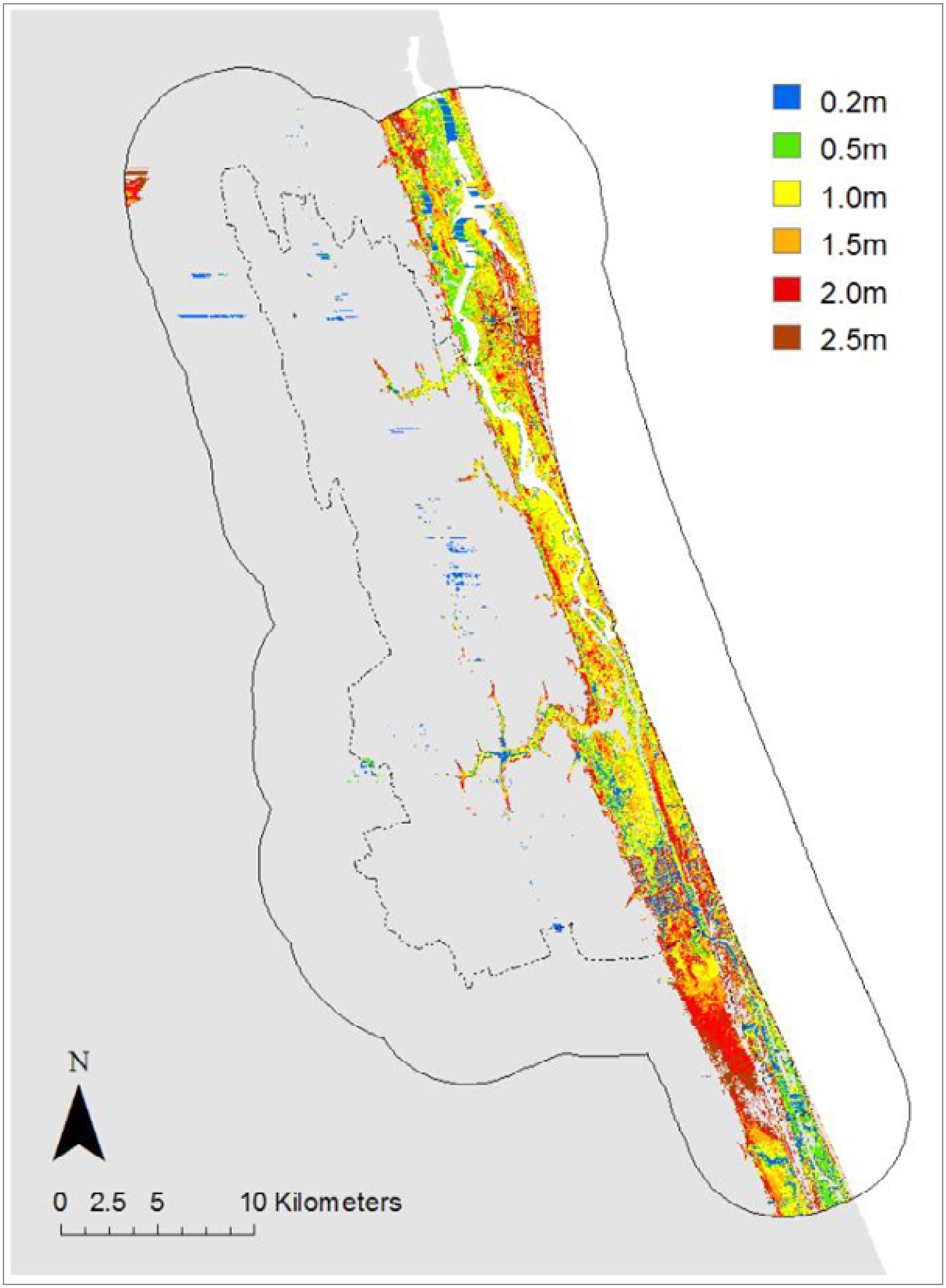


Figure 95. Area of change in land cover shown for each SLAMM sea level rise scenario (0.2, 0.5, 1.0, 1.5, 2.0, and 2.5 m) at 210

The Matanzas Basin's higher elevations having lower sea level rise and coastal hazard vulnerabilities is good news for inland communities (e.g., most of Palm Coast) and future development, however there other important concerns to take into account when assessing vulnerabilities and guiding growth. Inland communities may experience flooding due to sea level rise inhibiting the drainage systems and raising the water table, and the potential for high rainfall events with climate change, the analysis of which were beyond the scope of this project. The conservation priorities identified through this project are also vital considerations. The conservation priorities included a host of species and ecological values, which incorporated ecological adaptation to sea level rise and regional connectivity, as well as water resources. The maps of priorities demonstrated that most of the Matanzas Basin has conservation significance for wildlife and people, and watershed integrity is a critical component of a

Historic Princess Place Photo by Ed Siarkowicz Photographic Images, LLC resilient ecosystem. The project identified future conservation priorities for estuary habitat adaptation to sea level rise on lands adjacent to the Reserve that are not currently in conservation status. The interdependencies between coastal and inland areas, and between human and natural systems, led the project's Steering Committee to recommend that planning in the area be guided by sustainability and regional resilience principles.

The diverse vulnerabilities and regional interdependencies led the project team to investigate a wide variety of adaptation strategies for potential use in the Matanzas area. A matrix relating the level of vulnerability, land suitability for conservation or urban development, and adaptation goals proved to be a useful organizing framework. In vulnerable areas, goals for development applied: protection, accommodation, strategic relocation, and avoidance. In safe areas, goals for smart growth/low impact development (LID) and land conservation were relevant. The detailed findings from the project's landscape analyses can be used to inform planning for each these goals and locations. The project created an extensive set of custom policy toolboxes and governance resources for sea level rise adaptation, smart growth/LID, and land conservation for use in the Matanzas area.

The project team furthermore assessed local and regional governance capacities, including reviews of local comprehensive and hazards management plans. This assessment found a solid foundation for planning in the Matanzas area – for hazards, growth management, and natural resource conservation. The plans, however, did not reflect the concern of future sea level rise, the impacts it may have, and their implications for local policies and projects. Sea level rise will continuously intensify coastal hazards, and the increasing inundation will transform the landscape and its ability to support development, wildlife, and natural processes. The scope and permanence of the changes will eventually lead to shifts in the human-landscape relationship and corresponding goals. Some of the biggest challenges ahead for the Matanzas area involve management of the GTM Research Reserve, addressing the vulnerability of coastal developments, and regional growth management. These challenges will not only need to factor in sea level rise but also a host of other environmental, social, economic, and institutional changes on the horizon, both anticipated and presently unknown.

Continued research is important to support ongoing adaptation planning in the Matanzas area. This project focused on sea level rise impacts and strategies for landscapes. Future research could examine sea level rise impacts on other environmental aspects, including estuarine hydrology and erosion/ sediments. For example, the literature suggests that sea level rise may in some cases improve estuary water quality due to higher flushing rates with the ocean (Picado et al. 2010). Moreover, other climate change phenomena will profoundly affect the Matanzas estuary, such as increasing atmospheric temperatures likely leading to a prevalence of mangroves. Also essential to the region is a better understanding of the impacts of sea level rise to developed areas, particularly St. Augustine and other coastal communities. And, as stakeholders consider adaptation strategies, studies can provide economic and social information to assist decision making.

The planning and policy professions are developing concepts and tools to assist leaders with making critical decisions under uncertainties. One such concept is "no-regret," in which a decision is likely to be successful regardless of future conditions, be they similar to the present or radically different. An example of a no-regret strategy suggested by a workshop participant was the phasing of development infrastructure to provide future flexibility in land use. No-regret decisions are not options in every case, but there are accepted no-regret approaches in general, such ethical and fiscally responsible governance for sustainability and resilience, proactive planning, and civic engagement.

At the project's conclusion, the GTM Research Reserve and Matanzas area stakeholders had already begun using the generated information and data, and they held concrete plans to build upon the project and mainstream sea level rise adaptation concerns into day-to-day affairs. Across the Northeast Florida region, governments and organizations were coordinating their sea level rise and climate change initiatives. The GTM Research Reserve and the project's Steering Committee were essential to this study, and their leadership has undoubtedly been influential across the region, state, and nation. The future of the Matanzas Basin is in good hands.

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List of Appendices

Appendices are available at the Project's website: PlanningMatanzas.org.

Appendix A: ***Sea Level Rise Scenarios and Digital Elevation Model for the Matanzas Basin***, June 2015. Volk, Michael, and Russ Watkins. University of Florida.

Appendix B: ***Storm Surge Hazus Modeling for the Matanzas Basin***, June 2015. Volk, Michael and Paul Zwick. University of Florida.

Appendix C: ***Application of the Sea Level Affecting Marshes Model (SLAMM) in the Matanzas Basin***, June 2015. Frank, Kathryn, Greg Kiker and Anna Cathey Linhoss. University of Florida.

Appendix D: ***Conservation Impacts and Priorities in the Matanzas Basin***, June 2015. Hoctor, Tom, Michael Volk and Mingjian Zhu. University of Florida.

Appendix E: ***Matanzas Future Development Scenarios***, June 2015. Deledda, Max and Paul Zwick. University of Florida.

Appendix F: ***Land Conservation Policies and Programs***, June 2015. Hoctor, Tom, Julie Morris and Michael O'Brien. University of Florida.

Appendix G: ***Smart Growth and Low Impact Development (LID)***, June 2015. Volk, Michael and Matt Wolfe. University of Florida.

Appendix H1: ***Integrated Adaptation Framework and Toolbox***, June 2015. Ruppert, Thomas. Florida Sea Grant.

Appendix H2: ***Planning for Sea Level Rise Toolkit***, June 2015. Ruppert, Thomas. Florida Sea Grant.

Appendix H3: ***Review of Local Comprehensive Plans and Other Documents Relevant to Sea Level Rise Adaptation Planning in the Matanzas Basin***, June 2015. Brew, Hayley and Thomas Ruppert. Florida Sea Grant and Stetson Law.

Appendix H4: ***Relevant Comprehensive Plan Language for Sea Level Rise Adaptation Planning in the Matanzas Basin***, June 2015. Ruppert, Thomas. Florida Sea Grant.

Appendix I: ***Sea Level Rise in Florida: A Bibliographic Essay of Current Science***, June 2015. Ankersen, Tom, Lisa Gardner Chambers, Anna Cathey Linhoss and Kevin Wozniak. The University of Florida Conservation Clinic. University of Florida.

Appendix J: ***GIS Database Guide***, June 2015. Volk, Michael and Mingjian Zhu. University of Florida.

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